THE BRACHIOPODA
OF THE OSWAYO AND KNAPP FORMATIONS
OF THE PENN-YORK EMBAYMENT

A dissertation submitted to the

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of the University of Cincinnati

in partial fulfillment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

1958

by

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UNIVERSITY OF CINCINNATI

May 21, 1958.

I hereby recommend that the thesis prepared under my supervision by Frank Delno Holland, Jr.,

entitled The Brachiopoda of the Oswayo and Knapp Formations of the Penn-York Embayment

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

Approved by:

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This work was made easier by pleasant association with, and constant encouragement by, many students, colleagues, friends and relatives. The writer takes this opportunity to thank them for their aid; while the thanks are not personal they are none the less sincere.

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Much of the work was done under the auspices of the University of Cincinnati Museum while the writer was Curator of that Museum under the directorship of the late Dr. John L. Rich, from 1951-1954. The full

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Elizabeth A. Dalvé drew the text figures in

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Appendix B.

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ABSTRACT

The abundant brachiopod faunas of the Oswayo and Knapp formations occuring in the marine phase of the great Devono-Mississippian or "Catskill" Deltaic Plain of the Penn-York Embayment are reevaluated in order to determine the proper placing of the systemic boundary between the Devonian and the Mississippian. The brachiopods were collected principally in northwestern Pennsylvania from the Oswayo and Knapp formations of the Big Bend magnafacies in order to minimize facieological differences. The Tidioute shale, previously thought to overlie the Knapp, is believed to belong to the next western magnafacies, the Chagrin; and brachiopods of this formation were collected where it interfingers with the Knapp.

In all, 47 species, subspecies, and morphological variants are described. These are classified into 25 unquestioned species, grouped into 17 genera of which one is new. One new subgenus is also described. Of the 25 species occuring in these formations, 15 are new. With the systematic description of each form, wherever practical, the phylogeny of the form and its world-wide affinities are discussed.

Based upon differences in lithology, the presence of a slight disconformity, and upon considerable differences

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in the brachiopod faunas including (1) diminution in number and variety of forms in some genera, (2) first occurrence or rapid expansion of other genera which could be Devonian as well as Mississippian, (3) first occurrence in the Knapp of common Mississippian genera, and (4) considerable differences in the faunas due to the addition of new species in the Knapp and Tidioute, the writer concludes that the Devonian-Mississippian boundary is correctly placed between the Oswayo and Knapp formations in the southwestern New York-northwestern Pennsylvania sector of the Penn-York Embayment.

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INTRODUCTION

The brachiopod fauna herein described occurs in many strata deposited in the Penn-York Embayment (Caster, 1935b). Williams (1897), Barrell, (1913, 1914) Willard (1934, 1939), Caster (1938a) and Laird (1942) have shown the extent of the Penn-York Embayment (see Fig. 1 for shorelines in Pennsylvania).

Sediments were poured into this embayment around its periphery to form the great "Catskill delta" or medial and late Devonian exogeosyncline (Kay, 1951, p. 19); previously termed a deltageosyncline by Kay, 1942) following the Shickshockian orogeny in eastern Canada and New England in medial Devonian time (Kay, 1951, p. 54-56). Fig. 3 is a generalized restored northwest-southeast section of the exogeosyncline from northeastern Ohio to southeastern Pennsylvania, and Fig. 4 is an isopachous map of Pennsylvania and adjacent states. These figures, modified slightly from Kay (1951, Pl. 5, and Fig.), serve to illustrate the vast volume of sediment involved in this area.

Within the Penn-York Embayment, one of the most vexing problems has been the placing of the Devonian-Mississippian boundary. Within recent years stratigraphers in northwestern Pennsylvania (Caster, 1934; Fettke, 1938; and Willard, 1939) have been in agreement in placing the

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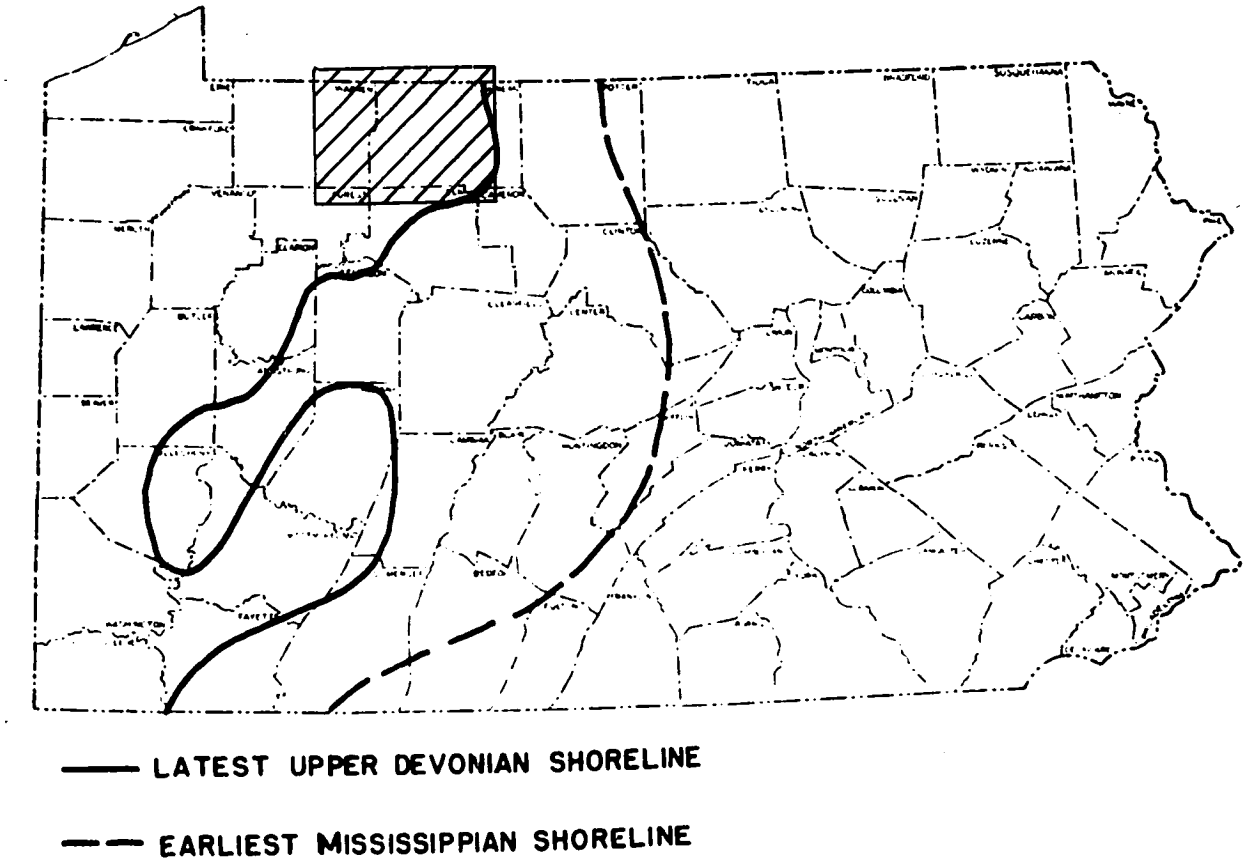
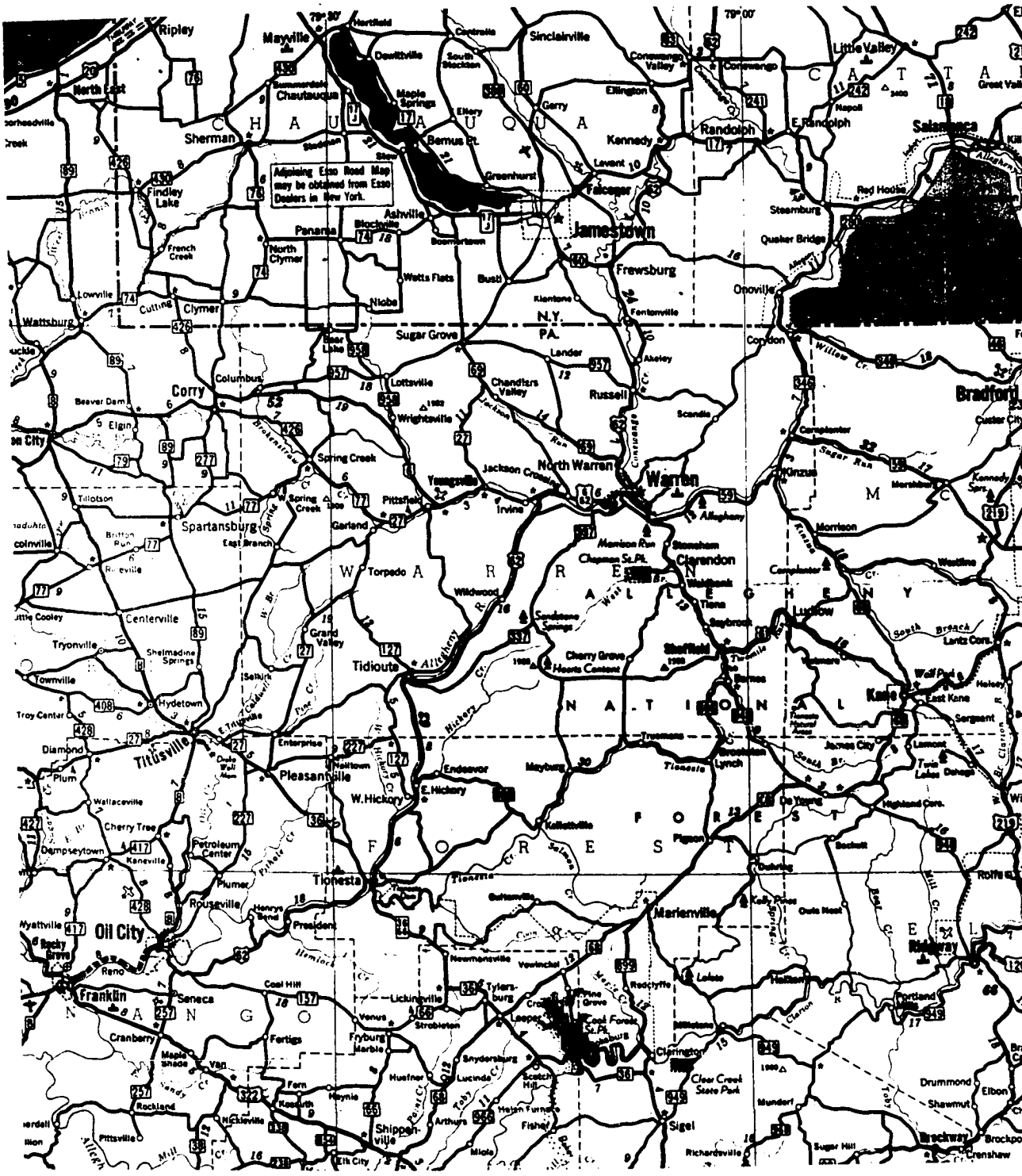
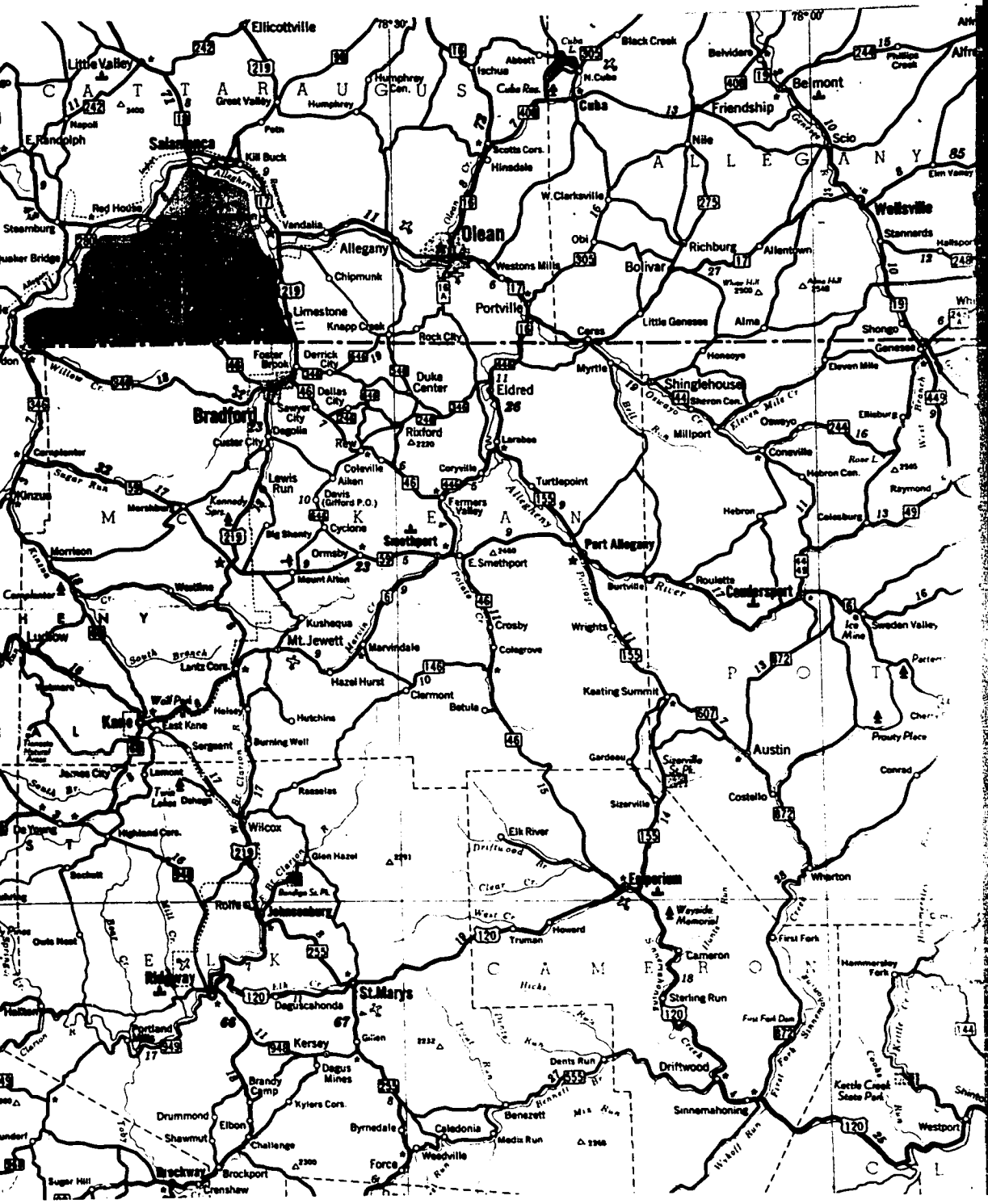


Fig. 1. - Paleogeographic map showing approximate position of the Upper Devonian and Lower Mississippian shorelines in the Penn-York Embayment. The brachiopods described herein were collected from the area indicated. (adapted from Laird, 1942, p. 212).


Ripley
Mayville
North East
Sherman
Findley Lake
Panama
Ashville
Jamestown
Frewsburg
Randolph
Salamanca
Little Valley
Steamburg
Onoville
Bradford
Warren
North Warren
Clarendon
Kane
Corry
Spartansburg
Centerville
Titusville
Pleasantville
Oil City
Franklin
Tionesta
Marienville
Ridgway
Sigel
Brockway
Brockport
Clear Creek State Park
Allegheny
Chautauqua
Conewango Valley
Kennedy
Levant
Frewsburg
Bemus Pt.
Maple Springs
Ellington
Gerry
Sinclairville
Centralia
Deckville
Hartfield
Sugar Grove
Lander
Russell
Chandlers Valley
Wrightsville
Lottsville
Columbus
Beaver Dam
Elgin
Tillotson
Spring Creek
Garland
Pittsfield
Irvine
Youngsville
Jackson Corners
Torpedo
Wildwood
Sandstone Springs
Cherry Grove
Hearts Content
Tidioute
Grand Valley
Shelmadine Springs
Tryonville
Townville
Troy Center
Hydetown
Diamond
Plum
Wallaceville
Cherry Tree
Dempseytown
Kanesville
Petroleum Center
Plumer
Rouseville
Enterprise
Endeavor
E. Hickory
W. Hickory
Hickory
Tionesta
Kellettville
Tylersburg
Lickingville
Venus
Fryburg
Marble
Cranberry
Seneca
Fertigs
Rockland
Reseburg
Haynie
Shippenville
Arthurs
Lucinda
Scotch Hill
Helen Furnace
Fisher
Elk City
Richardsville
Sugar Hill
Drummond
Elbon
Shawmut
Mundorf
Clarington
Cooksburg
Leeper
Cross Forks
Sinnamahoning
Rockyville
Lakeville
Portland
Mills
Ole Hoss
Quaker Bridge
Red Hooks
Conewango
Corydon
Kinzua
Lafayette
Scandia
Akeley
Fentonville
Klantone
Bush
Watts Flats
Nicbe
Clymer
North Clymer
French Creek
Lowville
Cutting
Wattsburg
Findley Lake
Summerdale
Stedman
Maple Springs
Adjoining Esso Road Map may be obtained from Esso Dealers in New York.
N.Y.
PA.
Allegheny
Conewango Cr.
Kinzua
Sugar Run
Willow Cr.
Morrison
Morrison Run
Chapman St. Pk.
Stoneham
Westline
Lucinda
Skyrock
Lantz Corn.
South Branch
Wolf Run
Sheffield
Tiona
Bullis
Tremont
Mineral Point
Jones City
Lamont
Twin Lakes Dehgo
Highland Corn.
Rolfe
Sargeant
East Kane
Wolf Run
Haley
Mayburg
Tionesta
Kellettville
Pigeon
Lynch
Broadstreet
Tionesta
Gutenville
Newmansville
Vowinckel
Tylersburg
Lickingville
Venus
Fryburg
Marble
Cranberry
Seneca
Fertigs
Maple Shade
Van
Fern
Haynie
Rockland
Reseburg



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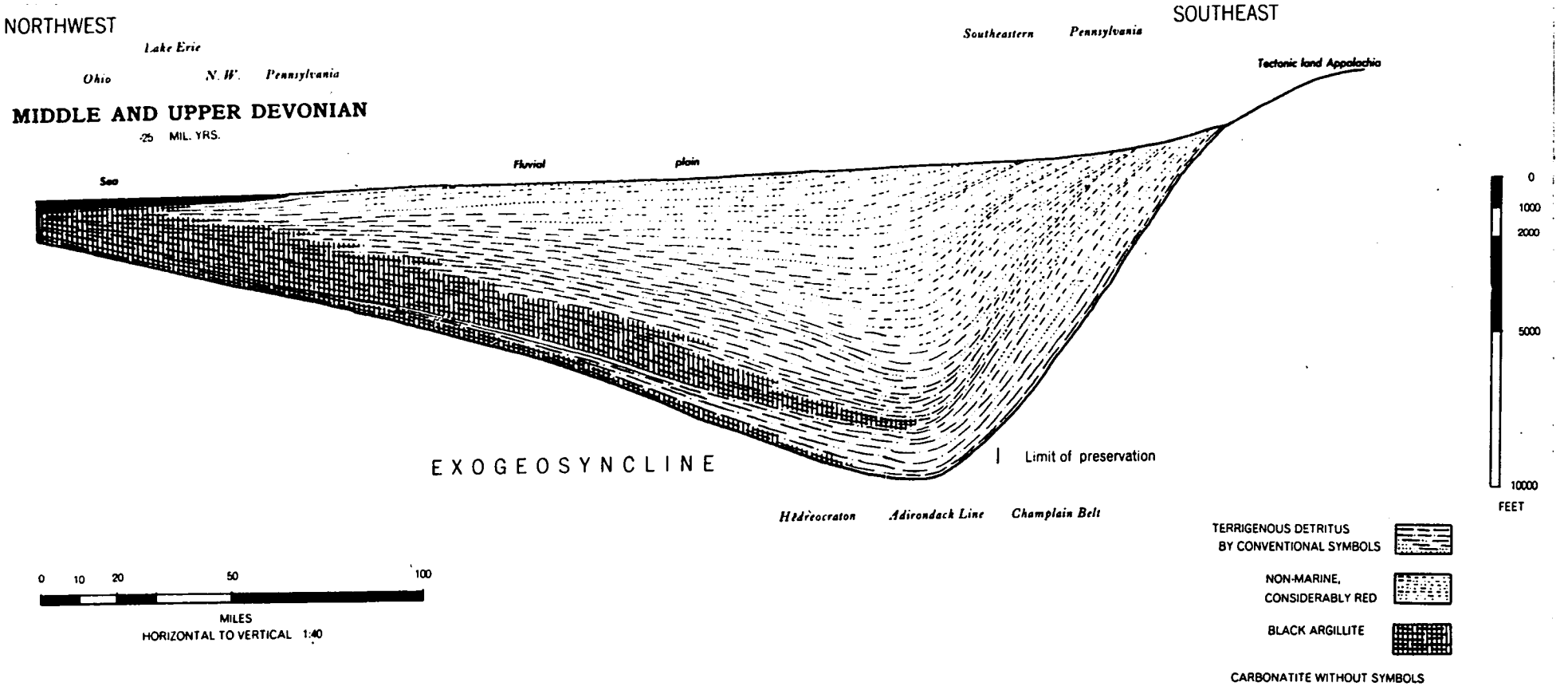

Fig. 3. - Restored sections of Middle and Upper Devonian exogeosyncline in Pennsylvania and adjacent states. (Modified slightly from Kay, 1951, Pl. 5).

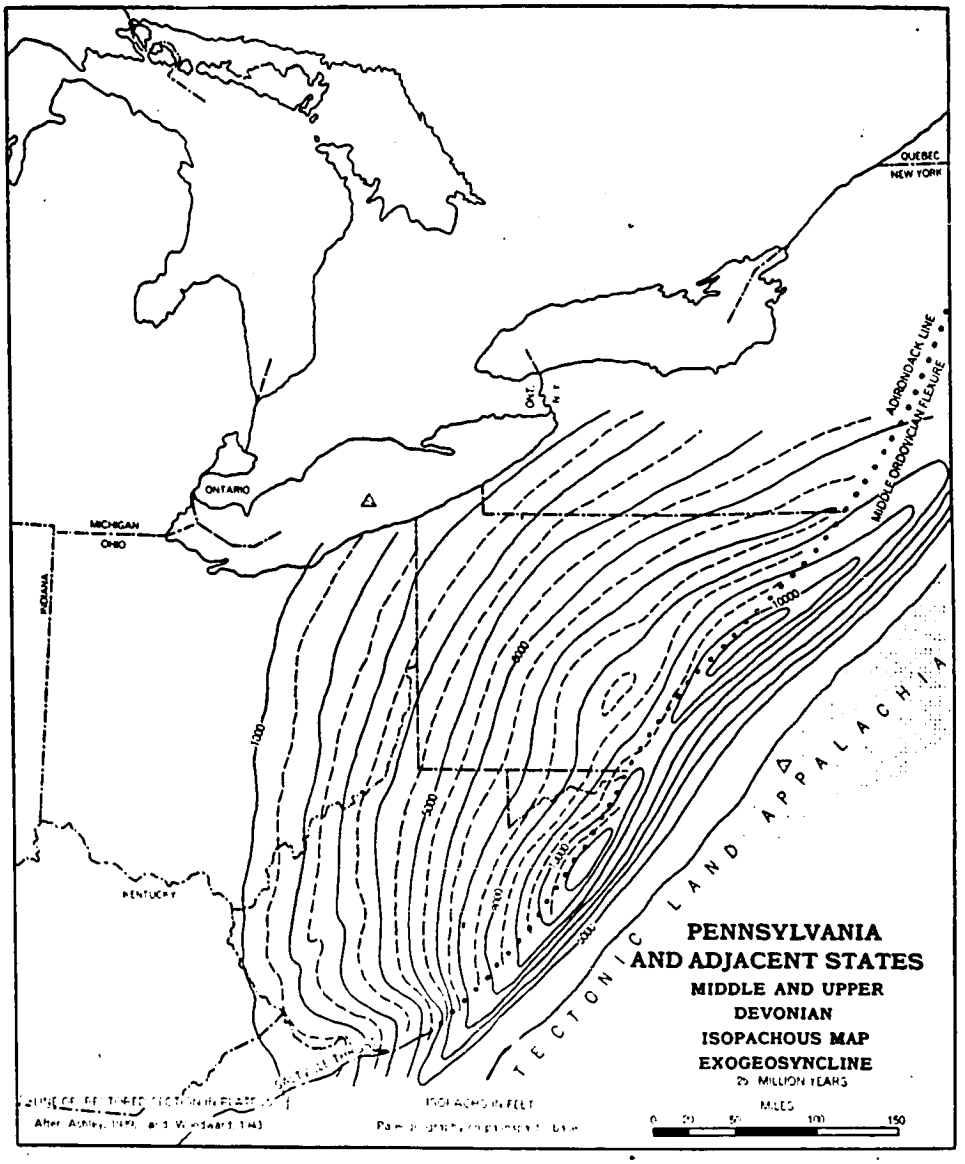

Fig. 4. - Isopachous map of Middle and Upper Devonian in the exogeosyncline, Pennsylvania, and adjacent states. (Reproduced from Kay, 1951, p. 19).

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boundary at the top of the Oswayo and the bottom of the Knapp. The current essential unanimity has not always been so, as shown on Fig. 5. However, the workers, while presenting faunal lists, have not described nor illustrated the fauna to support their contentions.

The purpose of this paper is to describe and illustrate the abundant brachiopod fauna of the Oswayo and Kanpp formations and reevaluate the evidence for the placing of the systematic boundary.

Marine faunas do not occur throughout the entire area of the Penn-York Embayment, and the brachiopods studied were collected principally in the Olean, New York to Bradford and Warren, Pennsylvania, area as delimited on Fig. 1. An enlargement of this approximate area is shown on Fig. 2 to indicate place names in the area.

Summary of Previous Work

"Heroic age". -- The middle of the nineteenth century with the beginnings of the New York and Pennsylvania Geological Surveys has been characterized as an "heroic age" by Caster (1934, p. 11) Such it was indeed as evidenced by the general excellence of the maps and the records left by the geological pioneers of southwestern New York (Hall, 1843) and northwestern Pennsylvania (Rogers, 1858). Yet Rogers was more occupied by greater structural complexity in eastern Pennsylvania and dismissed

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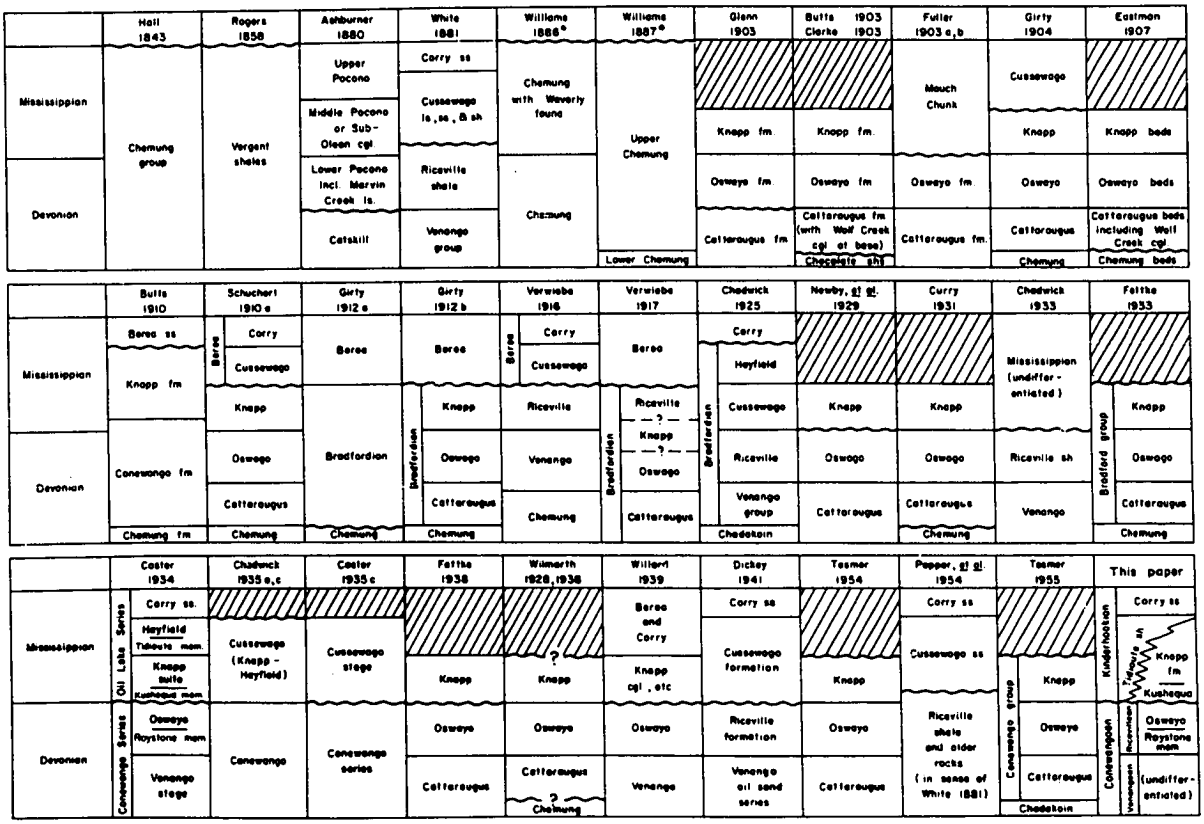

Fig. 5. - Generalized chart showing the various interpretations of the position of the Devonian-Mississippian boundary in southwestern New York and north-western Pennsylvania. Heavy undulatory line indicates the position of the boundary as interpreted by the various authors. Cross-ruling indicates not present in area worked by author or not considered by the author. Abbreviations the present writer's.

*Williams considered the Mississippian absent in the Olean area, but mentioned "Waverly" elements (Syringothyris) in the fauna.

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lightly the apparently simple geology of northwestern Pennsylvania saying (p. 576),

> We come now to consider the Geology of the N.W. corner of the State, embracing the whole of Erie, a large part of Crawford, and the N. half of Warren counties. This is much the simplest of all the natural divisions of the geological surface of Pennsylvania, as respects both the variety of its strata and their structural features. It includes, in fact, only two of our Paleozoic formations, namely, the Vergent flags and Vergent shales. These strata retain very nearly the horizontal position in which they were originally deposited. . . . No anticlinal undulations, having a more than barely perceptible degree of flexure, modify this gentle S. E. declension of all the rocks. The district is therefore not naturally subdivisible, and as its strata contain few or no mineral deposits of interest, it admits of being very succinctly described.

He proceeds with this description through barely six pages.

Hall (1843, p. 484-93) likewise dispenses with Allegany and Cattaraugus Counties, New York, in the shortest possible manner and records only rock of the "Chemung group" below the "Upper Carboniferous" (Olean) conglomerate in this area.

Pennsylvania Second Geological Survey. -- The finding of oil and the continued economic importance of coal mining in northwestern Pennsylvania caused the assignment of a number of men to make geological observations apace with the new activity and newly developed petroleum industry. In spite of the constant editorial muddlings of their superior, J. P. Lesley, the men of the second Pennsylvania Geological Survey did a creditable job in a region beset

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with difficulties, not the least of which is a relative paucity of outcrops. They were constantly hampered in their correlations by the prevalent disregard for fossils. Apparently this stemmed directly from on high for Willard says (1939, p. 7), "Lesley's antipathy for fossils was apparently as strong as his gift for sarcasm." Later, on the same page he continues, "Always, the Second Survey is to be mistrusted when Devonian fossils are cited. Distinctive fossils, even entire faunas, were sometimes completely missed or incorrectly classified." This, while the New York Survey using fossils, under Hall's direction made such strides!

None the less, these men, Lesley, I. C. White (1880, 1881), J. F. Carll, (1875, 1877, 1880, 1883, 1890) and C. A. Ashburner (1880, 1884, 1885), named, mapped and correlated the formations in the "Oil Region" of Pennsylvania. Caster (1934, p. 11-14) rightly lauds these men and discusses in detail their work in the several counties of the area.

As a result of their labors the strata below the "Pottsville" (Olean, Garland or Sharon) conglomerate were classified as shown in Fig. 6 which is a reproduction of White's (1881) interesting classification.

Carll (1880) has porposed the name "Crawford shale" for all of the strata beneath the Pottsville conglomerate and above the "Venango Oil Sand"; but White (1881, p. 68) restricted this name, if it were to be retained at all, to

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that part of the column beneath the Shenango sandstone and above the Corry sandstone. He then proceeded to replace it with his name, Meadville group. His grouping (p. 67) of the section shown in Fig. 6 was as follows:

	Shenango group
	Shenango shale and sandstone
Sub-conglomerate	Meadville group
	Meadville
	Sharpsville
	Oil Lake group
	Corry
	Cussewago
	Riceville
Venango Oil Sand Group	

As Caster (1934, p. 45) notes, White and Carll were perhaps more astute observers than subsequent neglect of their classification would seem to imply. Caster has chronicled the vissicitudes that their classification has suffered at the hands of Schuchert, Girty, Ulrich and others.

Turn of the century. -- After the report of the Pennsylvanian Second Geological Survey, Williams (1886, 1887) published the only papers which added substantially to our knowledge of the stratigraphy and paleontology of the area until Glenn (1903) published the results of his investigations of the geology in the Olean and Salamanca Quadrangles of New York. In this report he raised the question of the position of the Devono-Mississippian boundary. The problem was immediately taken up by Butts (1903), Clarke (1903) and Girty (1904, 1912a, 1912b). Their differences of opinion (see Fig. 5) formed the

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bone of contention about which stratigraphic studies in this area have hinged down to the present day and are the motivation for the present work.

Glenn (1903, p. 985), after considerable discussion, concludes that the "provisional" boundary between the "Devonic" and the "Carbonic" should be drawn at the unconformity "between the Cattaraugus and the Oswayo" because of this unconformity and because of the Catskill-like red beds in his Cattaraugus.

In the next paper, in the same volume, Butts, who was collecting with Glenn and studying the faunas, writes (1903, p. 991),

> This important faunal change with the incoming of the Wolf Creek (Panama) conglomerate, taken in connection with the fact that on stratigraphic grounds, the equivalent of the Waverly of Ohio, of Subcarbonic age, is pretty certainly present in this quadrangle, and in connection with the fact that the fauna of the conglomerate and higher beds contains a small Subcarbonic element, would indicate that the bed might be provisionally adopted as the base of the Subcarbonic in the quadrangle.

However, in listing the fauna farther on, Butts cautiously listed the "Cattagaugus formation" faunal lists under the heading "Devono-Carbonic" (p. 993) while he placed the "Oswayo formation" (including "Zone 4, limestone lentil" and "Zone 3, Oswayo shales and Knapp beds") under the heading "Subcarbonic" (p. 994). It is perplexing that while Glenn was busy describing and differentiating a new unit in the field, Butts should have mixed the fauna of the "Oswayo shales and Knapp beds."

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Generalized section.

SHENANGO,	*Shale,*	50
	SANDSTONE; massive; *fish bed,*	25′
Meadville,	*Upper shale,*	25
	Upper Limestone; fish bed,	1′
	Lower shale,	40′
Sharpsville,	*Upper flags,*	50′
	Meadville Lower Limestone,	2′
	Lower flags,	12′
Orangeville shale,		75′
CORRY SANDSTONE,		20′
CUSSEWAGO,	*Upper shales,*	5′
	Limestone,	2′
	Middle shales and flags,	30
	SANDSTONE,*	25′
Riceville shales,		80′
VENANGO,	UPPER SS. (*First Oil Sand*), 20′	
	Upper blue shales, 100′	
	MIDDLE SS. (*Second O. S.*), 20′	310′
	Lower shales, red, 15′; blue, 125′	140′
	LOWER SS. (*Third O. S.*), 30′	

Q4

* Mr. Carll has shown how it came to pass that this was named the *First Oil Sand* by the drilling in the Butler Fourth Sand cross belt; the sand below it thereby becoming Second, Third and Fourth sands respectively. Report I.I.I.

Fig. 6. - Pennsylvania Second Geological Survey classification of strata of the "Oil Region". (Reproduced from White, 1881, p. 66).

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Clarke (1903, p. 996) seemed compelled to comment on the difference in opinion of his two workers saying,

> The differing interpretations of the Olean section given by Professor Glenn and Mr. Butts in the papers preceding, afford an excellent illustration of the discrepancy which often results from the two modes employed. This discrepancy pertains however solely to the determination of a conventional boundary plane in sediments characterized by the uniformity of their succession. The sequence of events involves the independent construction of the lithologic or purely stratigraphic evidence and of the facts derived from the succession of faunas.

Thus, Clarke, a paleontologist, sided (p. 999) with Butts.

The unfortunate implication is the divorcing of faunal and "lithologic or purely stratigraphic" evidence as suggested by Clarke's words "two modes" and "independent construction." In this area, at least, geologists had not yet come to understand the impact of the physical environment on the life contained therein.

Girty (1904) aggravated the boundary question with the proposal of his "Bradfordian" to rank with "Senecan, Chautauquan, etc. (and which will include) the Cattaraugus, Oswayo, and Knapp beds of the New York section, and which may provisionally be accepted as its subdivisions." He stated that the "Bradfordian" lay "below the base of the Carboniferous system" and "above the Chemung beds, the recognized top of the Devonian." Thus he considered this interval "transitional" between the two eras with an "intermingling of Carboniferous and Devonian species."

Later in a prepared statement for Willis' "Index of

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North American Stratigraphy" Girty (1912a) said,

> . . . I originally assigned the "Bradfordian" without hesitation to the Devonian. After comparing "Bradfordian" faunas with the typical Chemung, however, I find that there exists a difference almost equally marked, and feel somewhat doubtful whether the "Bradfordian" would not better be placed in the Carboniferous.

After a study of the faunas of the Corry sandstone and Bradford-Berea strata in Ohio, Girty (1912b) concluded that the "Bradfordian" fauna was "distinctly Devonian" and that the Berea (Corry) formed the true base of the Mississippian.

Verwiebe's (1916, 1917a, 1917b) work was mostly with overlying Mississippian strata and has little bearing on the current problem. Caster (1934) has quite adequately discussed Verwiebe's work.

Chadwick (1924, 1925, 1933) wrote several papers, but, in the main, his revisions of nomenclature are not germane to this work as they dealt with underlying Devonian strata.

By far the most extensive work on the stratigraphy of southwestern New York and northwestern Pennsylvania was done by Caster (1934). This was an outgrowth of an earlier faunal study (1930). During the course of the early study Caster found (1934, p. 10), "Too many sets of conflicting and overlapping nomenclature were inadvertantly proposed and too many conjectural correlations made on the assumption of 'the parallelism of strata'." Consequently he restricted certain of the names (e.g., Riceville) and made other

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modifications including the quiet laying to rest of the "Bradfordian" (p. 42-45, 54; see also Caster, 1933, 1935a). His chart of the composite succession of strata in this area is reproduced as Fig. 7 for convenience of reference in subsequent discussion. (It might be mentioned that these names supplant names which Caster, 1933, had previously proposed in abstract due to the fact that the latter were either preoccupied or inappropriate.)

Several additions or corrections to Caster's talbe (Fig. 7) might here be pointed out. The name Conneaut should be supplanted by French Creek as explained by Caster (1934, p. 136). The Wolf Creek conglomerate and the LeBoeuf sandstone, both so often mentioned in earlier reports, should be added to the list of synonymic terms (Caster, 1934, p. 79-83) as equal to the Panama conglomerate. Indeed, Caster commonly interchanges these terms in his discussion.

The names as used in this table are essentially those currently employed by the writer (except as noted below) after field checking, especially those involved in the boundary dispute.

Other workers have but slightly altered this nomenclature. Flower and Caster (1935, p. 7) applied the name, Lewis Run sandstone to a local massive sandstone in the Amity shale. This name was preoccupied by prior use (Newby, et al., 1929, p. 422; Sisler, et al., 1933, p. 28; Fettke, 1938, p. 78, 238) for a subsurface "sand"

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6 to 12 feet thick approximately 100 feet below the Bradford Third "sand", the principal producer in the Bradford pool, which correlates roughly with the Laona sandstone well down in the Canadaway group of the Chautauquan series (Fettke, 1938, p. 107). Fettke (1938, p. 37) replaced Flower and Caster's Lewis Run by the name Hanley for the sandstone in the Amity shale.

The penetrating insight and clarity of thinking regarding the rejection of old nomenclature and definition and use of new is evident in the papers of Chadwick, not only in his earlier works, but also in more recent ones. At first he glimpsed and later embraced the concept of facies in the great "Catskill delta" (see especially Chadwick 1935b, 1935c, for facies distinctions in the New York Devonian). In another paper published the same year Chadwick (1935a) penetratingly analyzed the succession of Upper Devonian faunas as gleaned from the literature. He recognized six and possibly seven faunal groups in this portion of the column. For the first six of these groups he listed the "diagnostic" species, the species which ranged up from below, and those species which continued up into younger strata. Among other points emphasized in this paper was his current contention that the Devono-Mississippian boundary be placed above the Cussewago rather than below the Knapp-Kushequa beds as he had previously (1933) held (cf. Fig. 5). Surficially he presents a most convincing argument for this assignment

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STRATIGRAPHIC MEMBERS OCCURRING IN NORTHWESTERN PENNSYLVANIA

MISSISSIPPIAN SYSTEM		PARTIAL SYNONYMY	
Waverlyan subsystem			
Kinderhookian series			
(Crawford sub-series)			
Shenango stage			
(Shenango monothem)			
Hempfield shale member*		*Shenango shale*	
Shenango sandstone member (Johnsonburg sandstone*)		*"Sub-Olean conglomerate"; 2nd Mountain sand.*	
Meadville stage			
(Meadville monothem)			
Custards shale member*		*Upper Meadville shale*	Original Meadville group
Conneaut limestone member*		*Upper Meadville limestone*	
Harvest Home shale member*		*Lower Meadville shale*	
(Byham limestone member*)		*Middle Meadville limestone*	
Sharpsville sandstone member	Sharpsville formational suite	*"Sub-Olean conglomerate"*	Original Sharpsville formation
West Mead limestone member*		*Lower Meadville limestone*	
Shaws sandstone member*		*Sharpsville sandstone*	
Orangeville shale member (stage?)		*"Cuyahoga" of Pennsylvania*	
Oil Lake series			
Berea stage			
Corry sandstone member		*3rd Mountain sand; Pit Hole G*	
Cussewago stage			
(Cussewago monothem)			
Hayfield shale "formation"		*Cussewago shale*	
(Little's Corner limestone member*)		*Cussewago limestone, Hayfield limestone*	
Tidioute shale member*			
Cobham conglomerate member*	Knapp formational suite	*Upper Knapp conglomerate; Cussewago sandstone*	
East Kane shale member*		*Knapp shale (middle)*	
Wetmore conglomerate member*		*Lower Knapp conglomerate*	
Kushequa shale member*		*Knapp shale*	
(Marvin Creek limestone zone)		*Marvin Creek limestone ("Mea[illegible]e limestone")*	
DEVONIAN SYSTEM			
Conewango series			
Riceville stage			
(Riceville monothem)			
Oswayo shale member		*"Red Bedford" of the Oil Reg*	
Roystone coquinite member*		*Mistaken for the Marvin Creek [illegible]estone by some geolog*	
Venango stage			
(Venango monothem)			
Woodcock sandstone member		*First Venango oil sand*	
(Hosmer Run conglomerate)			
(Tuna-Kilbuck conglomerate lens)			
Saegerstown shale member			
Pope Hollow conglomerate	Salamanca formational suite	*"A"*	
North Warren shale member*		*Second Venango oil sand*	
Bimber Run conglomerate member*		*"B"*	
Amity shale			
(Dutchman's conglomerate lens*)			
Panama conglomerate member		*Third Venango oil sand*	
Chautauquan series			
Chadakoin stage		*"Upper Chemung"*	
(Chadakoin monothem)			
(Tanners Hill red band)			
Ellicott shale member*		*"Pink Rock"*	
Dexterville shale member*			
Lillibridge sandstone member*		*Quarry sandstone*	
Girard stage			
Girard shale			
Cuba sandstone			

*Note: Members marked with an asterisk (*) are designated by geographic name for the first time in this report.

Fig. 7. - Chart of composite stratigraphic section in southwestern New York and northwestern Pennsylvania. (Reproduced from Caster, 1934, chart facing p. 63).

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of the whole "Bradfordian" to the Devonian. Yet, here in his discussion of these controversial beds lurk numerous fallacies.

First, by conducting a literature survey, he fell heir to the very "egregious" mistakes Caster (1934, p. 10) had cautioned about --namely "conflicting and overlapping nomenclature" and "many conjectural correlations." Secondly, he was frequently lead astray by dubious reports (especially identifications which had been handed down from the early literature) of species which are not found in the strata as reported. Such ever is the lot of those who work with unillustrated faunal lists! Thirdly, he did not fully utilize (nor perhaps fully appreciate--for only a beginning had yet been made) the facies concepts (as reflected by the biofacies) advanced by himself and Caster. Fourthly, he was grossly mislead by too broad an interpretation being placed on certain species (especially the "ubiquitous Spirifer disjunctus") which occur not as a species, sensu stricto, (see Greiner, 1957) but a gens (a group of closely related species, subspecies, and Waagenons, Caster, 1944).

For economic reasons, the outstanding works of Fettke are probably the best known of any in the "Oil Region." Fettke (1938) has exhaustively studied the Bradford oil field, analyzed and correlated the subsurface "sands", traced them in the subsurface, and tabulated their productivity and has summarized this, the first

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oil-producing area of the world. He, more than any other one man in recent years, has contributed widely to the petroleum geology of this important region. In 1938, Fettke accepted Caster's placement of the Devono-Mississippian boundary, but differed with him on the naming and placing of several of the members in the outcrop. This too, rather than occupying space prematurely in this summary, will be discussed below.

Willard (1939) has brought together a vast amount of information on the Devonian of Pennsylvania. By his own admission he leaned heavily upon the works of Fettke and Caster in northwestern Pennsylvania and concentrated his own studies elsewhere in the state. Unfortunately he misinterprets statements made by other workers in the area. He accepts little of Chadwick's basic work and either refutes most of the latter's conclusions in application to Pennsylvania or ignores the fundamental facies studies in New York. While liberablly sprinkling his monograph with the word "facies" (commonly in awkward and ill-defined combinations, e.g. "facies group"), Willard not infrequently avoids utilizing in his correlations facies concepts which he has previously mentioned. Caster (1940) has reviewed Willard's monograph and pointed out the strides taken in our understanding of the Devonian of Pennsylvania and has also discussed some of the shortcoming of this work.

In more recent years, there have been few studies

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of the Upper Devonian and Lower Mississippian faunas of the Penn-York Embayment; however Caster has described certain elements of these faunas: limulid tracks (1938a) from the Senecan, a siphonophore (1942) from the Ithaca formation (Senecan), and a striking and unusual sponge fauna (1939a, 1939b, 1941) from Upper Devonian and basal Mississippian strata. Greiner (1957) has contributed an extensive resutdy of "Spirifer disjunctus" in this area but has not modified existing stratigraphic nomenclature.

It might be appropriate to mention here, in passing, work done on strata deposited in a more southern part of the Penn-York Embayment, namely in southwestern Pennsylvania. Willard (1933) correlated Devonian strata in this area with the lower Chemung of New York and proposed a considerable break between this "Chemung" and the previously known Mississippian. He later (Willard and Caster, 1935, p. 1546) reaffirmed this position, but Caster (Willard and Caster, 1935) and Laird (1941, 1942) have shown that a nearly continuous sequence of Upper Devonian and Lower Mississippian, comparable to the sequence in northwestern Pennsylvania, exists in the southwestern corner of the state. Laird (1941) has named the Conewangoan and Kinderhookian formations in this area and has begun (1942) a study of the paleontology which Rau (1955) has recently continued.

Pepper, De Witt, and Demarest (1954) and others (listed in De Witt's, 1951, bibliography) associated with

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the Appalachian Fuels Project have intensively studied the Berea sandstone and associated rocks in northern Ohio and extreme northwestern Pennsylvania. Their paper is likely to remain long as a classical example of paleogeographic interpretation of this general area and this part of the column. However, it is deficient on the biostratigraphic side, and in this area many correlation and stratigraphic problems are not resolvable, apparently, sans knowledge of the fossils involved.

Tesmer (1954, 1955) has published brief and preliminary accounts of the stratigraphy of extreme southwestern New York as parts of a more extensive study currently in progress.

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STRATIGRAPHY OF THE DEVONO-MISSISSIPPIAN BOUNDARY FORMATIONS

General. -- The "Bradfordian series" of Girty (1904) was rejected by Caster (1933; 1934, p. 42 et seq.; 1935a) because, as Caster (1934, p. 42) put the case,

> It develops that the Bradfordian series instead of embracing the Devono-Carboniferous transition beds in accordance with its original definition or being wholly of Devonian age as was subsequently suggested is really made up of a definite Devonian sequence which disconformably underlies a definite basal Mississippian sequence.

Chadwick (1933, p. 197) also considered the "Bradfordian" invalidated and pointed out that it was readily confused with the older Bradford oil "sands": but again in 1935 accepted the "Bradfordian" and used it as entirely Devonian in age.

Unfortunately the Devonian correlation chart (Cooper, et al., 1942) retains "Bradfordian (part)" as a series term embracing the same strata as the stage name Conewango. Yet the "Bradfordian" does not appear on the Mississippian correlation chart (Weller, et al., 1948) but is mentioned with a query in the text accompanying the chart (p. 159). Wilmarth (1938, p. 248) points out that the term was never adopted by the United States Geological Survey. There seems to be little virtue in persisting in the retention of this term in the face of abundant

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evidence against the "transitional" nature of the very beds for which it was proposed.

Butts (1908, p. 191, 197-198) first applied the name Conewango (although it is evident from the wording that the name was first to have appeared in the Warren Folio, Butts, 1910) to the beds between the Knapp and the "Cattaraugus" formations of Glenn. The Oswayo formation had been applied by Glenn (1903) to all of the Devonian strata above the highest red bed in the Olean area; the "Cattaraugus formation" of Glenn included all strata from the base of the Oswayo to the base of the "Wolf Creek conglomerate" (Panama conglomerate = Le Boeuf conglomerate of White and Chadwick). Because of the relative scarcity of red beds in the Warren, Pennsylvania, area, Butts (1910) could recognize only the Conewango "formation" below the Knapp, while in the Olean, New York area he could distinguish a lower "Cattaraugus formation" and and upper "Oswayo formation" equivalent to the "Conewango formation."

Caster (1934, p. 54 et seq.) elevated the Conewango to the rank of a series (although Wilmarth, 1938, indicates Survey usage as formational). He says,

> The Conewango series is the closing phase of Upper Devonian sedimentation in New York and Pennsylvania. At its base occurs a minor disconformity, separating it from the inferior Chautauquan series. At its top a minor disconformity occurs which is the break between the Mississippian and Devonian systems. The actual lithologic breaks at the top and bottom of the series are relatively inconsequential disconformities. The outstanding criterion for serial delimitation of the Conewango is the fossil fauna or faunas. They are highly distinctive.

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The present writer accepts this designation of series (epoch) for the Conewangoan. Thus it would rank with Ulsterian, Erian, Senecan and Chautauquan as a series in the Devonian heirarchy, replacing the outmoded "Bradfordian (part)" of the correlation chart (Cooper, et al., 1942) which used Conewango as a stage term. Stages of the Conewango series would then be the Venangoan below and the younger Ricevillean as advocated by Caster more than twenty years ago.

As in the case of "Bradfordian", White's (1881, p. 97) "Riceville Shale," which he delimited as lying between the "First Oil sand of the Venango group" (Woodcock sandstone) and the Cussewago sandstone, contained both Devonian and Mississippian strata (see Caster's 1934, p. 94-95 section, made on the Oil Creek bluffs just west of Riceville) Caster (p. 95) has, therefore restricted the Riceville to uppermost Devonian strata. However, as he (1934, p. 95) points out, the name Riceville is not ideal for these strata, for essentially the Riceville is composed of only the Oswayo formation including the Roystone coquinoid member. Moreover, on the meridian of Riceville, Pennsylvania, these strata are beginning to pass into a western facies, the Chagrin magnafacies. Yet farther east in the Bradford-Olean area the more typical Oswayo formation is better known. Hence rather than use the Riceville in a formational sense as others have done (Caster, 1934, Chadwick, 1933; Dickey, 1941) the present writer would prefer to employ the term Riceville in an age-stage sense of the

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modern nomenclature to rank in a similar way with the Venango age (stage) in the Conewangoan epoch (series). This however, leaves the western "Riceville shale" in Chagrin facies (Caster, 1934, p. 95,98) without a formational name. Greiner (1957, Fig. 4) has merely called this "Riceville" shale. Pepper, De Witt, and Demarest (1954) have reverted to White's original usage.

The Venango was named by Ashburner (1880, p. 72) as the "Venango oil sand group." Carll (1880) later used the term in a different sense, employing it for all the rocks between the Crawford (Meadville) and the Warren Oil sand group, well down in the Chautauquan. White (1881) also spoke of the "Venango Oil Sand Group" or the "Venango Group" (p. 101) and used the term for the beds below his "Riceville shale" down through the "Venango Lower Sandstone" or Panama conglomerate (see Fig. 6). Since White's time the Venango has been used rather consistently (Chadwick, 1923; Caster, 1934; and Chadwick, 1935a) as a term to include all the rocks between the base of the Riceville and the base of the Panama conglomerate (Wolf Creek conglomerate, Le Boeuf conglomerate). Only Chadwick (1933) wavered briefly from this opinion when he included the Riceville in the Venango. Fortunately he later forsook this contention (1935a, p. 329). Hence the writer advocates the usage of Venango as a time and time-rock term rather than as a group (rock) term. The Conewangoan series, then, is composed of the Venangoan stage and the

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younger Ricevillean stage.

The Mississippian portion of the "Bradfordian" would needs be included in the Kinderhookian series since this name is universally applied in North America to the basal Mississippian series. The "Oil Lake series" (Caster, 1934, p. 46 et seq.) if it is to be used, should be retained in a subseries or stage sense. The next higher subseries or stage within the Kinderhookian of this area is the Crawford. Divisions of the Kinderhookian series in the Penn-York Embayment then, would be the older Oil Lake subseries below, and the Crawford subseries above.

The use of the name Oil Lake for this part of the column is a restriction of White's (1881, p. 67) original "Oil Creek Lake group" which included strata of the Riceville below. In editorial notations on White's report, Lesley shortened White's cumbersome name to simply "Oil Lake". Carll (1880, p. 159) proposed the name "Crawford shale" to include all of the strata from the base of the Riceville through the Mississippian Shenango sandstone. The following year White restricted Carll's term to include only the strata between the Berea and the Shenango sandstones; but for many years following this, the term was not used, since most workers in the area believed that the "formation" included too much. Caster (1934, p. 45-46) has said, "The supra-Berea strata in northwestern Pennsylvania through the Shenango shale are

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TABLE 1. - Stratigraphic units of the Penn-York Embayment employed in this paper

RANK	UNIT	AUTHOR	DATE	TYPE LOCALE
System	MISSISSIPPIAN			
Series	Kinderhookian	Meek & Worthan	1861	Kinderhook, Pike Co., Illinois
Subseries	Crawford	Carll	1886	Crawford Co., Pennsylvania
Subseries	Oil Lake	White	1881	Oil Lake Creek, Crawford Co., Pa.
Formation	Corry	White	1881	Colegrove quarry, 1 mi. south of Corry, Erie Co., Pa.
Formation	Tidioute	Caster	1934	Dennis Run near Tidioute, Warren Co., Pa.
Formation	Knapp	Glenn	1903	Knapp Creek, Cattaraugus Co., N. Y.
Member	Cobham congl.	Caster	1934	Henry Cobham monument, Glade Warren Co., Pa.
Member	Wetmore congl.	Caster	1934	Hills between Wetmore and Ludlow, McKean Co., Pa.
Member	Kushequa shale	Caster	1934	Quarries at Kushequa, McKean Co., Pa.
"zone"	Marvin Creek coquinoid	Ashburner	1880	Marvin Creek valley, McKean Co., Pa.
System	DEVONIAN			
Series	Conewangoan	Butts	1908	Hills along Conewango creek in Warren Co., Pa.
Stage	Ricevillean	White	1881	Bluffs west of Riceville, Crawford Co., Pa.
Formation	Oswayo	Glenn	1903	Hills along Oswayo Creek, Cattaraugus Co., N. Y.
Member	Roystone coquinoid	Caster	1934	Hills between Roystone and Ludlow, McKean Co., Pa.
Stage	Venangoan	Ashburner	1880	Venango Co., Pennsylvania
Series	Chautauquan	Clarke & Schuchert	1899	Chautauqua Co., New York

a very closely related sequence", and has revived the term Crawford in a time-stratigraphic sense to embrace this sequence.

In order to preserve as much as possible Caster's terminology the names Oil Lake and Crawford are here provisionally retained as subseries of the Kinderhookian rather than stage terms to avoid confusion with Caster's Cussewago, Berea, Meadville, and Shenango stages. Since the faunas are so poorly known, the time does not yet seem ripe for subdivision of this part of the column into stages and these "stages" of Caster are herein rejected.

Devonian formations. -- The Oswayo formation lies immediately below the Devonian-Mississippian boundary and was named by Glenn (1903, p. 978) for "greenish limonitic shales" to which he ascribed a thickness of 160-250 feet, overlying the "Cattaraugus redbeds". Although Glenn did not definitely state a type section, the type area is normally taken as the hills along Oswayo Creek, Potter County, Pennsylvania. Both Glenn and Caster report that some of the better exposures in the type region occur in the vicinity of Knapp Creek village, Cattaraugus County, New York. One of the best and most accessible exposures is to be found along New York highway 16A south of Olean, New York, at the top of the hill on the way to Rock City (See locality 1 of this report. At this locality the writer measured a

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thickness of 153 feet of Oswayo. Sections of Oswayo measured by the writer along Fourmile Creek road north of Knapp Creek village (locality 130), along Pennsylvania highway 646 southwest of Knapp Creek (locality 109), and by Caster along Pennsylvania 546 south of Knapp Creek, gave thicknesses of 195 feet, 190 feet, and 180.5 feet respectively for the Oswayo (see Fig. 8). The Oswayo retains its typical character of this area throughout much of McKean County, occurring high on the hills south to the Marvin Creek area near Smethport and thence to the McKean-Elk County line where the sandstones take on the slightly reddish tinge of the next eastern-most magnafacies, the Smethport. The Oswayo retains its typical character west through Ludlow in western McKean County and thence to the Warren area; it is thinner in this area, and southwest from Warren it begins to take on the nature of the "Riceville" shale of the Chagrin magnafacies to the west.

Throughout much of this area where the Oswayo is typically developed, an outstanding feature is the repeated occurrence of fossiliferous, coarser sandstone bands or "coquinites" (coquinoids). Fragments of fossil shells are so crowded in these bands as to cause them to have been termed limestone; whereas in reality they are medium to coarse grained and shell fragments cemented by calcite and extremely fine grained ferruginous mud.

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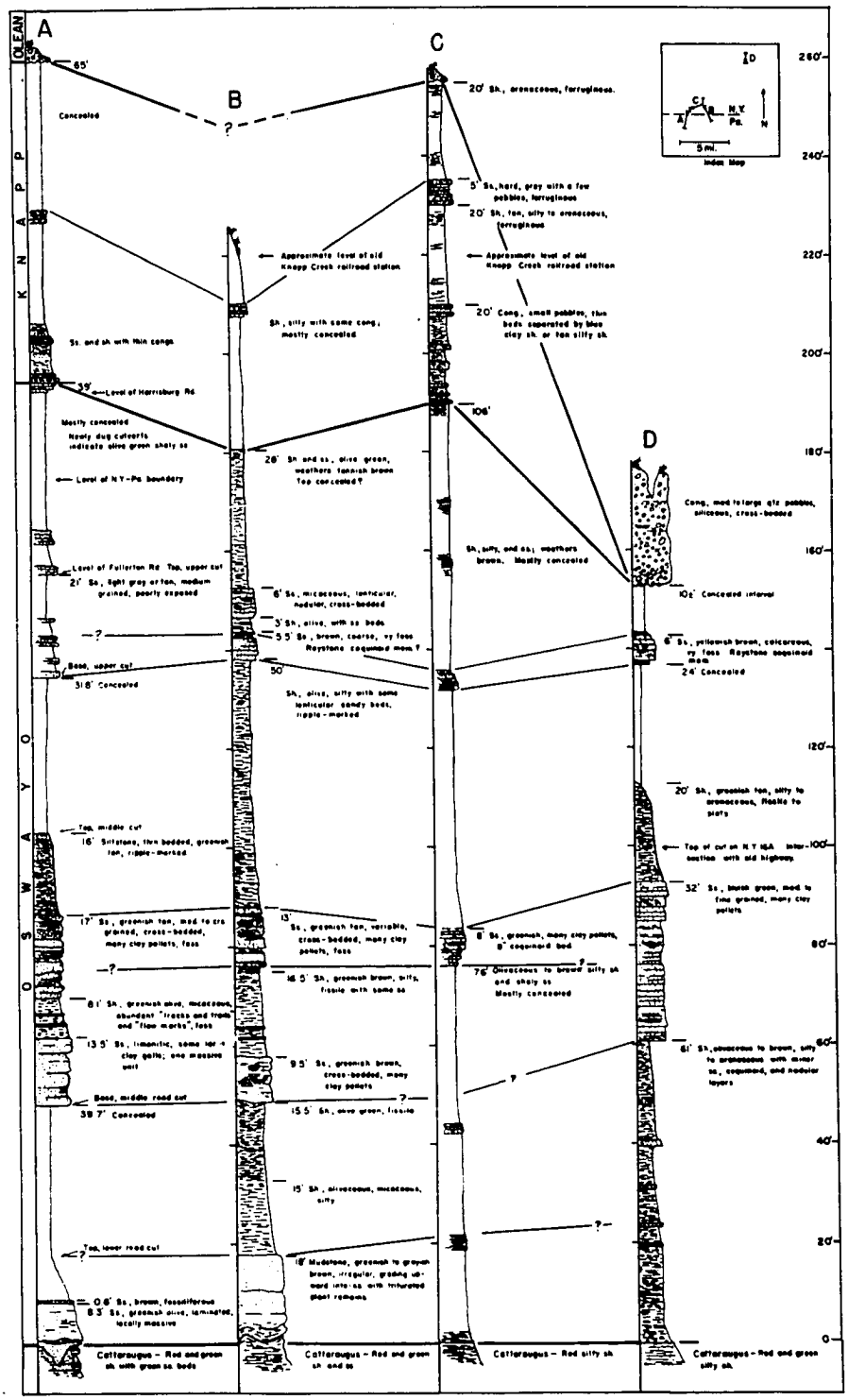

Fig. 8. - Sections of the Oswayo and Knapp near Knapp Creek, New York. The inset shows the relationship of the sections with arrows indicating the top of the sections. Section A is locality 109; B was measured on Pennsylvania highway 546 southeast of Knapp Creek (after Caster, 1934, p. 100-101); C is locality 130 (type section of the Knapp after Glenn, 1903, p. 981); D was measured along New York highway 16A just west of locality 1.

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Ashburner (1880, p. 68069) named one of these coquinoids the Marvin Creek limestone from its development in the Marvin Creek Valley. Ashburner did not cite a definite type locality, but indicated two places where this limestone might be seen; one along "Shepherd run" in southern Bradford township (along U.S. highway 219, southwest of Custer City, Bradford quadrangle) and the other on the "western slope of Chappel hill, in the northern part of Sergeant township" at an elevation of about 2080 feet. He gives the thickness at the former locality as 2 feet and at the latter as 5 feet. Glenn (1903, p. 979) presumed that the prominent and persistent coquinoid zone of the Oswayo to be seen at locality 1 of this report was the same as the Marvin Creek limestone of Ashburner. Caster (1934, p. 97) named the Oswayo coquinoid the "Roystone Coquinite zone" saying that it had frequently been mistaken for the overlying Marvin Creek limestone. In this regard, he says (p. 105),

> . . . it is utterly impossible to differentiate which one of the many limestones Ashburner saw on Marvin Creek when he denominated it. At least two separate lenses of limestone in the Kushequa occur along Marvin Creek. They are both of similar lithology and simply represent the reoccurrence of similar conditions at brief intervals in the midst of Kushequa time. Taken as a whole they represent a zone.

Fettke (1938, p. 33) has taken exception to Caster's designation of the persistent Oswayo coquinoid zone as the Roystone and to his placement of the Marvin Creek in the Kushequa. Fettke says,

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> Along Sheppard Run the limestone crops out in a cut on the southeast side of the new State highway about 1½ miles above Custer City. It is 2½ feet thick and lies about 60 feet above the highest exposed red shales of the Cattaraugus formation. East of Marvin Creek valley on the west slope of Chapel Hill along Irons Hollow road, about 1½ feet of the five feet of limestone, which Ashburner designated as the Marvin Creek, are exposed. The horizon is between 60 and 70 feet above the highest red bed of the Cattaraugus formation.

In 1955 the writer visited both of the localities mentioned by Fettke and found that the Sheppard Run exposure was then covered. Up the Irons Hollow road about 2.2 miles southeast of U.S. highway 6, the writer found 3.6 feet of calcareous sandstone with abundant, but badly broken and unidentifiable, Cyrtospirifer about 50 feet above the red beds. This is but one of at least three coquinoid zones to be found along the Irons Hollow road, but is some 100 to 110 feet below the 2080 foot elevation given for the Marvin Creek by Ashburner.

Thus the writer agrees with Caster that it is difficult, if not impossible, to differentiate at this time between the "limestones" which Ashburner had in mind. Since Ashburner suggested that it is probably the same as "Lower Meadville limestone" of Crawford County, it is likely that Ashburner had in mind a zone within the Mississippian. Also, since other writers (e. g. Greiner, 1957) have accepted Caster's terminology for these coquinoid zones, the writer also employs this terminology. Only mapping and carefull field tracing will decide which of these interpretations is correct. This remains one of

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the unsolved problems in Penn-York Embayment stratigraphy.

Mississippian formations. -- Glenn (1903, p. 980-982) proposed the term "Knapp beds" for two thin conglomerates interbedded with shale in the southern part of the Salamanca and Olean quadrangles, New York. He said that the Knapp formation extends over a large area in northwestern Pennsylvania and he identified it as the conglomerate previously known as the "Subolean". Glenn did not definitely cite a type locality, but described what he believed was the easternmost exposure of the formation at "Knapp's Creek station" (the present village of Knapp Creek, New York). He said (p. 981),

> Here there are two course beds separated by a varying thickness of shale. In the gutter beside the road leading from Knapp's Creek Station down into the head of Fourmile creek, in the interval from 20 to 40 feet below the station level, is found a thin bedded gritty to pebbly sandstone heavily charged with iron and containing marine invertebrate fossils. The layers are separated by partings of blue clay shale. A few hundred yards west of the station along the electric road just before reaching the summit there is a second sandstone about 40 feet higher than the first one, the interval between being occupied by sandy ferruginous shales. This sandstone is hard and gray and rings under the hammer. It is bedded in layers a few inches thick, some of which contain a few pebbles. The layers are separated by ferruginous sandy shales. It is also fossiliferous, bearing among other forms, Syringothyris. Above it are perhaps 20 feet of shale before the base of the Olean is reached. Beyond the summit one passes down through the same succession in reverse order, the upper sandstone being 20 feet thick and the lower coarse bed consisting of 20 feet of thin conglomerate and sandstone interbedded with shale, the pebbles being chiefly of wheat grain size.

The section on Fourmile Creek road north of the

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village of Knapp Creek is generally taken to be the type section (locality 130); a poorer exposure of a type section today can scarcely be imagined. Down this road, the upper part of the exposure is badly covered with glacial drift and a partion of the road ditch has been lined with a stone and cement gutter. Farther down the exposure slump, creep, and overgrowth have obscured all but the most resistant beds. A section measured on Fourmile Creek road by the writer in 1955 is given as Section C in Figure 9. The old station mentioned by Glenn was diagonally northwest across the highway from the present Knapp Creek post office; the electric railroad (Bradford Division of the Western New York and Pennsylvania Railroad) ran behind the present Knapp Creek fire department, north of New York highway 16A and came out onto the present highway 0.4 mile farther west where New York highway 16A turns south toward Bradford. The highway then follows the old trolley road south toward Bradford past the state line and on down the hill. Lower on the hill, highway construction has only deepened and widened the road bed of the trolley line to make New York highway 16A and Pennsylvania highway 646. The beds which were available to Glenn for examination along the trolley right-of-way in Knapp Creek are today badly overgrown and obscured. Nevertheless, the few outcrops which are available indicate that the information as presented by

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Glenn is essentially correct. An excellent exposure of the Knapp conglomerate (presumably the lower) is to be seen northwest of the junction of Harrisburg road and New York highway 16A.

In 1934 Caster (p. 103) extended the Knapp downward to include the arenaceous shale below the lower conglomerate of the Knapp. Although this shale is poorly exposed in the vicinity of Knapp Creek, New York, it thickens to the south where is carries the Marvin Creek zone of coquinoids (described above); this shale bears a Mississippian rather than a Devonian fauna and should thus be allied with the Knapp rather than the not dissimlar Oswayo below. Caster, (1934) named this shale the Kushequa from the excellent exposures in the old quarries along Kinzua creek near the village of Kushequa, Pennsylvania. Still farther south, at the southern limit of Johnsonburg, Pennsylvania, on U.S. highway 219 (locality 97) the calcareous sandstones of the Marvin Creek zone in the Kushequa are richly fossiliferous and carry an abundant and well preserved brachiopod fauna.

Glenn (1903, p. 980) suggested that the two conglomerates in the Knapp at Knapp Creek village continued northeast and were "doubtless in part at least the equivalents of the grits and shales just beneath the Olean at rock city and which are included in the Oswayo", but measured sections (see Fig. 8) clearly imply that

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these conglomerates are simply cut out by pre-Olean erosion northeast of Knapp Creek, and that they overlie the Oswayo and are in no part equivalent to it. This is also suggested by the persistence of these conglomerates southwest of the type section where both Glenn and Fettke (1938) report the conglomerate at a number of localities. Seemingly, conditions which determined the supply of pebbles to these conglomerates and conditions which governed the local deposition varied considerably at different times and localities; for, although both conglomerates thicken considerably to the southwest of Knapp Creek, the interval between the local exposure of a particular Knapp conglomerate and the known Oswayo below varies considerably. This suggests that at one place the lower conglomerate seems to be present while at the next place it may be the upper one. Fettke (1938, p. 27) reports that not more than one conglomerate was observed at any one locality over much of the Bradford quadrangle, and both Fettke and Glenn have suggested that it is likely that the lower conglomerate of the type section is the one which is the more persistent. Caster (1934, p. 111) suggests that, "the upper of the two conglomerates is the most extensive." He based this on the great thickness of what is presumably the upper conglomerate at Cobham Hill, Warren, Pennsylvania, and his belief (probably erroneous as will be shown below) that this conglomerate

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could be traced west into Ohio as the Cussewayo sandstone. Since there are two coarser sandstones carrying abundant syringothyrid brachiopods below the conglomerate on the Yankee Bush Hill, northwest of Warren it does, indeed, seem likely that it is the upper conglomerate which persists to Warren and that the lower conglomerate is replaced by the upper of the two syringothyrid zones. Thus, the lower syringothyrid zone represents the Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp.

Caster (1934, p. 111) named the lower conglomerate of the Knapp, the Wetmore conglomerate member, from exposures along the face of the hills between Wetmore and Ludlow, Pennsylvania. The Wetmore conglomerate is not definitely identifiable in the Johnsonburg area; although at locality 97, Caster (p. 112) has suggested that it may be the lenticular sandstone lying above the Marvin Creek coquinoid zone near the base of the section there. The writer has observed 3-4 mm quartz pebbles in the Marvin Creek coquinoid zone (see measured section of Caster, 1934, p. 111) of the Kushequa at locality 97 however, and it is possible that the Wetmore or lower Knapp conglomerate and the Marvin Creek zone of the Kushequa have come together at this locality.

Caster (1934, p. 113) has named the upper conglomerate of the Knapp, the Cobham conglomerate member, from the thick exposure on Cobham Hill, southeast of Warren at Glade, Warren County, Pennsylvania. There, this

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conglomerate is 50-75 feet thick and is well seen at the Henry Cobham monument.

In the five miles or so northwestward from Cobham Hill to the general upland of the Yankee Bush Hill northwest of Warren, the Cobham changes from a medium to coarse grained conglomerate to a conglomeratic sandstone or "millet-grained" granule conglomerate. It is this texture which Caster believed allied the Cobham with the Cussewago sandstone of Ohio. De Witt (1951) and Pepper, De Witt, and Demarest (1954, p. 21) show that the Cussewago sandstone disappears eastward from the section near Riceville, Pennsylvania, and they say:

> The Cussewago sandstone is separated laterally from Caster's Cobham conglomerate member of the Knapp formation by a belt of shale and therefore is not the western part of the Cobham.

They also show (p. 39-40 that the Cussewago was deposited from a different direction than the Knapp and Corry.

Caster (1934, p. 112) applied the name East Kane shale member to the olivaceous shale "highly reminiscent" of the Kushequa shale which he believed to overlie the Wetmore conglomerate and hence separate the two Knapp conglomerates. He said (p. 112) "In some places along Kinzua Creek the East Kane shale is apparently lacking, and the two Knapp conglomerates are in disconformable contact."

The extent and nature of the "East Kane shale" are not well known and the relationship of this shale to other shales in the Knapp of the Warren and Bradford,

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Pennsylvania, areas is not clear. 'Since the "East Kane shale" does not seem distinctive and the shale which separate the syringothyrid zones on Yankee Bush Hill and other collecting localities in northwestern Pennsylvania do not seem to be abundantly fossiliferous, the appellation "East Kane shale member" does not seem necessary and is not herein employed. It is possible that the thick shale of the Kane, Pennsylvania, area occurs far higher in the Mississippian section than was originally believed by Caster, and that it is not part of the Knapp formation.

In a broad arc from Johnsonburg, through Tidioute, to Corry, Pennsylvania, the Lower Mississippian formations are difficult to interpret. The conglomerates of the Knapp in the Bradford-Warren area thin throughout this arc south, southwest, and west of Warren. The conglomerates do not seem to reach the Johnsonburg area nor are they present in the Dennis Run section southwest of Tidioute; and Caster (1934, p. 114) states that the Cobham conglomerate is present in no more than "local pockets" of pebbles west of Warren. Throughout the area of this broad arc is a sequence of micaeous, olivaceous shale and shaly thin-bedded sandstones which appear quite different from the Lower Mississippian shales along the meridian of Kushequa and Bradford. This situation is well illustrated in the Dennis Run section southwest of Tidioute, Pennsylvania where Caster (1934, p. 117) has applied the name Tidioute shale to Units 5, 6, and 7 of

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his measured section (p. 120).

The difficulty comes in trying to trace this shale unit northeastward and relate it to the syringothyrid-bearing beds and the Knapp conglomerates of the Warren area. On Yankee Bush Hill, northwest of Warren, Caster (p. 116 et seq.) states that the Tidioute shale overlies the Cobham conglomerate and bears the rich echinoid faunule described by Jackson (1912). Caster (p. 117) says,

> On the top of Clark Hill (Clark farm), first of the small knob-like hills rising above the common level of the Yankee Bush, on Trapezoidal Hill (so-called from its geometric shape), and Cemetery Hill about two miles north of Warren are patches of Tidioute shale . . . .

This is difficult to reconcile with his earlier (p. 115) statement that the conglomeratic sandstone of the Cobham "caps the many peculiarly pyramidally shaped hills along the Yankee Bush road". This latter statement seems best to fit the actual case, for conglomeratic sandstone (the Cussewago lithology of Caster) goes clear to the top of Trapezoidal Hill and to within approximately ten feet of the top of "Cemetery Hill" (site of Yankee Bush Cemetery); the rest of the latter hill is covered but is presumed also to be of the loosely cemented Cobham conglomerate. Below this high level of conglomeratic sandstone olivaceous, mica-flecked shale bearing echinoderm fragments extends downward to the level of the upper syringothyrid-bearing sandstone. At this level this

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micacous shale is seen to blanket the fossiliferous sandstone (coquinoid) in extensively ripple-marked beds.

The interval between the upper syringothyrid coquinoid and the Cobham is thus seen to be olivaceous, micaceous shales and siltstones very like the Tidioute shale at its type section. Thus a thin finger of Tidioute shale is seen to extend northeastward from the type section to the Warren area and come to lie between the upper syringothyrid zone and the Cobham conglomerate. At other places Caster definitely reports the Tidioute on top of the Cobham for he says (p. 116),

> At Glade, Warren County, on the Allegany River, the Corry sandstone has been mapped as immediately overlying the Knapp upper conglomerate (Cobham). This is not actually the case, for about from 10 to 15 feet of Hayfield shale (Tidioute) intervene.

Thus we have the picture of the Knapp conglomerates feathering out to the southwest and west and the irregularly bedded arenaceous Knapp shales of the Kushequa type in the Warren-Bradford area being replaced to the southwest and west by shales of the Tidioute type. At Warren, one sees the northeasternmost advance of these latter shales interfingering with the Knapp and at last coming to lie between the Knapp and the Corry sandstone on Cobham Hill southeast of Warren. These latter shales are of markedly different type than the typical Knapp shales of the type area and bear the same relationship to the Knapp formation that the "Riceville shale" bears to the Oswayo of the Bradford area. Thus the Knapp formation of the Big Bend

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magnafacies can be seen to be passing westward into the shaly Chagrin magnafacies even as the Oswayo formation of the Big Bend magnafacies passed westward into the Chagrin magnafacies below it. Although the facies relationships herein described are not as readily apparent southwest of Warren because of the general paucity of outcrops and because of the gross similarity of the shales of the Chagrin magnafacies to the shale of the Big Bend magnafacies, to one familiar with the stratigraphy of this area, the situation described above is fully as striking an example of lateral facies relationships as is the more familiar "red bed" facies relationships farther east.

The stratigraphic relations outlined above present a picture consistent with the work of Pepper, De Witt, and Demarest (1954) despite the words of these authors (p. 24-25). Caster (1934) has included in his Hayfield "monothem", and upper unit, the Hayfield shale of Chadwick (1923, 1925; restricted) and a lower unit, the Tidioute shale. It is this upper "Hayfield shale" of Chadwick which Pepper, De Witt, and Demarest say (p. 25) "cannot possibly extend east of Meadville to the Allegany River." It is also this upper shale which these writers have identified with the Bedford, thus rejecting the names "Cussewago shale and Hayfield shale" as well as the names "Cussewago limestone, Hayfield limestone, or Littles

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Corner limestone" of Caster. While Caster (1934, p. 116) probably implied a too great westward extension of his Tidioute shale along with the "Hayfield monothem" west past Hayfield, Pennsylvania, this does not invalidate the use of the term Tidioute for shales between the Allegany River and the Meadville area, since Caster definitely stated that these were below the Hayfield shale of Chadwick. Pepper, De Witt and Demarest (1954, Plate 5) show the Corry sandstone in eastern Crawford County lying directly on the "Riceville shale". Thus the Tidioute shale is presumably lost long before its gets to the Meadville area in the limbo of their "Riceville shale" of the old usage of White (1881). The Tidioute then, is one of the formations of the vast belt (Chagrin magnafacies) of shales mentioned by these writers which separate the Cobham conglomerate from the Cussewago sandstone of eastern Ohio and extreme western Pennsylvania. These writers have clearly shown that the Cussewago is different from the Knapp and was derived from a southeastward source while the Knapp and Corry were derived from the northeast. They show (p. 40) on the Pennsylvania-Ohio line the convergence of three deltas with different directions of deposition - a northern Bedford (and Berea) delta lying mostly in Ohio, a southeastern Cussewago (Murrysville) delta, and a Knapp delta to the northeast.

In early Mississippian time the building of these three deltas then, constricted this northeastern portion

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of the Mississippian Penn-York Embayment into an arm of the sea which they term Corry Bay. The paleogeographic maps included at the end of their paper clearly show the relationship of this bay to the Mississippian epicontinental sea. These maps do not extend far enough eastward, however, to encompass the Warren-Bradford area; nor can detailed paleogeographic reconstructions of this area be undertaken until more complete faunal and stratigraphic analyses are made. Nonetheless, it is in this bay between converging deltas that the Tidioute shale was deposited, and it was within this bay that the Upper Devonian and Lower Mississippian organisms lived and evolved, thus restricted from the epicontinental sea beyond.

The present writer has undertaken to describe the brachiopod faunas of the Oswayo formation and the Knapp formation in their type areas. These formations nearly completely lie within the Big Bend magnafacies and are thus delimited from the red and chocolate sediments of the Smethport magnafacies to the east and the shales of the Chagrin magnafacies to the west. Only occasionally (as in the case of the red color of the Oswayo formation at locality 253 and in the case of the Tidioute shale in the Warren area) do these formations take on the aspects of the next adjacent magnafacies. Essentially, then, the Oswayo and Knapp formations constitute two parvafacies within the Big Bend magnafacies. The Oswayo formation is separated from the lower

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Conewangoan below by the plane of contemporaneity which bounds the Venangoan and the Ricevillean stages and above by the time plane which separated the Devonian from the Mississippian. In like manner, the Knapp formation is separated from the Oswayo by the Devonian-Mississippian time plane and from the Corry above by the plane which divides two yet unnamed Kinderhookian stages, since Caster's Cussewago and the Berea stages are rejected because of their current lithologic connotations in Ohio.

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REGISTER OF COLLECTING LOCALITIES

The numbers listed below are those assigned to collecting localities by Dr. K. E. Caster as outcrops were visited and hence do not imply stratigraphic sequence nor geographic relationships. In order to preserve continuity between this paleontologic study and the original stratigraphic work (Caster, 1934) the locality descriptions have largely been taken from his personal catalogue with only minor rewording. Most of these localities have been visited by the writer, and additional material has been added from some without distinguishing it from that collected by Dr. Caster. At most of the localities more section is exposed than is indicated here; but the fossils described come from the formation, member, or "zone" given.

LOCALITY 1 - Ditch and roadcut exposures east of abandoned asphalt highway just north of turn to east in present gravel road, east of New York highway 16A at top of hill about two miles north of Rock City, Cattaraugus County, New York. Roystone coquinoid member of the Oswayo formation.

This is near Flatiron Rock on the Olean, New York quadrangle. The lower part of the Oswayo crops out on

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New York highway 16A just north of the turn east onto the present gravel road, and the fossiliferous part of the formation crops out along the old macadam road east of the modern highway. This is the site of the old Flat Iron Station on the trolley route from Olean to Rock City. Remnants of the trolley tracks are still to be found among blocks of Olean conglomerate and Oswayo in the woods between the highway and the old road.

LOCALITY 51 - Pipeline ditch to east of gravel road about 500 feet south of crossroads in Rew (Bradford quadrangle), McKean County, Pennsylvania. This locality is no longer available. Sandstone in the Kushequa member of the Knapp formation.

LOCALITY 59 - Poor exposure in tree holes and small gullies in pasture near summit of "Devil's Den Hill", south of Smethport (Smethport quadrangle), McKean County, Pennsylvania, (same as locality 161). Shale and sandstone in the Oswayo formation.

LOCALITY 60 - Abandoned ceramic quarry of the former Kane Brick and Tile Co. between East Kane and Sargeant (Kane quadrangle), McKean County, Pennsylvania.

Sandstone and shale of the Oswayo formation crop out here north of the main road in front of the old plant and the Knapp formation forms the quarry wall behind the plant. The members of the Knapp could not be differentiated by the present writer and no identifiable fossils were found

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in the Knapp here.

LOCALITY 91 - Loose on Yankee Bush Road below crest of hill about 1½ miles south of Chandlers Valley (Youngsville quadrangle), Warren County, Pennsylvania. Cobham conglomerate member of the Knapp formation.

Locality 97 - Stone Haven Mix Co. (formerly Yingling-Martin Brick Co.) quarry east of U.S. highway 219, south edge of Johnsonburg (Ridgeway quadrangle), Elk County, Pennsylvania.

Rather complete section extending from the lower part of the Knapp formation up to the Pennsylvanian. Fossils included herein from this locality come from a four foot zone of calcareous, conglomeratic sandstone (Marvin Creek coquinoid zone) in the Kushequa member of the Knapp formation (unit number 3 in the measured section of Caster, 1934, p. 111). When the calcite shells and the calcareous cement are leached out, the framework remaining is mostly fine to medium grained sandstone, cemented by very fine limonitic clay. The limonitic sandstone thus formed is difficult to tell from certain beds higher in the Knapp section. The mixing of the faunules is believed relatively slight, however, and even if it occurred there is only approximately 70 feet of Knapp involved. High strata appear well back from the lip of the quarry on an upper level so that all of the fossils on the highway level must be Knapp even if not the Marvin Creek zone.

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LOCALITY 109 - Road cuts east of Pennsylvania highway 646 from 0.95 mile south of Pennsylvania-New York boundary north to Harrisburg Road (0.25 mile north of boundary); (Bradford and Salamanca quadrangles), McKean and Cattaraugus Counties, Pennsylvania and New York respectively. Section extending from the "Cattaraugus" formation through the Oswayo and Knapp to the Olean conglomerate of the Pennsylvanian. The majority of the fossils from this locality described herein came from the greenish sandstone unit some 80 feet above the base of the measured section (see section A, Fig. 8).

LOCALITY 118 - Road surface (and nearby field outcrops) in Bunker Hill Road 0.2 mile west of Stone Hill Road, Bunker Hill, north of Warren (Warren quadrangle), Warren County, Pennsylvania. Lower (First) Syringothyris zone of the Knapp formation.

LOCALITY 119 - "Clark Hill", west side of the Yankee Bush Road, about 2-2½ miles north of Warren (Warren quadrangle), Warren County, Pennsylvania. Upper (Second) Syringothyris zone (Cobham conglomerate?) of the Knapp formation. Tidioute shale is here interbedded with conglomeratic sandstones of the Cobham (?) member.

LOCALITY 121 - Outcrops along road near top of Stone Hill, southeast of Warren (Warren quadrangle), Warren County, Pennsylvania. Lower (First) Syringothyris

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zone of the Knapp formation.

LOCALITY 130 - Ditch exposure west of road leading down Fourmile Creek valley, north of Knapp Creek (Olean quadrangle), Cattaraugus County, New York. Section extending from the "Cattaraugus" formation through the Oswayo into the lower Knapp formation. This is the type section of the Knapp formation (section C, Fig. 8).

LOCALITY 161 - Same as locality 59.

LOCALITY 166 - Cut on abandoned railroad north of Pennsylvania highway 59, 2 miles west of Smethport (Smethport quadrangle), McKean County, Pennsylvania. Kushequa shale member of the Knapp formation.

LOCALITY 175 - The now abandoned E. K. Kane Co. quarry on Kinzua Creek, east of Kushequa (Bradford quadrangle), McKean County, Pennsylvania. Kushequa shale member (type locality) of the Knapp formation.

LOCALITY 183 - Road cut north of U.S. highway 6, $\frac{1}{4}$ to $\frac{1}{2}$ mile west of Ludlow (Kane quadrangle) McKean County, Pennsylvania. Roystone coquinoid member (type area) of the Oswayo formation.

LOCALITY 198 - Road side and cemetery excavation, Yankee Bush Cemetery ("Cemetery Hill" of Caster, 1934) on Yankee Bush Hill, northwest of Warren (Warren quadrangle), Warren County, Pennsylvania. Tidioute formation.

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LOCALITY 199 - Loose blocks and poor field outcrops at intersection of Weiler, Logan, and Yankee Bush roads 0.75 miles northwest of Yankee Bush Cemetery on the Yankee Bush Hill, northwest of Warren (Warren quadrangle), Warren County, Pennsylvania. Lower (First) Syringothyris zone of the Knapp formation.

LOCALITY 201 - "Trapezoidal Hill" (Caster, 1934, p. 117), 0.1 mile northwest of the junction of Bunker Hill and Follett Run Roads on the Yankee Bush Hill, northwest of Warren (Warren quadrangle), Warren County, Pennsylvania. Tidioute formation.

LOCALITY 202 - Ditch and roadcut exposures along Pennsylvania highway 127, along Dennis Run, about 1 mile southwest of Tidioute (Tidioute quadrangle), Warren County, Pennsylvania. Tidioute formation.

LOCALITY 253 - Deep roadcut on east side of U.S. highway 219, 1.9 miles north of Elk-McKean County boundary (Mt. Jewett quadrangle), McKean County, Pennsylvania. Red sandstone (probably about the horizon of the Roystone coquinoid member) in the Oswayo formation.

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METHODS EMPLOYED

Molds and casts. -- The Upper Devonian and Lower Mississippian strata in the Penn-York Embayment are justly famous for the excellence of preservation of the contained fossils, especially the brachiopods. The fossils of the shalier beds may have very delicate structures minutely preserved, but are commonly badly distorted. On the other hand, the more rigid framework of the coarser sandstone and conglomerate beds usually protects the fossils from very great distortion due to compaction. Many of these sandstone beds (e.g. the Roystone coquinoid member of the Oswayo formation) are calcareous and the brachiopod shells of these beds are very well preserved, although the shell may be exfoliated upon fracture of the matrix. Near the surface and along bedding planes and joints, however the calcite is usually removed by solution leaving excellent molds and casts. This combination of circumstances, i.e. the preservation of both shell and readily accessible internal structure (as molds of the interior), is especially fortunate for the study and classification of brachiopods.

Molds and casts are defined with reference to the hard parts of the organism. Thus, a cast, either natural or artificial, is an exact reproduction of the original shell and associated internal structures. A mold, then,

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whether natural or artificial, is the form or impression from which this reproduction may be made. Obviously, there may be molds of the interior or molds of the exterior of the brachiopod shell, and likewise there may be casts of either surface. Unless one considers the common permineralization (infiltration of mineral matter in minute voids of the shell, recrystallization, or molecule by molecule replacement of the shell substance) of a natural cast, natural casts are extremely rare (that is, gross replacement of the shell material, without interference from surrounding or included rock material which has occupied the place of the soft parts, rarely occurs in nature. The result is that the original shell, perhaps slightly permineralized, or molds of the exterior or molds of the interior is the material with which the paleontologist generally works.

It should be noted that in the terminology of molds and casts there is no direct reference made to whether the surface is concave or convex; in other words, the only consideration is whether the shell itself is exactly duplicated (cast) or whether one is dealing with the impression or form from which the shell <u>might</u> be reproduced. (mold). The more cumbersome expressions, mold of the exterior and mold of the interior, are hrerin employed instead of the surfically simpler "external mold" and "internal mold". This is done to avoid the confusion of the terms "internal mold" (mold of the interior) and "cast" (mold of the interior) so rampant in the literature. One

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should realize that a mold of the interior of a brachiopod shell is mostly composed of convex surfaces and hence simulates a cast of the exterior. This has lead many workers to call this "interior mold" a "cast". One should also eschew the term "impression" for an artificial cast. It is realized that the act may involve the taking of an "impression", but the result is still a cast.

In collecting the material studied a great deal of rock was cracked in the field and the best preserved and most complete specimens were there selected. In addition, many rock slabs were brought into the laboratory for preparation and detailed examination. Almost all of the material including the rock matrix to be discarded was passed under the microscope in the search for structural details and small specimens which might otherwise be overlooked. Rubber casts were made of virtually all the molds of the interior and exterior. Molds of the interior and exterior of the same specimen and the artificial casts were made therefrom and kept carefully correlated. These were compared for external morphology with whole specimens bearing the original shell material. Specimens which had thus been grouped by external morphology were then "back-checked" by grinding sections or by etching away the shell from the sandstone matrix and making artificial rubber casts and then comparing the results with rubber casts made from naturally etched molds of the interior and exterior. Thus, the greatest possible amount of correlation between

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external and internal morphology was at all times employed, and this made the material (especially that from the Roystone coquinoid member of the Oswayo formation) a delight to study.

Laboratory techniques. -- The rubber casts were made by first applying black Permamold (a liquid latex molding compound No. 61-305 obtained from the Polymer Chemical Co. 5920 Carthage Ave., Cincinnati 12, Ohio) thinned to water consistency and then applying successively thicker coats until the cast was built up to 1/8 to 1/4 inch in thickness after the technique elaborated by Von Fuehrer (1938) and Baird (1951, 1955). In certain of the samples the first thin coat was applied with a camel's hair brush on a water-wetted surface of the mold (the use of detergent as described by Baird introduced bubbles which the ariter could not eliminate); in other samples better results were obtained by the application of the first thin coat with the brush to a dry surface and then filling the undercut structures by powerful and forceful exhalation on the latex-wetted surface. The second and third coats of slightly thicker latex must also be blown into crevices and undercut areas or bubbles, caused by unoccupied space, will be formed weakening the cast. Undoubtedly use of a technique described by Gill, Caster, and Boswell (1956) would have been a great aid, but the apparatus was not available to the writer. The rubber casts thus prepared were of inestimable value in this study.

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The artificially etched molds of the interior were prepared by the careful painting of very dilute hydrochloric acid on the actual shell material with a thin camel's hair brush. The friable matrix, which was sandstone, partially cemented by calcite, was protected from the acid by prior and repeated coating of Duco household cement (thinned by a thinner especially prepared for this product).

Specimens were prepared for serial sectioning by embedding them with the median axis perpendicular in a small amount of plaster of paris. The small block of plaster of paris provided a better grip on the specimen while grinding and allowed better control in order to keep the sections parallel and at right angles to the midline. The smallest specimens and the extreme rostral portions of larger specimens were carefully sketched on graph paper after measurements of structures under the microscope. The polished surface was greatly clarified to view under the microscope by moistening this surface with a small amount of glycerine applied by the finger from a watch glass kept handy. Rather than use the cumbersome camera lucida, the majority of the specimens were sketched with a sharp pencil directly on very thin tracing paper which had been applied to the glycerine-moistened surface to be sketched. The glycerine so clarified the translucent tracing paper that even small structures, such as the thin bands of spiralia, could be easily traced, directly from the specimen under the microscope. These tracings on

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small pieces of paper were then clipped in a notebook with the recorded measurement of distance from the beak and were later arranged and traced for the final figures. This technique had the advantage of speed, accuracy and working at natural size.

Photographs were taken of the specimens and the black rubber casts after coating each with ammonium Chloride applied by the technique described by Teichert (1948). The stereo-photographs were taken with a stationary camera, but with the specimen mounted on a very small piece of wallpaper cleaner or clay on a simple device demonstrated to the writer by Harold K. Brooks. This consists of two small boards mounted horizontally between two thin upright strips of wood. The upper horizontal board is secured to the vertical strips by a single nail on each side which allows it to rotate on a horizontal axis. An inexpensive plastic protractor is mounted vertically in a saw-slit in the back vertical wooden strip; and a bent nail for use as a pointer, is positioned at the back of the upper board perpendicular to the horizontal axis of rotation. The specimen is then secured to the upper board by the clay and can be photographed with the nail indicator approximately 4° to the left of vertical and then photographed a second time with the nail point reading about 4° to the right of the vertical. When the finished prints are correctly positioned and viewed with a pocket steoerscope, surface

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features are seen in relief. The amount of relief can be reduced by lessening the amount of deviation from the vertical or increased to the point of exaggeration by rotating the upper board through a great angle between photographs.

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BRACHIOPOD FAUNA OF THE BOUNDARY FORMATIONS

The brachiopods of the Devonian-Mississippian boundary formations as represented in these collections are listed with the locality from which they were collected in Table 2. These forms are again listed by locality in Table 3. The occurrence of these forms in the various formations is summarized in Table 4.

From these data the brachiopods in the collections from the Devonian-Mississippian boundary formations are found to be distributed among 47 distinct forms (subspecies, morphological variants, and questionably identified species). The forms are assembled into 25 species which were identified without question, and 37 species are found if questionable and comparative identifications are counted. The species are ranked into 17 genera of which one genus and one subgenus are new.

Of the 25 unquestioned species, seven (28%) occur only in the Oswayo formation, none (36%) occur only in the Knapp formation, and three (12%) occur only in the Tidioute. Thus seven (28%) of the species are restricted to the Oswayo and 15 (60%) new species are added in the Knapp and Tidioute. The species data give strong evidence that the Devonian-Mississippian boundary should be placed

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TABLE 2. - List of brachiopods described herein and the localities from which they were collected

OSWAYO	Locality
Lingula arcta (?) Girty	1
"Lingula" inexpecta, n. sp.	183
Lingulodiscina exilis? (Hall)	1, 60
Orbiduloidea cf. O. alleghania (Hall)	1, 60
Oehlertella pleurites (Meek)	1
Rhipidomella pennsylvanica (Simpson)	60
Camarotoechia allegania (Wms.) s.s.	1, 59, 60, 109, 161, 183, 253
C. allegania obesa, n. subsp.	1, 109, 183
C. allegania lingulata, n. subsp.	109, 183
C. (Spathulata) spathula, n. subg., n. sp.	1, 60, 109, 183
Cyrtospirifer oleanensis Greiner	1, 183
C. oleanensis variant A., n. variant	183
C. extentus , n. sp.	1, 60, 183
C. horridus, n. sp.	1,
C. horridus variant A, n. variant	1, 60?
C. horridus strigosus, n. subsp.	183
C. sp. indeterminate	1, 109, 183
Athyris mardiae, n. sp.	1, 60
Athyris mardiae planaria, n. subsp.	1,
Athyris mardiae sulcula, n. subsp.	1, 60, 109
Athyris thrasyangelica, n. sp.	1, 60
Athyris thrasyangelica magna, n. subsp.	1

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TABLE 2. - Continued

KNAPP AND TIDIOUTE	Locality
Lingula tidioutensis, n. sp.	202
Lingulodiscina exilis? (Hall)	97
Orbiculoidea sp. A.	97
Orbiculoidea sp. indeterminate	202
Oehlertella pleurites (Meek)	97
Lissocrania parvula, n. sp.	97
Rhipidomella pennsylvanica (Simpson)	118, 119, 199, 201, 202
Schuchertella desiderata (Hall & Clarke)	97, 199, 201
Schuchertella, n. sp. A	166
Dictyoclostus dubitatus, n. sp.	97, 198, 201, 202
D. dubitatus variant A, n. var.	97
Chonetes cf. C. setigerus (Hall)	201
Camarotoechia mimelegantula, n. sp.	51, 97, 199
C. cf. C. contracta (Hall)	175
C. sp. indeterminate	91, 201
C. (Spathulata) spathula? n. subg. n. sp.	91
Cyrtospirifer extentus? n. sp.	51, 97
C. warrenensis Greiner	51, 118, 166
C. lobatimusculus Greiner	118, 121, 166
C. lobatimusculus parvus, n. subsp.	51, 118, 121, 166, 199
C. tionesta Greiner	91, 119, 202
"C". plenellus, n. sp.	118, 199
Syringothyris angulata Simpson	51, 97, 121, 166, 175, 199

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TABLE 2. - Continued

KNAPP AND TIDIOUTE cont.	Locality
Syringothyris warrenensis n. sp.	118, 121, 166, 175, 199
Syringopleura casteri, n. sp.	97, 121, 166, 175
Cyrtina triplicata Simpson	201
Proeumetria acroria, n. gen., n. sp.	51, 97, 166, 175, 201
Athyris minuta, n. sp.	97
Athyris sp. indeterminate	118
Brachiopod undetermined	97

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TABLE 3. - Faunules by Localities

OSWAYO

Locality 1

Lingula arcta (?) Girty

Lingulodiscina exilis? (Hall)

Orbiculoidea cf. O. alleghania (Hall)

Oehlertella pleurites (Meek)

Camarotoechia allegania (Williams) s. s.

C. allegania obesa, n. subsp.

C. (Spathulata) spathula, n. subgen. n. sp.

Cyrtospirifer oleanensis Greiner

C. extentus, n. sp.

C. horridus, n. sp.

C. horridus, variant A., n. variant

C. sp. indeterminate

Athyris mardiae, n. sp.

A. mardiae planaria, n. subsp.

A. mardiae sulcula, n. subsp.

A. thrasyangelica, n. sp.

A. thrasyangelica magna, n. subsp.

Locality 59

Camarotoechia allegania (Williams) s. s.

Camarotoechia allegania obesa, n. subsp.

Locality 60

Lingulodiscina exilis? (Hall)

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TABLE 3. - Continued

Orbiculoidea cf. O. alleghania (Hall)

Rhipidomella pennsylvanica (Simpson)

Camarotoechia allegania (Williams) s. s.

C. allegania obesa, n. subsp.

C.(Spathulata) spathula, n. subgen. n. sp.

Cyrtospirifer extentus, n. sp.

C. horridus variant A., n. variant

Athyris mardiae, n. sp.

A. mardiae sulcula, n. subsp.

A. thrasyangelica, n. sp.

Locality 109

Camarotoechia allegania (Williams) s. s.

C. allegania obesa, n. subsp.

C. allegania lingulata, n. subsp.

Cyrtospirifer sp. indeterminate

Athyris mardiae sulcula, n. subsp.

Locality 161

Camarotoechia allegania (Williams) s. s.

Locality 183

"Lingula" inexpecta, n. sp.

Camarotoechia allegania (Williams) s. s.

C. allegania obesa, n. subsp.

C. allegania lingulata, n. subsp.

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TABLE 3. - continued

Camarotoechia (Spathulata) spathula, n. subgen., n. sp.

Cyrtospirifer oleanensis Greiner

C. oleanensis variant A., n. variant

C. extentus, n. sp.

C. horridus strigosus, n. subsp.

Cyrtospirifer sp. indeterminate

Locality 253

Camarotoechia allegania (Williams)s. s.

KNAPP AND TIDIOUTE

Locality 51

Camarotoechia mimelegantula, n. sp.

Cyrtospirifer warrenensis Greiner

C. extentus?, n. sp.

C. lobatimusculus parvus, n. subsp.

Syringothyris angulata Simpson

Proeumetria acroria, n. gen., n. sp.

Locality 60

Lingulodiscina exilis? (Hall)

Locality;91

Camarotoechia sp. indeterminate

C. (Spathulata) spathula?, n. subgen., n. sp.

Cyrtospirifer tionesta Greiner

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Locality 97

Lingulodiscina exilis? (Hall)

Orbiculoidea sp. A.

Oehlertella pleurites (Meek)

Lissocrania parvula, n. sp.

Schuchertella desiderata (Hall & Clarke)

Dictyoclostus dubitatus, n. sp.

D. dubitatus variant A, n. variant

Camarotoechia mimelegantula, n. sp.

Cyrtospirifer extentus?, n. sp.

Syringothyris angulata Simpson

Syringopleura casteri, n. sp.

Proeumetria acroria, n. gen., n. sp.

Athyris minuta, n. sp.

Brachiopod undetermined

Locality 118

Rhipidomella pennsylvanica (Simpson)

Cyrtospirifer warrenensis Greiner

C. lobatimusculus parvus, n. subsp.

"Cyrtospirifer" plenellus, n. sp.

Syringothyris warrenensis, n. sp.

Athyris sp. indeterminate

Locality 119

Rhipidomella pennsylvanica (Simpson)

Cyrtospirifer tionesta Greiner

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Locality 121

Cyrtospirifer lobatimusculus Greiner

C. lobatimusculus parvus, n. subsp.

Syringothyris angulata Simpson

S. warrenensis, n. sp.

Syringopleura casteri, n. sp.

Locality 166

Syrtospirifer warrenensis Greiner

C. lobatimusculus Greiner

C. lobatimusculus parvus, n. subsp.

Syringothyris angulata Simpson

S. warrenensis, n. sp.

Syringopleura casteri, n. sp.

Proeumetria acroria, n. gen., n. sp.

Locality 175

Syringothyris angulata Simpson

S. warrenensis, n. sp.

Syringopleura casteri, n. sp.

Proeumetria acroria, n. gen., n. sp.

Locality 198

Dictyoclostus dubitatus, n. sp.

Locality 199

Rhipidomella pennsylvanica (Simpson)

Schuchertella desiderata (Hall & Clarke)

Cyrtospirifer lobatimusculus parvus, n. subsp.

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"Cyrtospirifer" plenellus, n. sp.

Syringothyris angulata Simpson

S. warrenensis, n. sp.

Locality 201

Rhipidomella pennsylvanica (Simpson)

Schuchertella desiderata? (Hall & Clarke)

Dictyoclostus dubitatus, n. sp.

Camarotoechia sp. indeterminate

Cyrtina triplicata Simpson

Proeumetria acroria, n. gen., n. sp.

Locality 202

Lingula tidioutensis, n. sp.

Orbiculoidea sp. A

Rhipidomella pennsylvanica (Simpson)

Dictyoclostus dubitatus, n. sp.

Cyrtospirifer tionesta Greiner

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TABLE 4. - Occurrence of brachiopods by formations

	Oswayo 1	Knapp 2	Oswayo & Knapp 3	Tidioute 4	Knapp & Tidioute 5	All 3 formations 6	Oswayo & Tidioute 7
Lingula arcta (?)	x						
L. tidioutensis				x			
"L." inexpecta	x						
Lingulodiscina exilis(?)			x				
Orbiculoidea cf. O. alleghania	x						
O. sp. A		x					
O. sp. indeterminate				x			
Oehlertella pleurites			x				
Lissocrania parvula		x					
Rhipidomella pennsylvanica						x	
Schuchertella desiderata					x		
S. n. sp. A		x					
Dictyoclostus dubitatus					x		
D. dubitatus var. A		x					
Chonetes cf. C. setigerus				x			
Camarotoechia allegania	x						
C. allegania obesa	x						
C. allegania lingulata	x						
C. mimelegantula		x					
C. cf. C. contracta		x					
C. sp. indeterminate				x			
C. (Spathulata) spathula							x
Cyrtospirifer oleanensis	x						
C. oleanensis var. A	x						
C. warrenensis		x					
C. lobatimusculus		x					
C. lobatimusculus parvus		x					
C. tionesta				x			
C. extentus			x				
C. horridus	x						
C. horridus var. A	x						
C. horridus strigosus	x						
C. sp. indeterminate	x						

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TABLE 4. - Continued

	1	2	3	4	5	6	7
Cyrtina triplicata				x			
Athyris mardiae	x						
A. mardiae planaria	x						
A. mardiae sulcula	x						
A. thrasyangelica	x						
A. thrasyangelica magna	x						
A. minuta		x					
A. sp. indeterminate		x					
Proeumetria acroria					x		
Brachiopod undetermined		x					
Total forms (47)	17	16	3	6	3	1	1
Total species (37)	9	14	3	6	3	1	1
Species identified without question	7	9	1	3	3	1	1

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between the Oswayo and Knapp formations in the Bradford-Warren areas. Only two (8%) species cross this line.

If all of the morphological variations (of which 34 or 72% are new) are considered, it is found that 17 (36%) are restricted to the Oswayo or Devonian and 26 (55%) are added in the Mississippian with four (9%) forms occurring on both sides of the line. These data are summarized in Tables 5 and 6.

The information derived from considering only genera (Tables 7 and 8) is nearly as decisive as when one considers species. Four genera are introduced in the Knapp formation and are restricted to it; and two genera were found restricted to the Tidioute. Although there are no genera restricted in their upper range solely to the Oswayo, nine new forms are introduced in the Knapp and Tidioute; but only eight of the 17 genera cross the Devonian-Mississippian line. If one places, then, the systemic boundary at the position of introduction of the greatest number of new elements into the faunas of formations presumed to be near the boundary, the line must be drawn between the Oswayo and Knapp formations.

No great brief is held for the completeness of the Tidioute fauna however, since this was described only where it interfingered with the Knapp formation. It is possible therefore that other genera will be found in common between the Mississippian and Devonian in the shaly magnafacies west of the Big Bend magnafacies studied

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TABLE 5. - Summary of occurrence of "forms" (47) described herein

	Number	Per Cent
Oswayo only	17	36.2
Knapp only	16	34.1
Tidioute only	6	12.8
Common to Oswayo and Knapp	3	6.4
Common to Oswayo and Tidioute	1	2.1
Common to Knapp and Tidioute	3	6.4
Common to all three formations	1	2.1
Devonian only	17	36.2
Mississippian only	25	53.2
Common to Devonian and Mississippian	5	10.6
New forms	34	72.3

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TABLE 6. - Summary of occurrence of "species" (37) and species identified without question (25) herein

	"Species"		Unquestioned Species	
	No.	%	No.	%
Oswayo only	9	24.3	7	28
Knapp only	14	40.5	9.	36
Tidioute only	6	16.5	3	12
Common to Oswayo and Knapp	3	8.1	1	4
Common to Oswayo and Tidioute	1	2.7	1	4
Common to Knapp and Tidioute	3	8.1	3	12
Common to all three formations	1	2.7	1	4
Devonian only	9	24.3	7	28
Mississippian only	23	62.2	15	60
Common to Devonian and Miss,	5.	13.5	3	12
New species			15	60

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herein. It may be that the argument for placing of a systemmic boundary on the basis of introduction of new forms may be slightly diminished by the occurrence in this western facies of such forms as Chonetes and Cyrtina (commonly present in Devonian faunas) which were found in this study only in the Tidioute. However, the Tidioute fauna is so closely allied with that of the Knapp in general aspect, and this formation is so intimately intertongued with the Knapp that the continuation of a few long-ranging forms in the shaly facies does not seriously hinder the assignment of the Tidioute to the Mississippian. It is believed that more important is the dissimilar aspect of the Knapp and Oswayo faunas which occur within the same magnafacies.

When considering generic elements in the fauna certain ones are normally considered more important than others. The inarticulate brachiopods generally make up a small proportion of the fauna and are or have so far been of relatively little use stratigraphically. This seems to be true in the formations here considered. Rhipidomella is present in all three formations although in greatly increased numbers in the Knapp where shells of Rhipidomella pennsylvanica (Simpson) contribute greatly to the coquinoid zones. Schuchertella was found only in the Mississippian; but it, along with Chonetes, Camarotoechia, and Athyris, may normally be as abundant elsewhere in the Mississippian as in the Devonian. Cyrtospirifer and Cyrtina are both

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TABLE 7. - Occurrence of brachiopod genera by formations

	Oswayo	Knapp	Oswayo & Knapp	Tidioute	Knapp & Tidioute	Oswayo & Tidioute	All three formations
	1	2	3	4	5	6	7
Lingula						x	
Linguloidiscina			x				
Orbiculoidea							x
Oehlertella			x				
Lissocrania		x					
Rhipidomella							x
Schuchertella					x		
Dictyoclostus					x		
Chonetes				x			
Camarotoechia							x
Camarotoechia (Spathulata)						x	
Cyrtospirifer							x
Syringothyris		x					
Syringopleura		x					
Cyrtina				x			
Athyris							x
Proeumetria					x		
Total genera	0	3	2	2	3	2	5

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TABLE 8. - Summary of occurrence of genera (17) described herein

	Number	Per cent
Oswayo only	0	0
Knapp only	3	18
Tidioute only	2	11
Common to Oswayo and Knapp	2	11
Common to Oswayo and Tidioute	2	11
Common to Knapp and Tidioute	3	18
Common to all three formations	5	29
Devonian only	0	0
Mississippian only	8	47
Common to Devonian and Mississippian	9	53
New genera and subgenera	2	11

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found in the Lower Mississippian formations, even though their acme is in the Devonian, but soon after the opening of the Mississippian they give way to other spiriferoid forms. The most important genera in discriminating the Mississippian from the Devonian in this area then become Dictyoclostus, Syringothyris, Syringopleura, and the new genus, Proeumetria. Each of these was found abundantly in strata herein considered Mississippian, but not in the Oswayo or Devonian. Dictyoclostus is an Upper Paleozoic form not considered to occur in the Devonian. Proeumetria is ancestral to and closely related to the Mississippian Eumetria which is not known from Devonian strata. Syringothyrids, on the other hand, have been reported from Upper Devonian as well as Mississippian strata. These reports lose much of their strength however, when such forms as Syringothyris occidentalis (Swallow) from the Middle Devonian of Missouri are assigned by other writers (Stainbrook, 1943b) to an earlier syringothyroid genus, Eosyringothyris, or occur in strata of questionable Devonian age. Such a situation exists in the reports of Devonian syringothyrids from the Sappington sandstone of southwestern Montana which the writer (1952) considers Mississippian rather than Devonian, but which other workers have placed in the Upper Devonian. Elsewhere around the world - Australia (Glenister, 1955; Maxwell, 1954), Argentina (Leanza, 1945, 1949; Amos, 1957), and Belgium and England - nearly universally Syringothyris appears at

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the base of the Carboniferous sequence. Certainly it is a far more characteristic Mississippian than Devonian genus, and reports of this genus, sensu stricto, in Devonian strata, are to be looked upon with doubt. Syringopleura (based on Syringothyris randalli Simpson from the Corry of the Warren area) has definitely been reported (as Septosyringothyris) outside of this area only in Mississippian strata in Argentina (Amos, 1957) and in Belgium (Vandercammen, 1955a).

In addition to the forms mentioned above, species of the genera Camarotoechia, Cyrtospirifer, and Athyris are especially valuable in delimiting Mississippian from Devonian strata in this area. Universally, throughout the Penn-York Embayment, within the writer's experience, Camarotoechia allegania (Williams) and its subspecies is known to occur only in strata of uppermost Devonian age; nowhere does this form, so abundant in the Oswayo, occur with the faunas of Mississippian aspect. At a number of localities, especially numbers 1 and 183, Camarotoechia allegania (Williams) occurs in some layers of the Roystone coquinoid along with species of Cyrtospirifer (namely Cyrtospirifer oleanensis Greiner and C. extentus, n. sp.) in such abundance that specimens of these two genera make up nearly the entire rock. On the other hand, camarotoechiids are greatly diminished in numbers in the Knapp formation. There the distinctive small form, Camarotoechia mimelegantula, n. sp. is restricted to this formation.

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In his monograph of the "Spirifer disjunctus tribe" Greiner (1957) describes a number of new species of Cyrtospirifer from the "Catskill Delta". With his reported occurrences of Cyrtospirifer in the Oswayo and Knapp formations, the writer finds a number of serious, inexplicable differences. One of the most common forms in the Oswayo is his Cyrtospirifer oleanensis, which he reports from the lower Conewangoan through the Corry sandstone of the Mississippian. Cyrtospirifer oleanensis (which the writer had otherwise named prior to the publication of Greiner's paper) is a distinctive and easily recognized form, but the writer has found that this does not occur above the Oswayo formation. Crystospirifer tionesta and C. warrensis of Greiner, which he likewise reports from Conewangoan, were not found by the writer below the Knapp. On the other hand, the writer has distinquished two new species, Cyrtospirifer extentus and C. horridus which occur abur.dantly in the Roystone coquinoid member of the Oswayo formation. Cyrtospirifer extentus is also herein reported doubtedfully from the Marvin Creek coquinoid zone of the Kushequa at Johnsonburg, Pennsylvania, but C. horridus and its subspecies and morphological variants are restricted to the Oswayo. Part of the apparent discrepency is undoubtedly due to the fact that Greiner reports Cyrtospirifer warrenensis and C. tionesta from the "Oswayo" (really the "Riceville shales") which would lie in the next magnafacies west of the Big Bend magnafacies studied.

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C. warrenensis occurs abundantly in the syringothyrid zones of the Knapp formation in the Big Bend magnafacies on Yankee Bush Hill, indicating a possible deepening of the water or otherwise mingling of environmental conditions in the Warren area in Early Mississippian times.

Athyrids are extremely abundant in the Roystone coquinoid member of the Oswayo formation, but are greatly reduced in numbers and variety in the Knapp formation. The Roystone is commonly characterized by the new species, Athyris mardiae Holland and A. thrasyangelica Holland and their subspecies. A. thrasyangelica Holland attains a very large size in the Oswayo. In the Knapp, however, again one finds a diminution in size, numbers, and variety of forms. The only Athyris occuring in the Knapp formation is a small form, Athyris minuta. n. sp,; and this species is restricted to the Knapp.

The phylogenetic relationships of the brachiopod species from the Devonian-Mississippian boundary formations are discussed wherever practical under each species in the systemmatic descriptions of this paper. Broader relationships of the faunas, however, may be pointed out here. As would be expected, the affinities of the Oswayo fauna are with older Devonian formations; many of the forms closely resemble similar ones in the Venangoan sandstones of the same magnafacies, particularly those of the Salamanca "suite". Cursory examination of the Salamanca indicates to the writer so many small morphological differences between Salamanca and Oswayo forms that it

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would indeed be premature to hazard suggested identifications or relationships in the guise of closer "scientific" comparisons without a full restudy of this prolific brachiopod faunas. In like manner, the fauna of the Knapp--augmented by a number of new forms normally considered to be Mississippian and also characterized by the absence or diminution in numbers and type of certain forms which occur in the Devonian (e.g., in Camarotoechia and Athyris) or great expansion in numbers of certain other forms which occur in the Devonian (e.g., in Rhipidomella and Schuchertella) --finds its closest ties with the Corry sandstone, next overlying it in the section. In the Corry, Rhipidomella, Schuchertella, Syringothyris, Syringopleura and many more Chonetes are found, but commonly in mutated form. In addition, the distinctive Spirifer allegheniensis Caster and the genus Paraphorhynchus are added.

It should be reiterated that as originally designed for this study, by far the greater part of the brachiopod faunas contained herein occur within one single magnafacies consisting of nearshore conglomerates, sandstones, siltstones and silty and sandy shales. The introduction of coarse clastic material in the Knapp implies to the writer change in stream regimen or increased tectonism in Early Mississippian time, rather than intrinsic local change in the lithotope (lithologic environment); thus the possibility that the faunal differences ennumerated above are due to "facies faunas" rather than heterochronous parvafacial

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(time) differences is ruled out.

That the brachiopods described herein inhabited the nearshore (littoral or inner sublittoral) marine phase of the great Devono-Mississippian Deltaic Plain is indicated by their occurrence with abundant, triturated, carbonaceous plant fragments and the relatively poor sorting of the enclosed sediments. That they were abundant is indicated by the common occurrence of coquinoid layers of calcareous sandstones as typified by the widespread Roystone coquinoid member of the Oswayo formation and the Marvin Creek coquinoid zone within the Kushequa member of the Knapp formation. While fragmental forms indicate that there was considerable sorting and concentration of the shells in the coquinoid layers by waves and currents, it is not believed that the shells were transported a great distance from where the organisms lived. This is indicated by the abundance of whole specimens occurring with the fragmental forms and by the fact that few of the unbroken forms seem to indicate much rubbing or abrasion of the delicate ornament of their shells. The same forms are seen to inhabit the shalier layers between coquinoid zones; but it seems as though once a "shell bank" became established by waves and currents, there the organisms flourished as indicated by the well-preserved unabraded forms, the delicate attached forms, and the tin-shelled forms such as

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Athyris occurring with the heavier, more abundant cyrtospiriferids.

Life in the time of the Knapp formation may have been more difficult, for the majority of the shells in the syringothyrid layers on Yankee Bush Hill occur as separate valves. Also many of the disjointed valves are broken in the Kushequa shale at locality 166. This was not universally so in the Knapp however; for at locality 97, at Johnsonburg, Pennsylvania, the Marvin Creek zone occurs as thick beds which might almost be called arenaceous limestone and which are crowded with extremely well-preserved shells. Here the percentage of conjoined valves is much higher than at most of the other localities collected. Here again little or no evidence of rolling or abrasion was seen on the shells.

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SUMMARY AND CONCLUSIONS

The abundant brachiopod faunas of the Oswayo and Knapp formations occurring in the marine phase of the great Devono-Mississippian or "Catskill" Deltaic Plain of the Penn-York Embayment are re-evaluated in order to determine the proper placing of the systemmic boundary between the Devonian and Mississippian. The brachiopod faunas were collected principally in northwestern Pennsylvania from the Big Bend magnafacies (Caster, 1934) in order to minimize facieological differences. The Big Bend magnafacies consists of olive green to brown alternating arenaceous shales, siltstones and medium to coarse grained sandstones and shaly sandstones. On the east, the Big Bend magnafacies is bounded by the Smethport magnafacies which consists of purple and reddish brown-weathering shales and sandstones which bear flat-pebble conglomerates as a normal feature. To the west the Big Bend magnafacies becomes finer and west of the Warren area changes to olivaceous fine-grained fissle shales, siltstones, and sandstones of the Chagrin magnafacies. In this region the conglomerates and coquinoids of the Smethport and Big Bend magnafacies become finer and more localized and eventually take on sandy facies.

In the Bradford, Pennsylvania area, the Knapp

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formation is distinguished from the Oswayo by being somewhat coarser brown sandstone and bearing two prominent conglomerate members. The lower one is the Wetmore and the upper one is the Cobham conglomerate member of the Knapp. In a broad arc from Johnsonburg through Tidioute and Corry, Pennsylvania the Tidioute formation of the Chagrin magnafacies interfingers with the Knapp formation. Southwest of the Bradford area, a thick sequence of irregularly bedded, arenaceous shale wedges in between the Oswayo formation and the Wetmore conglomerate. This shale, the Kushequa member of the Knapp formation, bears a distinctive zone of coquinoids called the Marvin Creek. The Oswayo also carries a prominent coquinoid zone which has been designated the Roystone member of the Oswayo formation. Although the Oswayo and Knapp are fossiliferous throughout, it is these coquinoid zones, principally the Roystone member of the Oswayo and the Marvin Creek zone in the Kushequa shale, which bear the abundant brachiopod fauna described herein. Ground water (especially active near the surface) in porous sandstones in these formations has removed the calcareous cement and leached away the calcium carbonate of the fossils, so the brachiopods occur as molds and casts in soft argillaceous sandstone. This preservation of molds of the interior, coupled with well-preserved unaltered specimens which occur in occasional fresh exposures of the sandstone affords an excellent opportunity to study the external nature and internal structure of these brachiopods.

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A total of 47 species and their morphological variants grouped into 17 genera are described herein.

Brachiopod genera found within the Oswayo include Lingulodiscina, Orbiduloidea, Rhipidomella, Camarotoechia, and its new subgenus Spathulata, Cyrtospirifer, and Athyris. None of these is restricted solely to the Oswayo. Brachiopod genera herein recorded from the Knapp and Tidioute formations include Lingulodicsina, Orbiculoidea, Ohlertella, Lissocrania, Rhipidomella, Schuchertella, Dictyoclostus, Chonetes, Camarotoechia, Camarotoechia (Spathulata), n. subgen., Cyrtospirifer, Syringothyris, Syringopleura, Cyrtina, Athyris and the new genus Proeumetria. Of these Lissocrania, Dictyoclostus, Syringothyris, Syringopleura and Proeumetria were not found within the Oswayo.

One of the most infallible indices to the Oswayo is Camarotoechia allegania (Williams) and the new subspecies C. allegania obesa Holland and C. allegania lingulata Holland. The only species of Camarotoechia which is restricted to the Knapp is the new species C. mimelegantula Holland. A number of cyrtospiriferid species were found to be restricted in their ranges, but only the writer's new species Cyrtospirifer horridus and its morphological variants have never been reported from the Knapp formation. Cyrtospirifer lobatimusculus Greiner is a Knapp addition to the fauna. The oft-reported "Reticularia praematura" (auct.) characteristic of the Mississippian formations is here described as a new species doubtfully assigned to Cyrtospirifer and is restricted to the Knapp formation.

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The writer considers the following genera to be diagnostic in a consideration of the placing of the Devonian-Mississippian boundary: Dictyoclostus, Syringothyris, Syringopleura, and Proeumetria. These genera are related more closely to Mississippian and post-Mississippian systems than they are to the Devonian.

The Knapp is characterized by the addition of Schuchertella desiderata (Hall and Clarke) which is unknown to formations older than the Mississippian. Rhipidomella pennsylvanica (Simpson) which occurs in lower Conewangoan and Oswayo strata is present in greatly expanded numbers in the Knapp formation. As opposed to these expansions in the Knapp, species and subspecies of Athyris which are extremely abundant in the Oswayo are absent in the Knapp except for one small species Athyris minuta Holland, herein described as new.

The brachiopods in the collections from the Devonian-Mississippian formations are found to be distributed among 47 distinct forms. These forms occur in 25 species which are identified without question. Of the 25 unquestioned species, seven (28%) occur only in the Oswayo, nine (36%) occur only in the Knapp formation and three (12%) occur only in the Tidioute. Thus seven (28%) of the species are restricted to the Oswayo and 15 (60%) of the species occur only in the Knapp and Tidioute or higher strata.

It is herein suggested that the Tidioute shale,

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previously thought to overlie the Knapp, belongs to a western shaly magnafacies, the Chagrin. The brachiopod fauna of the Tidioute where it interfingers with the Knapp is of Mississippian age; and it is believed that further study would show that the Devonian-Mississippian boundary in the Chagrin magnafacies to the west of the Warren-Tidioute area should be placed between the Tidioute (Mississippian) and the yet unnamed Devonian "Riceville shale" or "Oswayo formation".

It is further concluded, based upon the differences in lithology, the presence of a slight disconformity (Caster, 1934) and upon considerable differences in the brachiopod faunas including: (1) diminution in number and variety of certain forms in some genera, (2) first occurrence or rapid expansion of certain forms in other genera which normally occur in Devonian as well as Mississippian strata, (3) first occurrence in the Knapp of genera commonly considered to be restricted to the Mississippian, and (4) considerable differences in the faunas due to the addition of new species in the Knapp and Tidioute, that the Devonian-Mississippian boundary is correctly placed between the Oswayo and Knapp formations in the southwestern New York-northwestern Pennsylvania sector of the Penn-York Embayment.

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SYSTEMATIC PALEONTOLOGY

The higher categories within the phylum Brachiopoda are currently undergoing a "revolution" as Stehli (1945, p. 289) has said. Huxley's classes Inarticulata and Articulata and Beecher's ordinal units, especially his Protremata and Telotremata, are no longer acceptable to most systematists, but satisfactory replacements or suitable regroupings have not yet been devised. The current general dissatisfaction with older classifications is discussed by Cooper (1944), Moore (1952), Shrock and Twenhofel(1953), and many others reviewed by Muir-Wood (1955); this dissatisfaction is further emphasized by Williams (1956).

For these reasons a full ordinal classification is not employed, since any currently in existence will forthwith be changed. The classification used is essentially that of Muir-Wood (1955) except that differences in embryology of Thomson's (1927) "subclasses", Gastrocaulia and Pygocaulia, are deemed to necessitate that these taxa be accorded at least subphylum rank (see also Percival, 1944).

All specimens described are catalogued in the University of Cincinnati Museum, and UCM throughout the text and in the plate explanations refers to these collections.

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Phylum BRACHIOPODA Duméril, 1806*

Subphylum GASTROCAULIA Thomson, 1927

Order ATREMATA Beecher, 1891

Superfamily LINGULACEA Waagen, 1885

Family LINGULIDAE Gray, 1840

Genus Lingula Bruguière, 1797

TYPE SPECIES (By subsequent designation; Lamarck, 1801, p. 141): Patella uniguis Linnaeus, 1758, Systema Naturae, 10th ed., p. 783, no. 671 (= Lingula anatina Lamarck, 1801, Système des Animaux sans Vertèbres . . . , p. 141, fide Thomson, 1927, p. 124; Schuchert and LeVene, 1929, p. 76). Recent, Amboina Island, Banda Sea.

Shell thin, lenticular, gently biconvex and almost equivalved in lateral profile; linguiform, oblong, or subquadrate in outline modified by a slight posterior accumination of the beaks which are usually short and closely appressed. Brachial valve shorter than or equal to pedicle valve. Pedicle emerging freely between the two valves. Shell substance thin, of alternating chitinous and phosphatic lamellae, usually smooth but may be finely papillose, commonly marked with very fine radiating costellae or capilli and more or less conspicuous concentric growth

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*Muir-Wood (1955, p. 10) has pointed out that it was Duméril (1806) who first actually used the term "Brachiopoda" rather than the informal "Brachiopodes" of Cuvier (1802, 1805).

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lines.

The internal musculature and other characteristics are rarely distinct in Paleozoic forms; these have been discussed elsewhere in detail by Hall and Clarke (1892), Yatsu (1902), and others.

DISCUSSION: Barroisella Hall and Clarke is similar to Lingula externally but can be distinguished from it by the possession of a posterior triangular thickened area and an elevated median ridge in the brachial valve; although these features are rarely seen. Moreover, Barroisella most commonly inhabited the black shale lithotope.

Girty (1898) named the genus Lingulipora for the reception of "punctate" linguloids. In 1939, however, he abandoned this concept (p. 50) saying:

> . . . I have come to doubt whether punctate shell structure has the same significance in Lingulas that it has in some other brachiopods--and consequently to doubt the validity of Lingulipora as a generic name.

He showed that the species with which he was then dealing (Lingula limatula Girty) was not truly punctate but "that the 'punctae' are but an expression of the papillae on the inner layers of the shell".

Dunbar and Condra (1932, p. 35) erected the genus, Trigonoglossa, for "linguloid shells of subtriangular outline" in which "the surface is conspicuously ornamented by sharply raised, flange-like, concentric lirae, separated by much broader, flat interspaces". Girty (1939, p. 53 et seq.) has extensively compared Trigonoglossa with Lingula

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and other genera which are similar in appearance.

Cooper (1956), studying Middle Ordovician brachiopods, has amply demonstrated his statement (p. 189) that, "it is now clear that 'Obolus' and 'Lingula' are composite groups consisting of many genera". If silicified material were available or even if the specimens of scattered reports of linguloids in the Upper Devonian and Lower Mississippian of the Penn-York Embayment area could be assembled, it is not doubted that this would be true for these examples. There is little reason to believe that all of the linguloids of this area belong to the Recent genus Lingula, yet the present state of knowledge does not now permit of accurate generic discrimination. Hence until such a study is undertaken, individual shells must needs be assigned to the form genus "Lingula" under the broad description given above with the full knowledge that, undoubtedly, species which belong in separate genera are thus being lumped together.

Lingula arcta (?) Girty, 1939

Plate 1; fig. 1.

[?] Lingula arcta Girty, G. H., 1939, United States Geol. Surv., Prof. Paper 193-C, p. 47-48, pl. 9, figs. 1-4.

One single valve at hand is doubtfully referred to Girty's species. This specimen apparently had a very thin shell and is irregularly preserved; however the matrix is

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too coarse and protions of the shell too thick to tell ought of the internal characteristics.

The shell of this specimen is subelliptical in outline with the lateral edges of the shell gently convex. The posterior is bluntly pointed and the anterior is rounded but very slightly truncate near the midline. The valve is rather strongly convex longitudinally with the greatest convexity about midlength. Transversely the shell is also strongly convex but with the convexity lessening near the lateral margins. Very near the margins the curvature becomes concave to an almost flattened rim especially evident on the anterolateral edges as though the valve was tightly appressed to the other valve anteriorly. The surface, which is glossy, is marked by microscopic but distinct raised growth lines some of which,at remote but regular intervals, are stronger than the rest, thus becoming visible to the unaided eye. Under the microscope (at about 20X) there appears the faintest suggestion of irregular, raised, radiating lines.

DISCUSSION: This species is questionaly referred to Lingula arcta Girty because the specimens illustrated by him appear to have straighter sides than does the Oswayo form. Actually the side on the viewer's left of the specimen at hand is slightly crushed so that this side appears straighter than was probably the case; this enhances the resemblance to Girty's specimen. Another point which militates against the unquestioned assignment

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of this specimen to L. arcta is the statement by Girty that the width and length vary "but little from a ratio of 1:2". The length/width ratio of the Oswayo specimen is 1.76 and Girty's figures 1a, 2, 3, and 4 (as reconstructed) have ratios of 1.9, 2.39, 2.22, and 2.2 respectively. Thus it can be seen that his specimens are slightely longer and narrower in proportion than the Oswayo specimen. Girty says that figure 1a is "supposed to be a dorsal valve" and figure 3 is a "ventral (?) valve"; figures 2 and 4 are restored specimens. This leads one to suppose that the specimen at hand is a brachial valve and thus shows rather closer shape resemblance than the figures would at first indicate.

Girty has very carefully compared L. arcta with species of Lingula previously reported from the Ohio-Pennsylvania area in Upper Devonian and Mississippian strata. From all of these, L. arcta Girty seems truly distinct and the Oswayo form seems referrable to this species. Of all the other reported linguloids, the Oswayo form most nearly resembles L. cuyahoga Hall as figured by Herrick (1893, pl. 22, fig. 9) and Hall and Clarke (1892, pl. 1, fig. 18 as "Lingula sp.? cf. cuyahoga Hall"). Girty has shown, however, that there is doubt as to the exact form of L. cuyahoga because of differences in Hall's description and figures. Further collecting and a restudy of the types would probably resolve these discrepancies. Until this is done the writer prefers

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to use the more recent, better characterized and figured species of Girty

Rather than group a large number of reported Devono-Mississippian linguloids into a large "galaxy" as does Girty (1939, p. 48) the writer would prefer to consider the existence of several distinct species groups in this region in Devono-Mississippian times. Probably of temporal or geographic subspecific (or specific) rank are the slender, posteriorly pointed forms like L. cuyahoga Hall, L. melie Hall, L. membranacea Winchell, L. arcta Girty, and L. herrickiana Girty; and related, but distinct, is the group of subquadrate, somewhat posteriorly rounded forms such as L. atra Herrick, L. gannensis Herrick, L. paracletus Hall and Clarke, L. randalli Girty, L. limbatula Girty and L. papyracea Girty (perhaps the latter two should be grouped separately because both, as figured by Girty, seem to show holoperipheral growth). L. eriensis Girty and "Lingula" inexpecta, n. sp., do not seem to be closely related to these groups.

The relations and systematic rank of all of these "species" of scattered reports, infrequent occurrence, and commonly poor preservation is far from clear; yet the study of this matter, beyond the scope of this paper, would probably be as rewarding as it would be difficult. However it appears that the first group mentioned above descended from L. ligea Hall of the Middle Devonian and carries up, according to Girty, at least to the phyllocarid horizon

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(Amity shale) at Warren.

OCCURRENCE: One specimen in the Roystone coquinoid member of the Oswayo formation at locality 1.

REMARKS: It should be noted that the other (pedicle?) valve occurs with the valve described and has slipped posteriorly from under the exposed valve. Only a portion of the interior of this valve remains and little detail can be determined from it.

UCM No.	Length (mm)	Width (mm)	l/w
29768	11.1	6.3	1.76

Lingula tidioutensis, n. sp.

Plate 1, figures 1-6.

DESCRIPTION: Shell elongate, nearly straight-sided, low and gently convex in all directions. Posterior rather broadly rounded, not acuminate; beak low and indistinct. The lateral margins round abruptly into the truncated anterior margin. Anterior margin and growth lamellae indented medially. Shell thickened medially by a broad, low ridge; and it is over this that the growth lamellae curve posteriorly. Surface smooth except for lamellose increments of growth. Interior devoid of markings except the low median ridge or septum.

DISCUSSION: Slabs of Tidioute shale from locality 202 contain fragments of this form in great numbers. The

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shell is olive gray (5Y 4/1) to borwnish gray (5YR 3/1) but weathers nearly white. The valves occur separately, flat on the bedding planes, and usually as fragments so that there is no way of telling pedicle valve from brachial.

The truncated anterior with the growth lamellae curving posteriorally over the thickened median part of the valve make this form distinct and easily separable from other linguloids occurring in the same area. This species most resembles L. gannensis Herrick, 1888. However this latter has an even more quadrate appearance than L. tidioutensis; and apparently it lacks the median thickening of the valve. L. randalli Girty (1939) is much more rounded anteriorly, and the lateral margins are more curved than in L. tidioutensis. Girty (1939, p. 52) remarks that he once identified L. randalli near Tidioute "but as it has not seemed profitable to verify these identifications, it [L. randalli] is here definitely cited from only the two localities that furnished the types [unidentified horizon near Warren]." It is likely L. tidioutensis which Girty found in the vicinity of Warren, but which he hesitated to call his L. randalli.

Undoubtedly a close relationship exists between the more quadrate linguloids (L. tidioutensis, L. gannensis, L. paracletus, and L. randalli) within the Penn-York Embayment (see discussion under Lingula arcta(?) Girty).

TYPES: Holotype UCM No. 29825 (presumed pedicle valve

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slightly folded on the edges). Paratypes, UCM Nos. 29826 (interior), 29829. Hypotypes, UCM Nos. 29830, 29831.

OCCURRENCE: Fine grained shaly sandstone in the Tidioute at locality 202.

REMARKS: Measurements of some of the better specimens are given in the following table. Asterisks indicate estimates made due to broken condition of the specimens.

UCM No.	Length (mm)	Width (mm)	l/w
29825	16.3	9.3	1.75
29826	16.1*	9.1	1.77
29827	--	9.3	--
29828	13.3*	6.4	2.08
29829	--	8.0	--
29830	--	8.5	--
29831	--	9.7	--

"Lingula" inexpecta, n. sp.

Plate 1, Figure 27.

DESCRIPTION: Large, subovate, anteriorly evenly rounded, posteriorly subacuminate linguloid; greatest width well anterior to midlength. The valve is only faintly convex with the greatest convexity about one-fourth the length of the valve; anterior half of shell nearly flat (perhaps due to crushing). The postero-lateral margins are truncate to slightly concave, and the umbo is raised above the depressed unbonal flanks.

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The lateral edges are convex, rounding smoothly to the rounded anterior. Bits of shell remain high on the umbo but preserve no ornamentation. The surface is seen to have irregularly spaced growth lines and may have been faintly radially striate.

DISCUSSION: The large size and the shape are sufficient to separate this form from other known Devonian linguloids. The species is known from only one badly exfoliated mold. However, one fragmentary, badly-bored, concave mold is present in the collections which, because of its general outline, is doubtfully referred to this species. This specimen could be interpreted as part of a mold of the exterior of a pelecypod as easily as L. inexpecta however.

TYPE: Holotype, UCM No. 29117 (partial exterior).

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 183.

REMARKS: Measurement of this large specimen shows:

UCM No.	Length (mm)	Width (mm)	l/w
29117	30.2	25.0	1.21

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Order NEOTREMATA Beecher, 1891

Superfamily DISCINACEA Waagen, 1885

Family TREMATIDAE Schuchert, 1893

Genus Lingulodiscina Whitfield, 1890

TYPE SPECIES (By original designation): Lingula exilis Hall, 1860, New York State Cab. Nat. Hist., 13th Ann. Rept., p. 77, fig. 2. Marcellus formation, Erian, near Bridgewater, New York.

Whitfield (1890, p. 121) described this genus as "being linguloid on one side and discinoid on the other." The original description (p. 122) is given here.

> An inarticulate brachiopodous shell, in which the upper valve is linguloid in character, having a marginal or an essentially terminal beak, the accretions by growth being along the lateral and basal margins; lower valve discinoid in character and having its growth lines nearly equal on all sides of the initial point and perforated on the cardinal side by a byssal slit or opening as in Discina. Shell structure as in Lingula and Discina. Muscular scars yet unknown. Type, Lingula exilis, Hall. Geological horizon of the known species, Hamilton Group of the New York Series.

Girty (1928 , p. 243) took exception to this definition on several grounds: 1) taking Whitfield's diagnosis literally, "a brachiopod in which one valve had a terminal beak with shell accretions only at the front and sides while the other valve had a central beak with shell accretions equal all around, could not possibly occur in nature", 2) the holotype was in doubt, 3) the specimens on which Whitfield based his descriptions were

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crushed and hence the figures misleading, and 4) the resemblance of Whitfield's specimens to what Girty believed to be Lingula doria (Hall). He concluded that Whitfield's shells represented "a somewhat unusual species of Orbiculoidea" (p. 249).

Whitfield based his descriptions on the specimen figured in Hall (1867, Pl. 1, fig. 9) and on several other specimens. Hall had doubtfully referred this example of his Lingula exilis, but the designation of the specimen as the lectotype of exilis by Whitfield and Hovey (1900, p. 226), a fact overlooked by Girty, removes much of the question regarding the nature of the type species of Lingulodiscina. The lectotype of Lingulodiscina exilis is American Museum of Natural History no. 4584/1 figured by Hall on plate 1 as figure 9 not figure 8 (although the latter would undoubtedly have been Hall's choice); Clarke and Reudemann's subsequent designation (1903, p. 266) of New York State Museum no. 7860/1 (Hall's fig. 8) as the type is invalid.

In regard to point 1 (above), doubtless one should not take Whitfield's description too literally as regards his unfortunate use of "linguloid" to describe one side and "discinoid" to describe the pedicle valve. Undoubtedly he was employing these expressions as descriptive terms, not with their strict zoological connotation.

Girty's third point, that the apex was not truly marginal but only apparently so because of crushing, carries

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less weight in the light of discovery of well preserved brachial valves in the Oswayo which have the general characters ascribed to Lingulodiscina by Whitfield.

A revised description is thus given below based on these specimens, Whitfield's original descriptions, and amplified by Girty's observations of Whitfield's specimens.

DESCRIPTION: Small, nearly circular to subovate. Brachial valve with beak markedly eccentric being near the posterior margin or even overhanging the posterior margin. From the beak the shell curves smoothly to the anterior margin with the greatest convexity at, or slightly posterior to midlength. Transversely smoothly curved at midlength. Ornamentation consisting of fine lines representing increments of growth. Pedicle valve nearly circular to subovate, slightly concave, apex nearly central or slightly posterior; posterior cleft by pedicle groove the exact nature of which is unknown. Pedicle groove apparently like that of Orbiculoidea d'Orbigny but slightly open at the posterior margin although constricted posteriorly. Pedicle valve ornamented with more widely and regularly spaced growth lines than the brachial valve. Internal details not known.

DISCUSSION: In the systematic placement of this genus in the Trematidae the writer follows Schuchert (1897) and Roger (1952); but likely it is very near Oehlertella Hall and Clarke and Orbiculoidea d'Orbigny of the

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Discinidae. Probably it is intermediate in position between Orbiculoidea in which the pedicle groove is closed on the posterior margin and Oehlertella in which the posterior margin is deeply cleft. However, even if further investigation should prove that the pedicle groove fails to reach the posterior margin, the distinctive tumid contour and posteriorly placed beak of the brachial valve would be sufficient to separate it from Orbiculoidea. On the other hand, these same characters separate Lingulodiscina from Oehlertella and perhaps ally it with the other Trematidae rather than the Dicinidae.

Roger (1952) reports Lingulodiscina from Africa and Germany, but the writer has been unable to discover the source for this statement or to amplify the above description with information from European authors.

Lingulodiscina exilis? (Hall), 1960

Plate 1, figures 7-13.

Lingula exilis Hall, James, 1860, New York State Cab. Nat. Hist., 13th Ann. Rept., p. 77, fig. 2; Hall, 1867, Nat. Hist of New York, Paleont., v. 4, p. 7, pl. 1, figs. 8-9.

Lingulodiscina exilis (Hall), Whitfield, R. P., 1890, American Mus. Nat. Hist., Bull., v. 3, p. 122, figs. 1-8; Schuchert, Charles, 1897, United States Geol. Surv., Bull. 87, p. 261; Whitfield, and

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Hovey, E. O., 1900, American Mus. Nat. Hist., Bull., v. 11, p. 226-227.

Oehlertella exilis (Hall), Clarke, J. M., and Ruedemann, Rudolf 1903, New York State Mus., Bull. 65, p. 266.

[?] Lingulidiscina newberryi (Hall)?, Girty, 1928, United States Geol. Surv., Prof. Pap. 150E, p. 113-115 (partim).

Lingulidiscina exilis (Hall), Girty, G. H., 1928, Washington Acad. Sci., Jour., v. 18, p. 241 et seq.

Seventeen specimens from the Oswayo formation and the Kushequa member of the Knapp formation are questionably referred to this Hamilton species. The description of these specimens follows, and they are then compared with L. exilis.

DESCRIPTION: Brachial valve low, subcircular to subovate in outline. Beak small and obscure, bluntly pointed at the extremity, with a steep, concave slope to the posterior margin; commonly the beak nearly overhangs the margin. Remainder of valve smoothly curving to the anterior margin with the curve becoming steeper as the anterior margin is approached. Greatest convexity of the valve well anterior to the beak, commonly about midlength. Moderately to strongly convex transversely with the sides convex but more steeply curved than the central part of the valve. Growth lines fine, closely packed, irregular, yet not becoming strongly raised or lamellose as in

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Orbiculoidea. Shell commonly black and very thin.

Brachial interior apparently smooth throughout or with faint radially disposed anastomosing ridges which become quite pronounced peripherally.

Pedicle valve not present in the collections.

DISCUSSION: Many of the specimens have one part or the other of the periphery folded inward. Undoubtedly the extreme thinness of the shell and the resultant ease with which it became folded is what lead Girty (1928c) to interpret L. exilis as an Orbiculoidea; that is, he mentally restored much more to the posterior of the shell than was originally present. The beak is much farther posterior than he would imply.

The form of the species seems to be quite mutable. Several of the specimens very closely resemble L. exilis as figured by Hall and by Whitfield. Other s of the specimens at hand are somewhat higher and have the beak farther from the posterior margin; however these seem to intergrade with other specimens very like the Hamilton form. None of the specimens appears to have the "surface lamellose" as described by Hall (1867, p. 7); on the contrary, the growth lines are very low. Although it is doubtful that these stratigraphically much higher forms are conspecific with those from the Marcellus, no morphological criteria are readily apparent which would separate the two species. On the whole, the Kushequa specimens are smaller, possess a more marked and less

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posteriorly situated beak than those from the Oswayo and may eventually prove to be a third distinct species. This separation does not now seem wise, however, and the entire lot is questionably referred to L. exilis (Hall).

TYPES: Figured hypotypes, UCM Nos. 29833, 29834, 29838, 29846, 29849.

OCCURRENCE: Roystone coquinoid member of the Oswayo at locality 1 and a calcareous sandstone in the Oswayo at locality 60, and in the Marvin Creek coquinoid zone of the Kushequa shale at locality 97.

REMARKS: Measurements of the better specimens are given below. A question mark indicates that the specimen is folded or broken so that the measurement is an approximation of the original condition.

UCM No.	Length (mm)	Width (mm)	l/w	Remarks
Locality 1				
29833	15.9	15.6	1.02	brachial exterior
29834	18.4	15.8	1.16	brachial exterior
29835	20 ?	17.6	--	brachial interior, mold
29836	13.4	12.9	1.04	brachial interior, mold
29837	25.1	18.3?	1.37	brachial interior, mold
Locality 60				
29838	18.6	17.8	1.04	brachial interior, mold
Locality 97				
29842	8.9	8.0	1.11	brachial exterior
29843	9.6	8.0?	1.20	brachial exterior
29845	10.2?	8.2?	1.24	brachial exterior
29846	14.1?	12.7?	1.11	brachial interior, mold
29847	14.7	14.4?	1.02	brachial interior, mold
29848	--	12.3	--	brachial exterior
29848	--	12.1	--	brachial interior

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Family DISCINIDAE Gray, 1840

Subfamily ORBIDULOIDEINAE Schuchert and LeVene, 1929

Genus Orbiculoidea d'Orbigny, 1847

TYPE SPECIES (by subsequent designation, Dall, 1877, p. 51; fide Girty, 1928, p. 137): Orbicula forbesi Davidson, 1848, Soc. Géol. France, Bull., 2d ser., v. 5, p. 334.

Hall and Clarke (1892, p. 129-130) give the following description of this genus:

> Shells subcircular or subelliptical in outline, inequivalve. Apices excentric. Pedicle-valve depressed-convex or flattened, with the apex slightly elevated and inclined posteriorly. On the exterior of the valve a narrow pedicle-furrow, abruptly intercepting the ornamentation but not penetrating the substance of the shell, begins just below and behind the apex, extends over a greater or less portion of the radius of the valve, and, at its distal end, is produced into a short tubular sipho [sic], which traverses the substance of the shell obliquely backward, emerging on the interior surface, where it produces a narrow groove, and usually terminates before reaching the margin of the valve. On the interior, the position of the external groove is marked by a thickened ridge extending from the apex, and this is continuous with the thickened margins of the internal groove, which, in advanced age, may become so developed as to envelop this groove, except at its outer end.
>
> The larger or brachial valve is depressed-conical, with the apex more strongly directed backward than in the opposite valve. The interior shows a fine longitudinal ridge or septum extending from the apex forward. Otherwise the internal markings are not satisfactorily known.
>
> Shell-substance or alternating lamellae of corneous and mineral matter, the latter often removed in fossilization, making the shell appear essentially phosphatic. Surface ornamentation usually consisting of fine, crowded or distant, sometimes lamellose concentric lines, occasionally crossed by radiating lines or ridges.

DISCUSSION: Orbiculoidea is characterized by the

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subconical brachial valve, slightly convex or flat pedicle valve, and the pedicle tube which extends backward from near the eccentric apex to open internally near the posterior margin. On the interior, this tube and the lateral callosities which border it appear as a ridge extending from the apex backward toward the margin. Hall and Clarke (1892, p. 131) also point out that,

> . . . in the earlier stages of growth the pedicle-groove opens upon the margin, its distal edges gradually approaching as growth advances, until, at maturity, they are united, and with further increase in age, the distance of the groove from the margin is augmented. No adult example, however, presents any other condition of this part of the shell than that above described, except when a matter of imperfect preservation.

Further they say (p. 132), "We must therefore consider the enclosure of the groove an essentially adult character of Orbiculoidea. . . ."

Oehlertella Hall and Clarke then differs from Orbiculoidea in having the pedicle-groove opening into a deep and wide marginal fissure which extends nigh to the apex.

Lindstroemella was described by Hall and Clarke (1892, p. 134) as possessing, in the brachial valve, "two strong approximating ridges or muscular fulcra, beginning just behind a transverse line passing through the apex and rapidly converging to meet the median septum"; regarding the pedicle foramen they say, ". . . its distal margins, though lying in close juxtaposition appear not to have been united."

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Roemerella Hall and Clarke of the Middle Devonian is externally similar to Orbiculoidea except that in the former the pedicle valve is concave with the pedicle foramen raised on a subcentral boss while in Orbiculoidea the reverse is true. The internal characters of Roemerella are largely unknown.

Here in the discinoids, as in the linguloids, a plexus of genera is undoubtedly masquerading under a few generic names. An example might be the Lindstroemella patula (Girty) of Dunbar and Condra (1932, p. 48-50, pl. 1, figs. 8-11) which was originally described as Roemerella patula by Girty (1915, p. 51-52); this species is shown by Dunbar and Condra to possess a pedicle valve which is concave at least anteriorly, as in Roemerella but to have the brachial interior of Lindstroemella. This species, however, has the marginal part of the pedicle-groove completely closed, and the "characteristic sculpture passes around it without interuption".

Undoubtedly the key to the relationships within this plexus lies in the interior of these inarticulate brachiopods, but here, once again, the student is frustrated by preservation.

Orbiculoidea cf. O. alleghania (Hall)

Plate 1, figures 21-26; text figure 9.

[?] Discina alleghania Hall, James, 1860, New York State Cab. Nat. Hist., 13th Ann. Rept., p. 77, fig. 1;

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Hall, 1867, Nat. Hist. New York, Paleont., v. 4, p. 25, fig. 1, pl. 1, fig. 17.

[?] Orbiculoidea alleghania (Hall), Schuchert, Charles, 1897, United States Geol. Surv., Bull. 87, p. 277.

Orbiculoidea sp., Caster, K. E., 1931, Bull. American Paleont., no. 58, pl. 10, fig. 3.

Hall (1860, p. 77; 1867, p. 25) described Orbiculoidea alleghania as large, broadly elliptical or nearly circular, with the brachial valve depressed conical and flattened toward the margin; the apex is slightly inclined backwards and at a little more than one-third the length from the posterior of the shell.

Three brachial valves (two of which are molds of the exterior and one is a fragmental exterior with the shell preserved) and one pedicle valve which are very similar to this species are present in the collections. The brachial valves are subcircular; casts made from the natural molds show that the apex is posterior to midlength, but is not situated as far posterior as indicated by Hall. The anterior slope is broadly and gently rounded, but the posterior slope is straight to very slightly concave and the beak not inclined backward.

The pedicle valve is nearly flat anteriorly becoming convex posteriorly. The greatest convexity is just posterior to the apex where the sides of the pedicle trough are greatly raised. Further interpretation of intimate details of the pedicle area is confusing as pointed out by Hall

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and Clarke (1892, p. 126), and fraught with difficulties caused by the adherence of shell to the matrix of the opposing surface. Both surfaces of the matrix (each with bits of shell adhering) are present for the pedicle valve at hand and allow an unusual amount of detail to be gained. Relations of the shell to the matrix are shown in Figure 9.

The pedicle trough is "kite-shaped" with the longer portion posterior to the external pedicle foramen; the short portion extends from the external foramen anteriorly to the apex and was apparently closed by a listrium. Surrounding the pedicle groove posterior to the external foramen, is the "areal callosity" (figured by Hall and Clarke, 1892, pl. 4F in O. herzeri Hall and Clarke) which is a smoother part of the shell. The pedicle groove does not seem to have been enclosed completely by a pedicle tube but was rather an open groove filled by the pedicle (at least anteriorly). Near the external foramen the edges of the shell seem to have been flexed outward to form a raised lip around the edge of the opening. Shallow grooves, one from each side and one from the anterior, are impressed on this lip as though for pedicle adjustor muscles.

Seemingly concentric lines of growth (about 0.4 mm apart) are present on both valves. These are distinct raised lines which represent what were free edges of the shell. In some places they are raised to such an extent that they are flanges entirely free from the surface of the shell. While these lines give the impression of being perfectly concentric, closer examination shows that they

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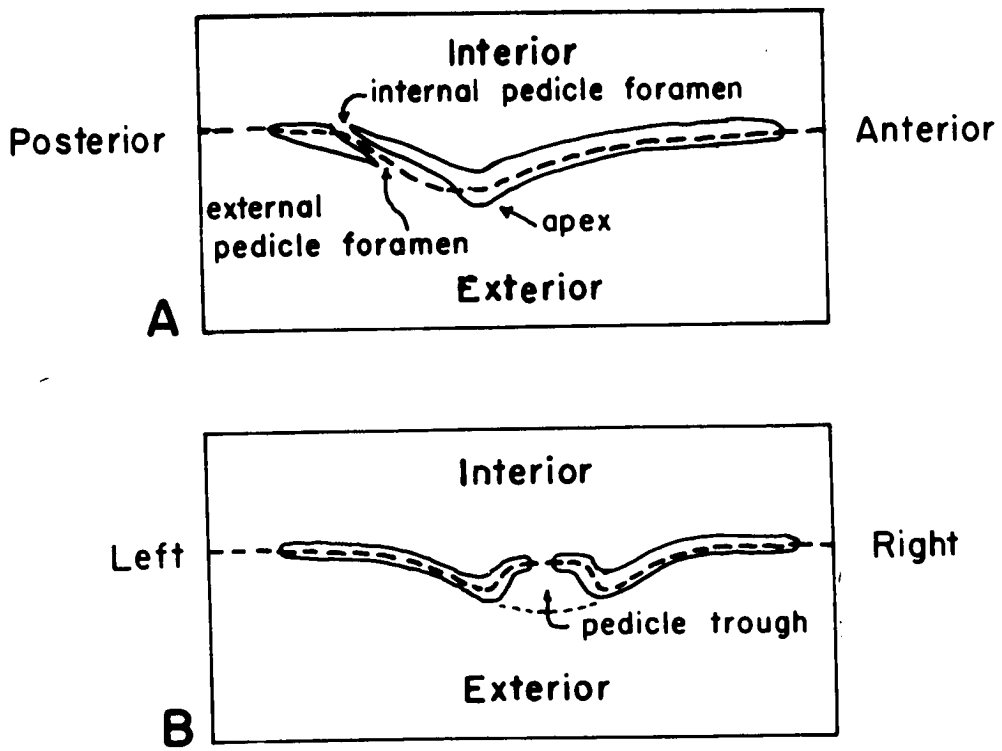

Fig. 9 -- Diagrammatic sections approximately x 2½ of the pedicle valve of Orbiculoidea cf. O. alleghania (Hall), with line of parting shown by heavy dashed line, showing how some internal features in the area of the pedicle trough can be shown on what is essentially a mold of the exterior. Because the shell commonly parts along the pedicle groove, shell adhering to the mold of the exterior may show the interior foramen. A, longitudinal section; B, transverse section posterior to apex.

curve and die out laterally, are overlapped by another growth increment, and are commonly wrinkled. Thus it is seen that the shell grows by adding increments in gentle arcuate lobes rather than perfectly regularly around the entire periphery. Between the more distinct raised lines are extremely fine lines or slight wrinkes of the shell which parallel the stronger growth increments.

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DISCUSSION: It is difficult to tell whether the four specimens at hand belong to the species with which they are compared, or whether they should for the basis of a new species. Apparently they differ from O. alleghania (Hall) in being smaller, higher and more evenly convex, in having a more centrally situated apex and in lacking the flattened rim. Hall's species gives every impression from his illustrations that the posterior inclination of the beak and flattening may be due to crushing. The general appearance of the Oswayo specimens so closely resembles O. alleghania, that if it were found that the flattening and posterior inclination of the beak could be removed by restoration, there would be little hesitation in referring these specimens to Hall's species. In any case, they are closely related to this lower form and if distinct, are assuredly derived from it. They differ from O. herzeri Hall and Clarke by being distinctly larger.

HYPOTYPES: UCM Nos. 29814 (exfoliated exterior and counterpart of one pedicle valve); 29758 and 29759 (molds of the exterior of brachial valves), 29815 (fragmental brachial valve.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 1 and in a coquinoid of Oswayo lithology at locality 60.

REMARKS: Approximate dimensions of the specimens

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are given below.

UCM No	length (mm)	width (mm)	thickness	remarks
29758	26.?	24.?	8.	brachial valve
29759	27.?	26.?	10.	brachial valve
29814	23.3	23.2	2.5	pedicle valve
29815	21.6	20.0	--	brachial valve

Orbiculoidea sp. A.

Plate 1, figures 28-30.

Two partial pedicle valves and one brachial broken valve are present which cannot be referred to any known species. It is possible that they are conspecific with the form from the Oswayo herein described as Orbiculoidea cf. O. alleghania (Hall). However they differ from the Oswayo form in having the brachial valve larger, higher, and more steeply conical, and having the pedicle valve more concave. The characters around the pedicle area are not preserved, however. Thus, although the markings, size, general appearance and stratigraphic proximity make it seem likely that they are conspecific, they are here separated with the expectancy that further collecting will prove them distinct.

The apex of the brachial valve is not preserved but appears to have been central or just slightly anterior to mid-length (assuming anterior as the steepest slope and the greatest width anterior to midlength). Thus the outline in brachial view is subovate. One specimen shows

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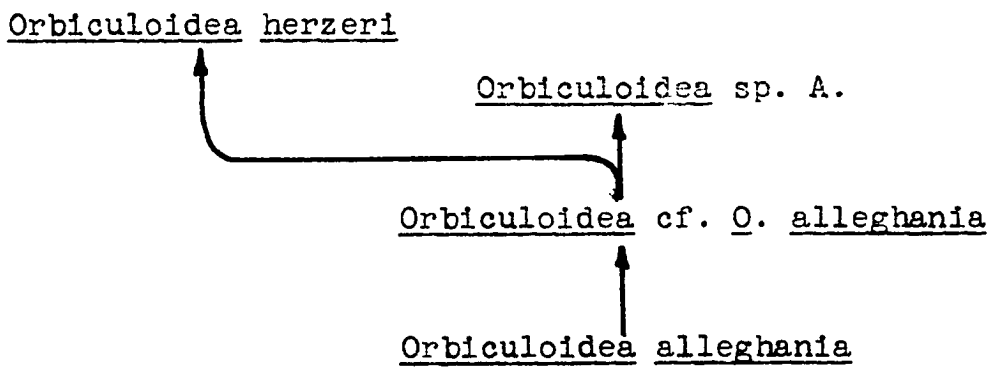
a section of the pedicle valve, which is quite concave in this area, joined to part of the brachial valve at the sharp anterior (?) margin. The other part pedicle valve is nearly flat or slightly concave.

All of the fragments have the shell quite well preserved. It is medium dark gray (N4 as compared to the Goddard, et. al. 1948, chart), lustrous and marked with slightly darker very faint radiating lines within the shell substance, 0.05 to 0,1 mm thick, and wrinkled and "ornamented" by growth lines as in the Oswayo form.

DISCUSSION: It seems likely that this form is specifically distinct from both Orbiculoidea alleghania (Hall) and the Oswayo Orbiculoidea compared with it. However three species and O. herzeri Hall and Clarke from the Berea sandstone seem to be closely related as shown in the following diagram.



HYPOTYPES: UCM Nos. 29820, 29821 (fragments of pedicle valves) and No. 29822 (broken brachial valve).

OCCURRENCE: Marvin Creek limestone member of the Kushequa shale at locality 97.

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REMARKS: The brachial valve figured as a hypotype is 26.3 mm long, 28.1 mm wide, and about 13 mm high.

Orbiculoidea sp. indeterminate

Plate 1, figure 20.

One small brachial interior of a discinoid embedded in fine grained shaly sandstone from locality 202 is present in the collections. It is broadly subovate in outline and moderately deep with the apex situated about one-third the length from the posterior margin. The slope to the posterior margin is nearly straight and rather steep; from the apex the surface is a smooth, convex, less steep curve to the other margins. Internally the valve is perfectly smooth.

DISCUSSION: Presumably this small shell is an Orbiculoidea. It is higher and has the apex farther anterior than Lingulodiscina exilis ? (Hall) from the Kushequa. It is easily separable from the other Orbiculoidea and from Oehlertella occurring in this area by the lesser size and lower form; the shape is not like that of Orbiculoidea cf. O. alleghania or Oehlertella pleurites (Meek), so it is not likely that this specimen is the young of one of these species.

HYPOTYPE: UCM No. 29832 (Interior of a brachial valve).

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OCCURRENCE: Tidioute shale at locality 202.

REMARKS: Dimensions of the specimen are given below:

UCM No.	length (mm)	width (mm)	l/w
29832	7.2	6.2	1.161

Genus Oehlertella Hall and Clarke, 1892

TYPE SPECIES (by monotypy): Discina (Orbiculoidea?) pleurites Meek, 1875, Ohio Geol. Surv., Rept., v. 2, pt. 2, Paleont., p. 278, pl. 14, fig. 2. Waverly group, Mississippian, Newark, Ohio.

DIAGNOSIS: Like Orbiculoidea but with the pedicle groove of the adult passing posteriorly into a deep fissure or cleft in the posterior margin.

DISCUSSION: Apparently the principal differences between this genus and Orbiculoidea d'Orbigny is the marginal fissure of the pedicle groove which extends to, or nearly to, the apex in Oehlertella instead of becoming closed during growth as in Orbiculoidea. Except for the posterior notch, the sides of which are sharply depressed in some specimens, the pedicle valve is commonly almost perfectly flat. The apex of the brachial valve appears to be rather more posterior than in Orbiculoidea; interior of the brachial valve unknown. The characteristics of other similar genera are given herein under the discussion of Orbiculoidea.

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Oehlertella pleurites (Meek)

Plate 1, figures 14-16.

Discina (Orbiculoidea?) pleurites Meek, F. B., 1875, Ohio Geol. Surv., Rept., v. 2, pt. 2, Paleont., p. 278, pl. 14, figs. 2a, 2b.

Orbiculoidea pleurites (Meek), Herrick, C. L., 1888 1890 Denison Univ., Sci. Lab., Bull., v. 4, p. 12, 19, p pl. 3, fig. 5; 1893, Ohio Geol. Surv. Rept., v. 7, pl. 22, fig. 12.

Oehlertella pleurites (Meek), Hall, James, and Clarke, J. M., 1892, Nat. Hist. of New York, Paleont. v. 8, pt. 1, p. 132, pl. 4E, figs. 21-24, pl. 4F, figs. 19, 20; 1893, New York State Geol., Ann. Rept. 11, p. 257, pl. 5, figs. 5-8; Caster, K. E., 1934, Bull. American Paleont., no. 71, p. 70.

Lingulodiscina pleurites (Meek), Schuchert, Charles, 1897, United States Geol. Surv., Bull. 87, p. 261; Weller, Stuart, 1898, United States Geol. Surv. Bull 153, p. 327; Caster, 1930, Bull. American Paleont., no. 58, p. 5, pl. 10, figs. 21-23.

Meek originally described this species from the brachial valve only saying:

> Shell very nearly circular, or slightly longer than wide. Upper valve much depressed; apex but little elevated, obtuse, and placed very near the posterior margin, with a backward inclination, and more depressed than the surface a little in advance of it; surface only showing fine, obscure, irregular lines, and some strong wrinkles of growth. Internal cast showing a linear

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impression along the middle of the anterior slope. Under valve unknown.

Length, 0.93 inch; breadth, 0.89 inch; height a little in advance of apex, 0. 16 inch; do. of apex, 0.10.

Hall and Clarke (1892) figure both valves and show the pedicle valve to have the pedicle groove unclosed at the posterior margin and with a low median septum extending anteriorly from the apex of this notch in one specimen (pl. 4F, fig. 19).

Two pedicle valves from the Oswayo formation and one from the Kushequa member of the Knapp formation show these characters. The valves are nearly circular and slightly concave. The shell bends sharply inward near the pedicle groove. In the specimens where it is visible this groove seems to have been closed anteriorly by a listrium; a short, shallow septum seems to extend anteriorly from the apex of the pedicle groove.

The specimen from the Kushequa has the shell well preserved; it is medium gray (N5) and lustrous. The surface is marked by rather regularly spaced, nearly continuous, concentric, raised, sometimes lamellose lines. Between these stronger lines are finer, less pronounced, concentric wrinkles; however the lines of growth are never lobate or die out laterally as in Orbiculoidea sp. A from locality. In the Kushequa specimen the pedicle groove is filled with rock matrix, but it seems to have an unusually large angle, i.e. about 105° whereas in those from the Oswayo the angle of the pedicle groove is about 55° to 60°.

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DISCUSSION: It seems likely that the Kushequa specimen may be specifically distinct on the basis of the unusually wide pedicle groove. However, it seems unwise to separate this single valve into a new species when further characters of this critical area are obscured.

PALEOPATHOLOGY: The Kushequa specimen shows what appears to be definite signs of a break in the anterior margin which was subsequently repaired by the animal. Apparently a distinct chip about 5 mm wide was broken from the edge of the shell. The growth lines, usually wrinkled in this region seem to curve around the edges of the break; and within 2 mm the break seems to have been repaired, and the growth lines are normal again.

HYPOTYPES: UCM Nos. 29816 (mold of the exterior), and 29817 (mold of the interior) from the Oswayo and 29818 (exterior and mold of the exterior) from the Kushequa.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 1 and the Marvin Creek coquinoid zone of the Kushequa shale at locality 97.

REMARKS: The approximate dimensions of the three pedicle valves in the collections are given in the following table.

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UCM No.	Length (mm)	Width (mm)	Remarks
Locality 1			
29816	18.?	17.0	mold of interior
29817	15.?	16.1	mold of exterior
Locality 97			
29818	11.?	16.6	

Superfamily CRANIACEA Waagen, 1885

Family CRANIIDAE Gray, 1840

Genus Lissocrania Williams, 1944

TYPE SPECIES (by original designation): Crania dodgei Rowley, 1908, Missouri Bur. Geol. and Mines, 2d ser., v. 8, p. 73, pl. 17, figs. 5,6. Louisiana limestone, Mississippian, near Louisiana, Missouri.

Weller (1914, p. 43) and Williams (1944, p. 71) recognized three distinct types of brachiopods referred to Crania Retzius to which the latter gave subgeneric names. The first of these has the "brachial" or upper valve ornamented by radial costae (Crania, s. s.); the second ornamented by growth lines or very faint radiating "striae" (Lissocrania); and the other type is ornamented by papillae or fine spines (Acanthocrania). Cooper (1956, p. 283) has elevated Acanthocrania to generic status, and it is proposed here to use Lissocrania in the same fashion.

Williams (1944, p. 71) described this form as,

> Cranias with dorsal valves devoid of radial costae or spines. Ornamentation, if any, consists of concentric growth lines or of fine radiating striae or both.

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The pedicle valve is unknown and little is known of the interior or the shell structure. Two tiny specimens (both brachial valves) from the Kushequa shale are tentatively referred to this genus. While they have the attaching habit of craniids they seem to be carcareous and impunctate. Cooper (1956, p. 282) has placed an impunctate form, his Eoconulus, in this family however. The interior of one brachial valve is exposed in the collection at hand, but it does not conform to the usual musculature of the Craniacea.

Lissocrania parvula, n. sp.

Plate 1, figures 17-19.

DESCRIPTION: Small, nearly circular, attached and closely adhering to the substrata with the margins reflecting the surface to which the shell adhers. Brachial valve a low cone; the beak is pointed, eccentric, and the highest point of the valve. From the beak the surface descends in a gently concave curve to the posterior margin and in a smooth, convex, more gentle curve to the other margins which are flattened near the periphery. Shell impunctate, medium dark gray (N4), marked only by exceedingly fine, irregular, lines of growth.

Brachial interior apparently with the muscles concentrated on a nearly circular, concave, raised, subapical platform; otherwise smooth.

Pedicle valve unknown.

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DISCUSSION: This species is represented by two brachial valves; one an interior and one an exterior. The exterior, the smaller of the two, is tightly adhering to the inside of the valve of a spiriferid. The margins fold over the costae of the shell to which it adhers; but the adhering shell seems otherwise unaffected. The outer layer of the shell of this specimen is exfoliated and the inner layer appears glossy, corneous, and devoid of puncta. On the exfoliated part of the shell very fine, irregular, radiating lines can be seen under the microscope. Perhaps it was these lines in a specimen similarly preserved to which Weller (1914, p. 44) alludes but which Williams (1944, p. 71) implies do not exist in the type species. A bit of what is interpreted as the pedicle valve extends from beneath the chipped anterior edge of the brachial valve. If this is indeed the lower valve, it is so thin as to be nearly translucent.

The other specimen appears to have been free when deposited; nearby is a shell fragment, but this appears to be at a different level in the piece of limestone so that presumably the Lissocrania was not attached to it. The interior shows the flattened periphery; however the margins are not warped so the substrate (pelecypod shell?) of this valve was apparently nearly smooth. The specimen seems to have been slightly crushed inward, and no details except the circular, subapical, muscle platform (mentioned above) can be discerned.

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The small size readily separates this species from other Mississippian cranioids, but the generic assignment is in doubt since the musculature apparently does not resemble that of Crania.

TYPES: Holotype: UCM No. 29851 (brachial exterior; hypotype: UCM No. 29850 (brachial interior).

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa shale at locality 97.

REMARKS: Measurements of the two specimens are given below.

UCM No.	Length (mm)	Width (mm)	l/w	Thickness (mm)
29850	4.8?	4.8	1.000	--
29851	3.7	3.2	1.156	.8(approximately)

Subphylum PYGOCAULIA Thomson, 1927

Suborder DALMANELLOIDEA Moore, 1952

Superfamily DALMANELLACEA Schuchert and Cooper, 1931

Family RHIPIDOMELLIDAE Schuchert, 1913, emend. Schuchert and Cooper, 1932

Genus Rhipidomella Oehlert, 1890

TYPE SPECIES (by original designation): Terebratula michelini L'Eveillé, 1835, Soc. Géol. France, Mém., v. 2, p. 39, pl. 2, figs. 14-17.

Schuchert and Cooper (1932, p. 133) fully describe

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this genus in the following manner:

> DESCRIPTION, Exterior. -- Subtrigonal to circular, anterior margin not uncommon emarginate, hinge-line narrow; lateral profile unequally biconvex, the brachial valve having the greater convexity, with the ventral one concave at the front in many species; anterior commissure faintly uniplicate or rectimarginate; in some instances a sulcus on each valve; ventral interarea the longer, curved, apsacline, umbo swollen or greatly convex, beak incurved; dorsal interarea greatly reduced, ortho- to apsacline; delthyrium open, notothyrium usually closed by the cardinal process or partially by chilidial plates; surface multicostellate, hollow costellae numerous. Fibrous, punctate.
>
> Ventral interior. -- Delthyrial cavity shallow; dental plates abbreviated, teeth strong, divergent, elongate; a broadly curved ridge extending from the bases of the low dental plates around the margin of the muscle field; muscle field large, flabellate, not confined to the delthyrial cavity, occupying from one-third to five-sixths the length of the valve and usually deeply impressed; diductor scars semiflabellate, separated from each other by a sharp or low broad ridge, completely enclosing the adductor scars, which form an elliptical patch just anterior to the pedicle callist; adjustor scar commonly discernible on the outside of the diductor scar; pedicle callist occupying the delthyrial cavity.
>
> Dorsal interior. -- Cardinalia confined, sockets wide, deep without concave fulcral plates, brachiophores long, bluntly pointed, supported by adventitious substance deposited beneath their anterior edge; sharp processes or points on the ends of the brachiophores have been interpreted as crura; cardinal process large, myophore commonly ponderous, lobate; shaft short. Median ridge extending to the middle of the shell. Muscle field quadripartite, the posterior scars the larger. Ovarial and pallial impressions occupying the area of the shell not covered by the muscle marks.

DISCUSSION: Rhipidomella differs from Thiemella Williams (1908) by lacking the latter's dalmanelloid fold of the pedicle valve and sulcus of the brachial valve. Reeftonia Allan (1947) has a wider hinge line, planoconvex lateral aspect, massive dental plates, generally smaller myophore, and lacks the brachiophore processes of Rhipidomella. In Perditocardinia Schuchert and Cooper (1931) the hinge line

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has narrowed to virtual disappearance, and the shell is rostrate. Platyorthis Schuchert and Cooper (1931) is characterized by a dalmanelloid appearance, planoconvex profile and a huge bilobed cardinal process.

Some of the more ventricose Rhipidomella might be confused with Schizophoria King (1850)but usually Schizophoria is more gibbose, more transverse, and has a more pronounced fold and sulcus. Internally the dental lamellae of Schizophoria are generally more strongly advancing, and the adductor muscles are borne on the median septum; in the brachial valve there are several differences which permit separation of Schizophoria from Rhipidomella, but perhaps the most striking are the greater size of the cardinal process in Rhipidomella and the lack of fulcral plates in this genus.

Rhipidomella pennsylvanica (Simpson), 1889

Plate 2, figures 1-8; text-figure 10.

Orthis pennsylvanica [nomen nudum] Simpson, G. B., 1889, Pennsylvanic Second Geol. Surv., Rept. 03, pt. 3, p. 258.

Orthis pennsylvanica Simpson, G. B., 1889, in Lesley, J. P., Pennsylvania Second Geol. Surv., Rept. P4, v. 2, p. 528-529, figs. 1,2; Simpson, 1890, American Phil. Soc., Trans., v. 16, n.s., p. 437, fig. 1 (nos. 1,2).

Rhipidomella pennsylvanica (Simpson), Hall, James, and

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Clarke, J. M., 1892, Nat. Hist. New York, Paleont, v. 8, pt. 1, p. 225; Schuchert, Charles, 1897, United States Geol. Surv., Bull. 87, p. 51; Caster, K. E., 1930, Bull. American Paleont., v. 15, no. 58, p. 8, pl. 17, figs. 9, 10.

Rhipidomella sp., Caster, 1930, Bull. American Paleont., v. 15, no. 58, pl. 15, fig. 9.

Schuchertella cf. chemungensis (Conrad), Caster, 1930, Bull. American Paleont., v. 15, no. 58, pl. 15, fig. 10.

Schizophoria sp.?, Caster, 1930, Bull. American Paleont., v. 15, no. 58, pl. 15, figs. 12, 13.

Rhipidomella? pennsylvanica (Simpson), Caster, 1934, Bull. American Paleont., v. 21, no. 71, p. 71.

Simpson (in Lesley, 1889; 1890) gives the following description of this species:

> Shell essentially circular, in nearly all the specimens observed, the height and width being equal; hinge line short, length equal to half the width of the shell; cardinal extremities rounded; lateral and basal margins regularly rounded, except in the middle basal margin of the ventral valve; where there is a slight constriction.
>
> Dorsal valve somewhat gibbous, greatest convexity a little above the middle; rapidly curving to the cardinal and lateral margins; a little more gradually to the basal margins. Along the middle of the valve is a flattened or slightly depressed area, narrow at the beak, gradually growing wider, and comparatively broad at the base.
>
> Ventral valve. A perfect specimen has not been observed, but gutta-percha casts have been taken from impressions of fragments in the rock which probably belonged to this species. The valve is flattened, or of much less convexity than the dorsal valve, with a slight elevation along the middle, corresponding to the depression of the cpposite valve.
>
> Surface marked by prominent, subangular, radiating striae, increasing by bifurcation, of uniform size at

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> the margins, where there are twelve in the space of 5 mm.; a short distance below the beak there are twenty in the same space. The radii are crossed by fine indistinct concentric striae, which on many specimens are obsolete; also, at irregular intervals, by lines or varices of growth.
>
> On the cast of the dorsal valve the distance from the beak to the lower margin of the muscular impression is about one-half the length of the valve. Impression ovate in outline; width equal to or very slightly less than the length, with a deep depression along the middle. On the ventral valve the impression is ovate, bilobed. The margins are distinctly lobed in four divisions. The greater portion of the specimens observed have a diameter of from 20 to 25 mm.
>
> This species may be distinguished from Orthis impressa, of this formation, by its smaller size and its more circular outline; from Orthis tioga, by its more circular outline, less conspicuous sinus and elevation, and ovate muscular impression.

It seems that without doubt the specimens at hand should be referred to Simpson's species. There are, however several details which might be emphasized or added from the sandstone molds at hand.

EXTERIOR: Shell markedly convexo-plane, usually wider than long, but varying to slightly longer than wide; greatest width at midlength. Greatest convexity of the very gibbous brachial valve posterior to midlength thence curving rapidly to the margins. Pedicle valve nearly flat or with slight convexity about one-fourth the valve length anterior of the beak. In a few specimens the brachial valve bears a very faint and gradual sulcus near the anterior margin but this is apparently not universal; the pedicle valve is apparently without fold or sulcus. Shell evenly multicostellate, with the costellae increasing by bifurcation; concentric striae not preserved. Shell

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finely endopunctate; puncta irregularly distributed but apparently concentrated along the crest of the costellae and rare in the troughs. Hinge line about one-third the greatest width; pedicle interarea 40° - 60° apsacline; brachial interarea greatly reduced or absent.

PEDICLE INTERIOR: Dental plates short, but advancing in their lower portion to enclose the posterior part of the muscle scar. Teeth elongate and massive extending deeply into the brachial valve; the teeth are tipped outward at their junction with the dental lamellae and welded to the thickened posterolateral margin of the valve just anterior to the interarea. The junction of the heavy tooth with the dental lamella is marked by a distinct crural fossette which articulates with the thickened upper margin of the opposing brachiophore of the opposite valve. Because of this groove at the base of the tooth, the tooth is rarely preserved but is usually broken from the dental lamella at this position. Posterior part of delthyrial cavity occupied by a smooth, triangular pedicle callist raised slightly above the floor of the valve. Diductor muscle scar large, distinct, ovate or flabellate, extending two-thirds to three-fourths the length of the valve, moderately impressed into the valve, but marked anteriorly and anterolaterally by a raised rim. The diductor scar is separated medially by a broad, low septum which is commonly forked posteriorly to enclose the elongate adductor muscle scars which are completely surrounded by the diductor scars.

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Raised rim of valve markedly crenulate.

BRACHIAL INTERIOR: Cardinalia dominated by enormous cardinal process. The huge kite-shaped myophore, traversed longitudinally by a median ridge from which the concave sides slope, is set on a short stocky shaft from which a heavy median ridge extends forward to approximately mid-length. Sockets deep, extending far posteriorly, bounded on the outside by thin like-lip socket ridges. Inwardly the sockets are bounded by the rather heavy, divergent brachiophores. The brachiophores are heavy, blade-like (scimitar-shaped) processes supported by thickened brachiophore plates which apparently grow upward by secretion of secondary material between the brachiophores and umbonal wall of the valve; it is actually the brachiophore supports which form the inner wall of the sockets, at least anteriorly. The brachiophores are tipped outward so that the blade-like upper edges rest firmly in the crural fossettes of the teeth when the valves are in juxtaposition. At the upper anterior edge of the brachiophore arises a distinct posterolaterally directed process or prong, the brachiophore tooth (see glossary in Appendix) which locks against the front of the tooth at the anterior end of the crural fossette. The brachiophore is transversed longitudinally by a distinct ridge which is evidently the trace of the brachiophore, since the brachiophore process is continuous with this ridge at the anterior terminus of the brachiophore well below the brachiophore tooth. The brachiophore process

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itself is elongate, rapidly tapering, and gently curved toward the brachial valve. Although the adductor scars are clearly separated by the low, rounded but heavy median septum, they apparently made little impression into the valve, for preservation permits only the faint impression of their oval form on each side of the septum but extending nearly to midlength; they are only faintly divided into posterior and anterior adductor scars and more commonly appear as indistinct oval impressions.

DISCUSSION: The distinctive characters of this species are the much inflated brachial valve and nearly flat pedicle valve, the lack of a sulcus in either valve, the small areas, and the ponderous cardinal process and heavy median septum in the brachial valve.

Perhaps closest to Rhipidomella pennsylvanica (Simpson) in general shape and size is R. mesialis Hyde (1953) but the brachial valve is not so convex in the latter species and it has a broad sulcus in the pedicle valve. Although not figured, the cardinal process of R. mesialis is said to be "rather small." In the form of the cardinalia, the molds of R. pennsylvanica at hand resemble those of R. missouriensis Weller figured by Hyde (1953, pl. 6, figs. 18, 30), yet the cardinal process appears small in the latter. Also this species has the valves of nearly equal convexity and is generally smaller and more nearly circular than R. pennsylvanica. R. burlingtonensis (Hall) also has the two valves nearly

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equal in convexity, and this species is characterized by a prominent pedicle umbo and a sloping posterolateral margin.

Internally R. pennsylvanica is not unlike R. oweni Hall and Clarke although the muscle scars of thelatter are smaller and more deeply impressed. R. oweni is distinguished externally by a sulcus in the brachial valve and an obscure fold bounded by shallow sulci in the pedicle valve. In R. penelope (Hall) of the Hamilton the brachial valve is less convex and curves more gradually from the posterior to the anterior margin, the interareas are larger; internally the muscle scars are smaller and the hinge structures are different in their configuration.

Because of the general similarity of R. pennsylvanica (Simpson) to R. penelope (Hall) it is thought likely that the former may have developed from the latter, perhaps through the smaller R. leucosia (Hall). The occurrence of Conewangoan Rhipidomella is little known or studied and much needs to be done to clarify the relations of R. pennsylvanica with lower forms. It is believed that R. burlingtonensis (Hall) and R. oweni Hall and Clarke developed from R. pennsylvanica, by rather minor shell modifications, in the more calcareous Midcontinent seas. Whether R. mesialis Hyde is a geographic subspecies of R. pennsylvanica or a valid coeval species is conjectural; but because of their morphological differences enumerated above, it is assumed that the latter is the case. Thus

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R. burlingtonensis and R. oweni may have descended through R. mesialis from R. pennsylvanica by progressive steps, as seems most likely.

The writer believes that Simpson (1890, p. 473) was misled by the appearance of molds of the ventricose brachial valve of R. pennsylvanica when he relates how to distinguish this species from Schizophoria (as "Orthis impressa" and "Orthis tioga") "of this formation." The more transverse specimens, especially, with their pronounced depression caused by the mold of the broad median septum, do indeed give the first impression of Schizophoria; but Schizophoria is not known to the writer to occur in upper Conewangoan or Lower Mississippian rocks in this area, but is a lower form occurring in the basal Conewangoan of the Penn-York Embayment. Schizophoria King frequently bears a brachial fold and pedicle sulcus and internally has the sockets defined by fulcral plates and in the pedicle valve the adductor muscles are borne on the median septum. Thus none of the specimens of the Oswayo or Knapp are believed to be referrable to Schizophoria.

PALEOPATHOLOGY: Several specimens of Rhipidomella pennsylvanica (Simpson) from locality 199 show filled tubules of boring organisms preserved in the molds of the exterior. Most of these are in brachial valves, but a few are in the umbonal regions of pedicle valves. These tubules are very slender and delicate, mostly in the order of 0.1 to 0.3 mm in diameter and up to 1 cm long. No hypertrophic deposits

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of the shell of the host organism have been observed; thus apparently no trauma was caused to the animal or else the shell was penetrated after death of the organism. The latter is believed to have been the case for the following reasons: a) lack of hypertrophic deposits, b) rarity of tubules entering the edge of the shell, c) concentration of the tubules on high parts of brachial valves which lay convex upward in the rock, d) dissimilarity of these tubules with those affecting Cyrtospirifer horridus, n. sp., of the Oswayo.

These tubules are tentatively interpreted as sponge borings and bear remarkable similarity, both in morphology and association, to the three "species" identified by Hyde (1933, p. 214-216) as Clionolithes ramosus Hyde, Clionolithes ? rectus Hyde, and Seminolithes linii Hyde. Some resemble Condranema Bassler (1952) as figured by Elias (1957, pl. 40, fig. 9). The penetrations of the shells of Devono-Mississippian brachiopods and its significance is deserving of further study (see below under Cyrtospirifer horridus, n. sp.).

TYPES: Figured hypotypes, UCM Nos. 29689, 29690, 29692, 29698, 29739.

OCCURRENCE: Fine grained sandstone in the Oswayo formation at locality 60; fine to medium grained sandstone in the Knapp formation at localities 118 and 199 (majority of the specimens; siltstone in the Tidioute shale at localities 119, 201, 202.

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REMARKS: This species is represented in the collections by four poorly preserved specimens from locality 60 of which two are molds of both interior and exterior and two are molds of the interior only. Specimens abound at locality 199 in association with Schuchertella desiderata (Hall and Clarke), Camarotoechia mimelegantula, n. sp., and "Cyrtospirifer" plenellus n. sp. One large slab collected from this locality contained about 20 well preserved molds of the interior; six of these specimens also have the mold of the exterior preserved on a slab which was split off the original slab. Only one specimen (UCM No. 29700) is known to have the valves conjoined, however, but rubber-casts from it admirably show the interior and exterior of the entire posterior portion of both valves. Fragments are numerous, some of which have the shelly material preserved. There are eight rather poorly preserved molds from locality 202, nine from locality 201, and one from locality 119. The cardinalia and dental lamellae from these latter localities are thinner and more delicate than those from localities 60 and 199 but the specimens are presumed to be the same species. Preservation will not permit fuller description of these specimens but the slight morphologic differences are thought to be caused by environmental conditions.

Dimensions of the better preserved specimens are given in the following table and these are plotted in the scatter diagram (Fig. 10). Note that Simpson's figures plot well within the spread of the other specimens, and

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that there are many which are more transverse than his but which are definitely not Schizophoria King.

Because of the preservation there was considerable estimation involved in measuring almost every specimen; in those specimens bearing asterisks no estimation was involved and themmeasurements are considered fully reliable. All measurements were made on molds, however.

UCM No.	Length (mm)	Width (mm)	l/w	Remarks
Locality 199				
*29689	24.1	30.1	.80	brachial valve
29690	22.5	27.1	.83	brachial valve
*29692	26.2	28.7	.91	
29696	25.1	29.5	.85	brachial valve
29697	24.7	30.4	.81	brachial valve
29699	21.8	27.2	.81	
*29700	28.7	26.8	1.07	
29739	24.-	32.5	.74	length estimated
29741	23.5	24.1	.98	brachial valve
29742	25.5	35.0	.73	length estimated
29743	26.8	28.6	.94	distorted brachial valve
29744	16.4	20.3	.81	
Locality 60				
*29745	21.0	21.3	.99	
29746	19.3	22.5	.86	
29747	20.2	22.4	.90	
Locality 202				
29748	26.0	32.6	.80	
Locality 201				
29750	26.0	32.6	.80	
29751	27.1	32.8	.83	
29752	7.8	8.8	.89	
Locality 119				
29755	23.0	33.7	.68	
Simpson's (1890, p. 437) illustrations				
No. 1	25.6	26.5	.97	
No. 2	25.0	25.9	.96	

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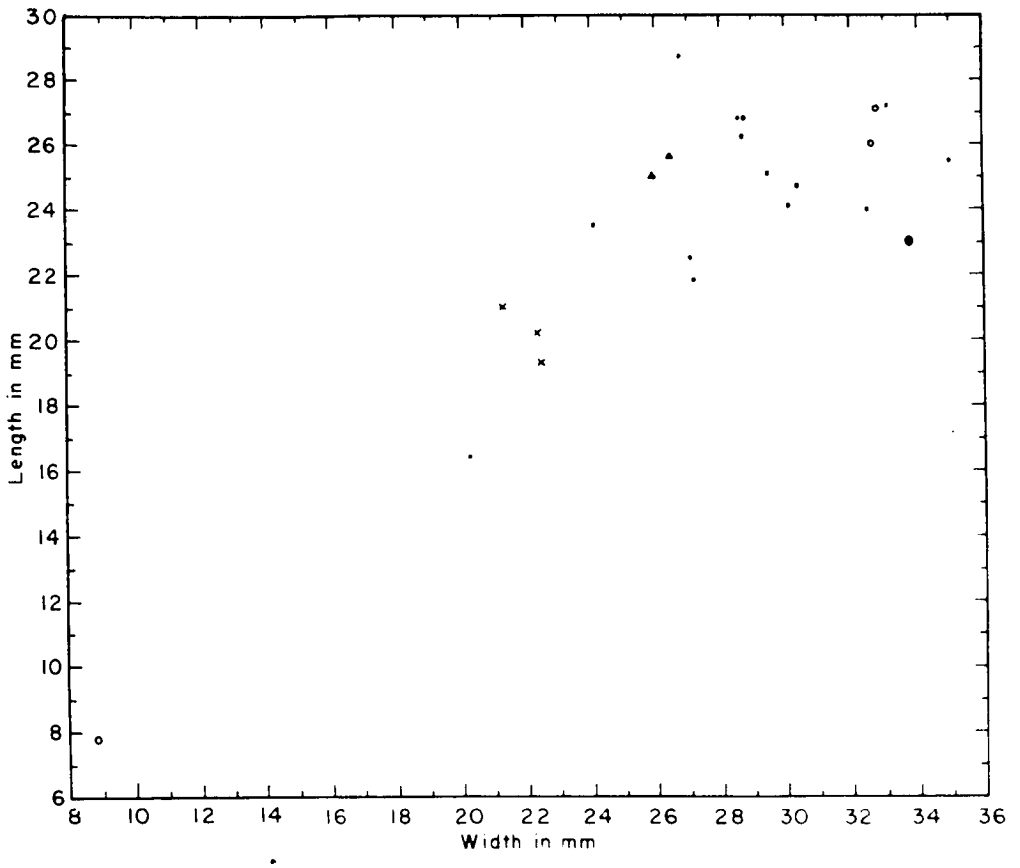

Fig. 10. - Scatter diagram of the better specimens of Rhipidomella pennsylvanica Simpson. Triangle indicates Simpson's figured specimens as measured from his illustrations; dot indicates specimen from locality 199 (lower Knapp coquinoid); circle indicates specimen from locality 201 (Tidioute); x indicates specimen from locality 60 (Oswayo); and large dot indicates specimen from locality 119 (upper Knapp coquinoid).

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Suborder STROPHOMENOIDEA Maillieux, 1932

emend, Öpik, 1934, emend. Williams, 1953

Superfamily ORTHOTETACEA Williams, 1953

Family SCHUCHERTELLIDAE Williams, 1953

[nom. transl. Stehli, 1954 (ex Schuchertellinae Williams, 1953)]

Subfamily SCHUCHERTELLINAE Williams, 1953, emend. Stehli, 1954

Genus Schuchertella Girty, 1904

TYPE SPECIES (by original designation): Streptorhynchus lens White, 1862, Boston Soc. Nat. Hist., Proc., v. 9, p. 28-29. Louisiana limestone, Mississippian, Hamburg, Illinois.

Girty (1904, p. 734) established this genus as

> a group of Streptorhynchoid shells which was without a septum or extended dental plates in the ventral valve, and in which the socket walls were not produced so as partially to surround the muscle scars in the dorsal.

Weller (1914, p. 53) described Schuchertella in the following manner:

> Shell biconvex, hinge-line usually equaling or sometimes a little shorter than the greatest width, the lateral and anterior margins rounded. Pedicle valve with a moderately high cardinal area, with a large delthyrium which is closed to the apex by the deltidium. The cardinal area is differentiated into two regions, the outer or primary area and the inner or secondary area slightly raised above the former, the lines separating the two regions pass from the apex of the beak to points about midway between the delthyrium and the cardinal extremities upon the hinge-line; the entire area is marked by horizontal lines of growth in addition to which the secondary area is marked by vertical striae which become more noticeable with the wearing of the surface. Internally the dental lamellae are

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> reduced to mere thickenings of the inner surface of the cardinal area at the margins of the delthyrium; a median septum is absent. The brachial valve is a little less convex than the pedicle valve, with a narrow cardinal area, and a short cardinal process.

Dunbar and Condra (1932, p. 117) add the following details:

> . . . the ventral beak only moderatedly elevated and usually not markedly distorted and without evidence of cementation. The shells are normally not strongly convex. The ventral valve has no septum and the dental lamellae are reduced to short dental flanges under the palintrope which do not reach the floor of the valve. The cardinal process is very low but broad. Posteriorly it is bifid but the paired muscular facets are tiny and low. The crural lamellae diverge laterally at a high angle and rise to a bluntly rounded terminus which is somewhat spoon-shaped and is concave on the postero-lateral face.

To these descriptions little can be added except Stehli's (1954, p. 298) statement that "Schuchertella is distinguished from an undescribed Devonian genus by its abundant fine costellation and the increase of the costellae by intercalation."

DISCUSSION: Since Schuchertella closely resembles other genera of the orthotetaceids externally, the diagnostic characters are to be found on the interior. The diagnostic internal characters are the very low dental flanges (delthyrial supporting plates of Thomas, 1910, p. 101) which bound the delthyrium but do not reach the floor of the valve, the general absence of a median septum in either valve (see Campbell, 1957, p. 46), the strong, widely divergent, unbuttressed crural lamellae and the transverse bifid cardinal process.

Schellwienella Thomas, (1910), which closely resembles

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Schuchertella externally, has short but strong, widely divergent dental lamellae. It becomes more difficult however, to describe the differences which separate Streptorhynchus King from Schuchertella. As Dunbar and Condra (1932, p. 121) have said,

> The differences are of degree rather than of kind and the separation may appear more or less arbitrary in the Mississippian faunas, but if Devonian or Mississippian Schuchertellas be compared with Pennsylvanian or Permian Streptorhynchi, the contrast is marked.

The following generalities seem to be useful in most cases: Streptorhynchus has a pedicle valve usually extended into a deep cone; the hinge line is generally shorter in comparison to the width of the shell than in Schuchertella; also according to Thomas (1910, p. 90) the cardinal process of Schuchertella is smaller, lower and with a more transverse base.

Girty (1908), Thomas (1910), Dunbar and Condra (1932), Williams (1953a) and Stehli (1954) have discussed more fully the genera related to Schuchertella and the probable phylogeny of the Orthotetacea. While the suprageneric categories and the phylogeny shown by Stehli (1954, Fig. 110 are tentatively accepted, it is believed that there is rather closer relationship between certain genera than this diagram would imply (see discussion following Schuchertella desiderata). Gross relations within the orthotetaceid have been well worked out, principally on the basis of the interior of the pedicle valve, by Girty, Thomas, and others, but a fertile field of study remains

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in Schuchertella and related genera. More attention will undoubtedly need to be paid to the nature of the cardinalia, especially the cardinal process, before details of classification and evolution within this group are clear.

Schuchertella desiderata (Hall and Clarke), 1892

Plate 2, figures 9-13; plate 3, figures 1-4; text-figure 11.

Streptorhynchus sp.? Hall, James, 1883, New York State Geol. Ann. Rept. for 1882, pl. 7 (11A) 42, figs. 26,27.

Orthothetes desideratus Hall, and Clarke, J. M., 1892, Nat. Hist. New York, Paleont., v. 8, pt. 1, p. 345, pl. 9A, figs. 26,27; Hall, 1897, New York State Geol. 14th Ann. Rept. p. 345, pl. 5, figs. 1-2; Schuchert, Charles, 1897, United States Geol. Surv. Bull. 87, p. 297.

[?] Schellwienella crenistria? (Phillips), Chadwick, G. H., 1935, Geol. Soc. America, Bull., v. 46, p. 336.

Schuchertella desiderata (Hall and Clarke), Cooper, G. A., 1944, in Shimer and Shrock, Index Fossils of North America, New York, John Wiley and Sons, p. 343, pl. 152, figs. 46-48.

EXTERIOR: Shell large for the genus, shield-shaped, wider than long with the greatest width slightly posterior to midlength. Brachial valve strongly convex with the greatest convexity about midlength thence curving rather

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regularly in all directions but flattening toward the cardinal extremities. Convexity of pedicle valve variable, being slightly convex throughout or nearly flat with the greatest convexity near the beak; or else being convex in the young stages until about half grown then with an irregular undulatory surface to the adult margins, or even becoming slightly concave just short of the margins. Shell multicostellate with the costellae increasing by intercalcation mostly within the anterior one-third or one-half of the shell. In some specimens the costellae are stronger and actually plicate the shell, especially near the commissure. The costellae are subrounded or subangular with the broadly concave intercostal space one to 1½ times the width of the costellae. Interarea moderately high, 40°- 60° apsacline, with perideltidial region distinct with an apical angle of about 90° and extending about one-third of distance to cardinal extremities but scarcely, if at all, raised above rest of area. Delthyrium completely closed by a massive highly arched xenidium whose apical angle is about 40°. Brachial area absent. Growth lines and irregularities of growth commonly well defined. Shell quite coarsely pseudopunctate throughout with the taleolae mostly radially disposed along the crest of the costellae; some finer spicules randomly distributed especially in the posterior of the shell.

PEDICLE INTERIOR: Teeth heavy, short, and blunt on anterior end. Dental lamellae merely low ridges, bounding

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the delthyrium along inner surface of interarea, representing the trace of the teeth during growth. Inner surface of xenidium highly vaulted. Diductor muscle area cordiform, faintly but distinctly delimited, commonly slightly impressed, extending anteriorly about one-third the length of the shell and occupying the central one-third of the shell transversely. Adductor muscle scars faint, small, elongate longitudinally, well posterior in the diductor area.

BRACHIAL INTERIOR: Cardinalia strong; the crural lamellae are erect septum-like plates diverging at an angle of about 90° and are curved so that they are concave laterally; they are shallowly excavated posteriorly to form the sockets but are extended anteriorly to rounded termini from which spring the long thin crural processes. Posteriorly the crural plates buttress the heavy bifid cardinal process which is high for the genus. It extends far posteriorly and is closely appressed to the arched under surface of the xenidium. The posterior face of each part of the bifid cardinal process is curved into a semi-cylindrical tube open to the rear to receive the diductor muscles. The anterior adductor muscle area is cordate-flabellate, faintly striated longitudinally, and slightly impressed into the shelf. The posterior adductor scars lie within this field and are faintly delimited far back between the crural plates and below the cardinal process. Ovarian and vascular markings are faintly and irregularly impressed into the shell. The brachidia are unknown.

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The whole interior of the shell, except the muscle fields, the cardinalia, and the teeth (but including the xenedium), is marked with minute pits marking the position of the taleolae of the fibrous layer.

DISCUSSION: Because of the large size and relatively thin flat shell, whole specimens of S. desiderata are rare. Yet this species is abundantly represented, both as juvenile and adult specimens in nearly every possible condition of preservation--molds of the interior and exterior, exfoliated whole valves, and hundreds of fragments.

This species is characterized by the large, shield-shaped, pseudopunctate shell with slightly conical or nearly flat pedicle valve and strongly convex brachial valve. Internally the high bifid cardinal process with semicylindrical seats of muscle attachment is distinctive.

Apparently only Schuchertella sciotoensis Hyde (1953) from the Byer member of the Logan formation at Scioteville, Ohio, strongly resembles S. desiderata; but S. sciotoensis differs from the latter in commonly having the greatest width at the hinge line, a broad shallow mesial brachial sinus, a less convex brachial valve, and a wider pedicle diductor muscle scar; the cardinal process of S. sciotoensis is unknown.

Under the generic disucssion (above) it was suggested that there may be closer relationships (or at least similarities) between certain forms within the Orthotetacea that Stehli (1954) would imply. For instance, Stehli

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characterizes both the Schuchertellinae and the Streptorhynchinae as having the crural plates recurved and joined to the posterior margin of the shell. Yet this is not markedly so in Schuchertella desiderata. In fact, in this respect, the configuration of these lamellae in S. desiderata is more like those in Derby cymbula Hall and Clarke of the Derbyiinae illustrated by Dunbar and Condra (1932, pl. 9, figs. 1a, 1d). Also the cardinal process of S. desiderata could scarcely be called "very low" and the muscular facets "tiny and low" (see Dunbar and Condra, 1932, p. 117 in their diagnosis of Schuchertella); moreover, in their semicylindrical nature the muscular facets of S. desiderata resemble those of Derbya cymbula (cf. Dunbar and Condra, pl. 9, fig. 1c). Schuchertella, of course, lacks the characteristic crural buttresses of Derbya (quite aside from characters of the pedicle valve which would separate the two).

On the other hand, Stehli (1954, p. 301) suggests that Derbyoides Dunbar and Condra (and hence probably the closely related genus, Tapajotia Dresser, 1954, which was seemingly unknown to Stehli) belongs in the Schuchertellinae because of the form of the cardinal process and the crural plates. The writer find this untenable because of the median septum of the pedicle valve in Derbyoides nebrascensis Dunbar and Condra plainly shown by them (1932, pl. 9, fig. 3), Stehli's statement to the contrary notwithstanding. Yet it is true that in this species the

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broad cardinal process with its paired spoon-shaped posterior faces and the recurved plates fused to the hinge line more nearly fit the characterization of the Schuchertellinae than do these features in S. desiderata (Hall and Clarke).

These similarities of Derbyia, Derbyoides, and Tapajotia of the Derbyiinae with Schuchertella of the Schuchertellinae make it entirely feasible that the Derbyiinae developed from the Schuchertellinae in Mississippian times (as suggested by Stehli, 1954, p. 300) through the stock of Schuchertella desiderata by the introduction and progressive increase in prominence of the median septum of the pedicle valve and modification of the cardinalia to provide Derbyoides and Tapajotia on the one hand, and Derbyia and succeeding genera on the other. It is unfortunate that so little is known of Cherterian orthotetaceids. It is obvious that within the Schuchertellidae the cardinalia will bear close examination.

(Although the above was written before Campbell's 1957, paper was published, apparently he has reached similar conclusions, p. 46).

'It is easy to state that Schellwienella Thomas of the Orthotetidea can be distinguished from Schuchertella Girty by the presence of well developed dental lamellae in the former, but Weller, (1914, p. 59) adds a note of caution when comparing Schellwienella with Schuchertella saying,

> Among the examples studied in which the characters of the dental lamellae can be determined there

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> seems to be some variation in the strength of their development, in some instances these lamellae being but little or not at all different from those of Schuchertella.

Thomas (1910, p. 94) says that Schuchertella is usually a flatter shell than Schellwienella, but Schuchertella desiderata is extremely gibbous.

The above discussion is intended to point out that there is yet a great deal to be learned about orthotetaceid brachiopods and especially their interrelationships and phylogeny. The progeny and the ancestry of S. desiderata remain unclear to the writer, but S. desiderata seemingly evolved from the Senecan Schuchertella chemungensis gens.

PALEOPATHOLOGY: Several specimens were apparently chipped at the anterior commissure or had the mantle injured but successfully repaired the damage. The effects of this injury can be readily seen in the extremely irregular nature of the costellae of the shell. Other specimens appeared to have been slightly bored parallel to the shell surface in the muscle-region of the brachial valve where the shell was thickest. These borings seemingly did not penetrate the shell or cause hypertrophy of the interior.

HYPOTYPES: UCM Nos. 29675 (partial mold of interior), 29679 (mold of interior of pedicle valve), 29677 (mold of interior of brachial valve).

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality

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97; sandstone in the Knapp formation on Yankee Bush Hill, north of Warren, Pennsylvania (exact locality unknown); sandstone in the Knapp formation at locality 199, Tidioute shale at locality 201 (one mold of the brachial valve).

REMARKS: This species is represented in the collections by more than 65 specimesn in various states of preservation. Actual population counts are virtually impossible to obtain because many of the valves are fragmental; at locality 97 especially, the shells are jumbled together in such an abundance as to form a coquinoid along with Syringopleura casteri, n. sp., Camarotoechia and the new genus Proeumetria. In local "pockets" the coquinoid is principally composed of Schuchertella indicating at least a degree of sorting by water movement.

Measurements of the better preserved specimens are given in the table below. An asterisk (*) indicates an estimated measurement.

UCM No.	Length (mm)	Width (mm)	l/w
29675	45.0*	51.3	.88
29676	41.6	60.1	.69
29679	39.6	51.8	.76
29683	20.3	30.4	.67
29684	21.6	30.3	.71
29685	23.5	31.1	.76
29686	12.0	18.7	.64

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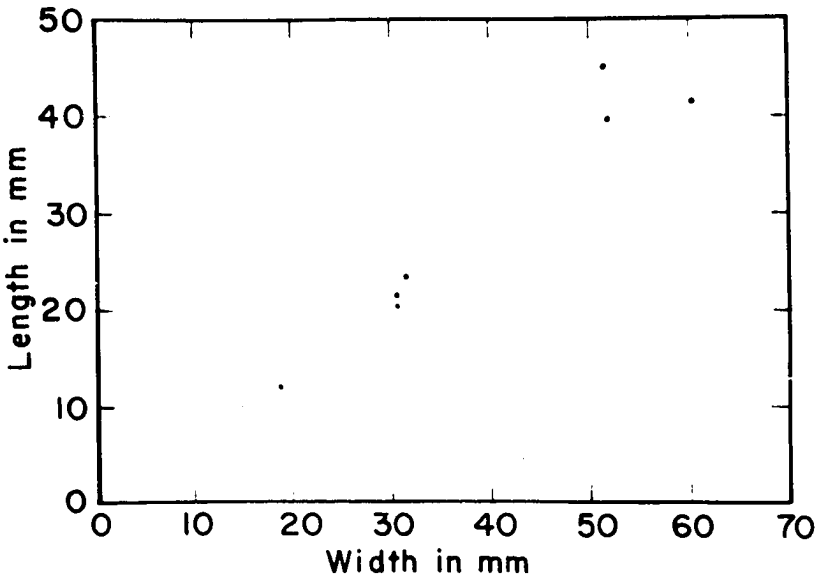

Fig. 11. - Scatter diagram of seven measured specimens of Schuchertella desiderata (Hall and Clarke) from the Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at locality 97.

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Schuchertella n. sp. A.

Plate 3, figures 5-10.

EXTERIOR: Shell rather small, shield-shaped, or subquadrate, wider than long, with the greatest width at about midlength. Brachial valve convex; pedicle valve slightly concave anteriorly. Pedicle valve commonly marked posteriorly with a cicatrix of attachment and irregular in its shape due to conditions of growth. Shell finely multiplicate with the plicae increasing by both bifurcation and intercalation; plicae subangular with the space between plications about equal to the width of the plicae. Interarea moderately high, distinct, with well-defined beak ridges; normally strongly apsacline, or, depending upon conditions of growth, even slightly procline. Delthyrium completely closed by a highly arched xenidium whose apical angle is about 30°. Brachial area absent. Increments of growth not well defined, but commonly developing rugosities near the anterior part of the pedicle valve. Shell material unknown.

PEDICLE INTERIOR: Teeth extremely short and blunt. Dental lamellae merely low ridges bounding the delthyrium along the inner surface of the interarea. Inner surfaces of the xenidium arched but not extremely high. Muscle areas not delimited, but central posterior portion of the valve smoothed by deposition of secondary material.

BRACHIAL INTERIOR: Cardinalia strong for size;

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crural lamellae erect, septum-like plates diverging at an angle of about 90°. Cardinal process low, nearly parallel to the commissure, faintly bilobed. Muscle marks not delimited, although the anterior adductor is sometimes bounded by a faint irregular ridge anteriorly.

DISCUSSION: This is undoubtedly the form which many authors refer to Schuchertella chemungensis (Conrad). Since its description, at one time or another, this species has had almost every conceivable kind of schuchertelloid brachiopod referred to it. Since these have not been recently studied or forms depicted since the days of James Hall, and since the form at hand does not occur in the Oswayo or elsewhere in the Knapp, little would be gained by referring the Kushequa form to the apparently ubiquitous S. chemungensis (Conrad). Chadwick (1935a, p. 333) thought that Schuchertella chemungensis (Conrad) continued on up through the Conewango into the Mississippian, although he (p. 316) lists "Schellwienella chemungensis, (typical form)" only in the Naples.

The form at hand most nearly resembles Schuchertella arctostriata (Hall) but surely not all of the forms which have been referred to this mutable Hamilton species are conspecific with it. One type within this latter species is a form which has pronounced alternation in the strength of the plications. This is not so in the Kushequa forms, nor are the muscle scars as deeply impressed as shown by the illustrations of S. arctostriata by Hall (1867a).

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Several of the specimens at hand superficially resemble the Schuchertella inequalis (Hall) illustrated as Streptorhynchus equivalvis by Hall and Whitfield (1877, pl. 4, fig. 2).

The Kushequa species differs from Schuchertella iowensis Stainbrook (1943a) in being smaller, less regular, and having finer plications. Schuchertella desiderata (Hall and Clarke) is entirely different from this form in all growth stages. Although this form is believed by the writer to be a new species, it is deemed wisest to refrain from naming it until Middle and Upper Devonian Schuchertella can be more thoroughly studied and illustrated.

HYPOTYPES: UCM Nos. 29952, 29953, 29957, 29960.

OCCURRENCE: Kushequa shale member of the Knapp formation at locality 160.

REMARKS: The hypodigm of this form consists of 18 small specimens of which seven are brachial valves; none of the specimens has the two valves connected. All are molds with none of the shell material preserved.

Dimensions of the better preserved specimens (all pedicle valves) are given below; those not followed by a decimal are estimations.

UCM No	Length (mm)	Width (mm)	Hinge Width (mm)
29952	16.2	23.0	18.8
29953	16.8	19.0	16.8
29954	13.4	18	11
29955	11.8	13.7	13.2
29957	16.5	20.3	--
29960	11.0	13.9	--

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Suborder PRODUCTOIDEA Maillieux, 1940, emend. Muir-Wood, 1955

Superfamily PRODUCTACEA Waagen, 1883

Family DICTYOCLOSTIDAE Stehli, 1954

Subfamily DICTYOCLOSTINAE Stehli, 1954

Genus Dictyoclostus Muir-Wood, 1930

TYPE SPECIES (by original designation): Conchyliolithus anomites semireticulatus, Martin (partim), 1809, Petrificacta Derbiensia, p. 7, pl. 32, figs. 1,2; pl. 33, fig. 4.(See Muir-Wood, 1951, and Muir-Wood and Stubblefield, 1951, for proposed use of plenary powers to validate several of Martin's species). Lower Carboniferous, Great Britain.

Muir-Wood's (1930, p. 103) original diagnosis follows:

> Shell elongate or quadrate in outline. Hinge moderately wide; pedicle valve evenly convex or produced into a short curved trail, brachial valve concave or geniculate. Costate in all growth-stages, costae often prominent, bearing numerous spine-bases. Spines also in rows on ears and cardinal slopes. Ribs on visceral disk numerous and forming net-like ornament by enlargement at point of intersection with costae. Diaphragm absent. Marginal ridges prominent, extending along hinge. Hinge-teeth, sockets, and cardinal area not developed.

DISCUSSION: With the groups typified by Productus productus (Martin) and Dictyoclostus semireticulatus (Martin) finally disentangled (Muir-Wood, 1928; 1930) there is little that has been added to the succinct diagnosis of the present concept given by Muir-Wood. Dunbar and Condra (1932, p. 213), and Sutton (1938) assert

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that a linear cardinal area is present although Dunbar and Condra (p. 219) show how a false appearance of an area may be created by preservation. The present writer echos Campbell's words (1957, P. 57) who writes,

> I have never observed mixoperipheral growth in a dictyoclostid and therefore prefer to maintain Muir-Wood's original opinion that a cardinal area is not developed.

As Dictyoclostus is presently conceived there seems to be considerable latitude in the extent of the development of marginal and brachial ridges, nature of the cardinal process (which is generally bilobed anteriorly but appears trilobate on the posterior face), and the nature and distribution of spines on the valves. Stehli (1954, p. 318) has created the genus Spinifrons, which "differs from Dictyoclostus in the possession of the tuft of enlarged spines on the ears and in the presence of an area of enlarged spines on the anteromedian part of the pedicle valve." Stehli also characterizes this genus by "a strong cardinal process supported by cardinal ridges; median septum low but crested towards the front; adductor scars elongate; brachial ridges seldom evident; the anterior edge of the visceral disc bearing low spines." He assigns only the type species, S. quadratus Stehli, to his new genus; but says regarding the position of Dictyoclostus pinguis Muir-Wood (which bears well developed spines on the ears) that it "is uncertain whether D. pinguis actually belongs in Spinifrons, or the spine pattern is one that was repeated in different stocks." He states,

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however, that D. portlockianus (Norwood and Pratten) "seems" to belong to the genus.

It may well be that more than one genus is now embraced by the genus Dictyoclostus; but until directly coupled with changes in more stable morphological characters (such as differences in the cardinal process or ridges within the brachial valve), or until the significance of spine patterns within the Dictyoclostinae is more amply demonstrated, the wrter agrees with Campbell (1957, p. 56) who places Spinifrons in synonomy Dictyoclostus saying,

> The proliferation of genera upon the basis of such minor variations in spine arrangement, especially when it can be shown that spines on the trail are frequently intraspecifically varially, is, in my opinion indefensible.

Dictyoclostus differs from Linoproductus Chao in having the pedicle umbo reticulate, relatively wider and in the possession of costae while Linoproductus is costellate and possesses few, fine spines.

Dictyoclostus dubitatus Holland, n. sp.
Plate 3, figures 11-18, text-figure 12.
Plate 4, figures 1 - 2.

EXTERIOR: Shell small to medium size for the genus, wider than long. Pedicle valve moderately to strongly arched across the visceral disk but less curved on trail, rapidly expanding from the small umbo which markedly overhangs the hingeline. Hingeline shorter than greatest width

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which occurs about midlength. Ears distinct, at least posteriorly, from the lateral slopes which curve gently outward to the lateral margins. Cardinal extremities gently rounded. In some specimens the shell is flattened along the midline, but more commonly rather evenly curved transversely; sulcus never developed. Trail well developed but the shell is never markedly geniculate. Brachial valve flat to slightly concave, sharply geniculate anteriorly; visceral cavity deep.

Rugae of pedicle valve distinct on ears, less distinct across the visceral disk, irregular in strength throughout. Thus while the disk is rugose the shell rarely presents a distinct reticulate appearence. Costae low, rounded, with interspaces relatively flat-bottomed and broader than the costae; about 10 castae in the space of 10 mm near the anterior margin. Costae increase by bifurcation and intercalation on the visceral disk but by intercalation only on the trail. Irregularly spaced, round, hollow, erect or semierect spines about one-half mm in diameter common on ears and lateral slopes, although less closely spaced on lateral slopes. Similar spines distinctly arranged on lower part of trail; these spines are commonly more or less arranged in a row a short distance above the anterior margin and in another row near the anterior margin. Smaller spine bases, elliptical in cross-section and oblique to the shell, scattered among the larger spines on the lateral slopes and more widely spaced

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on the visceral disk and anterior slope; those of the disk and trail often mere closed elongations not produced into spines. Entire surface showing irregular, rounded, undulatory growth increments. Brachial valve completely and rather regularly rugose across visceral disk; costae wider than furrows especially on trail; indentations (appearing as nodes on molds of the exterior) apparently corresponding to larger spines of ears of pedicle valve, present on ears; otherwise apparently aspinose or bearing only small oblique spines. The undulatory growth lines are distinct throughout.

PEDICLES INTERIOR: Teeth and dental lamellae apparently absent; shell thickened across umbo; diductor muscle scars semicircular, large (occupying most of the visceral disk), set on a platform which is radially grooved anteriorly. Adductor scars narrow and indistinctly separated from diductor platform which surrounds them. Remainder of shell anterior to the muscle platform covered by irregular, elongate, anastomosing pustules which appear as flexous grooves on molds of the interior.

BRACHIAL INTERIOR: Since the brachial valve is known mostly from molds of the exterior, little can be ascertained with any degree of assurance concerning the interiors. Cardinal process apparently bilobed anteriorly but the posterior face is unknown. Two short, broad, low ridges diverge at an angle of about 90 degrees from the base of the cardinal process. A low median septum, which

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crosses the visceral disk becoming much narrower anteriorly, lies between these low ridges. Marginal ridges apparently absent. Brachial ridges very low and narrow, arising at the midline about one-half the length of the disk, proceeding posterolaterally then recurving toward the midline in a smooth curve of about 3 mm radius. Muscle scars not preserved but evidently not leaving much impression on shell.

DISCUSSION: This species is broadly enough conceived so that it admits considerable external morphologic variation within any one population. Especially variable is the curvature immediately anterior to the pedicle umbo and the extent or amount of lateral "flare" in the trail. Thus quite different shapes are imparted to the shell. One type (to which the holotype belongs) is rather evenly curved longitudinally and is broadly anterolaterally extended. Another type is rather sharply curved near the umbo, then becomes medially flattened on the anterior slope and has moderate lateral extensions of the trail. Yet a third type is higly arched over the visceral disk but has steep lateral slopes; this latter type seems more distinct, and is described below as a separate morphological variant. There appears to be such complete intergradation between these morphological types occurring within one population that they are considered as individual variations, at least until further collecting provides some more accurate way (perhaps by internal characteristics which are presently

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imperfectly known) of discrimination between them.

Dictyoclostus dubitatus, n. sp., perhaps most closely resembles D. sciotoensis Hyde, but this species is not auriculate, has steeper sides, and coarser but more closely spaced costae than in D. dubitatus. D. bovis Hyde is much larger and has much steeper lateral slopes. D. burlingtonensis (Hall) has a more subquadrate shape, stronger reticulation of the umbo, and a well developed pedicle sulcus.

D. dubitatus bears a remarkable resemblance to Productella onusta Hall (1867, pl. 26, figs. 29-42) and Caster (1930, pl. 19, fig. 17, pl. 20, fig. 5-9), who photographed Hall's types, but there seem to be significant differences. D. dubitatus has nearly the same configuration as P. onusta, but the trail seems to be more developed in the former. P. onusta appears to have a more fully spinose surface than in D. dubitatus and the latter is more strongly costate and has the umbo more rugose. Although the area beneath the overhanging umbo of the pedicle valve could be excavated in only a few of the specimens of D. dubitatus, no evidence was found for dental lamellae which Hall (1867, p. 185) stated P. onusta possessed. Also P. onusta has a more concave brachial valve (and hence a smaller visceral cavity) and brachial ridges of different shape than in D. dubitatus.

Dictyoclostus dubitatus, n. sp., seems to be closely related to Productella onusta Hall but the nature of the

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relationship is in doubt. It seems likely that the dictyoclostids developed from productellids similar to P. onusta by loss of the articulation apparatus and the area, modification of the cardinal process, and deepening the visceral cavity. Hall (1867, p. 185) indicates that P. onusta has no area "beyond the thickness of the shell" and this situation prevails in D. dubitatus. Thus D. dubitatus stands intermediate in position between P. onusta of the Conewangoan and the more advanced Kinderhookian and Tournasian dictyoclositds with well developed mesial sulcus, more fully reticulate pedicle umbo, and well developed cardinal ridges e. g., D. burlingtonensis (Hall), and D. simplex Campbell, 1957, p. 57-60.

TYPES: Holotype: UCM No. 29771. Paratypes: UCM Nos. 29774, 29777, 29778 (exfoliated pedicle valves, locality 97), 29793 (mold of the exterior of a brachial valve, locality 97), 29810 (mold of interior and mold of exterior of brachial valve, locality 201).

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97; fine grained sandstone in the Tidioute shale at localities 198, 201, 202. Locality 97 is the type locality.

REMARKS: The hypodigm consists of 20 decorticated pedicle exteriors, 9 molds of the exterior of the brachial valve, and 11 fragmental specimens from the Marvin Creek

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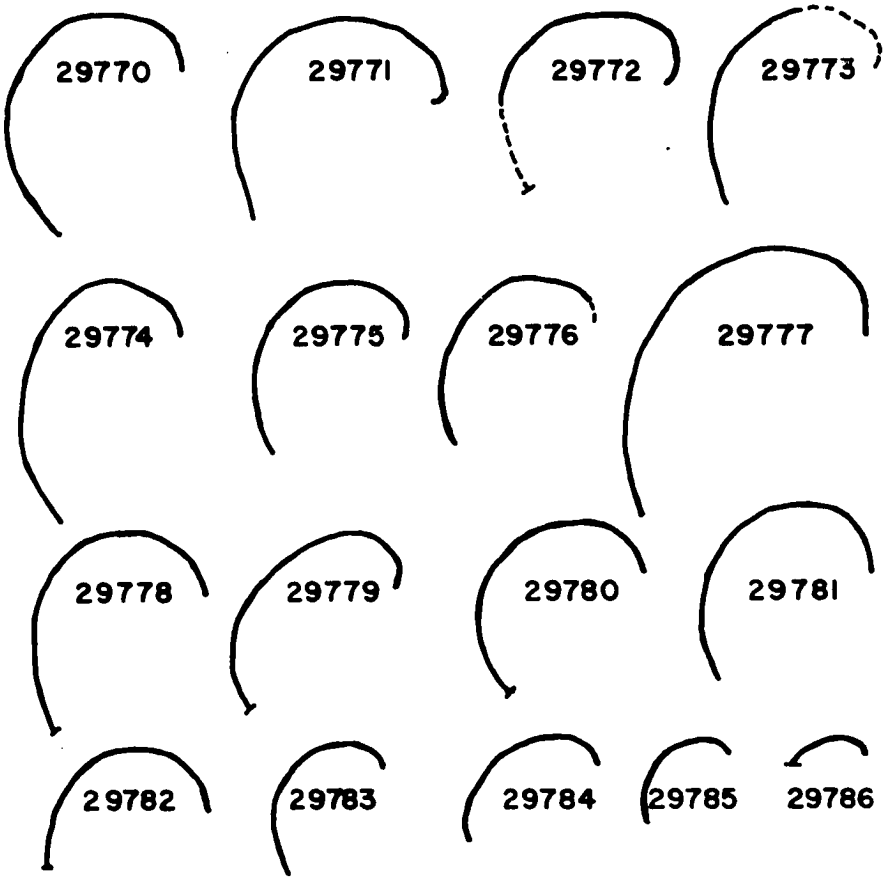

Fig. 12. - Lateral profiles (X1) of the better preserved pedicle valves of Dictyoclostus dubitatus, n. sp. from the Kushequa shale member of the Knapp formation at locality 97. Compare with profiles of D. dubitatus variant A, n. variant in the following text-figure. Numbers are University of Cincinnati Museum catalogue numbers. Dashed lines indicate where profile was inferred because of a break in the specimen. The short transverse line indicates that the trail was missing beyond that point.

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coquinoid of the Kushequa member of the Knapp formation at locality 97; 14 sandstone molds of the interior (of which 5 are brachial valves) from the Tidioute at locality 201; 5 fragmental molds from the Tidioute at locality 202; and 7 from the Tidioute at locality 198. In addition to the above, 8 specimens are assigned to the morphological variant given below.

Statistical data for the better preserved specimens are given below. SL indicates "straight" length (distance from edge of anterior margin to most distant point on the umbo), CL indicates length on curvature (measured from tip of umbo at the hinge to edge of anterior margin along the curve of the shell), HL indicates width at hinge line, W indicates greatest width.

UCM No.	SL	CL	HL	W	SL/W	CL/W	HL/W
29770	30.0	50.6	21.6	28.8	1.042	1.76	.75
29771	30.5	54.3	34.0	36.6	.83	1.48	.93
29772	27.0	--	26.4	29.4	.92	--	.90
29773	27.3	44.0	--	29.0	.94	1.52	--
29774	30.3	49.2	21.5	34.4	.88	1.43	.62
29775	23.9	40.2	16.6	25.4	.94	1.58	.65
29776	25.8	37.0	--	27.8	.93	1.33	--
29777	37.8	60.8	27.2	39.4	.96	1.54	.69
29783	18.9	28.2	19.0	23.0	.82	1.23	.83
29784	18.5	25.0	13.8	21.0	.88	1.19	.66

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Dictyoclostus dubitatus variant A, n. variant.

Plate 4, figures 3-5, text figure 13.

Seven pedicle valves and one brachial valve of this species are so distinctly different in shape that they are here set aside into a separate group as a morphological variant. These pedicle valves are all so badly exfoliated that they are really almost molds of the interior. Because of this and the fact that most are otherwise broken, accurate measurements cannot be made on these specimens. The characters which serve to distinguish this variant are the highly arched pedicle valve and the subquadrate outline. However, these characters seem to grade into the less highly arched and laterally flaring form more typical of the species. Only further collecting of better preserved specimens will tell whether this form is specifically distinct or whether the lattitude of D. dubitatus should be increased to embrace this form.

DESCRIPTION: Pedicle valve highly arched, umbo markedly overhanding hingeline. Subquadrate in transverse outline, lower lateral portions of the trail not strongly flaring. Greatest width anterior to hinge line. Anterior portion with lessening curvature so that the trail becomes nearly a straight line when viewed in lateral profile. Commonly with indentation or cinctures at extreme anterior edge of trail. Costae and spines apparently similar to those in typical form. One specimen exhibits a shallow median sulcus on the pedicle valve.

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Internally the diductor muscles are apparently slightly impressed into the shell and more evenly grooved longitudinally instead of being raised on a muscle platform and irregularly longitudinally grooved as in the typical form. The umbonal portion of the muscle area is transversely marked by curving undulatory striae which are but faintly seen on the typical form.

The brachial valve is know from but two fragmentary sandstone molds of the exterior. One of these is slightly concave but narrow and sharply geniculate. Otherwise these fragmentary valves add little morphological detail.

TYPES: Holotype: UCM no. 29800; hypotype, UCM No. 29801.

OCCURRENCE: Seven badly exfoliated pedicle valves and two fragmentary molds of the exterior of brachial valves are known from the Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97. Since this morphological variant seems to intergrade with D. dubitatus s. s., it is possible that some of the specimens referred to the latter from this locality or the poorer sandstone molds from localities 198, 201, or 202 might belong to this variant if further collecting or study were to prove it distinct or indicate a method of distinguishing between this and the more typical form.

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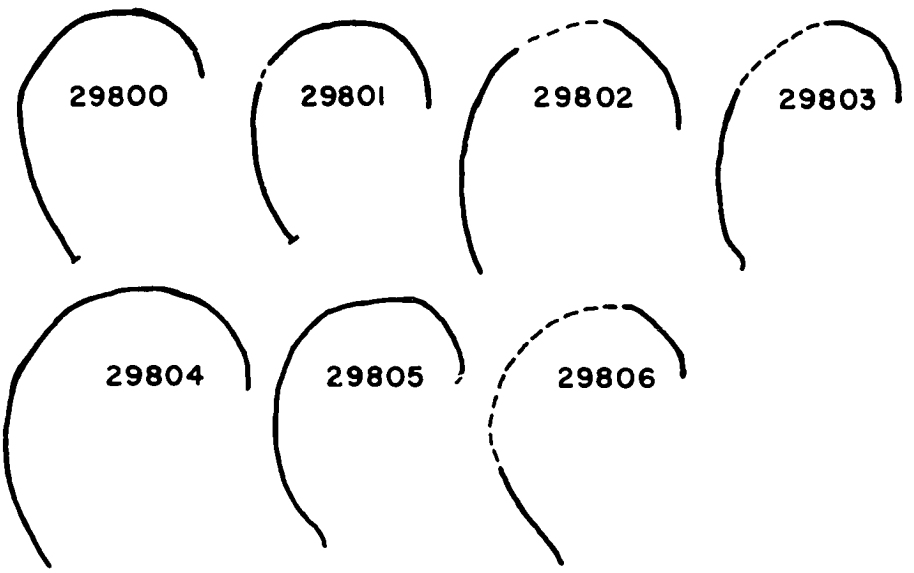

Fig. 13. - Lateral profiles (X1) of the better preserved pedicle valves of Dictyoclostus dubitatus varaint A, n. variant, from the Kushequa shale member of the Knapp formation at locality 97. Compare with D. dubitatus s. s. in the preceding text-figure. Numbers are University of Cincinnati Museum Catalogue numbers. Dashed lines indicate where profile was inferred because of a break in the specimen. The short transverse line indicates that the trail was missing beyond that point.

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Suborder CHONETOIDEA Muir-Wood, 1955

Superfamily CHONETACEA Schrock and Twenhofel, 1953

Family CHONETIDAE Hall and Clarke, 1895

Genus Chonetes de Koninck, 1842

TYPE SPECIES (by subsequent designation; de Verneuil, 1845, p. 238): Terebratulites sarcinulatus Schlotheim, 1820, Die Petrefactenkunde, pl. 29, figs. 3a,b. Lower and Middle Devonian, Harz Mountains, Germany (fide Campbell, 1957).

Following an extensive literature research Campbell (1957, p. 63) gives the following description of C. sarcinulatus:

> . . . a chonetid of medium size, semicircular to subrectangular in outline, and with a long hinge approximately equal to the greatest width of the shell. The surface is ornamented with approximately fifty striae which may dichotomise or remain simple. Internally the pedicle valve has a low median septum which extends beyond the middle of the valve, and the brachial valve has a very weak median septum and two slightly oblique septa which are higher and longer, extending to within 1 to 2 mm. of the anterior margin of the valve.

DISCUSSION: Ramsbottom (1952, p. 11) has reviewed the early history of this genera, and Stehli (1954, p. 309) has ably summarized the present situation regarding the chonetids:

> For many years all Chonetacea were placed in the single genus Chonetes sensu lato, and it was not until in the last century that a start was made in working out relationships within the group. At the present time some 20 genera and subgenera have been recognized, and it is apparent that many of the genera as they are

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> now used are heterogenous units. An inclusive and critical study of the Chonetacea as a biological group and from an evolutionary point of view is necessary for the solution of many of the taxonomic problems.

Until such a study can be made the writer prefers to maintain a rather broad concept of the genus Chonetes, essentially as is described by Campbell for the type. As Campbell has pointed out however, the above description would imply a need for another genus to be erected for "the multistriate species in which the brachial valve has a long median septum, flanked by two very short septa which divide the adductor muscle scars."

Chonetes cf. C. setigerus (Hall)

Plate 4, figure 6.

DESCRIPTION: The mold of the interior of one pedicle valve of a chonetid is present in the collections. It is a small form with the hinge line nearly equal to the greatest width and the greatest convexity well posterior to midlength. The mold gives indication of fine subrounded plicae which increase by bifurcation until they number about 40 near the margin. The teeth are not visible and no dental plates are present, however there is a suggestion of a very slight median septum. In the interspaces between plicae there are occasional faint pits in the mdd which indicate the presence of "papillae" (Dunbar and Condra, 1932, p. 135) or taleolae (?). Two closely spaced rows of these pits appear, one on either

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side of the median septum, arising at the center of the hingeline and diverging at an angle of about 90° from each other. The area is nearly absent in this specimen, but the interior mold of several fine hollow spines is seen to extend obliquely in toward the midline of the valve in a plane parallel to the commissure.

DISCUSSION: It does not seem likely that all of the forms that have been referred to the Middle Devonian black shale species, Chonetes setigerus (Hall) are conspecific with it (see Schuchert, 1897, for partial list of forms referred to C. setigerus). However, the specimen at hand closely approaches the description and illustrations given by Hall in 1867. A very similar form from the Corry sandstone on Sill Run shows essentially the same features. In this latter form, however, the median septum of the pedicle valve is more clearly delimited and the "papillae" show more distinctly in the interspaces between the plicae. The Corry specimens have 6-8 inwardly directed fine spines preserved. It is probable however, that these inwardly directed molds turn outward at the posterior shell margin as is shown in many of Hall's figures. More accurate description of these species must await the accumulation of better preserved and more numerous specimens.

TYPES: Hypotype: UCM No. 29769.

OCCURRENCE: Tidioute shale at locality 119.

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REMARKS: Dimensions of the specimen at hand are given below.

UCM No.	Length (mm)	Width (mm)
29769	6.4	8.2

Suborder RHYNCHONELLOIDEA Moore, 1952

emend. Muir-Wood, 1955

Superfamily RHYNCHONELLACEA Schuchert, 1896

Family CAMAROTOECHIIDAE Schuchert and LeVene, 1929

Subfamily CAMAROTOECHIINAE Schuchert and LeVene, 1929

Genus Camarotoechia Hall and Clarke, 1893

TYPE SPECIES: (by original designation): Atrypa congregata Conrad, 1841, New York Geol. Surv., Ann Rept. 5, p. 55. Hamilton group, Middle Devonian, Conklin's Falls, near Apulia, Onandoga County, New York.

Rostrate, small or below medium size, subovate to subellipsoidal, or subtriangular to subpentagonal, dorsibiconvex shells. Anterior commissure uniplicate with the generally well defined fold and sulcus extending about one-half the distance to the beak. Shell impunctate; pauciplicate with angular to subrounded plicae extending undivided from beak to commissure. Beak nearly straight to erect or slightly incurved; cardinal margin subterebratuloid to terebratuloid, mostly the latter. Definite, but usually not prominent, beak ridges bound the palintrope.

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The delthyrium is closed by conjunct deltidial plates, and the foramen is hypothyrid to submesothyrid. In the pedicle valve, slender, vertical dental lamellae support small but strong teeth, the surface of which is generally serrated or crenulated. The dental plates are free from the umbonal walls, thus forming two lateral umbonal cavities and a larger delthyrial cavity. Muscle scars more or less deep and well-defined. Genital markings rarely distinct. In the brachial valve the cardinalia are generally weak; the most distinctive feature is a divided hinge plate, the segments of which are supported on their inner edges by lamellae which unite with the distinct median septum to form a definite septalium in the median posterior portion of the valve. The septalium is a relatively wide V-shaped trough when the septalial plates support the otherwise free inner edges of the outer hinge plates, but restricted to a small cavity when the median inter-space is overhung by inner hinge plates. No cardinal process is present. Slender crura, arising from a position near the inner margin of the outer hinge plate curve toward the pedicle valve. Brachial muscle scars usually not definitely delimited.

DISCUSSION: The distinctive characters of Camarotoechia are the completely plicate rhynchonelliform exterior coupled with the interior characteristics of dental lamellae in the pedicle valve and in the brachial valve a divided hinge plate supported by the median septum

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which bifurcates posteriorly to form a septalium. The size and shape of the shell are quite variable as is the distinctness of the fold and sulcus.

Amsden (1951, p. 86) asserts that the type species, Camarotoechia congregata (Conrad), has the septalium "covered with growth of the inner hinge plate". Hall and Clarke (1893, p. 190) report, however, that "in normal conditions of development the median interspace of the hinge-plate is not closed"; and C. congregata (Conrad) is fugured (pl. 57, figs. 24-27) with a divided hinge plate. However, Cooper (1956, p. 628) has distinguished his new family, the Rhynchotrematidae, principally as having the "cruralium without covering plates as in Camarotoechia." Other authors have considered the hinge-plate to be divided; this discrepancy points to a definite need for restudy and refiguring the types of C. congregata.

Brown (1952, p. 91) has proposed Greenockia for camarotoechid shells in which the hinge plate is entire. If the implications of Cooper's statement (above) is true, this genus is a junior synonym of Camarotoechia. Wellerella Dunbar and Condra (1932) has similar conformatin and an undivided hingle plate but the plicae are obsolete posteriorly leaving the umbones smooth. Nudirostra Cooper and Muir-Wood (1951) and Pugnoides Weller (1910) have the camarotoechioid interior but also have plicae obsolete in the posterior portions of the valves. Paraphorhynchus Weller (1905), Paurorhynchus Cooper (1942), Sphaerirhynchia

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Cooper and Muir-Wood (1951), and Hemiplethorhynchus Von Peetz (1898) can be easily distinguished from Camarotoechia on the basis of external characters, the variations being mostly in size and shape. Allorhynchus Weller (1910) resembles Camarotoechia but lacks the median septum and the divided hinge plate entirely unsupported. Rhynchopora King (1865) and Trigeria Bayle (1878) both have an undivided hinge plate and are punctate. Rhynchospirina Schuchert and LeVene (1929) is punctate, lacks dental lamellae, and has the median septum supporting a ponderous complex hinge plate. Tanerhynchia Allan (1947) is multicostate, lacks dental plates in the pedicle valve, and has cardinalia entirely different from Camarotoechia.

Camarotoechia allegania (Williams), 1887, emend.

Plate 4, figures 7-13.

Plate 5, figures 1-2.

Rhynchonella allegania Williams, H. S., 1887, United States Geol. Surv., Bull. 41, p. 87-88, pl. 4, figs. 1-8; Schuchert, Charles, 1897, United States Geol. Surv., Bull. 87, p. 354.

Camarotoechia allegania (Williams), Butts, Charles, 1903, New York State Mus., Bull. 69, p. 994; Caster, K. E., 1930, Bull. American Paleont., no. 58, p. 13-14, pl. 12, figs. 9?, 10, 15-17, pl. 13, figs. 8, 16-17, pl. 14, figs. 2, 6, 8?, 12-14; Woodruff, J. G., 1942, New York State Mus., Bull. 326, p. 60,

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fig. 19A (A and B).

EXTERIOR: Medium to large, usually wider than long, markedly dorsiconvex, very rostrate Camarotoechia. In outline and end profiles the shell is generally subelliptical, but may be nearly quadrate, while in lateral profile the brachial valve appears much inflated and arcuate from beak to anterior margin; the pedicle valve is rather shallow and appears nearly rectangular in lateral profile. Greatest width a little anterior to, or about at, midlength. Lateral margins curving slightly posteriorly and then deflected abruptly at the hinge to the prominent, nearly erect beak. Cardinal margin terebratulid. Low beak ridges bound the palintropes; foramen appears to be hypothyrid with conjunct deltidial plates meeting only anterior to the foramen.. A low, broad fold rises one-third or one-half the distance to the anterior margin and becomes increasingly prominent toward the margin. In the pedicle valve a broad sulcus begins nearly at the umbo and generally becomes very deep and well defined at the anterior margin where it may extend the depth of the valve again above the lateral flanks. Generally subangular to subrounded plicae (approximately evenly divided between trough and crest) extend from the beaks to the commissure. Five to seven or more rarely eight plicae are present on the fold and four to six in the sulcus. Approximately 10-12 plicae are present on each lateral slope making a total of 24 to 30 on each valve. Each plication is

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deeply notched anteriorly to receive the corresponding plicae of the opposite valve, and the plicae of the slopes bend abruptly to the margin. No other sculpture is present except that very rarely, faint widely-spaced growth lines maybe seen near the anterior commissure.

PEDICLE INTERIOR: Thin, vertical dental plates separate the small lateral umbonal chambers from a much larger delthyrial cavity. The teeth are very deeply crenulate. The most conspicuous features are the very deeply impressed large bell-shaped muscle scars. While they are not strongly differentiated, the adductors and posterior diductors are much more deeply impressed into the valve between the dental plates than the anterior diductor scars which form a broad somewhat shallower anterior expansion frequently occupying half the valve. Near the posterior of the scar there is occasionally preserved the faintest suggestion of a short thin median septum. The pustulose genital markings are rarely preserved.

BRACHIAL INTERIOR: The divided hinge plate is composed of concave triangular outer hinge plates supported on their inner margins by stout septalial plates arising from the posterior one-third of the low medain septum which extends about one-half to two-thirds the length of the valve continually decreasing in height anteriorly. The septalium varies from a rather deep steep-sided V-shaped groove overhung slightly by the inner edges of the outer

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hinge plates, to a smooth broad shallow trough. The hinge plates are bounded laterally by pronounced socket ridges and mesially by the low crural bases which give rise to rather long tapering crura. Outer socket ridges, which are less prominent than the inner socket ridges bound the long, deep, strongly crenulated sockets. Faint semi-circular muscle marks sometimes present, appearing partially to obscure the internal plicae.

DISCUSSION: Williams well enumerated the distinctive characteristics: large size; broad flat fold and sulcus including five to seven plications; the broad, flat, "tongue-like" muscle platform (in molds of the interior) which represents a depression in the shell itself under the beak of the pedicle valve; the well defined serrations of the cardinal teeth; the strong but short medium septum and the "elongated rounded" beak. Especially distinctive are the large size, more numerous plications and the deep muscle impression; by these features C. allegania can be differentiated from other species of the genus. The closest allied form seems to be the Hamilton species, C. sappho (Hall) from which C. allegania was likely derived.

HYPOTYPES: UCM Nos. 29000, 29002, 29121, and 29122.

OCCURRENCE: Sandstone in the Oswayo formation at localities 1, 109, 183, 59, 161, 60, and 253. C. allegania (Williams) s. s. seems to be ubiquitous in

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the margine beds of this age in this area. However it most commonly occurs in the hard, calcareous, quartz sandstone coquinoids or in the weathered residue of these beds.

REMARKS: The most common preservation of these specimens is as molds. Over 300 specimens of C. allegania, s. l. are present in the collections; of these some fifty specimens with the original shell preserved were available from a small lens in the Roystone coquinoid zone at locality 1. While C. allegania is locally very abundant, this preservation is relatively rare and afforded unusual opportunity for study.

A large percentage of the molds are compressed either laterally or in an anterior-posterior direction. The posterior part of the shell almost invariably suffers the least distortion; this is especially true of the beak region of the pedicle valve where it is supported by the additional shelly material bordering the impressed muscle scar. It is likely that C. allegania (Williams) possesses thinner shells than other Devonian rhynchonellids as suggested by Caster (1930, p. 14); but although the species inhabited a near-shore lithotope, it is not likely that wave action caused the crumpled condition. It is more probable that the almost hermetically tight fit of the valves, leaving them empty in death, coupled with the compaction of the loosely cemented sandstone members of the Oswayo formation caused the crushing.

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Camarotoechia allegania obesa, n. subsp.

Plate 4, figures 14-21.

Camarotoechia allegania (Williams), Caster, K. E., 1930, Bull. American Paleont. no. 58, pl. 12, fig. 18, pl. 13, fig. 7, 9,15, pl. 14, figs. 4, 7.

EXTERIOR: Generally larger, more robust, and with the brachial valve strikingly more gibbous than other forms of the species. The fold is very high giving the shell a subquadrate appearance in outline and in end and lateral profile. Greatest width anterior to midlength. Fold and especially sulcus very broad; the fold not strongly curved transversely, adding to the quadrate aspect of the end profile. The plications are, in general, broader and more rounded than in other forms, and these plicae bend very abruptly to the margins. Six or seven plicae present on the fold and five or six in the sulcus; rarely a lower eighth plica may appear on one of the lateral flanks of the fold and sulcus. Each valve averages 24 plicae.

PEDICLE INTERIOR: Dental plates restricted to the rostral portion of the valve, and the posterior part of the muscle scar is very deeply impressed into the shell. Pustulose genital markings not infrequently preserved in the posterolateral flanks of molds of the interior.

BRACHIAL INTERIOR: The outer hinge plates slope toward the strongly concave floor of the valve. The

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median septum is very broad in its posterior part near the floor of the valve and the septalium is a smooth, broad, shallow trough. The area under the hinge plates is partially filled with shelly material.

DISCUSSION: In molds of the interior (the commonest mode of preservation) the saliant features are readily ascertained: very gibbous brachial valve and extremely shallow pedicle valve; broad rounded plications; the high squarish fold, especially anteriorly (in marked contrast to C. allegania lingulata n. subsp., described below); the extremely high rostral muscle platform, and in the brachial valve the short stubby points (representing the limited cavities under the hinge plates) which project posteriorly only a very short distance on each side of the wide groove of the median septum.

TYPES: Holotype: UCM No. 29005. Paratypes: UCM Nos. 29007, 29008, 29009, 29011; unfigured paratype, 29006.

OCCURRENCE: Roystone coquinoid of the Oswayo formation at localities 1, 109 and 183. Locality 183 is the type locality.

REMARKS: At the type locality 50 percent of the Camarotoechia collected were of this form and at locality 1 about 40 percent of the specimens belonged to C. allegania obesa n. subsp.

It would be most difficult to give a table of

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dimensions of this form because a large percentage of the specimens are distorted. It appears safe to state that the average of the adult forms is noticably larger than the typical Camarotoechia allegania. It is not believed that this form is constituted of gerontic individuals of C. allegania s. s., however, because small specimens of C. allegania obesa n. subsp., bear all of the essential characteristics enumerated above, while, conversely, much larger specimens of the typical form do not. It also might be suggested that the subspecies is composed largely of distorted specimens and their "distinguishing" characters imparted to them by the distortion. The former is true, but the latter statement would be disputed again on the basis of the specimens themselves. Similarly distorted specimens of the typcial form do not show the characteristics of this form and vice versa.

Camarotoechia allegania lingulata, n. subsp.

Plate 4, figures 22.32.

Camarotoechia allegania (Williams), Caster, K. E., 1930, Bull. American Paleont., no. 58, pl. 14, fig. 5, 16.

EXTERIOR: Generally large, elongate, subpentagonal, less noticably lenticular form. Each valve is more shallow so that the total depth is much less than other of the species. The low fold is poorly defined and the sulcus relatively shallow; each is broad and gently curving

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transversely so that the entire shell often presents a curved appearance in anterior profile. The fold proper is almost invariable composed of six plicae but two low lateral plications commonly occur well down on the flanks (one on each flank) of the low fold, making a total of eight on the fold. Correspondingly the deepest part of the sulcus bears five plicae and may bear seven. Commonly at least one of the lateral plications of the fold of the brachial valve may not be compensated for on the pedicle valve by a separate plication, but may be absorbed by the wider plica of the sulcus flank. The plicae are subangular and the average number of plicae for each valve is about 30.

PEDICLE INTERIOR: Dental plates relatively strong and muscle scars are not so deeply impressed posteriorly nor sharply defined anteriorly as in the typical form or C. allegania obesa, n. subsp. Genital markings unknown.

BRACHIAL INTERIOR: The median septum is very thin and the septalium is a steep-sided V-shaped groove. The area under the hinge plates is deeply excavated posteriorly.

DISCUSSION: This subspecies can be easily recognized in molds of the interior by the diagnostic features: lesser depth, elongate outline; transversely arcuate anterior profile; somewhat more numerous subangular plicae; the long pointed projections which extend posteriorly obscuring the cardinalia beside the narrow groove

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of the median septum in the brachial valve and the less well-defined muscular area of the pedicle valve. Molds of the interior of typical C. allegania also present these long projections which represent the deeper excavations under the hinge plates but can be distinguished from C. allegania lingulata n. subsp. by the higher muscle platform and more ellipsoidal shape of the former.

TYPES: Holotype: UCM No. 29012. Paratypes: UCM Nos. 29013 and 29015; unfigured paratype, 29014.

OCCURRENCE: Oswayo shale at localities 183 and 109. Locality 183 is the type locality.

REMARKS: At locality 183 about 10 percent of the Camarotoechia collected were of this form. Among these specimens, two are not molds but have the original shell. Remarkably, the individuals of this subspecies do not seem to have suffered as great distortion as other forms.

Camarotoechia mimelegantula, n. sp.

Plate 5, figures 3-15, text-figure 14.

EXTERIOR: Small to medium, wider than long, dorsiconvex Camarotoechia. Broadly subovate to semielliptical in lateral profiles the valves appear arcuate from beak to anterior but the brachial valve is the more inflated, commonly describing nearly a semicircle. Greatest width anterior to midlength. Cardinal margin terebratuloid;

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beak ridges weak to nearly absent. Beak incurved, usually broken; details of delthyrium and foramen unknown. Fold rather weak to moderately well defined, arising about mid-lenth and becoming more prominent anteriorly. Sulcus distinct only in the anterior one-third of the pedicle valve where it remains shallow and slightly convex transversely; near the anterior margin the shell bends more abruptly toward the brachial valve sending a short lingual extension into the fold. Anterior commissure broadly but gently uniplicate. Sixteen to twenty subangular plicae (which are wider than the bounding troughs) extend from the beaks to the commissure, those on the posterolateral flanks being very weak. The fold bears four to six plicae, and the sulcus four to five; the plicae bounding the sulcus are commonly the strongest of the pedicle valve. Well-preserved specimens show faint closely and evenly spaced growth lines. Shell material very thin.

PEDICLE INTERIOR: The dental plates are subparallel, very thin and very short, extending scarcely one-fifth the length of the valve. The teeth are small, stout and not known to be crenulated. Since, in well-preserved molds of the interior no muscle or genital marks can be seen, the muscles and genitalia seemingly left little impress on the thin shell; also no secondary deposits are present in the umbonal chambers.

BRACHIAL INTERIOR: Cardinalia small, confined to the

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extreme posterior portion on the valve; hinge plate divided by a deep steep-sided septalium. The concave outer hinge plates are supported on their inner edges by stout septalial plates borne on a low median septum which extends less than one-third the length of the valve. Sockets short but deep and bounded by very low socket ridges; the inner socket ridge is more pronounced than the outer ridge which blends with the wall of the valve. Muscular markings apparently absent as in the pedicle valve.

DISCUSSION: Although long known as a highly variable genus, the importance and extend of degrees of morphological difference within Camarotoechia yet remain unknown. Undoubtedly the environment plays a large part in the form of this ubiquitous mid-Paleozoic genus. Yet to what extent these morphological variants are species, exotypes, geographic or chronological subspecies remains obscure. Many of the "species" appear to be closely related, yes, even to intergrade with other population samples, yet the populations themselves seem to be separate distinct entities. Thus some of these populations seem to be at the very level of the rise of new species. (in the process of phylogenesis as used by Sylvester-Bradley, 1951, p. 91-93). Such a population (topodeme) seems to be illustrated by Camarotoechia mimelegantula n. sp., in the Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at locality 97. It can be recognized as distinct from other

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Devonian and Mississippian species yet it closely resembles several of these.

The distinguishing characteristics of C. mimelegantula, n. sp., are the relatively small size, the generally globose form with its convex postero-lateral slopes and rounded anterolateral flanks, the boradly uniplicate anterior commissure. Internally the short median septum and dental lamellae, small septalium, and short hinge plate are distinctive.

Camarotoechia mimelegantula most closely resembles C. elegantula Rowley from the Mississippi Valley. It differs from the latter in being larger, having more convex posterolateral slopes and especially in having more inflated valves which present a more nearly circular outline in all views; thus no specimens of C. mimelegantula are known in which the surface becomes concave as the anterolateral margins are approached as Weller (1914, p. 178) described in C. elegantula Rowley. In C. chouteauensis Weller (considered synonymous with C. tuta (Miller) by Branson, 1938, p. 45-46) the greatest inflation of the brachial valve is more anterior and the appearance of the fold is more quadrate in anterior aspect than in C. mimelegantula. Superficially C. mimelegantula, n. sp., resembles C. lauta Stainbrook, but closer inspection shows the latter to possess straight or concave posterolateral slopes, less inflated valves, and more plicae, the total number averaging 18-26.

C. mimelegantula seems to have come from the C.

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sappho - C. horsfordi stock; in fact, it is possible that it is what has previously been identified as C. sappho (Hall) in the Devonian and Mississippian of western Pennsylvania. While having much of the contours of C. sappho (Hall), C. mimelegantula, n. sp., has a more inflated pedicle valve curving convexly to the postero-lateral margins, more angular plicae, and is much smaller.

This species is easily distinguished from C. allegania (Williams) from the Oswayo formation which is larger, possesses a larger number of plicae, has heavier cardinalia, deeply impressed muscle scars, and, more adventitious material deposited in the rostral portions of the valve.

TYPES: Holotype: UCM No. 29701 (excellent mold of the interior with a small amount of shell remaining). Paratypes: UCM Nos. 29703, 29705, 29715 (well preserved but slightly exfoliated exteriors); unfigured paratypes, 29712 (exfoliated exterior with rostral portions of beaks ground away). Figured hypotype: 29720.

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97, sandstone in Kushequa shale at locality 51 (two specimens); sandstone in the Knapp formation on Yankee Bush Hill north of Warren, Pennsylvania, exact locality unknown (probably locality 199). Locality 97 is the

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type locality.

REMARKS: The hypodigm consists of 19 well preserved specimens and 37 dissociated valves and fragments from locality 97, two molds from locality 51, and one mold from locality 199 (?). Statistical data on the better preserved specimens are given below.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	Plicae on fold	Total plicae	l/w	w/t
Locality 97							
29701	13.1	15.2	9.6	5	18	.86	1.58
29702	13.4	14.2	9.8	5	22	.94	1.45
29703	12.2	13.8	9.1	6	20	.88	1.52
29704	12.5	13.0	8.4	4	19	.96	1.55
29705	11.8	13.7	7.5	6	18	.86	1.83
29706	11.5	13.8	7.5	6	20	.83	1.84
29707	11.6	12.1	6.5	5	19	.96	1.86
29708	11.2	11.2	6.9	6	19	1.00	1.62
29709	11.1	14.6	7.0	5	19	.76	2.09
29710	12.0	13.2	8.6	5	17	.91	1.54
29711	11.0	12.0	7.1	6	18	.92	1.69
29712	10.4	12.3	7.5	5	20	.85	1.64
29713	9.5	12.1	5.5	5	18	.79	2.20
29714	10.0	10.8	5.9	4 (5)	16(17)	.93	1.83
29715	10.2	11.2	4.8	4	16	.91	2.33
29716	9.8	11.9	5.8	4	16	.82	2.05
29717	9.2	10.1	5.1	5	18	.91	1.98
29718	7.2	7.7	5.3	4	16	.94	1.45
29823	5.2	5.1	3.2	-	14	1.02	1.59
Locality 51							
29720	11.1	10.4	5.8	5	20	1.07	1.80

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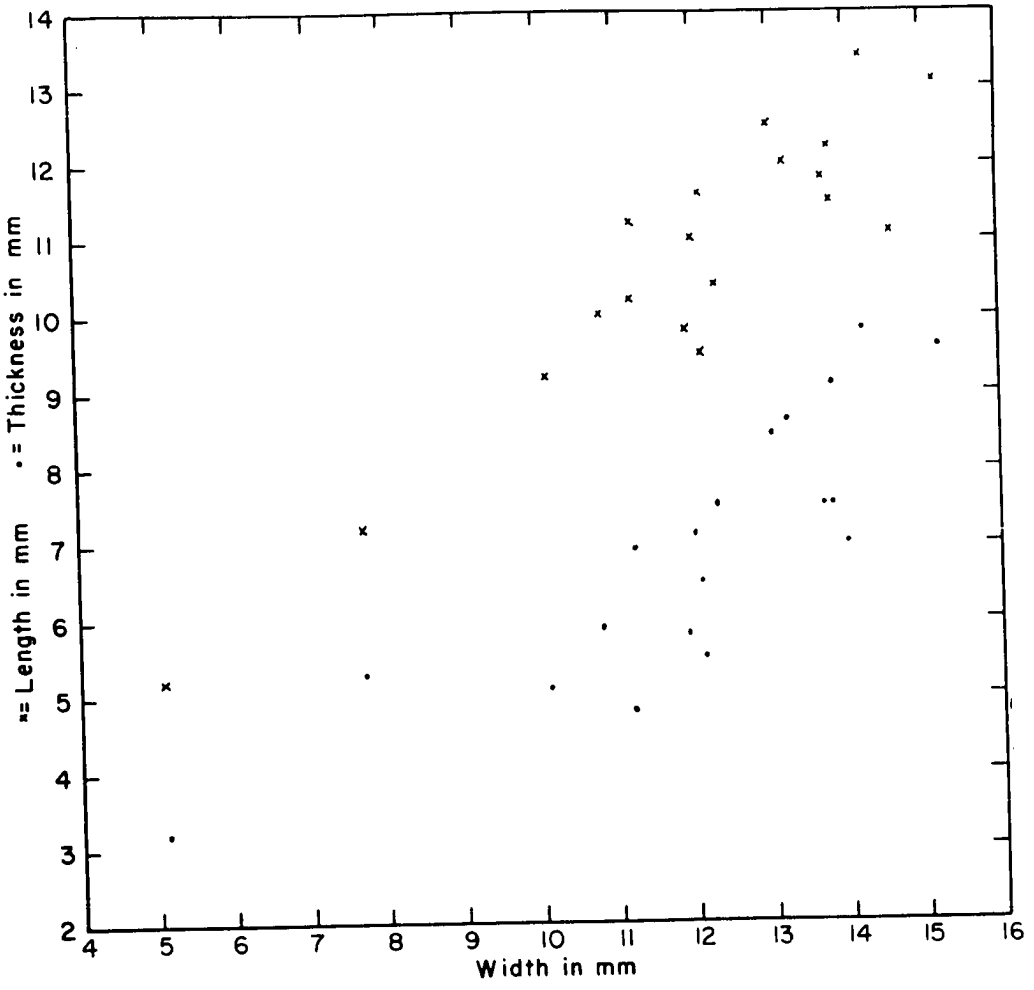

Fig. 14. - Scatter diagram of width plotted against length (x) and width plotted against thickness (dot) for 19 well preserved specimens of Camarotoechia mimelegantula, n. sp., from the Marvin Creek coquinoid zone of the Kushequa shale, Johnsonburg, Pennsylvania (locality 97).

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Camarotoechia cf. *C. contracta* (Hall)

Plate 5, figures 16-17

non *Atrypa contracta* Hall, James, 1843, Geol. Rept. Fourth Dist., p. 59, No. 66, fig. 3a; *et seq. opera*.

non *Camarotoechia contracta* (Hall), Caster, K. E., 1930, Bull. American Paleont., no. 58, p. 10, pl. 12, figs. 1, 2, 4-6, 11; pl. 14, figs. 16-21, 23-30.

A mold of the interior of a single elongate specimen with 20 angular plicae is present in the collection. This specimen is longer than wide with the greatest width well anterior to midlength. At midlength the shell is strongly and evenly curved transversly; the fold becomes apparent at about midlength and continues horizontally to the anterior margin where it is very pronounced. The sulcus becomes distinct at about one-fourth the distnace from the beak to the anterior commissure and possesses a considerable lingual extension. Six plicae are present on the fold of which one lateral plicae on each side is much reduced. Similarly there are three prominent plicae in the bottom of the sulcus with a much finer plication on each flank of the sulcus. Each plication is continuous, undivided from its origin to the margin.

Internally the widely divergent dental plates are very thin and very short being confined entirely to the rostral region. The teeth are thin and delicate but very

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elongate and strongly serrated. The median septum is very low and extends scarcely one-fourth the length of the valve but the septalium is deep and distinct in comparison to the delicate cardinalia. The plicae become partially obscured in the rostral areas by the deposition of adventitious deposits, but the limits of the muscle scars are not marked nor were they deeply impressed.

In the anterior elevation of the fold and the angularity of the plicae this specimen resembles C. contracta. Similarly, in the delicate nature of the cardinalia and the short thin dental lamellae, it is reminiscent of C. contracta. There the resemblance stops, however, for the latter is relatively much wider, has the greatest width at about midlength and generally possesses two to four plicae in the fold and a corresponding number in the sulcus. Hall (1867a, p. 351) also describes a division of the central plicae of the fold, and he figures C. contracta with the plicae curving more abruptly to the lateral margins.

Undoubtedly it is this form which appears in many Mississippian faunal lists as C. contracta, and it is likely that it is related to this species through the larger coarsely plicated Woodcock sandstone Camarotoechia figured by Caster (1930, pl. 14) as C. contracta. This latter is believed not conspecific with either the form under consideration nor with Hall's Hamilton forms, implying the necessity of a critical restudy of this whole species group.

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HYPOTYPE: UCM No. 29721.

OCCURRENCE: A single specimen from the Kushequa shale member of the Knapp formation at locality 175.

Camarotoechia sp. indeterminate

Plate 5, figure 18.

Five poorly preserved molds of the interior of single dissociated valves of a species which is definitely referrable to Camarotoechia are present in the collections; four of these are brachial valves and one is a pedicle valve. The pedicle valve shows the impressions of slender dental lamellae and the brachial valves show a low but distinct median septum. If these are all of one species (which is possible since they are of similar general configuration) the species was apparently characterized by its broadly ovate form with the greatest width anterior to midlength, low poorly defined fold (although one valve is more gibbous than the others and may belong to a different species) and about 18 broad subrounded plicae with those on the fold being more angular than the ones of the lateral slopes.

The lesser development of the fold, the fewer plicae, and the less developed median septum and dental plates, readily distinguish this form from Camarotoechia allegania (Williams). C. (Spathulata) spathula, n. subgen n. sp., is smaller, more attentuated posteriorly and has

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finer, more angular plicae. These specimens resemble Camarotoechia sappho (Hall) of the Middle Devonian but are less inflated than that species. Perhaps even more they resemble the Licking County, Ohio, specimens figured by Hall (1867a, pl. 55, figs. 47-52) as a variety of sappho.

The writer agrees with Chadwick and Caster (Chadwick, 1935a, p. 331, 336, footnotes) that Camarotoechia sappho (Hall) does not occur in the Conewangoan or Knapp faunas, but it is entirely possible that it is allied with forms, such as these dissociated valves, that have been reported as C. sappho by various authors. It is indeed unfortunate that more and better specimens have not been preserved.

With all due allowances for morphological variation dependent on habitat, it is unthinkable that these are ecotypes, conspecific with, or as derivations, of C. mimelegantula.

HYPOTYPE: Figured hypotype: UCM no. 29723.

OCCURRENCE: Fine grained micaceous sandstone of the Tidioute shale at locality 91 (UCM No. 29724) and from the Tidioute at locality 201 (UCM Nos. 29722 and 29723).

Subgenus Camarotoechia (Spathulata), n. subgen.

TYPE SPECIES: Camarotoechia (Spathulata) spathula, n. sp.

Oswayo formation, Upper Devonian, northwestern

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Pennsylvania.

ETYMOLOGY: Latin spathulatus spatha, broad blade or paddle.

DIAGNOSIS: Thin, weakly biconvex, ovate to obcuneate camarotoechiids which are completely and fully covered with numerous very fine plicae and which have the fold and sulcus very weak and indictinct or obscure. Shell impunctate; interior typically camarotoechioid with short dental lamellae and, in the brachial valve, a short median septum and delicate divided hinge plate.

REMARKS: Additional species which are likely to be referred to this subgenus are:

Rhynchonella? (Stenocisma?) royana Hall, 1867, Onondaga limestone, New York.

Rhynchonella depressa Kindle, 1901, Jeffersonville limestone, Indiana; Synder Creek shale, Missouri (Branson, 1924)

RANGE: Lower Devonian to Lower Mississippian (?)

Camarotoechia (Spathulata) spathula, n. sp.
Plate 5, figures 19-26; text-figure 15.

Camarotoechia sp., Caster, K. E., 1930, Bull. American Paleont., no. 58, pl. 14, figs. 9-11.

EXTERIOR: Small, generally longer than wide,

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obcuneate, weakly biconvex, rostrate Camarotoechia. The brachial valve is deepest near the beak well posterior to midlength, then commonly becoming flat about midlength thence curving gently to the anterior margin; pedicle valve most convex about one-third the distance from beak to anterior margin. Greatest width well anterior to midlength. Lateral margins nearly straight or curving slightly inward from points of greatest width to the attenuated suberect beak. Very low or nearly obscure beak ridges bound the palintropes; foramen large and hypothyrid with convex conjunct deltidial plates meeting anterior and posterior(?) to foramen. Fold very low, becoming distinguishable if at all, only in anterior one-third of valve where it occupies nearly the whole width of the anterior margin. In the pedicle valve a broad, very shallow sulcus usually becomes noticable at, or just anterior to, midlength. Twenty-three to thirty-one, fine, generally subrounded plicae extend undivided from beak to commissure; those on the flanks curve only slightly to the lateral margins. The anterior commissure is so slightly uniplicate and the fold and sulcus so faint that it is impossible to tell the number of plicae of the fold.

PEDICLE INTERIOR: Dental plates very thin and very short. Teeth long but narrow, moderately crenulate(?). Muscle marks obscure.

BRACHIAL INTERIOR: Thin, concave, outer hinge plates

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are supported on their inner margins by delicate septalial plates arising from the posterior part of the low, short median septum which extends less than one-third the length of the valve. Septalium fairly broad and open anteriorly, narrowing rapidly posteriorly, and constricted slightly at the extreme posterior end by the overhanding edges of the outer hinge plates where each is thickened by the trace of the crural base. Crura not well preserved but apparently long, thin, and tapering. Outer socket ridges obscure or wanting so that the long, narrow sockets are set against the wall of the valve; inner socket ridges slight. Adventitious deposits altogether absent, leaving deep rostral cavities under the hinge plates. Thus none of the rostral structures are thickened so that the cardinalia appear thin and delicate. Muscle marks unknown.

DISCUSSION: The distinctive characteristics of this species are the small size, the marked obcuneate shape, the very low indistinct fold, the abundant plicae, and the delicate cardinalia. By these characteristics this species can easily be separated from the robust Camarotoechia allegania (Williams) with which it is associated and from most other camarotoechiids. C. allegania lingulata, n. subsp., which this form resembles, has fuller development of all the rostral structures and the muscle scars.

This species most closely resembles Camarotoechia depressa (Kindle) as reported by Kindle (1901, p. 589)

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from the Jeffersonville limestone of southern Indiana and by Branson (1924, p. 90) from Snyder Creek shale of central Missouri. Kindle reports this species as rare in the Jeffersonville and does not include it in his faunal lists. Branson figures the one specimen from Missouri and reports (p. 91) that, "It is slightly crushed but seems to differ in no respect from Kindle's species though its occurrence so much higher in the geologic column is remarkable." The interior is not shown for either of these occurrences but the plicae appear to be fewer(?), broader, and much more rounded than in C. (Spathulata) spathula n. sp.

Hall (1867a, pl. 54, figs. 20-23) illustrated a single specimen which he names Rhynchonella? (Stenocisma?) royana. Although this solitary specimen came from the "Corniferous limestone, north of Leroy, New-York", Oliver (1954) does not list this species in his extensive study of the Onondaga limestone of central New York. It is entirely possible however, that he included it, if found, with C. tethys (Billings) or C. billingsi Hall and Clarke which he does list from this area. In any event, Hall described his species as having the central plicae bifurcate; in other respects it closely resembles C. (S.) spathula.

These isolated occurrences, if found to be valid, imply a rare but distinctive stock of Devono-Mississippian brachiopods which have internal characters similar to

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Camarotoechia but which differ markedly in exterior conformation and plication. The writer known of no descendants of this group, but these and other members of the subgenus should be sought in Devonian and Kinderhookian strata

TYPES: Holotype: UCM No. 29730. Paratype: UCM Nos. 29729, 29732.

OCCURRENCE: Roystone coquinoid in the Oswayo formation at localities 1 and 183; sandstone in the Oswayo at locality 60 and locality 109 and one specimen(?) from the Tidioute shale at locality 91. Locality 183 is the type locality.

REMARKS: This species is represented by eight reasonably complete exteriors and numerous fragments (including broken molds of the interior) from locality 183, six good to poor molds of the interior from locality 1, one mold of the interior and several molds of the exterior from locality 109, and one mold of the interior of the pedicle valve (doubtfully referred to this species) from locality 91.

Several of the better preserved molds of the interior faintly show a raised reticulate net work of the clay matrix between the sand grains. This would make it appear that the interior of the shell was covered with a pattern of fine diagonally crossed striae with vague diamond-shaped raised areas between the junctions of the striae. Neither exteriors nor exfoliated specimens show

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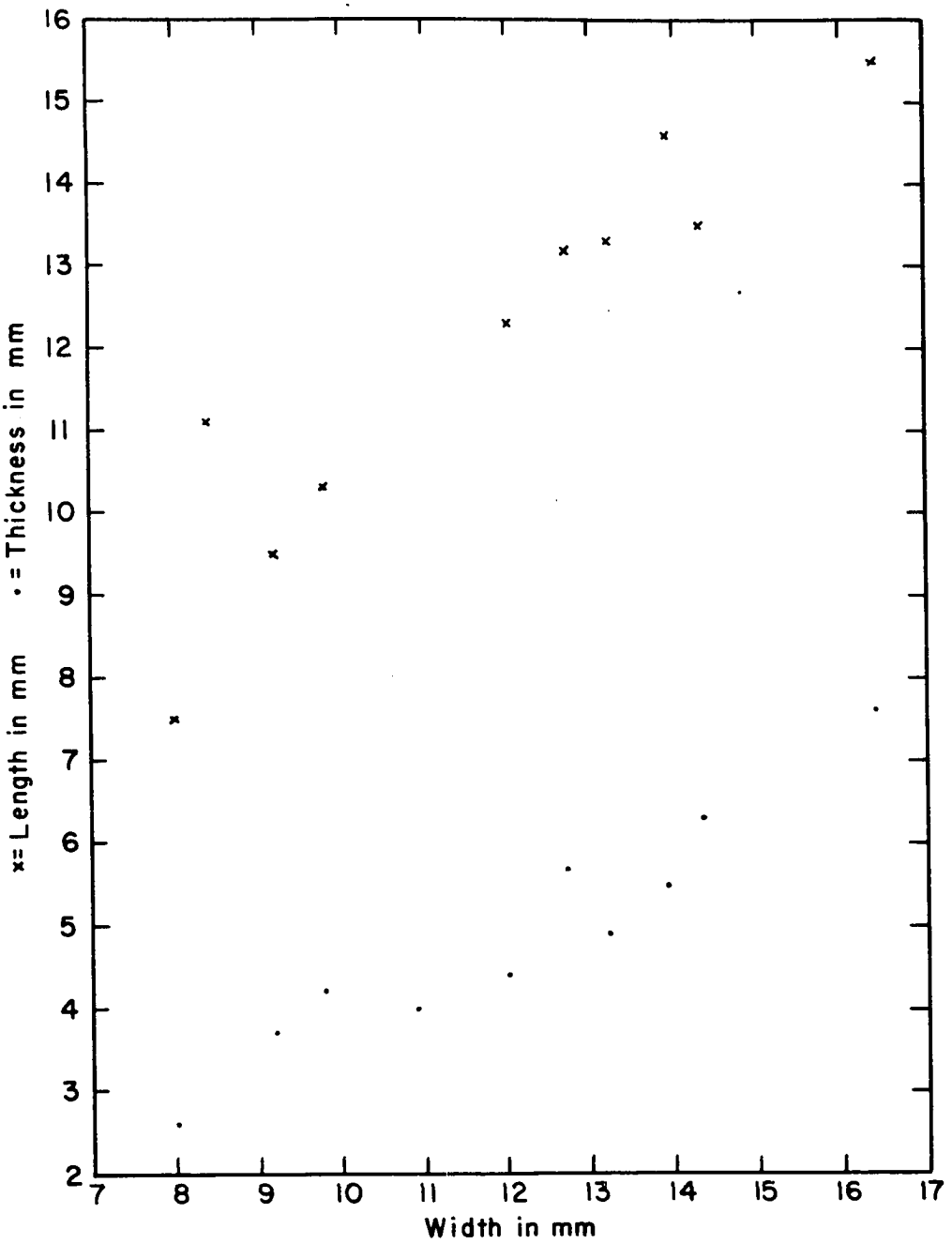

Fig. 15. - Scatter diagram of the better specimens of Camarotoechia (Spathulata) spathula, n. subgen., n. sp. from the Oswayo formation. Dot indicates width plotted against thickness; x indicates width plotted against length.

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this reticulate pattern however. Moreover, close examination and thin sections show the shell to be composed of dense steeply set lamellae and to be impunctate. This phenomenon remains inexplicable to the writer.

Dimensions of the better specimens are given below. The specimens from localities 1 and 109 are molds of the interior. An asterisk indicates that the dimension has been estimated.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	l/w	w/t	Total plicae
Locality 1						
29725	15.5	16.4	7.6	1.94	2.16	31
29726	13.3	13.2	4.9	1.00	2.69	31
Locality 183						
29728	13.5	14.3	6.3	.94	2.27	27
29729	13.2	12.7*	5.7	1.04	2.23	27
29730	9.5	9.2	3.7	1.03	2.49	27
29731	10.3	9.8*	4.2	1.05	2.33	27
29732	12.3	12.0	4.4	1.02	2.73	23
29733	--	10.9	4.0	--	2.73	25
29734	7.5	8.0*	2.6	.94	3.08	25
29735	14.6	13.9	5.5	1.05	2.53	25
Locality 109						
29737	11.1	8.4	--	1.32	--	25

Suborder SPIRIFEROIDEA Allan, 1940, emend., Muir-Wood, 1955

Superfamily SPIRIFERACEA Waagen, 1883

Family SPIRIFERIDAE King, 1846

Subfamily CYRTOSPIRIFERINAE Termier and Termier, 1949

Genus Cyrtospirifer Nalivkin, in Fredericks, 1926

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TYPE SPECIES (by original designation): Spirifer verneuili Murchison, 1840, Soc. Geol. France, Bull., v. 11, p. 252, pl. 2, fig. 3a-e. Upper Devonian, Ferques, Boulonnais, Belgium.

Medium to large, slightly to strongly transverse spiriferids of mutable shape. Hinge line identical with striaght cardinal margin which may be greatly extended. A moderate to strong, well-defined fold extends from the brachial beak to the commissure and a sulcus of corresponding strength extends the length of the pedicle valve. The sulcus is triplicate (divided into three subequal sections by two divergent, pronounced ribs which arise very near the beak). Shell impunctate. Shell marked with distinct, rounded to broad flattish plicae; superimposed on the plicae are fine costellae which may give way to papillae near the anterior margin. Plications of lateral slopes usually simple, more rarely bifurcating near anterior margin; those of the fold and sulcus increase by bifurcation or intercalation of by both. Pedicle valve the more convex, convexity of both valves greatest near umbo. Both valves curve gently to the anterior margin and a similar gentle curve may be developed toward the lateral margins, or the valves may become concave on the lateral slopes of alate forms. Interarea of pedicle valve sharply defined, orthocline to strongly apsacline, low and broad to highly trigonal. Delthyrium a broad triangular opening; nature of deltidial

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plates poorly known. In the pedicle valve more or less strongly developed teeth are supported by strong, short, straight or slightly curved, divergent dental lamellae which may be either re-entrant or pendant. Delthyrial and lateral umbonal cavities more or less filled by secondary callosity, the lateral cavities usually more so than the delthyrial cavity. The latter is roofed by a transverse delthyrial plate connecting the dental lamellae under the posterior part of the delthyrium well below the level of the area. Diductor muscle scars large, obovate to obcordate, usually quite deeply impressed into the shell; adductor scars small, central, commonly not well differentiated from diductor scars. Pitted area of genital markings usually well developed in umbonal region. No median septum in pedicle valve. In the brachial valve the cardinal process is a broad, heavy diamond-shaped apophysis with its surface scored by deep vertical grooves. The sockets are excavated into relatively strong heavy plates growing anteriorally from the umbonal walls not connected mesially and not well differentiated into their component parts. Inner socket ridges strong and outer socket ridges low and thin or absent. The crura spring from poorly defined crural bases on the innter edge of the inner socket ridges or from the anterior extremity of these ridges. The muscle scars of the brachial valve narrow, elongate, and less distinct than those of the pedicle valve. No supporting lamellae present under the socket plates.

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DISCUSSION: Greiner (1957, p. 14-15) has clarified the manner of naming and early descriptions of Cyrtospirifer. The description of Cyrtospirifer in Fredericks' 1926 publication is inadequate, and it is to Nalivkin (1930) that one turns for the author's more complete description. Since then much has been written concerning the genus Cyrtospirifer and its multifarious species. Indeed, even the type is in doubt, for although Nalivkin clearly stated that Spirifer verneuili Murchison was the type species, there has been considerable written on the possible synonomy of this species with Sowerby's Spirifer disjunctus and on the possibility that this name has priority over Spirifer verneuili. American and English paleontologists (notably Hall, and Davidson, but also the Belgian, De Koninck, 1898) have shown preference for S. disjunctus (although Davidson later, 1884, p. 35, said that S. verneuili holds priority), while European paleontologists have used S. verneuili to the exclusion of S. disjunctus. Gosselet (1894, p. 53-56) gives a careful summary of the facts as they exist; he says in part:

> In 1840, two very important paleontological descriptions appeared, containing several forms of the Spirifers in question and giving them different names. Murchison called them Spirifer Lonsdali, Verneuili, Archiaci while James Sowerby applied to them the names Spirifera calcarata, disjuncta, inornata, extensa, gigantea. These multiple names, introduced at the same time, created a troublesome synonomy. There is general accord that it is well to reunite these Spirifers in a single species, but some would apply to them the name, disjunctus Sow., and others Verneuili Murch.
>
> The celebrated memoir in which Sedgwick and Murchison established their Devonian system:

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Physical structure on older stratified deposits of Devonshire, was read at the second meeting of the Geological Society of London, 24 April 1839, but was not published until 1840. In the text (p. 694) the Spirifers of the Upper Devonian are listed as attenuatus and bisulcatus. But in the list which ends the memoir and which carries the date 30 May 1840, one sees the names Spirifer calcarata, disjuncta, inornata, extensa, gigantea. These are the names which figure in the short diagnoses which accompany the fossil plates, and which are due to James Sowerby; they are also dated May 1940.

The diverse species are established on internal or external molds in bad conditions, frequently broken, most often flattened and deformed. A single figure (pl. 54, f. 13) represents under the name Spirifer disjuncta, an individual well enough preserved to group it under hemicycli. However, one does not distinguish the almost constant difference in size between the ribs on the fold and those on the wings. The bifurcation of the primaries is not indicated either in the figures or the diagnosis. The fossil is compared to Spirifera bisulcata.

When Lonsdale communicated on 25 March 1840, to the Geological Society of London, his notes on the age of the limestone of Devonshire: On the age of the limestone of south Devon. (Trans. of the Geol. Society of London), he gave a list of fossils established in part by the study of Hennah's collections, with the aid of J. Sowerby; one could be surprised not to see figured there the new names which Sowerby was going to present a month later. However, Lonsdale had already known the characters of Spirifer Verneuili. While citing these fossils of the lower limestone system of Belgium, he mentioned Spirifer attenuatus, and he added in a note (p. 733): "The shell called Spirifer attenuata on the continent is one of the most characteristic fossils from the beds in question, for it is noted in all the published lists; but it differs essentially from Spirifer attenuata of the carboniferous limestone by its simple and regular ribs on the wings, and by the larger projection of the central plication (fold) of the upper valve."

Several pages further on (p. 735) he announces that he has seen this Spirifera attenuata among the fossils from Boulonnais of the Dutertre-Yvart collection.

Murchison left London immediately after the meeting of 25 March, read his note on the Devonian terrane of Boulonnais to the Geological Society of France 6 April and edited, during his stay in France the paleontological part of his memoir, where he described the Spirifers of Boulonnais with the aid of Verneuil and of d'Archiac. The geological

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illustrations show very well their characters, as already pointed out by Lonsdale, and the simplicity of ribs on the wings and their bifurcation on the fold and sinus. He made three species of these.

. . . . . .

The first two names on each list, Spirifer calcaratus and Lonsdalii, being isolated as established on incomplete and altered specimens, one my ask which has the priority Spirifer Verneuili Murch. or Spirifer disjunctus Sow.?

The two memoirs were completed at the same time, and in an independant manner, but not without the authors communicating their results among themselves.

Murchison already had the plates, if not the names of Sowerby when he presented these to the Geologic Society of France; on the other side, Sowerby tells us himself that when he edited the diagnosis of the fossils, he knew Spirifer Verneuili.

He says apropos of Spirifer gigantea (pl. 55, fig. 1 to 4): The ribs are at least as numerous as those in Spirifer Verneuili and are very regular.

Then, if Murchison had seen the fossils and plates of Sowerby, the latter knew the fossils and names of Murchison. But one or the other had not recognized the specific identity between the English molds and the better preserved fossils of Boulonnais.

If one examines the fact of publication it is very difficult to know now which was brought out first, the proceedings of the Geological Society of France, or the volume of the Geological Society of London.

Paleontologists were and still are divided on the two names.

. . . . . .

Murchison, it is true, had himself declared in Siluria, 3rd. edition, that the name disjunctus was older than Verneuili, but he gave no proof of this. The motives for his denial of author, which may have been in part his recognition of Sowerby who had described his bad fossils, should not have influenced his definitive judgement. Because it is not a question of knowing in which "epoque" the name was given by the author, but in which"epoque" it was published.

In resume, the question of authority, not being able to be resolved, or being at least very debatable, one must choose for authority, the good figures and good descriptions of Murchison, or the bad figures of Sowerby, of which only one is hardly determinable and which are accompanied by only a few words of diagnosis, where one can not even find mention of the fundamental species characters, the simplicity of the ribs on the wings.

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> In the uncertainty, it is wise, it seems to me, when it is a question of a fossil of the first order, characteristic of the Upper Devonian, of maintaining the name which belongs to the geologist who had done the most work on the Devonian terrane, who was the first to establish the relation between the ancient American terrane with those of the old world, who has contributed finally a great deal toward making paleontology the basis of geologic studies.

This long quotationoof Gosselet's summary is given here to show the complex nature of the problem of establishing priority of S. verneuili Murchison vs. S. disjunctus Sowerby. Numerous other workers have rendered their opinion, but none stated the case so clearly as Gosselet. However, it is entirely possible that S. disjunctus is a valid separate species from S. verneuili, and then the question of priority is completely academic and no great problem arises. Certainly the molds of the interior figured by Sowerby (1840, pl. 53, fig. 8 and pl. 54, fig. 12) differ in general shape and their large size from most Cyrtospirifer verneuili and resemble very little the Oswayo cyrtospiriferids with which we are especially concerned.

As Termier and Termier (1949, p. 99-100) have pointed out, most European paleontologists have tended to unite diverse forms with all sorts of morphologic varieties into the single species, C. verneuili: while in North America workers have the done the same but called the species C. disjunctus in the eastern United States and C. monticola (Haynes) or C. whitneyi (Hall) in the western United States. This has tended to hide morphologic

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differences whether due to temporal evolution through mutations, ecologic variation, or spatial distribution resulting in local interbreeding or mixing of characteristics from various gene pools. Thus from time to time there has been good cause (as Crickmay, 1953, p. 1, has said) for "a more critical discrimination of species and genera among fossils than has commonly been deemed necessary." This is the view that has been adoped herein in relation to the spiriferids; but each time this separation has been attempted in the past, a reuniting has then been effected by another worker. Only when documentation of the morphologic variations of Upper Devonian cyrtospiriferoids from different localities is completed, can a synthesis such as Paeckelmann (1942) has attempted by successful for the world.

The necessary type of documentation within the crytospiriferids of the Penn-York Embayment has been begun by Greiner (1957) who has recognized 18 species of Cyrtospirifer in the "Catskill Delta."

Peculiarly, though so well defined and so much having been written about Cyrtospirifer, a number of morphologic details remain in doubt, it is difficult to separate from allied genera, and it has been misidentified in a number of instances to the consternation of stratigraphers.

Among morphologic features of Cyrtospirifer about which there is some difference of opinion is the covering

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of the delthyrium. Neither Sowerby (1840) nor Murchison (1940) mention this feature. Davidson (1864, pl. 5, fig. 3 and pl. 6, fig. 1) figured Sowerby's Spirifer disjunctus (with which he considered S. verneuili synonymous) restored with the delthyrium covered by a "pseudodeltidium" (conjunct deltidial plates) extending about two-thirds or three-fourths of the distance from the beak. Hall (1867a, p. 244) apparently following Davidson not only in his synonymy but also in this detail, ascribed an "arching pseudo-deltidium" to S. disjunctus. Speaking of the delthyrium of Spirifer verneuili, Gosselet (1894, p. 7) says:

> It opens passage to the muscles of attachment but it is closed in time by a unique calcareous plate, the deltidium which grows from the summit to the base and little by little restricts the opening.

Nalivkin (1930, p. 196) in his description of Cyrtospirifer says: "Delthyrium of various width, sometimes wholly or in part covered by the pseudodeltidium." Grabau (1931, p. 232, quoting Davidson, 1853) ascribes a "pseudo-deltidium in two pieces" to his Sinospirifer (a genus very closely related to Cyrtospirifer), and Tien (1938, p. 111) adds that in his "Sinensis" group (which included C. disjunctus and C. whitneyi) of the Upper Devonian spiriferids (which corresponds to the Sinospirifer sinensis gens of Grabau exclusive of the forms Tien separates out as Tenticospirifer and Hunanospirifer) the "convex pseudo-deltidium . . . is rarely preserved."

It is likely that most of these aforementioned

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workers were mislead by Davidson's early statements and restorations; he in turn was considering the various species groups as Spirifer, sensu lato, many forms of which do possess deltidial plates. Gosselet was probably speaking of the transverse subdelthyrial plate since he was admittedly not concerned with internal characters, and since he recounted the method of growth as from the beak down toward the hinge (a xenidium of the present terminology; a deltidium auct.). One should note however that the subdelthyrial plates lies well below the position of the deltidial plates.

It is possible that Cyrtospirifer possessed no deltidial plates since Fredericks (1927), in discussing the "ostiolater Appikalapparat" possessed by Cyrtospirifer thus placing the genus in his group "Ostiolatus," does not mention the deltidial plates, nor does Paeckelmann (1932); nor does Harrington (1939), who mentioned sectioned numerous specimens of C. verneuili; nor does Stainbrook (1943b). In fact, Paeckelmann (1942, p. 49, 157) separates Cyrtospirifer from Cyrtiopsis Grabau (1925) on the basis of the presence of "Deltidium (Pseudodeltidium Bronn)" in the latter. Conjunct deltidial plates are clearly shown in the Cyrtiopsis which Paeckelmann figures on page 159, but are absent on all of his figures of Cyrtospirifer. Sartenaer (1955) has shown that the deltidium of Cyrtiopsis murchisoniana consists of numerous (about four) separate moveable plates or scales. Thus, much more

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work needs to be done on the delthyrial covering before classification or even terminology is complete.

None of the Cyrtospirifer from the Oswayo of the Penn-York Embayment have deltidial plates; although in one of the sections cut while studying these cyrsto-spiriferids, thin broken fragments of lamellar calcite were found in the correct position to have represented deltidial plates possibly. The longitudinal grooves or tiny shelves (delthyrial grooves) which lie along the edges of the delthyrium and which are noticably in many specimens may represent the attachment seat for the deltidial plates, which were destroyed during fossilization. Sartenaer (1955, p. 9) reports such grooves bordering the delthyrium in a number of spiriferids, and he also interprest these as grooves for the reception of the "deltidium".

In a mold of the interior of Cyrtospirifer warrenensis Greiner from the Knapp at locality 51 a slit was found in the sandstone filling of the delthyrium. A rubber cast of this specimen clearly shows that this crack represents the position of the deltidium which was preserved in this specimen before the calcite of the shell was dissolved. The cast shows a thin convex plate (or plates) fitted into the delthyrial grooves from apex to hinge line. Unfortunately the thin rubber of the cast of the deltidium was torn during removal from the mold. Thus only thin remnants of the deltidium can be seen along the edge of the groove and no definite information can be

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gained of the nature of the center of this area. Although this is enough to permit definite interpretation of a convex deltidium in Cyrtospirifer warrenensis Greiner and related species, the exact nature of this structure remains an enigma, and indeed, the presence of a deltidium has not been verified in the majority of forms.

Another feature about which a discrepancy exists in the leterature is the nature of the plicae of the lateral slopes. Murchison (1840, p. 252) was very explicit in saying that the plicae of S. verneuili which are always simple on lateral sections of the shell, are only subdivided on the fold and in the sinus. Davidson (1864, p. 25) was similarly explicit regarding S. disjuncta Sowerby thus separating it from S. striata Martin (type species of Spirifer, sensu stricto). Hall (1867a, p. 244) again followed Davidson, and Gosselet (1894, p. 8) makes a strong point of the simplicity of the ribs of the wings. Grabau (1931, p. 209-210) says of his Sinospirifer sinensis:

> Only in rare individuals have I observed intercalation of a plica between others on the sides of the pedicle valve, and a corresponding bifurcation of the equivalent plica on the opposite valve.

On the other hand Nalivkin (1930, p. 196) says in his description of Cyrtospirifer:

> Entire surface covered with multitudinous minute, flattish, subangular plications. The medial plications are usually dichotomizing, the lateral --simple. Sometimes, yet very seldom, dichotomy is to be observed in the lateral plications too.

Harrington (1939, p. 136) emended the Nalivkin

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definition to read in part,

> Surface of the shell covered by numerous costellae, always bifurcating on the fold and median sinus, and by smaller ones also on the lateral regions of the valves. The costellae can even trifurcate near the anterior margin.

However all of the specimens studied from the Oswayo and Knapp have simple lateral plicae. Greiner (1957, p. 20-21) has described his C. altiplicus as having a tendency towards bifurcation or trifurcation toward the anterior margin.

The diagnostic characters of Cyrtospirifer seem to be, then, the spiriferoid shape, triplicate sulcus, impunctate shell, apparent lack of deltidial plates, the strong divergent dental plates, the well-developed transverse delthyrial plate, and the absence of median septa in either valve. Lateral plicae apparently do bifurcate but this is relatively uncommon and simple lateral plicae the rule; fine radial micro-ornament may by variously developed.

Glenister (1955, p. 61) has recommended suppression of Sinospirifer as a subjective synonym of Cyrtospirifer, but Sinospirifer, s. s. apparently possesses a median septum in the pedicle valve (Tien, 1938, p. 180 and pl. 16, figs. 2-3) which extends from the adductor process for a short distance through the muscle scar; in addition, Maxwell (1951, p. 5) has emphasized that the dental plates of Sinospirifer are less strongly developed and tend to be more curved than in Cyrtospirifer. It should be mentioned , however, that Cyrtospirifer occurring lower

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in the Conewango (Salamanca suite) of the Penn-York Embayment likewise have an extension of the adductor process for a short distance anteriorally as a low median septum.

Cyrtiopsis commonly has the greatest width anterior to the hingeline but not universally so (Paeckelmann, 1942, and Crickmay, 1952); but in Cyrtiopsis the dental lamellae are characteristically thinner, less divergent, much longer, and more incurved than in Cyrtospirifer. Paeckelmann (1942, p. 157) also ascribes fine papillose surface sculpture and a definite "deltidium" to Cyrtopsis. The highly pyramidal pedicle valve of Tenticospirifer seems sufficient to separate it from Cyrtospirifer despite statements to the contrary (Glenister, 1955, p. 61).

Other Devonian spiriferoid genera are relatively easily distinquished from Cyrtospirifer on the basis of shape, gross differences of the ornamentation of the sulcus, micro-ornament, or internal morphology (see Maxwell, 1951, Stainbrook, 1943b, Roger, 1952). Glenister (1955) presents an opposing view however; his treatment of some spiriferoid genera is summarized in the following table on page 213.

On the other hand, Gatinaud has recently made an attempt further to subdivide Cyrtospirifer. In 1949 Gatinaud published a series of papers giving a new method of classifying spiriferid brachiopods which is an enlargement of Grabau's (1931) method of sinal formulae and

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TABLE 9. - Status of some proposed spiriferoid genera related to Cyrtospirifer according the Glenister (1955) Glenister suppresses first six genera (or subgenera of Spirifer) as subjective synonyms of Cyrtospirifer

GENUS	DISTINGUISHING FEATURES	GLENISTER'S COMMENTS
Sinospirifer, Grabau, 1931	Small size.	Many European forms of Cyrtospirifer verneuili are no larger than Chinese forms.
Centrospirifer, Grabau, 1934	Single, symmetrically placed, primary sinal plication.	Difference in plicae on two sides of sulcus commonly exist, so feature of no more than specific value.
Tenticospirifer, Tien, 1938	Hemipyramidal pedicle valve, thin shell, thin socket plates, absence of rostral filling, absence of brachial median septum.	Shape is extreme form of continuous variation; other features function of age and are only of specific value.
Hunanospirifer, Tien, 1938	Hinge plate thins between the sockets.	Universal among spiriferids and insufficient basis for anew subgenus.
Platyspirifer, Grabau, 1931	Hinge line slightly shorter than maximum width of shell	Shell ratios vary with ontogeny of individual doubtful if Grabau's are valid species.
Schizospirifer, Grabau, 1931	Coarse bifurcating lateral plications.	Founded on poor material. Further investigation needed before group can be recognized.
Indospirifer, Grabau, 1931	Ribs, bearing fine diverging striations, far less numerous than in Cyrtospirifer	Not closely related to Cyrtospirifer. Interior unknown. Probable that future study will prove worthy of generic status.
Plectospirifer, Grabau, 1931	Flanks with coarse ribs; sulcus smooth or finely plicate with a single, median, primary plication; with lamellose radial	Probably represents a valid genus.

Bancroft's (1945) statistical method. Based on his statistical method, Gatinaud has set up a complex taxonomic hierarchy of the Spiriferidae. The definitions of his subgenera, sections, and subsections are mostly statistical; and since, because of the preservation, it was not possible to make all of the calculations necessary, it was not possible to fit the Oswayo or Knapp cyrtospiriferids into Gatinaud's taxonomic units. Probably C. horridus, n. sp., and its variations belong to his subgenus Grabauispirifer while C. oleanensis Greiner and C. extentus n. sp., belong to his subgenus Cyrtospirifer, s. s. Possibly C. extentus might be placed in his subgenus, Eurytatospirifer. Glenister (1955, p. 57) and Greiner (1957, p. 17-18) have dismissed Gatinaud's "splitting" and declined to recognize his new taxa.

The real difficulty comes in trying to separate Cyrtospirifer from Lower Mississippian Spirifer, s. s. Dunbar and Condra (1932, p. 317) surely cannot be correct when they say regarding Spirifer s. s.,

> Distinctive generic features are the simple ribs, alike on fold and sinus and on lateral slopes, and the fine grilled surface sculpture.

Examination of any work on Mississippian spiriferids (e. g. Weller, 1914) will quickly show Spirifer s. s. with bifurcating and intercalary plicae.

Nor can the distinction always easily be made on the basis of internal structure, for again it is a matter of degree or of gradation from Upper Devonian and Lower Mississippian cyrtospiriferids to Lower Mississippian

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spiriferids. This makes it very probable that Cyrtospirifer represents the stock out of which Mississippian Spirifer, s. s.came. Thus Cyrtospirifer might well be ranked as a subgenus of Spirifer as Nalivkin defined it, and as such recent workers as Paeckelmann (1942) have done. Commonly however Spirifer, s. s. has shorter, thinner and less well developed dental lamellae and has a median septum in the pedicle valve. The lessened extent of the transverse subdelthyrial plate gives a good indication of Spirifer, s. s., but Stainbrook (1943b, p. 421 and Gatinaud, 1948, p. 202; followed Stainbrook) has held that Spirifer and Cyrtospirifer cannot be separated on the basis of lack of the transverse delthyrial plate in the former, saying,

> Davidson (1858) in his summary of the generic characters of Spirifer states that the ventral delthyrium is always more or less closed by a pseudodeltidium notched in the vicinity of the cardinal edge. His illustrations of the pedicle valves of Spirifer striatus (Martin) plainly show a transverse delthyrial plate.

The writer, however, has not been able to discover such an illustration; Davidson's (1858) figures 20 and 21 show a restriction of the delthyrium by a plate (or pair of plates) quite apparently lying above the level of the interarea and not below it. Glenister (1955, p. 60) considered the transverse delthyrial plate "never well developed" in Spirifer, s. s., but this also is obviously a matter of degree. He (1955, p. 57) places considerable reliance on the socket plates in separating Spirifer, s. s. from similar spiriferoid genera. He says,

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> The nature of the socket plates is often difficult to detect, but is doubtless of taxonomic value. The diverse types of socket plates are illustrated by Cyrtospirifer, Spirifer s. s. and Austrospirifer. The socket plates of Cyrtospirifer are not directly supported by lamellae beneath them, while those of Austrospirifer and Spirifer are supported to the extent that the sockets appear as pits in the posterior shell wall. Spirifer has long narrow sockets, while the sockets of Austrospirifer are uniformly hemispherical.

However, no socket criteria have been found by the writer to be useful in separating Cyrtospirifer from Spirifer, s. s.; until further study can be made, the differences in the sockets within these two genera are considered to be only of specific value.

It is intriguing to note that Sarytcheva and Sokolskaya (1952, p. 181) place Spirifer disjunctus under Spirifer, s. s. rather than under Cyrtospirifer.

In order to emphasize rather than mask whatever differences may exist, for the time being, the writer prefers to consider Cyrtospirifer a distinct and separate genus, if all gradations from one genus to the next were to be discounted and the forms grouped, zoology would lose the "handles" by which we denominate the numerous variations in animals.

In summary, then, Spirifer, s. s. differs from Cyrtospirifer in possessing fewer and generally stronger plications, lesser extent of the transverse subdelthyrial plate, dental plates confined to the rostral area, and common presence of a median septum in the pedicle valve. Glenister (1955, p. 60) also says,

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> Substantial differences in the form of the descending lamellae and development of the jugal process also appear to exist between the two genera, but insufficient information is at present available for them to be stated with any degree of certainty.

PHYLOGENY: Greiner (1957) has done a great deal to elucidate the evolution of Cyrtospirifer in the Upper Devonian on the "Catskill Delta". He records the earliest Cyrtospirifer as occurring in the Cayuta shale, Chemung stage, of the Senecan series (Frasnian, fide Cooper, et al., 1942) in agreement with Williams (1913, p. 23) who recorded "Spirifer disjunctus" in his Tropidoleptus zone No. 3 at this level. Greiner (p. 61) says:

> It seems only natural that among the numerous species of cyrtospirifers that arrived in great abundance on the Catskill Delta, some species should have their origin locally. Likewise it would seem quite possible, in view of the great length of time involved in the formation of the delta, that others of these would have had their origins in remote faunal provinces and would arrive as species foreign to the Appalachian province.
>
> The problem in this section is to distinguish between these two groups, and to reconstruct the phylogeny of the Cyrtospirifer tribe as represented in the Upper Devonian-Lower Mississippian strata of eastern America.
>
> . . . . . .
>
> The ancestry of the Cyrtospirifer tribe is not known. The most likely assumption would seem to be that the progenitor was one of the complete costate spirifers, which, more likely than not, also dwelt upon the Catskill Delta. Paeckelmann, in his phyletic lineage of the Spiriferidae considered Cyrtospirifer as derived from Spinocyrtia (1931, p. 58). While this is a possibility, the shape of the shell, distinctive surface ornamentation, and great separation in time seem to offer cogent objections.

Greiner (p. 62) derives the earliest form, Cyrtospirifer chemungensis (Conrad) questionably from Mucrospirifer mucronatus (Conrad) of the Naples. Although

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the writer has no better solution, this latter course seems fully as dubious as the derivation of Cyrtospirifer from Spinocyrtia Fredericks.

Greiner believes that the Cyrtospirifer chemungensis sotck was shortly augmented by foreign forms not "endemic to the Catskill Delta". From a plexus of species in the late Chemung Greiner derives the stock from which late Upper Devonian forms came. This stable form, Cyrtospirifer inermis (Hall), persisted into early Conewangoan times, and it is likely that the Oswayo cyrtospiriferoids were derived from this form.

Regarding the development of related spiriferoids elsewhere Grabau (1931, p. 208) has said:

> I use the name Spirifer sinensis because I believe these brachiopods to constitute a morphological series whose development and differentiation occurred in the epeiric waters which covered South China in Upper Devonian time. That they are closely related to, and probably genetically connected with the similar morphological series which in Europe has become known as that Sp. verneuili Murchs. (Commonly regarded as synonymous with S. disjunctus Sowerby) can hardly be questioned, but it is a more difficult problem to ascertain whether the Chinese group is derived from the European or the reverse, or whether both had a common ancestor.

Lee (1939, p. 124) in speaking of the Frasnian seas, says:

> The third wave of marine invasion into southwestern China is marked by the appearance of a group of Spirifers that are undoubtedly modifications of Spirifer verneuili of Europe. This group of Spirifers is known in China as Sinospirifer, with S. sinensis as its leading type. At this stage, it is almost beyond doubt that all faunal communication between China and the Arctic was severed. The European type of fauna must have wandered into the Chinese waters by way of the south. The Chinese Upper Devonian fauna therefore enjoyed the privilege of specialization under semi-isolated conditions.

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Lee goes on to say that the sea contracted somewhat and became shallower in southwestern China toward the close of the Devonian but that the boreal region was flooded in the latter part of Famennian times.

Grabau (1925, p. 167 et seq.) had previously said:

> Existing side by side with the goniatite fauna of the Boreal province, was the normal Upper Devonian faunas, which had arisen by modification from the preceding Middle Devonian fauna in partly circumscribed basins upon the European continent, as the Ithaca fauna had arisen in America. This is the typical Frasnian fauna, in which Spirifer verneuili Murch forms a leading element. The name is applied to a group of transverse Spirifer, the fold and sinus of which show a definite mode of costation and which in China is represented by numerous mutations referred to collectively as Sp. chinensis. Appearing in the late Middle Devonian (Givetian) in association with Stringocephalus in Belgium, developing numerous mutations this specific group quickly spread over Europe and Asia.

Grabau traces this Frasnian fauna across southern Asia (Bosphorus, southern Asia Minor, northern Syria, Persia, Hindu Kush Mountains in eastern Afganistan) and into southwestern China. He also reports the Cyrtospirifer verneuili fauna in southern Siberia and into Japan* and then in the "Dakotan" seas of North America. He says (p. 173),

> The Chemung fauna of North America is primarily a derivative of the Ithaca fauna of the preceeding epoch, as shown by J. M. Clarke, but with additions from the Frasnian elements of Europe which occupied the western or Dakota sea of North America. The

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*Grabau (1925, p. 442) says that Yabe (1911) has refuted the finding of C. verneuili in Japan.

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> most significant of these new elements is Spirifer disjunctus which, with its own series of mutations, represents a further modification of S. verneuili of Europe.

Grabau goes on to say (p. 173) that the spread of terrigenous clastics in eastern North America had shut off any connection with the Atlantic passageway in the Upper Devonian "so that the interior sea became eventually a nearly isolated body with connections only with the western or Dakotan sea, in which the Eur-Asian fauna continued to flourish to the last."

These concepts of Grabau's seem entirely tenable and extremely modern. Thus the Cyrtospirifer stock is indigenous to the Penn-York Embayment evolving to generic distinction by Cayuta time and spreading northwestward to China and Europe (an unlikely hypothesis in line with the preceeding discussion) or it entered North America by a boreal route and evolved in the Penn-York Embayment in a semi-isolated condition with connections only with a boreal sea. This latter is certainly true of earliest Mississippian time and only emphasizes Asiatic influences in early Mississippian faunas of the Northwest. Maxwell's (1954, p. 7) map of late Devonian and early Mississippian migration routes agrees well with these ideas.

The separation of Cyrtospirifer and Cyrtiopsis faunas which was pointed out by Crickmay (1952) in northwestern North America is quite possible in that area; but Cyrtospirifer certainly is present, and Cyrtiopsis

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not, in the highest Devonian beds in the Penn-York Embayment. Yet Grabau has reported these genera in association in other parts of the world and Cyrtiopsis may be present in lower Conewangoan strata. One should not think of these as existing necessarily each to the exclusion of the other. However, Greiner (1957) does not record Cyrtiopsis in Penn-York Embayment strata although his Cyrtospirifer preshoensis resembles species of this genus.

Cyrtospirifer oleanensis Greiner, 1957

Plate 6, figures 1-12.

Cyrtospirifer oleanensis Greiner, Hugo, 1957, Yale Univ., Peabody Mus. Nat. Hist., Bull. 11, p. 36, pl. 12, figs. 7-14 [non figs. 1-3 (Cyrtospirifer tionesta); figs. 4-6 (Cyrtospirifer extentus)].

EXTERIOR: Robust, transverse Cyrtospirifer of medium or slightly above medium size; winged, with a tendency to develop mucrones; hence greatest width always at hinge line; about twice as wide as long. Convexity of the valves about equal with the greatest convexity of each valve occurring well posterior to midlength. The valves are generally transversely convex throughout, strongly so near the midline and becoming less convex toward the extremities; however when mucrones are developed there is a tendency for the lateral slopes to become concave

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near the points. This transverse convexity gives the shells a relatively rotund appearance in anterior aspect. The anterolateral margins are never linear but instead, curve smoothly backward to the lateral extremities commonly giving the brachial valve a semi-elliptical outline. Anterior commissure parasulcate. Fold prominent, rather well developed, widening evenly from beak to commissure and commonly becoming more pronounced anteriorly. The fold rises abruptly above the general shell surface and is usually sharply delimited by a wide, deep plication trough. The sulcus is of moderate depth and commonly quite broad; other characteristics of sulcus as in Cyrtospirifer extentus, n. sp. The pedicle interarea is relatively low, orthocline to slightly apsacline, and finely capillate. The interarea may be only slightly curved, but more commonly is strongly curved, especially near the beak, so that in some cases the beak is nearly erect. Deltidial plates unknown, but distinct ridges run along the inner edges of the delthyrium. Brachial interarea obscured by the incurved beak. Plicae rather coarse, broad and rounded with plication trough and crest about equal, intercalary or, more rarely, bifurcating on fold and in sulcus. The plicae on the lateral slopes are simple, without intercalations; about 20 plicae occur on each flank. Micro-ornament not preserved, if any, but growth lines existed.

PEDICLE INTERIOR: Dental plates strong, heavy

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posteriorly but thinning anteriorly, re-entrant but with lower portion normally weakly developed, adventitious deposits variously developed. Dental plates divergent, lying between the third and fourth plication crest outside the sulcus. The muscle area may appear rather deeply impressed when much adventitious material is present but commonly is rather shallow. The dental lamellae do not extend far anteriorly around the muscle scar in most specimens, but the lower part of the lamellae may partly enclose the muscle area. The teeth are well developed and strong. The transverse delthyrial plate is usually strong and well developed in many specimens it extends well forward in the delthyrium. The adductor process is not well developed but may be a rather broad, low, indistinct ridge.

BRACHIAL INTERIOR: Brachial interior as in C. extentus except that the cardinalia are commonly somewhat heavier than in C. extentus and in many individuals of C. oleanensis n.sp. the socket plates hang downward into into the valve instead of extending straight out from the posterior of the valve.

DISCUSSION: Cyrtospirifer oleanensis Greiner is distinguished from C. extentus, n. sp. with which it occurs most commonly by the more inflated valves and the more robust appearance of the former. The lateral slopes of C. oleanensis are characteristically transversely convex, and if a concavity of the flanks is developed it is not

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noticeable until very near the lateral extremities. The anterolateral margins are characteristically rounded from midline to lateral extremities developing a semi-elliptical rather than a traphezoidal outline or a rectangular outline as in C. horridus, n. sp. The interarea is usually not so high as in C. extentus, n. sp., is more curved, and is not as strongly aspacline; rather in C. oleanensis Greiner the interarea is usually nearly orthocline and quite curved. The fold is more pronounced and the plicae coarser in C. oleanensis than in C. extentus.

Internally the componenet parts have essentially the same constitution in C. oleanensis and C. extentus, n. sp. Yet the two can usually be told apart on internal characteristics in the following manner. The specimens of C. oleanensis from locality 1 are those in which the lower portions of the dental lamellae are but weakly developed, the upper parts rounded and flaring, and the socket plates hang downward into the valves rather than jutting forward. Thus when the posterior part of the conjoined valves are viewed with the pedicle valve down, the dental lamellae and socket plates round into one another and appear not unlike a pair of ears. Commonly the subdelthyrial plate extends so far forward that it seems to form a loop connecting the ear-like posterior structures. The ear-like appearance of the posterior internal structures serves to separated interiors of C. oleanensis from C. extentus at locality 1. In those

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specimens from locality 183 the auriculate nature of the conjoined internal structures is not so pronounced, but the cardinalia and dental plates of C. oleanensis are heavier than those of C. extentus from this locality; in addition more adventitious deposit is developed in the former so that specimens of C. oleanensis from this locality have the muscle scar of the pedicle valve more deeply impressed than normal for this species.

C. oleanensis is not as gibbous as C. horridus variant A, n. variant and is more transverse than typical C. horridus, n. sp. or C. horridus strigosus, n. subsp.

A number of small specimens from locality 1 have a higher interarea than is common but it would seem unwise at the present to separate this ill-defined tendency into another variant or mutant.

HYPOTYPES: UCM Nos 29439, 29478 (partial exteriors) and 29451 (sandstone mold of interior).

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at localities 1 and 183. Greiner (1957, p. 37) reported this species in the Knapp formation, but it was not found in the Knapp by the present writer.

REMARKS: The species is represented at locality 1 by 26 exfoliated exteriors of which five appear to have an unusually high pedicle interarea, and by 41 molds of the interior of which seven appear to be of the high area type. At locality 183 the species is represented by 49

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individuals of which 15 are partial exteriors and the rest molds. One of the exteriors has a high interarea. Thus the typical form of the species is represented in the collection by a total of 116 specimens.

A table of measurements of some of the better preserved exteriors is given below with estimations represented by numbers without decimals.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)
Locality 1			
29439	29.2	50	23.0
29440	30.3	45	19.8
29441	24	33	15.5
29443	20.6	40	15.0
Locality 183			
29478	30.8	55	20.2
29479	29.3	46	18.3
29480	26.9	43	16.9
29482	27.2	41	14.9

Cyrtospirifer oleanensis, variant A, new variant

Plate 5, figures 27-34.

EXTERIOR: Mucronate form of Cyrtospirifer oleanensis; width more than twice the length when the mucrones are well developed. The exterior is like that of the typical forms of the species in that this variant possesses the well defined fold delineated by deep troughs on both sides, the coarse ribs, and usually the tendency toward inflated valves. The valves are concave near the extremities and the lateral extremities have a strong tendency to be

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produced into points or mucrones. The anterolateral margins round smoothly back to the point from which the mucrones arise. Fold and anterior commissure as in the typical form. The sulcus tends to be broader and less well defined than in typical C. oleanensis. The interarea is orthocline and strongly curved so that the beak is erect to slightly incurved. Other external features as in specimens typical of the species.

PEDICLE INTERIOR: Dental plates strong, re-entrant, well developed throughout with the lower part extending well around the deeply impressed muscle scar. Adventitious deposits variously developed, usually built up around the lower part of the dental plates and the muscle area. The entire muscle area is longitudinally striate, and in a few specimens the accessory diductor scars are weakly marked by irregular radial striae superimposed on the longitudinal striations. Adductor process well formed.

BRACHIAL INTERIOR: The cardinalia is but poorly represented in the collections but the brachial interior is presumably like that of the typical form of the species which do not have the socket plates pendant in the brachial valve, but rather, are not unlike the brachial interior of C. extentus except perhaps heavier.

DISCUSSION: Cyrtospirifer oleanensis variant A appears to be in a position of close relationship to both

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C. oleanensis Greiner and C. horridus strigosus, n. sp. This variant resembles C. oleanensis in general shape except that the mucrones are rather better developed (or possibly only better preserved, and this is one reason for withholding more complete taxonomic separation) and the sulcus is commonly broader and less well defined. Also in some individuals the shell proper, i. e., exclusive of mucrones, is longer and this causes the form to resemble C. horridus strigosus, n. subsp. Thus one might think of C. oleanensis variant A as occupying a position intermediate between C. horridus strigosus, n. subsp., and the typical form of C. oleanensis Greiner. Some of the specimens actually might be characterized as a C. horridus strigosus with mucronate lateral extremities.

C. oleanensis variant A somewhat resembles some individuals of C. extentus, n. sp., but the latter have a strongly apsacline interarea that is not so curved and possess more concave flanks.

TYPES: Holotype: UCM No. 29501. Paratypes: UCM Nos. 29503, 29504, (sandstone molds of the interior of the pedicle valve, unfigured) and 29505 (partial sandstone molds of the interior and exterior of the brachial valve, figured). Figured hypotype: UCM No. 29502.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 183.

REMARKS: This variant is represented by 17

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individuals of which only two are exteriors and these are broken and exfoliated. No table of dimensions is given because, although the development of mucroness coupled with the characteristic shape are the distinctive features, parts of one or both mucrones are very commonly broken, and also because all of the molds but two are of the interior of the pedicle valve only.

Cyrtospirifer warrenensis Greiner, 1957

Plate 11, figures 10-14.

[non] Spirifer disjunctus var. warrenensis [nomen nudum]
Caster, K. E., 1935, in Willard, Bradford, and Caster K. E., American Assoc. Petrol. Geol. Bull., v. 19, p. 1549; [?] Laird, W. M., 1941, Pennsylvania Topog. Geol. Survey, Prog. Rept. 126, p. 11, 19.

Cyrtospirifer warrenensis Greiner, Hugo, 1957, Yale Univ., Peabody Mus. Nat. Hist., Bull. 11, p. 35, pl. 11, Figs. 2-10.

EXTERIOR: Shell large, heavy and robust, wider than long, strongly biconvex with greatest convexity posterior to midlength. Lateral flanks convex but commonly depressed of concave near the cardinal extremities; umbones commonly strongly curved. Fold rather high, wide and well defined; sulcus broad, rounded, poorly defined, and commonly with a considerable lingual anterior extension. Pedicle inter-

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area rather high, apsacline, suberect to slightly incurved Plicae broad, rounded, wider than interspaces, commonly not strongly affecting interior of shell. Coarse growth lines commonly mark the anterior edges of the shell, giving it a rugose appearance.

PEDICLE INTERIOR: Dental plates thin to moderately heavy, receding to complete, greatly divergent, extending anteriorly about one-third the length of the valve enclosing a large diamond-shaped muscle scar which is faintly radially marked posteriorly and longitudinally striate anteriorly. Adductor process short, strong, medially striate so that the process appears bilobed. Delthyrium restricted by sub-delthyrial plate for one-third to one-half its length. Very commonly the dental lamellae are greatly thickened posteriorly and the lateral and rostral cavities are nearly filled by secondary deposits; these weld the subdelthyrial "plate" and the dental plates into a solid mass and partially or wholly obscure the adductor process. Teeth short, distinctly separated from the internal edge of the dental plates, commonly buttressed by a slim ridge along the delthyrial side of the dental lamellae.

BRACHIAL INTERIOR: Cardinalia weak, unsupported; outer socket ridges absent, inner socket ridges rather stout bounding short wide sockets. Crural attachment not evident; cardinal process unknown--apparently poorly developed or absent. Muscle marks weak to absent. Jugum and spiralia unknown.

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DISCUSSION: Distinctive characters of this species are the large size, robust nature, rugose external features, widely divergent dental lamellae and large diamond-shaped pedicle diductor muscle scar. The divergent dental lamellae, large muscle scar and filled lateral and rostral cavities make molds of the pedicle interior particularly easy to identify. These characters and the larger size readily separate C. warrenensis Greiner from C. lobatimusculus Greiner, with which it is associated.

One mold of the interior of theppedicle valve from the Knapp at locality 51 shows a crack or slit down each side of the sandstone filling of the delthyrium. A rubber cast of this specimen clearly shows that this represents the position of thd deltidium which was preserved in this specimen before the calcite of the shell was dissolved. The cast shows that the deltidium was a thin plate (or plates) which fitted in the delthyrial groove from apex to hinge line. The thin rubber of the cast of the deltidium tore during removal from the mold, so no information can be gained of the middle of the structure. Only the thin remnants of the plate can be seen along the delthyrial groove and at the apex of the delthyrium, but this is enough to permit definite interpretation of a convex deltidium in this and related species.

Greiner (1957, p. 35) describes this form as subquadrate; but the outline is quite variable, and indeed the holotype (as figured by him, pl. 11, fig. 5) is not

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subquadrate.

HYPOTYPES: UCM Nos. 29884, 29887 and 29890.

OCCURRENCE: Kushequa shale at locality 166. Kushequa member of the Knapp sandstone at locality 51 and doubtfully in a sandstone of the Knapp formation at locality 118. Greiner (1957 explanation of pl. 11) records the holotype from the Amity shale. He says (p. 35) that the greatest abundance of this form is in the Salamanca conglomerate of the lower Conewangoan. However, the writer has not found this species in the Oswayo formation, but it is relatively common in the shalier zones of the Knapp sandstones.

REMARKS: The valves of C. warrenensis are almost always dissociated and incomplete. Only about ten specimens from localities 51 and 155 can be identified with a degree of certainty. These are so broken as to thwart significant measurements.

Cyrtospirifer lobatimusculus Greiner, 1957

Plate 11, figures 4-9.

Spirifer disjuncta Sowerby, Hall, James, 1867, Nat. Hist. New York, Paleont., v. 4, pl. 42, fig. 3; 1883, New York Assembly Doc. no. 178, pl. 55, fig. 17.

Cyrtospirifer lobatimusculus Greiner, Hugo, 1957, Yale Univ., Peabody Mus. Nat. Hist., Bull. 11, p. 38-39, pl. 13,

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figs. 10-20.

EXTERIOR: Shell small to medium sized, slightly wider than long, strongly biconvex with greatest convexity of valves generally posterior to midlength. The lateral flanks curve continuously to the margins or are alightly depressed near the cardinal extremities giving the shell a rotund appearance. The anterior appears truncated so that in outline the shell presents a markedly traphezoidal aspect. Fold moderately high, rounded, well-defined; sulcus rather wide anteriorly, broadly U-shaped with rounded boundaries, triplicate with primary plicae undivided, and with a short round anterior lingula extension. Pedicle interarea rather high, apsacline, erect to slightly incurved. Plicae broad, rounded to rather flattish, wider than interspaces, averaging about 24 on each flank; commonly the plicae have little effect on the interior of the shell. Micro-ornament unknown. Growth lines occassionally very distinct even on the interior.

PEDICLE INTERIOR: Dental plates thin, complete, initially divergent but in the majority of specimens becoming subparallel, commonly advancing as a very low ridge nearly around the muscle scar. Transverse subdelthyrial plate thin throughout, restricting one-third or, more commonly, two-thirds of the delthyrium. Teeth thin and light but well developed. Diductor muscle scar distinct, usually deeply impressed, posteriorly radially

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anterior two-thirds. Adductor process distinct in ephebic shell, wide posteriorly but becoming low and thin anteriorly where it extends forward one-half to two-thirds the length of the diductor scar. Ovarian markings a series of isolated pits but are rarely preserved.

BRACHIAL INTERIOR: Cardinalia weak, unsupported; ou outer socket ridges absent, inner socket ridges long, thin, and high bounding moderate-sized sockets. Attachment of crura not evident; cardinal process unknown. Muscle marks of the brachial valve weak to absent. Jugum and spiralia unknown.

DISCUSSION: The small size, steeply traphezoidal outline, strongly convex lateral and anterior profile and broad rounded sulcus and bounding "shoulders" are distinctive external characteristics. Internally the thin, complete dental lamellae which bound the lobate muscle area are unique features which make this form rather easily identified. Cyrtospirifer lobatimusculus Greiner bears little resemblance to other species of Conewangoan and Knapp Cyrtospirifer.

HYPOTYPES: UCM Nos. 29870, 29871, 29872, and 29881.

OCCURRENCE: Kushequa shale at locality 166 and sandstone (lower or first Syringothyris zone) at the base of the Knapp formation at localities 118 and 121. Greiner (1957, p. 38) also reports C. lobatimusculus in the Corry

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sandstone and the Orangeville shale.

REMARKS: This species is represented in the collections by one crushed mold of the interior from locality 166, 12 molds of the interior of pedicle valves from locality 118, and several molds of the pedicle interior from locality 121 on slabs. Many of the specimens apparently were broken anteriorly and few are well preserved. This suggests that where not reinforced by secondary deposits the shell of this form is thin and rather fragile. Dimensions of two of the molds of the pedicle valves from locality 118 are given below.

UCM No.	Length (mm)	Width (mm)
29870	26.4	33.2
29871	24.7	32.5

Cyrtospirifer lobatimusculus parvus, n. subsp.

Plate 12, figures 1-4.

Cyrtospirifer lobatimusculus Greiner, Hugo, 1937, Yale Univ., Peabody Mus. Nat. Hist., Bull. 11, p. 38-39 [partim].

EXTERIOR: Small, wide to alate, moderately biconvex with greatest convexity of valves posterior to midlength. Lateral flanks convex near midlength but shortly becoming concave some distance from the acute cardinal extremities. In other aspects like the typical form of the species.

PEDICLE INTERIOR: Dental plates very thin, delicate,

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complete, slightly divergent or subparallel, extending less than one-third the length of the valve, not enclosing the muscle scar. Subdelthyrial plate, thin, restricting only the posterior part of the delthyrium. Diductor muscle scar rarely distinct, not deeply impressed, apparently longitudinally striate throughout. Adductor process very slight or lacking.

BRACHIAL INTERIOR: Like the typical form; one large specimen shows a diamond shaped cardinal process set with a great many very thin vertical lamellae.

DISCUSSION: This subspecies differs from the typical form externally in its small size, and more alate form. Internally the dental plates are shorter and more delicate and the muscle scar is not distinct nor impressed into the shell. In this form there is little deposition of secondary calcite in the rostral or umbonal cavities.

It was originally thought that this small form was the young of the typical form of C. lobatimusculus. Yet this subspecies lacks the steeply traphezoidal outline of the typical form, and the winged outline belies this idea. Interanlly also the differences seem to be too regular and consistent to conside this merely a growth stage of the more common typical form.

TYPES: Holotype: UCM No. 29900. Paratypes: UCM Nos. 29902, 29905.

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OCCURRENCE: Sandstone in the Kanpp at locality 51, Kushequa member of the Knapp formation at locality 166 and lower Syringothyris zone of the Knapp formation at locality 118. Locality 51 is the type locality.

REMARKS: This subspecies apparently has a thin delicate shell, for the hypodigm consists of nine crushed or otherwise broken molds of the interior. Two of these are from locality 51, and three from locality 166 and four are from locality 118. Measurements of the holotype are given below.

UCM No.	Length (mm)	Width (mm)
29900	13.6	24.9

Cyrtospirifer tionesta Greiner, 1957

Plate 14, figures 11-12.

Spirifer disjunctus (Sowerby), Caster, K. E., 1930, Bull. American Paleont., no. 58, pl. 3, fig. 5, pl. 2, fig. 3.

Spirifer disjunctus var. warrenensis [nomen nudum], Caster, 1935, in Willard, Bradford, and Caster, American Assoc. Petrol. Geol., Bull., v. 19, p. 1549; ? Laird, W. M., 1941, Pennsylvania Topog. Geol. Survey, Prog. Rept. 126, p. 11, 19.

Cyrtospirifer warrenensis Greiner, Hugo, 1957, Yale Univ., Peabody Mus. Nat. Hist., Bull. 11, pl. 11, fig. 1.

[?] Cyrtospirifer oleanensis Greiner, 1957, Yale Univ.,

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Peabody Mus. Nat. Hist., Bull. 11, pl. 12, figs. 1-3.

Cyrtospirifer tionesta Greiner, 1957, Yale Univ., Peabody Mus. Nat. Hist., Bull. 11, pl. 8, figs. 1, 3-11,12, (non fig. 2).

Greiner (1957, p. 31) gives the following description of this species:

> Pedicle valve with greatest arching at the beak, moderating toward the front of the shell. Lateral slopes convex, becoming slightly depressed for about the last one-quarter of the distance to the extremities. Sulcus shallow, broad, not well-defined but inflecting outwards onto the lateral slopes. Cardinal area fairly high (about 1:4, to width), gently curved, and vertically striate (about 40 striae per cm.). The area extends to the extremities, narrowing gradually. Delthyrium generally higher than wide and closed for the upper one-half or more by secondary growth from the floor of the shell, and the bases of the dental lamellae. The latter commonly extend well into the body of the shell, but are rather variable. Always initially straight and divergent, in some specimens they may become subparallel, and continue forward as a low slender ridge which converges and unites at the front of the muscle scar. The latter is ovate or spatulate, generally expanded somewhat at the front, and has striae which apparently radiate from near the posterior of the scar, those toward the rear deflecting laterally near the edges of the muscle area. The adductor muscle scar is fairly well-defined as a slender groove down the center of the larger cicatrix. An "apical callosity" is always more or less prominent. Fibrous, secondary shell growth is mainly confined to the hinge area lateral to the central lamellae. Teeth are rather small.
>
> Brachial valve convex, and gently arched from front to rear. The fold is very well-defined from the beak, and is rather high, narrow, and bounded at the sides by pronounced grooves. The lateral slopes are gently convex, flattening near the extremities. The dorsal muscle scar is not pronounced. Dental sockets small, but with rather stout crural plates.
>
> Exterior of both valves with very broad, flat-topped or slightly rounded costae, separated by very narrow, round-bottomed grooves. Costae are simple on the lateral slopes, but bifurcate after a general pattern in

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the sinus. In this, the median costa of the sinus bifurcates initially and very shortly after its emplacement between the two primary costae. Then its branches divide, and these again divide, and so on repeatedly. Bifurcation is rather uncommon in the two primary costae and in the costae of the lateral divisions. In the latter segments of the sinus, new costae arise from the borders of the sulcus. Costae on the lateral slopes number about 25 or so each side. Fine, distinctive, undulating lines of growth are present as micro-ornament. . . .

Discussion: This is undoubtedly the "variety" of "Spirifer disjunctus" mentioned by Caster (Willard and Caster, 1935, p. 1549) as characteristic of higher strata in northwestern Pennsylvania. It is very distinctive in form characterized by the shape, broad costae with narrow troughs, fine growth lines as micro-ornament, and broad sulcus with flattish bottom caused by the early bifurcation of the medial plication. Cyrtospirifer warrenensis Greiner is longer in proportion to its width, has the sulcus even more gently rounded, and has widely divergent heavy dental lamellae around the broad diductor scar indented by a strong adductor process. The interior of C. tionesta is not well known, inexplicably the forms in the collection at hand from the Tidioute rarely show the dental lamellae although they appear to be molds of the interior.

HYPOTYPES: UCM Nos. 29944 and 29948.

OCCURRENCE: Very fine-grained micaceous sandstone in the Tidioute formation at localities 91, 119, and 202.

REMARKS: The holotype is from the Tidioute shale

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All of the forms at hand are also from the Tidioute northwest of Warren, Pennsylvania. A similar form, though smaller and thinner, occurs abundantly in the Salamanca conglomerate low in the Conewangoan. Greiner interprets C. tionesta rather broadly and places these latter forms in this species without qualification. Thus he makes C. tionesta the stock from which several of the higher Devonian and lower Mississippian forms diverged and reports it commonly from below Conewangoan strata high into the Mississippian. This latter observation is undoubtedly correct, but it is believed that he must mistakenly include the Salamanca form, forms referable to C. spicatus Greiner, C. extentus, n. sp. and C. warrenensis Greiner to record C. tionesta so widespread and through such a range.

C. tionesta Greiner seems to be strongly controlled by facies; it is unknown to the writer from personal experience or reports from any lithology other than very fine-grained, shaly, micaceous sandstone. Thus since Greiner admits that C. tionesta is not found in the Oswayo formation in the Bradford, Pennsylvania area, it is possible that this species sensu stricto does occur in the Chagrin magnafacies lower in the Conewango far to the west of the typical development of the Oswayo formation to reoccur in the fine sandstones and shales of the Mississippian Tidioute farther east.

It does not seem likely that the form (typical of

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the Tidioute) shown by Greiner (1957, pl. 8, fig. 3) occurs in the Salamanca in Dennis Run as reported; instead it is probably from Mississippian Strata. Thus it is believed that the picture of cyrtospiriferid phylogeny in the Conewangoan is more complicated than depicted by Greiner and that the typical (at least, maximal) development of C. tionesta is higher--in the Mississippian, rather than in the Conewangoan as envisioned by Greiner.

Cyrtospirifer extentus, n. sp.

Plate 7, figures 1-15.

Plate 8, figures 1-8.

Plate 11, figure 3.

Spirifer disjuncta Sowerby, Hall, James, 1867, Nat. Hist. New York, Paleont., v. 4, pl. 41, figs. 6,9; 1883, New York Assembly, Doc. no. 178, pl. 55, fig. 15.

Spirifer disjunctus Sowerby, Hall and Clarke, J. M., 1894, Nat. Hist. New York, Paleont., v. 8, pt. 2, pl. 30, fig. 15.

Cyrtospirifer oleanensis Greiner, Hugo, 1957, Yale Univ., Peabody Mus. Nat. Hist., Bull. 11, pl. 12, figs. 4-6.

EXTERIOR: Transverse Cyrtospirifer of about medium size; winged, with greatest width invariably at the hinge line; about twice as wide as long. Convexity of the valves

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about equal; the greatest convexity of the brachial valve occurring about midlength or slightly posterior to midlength, but pedicle valve with greatest convexity generally markedly posterior to midlength. The lateral slopes of the shell may be gently concave near the wings, or they may be convex near the fold and sulcus and then become strongly concave away from the mid-line so that near the extremities the valves appear subparallel in anterior aspect. The anterolateral margin may be nearly linear from the edge of the fold and sulcus to the extremities or may be sinuous so that in outline the shell appears convex near the fold and sulcus becoming concave toward the extremities. In the first case the brachial valve is nearly traphezoidal in outline. Anterior commissure parasulcate. Fold definite, low to moderate in height, rounded, extending from beak to commissure, widening evenly without flaring throughout its length. Fold generally distinct, rising abruptly above the curved outer surface of the shell with trough of bounding plicae scarcely differentiated. In forms with a low fold, the fold generally becomes less pronounced anteriorly. Sulcus extending from apex, triplicate for entire length with primary plicae undivided. The sulcus is of moderate width and depth and is broadly and evenly U-shaped throughout. Anterior extension of sulcus rounded and never greatly protruding beyond the frontal margin. Crest of bounding plicae of sulcus usually is at point of greatest transverse convexity and is generally the most prominent on the valve

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with the flank of crest toward the sulcus longer than other flank. Number of plicae in sulcus average about eight; the number is less in younger forms and increases in number in larger specimens. The pedicle interarea is moderately high, broadly triangular, nearly straight to slightly curved in lateral profile, 25° to 45° apsacline, and is sharply delimited posteriorly by well defined beak ridges. The interarea is strongly marked horizontally by increments of growth, and is vertically marked by irregularly spaced capilli with concave flanks. The interspaces are two to three times as wide as a capillus; the number of capilli within one millimeter varies from three to seven, the average being about four. Deltidial plates not known, but distinct ridges lie inside the edges of the delthyrium. Brachial interarea low, not capillate, anacline near the lateral extremities, but usually obscured medially by the stronger incurved beak of the brachial valve. Plicae numerous, rounded, with plication trough and crest about equal, bifurcating or intercalary on the fold and in the sulcus, simple without intercalations on the lateral slopes; 25 to 30 or more plicae occur on each side of the fold and sulcus, the greater number being on the more alate forms. Microornament poorly preserved but believed to be fine radial lines covering entire plica; not pustulose or papillose.

PEDICLE INTERIOR: Dental plates strong, heavy posteriorly but thinning rapidly anteriorly, re-entrant,

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free or somewhat obscured by adventitious deposits. The dental lamellae diverge sharply, lying between the third and fourth plication crest outside the sulcus. The lower portion of the lamellae extend about one half of the distance around the deeply impressed muscular area but this posterior portion is frequently imbedded in callous so that molds of the interior show the lamellae extending only a few millimeters anterior of the cardinal shelf. The dental plates support well developed teeth. A transverse subdelthyrial plate lies between the dental lamellae well below the level of the delthyrial ridges and extends anteriorly one-third to one half of the distance of the delthyrium. This plate is generally thin but in some specimens this thinness is only in the medial portion and the transverse plate becomes greatly thickened laterally where it buttresses against the dental plates. The delthyrial plate joins the dental lamellae at the point where the latter are most strongly re-entrant or just above this point. Muscle mark deeply impressed; adductor scar longitudinally striate, diductors traversed by irregular radiating vein-like furrows. A short thick adductor process, which narrows sharply toward the floor of the valve, extends a very short distance into the posterior median part of the muscle mark in many individuals but is not universally present. Deeply impressed ovarian pits commonly occur on the lateral umbonal cavities under the cardinal shelf and also on the floor of the valve; in shells with a heavy deposit of adventitious material;

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these are frequently not preserved.

BRACHIAL INTERIOR: Cardinalia strong and heavy, jutting forward from the posterior portion of the valve without support from below. The socket plates extend straight out from the posterior wall of the valve; upper surface is a smooth steep slope. Inner socket ridges strong and high; outer socket ridges low and obscure or absent; then in effect, the trough-like sockets lie in close juxtaposition to the umbonal wall. In the median section of the valve a pair of rounded protruberances rise above the level of the rest of the cardinalia to support the lozenge-shaped, vertically striate, sessile cardinal process. A faint vertical ridge, in some cases quite broad is occasionally developed below the cardinalia. When developed this ridge presumably added strength to the area just beneath the cardinal process. In many individuals, however, this posteromedian thickening is not developed. Brachial musculature weak irregular markings. The divergent crura arise from poorly defined crural bases near the inner socket ridges. Jugum and details of spiralia not known.

DISCUSSION: Cyrtospirifer extentus, n. sp., is characterized by its winged form, the concavity of the lateral slopes, and the moderately high, nearly straight, apsacline interarea. There is considerable variation in degree of concavity of the lateral slopes and in the shape of the outline of the shell.

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C. extentus resembles in general shape some of the specimens Nalivkin (1941) included under C. scholonicus (cf. especially his pl. 6, figs. 4a, 4b, 4c). However the latter are relatively thicker, have a higher area, and this species is marked by flatter plicae than C. extentus. Nalivkin (p. 212-213) admits that his species is extremely variable and includes under it three distinct types, none of which resemble C. extentus in detail.

Among European forms C. extentus, n. sp., most closely resembles in shape the C. verneuili, group elongati, figured by Gosselet (1894, pl. 4, figs. 21 a, b, c) from Stolberg, Germany (Frasnian). Yet the paratype, UCM No. 29408, of C. extentus which most closely resembles the specimen figured by Gosselet possesses a higher, straighter, and more apsacline interarea than Gosselet's specimen. Some of the more transverse C. extentus slightly resemble Gosselet's C. verneuili, group attenuata, pl. 3, figs. 15 a, b, c, from Lompert (Frasnian). Other than these surficial resemblences in shape, there seems to be no basis for close comparison between Oswayo forms and any of those illustrated by Gosselet. Many of the Gosselet specimens are very large (80-110 mm wide) and none of the Oswayo forms show the micro-ornament illustrated by Gosselet on pl. 2. Paeckelman (1942) mentions a tendency toward reduction in size in Cyrtospirifer in the highest Upper Devonian and this seems to be partially borne out in the Conewangoan of the Penn-York Embayment.

Inexplicably the specimens from the Oswayo at

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Ludlow, Pennsylvania (locality 183), exhibit much less variation than those from "Flat Iron Station" (locality 1). The specimens from Ludlow are characteristically smaller, thinner, with subparallel extremities and nearly straight interarea. In all, these present a delicate, graceful appearance and do not seem so robust as those from locality 1. It was first thought to separate these into a different subspecies, but they seem to bear no marked characteristics which would differentiate them from the more robust specimens. Only one or two of these slighter specimens occur at locality 1 and none of the specimens from Ludlow (locality 183) differ markedly in size or shape from its fellows. Thus these latter seem to form a more closely knit population; yet if one did not know the geographic locality, it would be most difficult to find critera by which the Ludlow specimens could be differentiated from other specimens of C. extentus.

Six partial pedicle valves and five brachial valves from the Knapp formation at locality 97 and one mold of a pedicle interior from the Knapp at locality 51 have the contours of C. extentus and are doubtfully referred to this species. Most of the pedicle valves from the Knapp formation seem to be smaller than the forms from the Oswayo formation and the fold of the Knapp forms seems higher and more distinct. However, none of the specimens are preserved well enough to make identification certain. They seem definitely not to be referrable to other described

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species but are more closely related to C. extentus, if not conspecific with it.

TYPES: Holotype: UCM No. 29301. Paratypes: UCM Nos. 29305, 20309, 23408, (all exfoliated exteriors); 29319, 29321 (sandstone molds of interiors). Figured hypotypes: UCM Nos.29306 (partly exfoliated exterior), 29350 (sandstone mold of the interior), 29864 (partly exfoliated pedicle exterior from the Knapp formation doubtfully referred to this species).

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at localities 1, 60, and 183; Marvin Creek limestone zone of the Knapp formation at locality 97 (?) and a fine grained sandstone in the Knapp formation at locality 51 (?). Locality 1 is the type locality.

REMARKS: This species is represented by 114 individuals from the Oswayo of which 63 are partial exteriors. Of these 35 are from locality 183 of which 13 are molds of the interior. Given below is a table of measurements of exfoliated exteriors of adult individuals; the numbers without decimals are measurements of broken specimens in which estimations have been made.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)
Locality 1			
29301	31.0	55	18.6
29304	30	58	20.8
29305	25	60	18.0
29306	26.5	57.8	--
29307	31.1	52	19.2
29308	28.4	49	16.1

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29309	26.3	45	17.5
Locality 183			
29408	25.7	47	14.6
29409	25.3	46	14.9
29412	30.6	53	16.7
29416	29	51	17.7
29418	26	47	17
29420	27	44	16
29422	31	56	18.0

Cyrtospirifer horridus, n. sp.

Plate 8, figures 9-10.

Plate 9, figures 1-9.

EXTERIOR: Heavy, thick, obese, Cyrtospirifer of medium or above medium size; greatest width at hinge line; average just below 1½ times as wide as long. Convexity of the valves about equal; the greatest convexity of each valve about midlength. Except for the fold and sulcus the shell is transversely continuously convex; in the narrower specimens the lateral slopes arise abruptly from the lateral margins, but in wider individuals the lateral slopes are somewhat less strongly convex. The anterolateral margins curve strongly back to the lateral extremities; in some individuals this curve is so sharp that the sides are nearly straight and the brachial valve appears almost rectangular in outline. Anterior commissure parasulcate. Fold low, usually definite but in some cases quite indistinct; fold extends from beak to commissure widening evenly throughout its length; troughs of plicae bounding fold wider and deeper than

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others on the brachial valve. Sulcus extending from pedicle beak, triplicate for entire length with primary plicae undivided. Sinal formula simple; most commonly seven plicae in sulcus. The sulcus is of moderate depth and broadly and evenly U-shaped throughout. Anterior extension of the sulcus slight. The interarea is high, orthocline (except for one specimen which is apsacline), curved, and is defined posteriorly by sharp beak ridges. The interarea is strongly marked horizontally and is somewhat marked vertically by widely spaced capilli, but the details of these markings are not preserved. Delthyrial characteristics are obscured but delthyrial ridges seemingly not present and deltidial plates unknown. Brachial interarea low, orthocline to slightly anacline near the extremities, but medially quite obscured by the strongly incurved brachial beak. Plications numerous, broadly rounded, with crest slightly broader than bounding troughs, intercalary in sulcus and on fold but simple on lateral slopes; about 25 occur on each lateral flank.

PEDICLE INTERIOR: Dental plates very strong and heavy posteriorly but thinning somewhat anteriorly, re-entrant, in most cases nearly obsolete, the lateral umbonal cavities being nearly filled with adventitious deposit. Commonly, however, within this secondary deposit the dental lamellae extend anteriorly half way around the deeply impressed muscular area. The dental lamellae are divergent, lying between the second and third plication crests outside the sulcus. Teeth heavy as is the sub-

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delthyrial plate. This plate extends anteriorly only about one-fourth the length of the rather broad delthyrium and lies near the floor of the valve well below the level of the delthyrium. Musculature broad and deeply impressed into the valve; details not preserved. A posterior adductor process is commonly absent but is broad and weak when it is in evidence. Genital and pallial markings not known. Irregular elongate or hemispherical excresences occur on the interior of the valve becoming more prominent anteriorly.

BRACHIAL INTERIOR: Cardinalia very like that in the typical form of Cyrtospirifer extentus, n. sp., except that all of the component parts are thicker and heavier. The crural bases especially are broad, relatively heavy and arise very near the inner socket ridges. The crura do not seem to be more than slightly divergent. Brachial musculature a series of irregular, rather deeply impressed pits, but details are obscure. Irregular excresences common throughout interior of valve.

DISCUSSION: The form described herein as typical of the species is characterized especially by its great thickness which imparts a ponderous appearance to the shell. In the typical form the interarea is orthocline in almost all of the specimens. The dental plates and cardinalia are heavier and thicker in Cyrtospirifer horridus than in C. extentus, n. sp.

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C. horridus somewhat resembles C. verneuili var. gosseleti Grabeau in outline but the later is larger, more gibbous, possesses a strongly apsacline interarea that is only slightly curved. Similarly, C. horridus bears outward resemblance to Sinospirifer subextensus (Martelli) and (as illustrated by Tien, 1938) Hunanospirifer wangi Tien. Except for this gross resemblance in shape and proportion, the differences are apparent and on the generic level. C. horridus bears virtually no resemblance to earlier Conewangoan forms or Mississippian species.

All of the variants of Cyrtospirifer horridus characteristically exhibit the hemispherical or vermiform protuberances on the inside of the shell. Conversely this is but rarely seen in associated species; one specimen of Cyrtospirifer oleanensis Greiner bears some abnormalities on the inside of its shell.

PALEOPATHOLOGY: In many individuals the entire interior of the shell is covered with the irregular rugosities giving molds of the interior a warty appearance. Higher vermiform ridges cross the irregular rugose background, and the largest excrescences are rounded, slightly elongate, or nearly hemispherical mounds. The largest of these measures 10 mm long 5 mm wide and 2.5 mm deep. The rugosities are built up of successive layers of calcite so that it is apparent that the animal was attempting to protect itself, but whether from foreign inorganic matter or from parasitic animals is most difficult

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to say. The large hemispherical callus lumps appear to have been built up of secondary deposit as if covering a foreign body which was irritating the mantle.

This, however does not explain the lesser rugosities nor their universality. These do not appear to have been caused by crumpling of the edge of the mantle as has been sited in the case of the Miocene pelecypod Venus tridacnoides (Moodie, 1923, p. 31-32, pls. 6 and 7). Moodie (p. 31) says,

> This species seems to be established on pathologic individuals or a pathologic race of another calm Venus Rileyi. The pathology is apparently brought about through the crumpling of the edge of the mantle, possibly because of the incursion of fresh water into the normal sea in which the Rileyi was living.

He goes on to say that this pathologic condition was localized inthe vicinity of York River, Virginia, while normal Venus rileyi occurs in abundance in the Miocene of Maryland. In Venus tridachnoides the pathology resulted in "enormous roughening of the exterior of the shell and the hypertrophy of the calcareous and chitinous material" (Moodie, 1923, p. 58). In Cyrtospirifer horridus the exterior of the shell appears normal although irregular hypertrophy of the interior of the shell has resulted. In all, the rugosities are too irregular to be explained by the method of crumpling the edge of the mantle, or the breaking of the shell and resulting injury to the mantle as Fenton and Fenton (1932b, p. 71, 74) described in several species of Devonian Atrypa.

The more elongate excresences are most often preserved

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as depressions in molds of the interior, but, when the shell is preserved, they commonly appear as tubes filled with fine-iron-rich sand. In many instances the tubes begin near the commissure (most commonly in the sulcus) and follow plicae posteriorly; frequently they seem to taper from the point near the commissure where they can first be recognized, to a smaller end farther posterior on the shell. Commonly, however, after a straight beginning, they cut across several plicae. Since they do not radiate from a central cavity, branch, nor develop palmate channels or surface perforations, these tubes do not seem referable to the sponges Clionolithes Clarke, Clionoides Fenton and Fenton, Topsentia Clarke nor definitely to the forms described by Hyde (1953). Rather in their simple subclavate nature they resemble Palaeosobella Clarke* which Clarke (1921, p. 91) referred to annelids ". . . disregarding differences in size, which are often obvious, and of curvature, which are slight." It should be noted however, that neither the clavate termination illustrated by Clarke nor the "hook-curve" at the ends of the tubes, indicated by Clarke (1921, p. 96) as "Characteristic" was observed in the Oswayo material. Many of the specimens from the Oswayo formation exhibit irregularities quite similar to those on Atrypa waterlooensis

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*Fenton and Fenton (1932b) have discussed the relationships and nomenclatorial problems involving these aforementioned genera.

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Webster illustrated by Fenton and Fenton (1932b, pl. 10, fig. 6).

The smaller "background" rugosities may well have been caused by micro-endoparasites which damaged the mantle late in the life of the individual. Again these do not appear to be distortions due to pressure against adjoining objects or injuries to the edge of the mantle or repaired fracutres of the anterior margin during growth, but rather due to healed internal lesions of the ephebic or genontic individual. The antiquity of parasitism is amply documented; in 1923 Moodie listed, in a table opposite pate 287, at least four phyla as possible causes of disease in Devonian organisms; any small organism within these phyla might easily have cuased the lesions.

Ony may justifiably ask, "Why are these excrescenses and rugosities characteristic of Cyrtospirifer horridus?" Before answering the question it would be apropos to remind the interrogator that C. horridus, n. sp is, in general, made up of large, heavy, robust individuals, narrow in relation to their length, with gibbous valves and a high, curved interarea. Grabau (1931, p. 212), after a very detailed, meticulous study of growth in similar Chinese spiriferids has said,

> Considering now the question of relative length and width, this is seen to be primarily a matter of rate of development or the greater or less acceleration of the individual. In the young form the hinge line is always longest and generally mucronate. With increasing age the addition is chiefly at the front, diminishing towards the cardinal angles, these becoming less acute and finely rectangular or obtuse,

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> while at the same time the shell becomes thicker and more obese. . . . Thus in general, the mutations with mucronate hinge extremities are the more primitive, and those with short hinge line the more specialized in this respect.

In studying the morphogenesis of Platystrophia, Cumings (1903) found that loss of acuminate cardinal angles was a gerontic character. Moreover he said (1903, p. 133),

> Characters added at various times during the history of the genus are lost in the inverse order of their adquisition. For example, in P. acutilirata the latest added character is the acuminate cardinal angles. This is the first featureeto disappear in retrogression.

Cumings further discussed the same trend in Mucrospirifer mucronatus (Conrad). In his discussion of development of several common Devonian brachiopods, Raymond (1904, p. 298) in speaking of several spiriferid genera has said, "In the ontogeny the outline changes from rounded forms in the nepionic and early neanic stages, through a mucronate form in the later neanic, and back to a rounded form in the adult or senile condition."

Fenton (1931, p. 50) found this same trend through the ontogeny of several Upper Devonian spiriferids.

This trend toward obesity and decrease in the width/length ratio during ontogeny is demonstrable in the specimens of C. horridus (even though a table of measurements can not be presented because of the vagaries of preservation). Grabau has further said of the Chinese spiriferids, "The height of the hinge-area also varies greatly in this series and so does its degree of arcuation. The most primitive

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in this respect are the forms with a low hinge area."

Thus it becomes apparent that in several traits this species seems to be well advanced and this fact may suggest a phylogeronitic species. It certainly seems that a considerable amount of differentiation has gone on, even within the Oswayo, if Cyrtospirifer horridus, n. sp., has arisen through C. horridus strigosus n. subsp. from C. oleanensis Greiner stock. Moreover it is almost certain that when the spiriferids of the older Conewangoan faunas are fully studied an amazing multiplicity of forms will be forthcoming which will result in the weaving of a complex phyletic tapestry. Yet C. horridus does not bear close resemblance to any of the earlier Conewangoan forms.

This brings up and seems to support the intriguing possibility of a physiological as well as morphological basis for racial senescence as elaborated quite fully in relation to spiriferid brachiopods by Fenton (1931, p. 94-116) as treated by Child (1915). Fenton says (p. 106-107),

> There seems to be ample support, therefore, for the statement that in many phyla the development (or degeneration) of the race seems to be homologous with the differentiation of the individual. Yet it must be admitted that there is nothing here which offers direct evidence that racial differentiation is senescence. For that we must find something more definite than correspondence in sequence.
>
> There is, fortunately, at least one way of estimating the relative physiologic states of "young" and "old" taxonomic groups. It is well known that increasing age is accompanied in the individual by a decrease in ability to withstand and repair injuries and other ills. Mechanical or physiologic disturbances which affect but lightly the neanic or nepionic individual may have very serious consequences for the

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> senile (gerontic) one. The injury itself may be equal in both cases, or even greater in the younger one, but the efficiency of recovery and repair in the senile organism is so diminished that the results of the injury are greater and more lasting in its case. Since the basic factor in this diminution of ability for repair seems to be the same metabolic decrease which Child finds in sensecence, we have here a clue to the physiologic age of injured or otherwise modified organisms. If the phylogerontic types described in this paper actually are senile, they should give evidence of at least relative inability to withstand environmental disturbance in repair injury, while the reverse should be true in phyloneanic or phyloephebid groups.
>
> Actual conditions correspond closely to these theoretical ones.

He further says (p. 110),

> It seems, therefore, that there are physiologic as well as morphologic trends in at least four gentes of the genus Spirifer. One of these trends manifests itself in increasing suceptibility to environmental change; another in decreasing ability to repair injury.

So it seems with Cyrtospirifer horridus, n. sp. in the Oswayo formation. Here in uppermost Devonian strata, in a group without progeny, irritations or lesions that apparently caused little or no traumatic effect (if they occurred at all, and there is little reason to suspect that they didn't) in other species believed closer to the main stock, were healed only by extensive hypertrophy.

On the other hand, all of these irregularities may be caused by one host specific parasite. (For an excellent summary of host specificity see Allee, et al., 1949, p. 614, et seq.)

TYPES: Holotype: UCM No. 29352. Paratypes: UCM Nos. 29353 and 29359; unfigured paratype, 29358. The last two mentioned paratypes are sandstone molds of the

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interior; unfigured paratype UCM No. 29358 was etched from a complete specimen which was very like paratype UCM No. 29353 before preparation.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 1.

REMARKS: The typical form of this species is represented by 13 individuals of which five are partial exterior. In the following table of dimensions of five of the better preserved partial exteriors, the numbers without decimals represent estimations of broken specimens.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)
29352	30	48	27.2
29353	34.5	40.5	26.3
29354	--	44	21.7
29355	31.1	44	24.4
29356	31.5	48	22.5

Cyrtospirifer horridus variant A, n. variant

Plate 9, figures 10-14.

EXTERIOR: Wide form of Cyrtospirifer horridus; average width more than 1½ times the length. Convexity of the valves about equal, although commonly the brachial valve is the more inflated; greatest convexity of each valve generally posterior to midlength. Lateral slopes generally continuously convex but may become concave toward the extremities. Anterolateral margins nearly straight or they may curve gently backward to the lateral

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extremities; consequently the brachial valve appears nearly trapezoidal in outline. Fold like that of the typical form but commonly with more plicae; anterior extension of sulcus moderate to pronounced. Interarea high, slightly curved, strongly apsacline, but defined and marked like the typical form. Other external characteristics like the typical form.

PEDICLE INTERIOR: Dental plates very strong and heavy, thinning but slightly anteriorly, usually pendant but in a few specimens the lower portion of the lamellae are weakly developed against the posterior floor of the valve; in both cases the lateral umbonal cavities are nearly filled with adventitious deposit. The delthyrial plate apparently does not extend far forward below the delthyrium for it is rarely seen in molds. Musculature very broad and shallow, commonly developed well anterior to the dental lamellae. Other internal details not preserved except the internal rugosities which are characteristic of the species.

BRACHIAL INTERIOR: Cardinalia even heavier than in typical C. horridus, n. sp. The socket plates hang down toward the floor of the valve and are broadly rounded on their anteriolateral margin. Otherwise the brachial interior resembles that of the typical form.

DISCUSSION: The chief differences between this variant and typical Cyrtospirifer horridus is the shape.

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The wide wings give the shell an entirely different shape in outline and the strongly apsacline interarea coupled with the inflated valves gives the lateral profile a distinctive appearance. Internally the heavy, pendant, nearly obsolete dental lamellae, the heavy, rounded, slanting cardinalia and very large shallow muscle scar are features which will aid in distinquishing this variant from the typical form. Since these characteristics are almost entirely a matter of degree this variant is not separated as a distinct subspecies; although when a number of specimens are compared, this variant or forma can be separated from the short-winged, orthocline typical forms or from the short-winged, but thin Cyrtospirifer horridus strigosus, n. subsp. The ponderous, obese nature and the characteristic internal shell excresences readily separate this form from Cyrtospirifer extensus n. sp. and C. oleanensis Greiner.

TYPES: Holotype UCM No. 29365. Unfigured paratypes: UCM Nos. 29369 and 29370; the paratypes are sandstone molds of the interior.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 1; one pedicle valve from the Oswayo formation at locality 60 almost assuredly belongs to this form. Locality 1 is the type locality.

REMARKS: This variant is represented by 17 individuals, seven of which are partial exteriors; dimensions are

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given for three of these with estimations being represented by whole numbers without decimals where the specimens appear broken.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)
29365	33.2	51.5	24.6
29366	27.5	46	22.7
29367	28.3	41	20.7

Cyrtospirifer horridus strigosus, n. subsp.

Plate 10, figures 1-12.

EXTERIOR: Heavy, flat Cyrtospirifer of medium or above medium size; greatest width always at hinge line; average 1.3 times as wide as long. Convexity of the valves about equal, the greatest convexity of each valve being markedly posterior to midlength. Occasionally the pedicle valve is transversely continuously convex except for the sulcus, but generally the lateral slopes of both valves become concave near the lateral extremities. The longitudinal convexity is remarkably near an even curve from posterior to anterior. The anterolateral margins commonly curve strongly back to the extremities causing the brachial valve to appear quite nearly rectangular. In other adult individuals the margins round back more gently forming a nearly semicircular outline. The lateral extremities appear to be produced into short, sharp points at the hinge line without altering the general outline of the shell; these points

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are not preserved but only suggested. In other specimens these points seem to be entirely lacking. In neanic forms, as indicated by growth lines, the shell is more transverse; later growth appears mostly at the anterior commissure, and to a lesser extent at the anterolateral commissure. Anterior commissure parasulcate. Fold low, broad, rounded or somewhat flattened, extending from beak to commissure, flaring toward the anterior commissure, commonly not distinctly set off. Sulcus extending from pedicle beak, triplicate for entire length with primary plicae undivided; sinal formula simple. The sulcus is very broad and shallow with a short to moderate, rounded, anterior extension. The interarea is high, slightly apsacline or, more commonly, orthocline, slightly curved, and is set off posteriorly by sharp beak ridges. Interarea is strongly marked horizontally by growth lines and is marked vertically by capilli that appear to be somewhat more closely and regularly spaced than in the typical form of this species; however details of these markings are not well preserved. Delthyrial characteristics as in the typical form of the species. Brachial interarea low, orthocline to slightly anacline; commonly obscured medially by the incurved brachial beak. Plications numerous, rather wide, with the crest broader than bounding troughs; crests commonly flattened. About 20 to 25 simple plicae occur on each lateral flank but are intercalary on fold and in sulcus.

PEDICLE INTERIOR: Dental plates rather thick

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posteriorly but taper to a thin edge anteriorly, re-entrant, and free in all but the largest individuals. The dental lamellae are quite short but widely divergent, lying between the second and third, or the third and fourth, plication crests outside the sulcus. The teeth are broad and heavy in larger individuals but are quite delicate in small forms. The delthyrial plate is not as heavy and prominent as in the typical form, and it commonly joins the dental lamellae above the point of greatest re-entrance. The ovate musculature is very deeply impressed into the valve, generally extending about one-third the length of the shell. The narrowly ensiform adductor scars lie very close to the midline, entirely within the scars of the accessory diductor scars. The accessory diductor scars generally lie entirely within the dental lamellae and are distinctly radially striated by irregular striae. The principal diductor scars are larger than the accessory diductor scars and the former extend anteriorly some distance beyond the dental lamellae. The scars of the principal diductors are strongly marked longitudinally by relatively deep, straight striations. A strong adductor process is present in the posteromedial portion of the muscle mark. Commonly this process bears one fine groove on the anterior face, and the thin end of the process occassionally extends a short distance anteriorly as a very fine, indistinct ridge. Thus this process is almost assuredly the attachment seat of the adductors, but

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scarcely separates the adductors as does a true median septum. Genital and pallial markings not known. Irregular and hemispherical rugosities which are typical of the species common but not universally developed.

BRACHIAL INTERIOR: The interior of the brachial valve is like that of the typical form of the species but commonly a faint suggestion of a median septum lies between the irregular muscle marks.

DISCUSSION: This subspecies has in common with the typical form of Cyrtospirifer horridus, n. sp. the rather large heavy form, the lack of transverseness in outline of the adult, the high, nearly orthocline, slightly curved interarea, the rather heavy cardinalia, and the distinctive interior shell excresences. C. horridus strigosus, n. subsp. is distinguished from typical C. horridus by the much flatter (thinner) shell, the low wide fold and broad shallow sulcus, and the thinner dental plates. Thus it can be seen that in each case the general shell shape is most distinctive.

Although young of this subspecies are markedly more transverse than the ephebic forms they still retain the distinctive shape and can thus be differentiated from C. extensus, n. sp., although discrimination from small C. oleanensis Greiner is more difficult.

No lower Conewangoan species or Mississippian forms remotely resemble the large adults of this subspecies. In fact if it were not for the difficulty of separating

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small individuals of this subspecies from allied variants, subspecies, and species of the Oswayo cyrtospiriferid gens, this subspecies might well be made a species based on the distinctive and unusual shape. At first glance it would scarcely seem possible to consider these as giving rise to the subspecies of C. horridus n. sp. herein considered to be typical (in that it is the fullest development of the characteristic) of the species occurring at a nearby locality. However one might consider that if C. horridus strigosus were to be inflated (literally pumped up, as it were) the result would be the typical form of C. horridus; the valves would be inflated and hence the whole shell thicker, and the area would be more strongly curved, and the fold would become higher; mayhap we might even consider internal structures to be more "inflated" or ponderous.

TYPES: Holotype, UCM No. 29377. Paratypes: UCM Nos. 29378 (exfoliated exterior), 29387 and 29388 (natural sandstone molds of the interior); unfigured paratype, UCM No. 29385 (sandstone mold of the interior acid etched from specimen very like holotype before treatement). Hypotypes: UCM Nos. 29381 and 29395.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 183.

REMARKS: This subspecies is represented in the collections by 40 individuals of which ten are partial exteriors. Given below is a table of measurements of some

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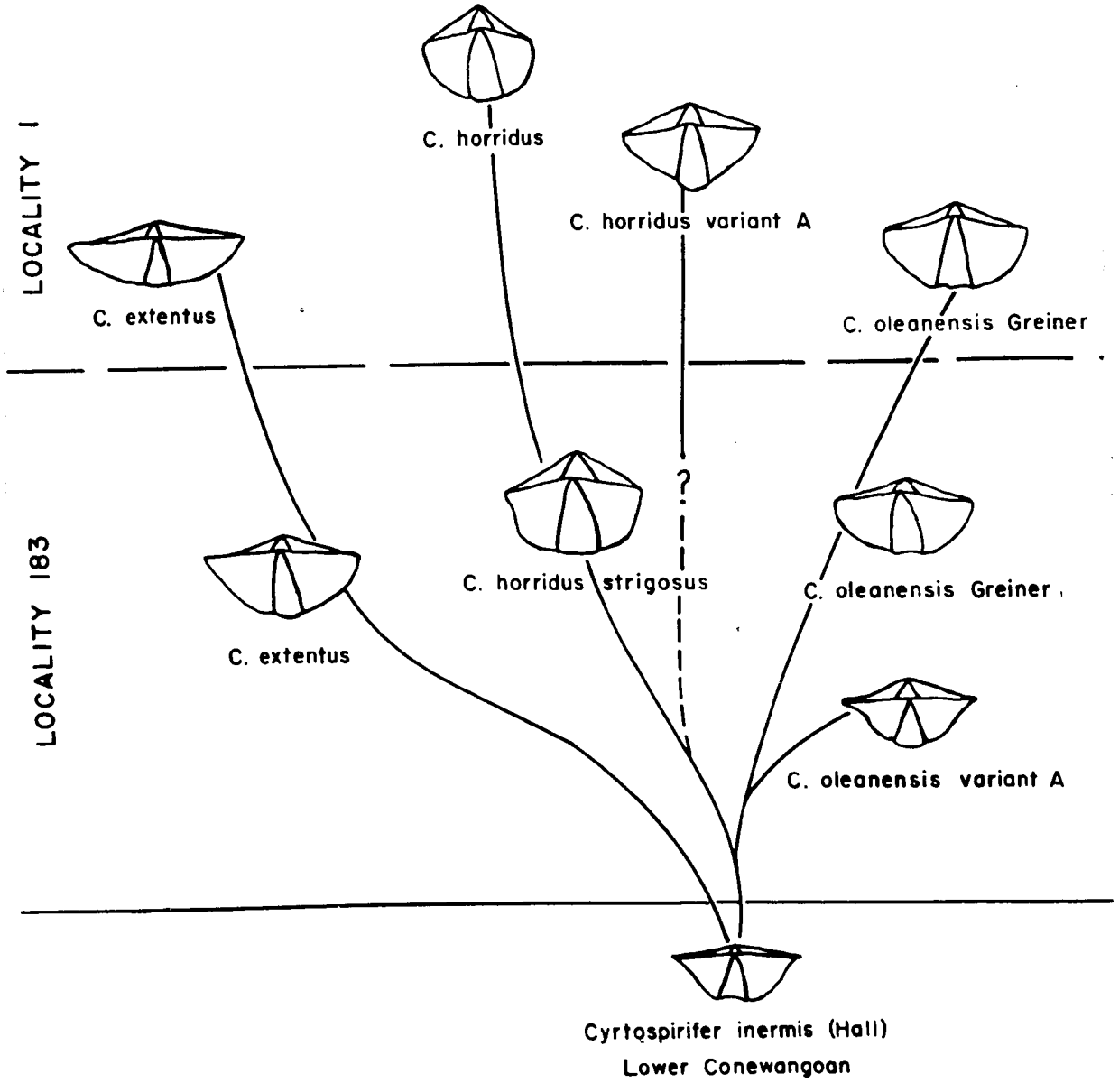

Fig. 16. - Possible relationships of some cyrtospiriferids from the Oswayo formation of the Bradford-Ludlow, Pennsylvania, area. Whether the individuals from locality 1 represent differentiation due to time or to differing coeval ecologic conditions, it is certain that in both internal and external features they are more advance--i.e. if the tendency was toward transverseness (as in C. extentus, n. sp.) the specimens from locality 1 are, in general, more transverse, or if the tendency was toward reduction of mucrones and toward obesity (as in C. horridus, n. sp., and C. oleanensis Greiner) those from locality 1 are, in general less transverse. While this is quite generally a matter of degree and can not always be separated into nomenclatural units, certainly the specimens from locality tend to be more robust, heavier, and more ponderous.

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of the more nearly whole specimens all of which are exfoliated exteriors; those numbers without decimals represent broken specimens in which estimations believed to be close approximations have been made.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)
29377	36.9	43.4	19.3
29378	39	48.6	21.5
29379	28.8	40	15
29381	26.2	36	13.3
29382	33.5	45	17.6
29383	29	39	17.6
29385	41	33	18

Cyrtospirifer sp. indeterminate

Plate 11, figures 1-2.

Twelve specimens, of which five are poorly preserved pedicle valves and the others partial brachial valves which cannot be classified in any known species of the genus are present in the collections. They are very transverse, about three times as wide as long yet the lateral extremities are not mucronate. The greatest convexity of the valves is about midlength or slightly posterior to mid-length, but the valves are not very convex. The lateral slopes are concave but not strongly so. The fold is pronounced throughout, flaring anteriorly, but is rather low. The plicae are fine and subangular with the plication trough wider than the crest. The dental lamellae are thin, subparallel at first and then

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weakly divergent lying between the first and second, or the second and third plication crest outside the poorly defined sulcus. The subdelthyrial plate is thin and not well developed. The rostral and umbonal cavities are free from adventitious deposits and the shell appears to have been very thin. The muscle mark is not at all impressed into the shell.

DISCUSSION: These specimens most nearly resemble C. extentus n. sp., those from locality 1 more so than the others; but one hesitates to place these few poorly preserved dissociated valves with the fine plicae, thin weakly divergent dental lamellae, poorly defined muscle area into this already mutable species. In general C. extentus is more coarsely plicate, the brachial valve more trapeziform or the anterolateral margin more sinuous, and the valves more inflated. It is highly possible, however, that these represent a mutant from the C. extentus stock.

It is possible that these forms are related to C. spicatus Greiner which seemed to prefer the more seaward, shaly environment, to the west and were thus only temporary, unsuccessful immigrants to this area.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at localities 183 and 1; sandstone low in the Oswayo formation at locality 109; represented by three, five and four specimens in these localities respectively. The figured specimens are UCM Nos. 29523 and 29525, both from locality 109. The specimens from locality 1 are more

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coarsely plicate and may belong to C. extentus.

"Cyrtospirifer" plenellus, n. sp.

Plate 12, figures 5.16.

Reticularia praematura (Hall), Caster, K. E., 1930, Bull. American Paleont., no. 58, p. 39, pl. 2, figs. 1, 5; pl. 3 figs. 1, 8; pl. 5, fig. 7.

Cyrtia alta (Hall), Caster, 1930, Bull. American Paleont. no. 58, p. 32, pl. 3, fig. 7.

EXTERIOR: Medium to large spiriferoids; nearly equidimensional or slightly wider than long; greatest convexity of the valves at midlength or slightly posterior to midlength. Except for the fold and sulcus, the shell is transversely continuously convex, so that the lateral slopes rise abruptly from the lateral margins. The anterolateral margins curve strongly back to the cardinal extremities which are sharp in some individuals and rounded in others; thus in some individuals the greatest width is at the hingeline, but more commonly the greatest width is just anterior to it. Anterior commissure parasulcate. Brachial valve known from but one individual. Sulcus of the pedicle valve broad, fairly deep and distinct, rather flattish medially, and broadly rounded into the lateral flank; pedicle valve with long anterior extension of the sulcus into the brachial valve. Surface covered with

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broad costae with narrow troughs, or in a few specimens weakly plicate. Interarea, low moderately to strongly apsacline, evenly and moderately curved, with well-defined beak ridges. Delthyrial characteristics unknown.

PEDICLE INTERIOR: Dental plates divergent, advancing anteriorly one-half to three-fourths the length of the shell. In some individuals the dental lamellae are nearly straight; but in others, after an initial divergence, they curve strongly outward and then converge medially, thus anteriorly surrounding a huge muscle area, as a low ridge, although most commonly, they do not quite meet near the midline. Teeth heavy, but not unduly so, in many specimens buttressed laterally by the anterolateral edges of the subdelthyrial plate. The subdelthyrial plate is set high in the valve and extends one-half to two-thirds the length of the delthyrium, anteriorly it is indented by a V-shaped or U-shaped notch, the sides of which extend forward to give lateral support to the teeth. The musculature is extremely large and distinct but is rarely impressed deeply into the shell. The entire posterior part of the subdelthyrial cavity is occupied by a very braod, but commonly low, adductor process; this process is extended far anteriorly as a low, tapering, commonly bilobed ridge well through the diductor scars. In other specimens, where the anterior part of the adductor process is obscure, the lanceolate adductor scars can still be observed at the same level as the adjacent diductors.

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The diductor scars are obscurely and irregularly radially marked posteriorly, but are longitudinally striate in the anterior portion. The delthyrial and lateral cavities are rarely filled with secondarily deposited material. Faint genital pits are present in the lateral cavities of a few specimens.

BRACHIAL INTERIOR: One specimen shows poorly preserved cardinalia which are closely adherent to the posterior valve wall. The socket plates are laterally elongated along the posterior edge of the valve and buttressed medially by a very low boss which is not at all extended anteriorly as a median septum.

DISCUSSION: The generic affinities of these abundant but poorly preserved forms are not at all clear, and it is with great reluctance that they are assigned to "Cyrtospirifer." This form apparently lacks secondary deposits and seemingly is a thin-shelled form, since the hypodigm consists almost entirely of the posterior part of pedicle valves which are, however, quite abundant at some localities. Thus, though abundant, there are a number of morphological features which, as yet, remain unknown.

This form does not seem to bear spine bases and hence is not referrable to the reticulate spiriferids as Caster's assignment would imply.

This form seems most closely related to Spirifer plenus Hall (1858) and hence, through the association of

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this latter form under Spiriferella Tschernyschew by Weller (1914) to Hall's (1858) Spirifer neglectus, the type of Dimegelasma Cooper (1942). Dimegelasma however, has deeply plicate flanks, a coarsely endopunctate shell, and a median septum in the brachial valve. Cooper (1942, p. 232) differentiates this genus from Spiriferella Tschernyschew (1902) by means of the short dental plates in the latter.

"Cyrtospirifer" plenellus, n. sp., lacks the contours, especially the hemipyramidal pedicle valve, of Pseudosyrinx. Also the dental plates and musculature are entirely different from this genus.

The specimens at hand do not seem to fit into Spirifer, s. s. since this genus has short dental lamellae and lacks the exaggerated muscle scar of the form at hand.

One specimen (the holotype) of "Cyrtospirifer" plenellus, n. sp., shows a short thin, median septum in the extreme posterior part of the delthyrial cavity, but in none of the specimens is there the slightest suggestion of a syrinx. Unfortunately this form is known only from sandstone molds; these show no suggestion of punctation or surface papillae or granulations. The Penn-York Embayment forms lack the median septum in the brachial valve shown for Spirifer plenus Hall by Weller (1914, pl. 64, figs. 3,4). Only these features of difference and the lack of study of specimens of Spirifer plenus prevent the writer from uniting S. plenus Hall, S. latior (Weller), and the Penn-York Embayment forms into a new

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genus, since such extravagent development of widely divergent dental lamallae and huge pedicle diductor muscle area is unknown to the writer in Cyrtospirifer.

TYPES: Holotype: UCM No. 29927. Paratypes, UCM Nos. 29928 and 29929; unfigured paratype, UCM No. 29941. The types are all sandstone molds of the interior of the pedicle valve except UCM No. 29928 which is an incomplete mold of the conjoined valves. Figured hypotypes: UCM Nos. 29933 and 29936.

OCCURRENCE: Sandstone in the Knapp formation at localities 118 and 199. Locality 118 is the type locality.

REMARKS: This form seems to be especially abundant in the coarser sandstones of the Knapp where it occurs in great numbers associated especially with Rhipidomella pennsylvanica (Simpson) and Syringothyris warrenensis, n. sp. The approximate dimensions of several of the better preserved molds are given below.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)
29927	30	33.4	--
29928	33.0	46.5	29.4
29932	40	--	--
29940	30	39	--
29941	--	33	--

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Subfamily SYRINGOTHYRINAE Schuchert and LeVene, 1929

Genus Syringothyris Winchell, 1863

TYPE SPECIES (by subsequent designation; International Commission on Zoological Nomenclature, Opinion 100, 1928): Syringothyris typa Winchell, 1863, Philadelphia Acad. Nat. Sci., Proc., v. 15, p. 6-7. Burlington limestone, Mississippian; Burlington, Iowa.

The following description is modified from descriptions by North (1913), Weller (1914) and North (1920).

Small to very large, punctate and impuncatate spiriferoid shells with a high pedicle area. Hinge line identical with cardinal margin which may be quite elongate but which invariably represents the greatest width of the shell. Fold strong, well defined, generally rounded, nonplicate, extending from the brachial beak to the commissure. Sulcus broad, strongly developed, generally nonplicate, commonly not well defined and with rounded indistinct shoulders, extending from the pedicle beak to the commissure where it is variously produced as a lingual extension into the brachial fold. Lateral slopes marked with rounded, subangular, or very broad flattish plicae which but rarely bifurcate; commonly the plicae become obsolete and the lateral slopes, especially on the pedicle valve, may be quite smooth. Entire external surface, exclusive of the area, marked with tiny elongate granules

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imparting a textile-like ("twilled-cloth") appearance to the shell. Pedicle valve mutable in shape, highly sub-semipyramidal, in which cases it is commonly twisted, or curving evenly from beak to anterior commissure. Lateral slopes strongly convex toward the extremities, or convex near sulcus and then becoming concave toward the lateral margin, or nearly straight from sulcus to the lateral extremities. Interarea of pedicle valve generally sharply defined by well developed beak ridges. It varies from nearly orthocline to strongly procline and from concave to convex in curvature. The interarea is divided into three portions; a broad triangular delthyrium, an impunctate perideltidial area vertically and horizontally marked bounding the delthyrium, and punctate lateral areas marked only by horizontal growth lines. The apical angle varies, but is generally about 100°, and the delthyrial angle is commonly about 25°. On the interior of the pedicle valve a transverse subdelthyrial plate extends forward from the apex for one-third to two-thirds of the length of the delthyrium. Two processes of the under side of the subdelthyrial plate form the syrinx which may be slit longitudinally on its under side, may be a complete tube, or may be a solid spine-like process. The syrinx extends forward beyond the anterior edge of the subdelthyrial plate for various distances into the valve. The dental plates are stout and well developed, commonly straight, but may be curved toward the midline anteriorly

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around the ovate, diductor muscle area. Testaceous shell deposits are variously developed in the lateral and rostral cavities or may be entirely absent. Ovariant pits are commonly quite deep and well developed.

The brachial valve is of variable shape depending on whether the cardinal extremities are produced or are rounded and on whether the transverse curvature of the lateral slopes is concave or convex. Posteroanterior curvature generally relatively even with the greatest convexity usually posterior to midlength. Internally the brachial valve agrees in all essential details with that of Spirifer. Commonly a low, broad, median septum is developed in the posterior half of the valve. The spiralia are spiriferoid and the primary lamellae and crura are strong and well developed; details of the jugum not known.

DISCUSSION: The generic characters are the development of the unsupported syrinx, the high area and the distinctive minute surface ornamentation. Weller, (1914, p. 385) further outlines the essential specific characters as the proportional height of the area, its degree of curvature, whether flat, concave, or convex, the inclination of the area, the different characteristics of the transverse plate, whether flat, concave or longitudinally keeled and the length, width, and shape of the free extension of the syrinx. One might add to this list, the gross characters of the shell, general shape, and

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nature and distribution of the plicae.

The history of the genus is rather well known but the highlights of the development of our present knowledge may profitably be reviewed here. Martin (1798, p. 44, and pl. 3, figs. 1-4; pl. 4, fig. 5) was the first to describe and figure a species now referred to Syringothyris when he described Anomia cuspidata, although Muir-Wood (1951) refers this form to Syringothyris cuspidata (J. Sowerby, 1816)* M'Coy (1855) and Davidson (1858a, p. 470) assigned cuspidata to the genus Cyrtia, although Davidson later abandoned this assignment following Deshayes' (1838) recording of a convex plate perforated near the apex covering the delthyrium. In addition M'Coy (1855, p. 426) recorded an "internal deep-seated pseudodeltidium, without perforation" (the subdelthyrial plate) clearly distinguishing it from the "external pseudodeltidium" (deltidial plates). De Koninck (1861) described and figured a specimen as "Spirifer distans" from the Carboniferous limestone of

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*According to Muir-Wood (1951, p. 97) in July 1948 the International Commission on Zoological Nomenclature (1950, Bull., Zool. Nomen., v. 4, p. 450, and v. 5, p. 114) at the Paris session ruled that the works of Martin (1793 and 1809) did not comply with the Règles since they are not binominal, and that the new trivial names published in these works are not available under the Règles. Since Martin's (1809) Conchyliolithus Anomites (cuspidatus) was next described by J. Sowerby in 1816 as Spirifer cuspidatus, she attributes the trivial name cuspidatus in the combination Spirifer cuspidatus, commonly known as Syringothyris cuspidatus to J. Sowerby, 1816. However North (1920, p. 165) says that this form was first described by Martin (1798, p. 44, and pl. 3) as "Anomia cuspidata from the 'Limestone' of Castleton, (Derbyshire)." This is apparently a good binomen; and since Martin's 1798 paper was not

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Vise, in which the transverse plate and syrinx are clearly shown, but he did not create a new genus. Thus De Koninck was the first to call attention to the subdelthyrial plate and syrinx, but when Winchell (1863) described Syringothyris he was apparently unaware of De Koninck's paper. Although Winchell did not definitely designate which of his two new species, S. typa or S. halli, was the type, it is apparent that S. typa would become the "type by original designation" (Rules of Zoological Nomenclature, Article 30, I, b, fide Schenk and McMasters, 1936/1948, rev. ed.). Prior to Winchell's description of the genus, numerous species now assigned to Syringothyris had been described under various genera, among them Spirifer carteri Hall, 1857. Schuchert (1890, p. 28) stated that Syringothyris typa Winchell was synonymous with Syringothyris carteri Hall and that thus Spirifer carteri Hall became the type species. Considerable controversy raged over the relative merits of S. typa, S. cuspidata, and S. carteri as the type of Syringothyris, finally to be settled after a length review and discussion by the International Commission as Opinion 100 in 1928 which states (I. C. Z. N., 1928) in summary:

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covered by the Commission's 1948 ruling; it is difficult, from the information presented (Martin, 1798, not being at hand) by these authors, to see why the species is not ascribed to Martin, 1798

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Under Suspension of the Rules the genotype of Spirifer Sowerby, 1816, is fixed as Anomia striata Martin, and the genotype of Syringothyris Winchell, 1863, is fixed as Syringothyris typa Winchell (= Spirifer carteri Hall).

During these years many authors had added to our knowledge of the genus; some of the outstanding contributions were by Davidson (1856, 1858, 1858a, 1867), Meek (1865, 1867), Carpenter (1867a, 1867b, 1868a, 1868b), King (1867, 1868) and Hall and Clarke (1894) besides those by authors already mentioned above.

It seems that many of the things we know the most about are the "things we know the least about"; thus, (as with Cyrtospirifer) after all of these writings, there are several details of morphology that are, of have been, controversial.

What nearly amounted to a personal quarrel developed among Carpenter, Davidson, King, and, to a lesser extent, Meek concerning the punctation (references cited above). Winchell (1863, p. 6) emphatically stated that the shell structure of Syringothyris was fibrous and impunctate. Meek and Carpenter reported punctations in specimens of S. typa sent them by Winchell himself. In other papers Carpenter and Davidson, on the other hand, stoutly maintained that the shell of S. cuspidata was impunctate while King maintained he had seen what resembled puncta on a specimen of S. cuspidata. Meek had seen puncta in other specimens of this species and later Carpenter admitted the presence of the punctate shell. North (1920, p. 177) states that in the majority of British specimens the

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intimate shell structure is obliterated by recrystallization.

During this study numerous oriented and random sections of the shell of Syringothyris from locality 97 were ground to optical thinness but no evidence of puncta could be found. These sections showed some evidence of recrystallization; in many places the fibrous structure remained, yet no puncta could be found even when wetted with glycerine.

Vandercammen (1955b), by means of a process using transmitted or reflected light on polished or thin sections or splinters of the shell, wetted with various agents, especially paraffin oil, has shown conclusively puncta in specimens of Syringothyris elongata North and Syringothyris cuspidata (Martin) from the Tournaisian of Belgium, which were not completely recrystallized. He (p. 391) said that the perforations are commonly arranged irregularly in quincunx and that they "cross all the thickness of the shell ending at the external face of the area and the valves in small tubercles which are part of the microsculpture." He warned, however, that when the test is entirely recrystallized, the presence of tubercles alone is insufficient evidence to prove that the test was definitely perforate. Unfortunately this illuminating paper by Vandercammen was received too late for these methods to be incorporated into the present study.

Glenister (1955) has named a new species of Syringothyris, S. spissus from Carboniferous limestone

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in Western Australia. Of this species he says (p. 80), "There can be no doubt that this species in impunctate, but in all other morphological features it is a typical Syringothyris." Carefully stating his reasons, Glenister discounts the possibility that punctation has been destroyed in this species by silicification. This obviously has grave taxonomic implications and he (p. 71) further says,

> It is difficult to believe that a complex structure such as the syrinx could appear simultaneously in two fundamentally different spiriferid groups (punctate and impunctate). The fact that both punctate and impunctate syrinx-bearing forms do appear simultaneously shows clearly the inadequacy of a classification which accepts the presence or absence of punctae as of primary taxonomic importance. As indicated earlier in this paper, the author is of the opinion that the presence of absence of punctae in the spiriferids is of secondary importance. For this reason, it is proposed that the species under discussion be assigned to Syringothyris and that this genus be expanded to include impunctate forms.

As a consequence of this, Glenister places Syringothyris in the superfamily Spiriferacea, family Spiriferidae, and the subfamily Spiriferininae.

Vandercammen (1955b) has taken an opposing view and placed greater importance on punctation in spiriferoid genera, says (p. 387),

> The perforation of the test is an important discriminating factor which decides the systematic position that the genera should occupy; the imperforate ones belong to the sub-family Spiriferinae, the others, belonging to the sub-family Spiriferininae.

Cooper (1944, p. 284) in criticizing the then current Beecher's ordinal classification proposed an informal group of the brachiopod superfamilies into three catagories, - impunctate, punctate, and pseudo-

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punctate. Consistent with this he removed the punctate spiriferoids to a new superfamily, the Punctospiracea. Moore (1952, p. 221) elevated the Punctospiracea to a suborder, but Muir-Wood (1955) has retained the Punctospiracea as a superfamily containing within it the Spiriferinidea which contains the Syringothyrinae.

Early (1952-1954) in this study of spiriferoid brachiopods the writer doubted the importance of punctation as a primary taxonomic character. Presence or absence of punctation seems little reason to place otherwise morphologically similar genera in two disparate superfamilies as has Vandercammen (among others). Now the writer's belief, based partly upon the apparent lack of punctation of Penn-York Embayment syringothyroids, has been augmented by Glenister's report of impunctate Syringothyris from Australia in a similar stratigraphic position.

Williams (1956, p. 253) has said,

> In effect, what has to be examined in order to test the significance of Cooper's classification is whether punctation is more likely to be polyphyletic than, for example, calcareous spiral supports for the lophophore, the pre-eminent feature of the endopunctate and impunctate spiriferoids.
> . . . . . .
> What has to be reconciled . . . is the existence of punctate spiriferoids and orthoids which are, in every other morphological respect, far more closely related to contemporary impunctate spiriferoids and orthoids respectively, than to each other.

Williams (p. 255) concludes,

> The condition of the brachiopod shell therefore does not seem to afford any clear cut divisions of the articulate brachiopods into neatly parcelled taxonomic catagories. Whether the endopunctate or impunctate condition be the more primitive, continual atrophy or the acquirement of caeca affected so many stocks

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> over so great a period of time, that an ordinal classification using only these particular features is impractical.

He therefore (p. 284) rejects the Punctospiracea of Cooper. This view is herein willingly adopted.

Morphologic details of the differentiation of the area into perideltidial and lateral regions are little known. Dunbar and Condra (1932, p. 67-68) report that thin sections of the Orthotetinae show several shell lamellae continuing unbroken from the perideltidium into the lateral region with only a sharp flexure in passing across the boundary. The veritcal markings in this subfamily appear to be corrugations of the external shell layer that are repeated with decreasing fidelity in successively deeper lamellae of the shell. They say, "The reason for this specialization of the cardinal area is an enigma." In thin sections of the posterior portions of Syringopleura casteri, n. sp., from the Penn-York Embayment no line of juncture between the perideltidial and lateral areas could be seen.

North (1920, p. 172) reports that in British Syringothyris partly exfoliated specimens show the vertical striae as a series of trough-like depressions, suggesting that the shell of the perideltidial area was traversed by numerous canals perpendicular to the hinge line. He has found no indications of such a system in thin section however. He also says,

> The striae are connected with a series of denticles along the hinge of the pedicle-valve, and

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> articulate with a row of pits in the hinge-line of the opposite valve.
>
> Davidson suggested that the function of the denticles was to steady the valves, especially when the hingeline was long and the teeth not very large. As the shell increased in size by the peripheral addition of shelly tissue, and the denticles receded from the apex, their course was marked by a series of lines, approximately parallel, and perpendicular to the hinge-line.

He further says that Young (1884) suggested that they were due to the presence of fibers of aragonite in the shell of the living animal, and that Young reported the existence of the denticles in Spirifer striatus (Martin). North says (p. 173), ". . . it is not unreasonable to assume their presence in all cases where there is a vertically striate area." This is seriously doubted as explained below.

Hall and Clarke (1894, pl. 31, figs. 1-3) clearly show the vertical canals and denticulated hinge of Spirifer increbescens Hall but these are heavier markings than the fine capilli on the perideltidium of Syringothyris and Syringopleura. No denticles were observed along the hinge of syringothyroids or Cyrtospirifer from the Penn-York Embayment. Moreover, while the impression of a regularly marked area or perideltidial area is gained by examination with the unaided eye or with a low-power hand lens, examination of Syringopleura casteri, n. sp. under the binocular microscope showed that the capilli are rather irregular, increasing or decreasing in height and width along their length, being slightly flexed laterally, many joining or bifurcating as they go from apex to

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hinge, and many dying out before they reach the hinge line. Hence any interpretation of these being produced into denticles and/or used in steadying the valves of syringothyroids appears suspect.

Cooper (1954) has reported similar markings of the interarea in Syringospira Kindle (1909) and Sphenospira Cooper. In speaking of Syringospira he says (p. 327),

> The interarea, or exterior surface of the palintrope (cardinal area of old terminology), is marked by narrowly rounded, straight, elevated lines running perpendicular regardless of irregularities. These lines meet the delthyrial margin and the posterior shell margin at acute angles. The ridges on the interarea of the pedicle valve are opposite ridges on the interarea of the brachial valve. These ridges are a feature of the outer shell layer and do not crenulate the hinge-margin of either valve.

Cooper (1954, p. 332) considers that these genera lived lying on the broad face of the area and he says, "The prependicular corrugations of the interarea, it is believed, would be helpful in preventing the individual from being moved sideways by bottom currents." This may be true for these genera, but is not likely the purpose of the markings in Syringopleura Schuchert (1910b) for these are much finer than the corrugations in Syringospira and Sphenospira. Although Cooper says that these ridges are features of the outer shell layer only, an exfoliated specimen of Syringospira prima Kindle (Cooper, 1954, pl. 37, fig. 12) appears clearly to show the mold of the interior reflecting the surface corrugations. This is never true of Syringopleura. The purpose of the capillate perideltidium is as yet unknown.

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In like manner the purpose of the pustulose exterior, the "twilled-cloth" appearance, of certain syringothyroids is unknown. Pseudosyrinx Weller (1914), Eosyringothyris Stainbrook (1943b), Syringospira and Sphenospira all have the minutely pustulose exterior, but only in Syringothyris, Syringopleura and Pseudosyrinx is the textile-like nature of the surface so well developed. In the syringothyrids of the Penn-York Embayment the pustules appear to be elongted into tiny cylindrical or polygonal spines which extend obliquely from the surface of the shell. This feature is especially well shown in molds of the exterior from localities 166 and 97 and in some exteriors from locality 97. These thick-set spinules are arranged in a series of chevron-shaped patterns down each plication crest. It is this regularity which imparts the characteristic "twilled-cloth" appearance; in contrast, Cooper (1954, pl. 37, fig. 1) shows "the fine, elongate granules" of Syringospira to be quite irregular in their arrangement. Stainbrook (1943, p. 431) describes Eosyringothyris as having the entire surface of the shell, except the perideltidial area, papillose; the lateral regions of the area of Syringopleura have not been observed to be spinulose as is the rest of the shell. It seems possible to the writer that the spinules of Syringothyris and Syringopleura represent the position of setae on the edge of the mantle unless the suggestion of Vandercammen (1955) that the spinules represent the termini of puncta proves universally correct.

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The question of the existence of plicae in the sulcus is one in which there is not complete unanimity. Winchell (1863, p. 6) merely mentions the sulcus and does not state whether or not it is plicate. Simpson (1890, p. 441) described Syringothyris randalli as having a plicate fold and sulcus. He says (p. 442), "From the external characters alone it would be impossible to separate this species from Spirifera disjuncta, but the internal characters are generic." Schuchert (1910b, p. 224) porposed the generic name Syringopleura for this form, but Girty (1911) rejected the genus saying (p. 548),

> Syringothyroid shells are extremely abundant at the locality and horizon at which S. randalli was found, and I have examined a large number of specimens without in a single instance finding any which possessed the characteristic mesial plications."

Yet on the types he does admit (p. 549) "obscure radial markings" in the sulcus. Girty, and Caster (1930, p 35) consider that Simpson confused Syringothyris with Cyrtospirifer, and Caster places S. randalli Simpson into synonomy with S. angulata Simpson. However, later Caster (1934, p. 71) lists S. randalli as a distinct. species. Simpson (1890, p. 435) says that Hall "was kind enough to review these specimens with me". Hall and Clarke (1893, p. 50) admist the plicate fold and sulcus in S. randalli but in their generic analysis (p. 47) say that the fold and sulcus are "generally non-plicate."

Weller (1914), p. 384) describes Syringothyris as having ". . . the fold and sinus well developed and usually non-plicate." North (1920) repeatedly states

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that Syringothyris has a nonplicate fold and sulcus, and Stainbrook (1943, p. 432) says, "Syringothyris never has a plicate pedicle sinus." Yet there are a number of illustrations of syringothyrids with plications creeping into the sulcus or with incipient plicae developed therein [see Weller, 1914, pl. 68, fig. 14 - S. newarkensis Weller; pl. 71, fig. 7 - S. subcuspidatus (Hall); pl. 71, fig. 1, S. testus (Hall); Hall and Clarke, 1893, pl. 27, fig. 18 - S. subcuspidatus (Hall)].

The writer has not seen specimens of syringothyrids from the Penn-York Embayment in which the sulcus is strongly or completely plicate. Moreover the fold does not seem to reflect even weak ribs to compliment those which may creep into the sulcus. Hence, while there are forms of syringothyroids with plicae developed in the sulcus; it is safe to say that these can be distinguished externally from associated spiriferoids by possession of a smooth fold and a smooth or weakly plicate sulcus. Thus while the writer agrees with Girty (1911) in rejecting Syringopleura Schuchert on the basis that it was originally conceived, it is accepted herein on the basis of a different character; namely, the possession by the type species, Syringothyris randalli Simpson, of a syrinx set low in the valve and supported from below by a median septum. Thus Septosyringothyris Vandercammen (1955) which was based on this characters is a junior subjective synonym of Syringopleura Schuchert (1910).

Pseudosyringothyris Fredericks (1916) and

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Prosyringothyris Fredericks (1916) do not possess the syrinx as fully developed. In Pseudosyringothyris the subdelthyrial plate merely bears on its lower side a "medial roller-like callostiy with a small longitudinal furrow" (Fredericks, 1916, p. 51). Prosyringothyris has extensions of the lateral portions of this bilobed process of the transverse plate, but these lack one-half or one-third of a circle of meeting on the lower side. Fredericks (1916, p. 51) calls this development the "prosyrinx". The relationship of Pseudosyringothyris to Pseudosyrinx Weller has not been investigated. Since Prosyringothyris is based on P. northi Fredericks (= Syringothyris aff. carteri, North, 1913, = S. principalis, North, (1920) it may be that this is merely a form with a variation of the normal development of the syrinx and should be considered synonymous with Syringothyris. However North (1920, p. 166) figures S. elongata North with a similar partial closure of the syrinx as does Amos (1957, p. 101-102) for his Syringothyris feruglioi.

Hyde (1953, p. 265 et. seq.), in explaining his concept of the function of the syrinx as a seat of muscular attachment (whether of the pedicle muscles or the adductor muscles), clearly shows that the edges of the syrinx are "seldom if ever united". This condition is generally well known and is common in Penn-York Embayment syringothyrids even when the posterior part of the syrinx is solid. Specimens of Syringopleura casteri, n. sp., and Syringothyris warrenensis, n. sp., show various

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degrees of enrollment of the edges of the syrinx from specimen to specimen which are otherwise morphologically identical. To some extent, the nature of the syrinx seems partly to be dependent upon the age of the specimen (the older specimens having a more tightly enrolled and more nearly filled syrinx) and partly upon ecological conditions (specimens in the shaly environment having the thinner, more delicate and less tightly enrolled syrinx, while those occurring in coarse sandstone have a heavy, enrolled, and nearly filled syrinx). Thus, degeee of enrollment of the syrinx is seen to be a poor generic (and perhaps even specific) criterion and the genera Pseudosyringothyris Fredericks and Prosyringothyris Fredericks should be considered synonyms of Syringothyris. Campbell (1957, p. 81) has also adopted this view.

Syringothyris can be distinguished from Pseudosyrinx Weller solely by the lack of the syrinx in the latter. Cooper (1954, p. 331-332) states that Pseudosyrinx does not possess a punctate shell, but Weller (1914) repeatedly says that the shell in Pseudospirifer is punctate. He describes the type species, Syringothyris sampsoni Weller (1909), as possessing a punctate shell and even describes in detail the punctation for some of his species (e. g., Pseudosyrinx gigas, p. 409).

Campbell (1957, p. 81) reports ". . . specimens from the Lower Carboniferous of New South Wales which are similar in all features to the American species referred

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by Weller to Pseudosyrinx, except that they are definitely impunctate." Thus it seems that here is another case of punctate and impunctate forms existing contemporaneously within the same genus. Campbell, however, has separated from these forms a new genus, Asyrinxia, with a punctate shell and the textile surface markings of syringothyroid genera. Asyrinxia lacks a transverse plate bearing a syrinx, has a high triangular pedicle area, and has 4-6 weak costae appearing in the lateral portion of the sulcus. Campbell (p. 81) says,

> It differs from Syringothyris Winchell in the absence of a transverse plate bearing a syrinx, in the development of costae on the fold and the sinus and the much lower cardinal area on the pedicle valve. The same features, apart from the syrinx, separate it also from Pseudosyrinx.

Since height of the area, shape and costation of the sulcus, and perhaps even punctation are known to be widely variable characters amongst syringothyroid genera, it appears that Asyrinxia, should be suppressed as a junior subjective synonym of Pseudosyrinx.

Minato (1952, p. 168) erected a genus Plicatosyrinx for impunctate, syrinx-bearing syringothyroid Lower Carboniferous brachiopods from Japan which possess a completely plicated fold and sulcus and which are "internally devoid of both dental plates and median septum." This genus is based upon poorly preserved and poorly illustrated specimens, but figures of the type species seem to imply dental lamellae which were deeply imbedded in secondary calcite in the rostral areas.

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Only further study will show the relation of this genus to other syringothyroid genera.

Cyrtella Fredericks (1919) has a high area, perideltidium, nonplicate fold and sulcus, and spinulose exterior. However, this genus lacks a syrinx, and thus may be a synonym of Pseudosyrinx (whether the shell of Cyrtella is punctate is unknown to the writer). Syringospira Kindle (1909) and Sphenospira Cooper (1954) have a high pyramical area, but they have a strongly plicate fold and sulcus, a more or less developed wide posterior frill extending from the sides of the area, a stegidium filling the anterior part of the delthyrium and they lack a syrinx. Eosyringothyris Stainbrook (1943) also has a high interarea with a distinct perideltidial area, nonplicate fold and sulcus, and a somewhat textillated exterior (as discussed above), but has an anteriorly spinose subdelthyrial plate, impunctate shell, and lacks a syrinx. In addition the members of this genus are smaller than most species of Syringothyris. It is possible that Syringothyris developed from this earlier genus.

The characters of syringothyroid genera are summarized in Table 10, but their inter-relationships are only poorly known.

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TABLE 10. - Status of proposed syringothyroid genera

GENUS	DISTINGUISHING FEATURES	COMMENTS
Syringothyris, Winchell, 1863	Mostly large, high area, textile-like exterior, punctate and impunctate syrinx.	
Syringopleura, Schuchert, 1910	Punctate and impunctate: dental plates short and thick, syrinx supported by median septum.	
Pseudosyringothyris, Fredericks, 1916	Subdelthyrial plate with median roller-like callosity with longitudinal furrow.	Junior subjective synonym (?) of Syringothyris.
Prosyringothyris, Fredericks, 1916	Bilobed extensions of the subdelthyrial plate ladks one-half to one-third of a circle of meeting on the underside.	Junior subjective synonym (?) of Syringothyris.
Plicatosyrinx, Minato, 1952	Impunctate, plicate fold and sulcus, no (?) dental plates or median septum, with syrinx.	Based on poor specimens poorly illustrated; internal structures may be buried in callosity. Junior subjective synonyn(?) of Syringothyris.
Pseudosyrinx, Weller, 1914	Punctate and impunctate syringothyroids without syrinx on subdelthyrial plate.	
Cyrtella, Fredericks, 1919	High area, perideltidium, nonplicate fold and sulcus, spinulose exterior, lacks syrinx	Junior subjective synonym of Pseudosyrinx.
Asyrinxia, Campbell, 1957	Punctate, "textile" surface, high area, alate, 4-6 weak costae in sulcus, perideltidium, no transverse plate or syrinx.	Junior subjective synonym of Pseudosyrinx(?)
Eosyringothyris, Stainbrook, 1943	Impunctate, high area, perideltidium, pustulose exterior, small subdelthyrial plate ends in short sharp spine.	
Septosyringothyris, Vandercammen, 1955	Punctate, dental plates short and thick, long syrinx supported by median septum.	Junior subjective synonym of Syringopleura.
Syringospira, Kindle, 1909	Impunctate, high area, granulose surface, fold and sulcus costate, frill on area, blister-like plates in posterior of pedicle valve, short dental plates, transverse plate without syrinx or delthyrial tube, stedidium.	
Sphenospira, Cooper, 1954	Like Syringospira but with frill only at cardinal extremities; long divergent dental plates, no blisters.	

Syringothyris angulata Simpson, 1890

Plate 13, figures 1-15.

Plate 14, figures 1,2.

Syringothyris angulata [nomen nudum] Simpson, G. B., 1889, Pennsylvania Second Geol. Surv., Rept. 03, p. 258.

Syringothyris angulata Simpson, 1890, American Phil. Soc., n. ser., v. 16, p. 440, fig. 5 (nos. 1-3); Schuchert, Charles, 1890, New York State Geol., Ann. Rept. 9, p. 32; Hall, J. and Clarke, J. M., 1893, Nat. Hist, New York., Paleont., v. 8, pt. 2, p. 50; Caster, K. E., 1930, Bull. American Paleont. no. 58, p. 32-25 (partim), pl. 6, fig. 7, pl. 8, figs. 1-3, 9.

Syringothyris angulatus Simpson, Lesley, J. P., 1890, Pennsylvania Second Geol. Surv. , Rept. P 4, v. 3, p. 1150, figs. numbered 1-3; Weller, Stuart, 1898, United States Geol. Surv., Bull. 153, p. 619.

Syringothyris randalli Simpson, Hall, and Clarke, 1894, Nat. Hist. New York, Paleont., v. 8, pt. 2, pl. 27, figs. 13, 15-17; 1894, New York State Geol. Ann. Rept. 13, pl. 21, figs. 10, 11.

Syringothyris texta (Hall), Willard, B., 1939, Pennsylvania Geol. Surv., (Ser. 4), Bull. G 19, pl. 22, fig. 7.

Simpson's original description of this species is meager; he says merely:

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> This species closely resembles S. randalli; but the specimens are usually of smaller size; the mesial sinus and fold proportionately narrower; the cardinal extremities angular and frequently attenuate.
> Formation and locality. Waverly group, near Warren, Warren county, Pennsylvania.

Schuchert,(1890, p. 32) adds little:

> This species is closely related to S. carteri, Hall. It holds the same geological position as that species, and may prove to be identical with it. Still it has a somewhat different expression in being smaller, with a hinge extremity drawn out, and having the plications more pronounced and sharper.
> Distribution. - Waverly group, near Warren, Pennsylvania.

Caster (1930, p. 32 et seq.) confused the various species of Syringothyris from the Penn-York Embayment under S. angulata, so unfortunately added little information on the morphology of this species. Hence the following new description of S. angulata is written from photographs of Simpson's types, only occasionally supplemented by information from specimens from locality 175 which are surely conspecific.

EXTERIOR: Small, thick Syringothyris with high area and strongly convex valves both longitudinally and transversely. Wider than long with greatest width at the hinge line, the width may be nearly equal to the length, or the shell may be markedly transverse. The anterior margin may appear almost semicircular in outline but on more transverse shells merely curves to the lateral extremities. The area is very high, curved and strongly apsacline. Transversely the lateral slopes of the pedicle valve are very strongly convex from the edge of the sulcus

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to very near the lateral extremities where they may become concave, or, more commonly, may meet the brachial valve at a very high angle. The brachial valve is not so strongly convex; but there too, the concavity of the lateral slopes, if developed, extends only a short distance inward from the extremities. The smooth fold is distinct and quite high but may be rather poorly delimited. The plicae of the brachial valve are quite strong, rather broadly rounded or broad and flattish, with the crest usually considerably wider than the trough. These become increasingly stronger anteriorly; in fact they may be quite weak or nearly obsolete, especially on molds, high on the umbo. On the pedicle valve the plicae appear to be broader and flatter, and usually are obsolete on interior molds except near the margins. The sulcus is very broad and shallow and poorly defined. The shell rounds smoothly into the sulcus with the last well defined plication high on the side of the sulcus but well inward of the highest edge of the sulcus. On the long inside flank of this last well defined plication toward the midline, a weak plica is commonly developed, but otherwise the sulcus is smooth. The anterior margin is strongly parasulcate with a long lingual extension of the sulcus produced anteriorly into the fold. Growth increments commonly very heavy, especially near the anterior of the shell.

PEDICLE INTERIOR: The dental lamellae are strong, subparallel, thinning anteriorly, complete or slightly

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re-entrant, and usually extend one-half to two-thirds the length of the valve. They may bend inward at their anterior ends around the muscle scars but this is commonly not so. The transverse plate is well developed, strongly slanted downward anteriorly but extends only one-third to one-half the length of the delthyrium. The syrinx, appearing well above the floor of the valve, is long, dorso-ventrally flattened, especially posteriorly, slit along the under side, unsupported from below, and projecting downward from the slanting syringal or subdelthyrial plate which is normally well developed. The delthyrial cavity is generally quite free from adventitious deposit but secondary testaceous deposits may be developed in the lateral cavities. This coupled with the high area and strong transverse convexity commonly gives a "humped-backed" appearance to molds of the interior. The muscle scars are rarely impressed into the shell; in fact, in some specimens the musculature is slightly raised from the general level of the floor of the valve. The adductor process is variously developed, although it commonly extends anteriorly nearly through the muscle scars as a very low, bipartite median ridge which decreases in height anteriorly. Commonly, however, it is not developed in the posterior part of the delthyrial cavity but is first discernible well anterior within the muscle scar, again as a low irregularly bilobed septum. Presumably the adductor muscles covered this whole ridge and were

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thus elevated above the place of diductor attachment. The posterior diductor scars are weakly marked by irregular radiating furrows or these may not be visible at all. The anterior diductor scars appear weakly to strongly striate longitudinally. Ovarian pits commonly appear over the entire surface of the lateral chambers and far anterolaterally along the lateral walls of the valve.

BRACHIAL INTERIOR: The cardinalia are strong and spiriferoid. Wide sockets, which narrow posteriorly, are excavated in the strong, pendant socket plates and bounded by high heavy inner socket ridges. The cardinal process is a low vertically striate area nearly flush against the posterior wall of the valve. Below this is commonly developed a low, broad, nearly vertical median ridge or buttress at the posterior of the valve. Lateral branches of this ridge may connect with the socket plates or these plates may hang free. In some specimens this vertical posterior buttress is produced anteriorly as a short low median septum. Interior markings obscure. Details of the spiralia not known.

TYPES: The Academy of Natural Sciences of Philadelphia specimen No. 9535 figured by Simpson as number 3 in his figure 5 is here designated as the type. Simpson's other cotypes Philadelphia Acad. Nat. Sci. Nos. 9533 and 9538 are paratypes (Simpson's number 2 and 1 respectively). The specimens shown by Simpson as 2 (9533) and 3 (9535) of Figure 5 are probably from the Kushequ and number 1

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(9538) is likely from the Tidioute shale as is another specimen Philadelphis Acad. Nat. Sci. No. 9480 with the type suite. Figures hypotypes: UCM Nos. 29531, 29535, 29546, 29922, 29923 (all molds of the interior) and 29541 (exfoliated specimen).

DISCUSSION: S. angulata Simpson is characterized by its small size, high area and great thickness, strong convexity (these combining to give the shell a "hump-backed" appearance) and the strong broad plicae becoming nearly obsolete on the umbones of molds of the interior. Interiorly it possesses long subparallel dental plates, low adductor process and/or median ridge, and a dorsoventrally flattened syrinx which projects downward into the valve.

It should be noted that the lectotype (designated above) is a crushed specimen. It appears that the left side of the pedicle valve is crushed anteriorly as indicated by the lesser projection posteriorly of the filling of the left lateral cavity. Also the horizontal growth markings of the interarea appear to slope downward to the left (observer's right). That the specimen is dorsoventrally crushed is indicated by the deep in-foldings of the troughs of the plicae bounding the fold (not seen in any other specimen), the sharpening of the other plicae (which probably lead Schuchert to make the remark on the sharpness of the plicae) and by the fact that the left side of the brachial valve projects up above the hinge when viewed in posterior aspect. Also in the lectotype, the

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area seems nearly orthocline, which is doubted.

If the broken lateral extremities of the lectotype were restored it would be a rather more transverse specimen than those from locality 175 but would be about like those from locality 97. The Tidioute specimen (Philadelphia Acad. Sci. No. 9538) shows the extremities slightly "attenuate" as described by Simpson, although most of this feature is probably attributable to the deformation observable on the right side. The more attenuate condition is accompanied by lesser deposition in the rostral area and seems to be common however in the Kushequa at locality 166 and in shaly zones higher in the Knapp at certain localities. Thus this variation may be ecotypic. Thus to some extent "angulata" is a misnomer because this species is the least transverse of those from the Penn-York Embayment.

S. angulata differs externally from Syringopleura randalli (Simpson) in its lesser transverseness, greater obesity, and stronger convexity. The syrinx is high-set, flattened or solid arising from a definite syringal plate in S. angulata while in Syringopleura randalli (Simpson) and Syringopleura casteri n. sp., the syrinx is nearly round, commonly without a definite syringal plate, and is located near the floor of the valve.

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at localities 97 and 175; Kushequa shale at localities 51 and 166;

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the lower (first) Syringothyris zone of the Knapp formation at localities 121 and 199; and the Cobham conglomerate member of the Knapp formation at locality 91.

REMARKS: In the pale yellowish brown fine-grained sandstones of the Kushequa member at locality 166, specimens of Syringothyris angulata Simpson occur in abundance. Here vast numbers of dissociated valves are crowded together. In general, the shells at this place are smaller, have thinner dental lamellae, and deep cavities unfilled by secondary deposition in the rostral area. This smaller, more delicate form is especially abundant in the shaly zones and thus seems to be an ecotype of the more typical form occurring elsewhere in the Knapp formation.

A number of robust specimens from locality 175 show the irregular vermiform, excresences of the shell interior not unlike Cyrtospirifer horridus. n. sp. from the Oswayo formation, as though the organism had repaired borings in the shell just under the mantle. Those which show these borings seem to have been badly afflicted, indeed.

Dimensions of the better specimens (all molds) are given below; the specimens which show the exterior are so broken that measurements would not be at all significant.

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UCM No.	Length (mm)	Width (mm)	Thickness (mm)
29531	23.6	41.5	28.2
29532	24.6	37.5	29.1
29533	25.2	43.7	28.6
29534	26.4	44.2	28.6
29536	25.6	44.1	26.1
29538	27	52.3	33.2
29539	30	53.5	35 ?

Syringothyris warrenensis, n. sp.

Plate 14, figures 3-11.

Syringothyris randalli Simpson, Hall, J. and Clarke, J. M., 1894, Nat. Hist. New York, Paleont., v. 8, pt. 2, pl. 27, fig. 14.

Syringothyris typa Winchell, Williams, H. S., 1913, United States Geol. Surv., Prof. Paper 79, pl. 5, figs. 6-7.

Syringothyris herricki Schuchert, Hyde, J. E., 1953, Ohio Geol. Surv., Bull. 51, pl. 35, figs. 8-10.

EXTERIOR: Medium-sized to quite large, thick, heavy Syringothyris. Wider than long with greatest width at the hinge line. Lateral slopes usually convex longitudinally and transversely; more rarely the slopes may be slightly concave near the extremities. The interarea is straight or very slightly curved, high, with a relatively high apical angle and is apparently very strongly apsacline. A very strong, arched xenidium extends two-thirds or three-fourths of the length of the delthyrium from the beak to the hinge line. The anterior margin is parasulcate

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and the anterolateral margin rounds smoothly in a broad curve backward to the lateral extremities. The sulcus is very broad, shallow, flaring anteriorly. The plicae are broad and flat with narrow troughs obsolete or nearly so on the umbo. Growth increments weak except near the anterior margin where they may become quite strong giving a rugose appearance to the shell. Brachial valve unknown.

PEDICLE INTERIOR: Dental plates very strong and heavy, strongly re-entrant with the lower limb on the floor of the valve very long, extending the entire length of the valve, very widely divergent posteriorly and strongly incurving at the anterior ends. The dental lamellae may be so thickened posteriorly that the delthyrium may be laterally restricted and completely closed below the deltidium for three-fourths its length. If it is not entirely buried within this rostral filling, the subdelthyrial plate, situated well above the floor of the valve, extends a short distance anteriorly as a heavy transverse plate bearing a very heavy, sharply tapering syrinx which is deeply slit along its under side. The syrinx, which is very thick posteriorly, slopes downward in the valve and is roughly "roof-shaped" above and essentially flat below. The muscle scars are variously developed but are invariably large and extend a long distance anteriorly. Most commonly the adductors were attached posteriorly to a broad, flat, smooth swelling and anteriorly connected to a pair of low irregular ridges separated by a groove of varying

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width. The diductor scars are irregularly furrowed; in general, these furrows tend to be radial posteriorly, and longitudianlly arrayed anteriorly. The lateral cavities are commonly partially filled with adventitious deposits connected with the posterior thickening of the dental plates. The walls of the lateral cavities are commonly partially filled with adventitious deposits connected with the posterior thickening of the dental plates. The walls of the lateral cavities are commonly marked by very small, fine, close-set ovarian pits.

DISCUSSION: This species is known only from sandstone molds of the interior, and much more rarely, molds of the exterior, of the pedicle valve. Molds of the exterior of the brachial valve of a large Syringothyris, presumed to be the same species, are so fragmentary as to add nothing to the description. No specimen of conjoined valves is present in the collections.

S. warrenensis n. sp., is characterized by the arched appearance, high, straight or slightly curved area, heavy transverse plate, syrinx and dental lamellae, and the extension of the latter far anteriorly to enclose a large, irregularly marked muscle area. S. warrenensis combines the high area, rounded contours and high-set syrinx of S. angulata Simpson with the transverseness of Syringopleura casteri, n. sp. and the large size and large musculature of Syringopleura randalli (Simpson). S. warrenensis differs from Syringopleura casteri, n. sp.

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in being thicker, commonly larger, having convex instead of concave slopes, longer dental lamellae and larger muscle area, and the syrinx is set high in the valve of the former instead of being attached to the floor. The principal differences between S. warrenensis, n. sp., and Syringopleura randalli (Simpson) are the convex lateral slopes, higher apical angle, high-set syrinx, larger muscle area, and apparent lack of any plicae in the sulcus of the former.

It is apparently this species which various authors have identified as S. texta (Hall) in the Knapp formation, but S. texta has an even higher area, more pyramical pedicle valve, smaller musculature and the posterior portion of this muscle area is apparently deeply cleft (in molds) by the adductor process or a median septum ? (see Hall and Clarke, 1894, pl. 27, fig. 5). S. texta is unknown to the writer from this area. In fact, none of the Mississippi Valley species seem to occur in the Penn-York Embayment.

Syringothyris warrenensis resembles S. herricki Schuchert from the Byer member of the Logan sandstone of Ohio. Schuchert (1890, p. 36) describes this latter species as having the syrinx connected to a median septum in the bottom of the valve. Hyde (1953, p. 277) states that this character "is obviously a variable feature". It is likely that Hyde was including two separate forms under one name; the first should be referred to Syringopleura

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herricki (Schuchert) and the other to Syringothyris warrenensis n. sp. The forms here referred to Syringopleura herricki (Schuchert) apparently have thinner dental lamellae and stronger lateral plicae than Syringothyris warrenensis, in addition to possessing a low-set syrinx which is tied to the floor of the valve (see Hyde, 1953, pl. 35, fig. 11).

TYPES: Holotype: UCM No. 29621 (sandstone mold of the interior of pedicle valve). Paratypes: UCM Nos. 29622, 29623, (sandstone molds of the interior of the pedicle valve), and 29629 (fragmentary sandstone mold of the exterior). All of the paratypes are on one slab and are not figured. The holotype is now free, but it was from the same slab that the three paratypes are on. Figured hypotypes: UCM Nos. 29534, 29916 and 29917 (molds of the interior). Locality 199 is the type locality.

OCCURRENCE: Lower (first) Syringothyris zone of the Knapp formation at localities 118, 121 and 199; and sandstone in the Kushequa shale member of the Knapp formation at localities 175 and 166.

Genus Syringopleura Schuchert, 1910, emend.

TYPE SPECIES (by original designation): Syringothyris randalli Simpson, 1890, American Phil. Soc., Trans., n. s., v. 16, p. 441, fig. 6. Corry sandstone,

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Lower Mississippian, near Warren, Pennsylvania.

DIAGNOSIS: Punctate or impunctate syringothyroids with the fold and sulcus smooth or with the sulcus weakly plicate on its sides. Dental lamellae strong and relatively short; syrinx set low in the pedicle valve, and supported by a strong median septum which is sometimes bifid.

DISCUSSION: Schuchert (1910, p. 224) erected Syringopleura for syringothyroid brachiopods which differed from Syringothyris only ". . . in having a strongly plicated fold and sinus." Girty (1911) rejected Syringopleura as a junior subjective synonym of Syringothyris saying (p. 548),

> syringothyrid shells are extremely abundant at the locality and horizon at which S. randalli was found, and I have examined a large number of specimens without, in a single instance, finding any which possess the characteristic mesial plications.

Vandercammen (1955a) recognized in a Belgian Tournaisian species a distinctive character, the possession of a long syrinx supported by a strong median septum; and he named the genus Septosyringothyris (based on a new species, S. demaneti) saying (p. 3), "The genus Septosyringothyris is separated from all other syringothyrids by the presence of a strong, simple or bifid, ventral median septum." Amos (1957) referred some Argentinian forms to Septosyringothyris, stating that they were characterized by the presence of a "euseptum" connecting the syrinx with the floor of the valve.

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The type specimen of Simpson's Syringothyris randalli (which is presumably from the Corry sandstone) possesses a well developed septum connecting the syrinx with the floor of the valve (see Plate 15, Figures 8,9) as do other specimens of this species from the Corry sandstone in the Warren, Pennsylvania, area. Therefore, it becomes necessary to resurrect Schuchert's long forgotten genus Syringopleura for the group of syringothyrid brachiopods possessing this distinctive character and to suppress Septosyringothyris. Vandercammen as a junior subjective synonym for Syringopleura.

Many of the specimens from the Marvin Creek coquinoid zone of the Kushequa shale at locality 97 as well as the typical form of Simpson's Syringothyris randalli from the Corry, near Warren clearly show the septate condition. In all of these specimens the solid syrinx is set very near to the bottom of the valve. Certain specimens, however, give little evidence of support of the syrinx from a septum arising from the floor of the valve. In most of these latter, however, it is apparent that there had been deposition of secondary calcareous material in the subdelthyrial cavity and it may be that this condition obscures the septum which supports the syrinx.

It has been the writer's experience, that, in general, taxa based on a single, diagnostic, morphologic characteristic which separate it from other similar taxa do not stand the test of time; yet the condition of a low-set, round and normally solid syrinx, supported by a median

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septum apparently separates a group of species, namely Syringopleura casteri, n. sp. and Syringopleura randalli (Simpson) from the Corry, from a clearly different group typified by Syringothyris angulata Simpson. Only further collecting and more intensive study will fully tell whether these differences are generic or merely specific.

It is believed that Syringopleura casteri, n. sp. from the Knapp is impunctate and hence Vandercammen's concept of this genus is herein expanded to include impunctate forms.

Syringopleura casteri n. sp.

Plate 15, figures 1-7.

Plate 16, figures 1-8.

Syringothyris angulata Simpson, Caster, K. E., 1930, Bull. American Paleont., no. 58, p. 32-35 [partim], pl. 7, fig. 3 ? .

EXTERIOR: Small to medium-sized, more rarely large, transverse syringothyroids. Much wider than long with greatest width always at hinge line. Anterior margin parasulcate; the anterolateral margins may curve strongly posteriorly from the midline, be more gently curving and sinuous near the lateral extremities of attenuate forms, or in the most transverse forms they may be nearly a straight line. The area is moderately high, slightly to

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moderately curved, set off by distinct, sharp beak ridges, and has a very broad perideltidial region which occupies the greater portion of the interarea. Apical angle about 130°. Transversely the lateral slopes of each valve are strongly convex adjacent near the fold or sulcus but commonly become concave toward the extremities. This gives the shell an appearance of being relatively quite flat and very wide-winged. The greatest thickness of each valve is posterior to the midlength. The fold is smooth and well defined, but not high; commonly it is flaring anteriorly. The plicae of the brachial valve are rounded with the crest wider than the plication trough. On the pedicle valve the plicae are more broadly rounded; on molds of the interior of the pedicle valve the plicae are weaker on the umbo than anteriorly, but they are almost never obsolete. The sulcus is broad and shallow and poorly delimited with the shell rounding gently into the sulcus. Commonly one to three plicae, usually of lesser prominence than those on the lateral slopes, lie inside the highest part of the valve, the long sulcar flank of these plicae are interrupted by a weak plication. The ribs in the sulcus are much weaker than those on the lateral slopes, but are almost universally present, expecially on molds of the interior where occasionally these weak plicae are present clear across the sulcus, yet only the faintest suggestion of plicae is to be seen on the exterior surface. The sulcus has a broad, relatively short, anterior extension into the fold.

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Growth lines prominent but rarely heavy. Entire surface, exclusive of the interarea, spinulose; spinules regularly arranged in chevron-like rows over the plicae imparting the typical "twilled cloth" appearance to the shells.

PEDICLE INTERIOR: Dental plates relatively thin for the genus, thicker toward the posterior but thinning rapidly anteriorly, slightly re-entrant or nearly complete, fairly short, extending one-fourth to one-third the length of the valve, divergent but not strongly so. Initially the dental plates lie just outside the sulcus but then curve inward until they enclose or nearly enclose an oval muscle area. A ridge is commonly developed along the upper edge of the dental plate laterally restricting the delthyrium. The syringal plate is very short or obsolete; if persent it slants strongly downward and lies well below these ridges, never traversing more than one-fourth the length of the delthyrium from the apex. The syrinx usually emerges from a slight apical callus; it may be partly hollow, slightly open at the bottom, or it may be a solid rod. Yet it is tied, usually on the left side, through the adductor process by means of a vertical plate or septum, to the bottom of the valve for one-third to three-fourths the length of the syrinx. In molds then, the posterior part of the muscle scar is usually posteriorly cleft clear into the syrinx. In some shells the rostral callus extends anteriorly far enough to obscure the connection of the syrinx and the adductor

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process; in these cases the syrinx is first seen free but lying very near the bottom of the valve. The lateral cavities are generally quite free of adventitious deposits. Muscle scars small, set far back in the valve, impressed slightly into the shell posteriorly. The scars are poorly differentiated into their componenet parts, and faintly marked. The position of the adductor muscles is sometimes shown by a weak irregular ridge extending anteriorly from the adductor process through the center of the muscle impression. Ovarian markings obscure.

BRACHIAL INTERIOR: Socket plates rather small for the size of the shell yet generally quite thick postero-laterally. The sockets are deep and the inner socket ridges high and tipped backward so that the ridges along the sides of the dental lamellae interlock strongly with the sockets. Other details of the brachial interior obscure on the molds of the interior, hence presumably weakly developed. Median septum lacking.

DISCUSSION: Syringopleura casteri n. sp., is characterized externally by its relatively small size, transverseness, concave lateral slopes, and partially plicate sulcus. Internally it is identifiable by the short, relatively thin, curved dental plates, small muscle impression, round syrinx placed low in the valve and usually connected to the floor of the valve, and the lack of secondary deposits in the lateral cavities.

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Syringopleura casteri differs from Syringothyris angulata Simpson with which it is associated, by its greater transverseness, concave lateral slopes, and in having short divergent, but curved, dental lamellae, small muscle scar and low-set, round syrinx supported by a median septum. Molds of Syringothyris angulata are rather more "hump-backed" and it has a dorsally-ventrally flattened syrinx. Syringopleura randalli (Simpson), which also has convex lateral slopes, a weakly or partially plicate sulcus, and a syrinx connected to the floor of the valve, is generally larger, has a larger muscle scar in proportion to its size and widely divergent and heavy dental plates. Moreover Syringopleura randalli is not known to occur below the Corry sandstone in its most typical form.

It is possible, however, that Syringopleura casteri, n. sp., is present in the Corry; a few small specimens (molds of the interior from the Corry sandstone of Sill Run southwest of Warren, Pennsylvania, present in the collections resemble S. casteri. These strongly resemble other associated small specimens with larger muscle scars, and it is more plausible that these are young Syringopleura randalli (Simpson).

Syringopleura casteri, n. sp. differs from Syringothyris warrenensis n. sp., of the Knapp formation in the lesser thickness, greater transverseness, and lower-set syrinx of the former.

There are variations within S. casteri that permit

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of separating the specimens from locality 97 in five groups. These groups are tentative, rather nebulous, and scarcely worthy of separate description and designation. The variations are so small as to be nearly on the mutational level. Yet further collection and restudy may prove these variants, especially if they can be identified elsewhere, to be of taxonomic value. Certainly they merit brief notice here to allow delimitation of the characters of the species. Terms such as large or small, thick, transverse, etc., used in the following discussion are relative and within this species only.

Group I - Large, very wide, lateral slopes very concave, anterolateral margin nearly straight from fold to the wide wings, interarea slightly curved, sulcus broad, usually with relatively strong ribs crossing sulcus near the anterior part or several on the sides of the sulcus, syrinx strongly tied to adductor process, dental lamellae long.

Group II - Large but not as large as Group I, thick lateral slopes weakly concave, anterolateral margins more curving to the extremities, inclination of the interarea less strong than in other groups, area nearly straight or only slightly curved, bottom of sulcus smooth, interior like group I except dental plates shorter.

Group III - Medium-sized, transverse, moderately thick, anterior lateral margins curving to the extremities, lateral slopes moderately concave transversely but markedly

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convex longitudinally, plicae relatively course, interarea moderately curved, muscle scar more deeply impressed, apical callus better developed as anterior portion of syrinx not tied to ventral valve.

The plicae of Groups II, III, and IV are spaced wider apart and are somewhat broader than Group I and V. In the latter groups the plicae are very fine for the genus.

Group IV - Medium to small, less thick, anterolateral margins slightly sinuous or nearly straight, or rarely slightly curved, bottom of sulcus smooth, dental lamellae nearly straight.

Group V-- Medium to small, anterolateral margins sinuous, interarea curved, lateral slopes of pedicle valve slightly concave, slopes of brachial valve strongly concave so that the ears appear bent forward in lateral aspect, plicae fine, occasionally bifurcating on brachial valve.

Between each of the above groups there is intergradation and the species is seen to be quite mutable. It seems as if a stock, new to the area, was experimenting by combining features to find the most successful combination of traits. If this be true, then it is suggested that the mutations which produced the combination of features in Groups I and II -- robustness and strongly concave slopes with coarse plications, and a strong syrinx well tied to the floor of the valve--best fitted this lineage for survival, for members of these groups

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most nearly resemble Syringopleura randalli (Simpson) of the Corry sandstone.

TYPES: Holotype: UCM No. 29557; the holotype (Group II) is a sandstone mold of the interior. Paratypes: UCM Nos. 29549 (Group I - decorticated exterior), 29558 (Group II - sandstone mold of the interior, pedicle valve only), 29564 (Group III - partial exterior), 29572 (Group IV - partial exterior), and 29578 (Group V - partial exterior, unfigured).

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97. Kushequa shale at localities 175 (one specimen) and 166 (?). It would be most difficult even to estimate the relative abundance of this species at locality 97 because of the hundreds and hundreds of fragmentary specimens and dissociated valves. Locality 97 is the type locality.

It is possible, but not likely, that this species also occurs in the Corry sandstone as mentioned above.

REMARKS: This species is named in honor of Dr. Kenneth E. Caster.

Some dimensions of various specimens are given below; yet these are not tought to be of very great significance because so many specimens, especially the young are broken or are of dissociated valves. Estimations are indicated by numbers without decimals.

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UCM No.	Length (mm)	Width (mm)	Thickness (mm)	Remarks
Group I				
29549	38.7	73	22.7	
29556	34.2	54.4	20	
29583	37.8	75		pedicle valve
29600	38	80		pedicle valve
Group II				
29557	35.0	56.2	27.0	interior mold
29560	36	73	28.3	
29561	37	60	28.0	
29562	36.0	68	28.3	
Group III				
29564	29.2	55	19.9	
29565	26	47	20.6	
29566	27	60	20.0	interior mold
Group IV				
29572	31.0	52	21.2	
29573	27	61	19.9	
29575	21.5	44	17.4	
29576	25.2	60	22	
Group V				
29578	27.3	52	20.0	
29579	30	45	17.8	
29580	22.5	47.0	19.1	interior mold

Family CYRTINIDAE Fredericks, 1912 [nom. trans., Stehli, 1954, (ex. Cyrtininae, Fredericks, 1912)].

Subfamily CYRTININAE Fredericks, 1912

Genus Cyrtina Davidson, 1858

TYPE SPECIES (First species auct.): Cyrtia heteroclita Defrance, 1829, Dict. Sci. Nat., v. 80, fig. 3

Cooper (1944, p. 359) gives the following diagnosis

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of this genus suitable for the present purposes.

> Spiriferoid, small to middle sized, costate, with hemipyramidal ventral valve having a long, often deformed interarea; small slightly convex dorsal valve with prominent median fold; delthyrium covered with a convex pseudodeltidium? bearing a large foramen near apex; ventral interior with spondylium, the median septum appearing as a ridge in the spondylium; dorsal interior with spire like Spirifer and having complete jugum.

Cyrtina triplicata Simpson, 1890

Plate 18, figures 2,3.

Cyrtina triplicata [nomen nudum] Simpson, G. B., 1889, Pennsylvania Second Geol. Surv., Rept. 03, pt. III, p. 257; [nomen nudum], Simpson, and Hall, James, 1889, in Lesley, J. P., Pennsylvania Second Geol. Surv., Rept. P4, v. 1, p. 181.

Cyrtina triplicata Simpson, G. B., 1890, American Phil. Soc., Trans., v. 16, n.s., p. 434-440, fig. 4 (nos. 1-5); Schuchert, Charles, 1897, United States Geol. Surv., Bull. 87, p. 199; Caster, K. E., 1930, Bull. American Paleont., v. 58, p. 19-20, pl. 9, figs. 4-12.

Although most of the generic characters are not present, two brachial valves which are surely referrable to this species are present in the collections. Simpson (1890, p. 439) gives the following description of this species:

> Shell more or less triangular, subpyramidal; hinge

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line equal to the greatest width of the shell; proportional length and width somewhat variable; length of the dorsal valve from one-half to two-thirds the width; length of ventral valve about equal to the width; height of the area greater than the length of the dorsal valve.

Ventral valve quadrilateral, subpyramical; most prominent at the beak, which is variable in elevation, straight, not arching over the area, usually attenuate; lateral margins regularly rounded. Mesial sinus narrow at the beak, rapidly widening as it extends forward, and becoming deep; where it reaches the margin the shell is produced in a conspicuous sublinguiform extension. Sides of the sinus flat, abruptly sloping, making the bottom angular. Area large, triangular, varying in height; sometimes nearly equal to the width of the shell, at other times not more than half the width; slightly oblique; striated in both directions; the longitudinal striae distinct; the vertical striae much fainter and frequently obsolete; fissure moderately narrow and closed by a convex pseudo-deltidium.

There are three or four plications on each side of the sinus, the two bounding the sinus being much more prominent than the others.

Dorsal valve semicircular or subtrigonal in outline; length from one-half to two-thirds the width. Mesial fold broad, prominent, extremely elevated in front, bounded by broader furrows than those between the plications. There are two plications on each side of the mesial fold, the two plications adjacent to the fold being much more prominent than the others; on some of the specimens nearly as prominent as the fold itself, the other two plications being obscure.

The surface of both valves is ornamented by very fine and delicate concentric striae, which are obsolete on all but the perfectly preserved specimens. There are also more conspicuous lines of growth which are most prominent on the anterior portions of the shell.

This species most closely resembles Cyrtina hamiltonensis, but may be distinguished by the two prominent plications adjacent to the medial fold; this feature will serve to distinguish it from other species of the genus at present known.

Formation and locality. Chemung group, three miles north-west of Warren, in Warren county, Pennsylvania.

DISCUSSION: Since only molds of the interior of brachial valves were found, of course no information can be given for the pedicle valves. The brachial valves agree very well with Simpson's description, however. The specimens found have the length about two-thirds the width.

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Although Simpson (p. 440) says that there are "two plications on each side of the mesial fold" in this species, his Fig. 4 (no. 4) clearly shows three, and Caster's (1930, pl. 9) Figs. 7 and 12 show three and Fig. 8 shows four. One of the specimens at hand has two and the other three plicae on each side of the fold. Both show the plicae bounding the fold as much stronger than the other lateral plications.

From the C. hamiltonensis gens C. triplicata can be told by the fewer plicae of the latter. C. triplicata Simpson resembles C. burlingtonensis Rowley but possesses a much more pronounced fold and stronger bounding plications than the latter; of the fold in C. burlingtonensis Rowley, Weller (1914, p. 289) says, "scarcely elevated above the plications on either side." C. triplicata most closely resembles C. acutirostris (Shumard) from the Louisiana limestone of Missouri. The latter species has a broader less sharp, high fold and almost universally has a slight mesial depression in the fold.

It is difficult to tell exactly what form Herrick (1888, pl. 11, fig. 20) intended when he illustrated a form from Lodi, Ohio, as C. acutirostris. Williams (1944, p. 90) has rejected it from C. acutirostris (Shumard) and it does not appear to be C. triplicata because of the greater length of the shell and higher area than in C. triplicata.

There seems little reason to believe that Cyrtina triplicata (or C. acutirostris, for that matter) belongs

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to Davidsonina Schuchert and LeVene as suggested possible for C. acutirostris by Williams (1944, p. 90).

HYPOTYPES: UCM Nos. 29853 and 29854, both molds of the interior of the brachial valve.

OCCURRENCE: Fine grained sandstone in the Tidioute shale at locality 201. This is one of Randall and Beecher's old localities and these specimens are almost surely topotypes of Simpson's specimens from the Randall collection.

Superfamily ROSTROSPIRACEA Schuchert and LeVene, 1929

Family ATHYRIDAE Waagen, 1883, [nom. transl. Davidson, 1884, (ex. Athyrinae Waagen, 1883)] (non Phillips, 1841)

Subfamily ATHYRINAE Waagen, 1883

Genus ATHYRIS McCoy, 1844

TYPE SPECIES (First sp., Auct.): Terebratula concentrica Von Buch, 1835, (K.) Acad. der Wissenschaften, Berlin, Abh., Jahrg., 1833, p. 103.

Subrostrate, biconvex, transversely subelliptical, subcircular, or subovate shells, varying from below medium size to slightly larger than medium size. Anterior commissure uniplicate to parasulcate with the fold and sulcus rather strong and extending nearly to the beaks, or the fold and sulcus may be nearly obsolete. Shell

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impunctate, usually devoid of radiating sculpture, but with distinct concentric lamellae which may become strongly lamellose or fimbriate. Beak erect or incurved, beak ridges usually indistinct, cardinal margin subterebratuloid to terebratuloid, circular foramen mesothyrid to permesothyrid or sometimes cryptothyrid, deltidial plates ususally absent. In the pedicle valve short rather stout dental plates support strong, prominent teeth which are frequently curved especially at the posterior tip. Between the dental lamellae, which do not extend anteriorly about the muscle area, passes a deep, frequently transversely striated, pedicle cavity; anterior to this lies a more or less indistinct ovate muscular area. Within this muscle area the adductor scars occupy a narrow fairly sharply defined area anteriorly, surrounded by the diductors which make a flabellate, usually more poorly defined mark. In the brachial valve broad deep sockets are borne on lateral edges of a subtriangular cardinal plate which is perforated by a dorsal foramen. The median portion of the cardinal plate may be concave, flat, or thickened irregularly until it appears convex; the lateral margins of the cardinal plate are elevated into prominent socket ridges; the crura arise at a large angle from the outer hinge plates. The depressed spiral cones of the brachidium lie base to base with the apices directed laterally; spiralia essentially conform to the curvature of the shell. The primary lamellae abruptly recurve at

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points of origin passing deep into the pedicle valve and thence into the brachial valve outside the crura, each by means of this recurvature appearing to form a loop or "noose" with its crus when seen in brachial or pedicle view. The jugum is complex being saddle shaped in its main (anterior) portion at about the middle of the shell; the posterior limb of the jugum is much narrower and rises steeply toward the umbo of the pedicle valve, bifurcates near the extremities of the crura, each branch following the curvature of the primary lamellae, thus forming narrow accessary lamellae which lie between the primary lamellae and the first band of the secondary lamellae. Each band is flattened, being wider than it is thick, with the inner edges noticeably thick and the muscle area consists of two mesial elongate areas longitudinally separated by a low ridge which does not reach the proportion of a median septum.

DISCUSSION: In Cleithyridina Buckman which closely resembles Athyris, the fimbriate extensions of the concentric lamellae are flat and smooth except at their anterior margins where each is deeply subdivided into slender, flattened, hair-like spines the bases of which, at least, are usually preserved. In Cleiothyridina the hinge plate is essentially triangular and the primary lamellae are attached to the crura not only at their apices but for a short distance along their inner faces and do not form the nooses as in Athyris.

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Contrary to an earlier tendency to refer non-lamellose species of athrids to Seminula of Hall and Clarke non McCoy (= Composita Brown), there are several differences which will separate Athyris McCoy from Composita. Brown. Dunbar and Condra (1932, p. 362) state that the dental lamella of Composita do not reach the floor of the valve but are usually evolved in heavy adventitious deposit. Composita is also characterized by a subquadrate hinge plate which posteriorly rises above the valve margin and extends into the rostral cavity of the pedicle valve. This is in contrast to the more subtriangular form of the hinge plate in Athyris. Composita has short, erect crural plates which form the inner side of the dental sockets, and also in Composita the median saddle-shaped plate of the jugum is often bilobed anteriorly.

Athyris mardiae, n. sp.

Plate 17, figures 1-12, 27, 28.

Text-figures, 17-19.

EXTERIOR: Medium to large, subelliptical Athyris. In outline the shell is markedly transverse; in end and lateral profiles the shell is shallowly lenticular, although in lateral profile ephebic or gerontic individuals are more strongly biconvex. Greatest width slightly anterior to midlength. Pedicle valve generally slightly more gibbous; the gibbosity of the pedicle valve occurs

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well posterior to midlength, generally on the umbo; but the brachial valve is more gibbous at or only slightly posterior to midlength. Anterior commissure gently uniplicate to slightly parasulcate. The broad, very gentle fold rarely becomes distinct before midlength but increases steadily in height and width anteriorly; although the fold may become quite high near the anterior margin the flanks are gentle slopes so that the total is of a broad, low fold. The sulcus a broad gentle depression beginning about midlength, is shallow thoughout, occasionally with a linguiform anterior extension. Concentric lamellae fine but pronounced, however these not known to become fimbircate or bearllamellose extensions. Weakly nodose stronger increments of growth commonly form irregularities in the shell surface. Shell also weakly capillate. Exfoliated specimens show weak, interrupted, radiating lines. Bear nearly erect to slightly incurved, beak ridges poorly defined, cardinal margins subterebratulid, subcircular foramen mesothyrid, deltidial plates unknown.

PEDICLE INTERIOR: Short, stout, slightly divergent dental plates support strong, heavy teeth which taper posteriorly. The deep pedicle cavity is generally posteriorly impressed into the shell and frequently on casts of the interior, low ridges can be seen to run along the lateral margins of this cavity at the base of the dental lamellae. The muscular area is, in general,

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poorly defined; a central, elongate adductor scar lies within a fainter, nearly circular, rather small diductor scar.

BRACHIAL INTERIOR: Sockets broad and moderately deep to receive the heavy teeth; dental socket welded tightly to side of the valve with only a suggestion of outer socket ridges developed posteriorly. Inner socket ridges strong, rounded to a broad posterior prominence but becoming lower anteriorly. Outer hinge plates concave between the inner socket ridges and the rather prominent, divergent crural bases. The median plate between the crural bases concave or nearly flat with a low indistinct process on the posterior portion. Dorsal foramen quite large, nearly circular, truncating the posterior part of the sub-triangular cardinal plate. The crura are divergent, curved toward the pedicle valve, triangular in section and very wide at their base, tapering rapidly roward their juncture with the primary lamellae. Spiralia typically athyrid; the jugum lies slightly posterior to middle, and the posterior limb rises steeply to the point of bifurcation without an initial depression toward the brachial valve. Accessory lamellae short, sickle-shaped, and apparently free terminally. Spiral cones with 15-20 bands. The muscle scars are very narrow, separated longitudinally by a very low ridge which extends about two-thirds the length of brachial valve.

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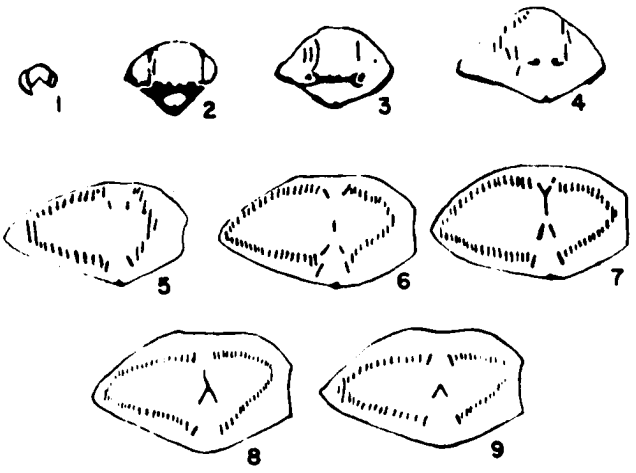

Fig. 17. - A series of cross-sections of the rostral portion of the shell of Athyris mardiae, n. sp. (approximately natural size), showing the dental plates and teeth of the pedicle valve (shown on top), cardinalia, spiralia, and weak median septum of the brachial valve. See also the reconstruction of the central portion of the spires of this species from these and other sections, Fig. 18. Note that part of the shell was broken away and that no shell appears after section 4. Distances of sections from pedicle beak: No. 1, 1.6 mm; No. 2, 3.7 mm; No. 3, 4.8 mm; No. 4, 5.4 mm; No. 5, 7.4 mm; No. 6, 9.6 mm; No. 7, 10.6 mm; No. 8, 11.2 mm (preserved as "back" of slide); No. 9, 12.9 mm (preserved as "front" of slide). Original dimensions: Length, 25.1 mm; width, 30 mm (estimated due to break); thickness, 14.3 mm. Specimen is a paratype (UCM No. 29072) from the Roystone coquinoid member of the Oswayo formation at locality 1.

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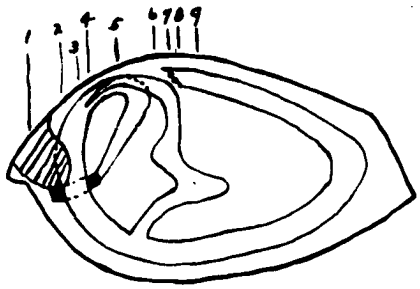

Fig. 18. - Reconstruction (X2) from serial sections of central portion of spires showing nature of jugum of Athyris mardiae, n. sp. (pedicle valve up). Numbers indicate approximate planes of sections (see Fig. 17); cross-ruled areas represent dental lamella; black area represents crus. Second band of spire (shown broken) would continue outside thin sickle-shaped accessory lamella. Reconstruction from several specimens.

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DISCUSSION: The distinctive characters (other than the pointed filling of the passage of the dorsal foramen, seen in casts, which is characteristic of the genus) are the large size, transverse shape, broad low fold and shallow sulcus. This species seems related to A. angelica Hall of the pre-Conewangoan beds through A. thrasyangelica, n. sp. (see Fig. 23), but is more uniformly transverse, larger, and lacks the rostrate appearance, and "deeply sinuate" character of A. angelica. The genital markings are not preserved even in fine material; and, in contrast, Hall (1867a, p. 292) says that the surface of "casts" of A. angelica are strongly papillose adjacent to the muscular imprints.

The disposition of A. polita Hall, whether conspecific (see Caster, 1930, p. 36) with A. angelica or not (in which case the former would have priority) remains an enigma to the writer; but in any case, A. polita does not appear represented in the collections from the Oswayo formation nor is it likely that any but a few of the small individuals of A. mardiae n. sp. could be mistaken for A. polita Hall.

TYPES: Holotype: UCM No. 29016: paratypes: UCM Nos. 29017, 29018, 29019 and 29072(slide). Figured hypotypes: UCM Nos. 29059 and 29071.

OCCURRENCE: Roystone coquinoid zone of the Oswayo formation at locality 1 and the Oswayo formation

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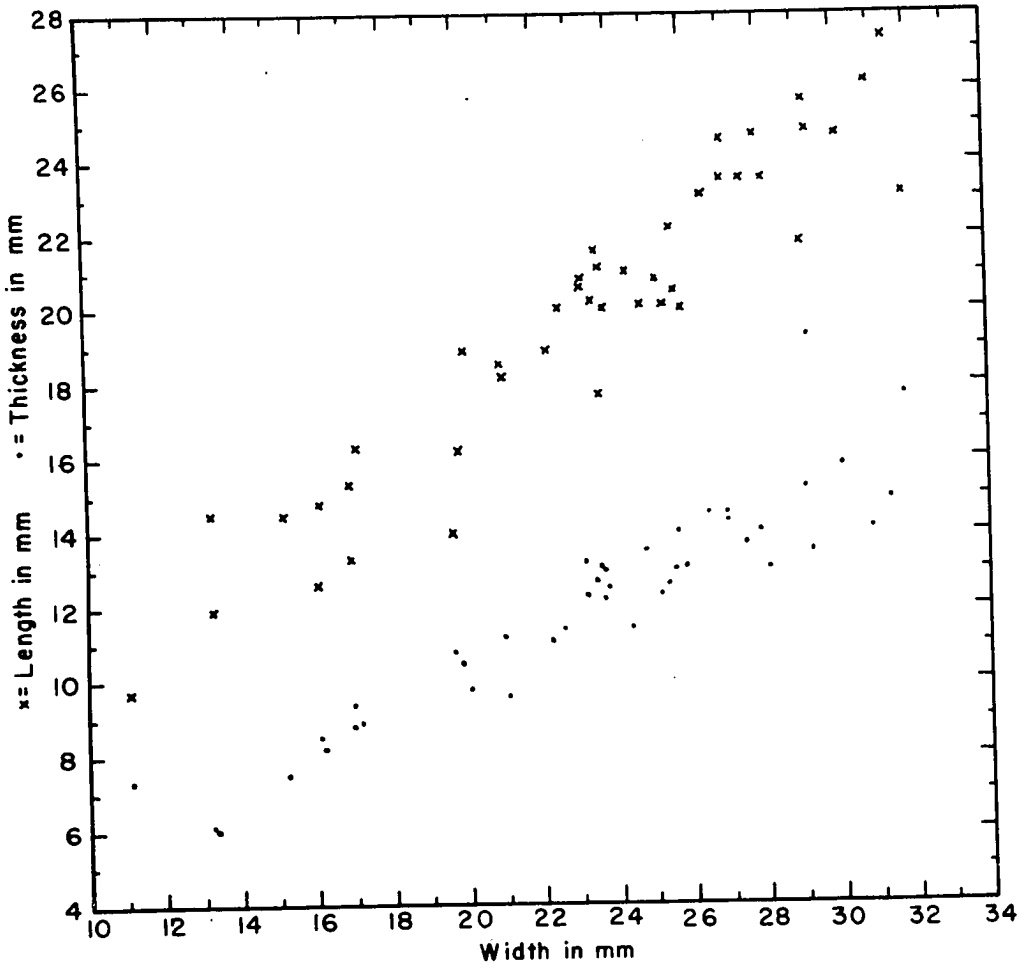

Fig. 19. - Scatter diagram of the better specimens of Athyris mardiae, n. sp. from the Oswayo formation at locality 1. Dot indicates width plotted against thickness; x indicates width plotted against length.

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at locality 60. Locality 1 is the type locality.

REMARKS: Of about 140 specimens belonging to this species approximately 75 have a portion of the original shell preserved and the rest are molds of the interior. Of approximately 180 specimens of Athyris collected from these localities, 75 percent were of this species. Dimensions of the better preserved specimens are given in the table below; most are exfoliated exteriors. A question mark (?) after a figure indicates that due to breakage an estimate has been made. An asterisk (*) indicates the specimen is laterally distorted.

This species is named in honor of my wife, Margine "Mardi" McVey Holland.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	l/w	w/t
29016	25.7?	30.1	15.8	.82	1.91
29017	20.0	22.6	11.4	.89	1.91
29018	20.2	23.5	12.7	.86	1.85
29019	24.8	29.3	13.5	.85	2.17
29020	11.9	13.3	6.0	.90	2.22
29021	14.5	13.2	6.1	1.10	2.16
29022	9.7?	11.1	5.3	.87	2.09
29023	12.6	16.1	8.5	.78	1.89
29024	20.9	23.2	12.3	.90	1.87
29025	18.2	21.1	9.6	.86	2.20
29026	16.3	17.2	8.9	.95	1.93
29027	18.9	20.1	9.8	.94	2.05
29028	14.0?	19.7	10.8	.71	1.83
29029	14.5	15.2?	7.5	.95	2.03
29030	13.2	18.0	9.4	.74	1.92
29031	15.3	17.0	8.8	.90	1.93
29032	14.8	16.2	8.2	.91	1.98
29033	18.5	21.0?	11.2	.88	1.87
29034	16.2	19.9	10.5	.81	1.89
29035	18.9	22.3	11.1	.85	2.00
29036	20.6	25.2*	13.2	.82	1.91
29037	21.6	23.8	13.1	.91	1.82

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29038	20.1	25.4	12.6	.79	2.02
29039	20.0?	25.9	13.1	.77	1.98
29040	17.7?	23.7	12.2	.75	1.94
29041	20.5	25.7	14.0	.80	1.84
29042	21.0	24.4	11.4	.86	2.14
29043	20.0	23.8	12.5	.84	1.90
29044	20.1?	24.8	13.5	.81	1.84
29045	21.1	23.7	11.0	.89	2.15
29046	23.1	26.5	14.5	.87	1.83
29047	22.5	27.0	14.5	.83	1.86
29048	20.8	25.2	12.3	.82	2.05
29049	26.1	30.9	14.1	.85	2.19
29050	23.5	27.5	12.7	.86	2.16
29051	23.5	28.1	13.0	.84	2.16
29052	24.7	27.9	14.0	.89	1.99
29053	22.2	25.6	13.0?	.87	1.97
29054	21.8	29.1	15.2	.75	1.91
29055	24.6	29.2	19.3?	.84	1.51
29056	24.6	27.0	14.3	.91	1.89
29057	22.1?	31.8	15.7	.70	2.02
29058	27.3	31.4	14.9	.87	2.11

Athyris mardiae planaria, n. subsp.

Plate 17, figures 13-18, 29; text-figure 20.

EXTERIOR: Generally larger, more transverse, and thinner than other forms of A. mardiae. Pedicle valve most gibbous high on umbo; brachial valve most gibbous posterior to midlength; usually near the umbo. Both fold and sulcus begin on the umbo but are very gentle thoughout. Linguiform extension of anterior margin of the pedicle valve rarely pronounced. Anterior commissure very gently uniplicate. Beak erect. Other external characteristics typical of the species.

INTERIOR: Interior characteristics not well known. In the few specimens at hand, it appears that the dental lamellae may be more widely divergent than is common for

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the species and the low median ridge of the brachial valve becomes obsolete about midlength.

DISCUSSION: The strongly transverse shape, the thin lateral profile and very low fold and shallow sulcus are characteristic of this subspecies.

TYPES: Holotype: UCM No. 29081. Paratypes: UCM Nos. 29082, 29083 (both unfigured) and 29084.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 1.

REMARKS: It is conceivable that dorso-ventral compression might account for the thinness, but such does not appear to be the case. Of the eight individuals only one shows signs of distortion. It is thought, rather, that this variety represents a true intrafacial variant.

In the dimension table given below a question mark (?) after the figure indicates that an estimate have been made. An asterisk(*) indicates that the shell may have been flattened.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	l/w	w/t
29081	20.1	27.1	11.2	.74	2.42
29082	21.5	27.3	12.4	.79	2.20
29083	22.6	28.3	11.2	.80	2.53
29084	16.5	20.8	9.4	.79	2.21
29085	25.2	29.2	11.2	.86	2.61
29086	21.3	27.3	11.6	.78	2.35
29087	18.2?	21.2	9.2*	.85	2.30
29088	17.9	20.0	8.8	.90	2.27

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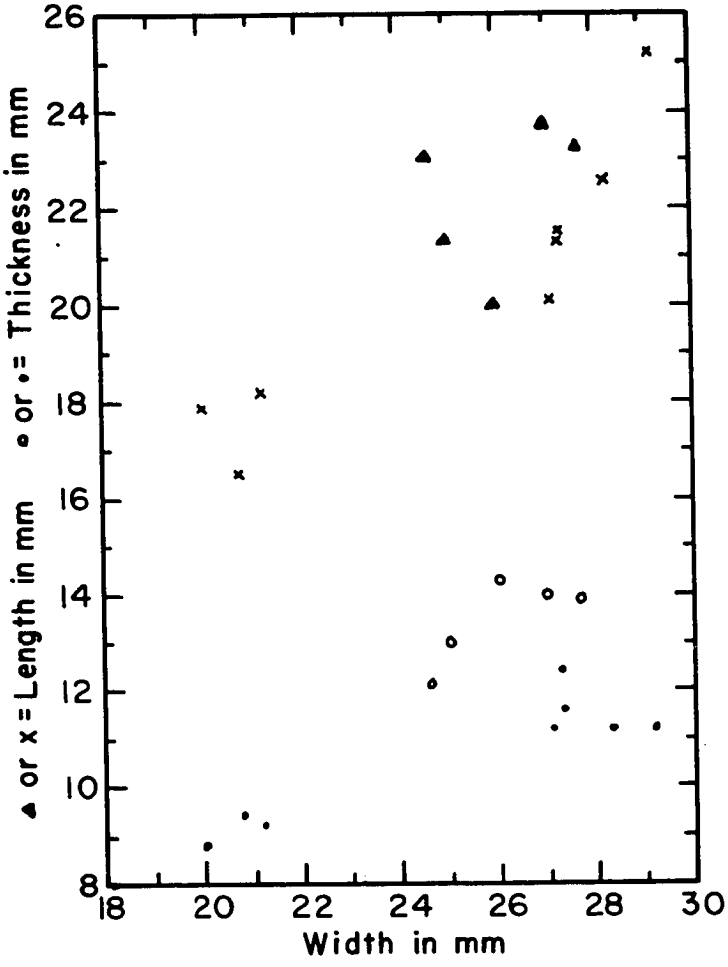

Fig. 20. - Scatter diagram of the better specimens of Athyris mardiae planaria, n. subsp. and Athyris mardiae sulcula, n. subsp. . Dot indicates width plotted against thickness and x indicates width plotted against length for A. mardiae planaria. Circle indicates width plotted against thickness and triangle indicates width plotted against length for A. mardiae sulcula.

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Athyris mardiae sulcula, n. subsp.

Plate 17, figures 19-26; text-figure 20.

DIAGNOSIS: Differing from typical *A. mardiae* principally in that the fold begins on the brachial umbo and is narrower and more pronounced anteriorly; as a corallary the sulcus is deeper and the linguiform extension of the anterior margin more marked than in forms typical of the species. Greatest width at or slightly anterior to midlength. Gibbosity of valves about equal; greatest gibbosity just posterior to midlength of each valve. Otherwise characteristics as in the typical form of *A. mardiae*, n. sp.

TYPES: Holotype: UCM No. 29089. Paratypes: UCM Nos. 29090 and 29091; unfigured paratypes UCM Nos. 29092 and 29093.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 1; sandstone in the Oswayo formation at localities 60 and 109. Locality 1 is the type locality.

REMARKS: This subspecies at hand serves to form a natural link between *Athyris mardiae*, n. sp. and *A. thrasyangelica*, n. sp (see Text-figure 23). They share their transverseness with *A. mardiae* and their greater development of fold and sulcus with *A. thrasyangelica*. From the latter they may be distinguished by their more transverse outline and their thinness. Also the greatest

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width of A. thrasyangelica is quite uniformly well anterior to the midlength

Dimensions of the better specimens referred to this subspecies are given below.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	l/w	w/t
Locality					
29089	20.1	26.0	14.3	.77	1.82
29090	23.1	24.6	12.1	.94	2.03
29091	21.4	25.0	13.0	.86	1.92
29092	23.8	27.0	14.0	.88	1.93
Locality 60					
29643	23.3	27.7	13.9	.84	1.99

Athyris thrasyangelica, n. sp.

Plate 18, figures 16-26; text-figure 21.

EXTERIOR: Medium to large, generally subpentagonal Athyris. Length about equal to width, frequently longer than wide, but in larger individuals width usually slightly greater than length. Greatest width generally well anterior to midlength. Gibbosity of the valves about equal; pedicle valve generally more gibbous, but frequently the brachial valve is slightly the more inflated. Thickness great in relation to the width. Anterior commissure parasulcate. Fold marked, arising high on the umbo even in neanic forms; fold rounded and even but pronounced and with rather steep sides. Sulcus beginning on pedicle umbo; sulcus wide, pronounced, but rarely deep; usually with long linguiform anterior extension. Concentric lamellae

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distinct but not fimbriate or with lamellose extensions. Surface distinctly capillate; capilli slightly raised into tiny nodes at junction with each varix of growth. Exfoliated specimens reveal rather well developed, fairly persistent, radiating lines. Beak rather prominent, erect to incurved, beak ridges weak, cardinal margin terebratulid, foramen permesothyrid, deltidial plates unknown.

PEDICLE INTERIOR: Like that of A. mardiae, n. sp., except that the poorly defined diductor scar is more elongate.

BRACHIAL INTERIOR: Generally like that of A. mardiae, n. sp. Crural bases heavy, occupying greater part of cardinal plate; inner socket ridges and posterior prominence less pronounced than in A. mardiae. Muscle scars somewhat impressed into shell and separated longitudinally by a low ridge of rather greater height than in A. mardiae.

DISCUSSION: The most distinctive features of this species are the large size, elongate subpentagonal shape, rather prominent beak, the pronounced fold and sulcus and the strong radiating lines of exfoliated specimens. This species seems more closely related to A. angelica Hall than the associated new species, A. mardiae; in fact, one may consider the Oswayo athyrids as lying intermediate in position between the "Chemung" A. angelica and the

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Kinderhookian form A. lamellosa Leveille

A. thrasyangelica n. sp., is generally larger than its precedessor, A. angelica Hall, the posterior slope of the former is less concave in outline, the beak less pronounced, and the concentric lamellae of the former are not known to possess lamellose extensions.

TYPES: Holotype: UCM No. 29094. Paratypes: UCM Nos. 29095, 29098, and 29109; unfigured paratypes UCM Nos. 29096 and 29097.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 1 and calcareous sandstone in the Oswayo formation at locality 60. Locality 1 is the type locality.

REMARKS: Of approximately 180 specimens of Athyris collected from locality, 25 percent are of this species. Only a few of these are molds.

Measurements of 16 whole, or nearly so, individuals of this species are given below. A question mark (?) after a figure indicates that due to breakage an estimate has been made. An asterisk (*) indicates the specimen is laterally distorted.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	l/w	w/t
Locality 1					
29094	23.1	24.7	15.4	.94	1.60
29095	24.8	25.7*	17.0	.96	1.51
29096	25.2	25.2	14.6	.99	1.75
29097	21.6	19.6	14.5	1.10	1.35
29098	10.0	9.3	5.1	1.08	1.82

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29099	20.4	20.8	12.5	.98	1.66
29100	25.1	26.5?	17.9	.95	1.48
29101	25.2	24.9	16.3	1.01	1.53
29102	17.6	15.7?	9.9	1.12	1.59
29103	24.5	27.3?	17.2	.90	1.59
29104	22.1	23.8	14.7	.93	1.62
29105	23.0	23.1	13.7	1.00	1.69
29106	24.8?	26.0	15.9	.95	1.64
29107	22.9	24.7	15.0	.93	1.65
29108	20.2	21.5	12.2	.94	1.76
Locality 60					
29645	27.9	30.1	18.7	.92	1.61

Athyris thrasyangelica magna, n. subsp.

Plate 18, figures 27-33; text-figure 21.

DIAGNOSIS: Differing from typical A. thrasyangelica in extreme thickness of the valves, the heavy growth increments near the anterior commissure, and the more transverse nature of the outline. The prominent fold and sulcus are squarish anteriorly rather than evenly rounded as in other Oswayo athyrids.

TYPES: Holotype: UCM No. 29113. Paratype: UCM No. 29114.

OCCURRENCE: Roystone coquinoid member of the Oswayo formation at locality 1 and calcareous sandstone in the Oswayo formation at locality 60. Locality 1 is the type locality.

REMARKS: Six specimens of this form are at hand. Length/width and width/thickness ratios and the pro-

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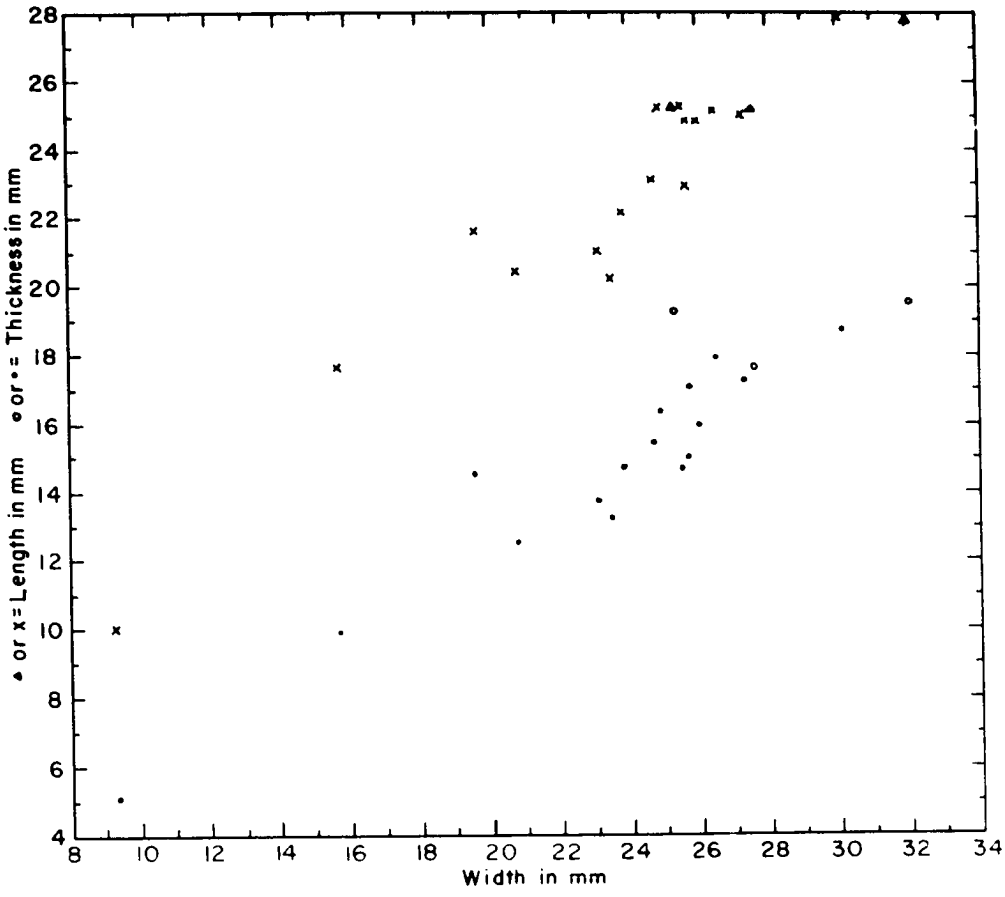

Fig. 21. - Scatter diagram of the better specimens of Athyris thrasyangelica, n. sp., and Athyris thrasyangelica magna, n. subsp. Dot indicates width plotted against thickness, and x indicates width plotted against length for A. thrasyangelica. Circle indicates width plotted against thickness, and triangle indicates width plotted against length for A. thrasyangelica magna.

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minent fold and sulcus ally this variety with A. thrasyangelica n. sp., rather than the transverse A. mardiae, n. sp. It is possible that further collecting and study may prove that this form is composed merely of gerontic individuals of A. thrasyangelica.

Dimensions of better specimens of this form are given below. A question mark (?) after a figure indicates that due to breakage an estimate has been made.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	l/w	w/t
Locality 1					
29113	27.8	32.0	19.5	.87	1.64
29114	25.2?	27.6	16.6	.91	1.66
Locality 60					
29646	25.2	25.3	19.2	1.00	1.32

Athyris minuta, n. sp.

Plate 18, figures 4-14; text-figure 22.

EXTERIOR: Small, lenticular, subcircular to subelliptical Athyris. In end profile the shell is lenticular; but in lateral profile the lenticular form is not so apparent since the greatest thickness is considerably posterior to midlength. Convexity of the valves about equal with the greatest convexity of each valve occuring well posterior to midlength. Anterior commissure weakly uniplicate. Weak fold and sulcus apparent only in anterior one-third of the valve. Shell surface completely smooth except for very fine concentric growth

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increments. Beak suberect to nearly erect, beak ridges absent, cardinal margins subterebratulid; foramen apparently circular, mesothyrid; deltidial plates unknown.

PEDICLE INTERIOR: Dental lamellae very slightly divergent, short and thin but supporting stout teeth. The elongate pedicle cavity extends far posteriorly between the dental plates; floor of cavity slightly raised by secondary callist deposited by the adjustor muscles. Other muscle scars unknown.

BRACHIAL INTERIOR: Sockets moderately deep with outer socket ridge apparently lacking. Outer hinge plates concave between low inner socket ridges and moderately prominent crural bases. Dorsal foramen large, penetrating the posterior portion of the cardinal plate. Crura and brachidia unknown. A very low, thin, median ridge is present in the umbonal cavity below the cardinalia but never extends more than one-fourth to one-third the length of the valve. The muscle scars are very narrow and tightly appressed to this ridge.

DISCUSSION: The distinctive characteristics seem to be the small size, lenticular form, smooth exterior and the faint fold and sulcus coupled with internal athyroid characters. In external form A. minuta n. sp., closely resembles Cleiothyridina tenulineata (Rowley) especially as figured by Weller (1914, pl. 80, figs. 1-12) but the latter has spines arranged in regular series which

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give the shells the appearance of radial costellae as clearly shown on Weller's figures. Examination with the binocular microscope under high power of both specimens and matrix removed from the exterior of the shells of A. minuta failed to reveal any sign of lamellose growth extensions, radial lines, or spines.

From Athyris vittata Hall and its varieties as as described by Stainbrook (1942, p. 616-617), A. minuta n. sp., differs in its smaller size, less pronounced fold and sulcus, and lack of imbricating growth lamellae. Though A. minuta is about the same size as A. zonulata Stainbrook from the Cedar Valley beds, the latter has a more pronounced fold delimited by lateral depressions and it also possesses extensions of the growth laminae. A. minutissima, described by Webster (1888, p. 1015) from the "lower portion of Rockford Shales Juniper Hill" is said to be only about 3 mm long, have "equidistant imbricating lines', and lack a fold and sulcus. The writer could find no record of this tiny species other than the original unillustrated description.

A. minuta n. sp., is smaller than any of the adults of species of athyrids from the Oswayo formation, but it is conceivable that young of Athyris mardiae, n. sp. might be confused with adults of A. minuta if divorced from the matrix and placed side by side. A. minuta is much less gibbous than A. polita Hall and is more transverse than this species.

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One or more yet undescribed species of Athyris (see Caster, 1930, pl. 18) from the Corry sandstone on Cobham Hill east of Warren, Pennsylvania, are easily told from A. minuta by the greater gibbosity, size and more pronounced fold and sulcus of the former. Although Caster (1930, p. 35) placed Simpson's (1890, p. 442) Meristella incerta in synonomy with his "Athyris angelica" it is possible that Simpson's types will be found to be from the Corry material. In any event Simpson described his species as having a depression bounding the fold and having "radiating striae." There are lacking in these in A. minuta.

The relation of A. minuta, n. sp., to described Mississippian athyrids is not known. Apparently this species was derived by diminution of characters from A. mardiae, n. sp., of the Oswayo but has no known descentents. The Corry athyrids are similar to A. mardiae; but no species in this lineage, which was seemingly distinct from that of A. minuta is known from the Knapp strata.

TYPES: Holotype: UCM No. 29760. Paratypes: UCM Nos. 29761, 29762 (all partially exfoliated exteriors). Figured hypotype: UCM No. 29824.

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97.

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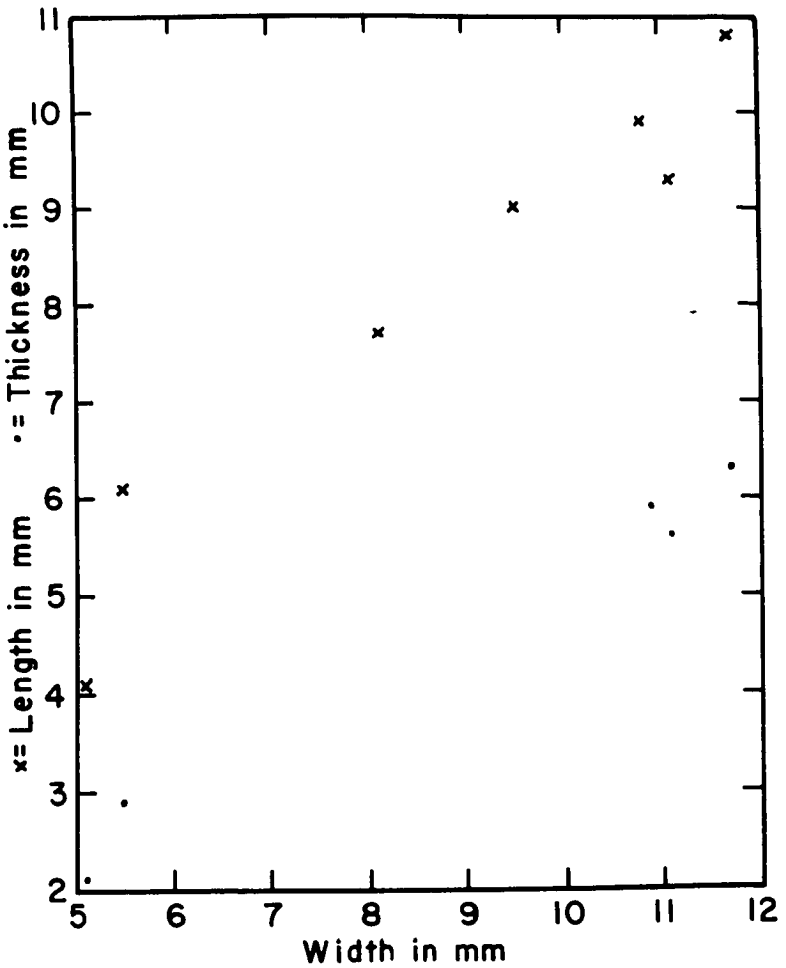

Fig. 22. - Scatter diagram of the better preserved specimens of Athyris minuta, n. sp., from the Marvin Creek coquinoid zone of the Kushequa shale at locality 97.

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REMARKS: This species is represented by five partially exfoliated exteriors of the conjoined valves, three separate valves and one mold of the interior. Measurements of the better specimens are given in the following table.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	l/w	w/t	Remarks
29760	10.8	11.8	6.3	.92	1.86	
29761	9.9	10.8	5.9	.92	1.83	
29762	9.3	11.1	5.6	.84	1.98	
29763	9.0	9.5	-	.95	--	Pedicle valve
29764	7.7	8.1	-	.95	--	Valves gaping
29765	6.1	5.5	2.9	1.11	1.90	
29824	4.1	5.1	2.1	.80	2.43	

Athyris sp. indeterminate

Plate 18, figure 1.

Four molds of the interior of the pedicle valve of an athyroid brachiopod are present in the collections from the lower Syringothyris zone of the Knapp at locality 118. They are about the size of a small Athyris mardiae, n. sp., from the Oswayo formation, but apparently lack a sulcus in the pedicle valve. Moreover, three of the specimens are unusual in that the lateral cavities are nearly filled with the deposition of secondary calcite so that the dental lamellae are all but obscured. The dental lamellae however are set much closer to the midline than in the Oswayo forms, leaving but a narrow passage for the pedicle. One of the specimens has the

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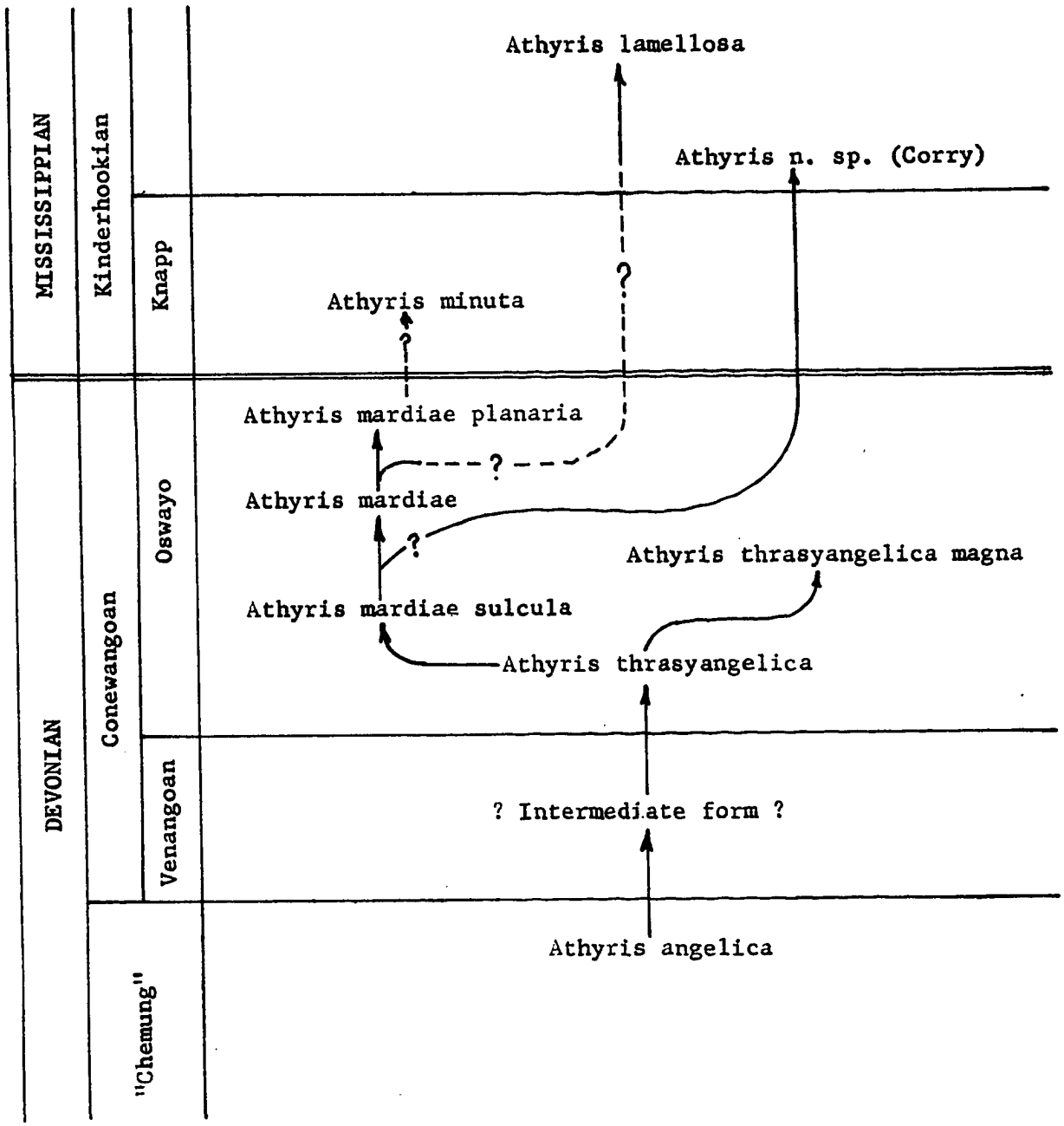

Fig. 23. - Suggested relationships of some Upper Devonian and Lower Mississippian species of Athyris based on morphologic similarity.

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muscle scars deeply set into the shell just anterior to the farthest extent of the dental lamellae. Between the is a peculiar raised boss which is terminated anteriorly by the hoofed-shaped adductor muscle scar. Three of the specimens show pits of the genital markings throughout almost the entire shell.

The fourth specimen, which is much smaller, is apparently different; it has very thin delicate dental lamellae which extend anteriorly only a short distance into the interior. Otherwise the interior is smooth except for very faint centrally located longitudinal muscle markings.

These intriguing specimens do not seem referrable to any previously described species, but are yet too poorly preserved to admit accurate description.

FIGURED SPECIMEN: UCM No. 29964.

OCCURRENCE: Lower (first) Syringothyris zone of the Knapp formation at locality 118.

Family RHYNCHOSPIRINIDAE Schuchert, 1894 [nom. trans. Schuchert and LeVene, 1929 (ex. Rhynchospirinae Schuchert, 1894)].

Subfamily RHYNCHOSPIRININAE Schuchert, 1894

Genus Proeumetria, n. gen.

TYPE SPECIES: Proeumetria acroria, n. sp.: Knapp formation,

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Lower Mississippian, northwestern Pennsylvania.

ETYMOLOGY: Greek prefix pro-, before; plus Eumetria.

EXTERIOR: Rostrate, medium-sized, subovate, endopunctate shells. Valves subequally convex with the convexity of the pedicle valve slightly greater; brachial valve with flattish zone or weak, poorly defined fold, and pedicle valve bearing weak sulcus. Shell pauciplicate with broad rounded or subrounded plicae extending from beak to commissure. Beak erect or nearly so; cardinal margin terebratuloid; beak ridges indistinct or absent. Foramen large, circular, permesothyrid; and the triangular delthyrium is closed by endopunctate conjunct deltidial plates.

PEDICLE INTERIOR: Moderate-sized to heavy teeth arise from the sides of the valve; dental plates are lacking; genital marking and muscle scars unknown or absent.

BRACHIAL INTERIOR: The hinge plate is heavy and connects the heavy, elongate, unsupported sockets. The posterior portion of this plate is crescentic with the lateral horns of the crescent directed posteriorly. The cardinal process is a sharp ridge which arises from the anterior arc of the crescent and runs the length of the hinge plate, decreasing in height anteriorly. Parallel to this ridge the crural bases traverse the length of the hinge plate, decreasing in height anteriorly.

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Parallel to this ridge the crural bases traverse the length of the hinge plate on its lateral margins. From the edge of the hinge plate the crura rise rapidly to give rise to the laterally directed spiralia high in the pedicle valve. The jugum arises anteromedially on simple limbs to a saddle which sends a posteriorly forked process high in the pedicle valve to a position near the end of the crura. The crura are unsupported, and there is no median septum proper but in some specimens a very low ridge extends one-fourth the length of the valve. Muscle marks unknown or absent.

DISCUSSION: This genus is very near to Eumetria; however there are certain differences which allow the two to be separated readily. Still the relationship is close enough to permit interpretation of Eumetria (a later Mississippian form) as having evolved directly from Proeumetria. The form figured by Weller (1914, pl. 76, figs. 7-10) and Cooper (1944, pl. 141, figs. 35-37) as Eumetria altirostris (White) most likely belongs to this genus. This is discussed under the description of the type species.

The distinction between Eumetria Hall and Proeumetria n. gen., most readily apparent is the coarser more rounded and less numerous plicae of the latter. The fold is also slightly more pronounced in Proeumetria and the brachial valve of this genus lacks the auriculations

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of the posterior margin of Eumetria. The interior of the pedicle valve is like that of Eumetria, but it is in the brachial valve that the greatest distinctions lie. First, Proeumetria lacks crural lamellae and lamellae for support of the hinge plate; secondly, the anterior portion of the hinge plate could scarcely be called "spoon-shaped" (Hall and Clarke, 1893, p. 116; Weller, 1914, p. 437) for the axial ridge is apparently more pronounced in Proeumetria and extends farther forward. Thirdly, the jugum is entirely different since it does not extend anteriorly on slender bands from the point of origin on the posterior part of the primary lamellae, but instead rises on sturdy supports from the primary lamellae even a bit anterior to the middle; it is saddle-shaped rather than being slender bands. Lastly, the spires of Proeumetria have 12 or 13 bands in adult forms, rather than the eight or nine of Eumetria.

In molds of the interior of the type species of Proeumetria a cylindrical callous deposit lining the foramen is evident; this appears as a slightly elevated rim on the exterior. At first it was thought that this might represent the pedicle tube or pedicle sheath spoken of by Hall and Clarke (1893, p. 119) in Acambona White such as is present in Hustedia Hall and Clarke (see Hall and Clarke, 1893, p. 121, and Dunbar and Condra, 1932, p. 355, 357). However in Proeumetria this deposit is very short on the interior of the valve; it does not come to lie against the interior of the deltidial plates

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nor is it split on the interior side. Also Acambona White has vastly more and finer plications, apparently more pronounced increments of growth and is larger and differently shaped than either Eumetria Hall or Proeumetria. Little is known of the interior of Acambona White, although Hall and Clarke (1893, p. 120) place it rather closer to Hustedia Hall and Clarke than to Eumetria Hall. Concerning Acambona the writer agrees with Weller (1914, p. 448): "Until further information concerning the genus can be secured it seems best to allow it to stand with the genotype as the single representative . . . ."

RANGE: Kinderhookian series, Mississippian; eastern United States.

Proeumetria acroria, n. sp.

Plate 16, figures 9-17, text-figures 24, 25.

EXTERIOR: Shell medium-sized, subovate, valves subequally convex. Convexity of the pedicle valve slightly greater than that of the brachial valve; greatest convexity of the pedicle valve obtained well posterior to the middle; that of the brachial valve about the middle or slightly posterior to it. Greatest width anterior to midlength. The pedicle valve is rather evenly arched transversely with the lateral slopes only somewhat steeper than the middle, but the lateral slopes of the brachial valve are much steeper than the middle part. From the

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point of greatest convexity the median line of each valve becomes increasingly arcuate posteriorly, but the curvature gradually decreases toward the front. In juvenile specimens the anterior commissure is nearly straight being marked only by the low plicae, but in adult forms the brachial valve bears a broad, low, gentle fold which becomes distinct only in the anterior third of the valve; the pedicle valve has an even less pronounced sulcus. The plicae are distinct from beak to commissure increasing gradually in size toward the front; they are subrounded, rounded or even flattish anteriorly, especially near the middle of the anterior margin; axial one or two plicae stronger than the others. Number of plicae variable, being from 11 to 21 but the most common number is 13; occasionally a plication, smaller than those on either side, is intercalated about midlength and near the midline of the valve and continues to the anterior margin. Beak suberect to erect; beak ridges poorly defined or absent; foramen large, circular, permesothyrid with a slightly raised lip; cardinal margin terebratuloid, brachial valve not auriculate. Delthyrium nearly an equilateral triangle and closed by conjunct deltidial plates each of which is slightly concave. Growth lines visible but never promenent; shell minutely and closely endopunctate; puncta apparantly arranged in interrupted concentric rows but this can rarely be ascertained.

PEDICLE INTERIOR: Teeth generally heavy, elongate,

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and unsupported; complete cylindrical callous lining foramen and extending slightly into pedicle valve; muscle scars and genital markings unknown or absent.

BRACHIAL INTERIOR: Sockets elongate, moderately deep, and with heavy walls to receive the heavy teeth. Posterior part of the hinge plate produced posteriorly into a crescentic process, the upper suface of which describes nearly a perfect semicircle; from the posterior crescent lying supine against the walls of the pedicle valve, an axial ridge extends downward and nearly to the anterior edge of the hinge plate. Anterior part of hinge plate consists of a long narrow process traversed longitudinally by three ridges: the axial ridge and on the lateral edges of the crural bases. The crura rise sharply to unite with the primary lamellae high in the pedicle valve; crural supports not present. Spiral cones each with 13 volutions; bands thin, but thicker on outside edges and thinning markedly inward. Jugum arises anterior to midlength on sturdy limbs inclined posteriorly; central portion shaped like an inverted U with an axial crest or ridge, then declining posteriorly to a narrow band only to rise again as a heavy forked process which extends nearly to the junction of the crura and primary lamellae. No true median septum; but a low ridge extending from under the hinge plate to near the midlength of the brachial valve, is commonly present. Muscle marks unknown or absent.

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DISCUSSION: The specific and generic characteristics of this species are inextricably interwoven at this status of knowledge. The only other species seemingly referrable to Proeumetria is that described by White (1862, p. 28) as Retzia (Acambona?) altirostris. Weller (1914, p. 439) assigned White's species to Eumetria and said of this assignment:

> Neither the characters of the brachidium nor the peculiar characters of the hinge of Eumetria [peculiar internal characters of Proeumetria would have been fully as apt] have been observed in this species, and unless individuals in a different condition of preservation than those at hand are secured at some future time, there can be no hope of certainly determining the generic relations of the species.

While it is entirely possible that Proeumetria altirostris (White) and P. acroria are conspecific (but not likely that either properly belongs to Acambona or Eumetria), it would seem ill-advised to make White's altirostris the type of Proeumetria and thus to found a new genus on a species the interior of which is unknown, when specimens with both internal and external characteristics well displayed are so readily available. Considering the conditions and the distance separating the Penn-York Embayment and Burlington, Iowa, there is little reason to believe that the time Weller spoke of has arrived and to use White's long established but little known species as the type species.

Moreover, there are features which would indicate that P. altirostris (White) is specifically distinct from P. acroria. In the holotype and most of the specimens

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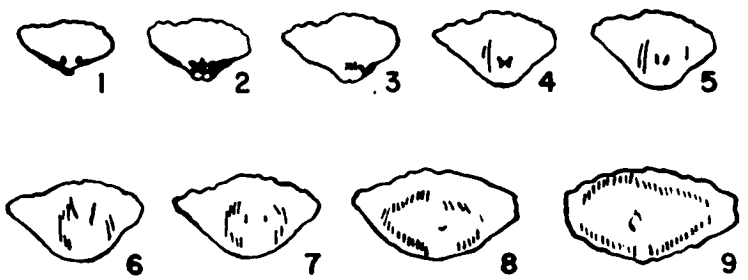

Fig. 24. - Serial sections of Proeumetria acroria, n. gen., n. sp. (natural size), showing the teeth and spiralia of the brachial valve. Note that the outer shell is mostly broken away and appears only in the first three sections. The spiralia are tipped within the shell so that the right side (viewer's left) appears more complete throughout, and the primary lamella is shown as broken from the right crus in section 6. After the last section shown here, the crest of the jugum becomes shaped like an inverted U, and then the limbs of the jugum descend anteriorly to join the first band. Distances of sections from the pedicle beak; No. 1, 4.1 mm; No. 2, 5.0 mm; No. 3, 5.7 mm; No. 4, 6.2 mm; No. 5, 6.7 mm; No. 6, 7.6 mm; No. 7, 8.2 mm; No. 8, 11.0 mm; No. 9, 15.0 mm. Original dimensions: length, 28.4 mm (beak slightly broken but not materially affecting length), width, 25 mm (estimated); thickness, 11.6 mm. Specimen is a paratype from the Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation, locality 97; UMC No. 29653. These may be compared with sections of Eumetria vera (Hall) in Campbell (1957, p. 84, fig. 23).

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of the latter, the plicae are less in number, coraser, and have wider interspaces than in P. altirostris. White (1862, p. 28) indicates 20 to 22 plicae for this species and 17 or 18 can be counted on Weller's figures (pl. 76, figs. 7, 11). Also P. acroria generally has a stronger fold and sulcus than P. altriostris.

There is considerable variability in the number of plicae in P. acroria, however, and this seems to be in some extent ecologially controlled. The number of plicae on the brachial valve were counted on the better preserved specimens at three localities with the results shown in the following table.

Locality	Number of Individuals	Number of Plicae
97	1	16
	1	15
	4	14
	10	13
	3	12
	6	11
	1	10
175	2	21
	1	20
	2	18
	1	17
51	1	21
	2	20
	3	18
	1	17
	1	15

The number of plicae on the brachial valve per individual is summarized for these 40 specimens in the table below.

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Total Number of Individuals	Number of Plicae
10	13
6	11
5	18
3	20
4	14
3	12
3	21
2	17
2	25
1	16
1	10

These data show the mean number of plications to be 15. It can be seen that almost universally specimens preserved as exteriors in Marvin Creek coquinoid zone in the Knapp formation from locality 97 have fewer plicae than specimens from localities 175 and 51, all of which are molds of the interior preserved in fine grained sandstone.

The mean average length/width ratio of 12 well preserved specimens is 1.22. Length and width for the better preserved specimens are plotted as a scatter diagram in Fig. 25.

TYPES: Holotypes UCM No. 29650. Paratypes: UCM Nos. 29651, 29653 (sections cut and slide made), (exfoliated exteriors); 29661 (slightly crushed sandstone molds of the interiors).

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97; sandstone in the Kushequa shale at localities 51, 166, and 175; sandstone in the Tidioute formation at locality

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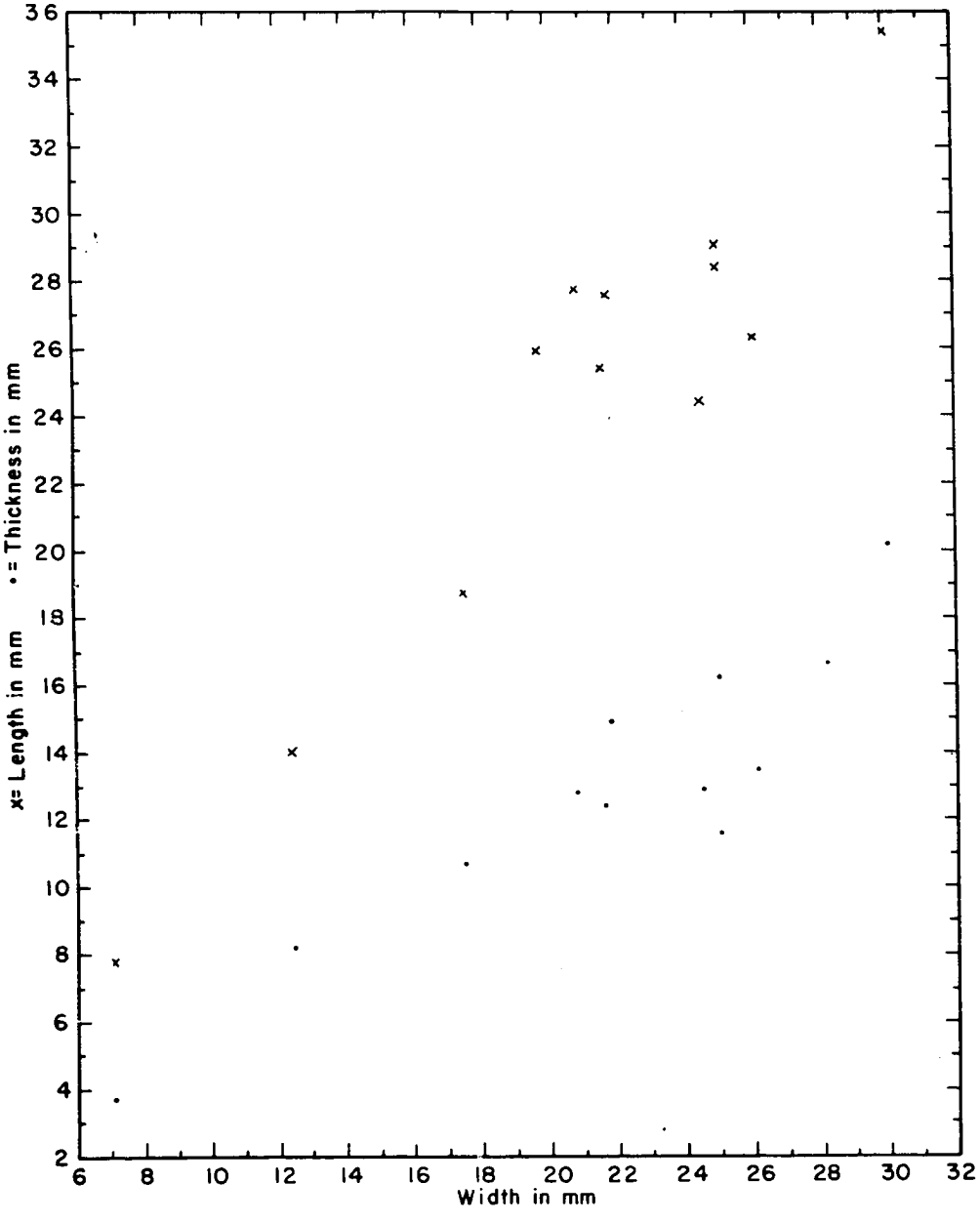

Fig. 25. - Scatter diagram of the better specimens of Proeumetria acroria, n. gen., n. sp., from the lower Knapp formation of northwestern Pennsylvania.

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201 (one brachial valve questionably referred to this species although more likely a new species). Locality 97 is the type locality.

REMARKS: This species is represented in the collections by 12 reasonably complete exteriors, numerous fragmental exteriors and single valves and 2 broken molds of the interior from locality 97; 8 molds of the interior from locality 175; and numerous molds of the interior (only two of which show the conjoined valves reasonably complete) from locality 51.

Some of the rock fragments from locality 97 have Proeumetria acroria n. sp., in all sizes in association with Syringopleura casteri, n. sp., Schuchertella desiderata (Hall and Clarke) and Camarotoechia mimelegantula, n. sp., so closely packed as to form a coquinoid. Virtually all of the specimens, including the molds show evidence of closely spaced endopuncta. Dimensions of the better specimens are given below; an asterisk (*) indicates that an estimate has been supplied for broken specimens in lieu of actual measurement.

UCM No.	Length (mm)	Width (mm)	Thickness (mm)	l/w	w/t
Locality 97					
29650	29.1	25.0*	16.2	1.16	1.54
29651	25.4*	30.0	20.2	1.18	1.48
29652	18.7	15.5	10.7	1.21	1.45
29653	28.4*	25.0*	11.6	1.14	2.16
29654	26.2	26.1	13.5	1.00	1.93
29655	14.0	12.4	8.2	1.13	1.51
29656	7.8	7.1	3.7	1.01	1.92

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Locality 175					
29664	27.7	20.8	12.8	1.33	1.63
29665	25.4	21.6	12.4	1.18	1.74
29666	25.9	19.7	--	1.31	--
Locality 51					
29669	25.6	21.8	15.9	1.17	1.46
29670	24.4	24.5	12.9	1.00	1.90

INCERTAE SEDIS

Brachiopod undetermined

Plate 18, figure 15.

DESCRIPTION: Small, subcircular, wider than long, plano-convex (?) with greatest width near the midlength and with rounded cardinal extremities. Area virtually lacking; beak prominent, shell impunctate. The brachial valve appears to be crushed inward, but it bears about six weak plicae and a median depression (?). Pedicle valve with greatest convexity posterior to the midlength, with weak plicae and lacking a sulcus. Lateral flanks very weakly concave. Interior unknown.

DISCUSSION: In general contour this small specimen resembles Plectospira sexplicata (White and Whitfield) as figured by Weller (1914, pl. 76, figs. 35-37), but it lacks the punctate shell, biconvexity, and brachial fold and pedicle sulcus of that form. It is also reminiscent of Metaplasia pyxidata (Hall) from the Lower Devonian of New York (cf. Cooper, 1944, pl. 126, figs. 40-43) but this shell is not known above the Onondaga. It is possible that

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it is a crushed Hustedia Hall and Clarke, but again the lack of a punctate shell militates against this assignment.

It seems more likely to the writer that this form is a juvenile spiriferoid or an unknown genus.

OCCURRENCE: Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97.

REMARKS: The measurements of this specimen are:

UCM No.	Length (mm)	Width (mm)	Thickness (mm)
29899	4.6	5.1	1.9

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APPENDIX A

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APPENDIX A

REVIEW OF GATINAUD'S EXTERNAL MORPHOLOGY METHOD OF STUDYING SPIRIFERID BRACHIOPODS

Introduction

In a series of papers published in 1949, G. Gatinaud outlines a method of studying and classifying the Spiriferidae based on the plications of the sulcus, and proposes a hierarchy within the Spiriferidae based on his method. He calls his technique (p. 153) "a method of sinal diagrams and formulas". The method is not entirely new, as Gatinaud asserts, for it was pioneered by Grabau who said (1931, p. 209):

> Among the characters which have not previously received the attention which they merit, is the nature and appearance of the sinal plications of the pedicle valve, to which in the brachial valve, corresponds the grooving of the fold. These features have a definite morphological value and may easily assume the first rank among the variable morphic structures.

The method was utilized in part by Huang (1933), Chang (1934), Tien (1938), and Semikhatova (1941). In addition, Gatinaud uses some of the concepts which Bancroft (1945) employed in studying the Dalmanellacea. Gatinaud had been developing the plan for his statistical method for some time as is intimated in his earlier

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papers (1947 and 1948).

Figure A1, below, is a typical sulcus diagram of Tenticospirifer canaliferus (Lamarck) with Gatinaud's method of plical notation.

The "sinal" diagram is a schematic representation of the sulcus; the two straight borders represent the plications which bound the sulcus, and the curved line represents the portion of the anterior commissure within the sulcus. The plicae of the sulcus are represented by straight lines; heavy lines indicate the primary or most pronounced plicae and finer lines the other plicae. Only in the case of the primaries does the width of the line have any correlation with the prominence of the plication; the primaries are, in fact, virtually always the most prominent throughout their length, but the prominence of the other ribs varies from specimen to specimen. Usually those secondary ribs which arise nearest the beak are strongest, but no attempt is made to portray this in the diagrams.

It may be noted that Gatinaud reversed the morphologic right and left,-- an error that persists throughout his analyses. One should remember that the right and left sides lie to the right and left, respectively, of the organism when it is oriented with the anterior facing the same way as the observer. Further the animal has only one right side and one left side no matter the direction from which it is viewed. Hence the diagram of

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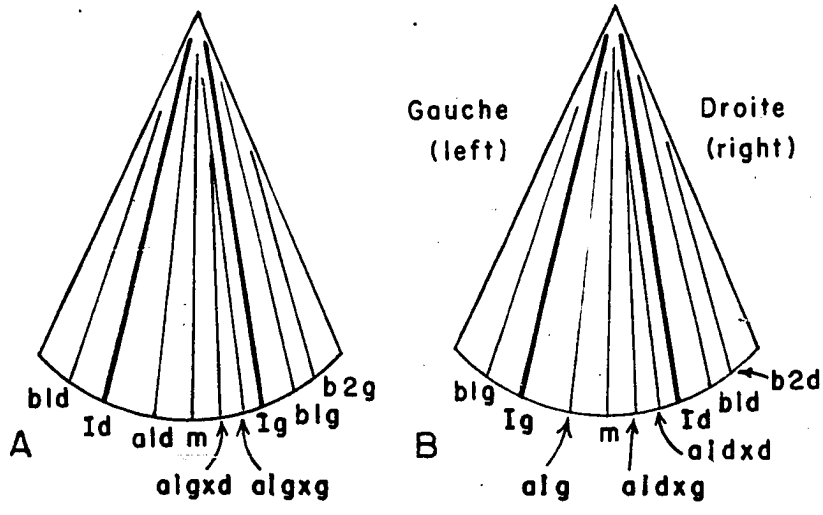

Fig. A1. - Sinal diagram of type specimen of Tentico-spirifer canaliferus (Lamarck) illustrating systems of plical notation. A - System as given by Gatinaud, 1949; B- relettered according to Gatinaud's system, but notation corrected to correlate with morphologic right and left. According to the notation system developed by Grabau, the formula of this spiriferid would be; 1 + I + 1 + 1 + 1x + I + 2; according to the Bancroft system it would be I)m)a1)blg)bld)algx)b2g.

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the sulcus (on the pedicle valve) of Tenticospirifer canaliferus (Lamarck) is shown in Fig. A1-B with the corrected rib designations of Gatinaud and Bancroft.

The French terms droite and gauche might have been translated to right and left, and r. and l. correspondingly employed for d. and g in the formulas, but this would have changed completely the appearance of a formula and would have merely added additional hieroglyphics, hence the terms droite (right) and gauche (left) are retained but in their correct morphologic usage.

In forms where the primaries are divergent and divide the sulcus into three parts as in Tenticospirifer, Cyrtospirifer and other spiriferid genera, the sulcus is said to be triplicate (triplissé). In forms with the primaries subparallel, that is when they come to lie very near the axis, the sulcus is termed dupliplicate (dupliplissé). Finally a type is distinguished in which there is a single median primary rib which divides the sulcus into two sections; this type is called uniplicate (uniplissé).

The primaries are the first ribs to appear in ontogeny and are designated by I by Grabau, Bancroft, and Gatinaud. Bifurcations of the ribs were designated by Grabau as x and intercalated ribs as y; other ribs were not given a definite designation (see formula of Grabau, figure 1) but were simply counted. Gatinaud

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modified Bancroft's method of designation and adapted it to the Spiriferidae. One of Gatinaud's principle additions to Bancroft's system was the designation of d (droite - right) and g (gauche - left) to Bancroft's designations, thus rendering the terminology more specific. In this manner each rib has its own particular designation.

Gatinaud's Method of Rib Resignation (corrected)

The Gatinaud system of rib designation (right and left corrected) is as follows: primary ribs are designated I; the one to the right is Id, the one to the left Ig. The median rib is designated by the letter m. In the median section the other primitive ribs (strong ribs arising, generally near the beak, in succession) are designated by the letter a and numbered in succession, a1, a2, a3, etc. going from the primary rib toward the axis of the sulcus in the order of their appearance; those to the right of the axis are a1d, a2d, a3d, etc. and those to the left a1g, a2g, a3g, etc. Intercalary ribs of the first order are ay, more precisely, ay1 for those which intercalate between the primaries and a1, ay2 for those which lie between a1 and a2, etc. Those to the right are ay1d, and ay2d, etc.; while those to the left are ay1g and ay2g, etc. The intercalary ribs of the second order are designated an, more

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precisely, anla for those between ayl and al, an2a between for those which lie between ay2 and a2, etc. All bifurcations in the median section are designated by ax; if al bifurcates it will be called alx, if ayl should bifurcate it is to be called aylx, etc. The right branch of a bifurcation is designated by the letter d and the left by g. In the example (see Fig. A1-B) ald bifurcates and its right and left branches are then called aldxd and aldxg respectively.

In the lateral sections of the sulcus the primitive ribs are designated by the letter b and enumerated bl, b2, etc. going from the primary ribs outward toward the bordering ribs, in the order of appearance. The various notations bld, b2d, b2g, byld, bnlad, bnlbd, bldx, byldx, etc. are applied as appropriate following the principles expressed above.

In the formulas themselves ribs or bifurcations which appear on different levels are separated by the sign,), which, according to Gatinaud, represents "a real or theoretical growth line." Those which appear on the same level are separated by a comma. If two ribs of the same order appear on the same level, it is not necessary to write, for example: ald, alg; it is sufficient to unite the two ribs under the designation al since they obviously belong to the same pair. One should refer (for an example) to the Bancroft-Gatinaud formula for Tenticospirifer canaliferus (Larmack) under Fig. A1.

Gatinaud states that it is not in the Bancroft formulas, themselves, that the interest resides, for they

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are merely a means to an end. But the formulas, he says, since they express exact relationships of the plicae, can be used in statistical computations. For groups within the Dalmanellacea, Bancroft determined the proportion of case in which a certain rib appeared before a certain other rib for his entire suite of individuals; he then expressed these proportions as classes of percentage (Table A1) As an example, b2)m : 70 means that the rib (or a pair of ribs) b2 appears before the median rib (m) in 70 per cent of the individuals counted. Sometimes the class notation is used alone; as in the example, b2)m : H1.

TABLE A1 - Classes of Percentages of the Order of Rib Appearance (from Bancroft, 1929, Table 1, p. 187)

66-100 percent	H	H3	88-100
		H2	77-88
		H1	66-77
33-66 percent	M	M3	55-66
		M2	44-55
		M1	33-44
0-33 percent	L	L3	22-33
		L2	11-22
		L1	0-11

Gatinaud states that the successions which are interesting to compare in the Spiriferidae are: b2)m; b2)a2; b3)a2; b3)a3.

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Gatinaud's Statistical Method

Gatinaud uses the rib designations outline, above, in a series of computations which compares the relative time of development or dichotomy of the various ribs. As the various computations are explained herein under Gatinaud's subtitles, his formulas are given, but examples are not given within the text; instead the reader should refer to Table A2 which is an analysis made by the writer of Cyrtospirifer lonsdalii mut. ✓ Grabau from Grabau's (1931) diagram. Then as an example, these data are inserted in Gatinaud's formulas and the various calculations made.

It should be fairly stated that a very large number of typographical errors exist in the French text; a number of these were caught, presumably by M. Gatinaud, and corrected in ink in the reprint at hand (from the library of Dr. K. E. Caster) but an inordinate number persist. The present writer opened the papers at random and found 12 errors (p. 411) - nine in formulas (corrected by Gatinaud), one in a table, one misspelling, and one ommission of brackets in a formula.

While it is to be admitted that the typesetter was confronted with a most difficult task in reproducing the Greek letters and complex mathematical symbols, one gains the impression that something prevented M. Gatinaud from reading the galley proofs. Part of the mistakes are

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in Greek letters, part in mathematical signs and part are errors in the French text and in zoological names. The present writer has taken the liberty of eliminating these errors wherever they were discovered; hence the following exposition does not conform to the "letter" of Gatinaud's text but it is hoped that the spirit is retained.

Stages of appearance and of bifurcation.-- The "level" at which a rib appears is called its appearance stage (échelon d'apparition) and is numbered from the beak; thus in the specimen of Tenticospirifer canaliferus (Lamarck) (Fig. A1) the primary ribs appear at step one, the median at stage two, the ribs al at step three, etc. A table of the stages of appearance of the ribs of each individual studied is set up, and one determines for each rib its arithmetic mean stage of appearance to the nearest half unit. The mean stages are designated by the letter e and certain of these will enter into the following calculations.

The stage of bifurcation (échelon de bifurcation) of a rib is the level at which the rib bifurcates. The mean bifurcation stage (designated by the Greek letter ϵ) is defined as the difference of the means of appearance stages of the bifurcations and the means of appearance stages of the ribs plus1; thus:

$$\epsilon(alg) = e(algx) - e(alg) + 1$$

It can readily be seen that since the mean appearance stage of the primary ribs is usually one, the general

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rule for (I) is:

$$\epsilon(I) = e(Ix)$$

Compatibility of ribs of the sectors of the sulcus. -- One works in the following manner. Count the number, α, of primitive ribs; the number, αx, of bifurcation (i.e. the number of ribs added by bifrucation); the number, αy, of intercalated ribs. These are added to obtain the total number, A, thus $\alpha + \alpha x + \alpha y = A$. Both real and incipient bifurcations are united under αx and both secondaries and tertiaries are included in αy.

In the lateral sectors one counts the number of primitives, β; the number βx, of bifurcations, the number, βy, of intercalaries, and the total number, B, thus $\beta + \beta x + \beta y = B$.

Then one counts the total number, δ, of the primaries and primitives in the sulcus; the number, δx, of bifurcations; the number, δy, of intercalaries; and the total number of ribs in the sulcus is Δ, thus $\Delta = \delta + \delta x + \delta y$.

It is evident that in the uniplicate species $\delta = \beta + 1$, and in the triplicate species $\delta = \alpha + \beta + 2$. In dupliplicate species, in general, $\alpha = 1$; hence in dupliplicate forms $\delta = \beta + 3$. The number, δx, is obtained by adding to the sum, $\alpha x + \beta x$, the number of bifurcations of the primaries. Finally, one may note that $\delta y = \alpha y + \beta b$.

The total number of ribs on the wings is designated Γ. E is the total number of plicae on the pedicle valve,

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$E = \Gamma + \Delta$; and the difference, Z, is obtained by subtracting Δ from Γ: $Z = \Gamma - \Delta$.

The arithmetic means of these various notations may be obtained by adding the counts for the number of individuals considered and then dividing by that number; the mean is designated by a subscript m; thus α and its mean, α_m, β and β_m, δ and δ_m, Δ and Δ_m, Γ and Γ_m, E and E_m, Z and Z_m.

Ratios may be set up, the most interesting of which are, according to Gatinaud:

$$\frac{\beta_m}{\alpha_m}, \frac{B_m}{\beta_m}, \frac{B_m}{\alpha_m}, \frac{\delta_m}{\alpha_m}, \frac{\Delta_m}{\alpha_m} \text{ and } \frac{E_m}{Z_m}.$$

Concerning these ratios Gatinaus makes the following statement (p. 303-304):

> I have been able to assure myself by the consideration of the species of Sinospirifer subextensus Martelli studied by Grabau that the ratios $\frac{B_m}{\beta_m}$ and $\frac{\Delta_m}{\delta_m}$ are practically independent of the age of the individuals, which is a criterion to assure oneself that the specimens which one considers as young of a species are really good. The other ratios depend a little on the age of the individual; but provided one considers exclusively, or nearly so, adults, the ratios $\frac{\beta_m}{\alpha_m}$, $\frac{\delta_m}{\alpha_m}$ and especially $\frac{\beta_m}{\alpha_m}$ [sic[1]] and $\frac{\Delta_m}{\alpha_m}$ have systematic value. As for the ratio $\frac{E_m}{Z_m}$ which has for a value $\frac{\Gamma_m + \Delta_m}{\Gamma_m + \Delta_m}$ [sic[2]], it is interesting if it is equal to 1, when $\Delta = 0$, that is to say,

---

[1]Undoubtedly means $\frac{B_m}{\alpha_m}$ here, since $\frac{\beta_m}{\alpha_m}$ has just been mentioned.

[2]In reality: $\frac{\Gamma_m + \Delta_m}{\Gamma_m - \Delta_m}$.

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when the sinus is smooth; consequently if a species has a high $\frac{E_m}{Z_m}$, one should hold it to be evolved; if the $\frac{E_m}{Z_m}$ is low, in the neighborhood of 1, one must consider that the species is archaic, regressive, or neotenic.

Indices of appearance and of bifurcation. -- Gatinaud was able to separate Tenticospirifer and Hunanospirifer on the basis of the compatibility of the ribs, but states that this does not permit discrimination between the genera Sinospirifer and Cyrtospirifer. He therefore evoked a new criterion, the indices of appearance (indices d' apparition) He calls the indes of appearance of the ribs bl the variable ibl.

$$1(bl) = \frac{\beta_m \times e(bl)}{e(m) + e(al) + e(bl)}$$

In like manner the index of appearance of the rib b2 is: $i(b2) = \frac{\beta_m \times e(b2)}{e(m) + e(al) + e(bl)}$

Considering the indices of bifurcation he calls the index of bifurcation (y)of a rib, the quotient of $\frac{\Delta_m}{\delta_m}$ divided by the mean stages of bifurcation for that rib. Thus the primaries, the median, and the ribs bl have the following formulas for the indices of bifurcation respectively:

$$y(1) = \frac{\frac{\Delta_m}{\delta_m}}{e(1)} \; ; \; y(m) = \frac{\frac{\Delta_m}{\delta_m}}{e(m)} \; ; \; y(bl) = \frac{\frac{\Delta_m}{\delta_m}}{e(bl)} .$$

These seem to be discrete quantities, says Gatinaud, and are considered as specific characteristics.

Counter indices of appearance. -- In studying Cyrtospirifer lonsdalii (Murchison) in which Grabau

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distinguished three mutations which he called ν, ϕ, and χ, Gatinaud noticed that mutation ν gives appearance indices too high in proportion to mutation ϕ. Since he also noted that mutation ν has a Γ_m much higher than ϕ and that in several species Γ_m varied directly as the indices of appearance, he decided to call these the counter indices of appearance (contre-indices d'apparition). He defines partial counter indices and total counter indices. The partial counter indices are the quotients of the means of Γ divided by the indices of appearance; thus the counter index of appearance of the ribs b1 is $ci(b1) = \frac{\Gamma_m}{i(b1)}$ and that of the ribs b2 is $ci(b2) = \frac{\Gamma_m}{i(b2)}$. The total counter index is the sum of the partial indices $cit = ci(b1) + ci(b2)$.

Modules of bifurcation. -- He calls the absolute module of bifurcation (μ) the difference between the sum of the mean stages of appearance of the ribs b1 and their first bifurcation:

$$\mu = [e(mx) + (m)] - [e(b1x) + e(b1)]$$

The module of bifurcation is, in short, a manner for comparing the behavior of the ribs m and b1; μ is positive when the ribs b1 bifurcate quicker than the median and negative when m bifurcates before b1.

He calls the relative module of bifurcation (μ') the quotient of the absolute module over the total of mean stages of appearance of the primaries and of their

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primary bifurcations:

$$\mu' = \frac{\mu}{e(Ix) + e(I)}.$$

This variable, he states, has a real systematic value and permits, in particular the separation in the genus Theodossia Nalivkin, the two subgenera Theodossia s. s. and Platyspirifer Grabau*.

Quotients of appearance. -- He defines the appearance quotient of a rib as the quotient of the difference of the main stages of appearance for that rib and the first bifurcation over the sum of the same mean stages. Thus, the median has for an appearance quotient:

$$qm = \frac{e(mx) - e(m)}{e(mx) + e(m)}$$

One also has:

$$q(mx) = \frac{e(mxx) - e(mx)}{e(mxx) + e(mx)}$$

and:

$$q(Ix) = \frac{e(Ixx) - e(Ix)}{e(Ixx) + e(Ix)}$$

---

*Gatinaud gives a table of μ and μ' for Tentico-spirifer and Hunanospirifer and in speaking of the figures in this table he says:

> . . . dont ceau de gauche sont calculés à partir des valeurs des échelons moyens d'apparition obtenues en première analyse at ceux de droit à partir des valeurs des mêmes échelons corrigées après rectification des indices de bifurcation.

The writer, however, has not been able to ascertain for sure how to make this correction.

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In the forms with a uniplicate sinus (q(mx) is lost in q(Ix). Corrections are applied as in the bifurcation modules. These variables, except of q(mx) are not significant in themselves, but they serve in the following calculations.

Perquotients of appearance and of bifurcation. -- Gatinaud defines the perquotient of appearance of a rib as the quotient of the appearance quotient of a rib over the index of appearance of the ribs bl. Thus the rib has for a perquotient of appearance (perquotient d'apparition),

$$p(m) = \frac{q(m)}{1(bl)}$$

Likewise the perquotient of bifurcation of a rib is the quotient of the quotient of appearance of its first bifurcation over the index of bifurcation of the said rib. Thus the median has for a perquotient of bifurcation:

$$\pi(m) = \frac{q(mx)}{y\ (m)}$$

In like manner the primaries give:

$$\pi(I) = \frac{q(Ix)}{y\ (I)}$$

In uniplicate forms $\pi(m)$ is lost in $\pi(I)$. The same corrections are applied as above.

Logarithmic Indices of Appearance. -- He calls the simple logarithmic index of appearance of the ribs of the sinus the product of the total counter indices times the logarithm of the sum of the perquotient of appearances of the median and the perquotient of the bifurcation of

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the primaries multiplied by 100:

$$\lambda = \text{cit} \times \log 100 \left[p(m) + \pi(I)\right]$$

He calls the compound logarithmic index of appearance the product of the logarithm of the simple logarithmic index times the logarithm of the ratio $\frac{E_m}{Z_m}$:

$$\lambda' = \log \lambda + \log \frac{E_m}{Z_m} .$$

Log 100 $\left[p(m) + \pi(I)\right]$ is recommended to be taken to five decimal places and the other logarithms to only two decimal places.

Logarithmic Quotient of Appearance. -- The logarithmic quotient of appearance of the median is defined as the quotient of the logarithm of 100 times the perquotient of bifurcation over the logarithm of the ratio

$$\chi(m) = \frac{\log 100\, \pi(m)}{\log \frac{E_m}{Z_m}}$$

In the forms with uniplicate sinus $\chi(m)$ becomes $\chi(I)$.

Systematic Essay. -- With the aid of the mass of date "without doubt of unequal value", Gatinaud sets up a "still fragmentary systematics" for the Spiriferidae; but since the definitions in this classification are principally numerical results of calculation, the detailed systematics are not elaborated herein. One new genus, Deothossia, with the type species Spirifer (Sinospirifer) anossofioides Grabau (1931) and several new subgenera are proposed.

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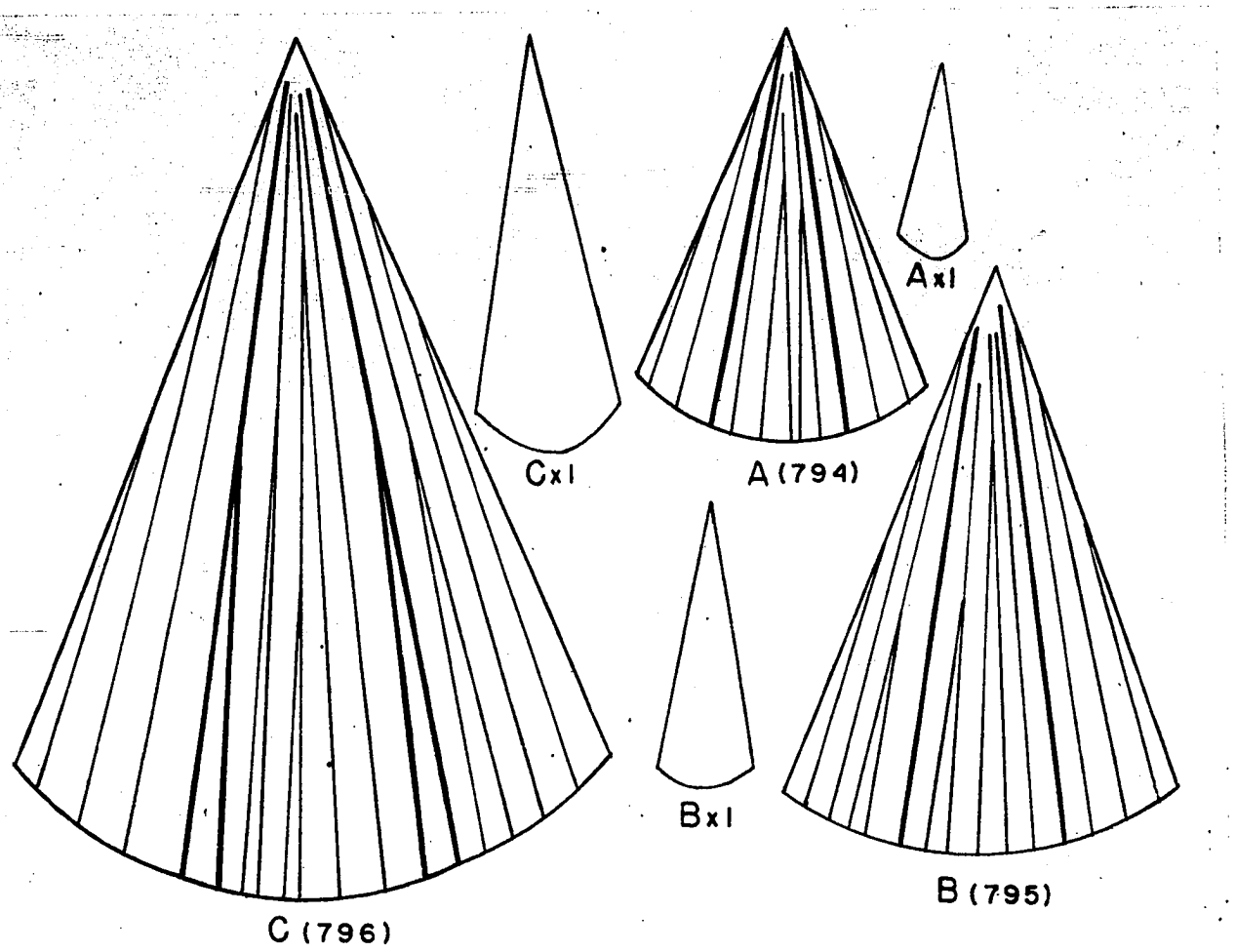

Figure A2. - Diagram of the sulcus of three specimens of Cyrtospirifer lonsdalii mut. ✓Grabau (from Grabau, 1931, Fig. 18 A-C). Outlines of sulcus natural size; diagrams showing plicae enlarged; length x2, basal width x4.

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Sample Calculation

As an example of Gatinaud's statistical method the present writer made an analysis of the ribs of the sulcus of Cyrtospirifer lonsdalii mut. ∨ Grabau, 1931, from Grabau's illustrations (Figs. 18A, 18B, and 18C, p. 222). Grabau's diagrams are drawn here (Fig. A2) for the reader's convenience. The calculations for this analysis are given below and the results are given in Tables A2 and A3.

$$\frac{\beta_m}{\alpha_m} = \frac{5.33}{3} = 1.78$$

$$\frac{B_m}{\beta_m} = \frac{6}{5.33} = 1.13$$

$$\frac{B_m}{\alpha_m} = \frac{6}{3} = 2.00$$

$$\frac{\gamma_m}{\alpha_m} = \frac{10.33}{3} = 3.44$$

$$\frac{\Delta_m}{\gamma_m} = \frac{13.67}{10.33} = 1.32$$

$$\frac{\Delta_m}{\alpha_m} = \frac{13.67}{3} = 4.56$$

$$i(b1) = \frac{\beta_m \times e(b1)}{e(m) + e(a1) + e(b1)} = \frac{5.33 \times 2}{2.5 + 2 + 2} = \frac{10.66}{6.5} = 1.639$$

$$i(b2) = \frac{\beta_m \times e(b2)}{e(m) + e(a1) + e(b1)} = \frac{5.33 \times 4}{2.5 + 2 + 2} = \frac{21.32}{6.5} = 3.28$$

$$\epsilon(I) = e(Ix) = 8$$

$$y(I) = \frac{\frac{\Delta_m}{\alpha_m}}{\epsilon(I)} = \frac{4.56}{8} = .570$$

$$\epsilon(m) = [e(mx) - e(m)] + 1 = [6 - 2.5] + 1 = 4.5$$

$$y(m) = \frac{\frac{\Delta_m}{\alpha_m}}{\epsilon(m)} = \frac{4.56}{4.5} = 1.103$$

$$\epsilon(b1) = [e(b1x) - e(b1)] + 1 = [7.5 - 2] + 1 = 6.5$$

$$y(b1) = \frac{\frac{\Delta_m}{\alpha_m}}{\epsilon(b1)} = \frac{4.56}{6.5} = .703$$

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$\Gamma_m = 70$ (Gatinaud, 1949, p. 307)

$$ci(b1) = \frac{\Gamma_m}{i(b1)} = \frac{70}{1.639} = 42.7$$

$$ci(b2) = \frac{\Gamma_m}{i(b2)} = \frac{70}{3.28} = 21.4$$

$$cit = ci(b1) + ci(b2) = 42.7 + 21.4 = 64.1$$

$$\mu = [e(mx) + e(m)] - [e(b1x) + e(b1)] = [6 + 2.5] - [7.5 + 2] =$$

$$8.5 - 9.5 = -1$$

$$\mu' = \frac{\mu}{e(Ix) + e(I)} = \frac{-1}{8+1} = \frac{-1}{9} = -.111$$

$$q(m) = \frac{e(mx) - e(m)}{e(mx) + e(m)} = \frac{6 - 2.5}{6 + 2.5} = \frac{3.5}{8.5} = .412$$

$$q(mx) = \frac{e(mxx) - e(mx)}{e(mxx) + e(mx)} = \frac{9 - 6}{9 + 6} = \frac{3}{15} = .200$$

$$q(Ix) = \frac{e(Ix) - e(I)}{e(Ix) + e(I)} = \frac{8 - 1}{8 + 1} = \frac{7}{9} = .777$$

$$p(m) = \frac{q(m)}{i(b1)} = \frac{.412}{1.639} = .2512$$

$$\pi(m) = \frac{q(mx)}{y(m)} = \frac{.200}{1.013} = .1974$$

$$\pi(I) = \frac{q(IX)}{y(I)} = \frac{.777}{.579} = 1.363$$

$$\lambda = cit \times \log 100 [p(m) + \pi(I)] = 64.1 \times \log 100 [.251 + 1.363]$$

$$= 64.1 \times \log 100 [1.614] = 64.1 \times \log 161.4 = 64.1 \times 2.20790$$

$$= 119.53$$

$$\lambda' = \log \lambda \times \log \frac{E_m}{Z_m} = \log 1.488 = 2.08 \times .172 = 3.58$$

$$\chi(m) = \frac{\log 100 [\pi(m)]}{\log \frac{E_m}{Z_m}} = \frac{2.0 \times .1974}{.172} = \frac{.395}{.172} = 2.29$$

Critique of Gatinaud's Method

In order to check farther Gatinaud's technique, his method was applied (as above for mutation ν) by the present writer, to Grabau's three mutations (ν, ϕ, and χ)

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TABLE A2 - Appearance stages and mean appearance stages of Cyrtospirifer lonsdalii mut. ? Grabau. All figures by the present writer from Figs. 18A-C of Grabau (1931)

	Ig	Id	m	b1g	b1d	a1g	a1d	b2g	b2d	b3g	b3d	mx	Igx	Idx	b1gx	b1dx	a1gx	a1dx	mxgx
#794 Fig. 18A	1	1	3	2.5	3	2	2	4	4			4.5							
#795 Fig. 18B	1	1	2	2	2	3	2	3.5	3.5	6	6	4			7		7	6	
#796 Fig. 18C	1	12.5		1.5	1.5	1.5	1.5	4	4			4.5	8	8		8	8.5		9
Totals	3	37.5	6		6.5	6.5	5.5	11.5	11.5	6	6	17	8	8	7	8	15.5	6	9
No. Specimens	3	3	3	3	3	3	3	3	3	1	1	3	1	1	1	1	2	1	1
Means	1	12.5	2	2	2	2	2	4	4	6	6	6.5	8	8	7	8	8	6	9

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TABLE A3. - Compatibility of the ribs of Cyrtospirifer lonsdalli mut. ∨ Grabau. All figures determined by the present writer from Figs. 18A-C and Table 54 of Grabau (1931)

	α	αx	αy	A	β	βx	βy	B	δ	δx	δy	Δ	Γ	E	Z
#794 Fig. 18A	3	1		4	4			4	9	1		10	60	70	50
#795 Fig. 18B	3	2		5	6	1		7	11	3		14	70?	84?	56?
#796 Fig. 18C	3	3		5	6	1		7	11	6		17	80	97	63
Totals	9	6		14	16	2		18	31	10		41	210	251	169
No. Specimens	3	3		3	3	2		3	3	3		3	3	3	3
Means	3	2		4.67	5.33	1		6	10.33	3.33		13.67	70	84	56

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TABLE A4. - Appearance stages and mean appearance stages of Cyrtospirifer lonsdalii mut. ∅ Grabau and C. lonsdalii mut. X Grabau. All figures determined by the present writer from Figs. 18E-G and 18H of Grabau (1931)

MUTATION ∅	Ig	Id	m	b1g	b1d	a1g	a1d	b2g	b2d	b3g	b3d	b4g	b4d	mx	b1gx	b1dx	a1gx	a1dx	by1g	by1d
#797 Fig. 18E	1	1	4	1	2	4	2	2	3	4	5	6	7	9	7	7				
#798 Fig. 18F	1	1	3	1.5	1.5	2	2	4	4					8						
#803 Fig. 18G	1	1	2	2	2	2	2	4	4					3.5	7	7	3.5		7	7
Totals	3	3	9	4.5	5.5	8	6	10	11	4	5	6	7	20.5	14	14	3.5		7	7
No. Specimens	3	3	3	3	3	3	3	3	3	1	1	1	1	3	1	1	1		1	1
Means	1	1	3	1.5	2	3	2	3	4	4	5	6	7	7	7	7	3.5		7	7
MUTATION X																				
#799 Fig. 18H	1	1	3	1	2	2	2	3	4					10						

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TABLE A5. - Compatibility of the ribs of Cyrtospirifer lonsdalii mut. ∅ Grabau and C. lonsdalli mut. χ Grabau. All figures determined by the present writer from Figs. 18E-G and 18H and Table 54 of Grabau (1931)

MUTATION	∝	∝x	∝y	A	β	βx	βy	B	∂	∂x	∂y	Δ	Γ	E	Z
#797 Fig. 18E	3	1		4	8	2		10	13	3		16	58	74	42
#798 Fig. 18F	3	1		4	4			4	9	1		10	42	52	32
#803 Fig. 18G	3	2		5	4		2	6	9	2	2	13	36	49	23
Totals	9	4		13	16	2	2	20	31	6	2	39	136	175	97
No. Specimens	3	3		3	3	1	1	3	3	3	1	3	3	3	3
Means	3	1.3		4.3	5.3	2	2	6.7	10.3	2	2	13	45	58	32
MUTATION															
#799 Fig. 18H	3	1		4	4			4	9	1		10	23	33	13

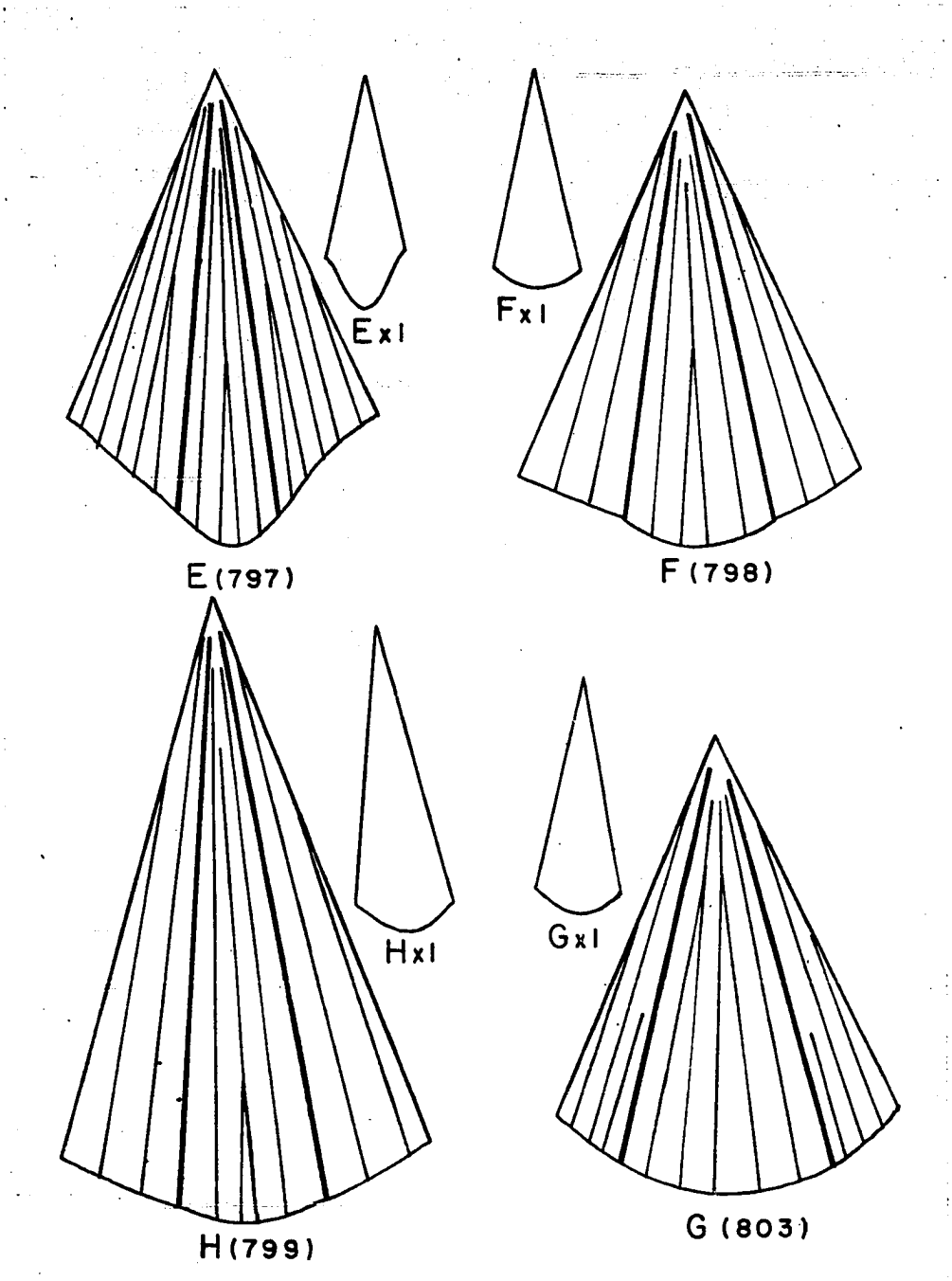

Fig. A3. - Diagrams of the sulcus of three specimens (E-G) of Cyrtospirifer lonsdalii mut. ϕ Grabau and one specimen (H), C. lonsdalii mut. χ Grabau (from Grabau, 1931, Fig. 18 E-G, and H). Outlines of sulcus natural size; diagrams showing plicae enlarged; length x2, basal width x4.

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of Cyrtospirifer lonsdalli (Murchison). The appearance stages and compatibility of ribs were determined from Grabau's Fig. 18 A-C (mut. ν), 18 E-G (mut. ϕ) and 18 H (mut. χ). The results are tabulated herein as Tables A2 and A3 (mut. ν), and Tables A4 and A5 (mut. ϕ and mut. χ). Grabau's diagrams are reproduced as Fig. A2 (mut. ν) and Fig. A3 (mutations ϕ and χ).

Since Gatinqud (1949, p. 307) had given a table of some of his results on these same specimens from the same source in the course of explaining the counter indices of appearance, it was possible to make a direct comparison of the results of two workers from data obtained from the same specimens. The two sets of results are compared in Table A6.

TABLE A6. - Comparison of results of two workers from data obtained from the same source

MUTATION	WORKER	$\frac{\beta_m}{\alpha_m}$	$\frac{\Delta_m}{\alpha_m}$	Γ_m	i(b1)	i(b2)	ci(b1)	ci(b2)	cit
C. lonsdalii	Gatinaud	2.00	4.56	70	1.87	3.20	37	22	59
mut. ν Grabau	Holland	2.00	4.56	70*	1.64	3.20	43	21	64
C. lonsdalii	Gatinaud	2.22	4.33	44	1.27	2.79	35	16	51
mut. ϕ Grabau	Holland	2.22	4.33	44*	1.62	3.20	30	14	44
C. lonsdalii	Gatinaud	1.33	3.33	46	0.77	2.31	60	20	80
mut. χ Grabau	Holland	1.33	3.33	46*	0.92	2.16	49	21	70

* The value of Γ_m (arithmetic mean of total number of plications outside the sulcus) given by Gatinaud (1949, p. 307) was accepted in these computations.

It will be seen from examination of Table A6 that the results for the ratios for the compatibility of the ribs check exactly, for these are dependent only upon counting the number of ribs accurately. However, as soon as date involving appearance stages are introduced it can

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be seen that wide variances are produced.

It appears to the present writer that this must always be so, for no quantitative way of ascertaining the appearance stage of a rib on a certain specimen is given by Gatinaud. It is a relatively easy matter for several workers to be in agreement at "appearance stages" 1,2, or 3; but above 3 the determination of the "level" at which a rib appears amounts to "guesstimation." As an example, let us consider a hypothetical individual in which the primaries appear at 1; a1 and b1 appear shortly - stage 2, and the median very soon thereafter - stage 2½. Let us say this takes place within 4 mm of the beak. Then let us assume no changes are introduced until the median bifurcates 30 mm from the beak, this bifurcation taking place 5 mm from the anterior margin of the valve. What value are we to assign to mx - 7 perhaps, or 8, or 9, or 10? The wirter can discover no way to make this assignment from Gatinaud's papers. One might suggest, here, introducing measurement into the appearance stages to make them quantitative instead of subjective.

Until further investigation proves otherwise the writer will remain convinced that any computation involving the "appearance stages" must be subjective. One researcher may be consistent with his estimations of appearance stages so that he can make adequate correlations with his own figures, but it is difficult to see how the results of various workers can be compared. If this be true, then the systematic value of Gatinaud's method is negated.

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Gatinaud's taxonomic system also contains internal inconsistencies. He places Cyrtospirifer lonsdalii (Murchison) and C. verneuili (Murchison) in the subsection Cyrtospirifer s. s., section Cyrtospirifer, s. s., subgenus Cyrtospirifer s. s., genus Cyrtospirifer. He then gives as a partial characterization of his subgenus Cyrtospirifer s. s.: i(b1) 1.2 - 1.65 and 1(b2) 2.4 - 2.84. Yet (see Table A6) Gatinaud himself gives i(b1) 1.87 and 1(b2) 3.2 for mut. ν of C. lonsdalii.

Mayhap the present writer is reactionary, but it is difficult to reconcile oneself to see such a diagnosis (quoted below; brackets are Gatinaud's) of a new genus as Gatinaud (194, p. 488) gives for his new genus Deothossia.

> Genre Deothossia nov. g.
> Genotype: Spirifer (Sinospirifer) anossofioides Grabau 1931.
> Aréa basse, étroite et peu arquée, bourrelet proéminent; côtes arrondies.
> β_m/α_m : 1 à 3; Δ_m/α_m : 5 à 9; i(b1): 0,84 à 1,12; i(b2): 2,72; cit: 57; μ' : - 0,9 à -0,92 [-0,91 à - 0,93] ; p(m): 0.29 à 0,51 [0,29 à 0,51] : λ (I) : 0,36 à 0,98 [0,38 à 0,93]; λ : 120 [119] ; λ : [sic] 0,67 [0,67] ; q(mx): 0,27 à 0, 29 [0, 27 à 0,29]; χ (m) : 5 à 11,5 [4,97 à 11,5].
> (Les chiffres isolés sont exclusivement ceux de D. anossofioides).
> Espèces: (Gr) anossofioides Grabau; (Gr) vicarii Pellizzari.

In this critique it might be well to mention again the typographical erros and to warn the research worker to use due caution in utilizing Gatinaud's papers.

The writer familiarized himself with Gatinaud's method in hopes that he might be able to use the statistics of sulcus ribs in differentiating between groups within

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within the "Cyrtospirifer disjunctus" gens in the Oswayo formation (Upper Devonian) of southwestern New York and northwestern Pennsylvania. Twenty-six specimens from two localities were studied; but it was found that, due to imperfect preservation, ⌐ could not be determined with any certainty and hence the calculations could not be completed. It was found, however, that the diagrams, formulas, and the stages of appearance of the ribs were of some use in grouping the variations found with the gens complex.

One may well ask if such criteria as difference in patterns of the ribs of the sulcus are valid generic and subgeneric characters. To the writer it seem that the answer is emphatically yes--IF, through use and practice it is found that these characters are consistently useful. Systematists should beware of arbitrarily declaring what are suprageneric, generic or specific characters and then not examining other features of morphology. Surely rib patterns are not mere decoration, but may in this group or that one possess systematic value. Greiner (1957, p. 17-18) has said, however:

> The plications of the shell are said to be a result of the organization of the mantle, which evolves parallel to the internal calcareous structures, hence is considered to be of prime importance. This is open to question, it seems to me, for the generally prominent costae on the sides of a spirifer certainly do not follow the evolutions of the spiralia--the only known internal calcareous structure in that part of the shell (cf. Caster, 1930, Pl.5 (26), fig. 1). What conceivable internal structures in the section of the shell beneath the sinus exist that should be of such fundamental importance in the shell's development,

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and that should be reflected on the sinus?

It is suggested that a way to test these criteria of differences of plicae in the sulcus of the spiriferids, might be to select some group of well preserved specimens such as the types of the Cyrtospirifer whitneyi gens and make a complete analysis of variance as was done by Miller (1949). Conclusions drawn from this analysis could then be checked against results from Gatinaud's technique involving only the sulcus. If the results of this comparison showed sufficient correlation and if this were to be done carefully done throughout the Spiriferidae, then eventually it might be possible, indeed to drop an unidentified specimen into a well defined "pigeon hole" in the taxonomic hierarchy by means of sulcus characteristics alone (providing a way could be devised to make all the observations thoroughly objective and quantitative).

Further work must be done before one can dismiss lightly, however, the apparently formidable statistical diagnoses of M. Gatinaud which were based on an elaborate, painstaking study.

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APPENDIX B

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APPENDIX B

GLOSSARY OF SOME TERMS OF BRACHIOPOD MORPHOLOGY

Introduction

Variance in the employment of terms and the gradual evolution of terminology in morphological descriptions of brachiopods have caused me to deem the inclusion of a glossary of some of the most often employed terms not only useful to the reader but necessary to his fullest understanding of the descriptions. It is hoped that this glossary may, in some measure, help to standardize the terminology; for the purpose of scientific terms is to include in a word or a phrase a whole concept, definition, or description of a certain features. It is necessary, then, that both the writer and the reader employ the same usage of the word, and that the term means precisely the same to each. That the reader may understand my usage, this glossary is included.

What is "standardization" of terminology? Authoritarian standardization is set against a kind of standardization attained by the prevailing custom of usage. Each has its advantages and disadvantages. Regardless of the nammer, standardization will come about

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only when each writer employs the term for the features involved and each reader understands this usage. When the scientific terminology has evolved through our better understanding of the physical structures and the manner in which they develop, and all specialists read the same meaning into a usage then the terminology will have become standardized. This will come about by the slow acceptance of the "right" usage as set against a "wrong" or incorrect usage (a combination of the two processes mentioned at the beginning of this paragraph).

In each case where an author has clearly and correctly defined a new term and has employed this term consistently and with clarity in elucidating the feature involved, the original definition has been cited. Where the usage of a term has become modified by a subsequent better understanding of the structure, I have chosen a later definition or have formulated what I conceive to be a more accurate definition. Thus, the general tendency herein is to rely more heavily on the writing of more recent workers such as Thomson (1927), Kozłowski (1929), Schuchert and Cooper (1932), Cooper (1944) and Cloud (1942), rather than to draw more frequently on the classic writings of Beecher, Buckman, and Schuchert. The works cited above, as well as Shrock and Twenhofel (1953) and Moore (1952), are indispensible to the beginning student of brachiopods since this glossary is admittedly not complete.

Where a bibliographic citation is included after the

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definition, this definition is quoted from the author cited. Where two or more terms for the same feature are in good usage, the term preferred by the writer is listed first. An asterisk (*) preceeding a term indicates that the term is new herein.

A

ACCESSORY DENTAL SOCKET - Small socket for the reception of the denticle of the brachial valve; it is situated on the posterolateral face of the tooth of the pedicle valve.

ACCESSORY DIDUCTORS - See diductor muscles.

ACCESSORY LAMELLAE - Paired partial whorls or revolutions of thin bands arising from the jugum and coming to lie between the first and second coils or bands of the cones of the spiralia.

ADDUCTOR MUSCLES - Paired muscles which cross the body more or less perpendicular to the plane of the commissure, and which close the valves by contractions. They are extended when the shell is open.

At one end they are attached to the inner surface of the pedicle valve, one on each side of the median line, where, being close together, they make a heart-shaped impression. About midway across the body cavity each muscle splits so that pairs are attached to the inner surface of the brachial valve- an <u>anterior</u> pair fairly close together and a <u>posterior</u>

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pair farther apart. Hence two pairs of adductor muscle scars are left on the inner surface of the brachial valve (Shrock and Twenhofel, 1953, p. 275, italics present writer's).

*ADDUCTOR PROCESS - A short, thick, median, tubular or flattened tubular process which tapers anteriorly, situated in the posterior portion of the delthyrial cavity in certain spiriferoids. Its posterior end

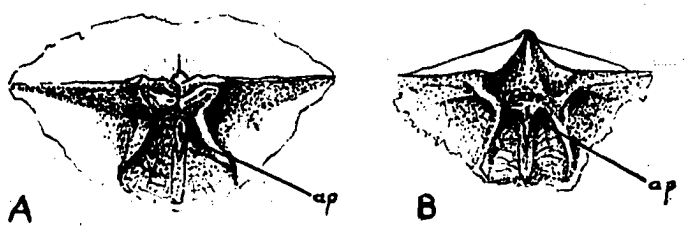

Fig. B1. - Adductor process (ap) in (A) Cyrtospirifer horridus strigosus, n. subsp. from the Oswayo of the Penn-York Embayment and (B) Platyrachella oweni (Hall) from the Middle Devonian Silver Creek limestone of southern Indiana.

is buttressed against the delthyrial plate and the anterior end may be produced into a median septum The adductor process serves as an attachment seat for the posterior portion of the adductor muscles. In molds of the interior this process appears as a deep cleft in the accessory diductor muscle scar.

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ADJUSTORS - Adjustor muscles.

ADJUSTOR MUSCLES - See pedicle muscles.

ADVANCING DENTAL PLATES - See dental plates.

ADVENTITIOUS DEPOSIT - A callist or secondary deposit (q.v.).

AMPHITHYRID - See foramen.

ANACLINE - See interarea.

ANTERIOR - Part of the shell toward the observer (see orientation) adjacent to the mid-line at extremity opposite beak.

ANTERIOR ADDUCTORS - See adductor muscles.

ANTIPLICATE - See commissure.

APEX - Point of beginning of shell growth. Same as beak.

APICAD - Direction toward the apex.

APICAL ANGLE - Angle between the posterolateral edges of the area.

APICAL APPARATUS - Structures associated with the posterior part of the ventral valve (i. e. dental plates, deltidium, subdelthyrial plate, median septum, etc.).

APICAL PLATE - Delthyrial plate.

APICATE - Condition in which the beak has not been resorbed by the pedicle (see truncate).

APSACLINE - See interarea.

AREA - A general term for any surface or pair of surfaces lying between the borders of the delthyrium, the posterior margin, and the beak ridges (Cloud, 1942, p. 8). Not synonymous with interarea as originally proposed by Von Buch (1835, p. 37) and as used

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herein; other authors have used the terms interchangeably, however. The term should be used as a general term and not restricted to a specific type of surface. See also cardinal shelf, interarea, palintrope, and planarea.

ARTICULATES - The hinged brachiopods. The valves are in most cases held together by interlocking hinge teeth and dental sockets (q. v.) as well as muscles.

ATRYPOID - See spiralia.

ATHYROID - See spiralia.

Axis - Midline.

B

BACKWARD - Posteriorly.

BEAK OR ROSTRUM - Posterior more or less pointed extremity of either valve. When used without modification the term is understood to refer to the beak of the pedicle valve. For terms applicable to the curvature of the beak, see curvature. For other terms applied to the beak see rostrate, apicate, and truncate. See also apex.

BEAK RIDGE - Angular ridges diverging from the apex or sides of the foramen to the cardinal extremities and separating the area from the rest of the shell.

BICONVEX - Both valves convex but the pedicle more than the brachial valve.

BRACHIAL RIDGES - Hook-shaped ridges given off the anterolateral extensions of the adductor muscle scars in

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the brachial valve of productoids.

BRACHIAL SUPPORT - Brachidium.

BRACHIAL VALVE - Usually the smaller valve and the one to which the brachia are attached. Other names: dorsal, socket, entering, haemal. Percival (1944) found in his embryological study of Terebratella inconspicua (Sowerby) that "the current use of dorsal and ventral for the valves of articulate brachiopods is the reverse of their primary embryological orientation in relation to the blastopore" (fide Cloud, 1948, p. 247). Yatsu (1902), however, has shown the so-called ventral and dorsal valves of Lingula to be embryologically ventral and dorsal. Also Cooper (1956, p. 131) reports that in a recent paper Percival "discards his views of 1944 and indicates that the orientation of Terebratella inconspicua agrees with that of Tegulorhynchia and the pedicle valve is ventral in orientation." At the present state of knowledge it seems best, therefore, to abandon the use of "dorsal" and "ventral" for the brachial and pedicle valves, respectively.

BREADTH - See width.

BRACHIDIA - Plural of brachidium.

BRACHIDIUM - Any calcareous structure which acts as a support for the lophophore. The two main types of brachidia are the loop and the spiralium (q.v.)

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BRACHIOPHORE - Divergent, elongate, plate-like structures on either side of the midline of the brachial valve which bound the sockets on their inner sides and to which are attached the elongate brachiophore processes. The brachiophore of the orthids is homologous with the crural base of rhynchonelloid genera. See Schuchert and Cooper (1932, p. 37-39) for numerous types of brachiophores.

*BRACHIOPHORE TOOTH - A posterolaterally directed process, prong, or tooth present on the anterior treminus of the upper edge of the brachiophore (e. g. Rhipidomella). The function of this tooth-like process is apparently to lock the tooth into the anteriorly expanding socket (as suggested by Schuchert and Cooper, 1932, p. 134) since it presses against the inner face of the tooth; hence it functions only as an extension of the "socket ridge" and not as a "socket plate" as stated by Stehli (1954, p. 291). It is entirely independent of the brachidium since the "crural base" traverses the brachiophore below this process, and the brachiophore process springs from the forward terminus of this ridge (homologous with the crural base of the rhynchonellids) well below the terminal brachiophore tooth.

C

CALLIST - A callus; a callosity, see secondary deposit.

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CAPILLATE - A term applying to a condition of the shell when ornamented with capilli.

CAPILLI - Plural of capillus.

CAPILLUS - A fine raised line, a thread. (Cloud, 1942, p. 8)

CARDINALIA - The varied structures of the brachial interior in the beak region having to do with articulation, muscle attachment, and attachment of the brachial supports.

The cardinalia are weak if they consist of thin platelike processes and strong if they are composed of stout rounded processes more or less fused together. Strong cardinalia form along the cardinal margin a bench or step that descends steeply to the floor of the valve in front. (Shrock and Twenhofel, 1953, p. 304).

CARDINAL AREA - See interarea.

CARDINAL EXTREMITIES - Lateral extremities of the cardinal margin.

CARDINAL LINE - Hinge line.

CARDINAL MARGIN - The posterior margin of articulate brachiopods. The term cardinal margin is not synonymous with hinge line; the two may coincide in fact but the hinge line may also truncate the cardinal margin (Cloud, 1942, p. 9).

Thomson (1927, p. 53) uses the following first four adjectives to describe the cardinal margin:

Megathyrid - Cardinal margin long and straight.

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Submegathyrid - Cardinal margin slightly shorter than the greatest width of the shell and straight or nearly straight.

Terebratulid - Cardinal margin much shorter than the width of the shell and strongly curved.

Subterebratulid - Cardinal margin much shorter than the greatest width of the shell but not strongly curved.

Spiriferid - Hinge line quite long and straight, or nearly so; sommonly drawn out well beyond lateral margins in alate shells (Shrock and Twenhofel, 1953, p. 292).

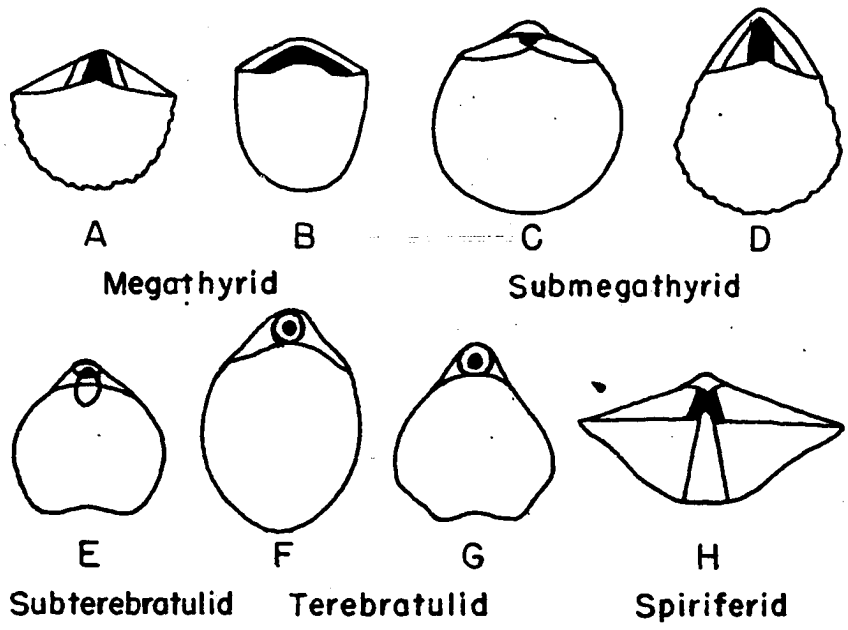

Fig. B2. - Types of cardinal margin. A. Megathyris detruncata; B. Kraussina cognata; C. Chilidonophora incerta; D. Eucalathis tuberata; E. Kraussina pisum; F. Gryphus vitreus; G. Dallina floridana; H. Spirifer increbescens. (Adapted from Shrock & Twenhofel, 1953, Fig. 9-24, p. 293, and Thomson, 1927, Fig. 16).

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CARDINAL PLATE - A composite structure at the middle of the posterior margin of the dorsal valve serving for the attachment of the diductor and pedicle adjustor muscles. The term is morphologic and not genetic. The lateral portions of a cardinal plate are invariably outer hinge plates, but the inner portion may be inner hinge plates, a single median transverse plate or band, . . . or a crural trough. . . . In the first two instances the cardinal plate is commonly perforate, in the latter case a dorsal foramen is unknown. The cardinal plate may be varisouly modified by crural plates, secondary thickening, or a true cardinal process. In general the present usage is that of Kozłowski (1929, p. 232, et seq.) except that he used the term even when the hinge plates were discrete. (Cloud, 1942, p. 9).

CARDINAL PROCESS - A median unpaired but commonly forked process arising at the posterior extremity of the brachial valve and extending anteriorly over the other parts of the cardinalia (hinge plates, hinge platform, etc.). It serves as a seat of attachment of the diductor muscles. It may be a broad sessile boss, a thin low ridge, a series of low ridges, a more complex structure, or it may be altogether absent.

If complex, the structure is commonly curved

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posteriorly and up into the pedicle valve and is divisible into two parts:

SHAFT - Anterior or basal element.

MYOPHORE - Posterior roughened element on the end of the shaft; the seat of the diductor muscular attachment.

The cardinal process is important taxonomically. Schuchert and Cooper (1932, p. 35-37) distinguish nine types of cardinal process in the orthids alone and it is becoming increasingly important in distinquishing productoid genera.

CARDINAL SHELF - The shell substance underlying an interarea, a planarea, or a palintrope (Cloud, 1942, p. 9).

CARINA - A sharp angular plication.

CATACLINE - See interarea.

CHILIDIAL PLATES - A pair of low plates projecting posteriorly from the notothyrial margin which serve to restrict the notothyrium.

CHILIDIUM - A single plate restricting or closing the notothyrium (q. v.). It is punctate in punctate shells and impunctate in impunctate shells.

CLISTOTHYROID - See foramen.

COMMISSURE - The line of juncture between the valves. The line of lateral and anterior contact of the margins of the valves. It may lie in a single plane or be waved or angled according to the development of the margins. Figure B3 shows

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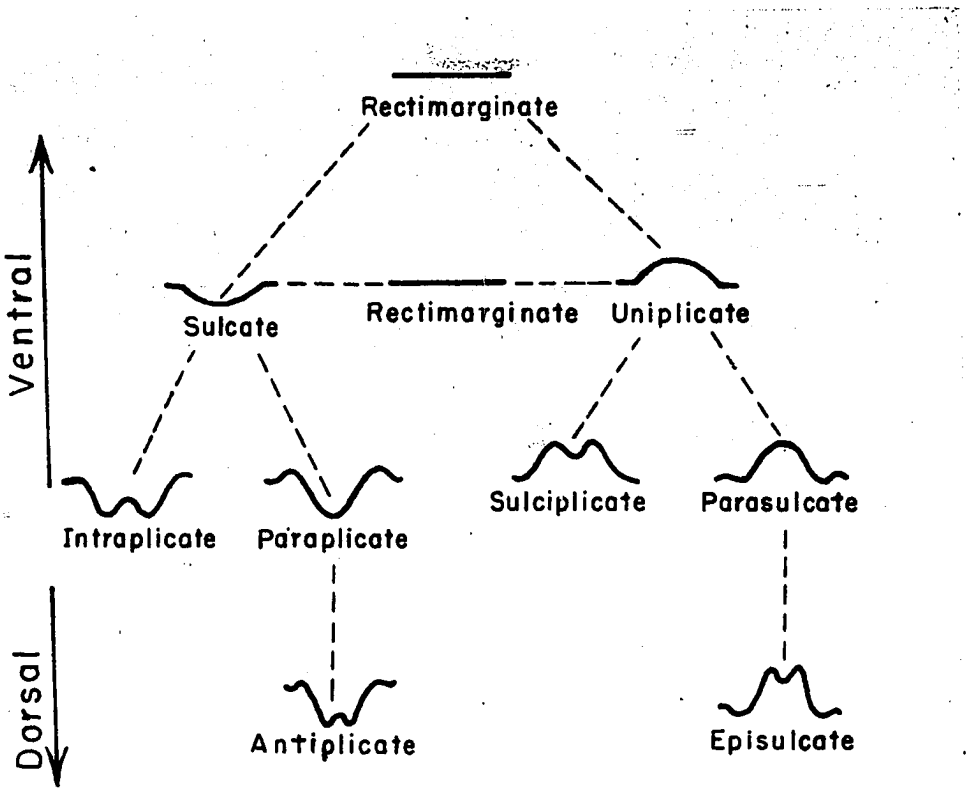

Fig. B3. - Diagram of anterior commissures. Illustrating types of folding in their various lines of development. (Figure and legend adapted from Shrock & Twenhofel, 1953, Fig. 9-27, p. 296, modified from Thomson, 1927, Fig. 17).

various conditions of the anterior commissure and illustrates their lines of development. Thomson (1927, p. 55 et seq.) gives a more complete discussion of the types of folding.

*COMPLETE DENTAL PLATES - See dental plates.

CONCAVO-CONVEX - Shells with concave brachial and convex pedicle valve.

CONJUNCT DELTIDIAL PLATES - See deltidial plates.

CONVEXITY - The degree of inflation of the valve. The dorsal valve is always mentioned in describing convexity by the terms (q. v.): biconvex, or lenticular;

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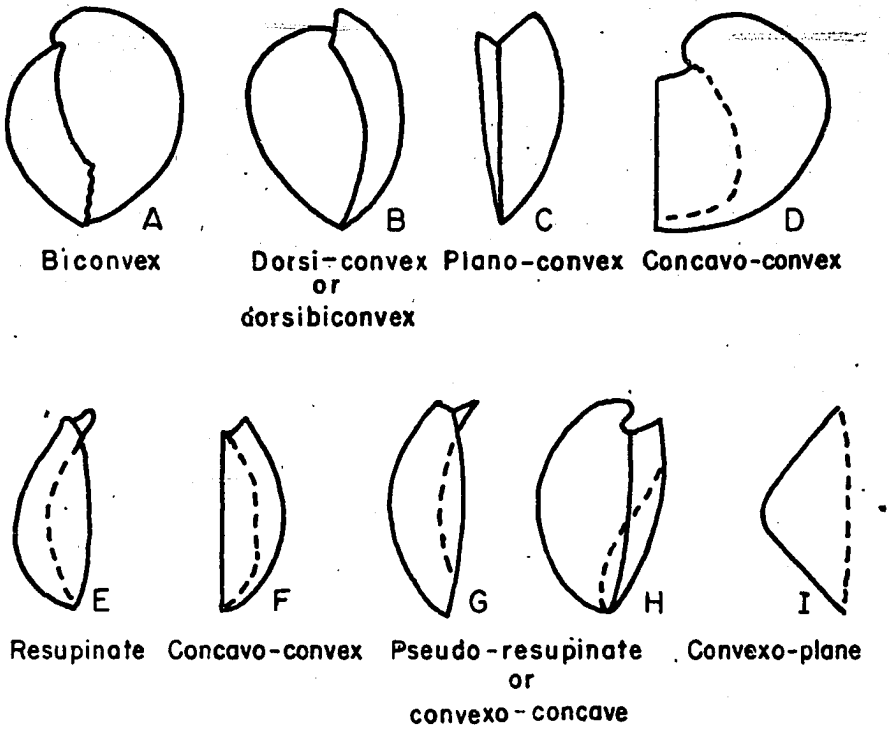

Fig. B4. - Convexity and concavity of brachiopods in lateral views. The valve shown on the left is brachial; that shown on the right is the pedicle valve. Dashed lines indicate the position of the concealed valve along the plane of symmetry. Representative genera: A. Conchidium, B. Atrypa, C. Hesperorthis, D. Dictyoclostus, E. Strophomena, F. Rafinesquina, G. Valcourea, H. Hebertella, I. Orbiculoidea. (Modified from Shrock & Twenhofel, 1953, Fig. 9-23, p. 291).

dorsi-convex or dorsibiconvex; plano-convex; concavo-convex; resupinate convexo-plane, pseudo-resupinate or convexo-concave, illustrated in Fig. B4.

McEwan (1939) has a key for the identification of articulate brachiopods based largely on Convexity. Her usage of the terms, although defined clearly in her paper, differs from the definitions herein.

CONVEXO-PLANE - Shells with convex brachial valve and plane pedicle valve; especially characteristic of

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neotremate brachiopods which cement themselves by much of the surface of the pedicle valve.

COSTAE - Plural of costa.

COSTA - A course radial rib on the external surface (Schuchert and Cooper, 1932, p. 7). Plural: Costae. Costae may be angular, subangular, or rounded. Several descriptive terms are applied to the costation of a form; paucicostate, multicostate, of fascicostate (q. v.). See also plication and carina.

COSTELLA - Fine radial ribs on the external surface. The same prefixes may be used with this term as with costa to form descriptive terms for the costellation of a shell. In addition, the term parvicostellate may be applied to the condition of extremely fine radial ribs.

COSTELLAE - Plural of costella.

CRURA - Proximal parts of the brachial support attached to the hinge plate of the brachial interior.

CRURAL BASE - The trace of a crus on the hinge plate.

CRURAL FOSSETTE - Groove, usually defined by an oblique ridge, located on the inner face of the tooth. The crural fossette articulates with the face or edge of the brachiophore.

CRURAL PLATES - A pair of shellyplates extending from the floor of the brachial valve to the hinge plate supporting the crural bases in the terebratuloids.

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They may unite to form a duplex median septum or they may be discrete.

CRURAL TROUGH - A ventrally concave structure at the posterior of the dorsal valve of some terebratuloids, formed by the basal convergence of crural plates to form a duplex median septum while their ventral ends remain in contact with the edges of the outer hinge plates. The crural trough so formed is then the median portion of one kind of a cardinal plate.

A crural trough is not the same as a septalium (Leidhold, 1920, p. 354), which is a structure of similar appearance in the Rhynchonellacea formed by the forking of the dorsal median septum at its posterior end. Neither is a crural trough the same as a cruralium, a pentameroid structure serving as a place of attachment for the dorsal ends of all the muscles (Cloud, 1942, p. 10-11).

CRUS - Singular of crura.

CRYPTOTHYRID - See foramen.

CURVATURE - Bending. Usually used to mean curvature of the beak of the pedicle valve. The following diagram illustrates the terminology of beak curvature as recommended by Thomson (1927) and Cloud (1942).

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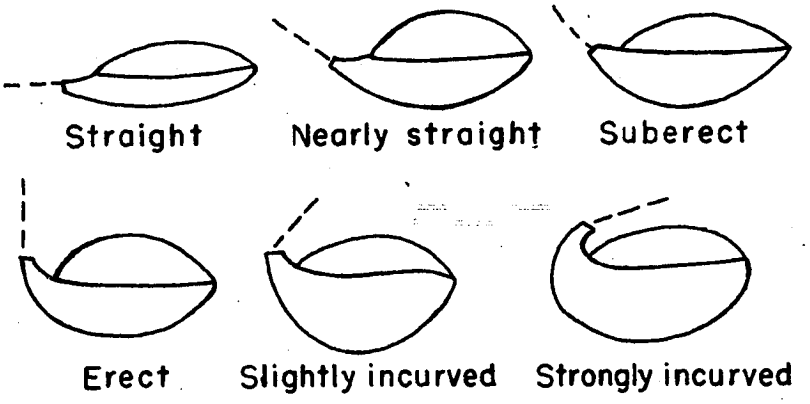

Fig. B5. - Diagram illustrating terminology for beak curvature. (Modified from Cloud, 1942, Fig. 1, after Thomson, 1927, Fig. 23).

D

DELTHYRIAL ANGLE - Angle between the delthyrial edges at the junction.

DELTHYRIAL CAVITY - The posteromedial umbonal cavity of the pedicle valve bounded on each side by dental plates if they are present or by the shell walls if dental plates are absent.

DELTHYRIAL EDGES - Lateral edges of the delthyrium.

DELTHYRIAL PLATE - Subdelthyrial plate. See also delthyrial supporting plates.

DELTHYRIAL PLATES - Dental plates. See also delthyrial supporting plates and subdelthyrial plate.

DELTHYRIAL SUPPORTING PLATES - Dental lamellae (q. v.). Also called delthyrial plates. Thomas (1910, p. 100-101) proposed the term "delthyrial supporting-plates" for the dental plates as they are developed

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in Orthotetes, and North (1920, p. 164) has urged the adoption of this term especially in some spiriferoid brachiopods since "the plates have almost disappeared long before they reach the hinge-line, it would seem that their primary function is not to support the teeth, but to strengthen and support the thin shell of the cardinal area where it is interrupted by the delthyrial fissure." While this may be true in some cases, there can be little advantage of suppressing the more widely used term, dental plates. "Delthyrial supporting plates" might be confused with the delthyrial plates, the transverse or subdelthyrial plate (q. v.).

DELTHYRID - See foramen.

DELTHYRIUM - A subtriangular median interruption in the ventral area [of the pedicle valve] (Cloud, 1942, p. 11). It may be modified (or not) in the following ways:

1. It may be open - unmodified.
2. It may be partially restricted by a pair of plates growing from its sides - discrete deltidial plates.
3. It may be closed by a similar pair of plates, still retaining their individuality, which may meet with a visible juncture above the

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foramen, below it, or both - conjunct deltidial plates (pseudodeltidium of authors).

4. It may be closed apically by a pair of such plates and basally by a single secondary plate - conjunct deltidial plates and a henidium.
5. It may be closed by a single plate arising from the base - henidium.

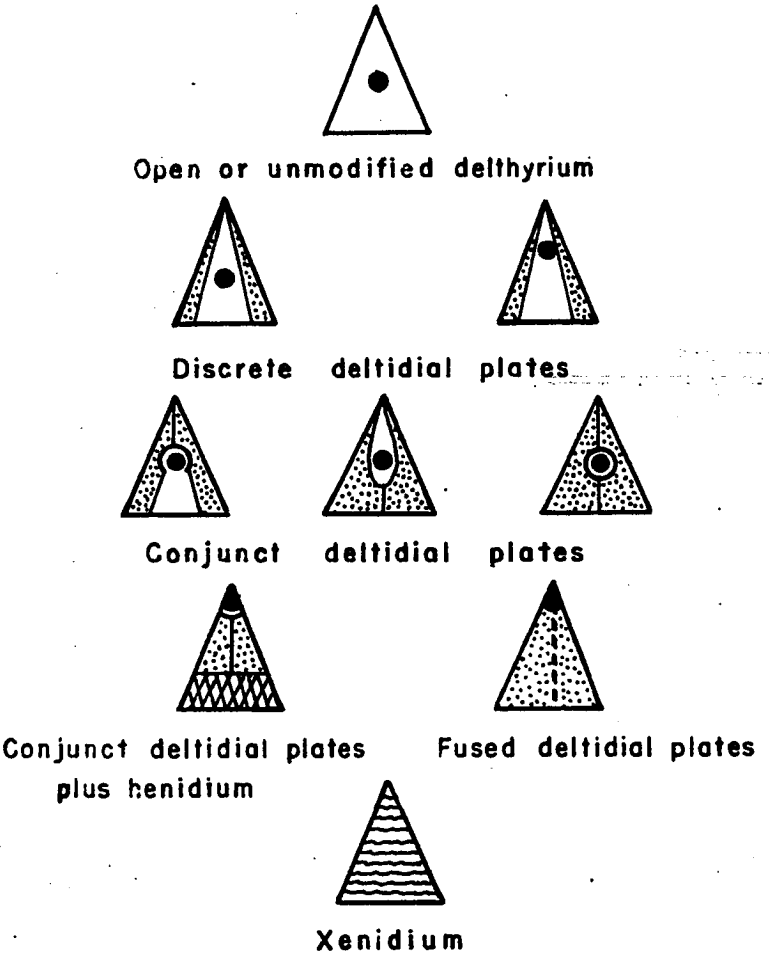

Fig. B6. - Highly diagrammatic figure to show various modifications of the delthyrium in telotrematous brachiopods.

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6. It may be closed by a pair of lateral plates which are welded medially into a unit - fused deltidial plates (symphytium of authors).
7. It may be closed by a single plate arising from the apex - xenidium (deltidium of authors).
8. Sartenaer (1955) believes that the stegidium of Cooper (1954) is a delthyrial covering and had also described a covering of four movable plates in Cyrtiopsis murchisoniana This implies that much more needs to be done before our knowledge and classification of the modifications of the delthyrium is complete.

DELTIDIAL PLATES - A pair of shelly plates extending medially from the sides of the delthyrium and serving there to close or partially close the delthyrium. They have the same structure as the rest of the area, i.e. they are punctate in punctate shells and impunctate when the shell is impunctate. See also deltidium and delthyrium.

When these plates fail to meet medially they are said to be discrete; when they meet with a visible suture they are called conjunct deltidial plates and when they meet without visible suture they may be called fused deltidial plates.

This latter condition has been termed a

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symphytium by Buckman (1918, p. 98), but in a later paper (1919, p. 454) he hopelessly confused the usage. I agree with Cloud (1942, p. 19) that the term should not be used; he says, "If it refers to fused deltidial plates we cannot know that a structure is a symphytium until the individuality of the plates has been proved, and then they are still deltidial plates.

DELTIDIUM - A general term for any shelly plate or group of such plates restricting or closing the delthyrial opening regardless of time or mode of formation.

Von Buch (1835, p. 35) originally originally proposed the word as a general term and Davidson so used it. However, Beecher, Schuchert, Thomson and others (mostly North American authors) have restricted the term to the single plate closing the delthyrium of the pretremates and used Bronn's term (1862 p. 242) pseudodeltidium for the duplex structures among the "telotremates" where the deltidial plates are conjunct. Meanwhile most European authors have used the word deltidium for conjunct deltidial plates.

It now appears best tc retain the term deltidium as a general term since this conforms to the original proposal and also there is need for such a term. For further discussion see Cloud (1942, p. 17-20), Shrock and Twenhofel (1953, p. 284-

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285, and 300-301), or Arber (1939, p. 82 and 1942, p. 179). See also delthyrium, pseudodeltidium and deltidial plates.

DEMICOSTA - A very low, gently convex rib, that occurs on the fold and sulcus in brachiopods. It is apparently formed in the same manner as a costa (Ehlers and Wright, 1955, p.6, footnote).

DENTAL LAMELLAE - See dental plates and also muscle-bounding ridges.

DENTAL PLATES OR DENTAL LAMELLAE - Vertical or subvertical plates in the pedicle valve which bear the hinge teeth at their dorsal ends. They occur at the posterior end of the valve and when free, divide it into a pair of outer umbonal cavities and a median delthyrial cavity.

Dental plates are termed free when they are not enveloped by deposition of adventitious deposits and do not form a spondylium (q. v.); they are termed obsolete when they become obliterated by adventitious testaceous deposits which fill the umbonal cavities. The free dental ridges of Schuchertella should not be termed obsolete. There are all gradations between free and obsolete dental plates.

Free dental plates may be further classified in the following manner:

*Complete - An entire lamella acting as a brace forms the dental plate. This is the

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most common type. The anterior edge may be straight or curved (anteriorly or posteriorly) and may descend vertically to the floor of the valve or the anterior edge may slope anteriorly.

Advancing - Lamella which slopes forward and continues anteriorly around the lateral margins of the muscle field as a more or less well defined ridge (e. g., Schizophoria) (Schuchert and Cooper, 1932, p. 26). A more advanced case of the more normal complete condition.

*Re-entrant - Lamella in which the anterior edge is markedly modified by a re-entrant.

*Pendant - Small, but frequently thick, lamella under the area; the "front" edge may be strongly curved anteriorly or may be nearly straight.

Receding - Ridges along the ventral surface of the area which finally reach the inner surface of the valve at the posterior of the the shell only (Schuchert & Cooper, 1932, p. 726).

There is complete gradation from one type to the next within these modifications of free dental plates even as there is gradation from free to obsolete dental plates.

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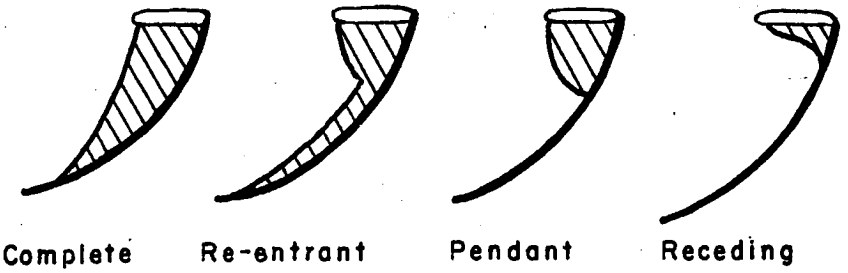

Fig. B7. - Various types of free dental plates in lateral view. Any of these types may become obliterated by the deposition of adventitious deposit in the umbonal cavities. Section of the shell represented by the heavy lines, the dental plate by the lined area, and a section of the tooth and area by the blank space.

DENTAL SOCKETS - Cavities in the posterior margin of the brachial valve for the reception of the hinge teeth of the pedicle valve. Most commonly called merely, sockets.

DENTAL VALVE - See pedicle valve.

DENTICLE - Accessory tooth-like process of the brachial valve located on the outer wall of the socket. The denticle fits into a small accessory dental socket (q. v.) on the posterior face of the tooth of the pedicle valve. Not to be confused with the small denticles along the cardinal margin of many strophomenoids.

DEPTH - See thickness.

DIDUCTOR MUSCLES - Two pairs of paired muscles which open the shell by contraction (relaxed when closed). They are attached at one extremity to the inner surface of the pedicle valve while the other end is attached

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to the cardinal plates, hinge plates, or the cardinal process where present. There are two pairs of diductors; the principal diductors form the larger and more anterior pair of scars in the pedicle valve and the accessory diductors make the smaller pair. The principal diductors pass outside of the accessory diductors and attach to the anterior part of the cardinal process while the shorter accessory diductors attach to the posterior part.

These muscles open the shell by lever action, the hinge line being the axis of rotation. They are attached anteriorly to the hinge line in the pedicle valve and posteriorly to it in the brachial valve, and thus, since they have a short lever arm, are quite powerful muscles. The closing muscles are called adductors (q. v.).

DIPLOSPIRE - A secondary spire developed within the spiralium in a few highly specialized spiralia.

DISCRETE DELTIDIAL PLATES - See deltidial plates.

DISCRETE SPONDYLIUM - See spondylium.

DISTAL - Direction away from the beak; measured either anteriorly or posteriorly (and thus said of the most distant portion of the pedicle). Opposite of proximal.

DIVARICATORS - Diductor muscles.

DIVIDED HINGE PLATE - See hinge plate.

DORSAL - Direction toward the brachial ("dorsal") valve.

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DORSAL ADJUSTORS - See pedicle muscles.

DORSAL FOLD - Dorsally directed (toward the brachial valve) major curve of the commissure (see fold).

DORSAL VALVE - Brachial valve (q. v.).

DORSIBICONVEX - Dorsi-convex.

DORSI - CONVEX - Both valves convex but the brachial more than the pedicle valve.

DUPLIPLICATE - Condition in which the sulcus is divided into three unequal sectors by subparallel primary ribs which lie very near the axis. Two large equal lateral sections lie on either side of a small median section. (See also uniplicate and tripliplicate).

E

EARS - The regions of the shell, usually triangular, flattened, and ear-like adjacent to the cardinal extremities of productoids.

ENCOPUNCTA - Minute perforations which represent spaces in the inner fibrous shell layer left by minute papillae or caeca of the mantle. Each pore is somewhat expanded near its outer portion. Hobbs and Cloud (1942, p. 26) report tiny tubules were seen extending from the ends of some puncta through the remainder of the outer carbonate layer of Laqueus californicus, but they could not determine whether they penetrated the periostraum. These authors give a very complete account of puncta and

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shell structure. Among other features they mention and figure bifurcating puncta.

The function of endopuncta is conjectural. Hobbs and Cloud (1942, p. 27) believe that shell nourishment is unlikely as a primary function for the thickest and most used parts such as septa, dental plates and hinge teeth are impunctate. They suggest that a respiratory function may be served and this view is strengthened by the presence of tiny tubules extending outward toward the surface of the shell. In addition they state, "It is almost certain that the punctae help to hold the mantle to the shell, but whether this is a primary or a purely coincidental function is difficult to say."

ERECT - See curvature (of beak).

EXOPUNCTA - Pores indenting the outer laminated shell layer. However these do not penetrate the shell deeply and are not known to pass through to the interior surface.

F

FASCICLE - A small bundle or cluster.

FASCICOSTATE - Condition in which the shell bears costae which are bundled or grouped into fascicles. (See also paucicostate and multicostate).

FASCICOSTELLATE - Condition in which the shell bears costellae which are bundled or grouped into fascicles (See also

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paucicostellate and multicostellate).

FASCICULATE - Condition of being grouped into bundles (fascicles). See fascicostate and fascicostellate.

FASCIPLICATE - See plication.

FIMBRIATE - Fringed.

FLANKS - Lateral slopes (q. v.).

FOLD - Major rounded elevation of the shell along longitudinal mid-line, affecting both outer and inner shell surfaces; generally on brachial valves (Moore, 1952, p. 209). When ventrally directed such an elevation would be a ventral fold and when dorsally directed a dorsal fold. See commissure.

FORAMEN - An opening. When unqualified the term refers to the pedicle foramen or pedicle opening (q. v.). The term is most generally used in connection with those types of pedicle opening which lie wholly within one valve.

When the pedicle-opening is in the ventral valve, it is gastrothyrid. If it were in the dorsal valve, a position never completely attained, it would be notothyrid. When it is situated at the junction of the two valves, - part being in each valve, it is symbolothyrid. (Thomson, 1927, p. 68). The position of the foramen is further described by means of adjectives indicative of its relation to the beak ridges, deltidial plates and delthyrium. Thomson (1927, p. 71) says, "In general

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the movement of the pedicel-opening in Telotremata during growth is in the contrary direction - i. e., away from the dorsal umbo in the direction of the ventral apex - and in this movement it may destroy the apex and cut through the line of the beak-ridges and ultimately attain the ventral side of them." See diagram below.

The foramen is said to be:

Hypothyrid: When it is in the interarea and the apex is intact.

Submesothyrid: When the apex has been absorbed, yet the foramen lies mainly in the interarea but partly into the ventral umbo.

Mesothyrid: When the foramen lies about equally on each side of the beak ridges.

Permesothyrid: When little of the foramen lies in the interarea and most of it is in the ventral umbo.

Epithyrid: When the foramen lies wholly in the ventral umbo and the line of the beak ridges lies dorsal of it.

Amphithyrid: A secondary symbolothyrid condition brought about when, "concurrently with the partial closing of the delthyrium by deltidial plates, there is a resorption of a semicircular notch in the dorsal valve, the apex of which is destroyed." (Thomson,

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1927, p. 71).

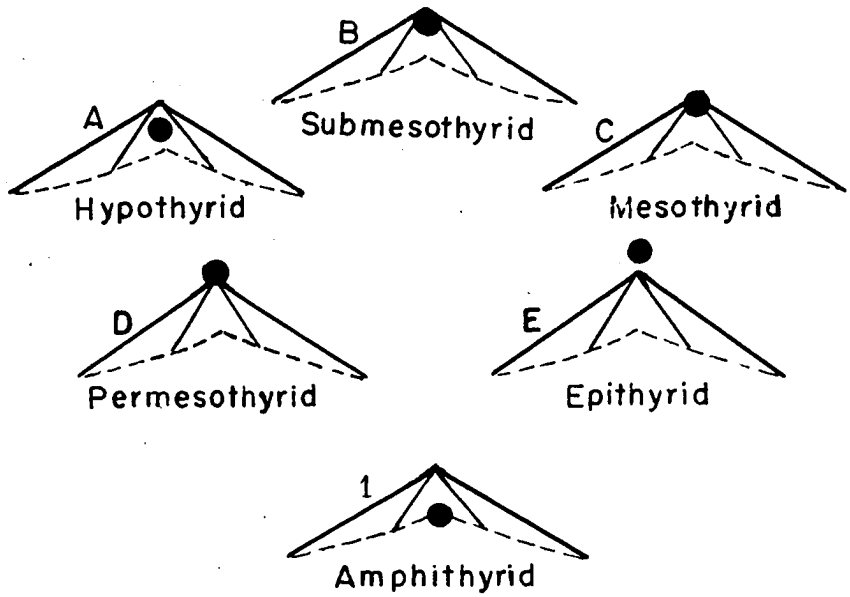

Fig. B8. - Diagram showing position of foramen. The upper heavy lines represent the line of the beak-ridges, the lower broken lines represent the posterior margin of the dorsal valve, the inner thin lines represent the margins of the delthyrium, and the circles represent the foramen. (Modified from Thomson, 1927, Fig. 20).

This general trend of ventral movement of the pedicle appears to be due to increase of incurvature of the ventral beak. When the ventral beak has become so much incurved that contact is made with the dorsal umbo, the pedicle must have atrophied and the condition is termed clistothyrid. When the foramen is known to exist but is hidden by the incurved ventral beak so that the pedicle must have been almost functionless the condition is termed cryptothyrid.

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Finally Buckman (1919, p. 451) has applied the term delthyrid to the condition in which there is no true foramen but only an open delthyrium.

FORWARD - Anteriorly.

FREE DENTAL PLATES - See dental plates.

FREE SPONDYLIUM - see spondylium.

FRONT - Anterior.

FULCRAL PLATE - Small concave plate joining the brachiophore to the posterior wall of the brachial valve and defining the socket (especially well seen in the Schizophoriidae).

FUSED DELTIDIAL PLATES - See deltidial plates.

G

GENICULATE - Shell bent apruptly at an angle.

GENITAL MARKINGS - Radial markings, ridges, or pits within the posterior portion of the visceral space, indicating the position and extent of the genitalia, and used for attachment of muscles which fix the ovarian bodies. Best seen on the ventral shell (Schuchert and Cooper, 1932, p. 8). Also called ovarian markings or impressions.

GROWTH (Shell growth) - Addition of increments of shell material at the outer margin of the valve. Beyond the margins of the protegulum. This is accomplished in three manners:

HEMIPERIPHERAL GROWTH - Successive shell increments extend the lateral and anterior margins but

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not the posterior margin.

HOLOPERIPHERAL GROWTH - Successive shell increments are added to the entire valve margin. The apex recedes from the posterior margin to some point between it and the center of the valve. There is a tendency to develop circular or oval outlines and conical valves.

MIXOPERIPHERAL GROWTH - Successive shell increments are added in the usual manner to the lateral and anterior margins, but on the posterior margin they are added in such a way that, rather than enlarging backwards, the shell surface is turned forward from the protegulum toward the plane of commissure resulting in a cardinal shelf whose surface faces the opposite valve. The apex or beak thus constitutes a posterior extremity lying farther back than the growing posterior margin of the valve. Thomson (1927, p. 50) says that mixoperipheral growth arises as a direct succession to hemiperipheral growth. "Whether phylogenetically this method of growth has ever arisen through a holoperipheral stage may be doubted."

One form of growth may follow another, and the two valves of a shell commonly have different manners of growth.

For further discussion of the phylogenetic succession of growth modes and of the details of

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evolution of the areas see Thomson (1927, p. 47-520 and Moore (1952, p. 213-216).

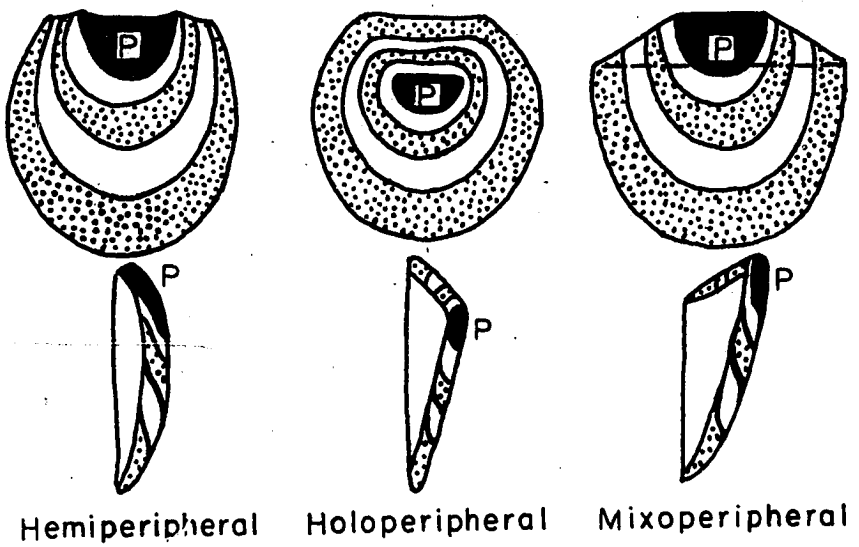

Fig. B9. - Diagrams showing growth of brachiopod shells. Normal and sectioned views of very young shells greatly magnified. Shell accretions along various parts of the valve margin shown by alternating blank and stippled bands; protegulum (P). (Redrawn from Moore, 1952, Fig. 6-13, p. 215.

GROWTH LINES - Concentric lines caused by increments of shell material being added at the outer margin of the valve. They occur at irregular intervals and apparently indicate periods of cessation or marked retardation of the growth of the valves.

H

HENIDIUM - A single shelly plate lying between the cardinal margin and the dorsal edges of the conjunct deltidial plates of some shells and possibly replacing them completely in others, thus simulating a zenidium (Cloud, 1942, p. 12). It is secreted presumably by a flap of the mantle of the pedicle valve and

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thus has the same punctation as the shell.

HEMIPERIPHERAL GROWTH - See growth.

HINGE - Hinge line.

HINGE AREA - See interarea.

HINGE LINE - The line joining the points of articulation. It may coincide with the cardinal margin or be simply an imaginary line truncating the cardinal margin (Cloud, 1942, p. 12).

HINGE PLATE - Subhorizontal, flat, or nearly flat plates, or group of plates, at the posterior end of the brachial valve, separated anteriorly from the floor of the valve by a cavity. Inner hinge plates extend medially from the crural bases; outer hinge plates lie between the dental sockets and the crural bases.

When only outer hinge plates are developed they are described as free or discrete and the form is said to possess divided hinge plates. When an inner plate is formed uniting the crural bases and welding the structures into a unit, the whole structure is called undivided hinge plate. Thomson (1927, p. 86) also speaks of inner hinge plates between the crural bases in Terebratula with free inner edges, not meeting along the middle line of the valve (divided hinge plate).

Thomson (1927, p. 87) points out that the term hinge plate, is not really appropriate for a structure which takes no part in articulation; it is still true

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as he adds, that "no more suitable comprehensive name has yet been proposed."

HINGE PLATFORM - Those types of cardinalia exhibited by Boudhardia, in which the area between the socket ridges is occupied by a solid platform of shell-matter. It may or may not be buttressed anteriorly by a median septum (Thomson, 1927, p. 87).

HINGE SOCKETS - Dental sockets.

HINGE TEETH - The two major articulating processes occurring on the hinge line in the pedicle valve; they fit into the corresponding dental sockets of the brachial valve.

HINGE TROUGH - Those types of cardinalia in which there are no excavate hinge-plates, but a strong septum uniting with the cardinalia by posterior bifurcation, the two forks of the septum running to join the inner anterior corners of the combined socket-ridges and crural bases. The latter descend more or less steeply to meet one another in the middle line of the valve, enclosing a trough of simple outline terminated anteriorly by the forks of the septum, e, g. Pachymagas. The pedicle-muscles are attached to the sides of the hinge-trough (Thomson, 1927, p. 86-87).

HEMIPERIPHERAL GROWTH - See growth.

HYPERCLINE - See interarea.

HYPOTHYRID - See foramen.

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I

IMPLANATATION - Intercalation (q.v.).

IMPUNCTATE - Condition in which the shell substance is dense and lacking in puncta. This is the most common condition.

INARTICULATES - Brachiopods in which the valves are kept in apposition principally, and in many cases solely, by muscles; there is no articulation in the same sense that it obtains in the articulates (q. v.).

INCLINATION - See interarea.

INCURVED - See curvature.

INNER HINGE PLATE - Hinge plate formed from the union of a pair of plates extending medially from the crural bases. See also cardinal plate and hinge plate.

INNER SOCKET RIDGE - Socket ridge lying inside (toward the midline) of the dental socket.

INTERAREA - A type of area extending directly from one posterolateral corner to the other so that any transverse line on its surface is straight or nearly straight. Genetically an interarea is a trace of the hinge line. Equals cardinal area, hinge area, palintrope of some authors, and area of some authors (Cloud, 1942, p. 13). An interarea, then, is formed when the hinge line is coincident with the posterior margin.

Cloud (1942, p. 21) further says, "In one sense the interareas, planarea, and palintropes are genetically the same in that they are all surfaces resulting

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from increments to the posterior margin. In another sense, however, the interarea differs from the planarea and palintrope in being an actual trace of the hinge line for the hinge line must be coincidental with the posterior margin in order for an interarea to form, while in the case of palintropes and planareas the hinge line is an imaginary chord truncating the subarcuate line subtended by the posterior margin "

Schuchert and Cooper (1931, p. 251) proposed the following terms for the inclination of the interareas. They say, "In studying the inclination, the ventral [pedicle] valve should be below the horizontal and the beaks (arbitrarily) on the observer's left. The plane of the commissure (the boundary line between the margins of the valves) is then horizontal and the dorsal valve is up."

Pedicle interarea:

Anacline - between vertical and horizontal.

Orthocline - horizontal.

Apsacline - bent down between horizontal and vertical, 90° - 180° from erect vertical.

Catacline - bent down 90° from horizontal (pedicle valve only).

Procline - bent more than 180° from erect vertical (pedicle valve only).

Brachial interarea:

Anacline, orthocline, and apsacline conditions

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recognized; in addition:

Hypercline - bent in an anterior direction more than 90°.

The diagram illustrates these conditions and shows the direction in which specific angle measurements are to be taken if used.

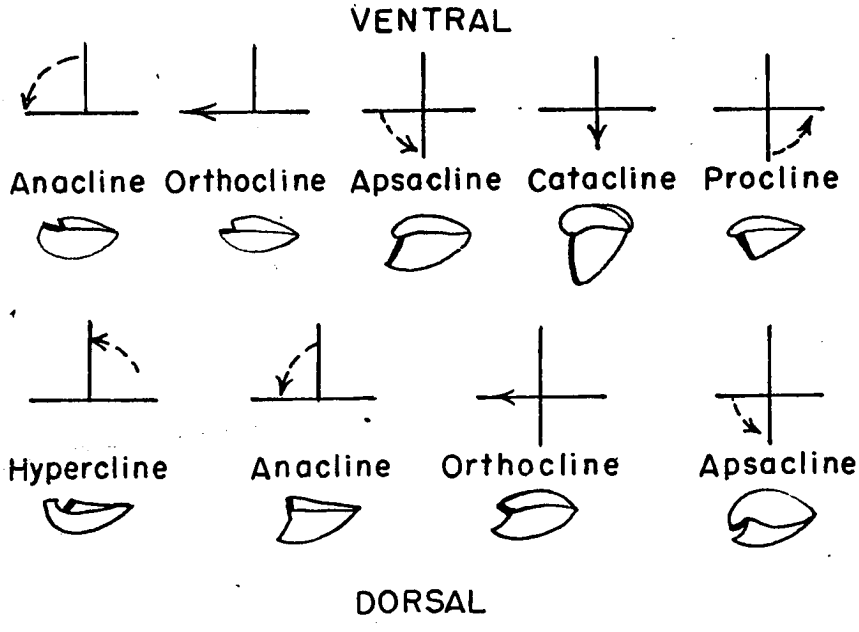

Fig. B10. - Diagram showing the various positions of the brachial and pedicle interareas with relation to the plane of commissure. (After Schuchert and Cooper, 1932, Fig. 1, p. 20).

INTERCALATE - To insert between.

INTERCALATION - Insertion between (used with plicae, costae, or costellae to indicate the method of increase of numbers on the shell.)

INTRAPLICATE - See commissure.

J

JUGAL PROCESS - Process, directed more or less medially,

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which arises from the lateral bands of the loop or from the primary lamellae of the spiralia. These processes may be simple or may be united medially to form a supporting structure, the jugum.

JUGUM - Variously shaped connecting structure between spiralia formed by union of the jugal processes (q. v.)

L

LATERAL PROFILE - Appearance of the outline of the shell when viewed from the side (see orientation).

LATERAL SLOPES - Those portions of the surface of both valves which lie on either side of the fold or sulcus or the midline if these latter are absent. The anterolateral sides of the trail in productoids.

LEFT - See orientation.

LENGTH - Linear distance in plane of bilateral symmetry from the anterior margin to posterior margin or beak, whichever distance is greater. Surface length is the linear distance measured in the same manner but on the exterior surface of geniculate forms.

LENTICULAR - Biconvex.

LOOP - The internal calcareous support of the brachia in the terebratuloids. The loop is composed of crural bases, crura, crural points, and the loop proper (Cloud, 1942, p. 13). Cloud includes a further discussion with examples of terminology.

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M

MARGIN - The edge of the shell in any direction.

MEDIAN RIDGE - Median septum.

MEDIAN SEPTUM - A longitudinal vertical median plate occurring in either valve. Median septa are ordinarily more conspicuous and platelike than myophragms (Cloud, 1942, p. 13).

MEGATHYRID - See cardinal margin

MIDLENGTH - One half the distance from most posterior to most anterior point on the valve.

MIDLENGTH - Hypothetical trace of plane of symmetry on exterior of shell.

MIXOPERIPHERAL GROWTH - See growth.

MUCRONATE - Condition of the shell in which the cardinal extremities are greatly produced laterally into sharp points.

MUCRONE - Cardinal extremity drawn into a sharp point.

MULTICOSTATE - Condition inwhich the shell bears costae that increase by bifurcation or implantation. See also paucicostate and fiscicostate.

MULTICOSTELLATE - Condition in which the shell bears costellae that increase by bifurcation or implantation (See also paucicostellate and fascicostellate).

MULTIPLICATE - See plication.

MUSCLE IMPRESSION - See muscle scar.

MUSCLE MARK - Any mark indicating muscular attachment (Buckman, 1918, p. 90).

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MUSCLE SCAR - More or less defined areas representing the ultimate muscular attachment (Buckman, 1918, p. 90).

MUSCLE TRACK - The course down the valve shown by successive muscular attachments (Buckman, 1918, p. 90).

MUSCULATURE - Pertaining to the muscles or their arrangement.

MYOPHORE - See cardinal process.

N

NOTOTHYRIAL CAVITY - Cavity below the notothyrium in the brachial valve.

NOTOTHYRIAL PLATFORM - Testaceous deposits built up from the floor of the valve in the notothyrial cavity.

NOTOTHYRIUM - Subtriangular reentrant of the posterior margin of the brachial valve similar to the delthyrium of the pedicle valve. It may be closed by two discrete plates, chilidial plates, arising from sides of the notothyrium, or by a single plate, the chilidium.

O

OBLIQUE - See spine.

OBSOLETE DENTAL PLATES - See dental plates.

ORIENTATION - In studying or describing the shell it is customary to lay it on the table with the ventral [pedicle] valve below and the dorsal [brachial] valve uppermost, but in studying the interior of the dorsal valve after the valves have been separated this valve is laid in a reversed position. To avoid all ambiguity between 'up' and 'down' it is

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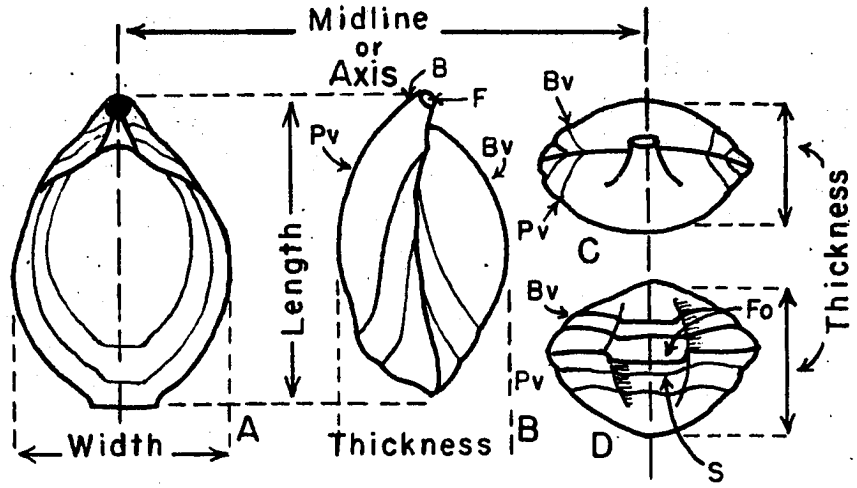

Fig. B11. - Diagram showing conventional orientation; based on Magellania flavescens (Modified from Shrock and Twenhofel, 1953, Fig. 9-3, p. 264). A. Brachial or dorsal view; B. Right lateral view; C. Posterior view; D. Anterior view. Symbols: Bv - brachial valve, Pv - pedicle valve, F - foramen, Fo - fold, S - sulcus, B - beak.

expedient to think of these two directions as dorsal and ventral. A process which rises from the bottom of the interior of the dorsal valve when this valve is placed with its exterior to the table points upwards in this position, but downwards when the united valves are placed with the ventral valve below - i.e., it points ventrally.

It is further customary to place the shell for study with the beak or apex away from the observer. The end nearest the observer is the front or anterior end, and the beak forms the posterior end (Thomson, 1927, p. 5-6).

In this position then, the right side of shell is on the observer's left and the left side

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of the shell is to the right of the observer. Right and left are best taken when the observer is looking with the shell in the same direction, i. e., both look toward the front (anterior). When the valves are separated and the position of the brachial valve reversed for study of the brachial interior, the right and left side of the brachial valve become the right and left (respectively) of the observer. See also the discussion under brachial valve.

ORNAMENT - Modifications of the surface of the shell (usually when unqualified, the exterior surface).

Gill (1949, p. 572) has proposed the term, prosopon, to replace the biologically erroneous term ornament as an overall term for the description of the surface appearance. He points out that, "There is no such thing as ornament from the biological point of view. The so-called ornament is an organ, a structure with a function."

Wright (1950, p. 497) contends, that, "Many terms used commonly in science are misleading if interpreted strictly according to their everyday use but need not be abandoned on that account. Everyone knows what is meant by ornament in natural science and it is very unlikely that anyone would take seriously in a scientific context the contrast between ornament and function, unless there was evidence that the point was under

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discussion." Wright also considers prosopon objectionable since it is the name of a genus of Brachyura.

Wright's first point seems well taken but the last is not a valid objection because this proposal is in no way contrary to the rules applied to animal taxonomy.

Remembering that ornament is not purely embellishment for decorative purposes it seems that the student may well continue to use the word ornament, but the term prosopon may also find good use in description. At best, it is difficult to see how there can be any serious objection to it.

ORNAMENTATION - Ornament.

ORTHOCLINE - See interarea.

OUTER HINGE PLATE - That part of the hinge plate between the crural base and the dental socket.

OUTER SOCKET RIDGE - Socket ridge lying outside the dental socket.

OVARIAN MARKINGS or IMPRESSIONS - Genital markings (q. v.)

P

PALINTROPE - The term is here restricted to a type of area which is curved in all directions and ordinarily not sharply defined. Palintropes occur in pairs on either side of the ventral beak, and either in pairs or singly on the dorsal valve. Where the word is used without modification it

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refers to the ventral valve. Palintropes are characteristic of rostrate shells which lack planareas (Cloud, 1942, p. 14).

PALLIAL OR VASCULAR MARKINGS - Impressions or low elevations on the shell interior marking the position of the pallial or vascular sinuses.

PALLIAL OR VASCULAR SINUSES - Extensions of the visceral cavity or coelom between the two epithelial layers of the mantle.

PALLIUM - The mantle.

PARAPLICATE - See commissure.

PARASULCATE - See commissure.

PARTICOSTELLATE - See costella.

PAUCOSTATE - Condition in which the shell bears costae that are simple and distant. See also multicostate and fascicostate.

PAUCICOSTELLATE - Condition in which the shell bears costellae that are simple and distant. See also multicostellate and fascicostellate.

PAUCIPLICATE - See plication.

PEDICLE OR PEDUNCLE - Muscular protruding stalk which serves as an attachment organ in anchoring the shell to the substratum. It is attached to the valves by muscles within the shell or issues through a pedicle opening or foramen which is entirely within one of the valves or is shared by the valves.

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PEDICLE FORAMEN - Pedicle opening. For terms applied to the pedicle foramen in various positions see foramen. See also dorsal foramen.

PEDICLE MUSCLES - The pedicle muscles, five in number, serve partly to attach the pedicle to the larger valve and partly to adjust the shell on the pedicle. They consist of a single muscle, the protractor, and a pair each of ventral adjustors and dorsal adjustors. The protractor joins the pedicle to the pedicle valve and leaves an elongate scar posteriorly to the other scars. The dorsal adjustors are attached to the posterior part of the brachial valve, whereas the ventral form two scars that lie outside the adductor scars. The pedicle muscles are relatively weak; hence their scars are not prominent and are not likely to be as obvious as those of the adductors and diductors (Shrock and Twenhofel, 1953, p. 275.

PEDICLE OPENING - Perforation at or near the ventral beak for passage of the pedicle. For terms applied to the foramen in various positions, see foramen.

PEDICLE VALVE - Usually the larger and deeper of the two valves and bearing teeth on either side of the delthyrium in the articulates. Other names: ventral, dental, receiving, neural. See discussion under brachial valve.

*PENDANT DENTAL PLATES - See dental plates.

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PERIDELTIDIAL AREA OR PERIDELTIDIAL REGION - Impunctate portion of the area, on each side of the delthyrium and bounding it, sharply set off from the lateral regions by lines which diverge from the apex to points on the hinge line part way between the delthyrium and the cardinal extremities. This region may be slightly elevated above the level of the lateral region (Orthotetacea) or may be level with the rest of the area (as in Syringothyris). In either case it is differently ornamented; while the entire area bears horizontal striations (growth lines) the perideltidial area is marked in addition by vertical striations (actually capilli).

De Koninck (1861, p. 50, pl. 2, fig. 5) was among the first to describe this condition in a specimen now referred to Syringothyris and called the perideltidial area the "pseudodeltidium complementaire".

Thomas (1910, p. 96) recorded that in his Orthotetinae "a separate areal portion in the form of a raised triangular platform is sometimes marked off around the delthyrium. This secondary area is distinguished by vertical striation in contrast to the horizontal striation of the larger surrounding primary area." Dunbar and Condra (1932, p. 68) comment that "the connotation thus implied has no support whatever" and it "appears more probable that both divisions are parts of the original area."

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They further point out that the perideltidial area is not homologous with the narrow striated border of the delthyrium formed as the trace of the hinge teeth in certain orthoids.

For further discussion of the perideltidial area see Dunbar and Condra (1932, p. 67-68) North (1920, p. 171-173), and Williams (1953, p. 9-10).

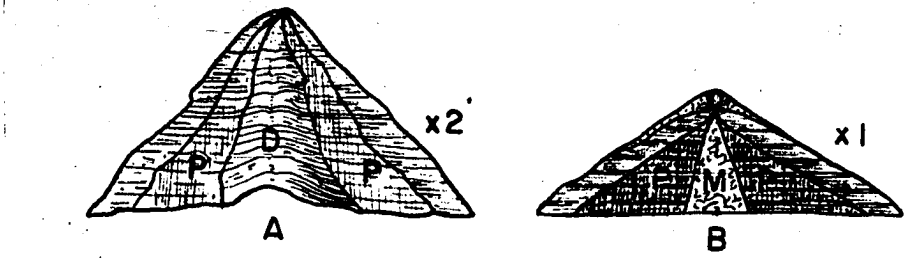

Fig. B12. - Perideltidial area in (A) Derbya ciscoensis (after Dunbar and Condra, 1932, text-fig. 1, p. 67) and (B) Syringopleura casteri, n. sp. Perideltidial area (P), Deltidium (D), rock matrix filling delthyrium (M).

PERIDELTIDIUM - Perideltidial area (q. v.)

PERMESOTHYRID - See foramen.

PLANAREA - A type of area similar to an interarea in that it may be plane or curved in a vertical direction, but curved so that any longitudinal line on the surface is straight or nearly straight.

Planareas occur in pairs, one on each side of the beak, and are typical of rostrate shells, thereby differing from interareas which are traces of the growing hingeline and occur singly in any valve. (Cloud, 1942, p. 16). See note following interarea.

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PLANE OF COMMISSURE - The plane passing through the anterior commissure and the hinge-line (Schuchert and Cooper, 1932, p. 9).

PLANO-CONVEX - Shells with convex pedicle and plane brachial valves.

PLICA - Plication.

PLICAE - Plural of plica.

PLICATION - Corrugation affecting both outer and inner shell surfaces, disposed radially with respect to beak; smaller in amplitude than fold and may be located in any part of the shell except palintropes (Moore, 1952, p. 210). See also carina and commissure. Shells may be termed pauciplicate, multiplicate or fasciplicate in the same sense that these terms are applied to costae.

PLICATION CREST - Convex upper part of a plication (Moore, 1952, p. 210).

PLICATION FURROW - Concave lower part of a plication (Moore, 1952, p. 210).

POSTERIOR - Part of the shell away from the observer (see orientation) containing the viscera and generally marked externally by the pedicle opening or the beaks when present.

POSTERIOR ADDUCTORS - See adductor muscles.

POSTERIOR EXTREMITY - Part of valve farthest from anterior margin. Usually is not identical (in articulates) with the posterior margin which is located forward of the beak.

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PRIMARIES - See primary ribs.

PRIMARY LAMELLAE - Initial parts of the spiralia (q. v.) attached posteriorly to the crura. Part of spiralia posterior to the first curve.

PRIMARY RIBS - First ribs of the sulcus to appear in ontogeny; these are usually the strongest plicae.

PRINCIPAL DIDUCTORS - See diductor muscles.

PROCLINE - See interarea.

PRODELTIDIUM - The embryonic deltidium.

PROPAREA - Planarea.

PROSOPON - General term for the description of the surface appearance of the shell (usually exterior surface). The verb is prosoponise. See discussion under ornament.

PROTEGULUM - The initial embryonic shell of all brachiopods. In Lingula the protegulum is a single thin horny plate, in Argyrotheca, a tiny bivalve shell, and in Lacazella a three-piece covering. The adult shell, usually of different shape, is formed by addition of calcium phosphate or calcium carbonate to this horny cuticle along the margin.

"Because of its delicate nature and minute size, the protegulum is not generally present on mature shells and is almost never preserved on fossil shells, though its form and other characteristics may be determined from impressions remaining in the calcareous shall." (Schrock and Twenhofel, 1953, p. 286).

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PROTRACTORS - See pedicle muscles.

PROXIMAL - Direction toward the beak. Opposite of distal.

PSEUDODELTIDIUM - This term, used in various ways as discussed below, had best be dropped altogether. The various usages:

1. Bronn (1862, p. 242, pl. 23, figs. J, M; pl. 24, figs. A, B, D, N) proposed the term for (a) the single plate covering the delthyrium of such genera as Thecidium and Chonetes. However, he called (b) the conjunct deltidial plates of Stringocephalus a pseudodeltidium (his pl. 23, fig. M) and referred to his pseudodeltidia as being (c) deltidia as well.
2. Beecher and later Schuchert used pseudodeltidium for conjunct deltidial plates; (usage b of Bronn above). Most North American authors have followed this usage.
3. Ting (1936, p. 345) used pseudodeltidium for "a single median plate secreted ventral to the pedicle in Stringocephalus, so that the delthyrium in that shell would be covered by conjunct deltidial plates, equaling the 'pseudodeltidium' of American authors, plus a 'pseudoltidium' of Ting" (Cloud, 1942, p. 19). Cloud reports that this plate had not been observed by him, but "'it' appears

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to be simply the portions of the conjunct deltidial plates ventral to the pedicle."

4. Arber (1939, p. 82) has proposed adoption of pseudodeltidium for the embryonic deltidium secreted by the dorsal surface of the thoracic segment in embryonic protrematous articulates. Arber (1939, p. 88) also proposes the term secondary pseudodeltidium for a "transversely striated thickening, or callist, facing dorsally within the apex of the delthyrium and forming an integral part of the ventral valve" by reduction of the pseudodeltidium. "Such a callist . . . is commonly associated with a pedicle which was either lost at an early stage or which migrated in an anterior direction so that it was removed from the hinge region."

Thus, in the words of Cloud (1942, p. 20), "The word pseudodeltidium, besides being hopelessly involved in ambiguity, is awkward and might well be abandoned." See deltidial plates and delthyrium.

PSEUDOPUNCTATE - Condition in which the shell lacks pores, but the inner fibrous layer contains spicules (rod-like bodies) of calcite which commonly form projections on the shell interior. These spicules tend to be dissolved more readily than the surrounding material in weathering, thus in weathered, worn or exfoliated specimens, course rounded pits that

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simulate endopuncta remain. Also holes left by surface spines on decorticated specimens have been taken for puncta.

PSEUDORESUPINATE - Shells that are convexo-concave without the early concavo-convex or flat stage in the brachial valve may be called pseudoresupinate (or simply convexo-concave).

PSEUDOSOCKETS - See pseudoteeth.

PSEUDOSPONDYLIUM - See spondylium.

PSEUDOTEETH - Small nodes of the ventral process protruding beyond the hinge line. These fit into small sockets (pseudosockets) immediately dorsal to the cardinal process lobes of the brachial valve.

PUNCTA - Plural of punctum (q. v.) Also the singular form of punctae. (See Williams, 1956, p. 250, et seq.)

Note: Shrock and Twenhofel (1933, p. 267) state that both punctum (neuter) and puncta (feminine) come from the perfect participle of the Latin pungere, to prick or puncture and hence should have identical meanings. The later form, however, is extremely rare while punctum (neuter), by contrast, has been traditionally used for the past three centuries and is the one defined in Webster's New International Dictionary and in the large Oxford English Dictionary. Punctum (neuter) is adopted for these reasons.

PUNCTAE - Plural of feminine form, puncta (q. v.)

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PUNCTATE - Condition in which the shell is characterized by endopuncta.

PUNCTUM - (Plural, puncta) Tiny cavity left in the shell after death. Also called puncta (plural punctae). See discussion under puncta above. Puncta are of two kinds, exopuncta and endopuncta; and brachiopod shells are described as punctate, impunctate, or pseudopunctate (see these terms). Williams (1956, p. 250, et seq.) has discussed puncta in more detail.

The function of a punctum is conjectural. Hobbs, and Cloud (1942, p. 27) suggest that they serve a respiratory function as indicated by the thin tubules extending outward toward the surface.

R

REAR - Posterior

RECEDING DENTAL PLATES - See dental plates.

RECTIMARGINATE - See commissure.

*RE-ENTRANT DENTAL PLATES - See dental plates.

RESUPINATE - Condition in which the lateral shell profile is concavo-convex in youth but reversed to convexo-concave in maturity.

RIB - General or noncommittal term for costa or plica. Also as used by some workers on productoids rib is synonymous with the preferable term ruga (Dunbar and Condra, 1932, p. 178). Other more exact terms should be employed in preference to this term.

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RIDGE - See socket ridge.

RIGHT - See orientation.

RUGA - Concentric shell corrugation which affects both outer and inner surfaces (Moore, 1952, p. 210).

RUGAE - Plural of ruga.

RUGOSE - Marked by rugae.

RUGOSITY - Condition of being rugose.

ROSTRAL CAVITIES - General and collective term for the cavities at the extreme posterior of the valve.

ROSTRATE - Having a beak or rostrum.

ROSTRUM - See beak.

S

SCULPTURE - Collective term for surface modifications of the exterior of the shell. See prosopon and ornament.

SECONDARY AREA - Perideltidial area (q. v.).

SECONDARY DEPOSIT - Shelly material deposited by the animal on the interior of the shell.

SEPTA - Plural of septum.

SEPTALIAL PLATES - A pair of plates arising from the bifurcation of the median septum and supporting the hinge plates in rhynchonelloids. Homologous with the crural plates of the terebratuloids.

SEPTALIUM - Spoon-shaped to triangular excavation between the divided hinge plates of the dorsal valve originating from a bifurcation of the dorsal septum at its posterior end and fusion of the connecting pieces with the hinge plates. (Leidhold, 1920, p. 354)

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It should be noticed that Leidhold does not refer to the structure but to the excavation although Thomson, Cloud, and Shrock and Twenhofel say "structure".

Although Shrock and Twenhofel (1953, p. 305) say that "the structure is not the result of the bifurcation of the septum, as it might seem to be, but is formed by the posterior reflection of the cardinal plate", Kozłowsli's figures (Kozłowski, 1929, Fig. 43, A & B, p. 145) seem to belie this statement.

SEPTUM - A partition, see median septum.

SESSILE SPONDYLIUM - See spondylium.

SHAFT - See cardinal process.

SHELL - External hard covering of internal soft body structures. The adult shell consists of two bilaterally symmetrical valves more or less dissimilar in shape. Brachiopod shells fall into two principal groups on the basis of original shell composition.

1. Chitinophosphatic shells - Shells composed of chitin, calcium phosphate, and lesser amounts of magnesium carbonate and sulphate and calcium carbonate - Lingula.
2. Calcareous shells - Shells composed almost entirely of calcium carbonate (98 plus percent) with traces of a few other salts -Laqueus.

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SINUS - A term used by many authors as synonymous with sulcus but which has now fallen into disfavor with specialist. Thomson (1927, p. 55) has suggested that the term "be restricted to a ventrally directed curve in course of the commissure." This seems unnecessary and the word had best be dropped altogether. The condition described by Thomson would be termed a ventral fold (see fold).

SOCKET RIDGES - Shelly ridges bounding the sides of the dental sockets. There are inner socket ridges and outer socket ridges, and neither, either, or both may be present.

SOCKET - Dental socket (q. v.).

SOCKET VALVE - See brachial valve.

SPINE - Long or short, straight or curved, solid or hollow projection of the shell surface (Moore, 1952, p. 210). Spines may also develop not only at the intersections of growth lines and radial features, but elsewhere over the shell surface. . . (Shrock and Twenhofel, 1953, p. 297). When they rise at a high angle to the surface they are said to be erect, when they lie at an angle approaching tangency they are described as oblique.

SPIRALIA - A pair of spirally enrolled calcareous ribbons produced anteriorly from the crura. A brachidium of this type may be divided into three parts: primary lamellae, the jugum, and the spiralia themselves. (See also diplospire).

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There are three general types of spiralia (from Shrock and Twenhofel, 1953, p. 308):

ATRYPOID - The primary lamellae extend anteriorly, following the lateral margin of the valve, and give way to spiralia whose apices are directed toward the plane of symmetry or in a dorsal or ventral direction.

SPIRIFEROID - The primary lamellae extend directly anteriorly to the central part of the shell where the spiralia arise and point laterally.

ATHYROID - The primary lamellae extend directly anteriorly for a short distance and then are deflected backward upon themselves; the spiralia begin following the deflection, and the apices are usually directly laterally.

Shells with atrypoid and athyroid brachidia usually have short hinge lines and those with spiriferoid brachidia, long ones.

SPIRALIUM - Singular of spiralia.

SPIRE - Spiralium.

SPIRIFEROID - See spiralia.

SPLIT TUBE - Syrinx.

SPONDYLIUM - A dorsally concave plate extending anteriorly from the posterior border of the pedicle valve and serving as a place of all muscular attachment in the pedicle valve. Schuchert and Cooper (1932, p. 26-29)

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give a complete discussion of the history and application of the term. The following definitions for various types of muscle platforms are largely taken from their work (with modifications).

When used unmodified the term refers to a spondylium simplex (see below).

PSEUDOSPONDYLIUM - A callus resembling a spondylium, developed in some shells beneath the muscles of the ventral [pedicle] valve and confluent with the inner lower surfaces of the dental lamellae.

SPONDYLOID - A structure simulating a spondylium in form but produced by the deposition of testaceous material on and about the dental lamellae, swelling them lateraally until union is effected.

SPONDYLIUM DISCRETUM OR DISCRETE SPONDYLIUM - Muscular attachment formed by slight convergence of dental lamellae which do not meet but extend clear to the floor of the valve. This is not, strictly speaking, a spondylium, but, being a primitive condition may show how the duplex spondylium arose.

SPONDYLIUM SIMPLEX - Spoon-shaped muscle platform formed by the convergence and union of the dental plates with a single simple median septum, the whole forming a unit. It is

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considered to have been formed by the resorbtion by the genital organs of the testaceous deposits about the base of the dental lamellae in a pseudospondylium thus leaving a single narrow septum underneath.

SPONDYLIUM DUPLEX - Spoon-shaped muscle platform formed by the convergence and union of the dental plates, near the floor of the valve, into a septum composed of two united vertical plates. It is considered to have originated through a lateral crowding together of the dental lamellae by sexual glands.

SESSILE SPONDYLIUM - Convergent dental plates are united to form a spoonlike muscle platform which rests on the floor of the valve.

FREE SPONDYLIUM - Convergent dental plates are united to form a spoonlike muscle platform that hangs suspended in the pedicle valve since it is not supported anteriorly by a septum.

Only the latter four of these six spondylium-like muscle platforms are true spondylia - i.e., they are formed by convergence of the dental lamellae. The others are discussed here merely for convenience and because of their superficial similarity and not to be construed as types or subdivisions of spondylium.

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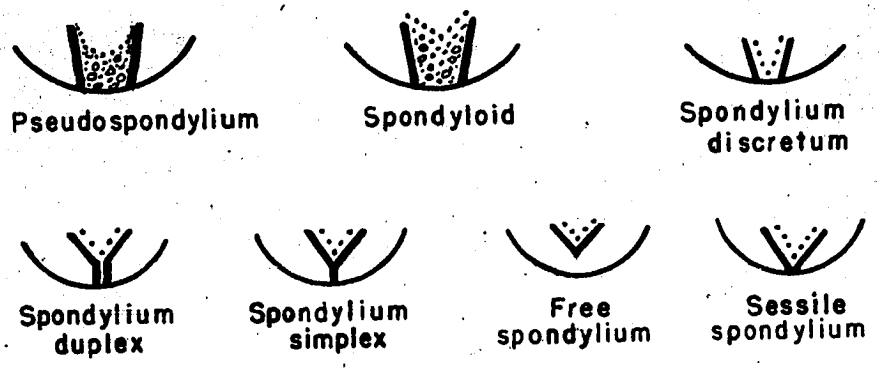

Fig. B13. - Various types of muscle platforms in the pedicle valve of articulate brachiopods. Very diagrammatic sectional representation of the posterior portion of the pedicle valve. Heavy black lines represent dental lamellae and shell; dotted lines indicate area of muscle attachment and gray vesicular area indicates adventitious shelly deposit.

SPONDYLIUM DISCRETUM - See spondylium.

SPONDYLIUM DUPLEX - See spondylium.

SPONDYLIUM SIMPLEX - See spondylium.

SPONDYLOID - See spondylium.

SPYRIDIUM - A spoon-like "basket" formed in the posterior part of the brachial valve "by the union of adductor muscle platforms elevated high above the valve floor by special vertical plates without the involvement of the median septum (Cooper and Stehli, 1955, p. 472).

STEGIDIUM - Heavy, convex plate built of concentric layers successively restricting the pedicle opening in certian syringothyroid genera (notably Syringospira Kindle). The stegidium is built by the adult animal from about the anterior edge of the transverse subdelthyrial plate toward the brachial valve until the pedicle opening is completely sealed. (See

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Cooper, 1954, p. 328).

Sartenaer (1955) reaches different conclusions on the formation and purpose of the stegidium than Cooper and says (p. 6) that the stegidium is only a particular kind of deltidium of an usual adaption. He purports to have found a Syringothyris? with a structure intermediate between a stegidium and an entire deltidium.

STRAIGHT - See curvature.

STRIA - Singular of striae.

STRIAE - Interspaces between costae and costellae. This term has been much abused and its current use for a radial rib is incorrect (Schuchert and Cooper, 1932, p. 11).

STRONG CARDINALIA - See cardinalia.

SUBDELTHYRIAL PLATE - A transverse horizontal septum more or less developed in spiriferoids between the dental plates well below the level of the delthyrium in the extreme rostral part of the pedicle valve. In some forms the delthyrid cavity below it is filled by secondary deposit and the structure appears as an apical callosity. Also called the delthyrial plate, transverse plate, apical plate, apical apparatus, and in syringothyrids the syringal plate.

This structure is not to be confused with the deltidium.

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SUBERECT - See curvature.

SUBMEGATHYRID - See cardinal margin.

SUBMESOTHYRID - See foramen.

SUBTEREBRATULID - See cardinal margin.

SULCATE - See commissure.

SULCI - Plural of sulcus.

SULCIPLICATE - See commissure.

SULCUS - Major more or less rounded depression of shell along longitudinal mid-line affecting both outer and inner surface, generally on pedicle valve - replaces sinus.

SURFACE LENGTH - See length.

SYMPHTIUM - See deltidial plates.

SYRINGAL PLATE - The subdelthyrial or transverse plate of the syringothyrids which bears the syrinx. See Hyde (1953, p. 265).

SYRINGOTHYROID TUBE - Syrinx (q. v.)

SYRINX - Solid or hollow subcylindrical, tapering calcareous tube which extends anteriorly into the pedicle valve from the subdelthyrial or syringal plate of the syringothyrids. It may have served as a sheath for the pedicle or as the seat of attachment of either the pedicle or adductor muscles. See discussion by Hyde (1953, p. 265, et seq.)

T

TALEOLA - Rod of calcite penetrating the shell surface and producing the pseudopunctate condition.

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> The taleolae are cleaved cylinders of granular calcite inclined inwardly and anteriorly to the shell surface . . . (Williams, 1956, p. 251).

TEETH - Hinge teeth (q. v.).

TEREBRATULID - See cardinal margin.

TEST - The shell.

TESTACEOUS DEPOSIT - Secondary deposit (q. v.).

THICKNESS - Linear distance from farthest opposite points on the surface of the two valves measured perpendicular to length and width.

TRAIL - Extended anterior part of the shell of productoids separated from the visceral disk by a geniculation of the shell.

TRAVERSE - Descriptive adjective applied to shells or shell structures that are wider than long.

Also, a direction perpendicular to the plane of symmetry or measurement in that direction.

TRANSVERSE PLATE - Subdelthyrial plate.

TRIPLICATE - Condition in which the sulcus is divided by the primaries into three nearly equal parts (see also uniplicate and dupliplicate).

TRUNCATE - Condition in which the beak has been resorbed by the pedicle.

TUBE - Syrinx (q. v.).

U

UMBO - Rounded convex prominence of valve adjacent (anterior) to the beak.

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UMBONAL CAVITIES - A pair of posterolateral cavities in the interior of either valve. In the ventral (pedicle) valve, when present, they are bounded by the dental plates and the shell walls. In the dorsal valve they are present only in those shells which have crural plate to separate them from the notothyrial cavity (q. v.) and the shell walls (Cloud, p. 1942, p. 16).

UMBONES - Plural of umbo.

UNDIVIDED HINGE PLATE - See hinge plate.

UNIPLICATE - Condition in which the sulcus is divided into two sections by a single primary rib. See also commissure, dupliplicate and triplicate.

V

VALVE - One of the distinct separate pieces of the shell usually more or less articulated with the opposite valve or part of the shell.

VASCULAR MARKING - Pallial marking.

VASCULAR SINUSES - Pallial sinuses.

VENTRAD - Direction toward the pedicle ("ventral") valve.

VENTRAL ADJUSTORS - See pedicle muscles.

VENTRAL FOLD - Ventrally directed (toward the pedicle valve) major curve of the commissure. (See fold).

VENTRAL PROCESS - Median callus of the cardinal margin of the pedicle valve which buttresses the xenidium of stropheodontids. It fits between the lobes of the

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cardinal process protruding from the brachial valve into the pedicle umbo. Caster (1939) and Williams (1953, p. 13-15) give a more thorough discussion of this feature.

VENTRAL VALVE - See pedicle valve.

VENTRALLY UNIPLICATE - Sulcate.

VISCERAL DISK - The posterior part of the shell of productoids which bounds the visceral cavity.

W

WEAK CARDINALIA - See cardinalia.

WIDTH OR BREADTH - Linear distance from side to side (see orientation). The position of maximum width should be given and in narrow-hinged forms the hinge width should also be cited.

X

XENIDIUM - A single shelly plate closing or restricting the delthyrium of shells such as those of the strophomenoids (Cloud, 1942, p. 17). Impunctate in both punctate and impunctate shells. See also delthyrium.

Williams (1953, p. 13) does not subscribe to this term but does little himself to clear up a confusion with pseudodeltidium (q. v.).

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PLATES

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EXPLANATION OF PLATES

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Explanation of Plate 1

Figure

1. *Lingula arcta* (?) Girty p.92

   Exterior of a presumed brachial valve from the Roystone coquinoid member of the Oswayo formation at locality 1, UMC No. 29768. Note that the other valve has slipped posteriorly.

2 - 6. *Lingula tidioutensis*, n. sp. p.96

   Specimens from the Tidioute shale at locality 202. 2, exterior of broken specimens, holotype, UCM No. 29825; 3, interior of broken specimen, paratype, UCM No. 29826; 4, exterior of broken specimen, paratype, UMC No. 29829; 5-6, exterior of broken specimens, UCM Nos. 29831 and 29830.

7 -13. *Lingulodiscina exilis* ? (Hall) p. 103

   7, Interior of a broken brachial valve showing faint radial ridges from the Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at locality 97, UCM No. 29849; 8-9, brachial and lateral views of exfoliated exterior of specimen from the Oswayo formation at locality 60, UCM No. 29838; 10, brachial exterior from the Roystone coquinoid member of the Oswayo formation at locality 1, UCM No. 29833; 11-12, brachial and lateral views of broken specimen from the Marvin Creek coquinoid at locality 97; UCM No. 29846; 13, brachial exterior of specimen from the Roystone coquinoid at locality 1, UCM No. 29834.

14-16. *Oehlertella pleurites* (Meek) p. 118

   14, Exterior of pedicle valve of specimen with unusually wide pedicle groove from the Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at locality 97, UCM No. 29818; 15, mold of the exterior of the pedicle valve showing the unclosed pedicle groove of specimen from the Roystone coquinoid at locality 1, UCM No. 29816; 16, mold of the interior of another specimen, from the same faunule, UMC No. 29817.

17-19. *Lissocrania parvula*, n. sp. p. 122

   17-18, Brachial exterior from the Marvin Creek coquinoid zone of the Kushequa member of the Knapp

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formation at locality 97, holotype, UCM No. 29851; 18, X 3; brachial interior showing indistinct subapical muscle platform, from same faunule as above. UCM No. 29850.

20. Orbiculoidea sp. indeterminate p. 116

Brachial interior from the Tidioute shale at locality 202, UCM No. 29832.

21-26. Orbiculoidea cf. O. alleghania (Hall) p. 109

21, Broken exterior of brachial valve from the Oswayo formation at locality 60, UCM No. 29815; 22-23, lateral and apical view of rubber cast of exterior of brachial valve from the Roystone coquinoid member of the Oswayo formation at locality 1, UCM No. 29758; 24, apical view of rubber cast of exterior of broken brachial valve from the same faunule, UCM No. 29759; 25-26, exfoliated pedicle valve and counterpart, respectively, from the same faunule, UCM No. 29814.

27. "Lingula" inexpecta, n. sp. p. 98

Holotype from the Roystone coquinoid member of the Oswayo formation at locality 183; UMC No. 29117.

28-30. Orbiculoidea, sp. A. p. 114

Two partial pedicle valves and a broken brachial valve respectively from the Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at locality 97, UCM Nos. 29820, 29821, and 29822.

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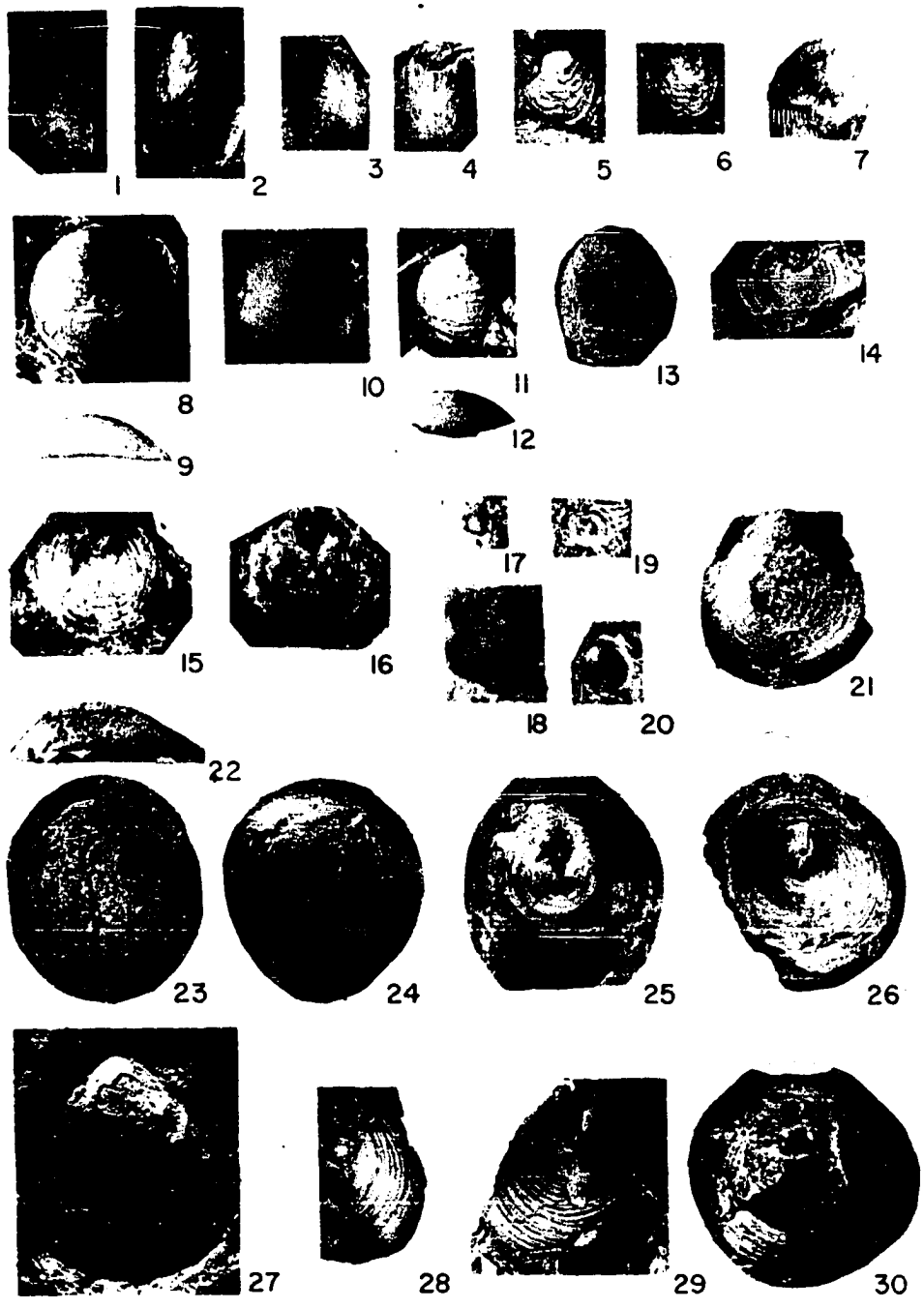
Plate I



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Explanation of Plate 2

Figure

1 - 8. Rhipidomella pennsylvanica (Simpson) p. 126

Specimens from the lower Syringothyris zone of the Knapp formation at locality 199. 1, mold of the interior of the brachial valve with a piece of shell adherring and showing the deep pits occupied by the cardinalia, UCM No. 29698; 2, rubber cast of exterior of pedicle valve with piece of Schuchertella appressed to surface, UCM No. 29692; 3, rubber cast of interior of same specimen (from counterpart slab) showing the pedicle callist and the large flabellate diductor muscle scar; 4, rubber cast of exterior of brachial valve showing tubules of boring organisms on the umbo, UCM No. 29690; 5, rubber cast of interior of posteriorly broken pedicle valve showing an unusually strong forked median septum enclosing the adductor muscle scars, UCM No. 29739; 6, rubber cast of interior of brachial valve showing large kite-shaped myophore of the cardinal process, deep sockets, and heavy brachiophores, UCM No. 29743; 7, rubber cast of interior of another brachial valve showing the brachiophore supports and the shaft of the cardinal process, UCM No. 29689; 8, same as figure 6, enlarged X 1.7 to show the brachiophore tooth preserved on the right brachiophore.

9 -13. Schuchertella desiderata (Hall and Clarke) p. 142

Specimens from the Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97. 9, Posterior view of pedicle valve of a mold of the interior showing the shallow depression for the low ridges which represent the dental lamellae and the filling of the inner surface of the arched xenidium, UCM No. 29676; 10, same, showing the faint cordiform diductor muscle area; 11-13, rubber cast of the interior of the brachial valve, exterior of the pedicle valve with a portion of the shell adherring, and mold of the interior of the brachial valve of a specimen from the same locality, UCM No. 29675. The rubber cast of figure 11 was made before the posterior part of the valve shown in figure 13 was treated by brushing with very dilute hydrychloric acid to remove partly preserved cardinalia and dental lamellae; hence the dental ridges in figure 11 do not appear quite as strong as the depressions in figure 13 would indicate.

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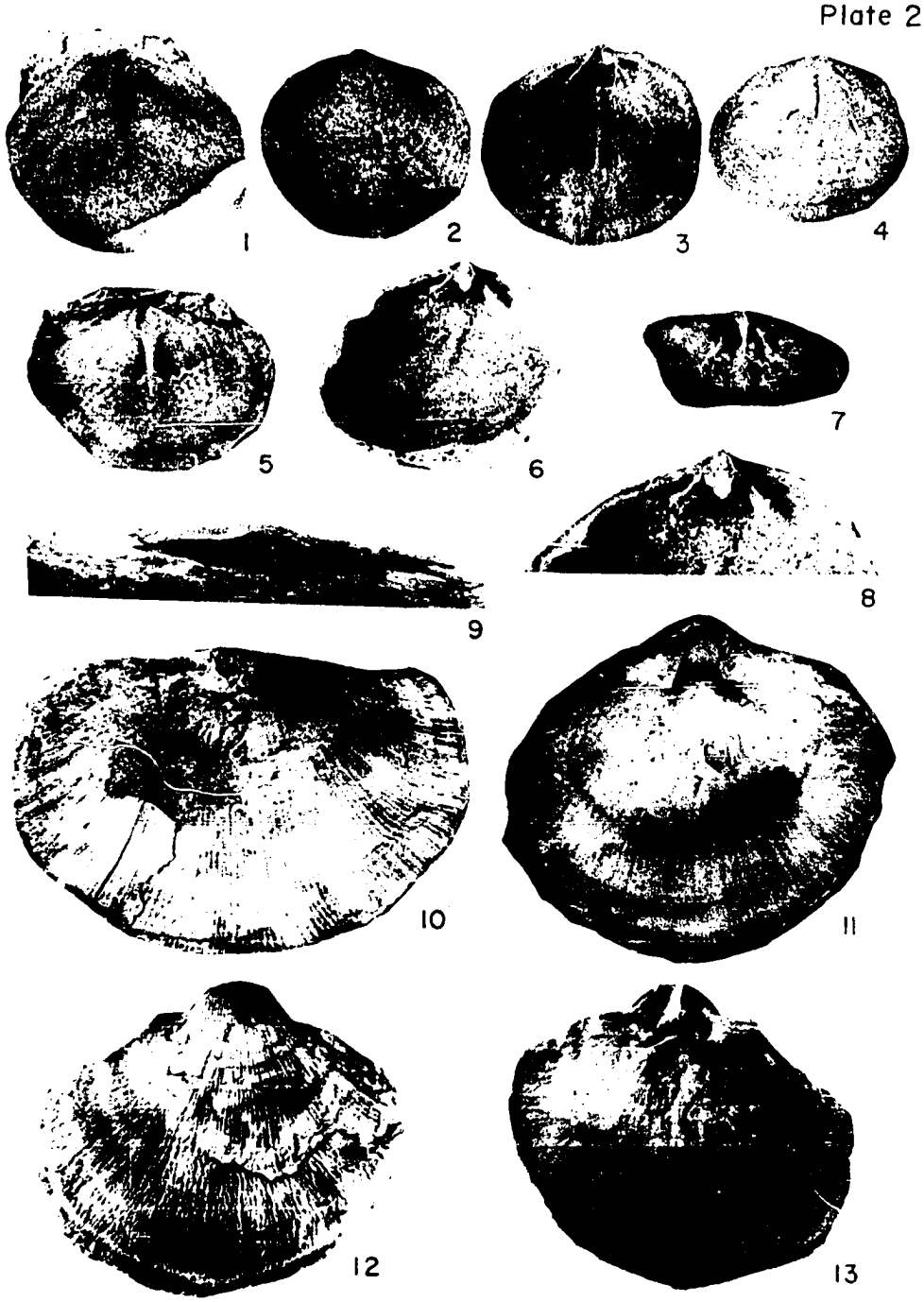
Plate 2



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Explanation of Plate 3

Figure

1 - 4. Schuchertella desiderata (Hall and Clarke) p. 142

1, Posterobrachial view of mold of the interior of a large specimen showing the deep pits for the cardinalia, lower Syringothyris zone of the Knapp formation at locality 199?, UCM No. 29677; 2-3, rubber casts of same tipped at various angles to show the high bifid cardinal process with its semi-cylindrical seat of muscle attachment; 4, pedicle valve of a partially exfoliated specimen showing the implantation and bifurcation of the costellae, Marvin Creek zone of the Kushequa member of the Kanpp formation at locality 97, UCM No. 29584.

5 -10. Schuchertella n. sp. p. 151

Specimens from the Kushequa shale member of the Knapp formation at locality 166. 5-6, Posterior and pedicle view of the mold of the interior of a pedicle valve, UCM No. 29953; 7, view of the posterior part of the rubber cast of the interior of the pedicle valve showing the slight development of dental ridges, UCM No. 29952; 8, mold of the interior of pedicle valve of the same; 9, mold of the interior of pedicle valve of a specimen showing a very twisted beak, UCM No. 29957; 10, rubber cast of a pedicle valve, UCM No. 29960.

11-18. Dictyoclostus dubitatus, n. sp. p. 156

11-13, Posterior, pedicle, and lateral views of a pedicle valve, Marvin Creek zone of the Kushequa shale member of the Knapp formation at locality 97, holotype, UCM No. 29771; 14-15, pedicle views of two specimens from the same locality, paratypes, UCM Nos. 29777 and 29774, respectively; 16, rubber cast of the interior of a brachial valve showing the low median septum, Tidioute shale at locality 201, paratype, UCM No. 29810; 17-18, lateral and brachial views of a mold of the exterior of a brachial valve from the Marvin Creek coquinoid zone at locality 97, paratype UCM No. 29793.

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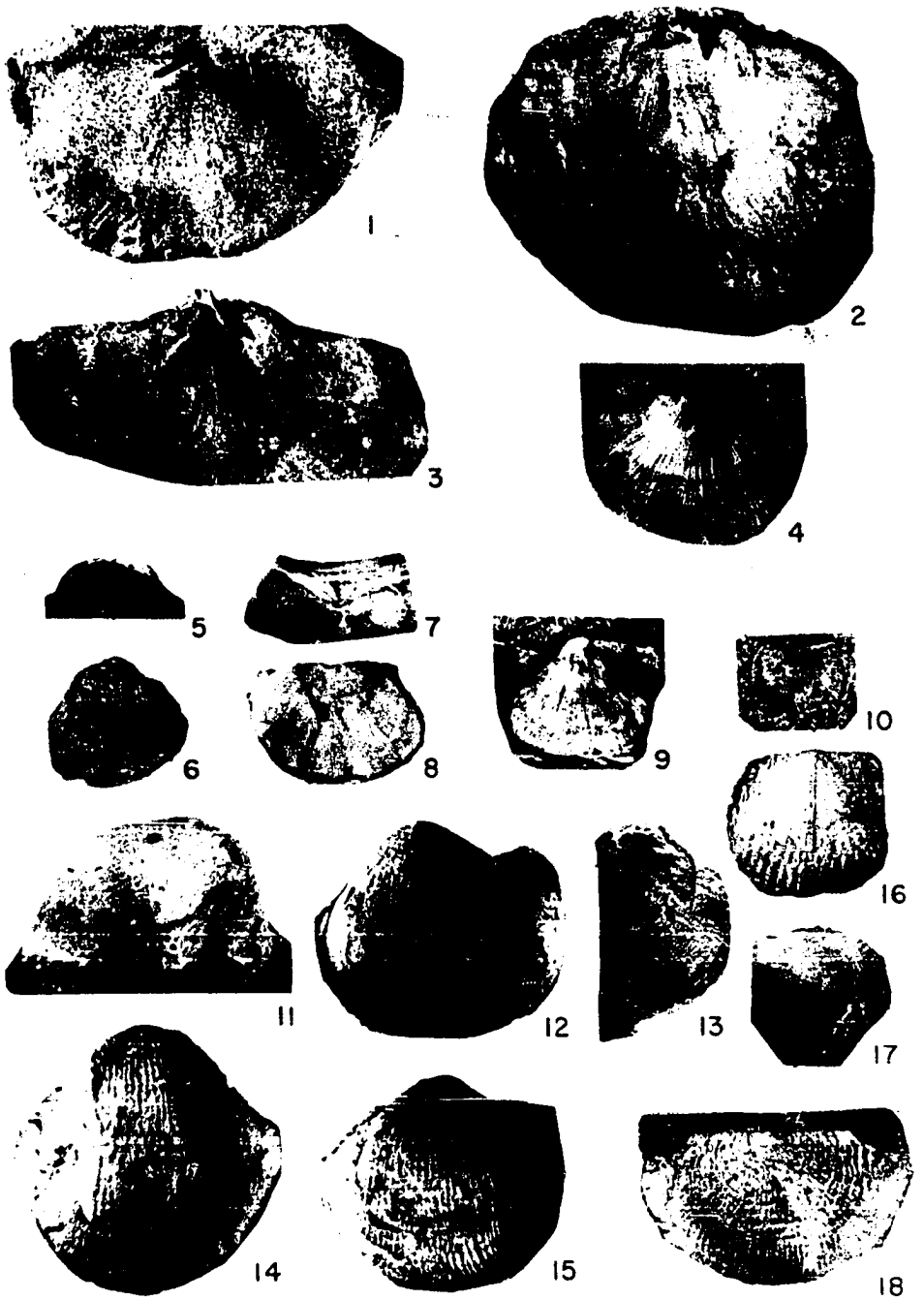
Plate 3



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Explanation of Plate 4

Figure

1 - 2. Dictyoclostus dubitatus n. sp. p. 156

Specimens from the Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97. 1, Anterior part of pedicle valve of a small specimen, showing the rounded costae and a row of spines on the left corner near the broken trail, paratype, UCM No. 29774; 2, posterior view of a badly exfoliated pedicle valve showing a mold of the interior of the large muscle area of the umbo, UCM No. 29778.

3 - 5. Dictyoclostus dubitatus variant A. n. variant p. 164

Specimens from the Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97. 3-4, Pedicle and lateral views showing the steep flanks and the overhanging umbo, UCM No. 29800; 5, posterior view of a badly exfoliated pedicle showing the muscle scar beneath the pedicle umbo, UCM No. 29801.

6. Chonetes cf. C. setigerus (Hall) p. 168

Mold of the interior of the pedicle valve of the only specimen. Tidioute shale at locality 119, UCM No. 29769.

7 -13. Camarotoechia allegania (Williams) s. s. p. 173

Specimens from the Roystone coquinoid member of the Oswayo formation at locality 1. 7-10, Posterobrachial, pedicle, lateral, and anterior views of a mold of the interior of a well preserved specimen, UCM No. 29000; 11-13, brachial, pedicle and anterior views of a mold of the interior of a specimen, UCM No. 29002. Note especially the prominent muscle scar shown in fig. 12.

14-21. Camarotoechia allegania obesa, n. subsp. p. 178

Specimens from the Roystone coquinoid member of the Oswayo formation at locality 183. 14, Lateral view of a badly exfoliated specimen, holotype, UCM No. 29005; 15, posterobrachial view of the mold of the interior of a crushed specimen, paratype, UCM No. 29007; 16-17, posterior view of the mold of the interior and rubber cast of the same, showing the

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deeply impressed muscle scar, paratype, UCM No. 29008; 18-20, brachial, lateral and anterior views of mold of the interior, paratype, UCM No. 29009; 21, rubber cast of the posterior part of conjoined valves showing the strong cardinalia, the septalium, and the median septum, UCM No. 29011. Note the extreme gibbosity and the high squarish fold as shown especially in figs. 14, 19 and 20.

22-32. Camarotoechia lingulata, n. subsp. p. 180

Specimens from the Roystone coquinoid member of the Oswayo formation at locality 183. 22-24, Brachial, lateral and anterior views of a partially exfoliated specimen showing the broad gently curving fold, holotype, UCM No. 29012; 25-27, brachial, lateral and anterior views of a mold of the interior, paratype, UCM No. 29015; 28-32, brachial, pedicle, posterior, lateral and anterior views of a mold of the interior, paratype, UCM No. 29013. Note the elongate outline, and transversely arcuate anterior profile of this form.

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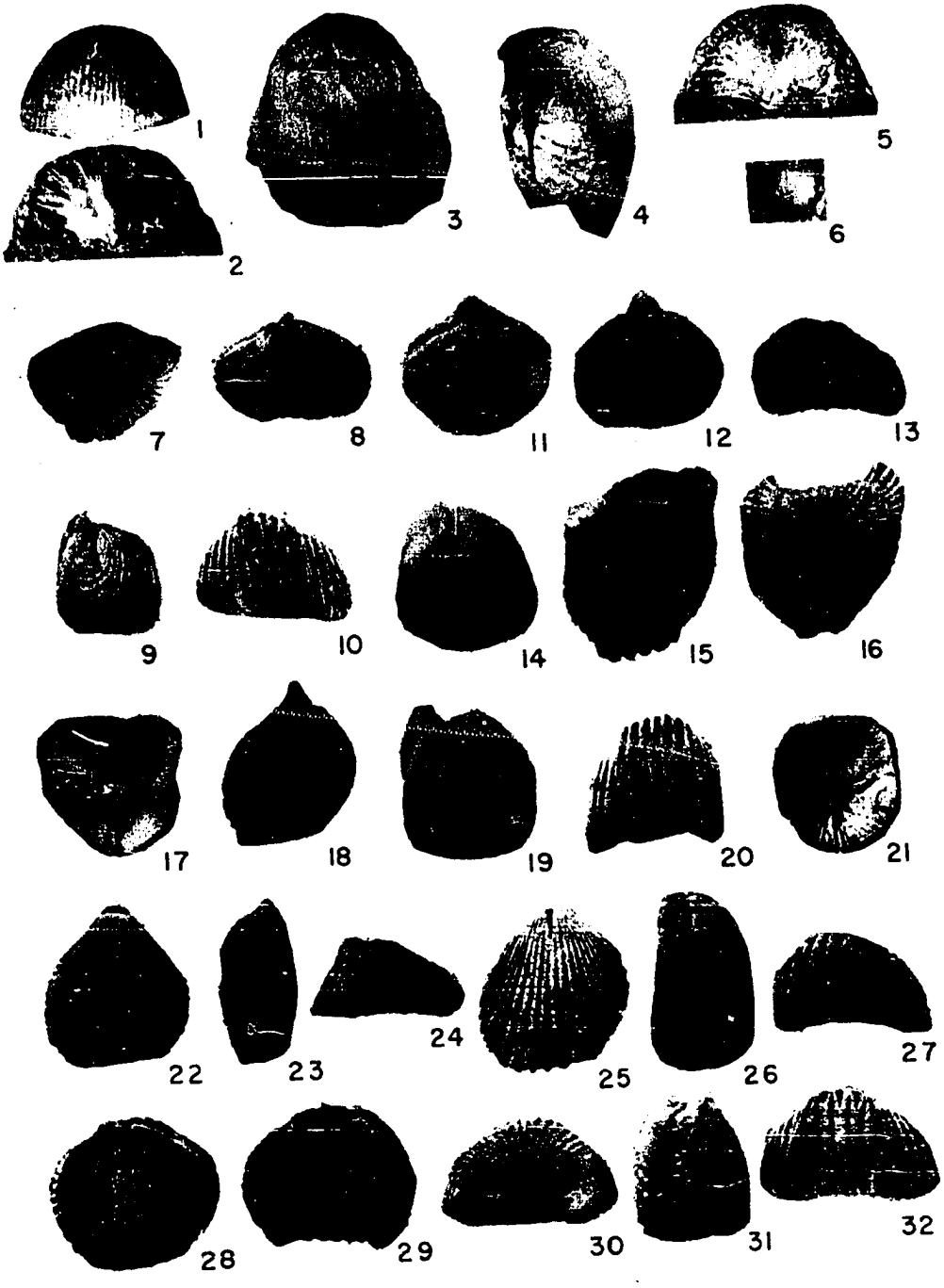
Plate 4



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Explanation of Plate 5

Figure

1 - 2. Camarotoechia allegania (Williams) s. s. p. 173

Enlargements (X 2) of the interior of rubber casts of the posterior part of the shell showing the cardinalia with the divided hinge plate, median septum, heavy teeth and broad sockets. 1, specimen from the Roystone coquinoid member of the Oswayo formation at locality 183, UCM No. 29122; 2, specimen from the Roystone member at locality 1, UCM No. 29121.

3 -15. Camarotoechia mimelegantula, n. sp. p. 182

3-6, Brachial, pedicle, lateral and anterior views of a mold of the interior with a small amount of shell remaining, Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97, holotype, UCM No. 29701; 7-9, brachial, lateral and anterior views of a well preserved specimen from the same faunule, paratype UCM No. 29703; 10-12, same, paratype UCM No. 29715; 13, brachial view of a specimen from the same faunule, UCM No. 29705; 14, same, UCM No. 29709; 15, brachial view of a sandstone mold of an interior from the Kushequa member of the Knapp formation at locality 51, UCM No. 29720.

16-17. Camarotoechia, cf. C. contracta (Hall) p. 189

Brachial and anterior views of a mold of the interior from the Kushequa member of the Knapp formation at locality 175, UCM No. 29721.

18. Camarotoechia sp. indeterminate p. 191

Mold of the exterior of a small specimen from the Tidioute shale at locality 201, UCM No. 29723.

19-26. Camarotoechia (Spathula) spathulata, n. sp. p. 193

19-22, Brachial, pedicle, lateral and anterior views of a mold of the interior with part of the shell remaining, Roystone coquinoid member of the Oswayo formation at locality 183, holotype, UCM No. 29730; 23, brachial valve of an exfoliated specimen from the same faunule, paratype UCM No. 29732; 25, brachial view of a mold of the interior

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of a specimen from the Roystone member of the Oswayo formation at locality 1, UCM No. 29729; 26, brachial view of a mold of an interior of a specimen from the lower Oswayo formation at locality 109, UMC No. 29737.

27-34. Cyrtospirifer oleanensis var. A., n. variant p 226

Specimens from the Roystone coquinoid member of the Oswayo formation at locality 183. 27-31, Brachial, pedicle, anterior, lateral and posterior views of an exfoliated specimen, holotype, UCM No. 29501; 32, pedicle view of a similar specimen, UCM No. 29502; 33-34, mold of the interior and mold of the exterior showing the developed mucrones, paratype, UCM No. 29505.

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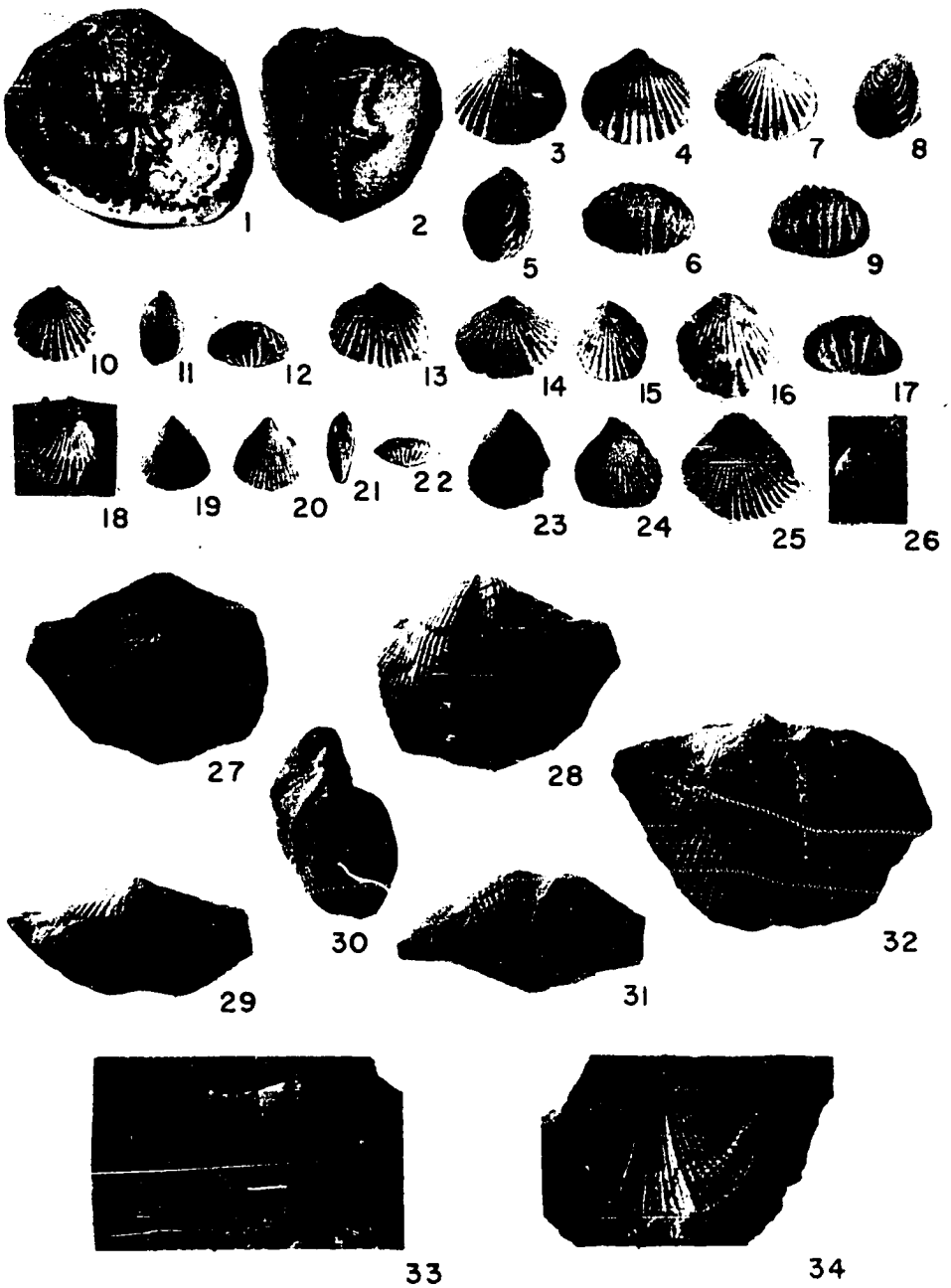
Plate 5



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Explanation of Plate 6

Figure

1 -12. *Cyrtospirifer oleanensis* Greiner p. 221

Specimens from the Roystone coquinoid member of the Oswayo formation. 1-5, Brachial, pedicle, anterior, lateral and posterior views of an exfoliated specimen showing the semicircular outline from locality 1, UCM No. 29439; 6-10, brachial, pedicle, anterior, lateral and posterior views of an exfoliated specimen showing the semicircular outline and the convexity of the lateral slopes, locality 183, UCM No. 29478; 11, brachial view of the mold of an interior from locality 1, UCM No. 29451; 12, stereo pair of a rubber cast of the specimen in fig. 11, showing the distinctive hinge plate with the dental lamellae rounding into the socket plates to form an ear-like structure.

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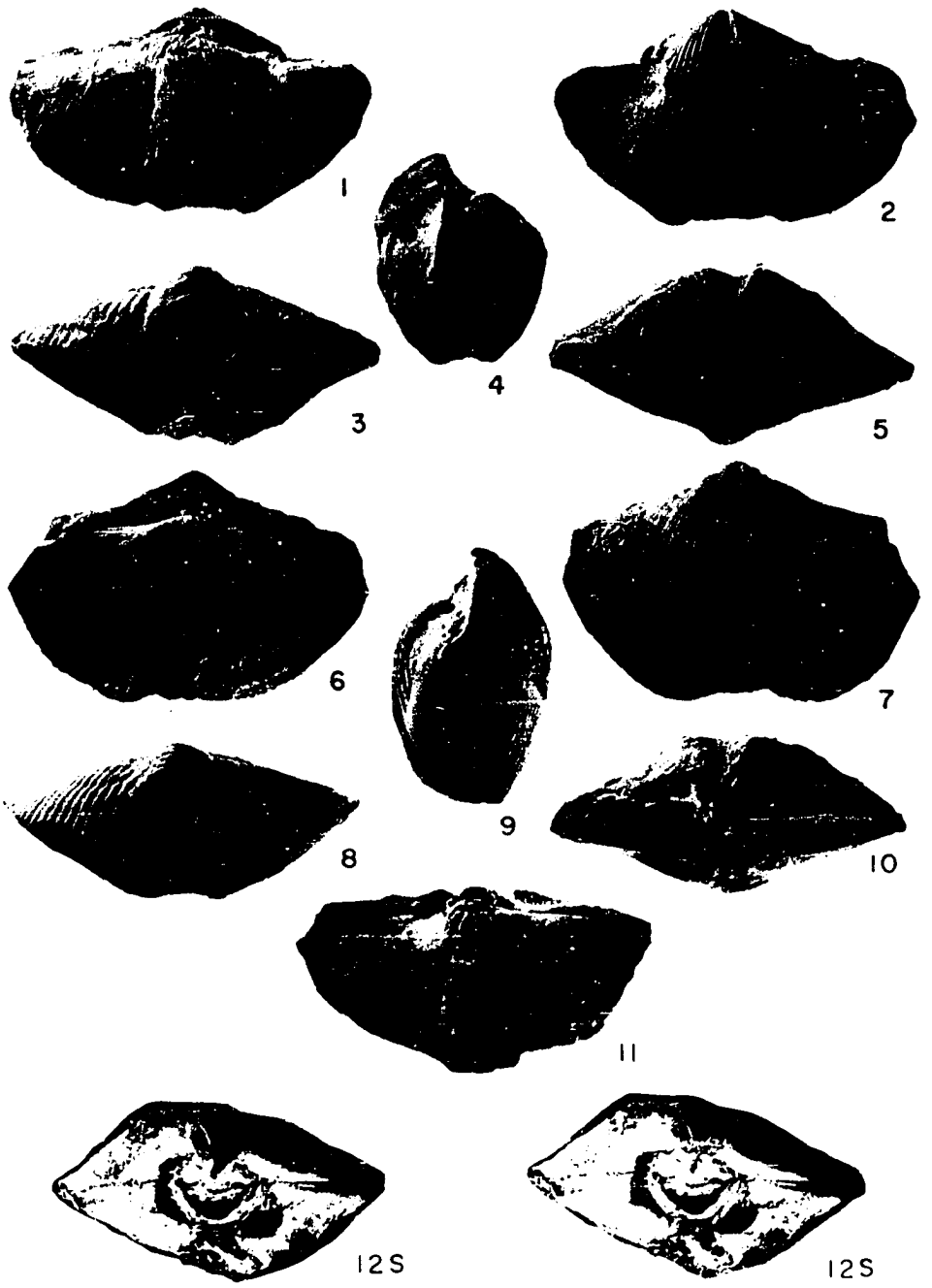
Plate 6



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Explanation of Plate 7

Figure

1 -15. Cyrtospirifer extentus, n. sp. p. 241

1-5, Brachial, pedicle, anterior, lateral and posterior views of an exfoliated specimen, showing the concave lateral slopes, apsacline and capillate area and the tendency to develop mucrones, Roystone coquinoid member of the Oswayo formation at locality 1, holotype, UCM No. 29301; 6-10, Same, paratype, UCM No. 29309; 11-15, Same views of a more attenuated specimen from the same faunule, paratype, UCM No. 29305.

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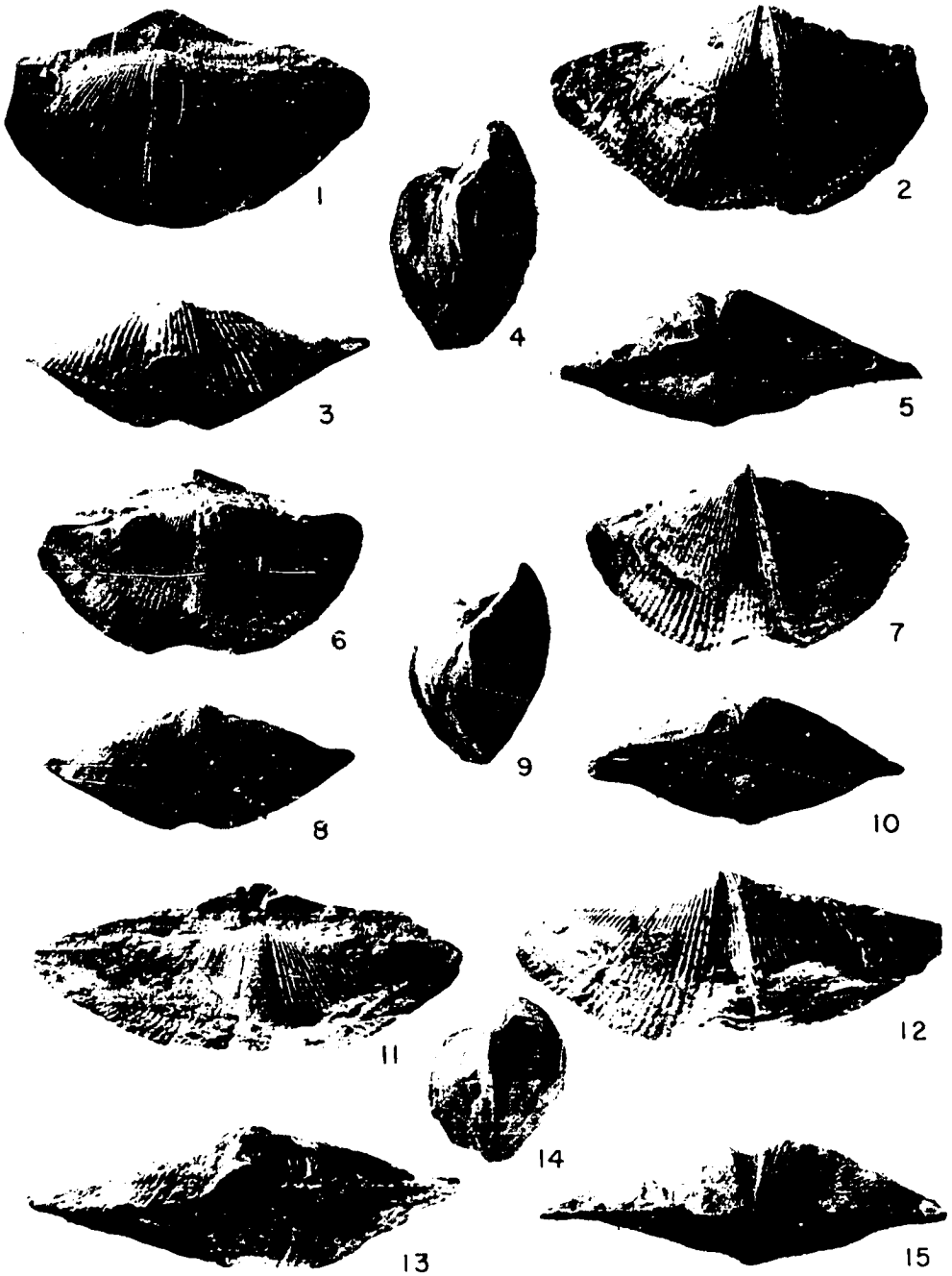
Plate 7



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Explanation of Plate 8

Figure

1 - 8. *Cyrtospirifer extentus*, n. sp. p. 241

Specimens from the Roystone coquinoid member of the Oswayo formation. 1, Partly exfoliated pedicle valve showing the lateral extent of the wings, locality 1, UCM No. 29306; 2, lateral view of a partly exfoliated exterior showing the nearly straight apsacline interarea, although the delthyrium is filled with rock matrix, locality 183, paratype, UCM No. 29408; 3-5, lateral, posterior and anterior views of a mold of the interior showing the depressions for the cardinalia, dental lamellae, and in fig. 4 the depression for the adductor process, locality 1, paratype, UCM No. 29319; 6, stereo pair of posterior part of a rubber cast of the same specimen showing the relatively thin dental lamellae, thin teeth, and the adductor process in the pedicle vavle (below); 7, posterior view of mold of the interior from the same faunule, paratype, UCM No. 29321; 8, posterobrachial view of a mold of the interior, showing the position of the cardinal process and brachial muscle scars, same faunule, UCM No. 29350.

9 -10. *Cyrtospirifer horridus*, n. sp. p. 249

9, Posterior view of a mold of the interior showing the deep wide cavities for the cardinalia and the dental lamellae, Roystone coquinoid member of the Oswayo formation, locality 1, UCM No. 29359; 10, stereo pair of a rubber cast of the specimen shown in fig. 9 showing the heavy dental lamellae and ponderous cardinalia. Note the median lamallar plates of the cardinal process.

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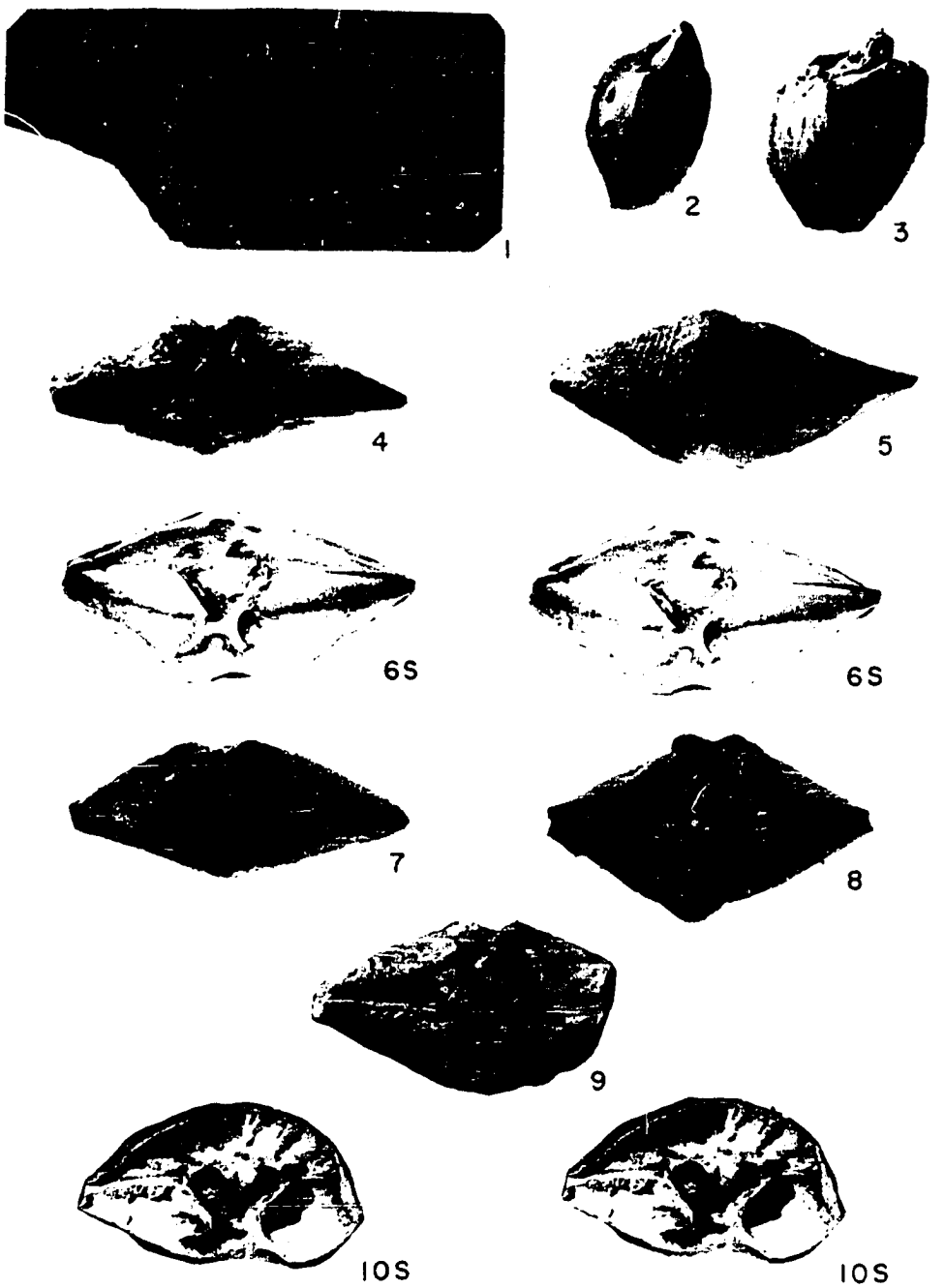
Plate 8



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Explanation of Plate 9

Figure

1 - 9. Cyrtospirifer horridus, n. sp. p. 249

1-5, Brachial, pedicle, anterior, lateral and posterior views of an exfoliated specimen from the Roystone coquinoid member of the Oswayo formation at locality 1, showing the great thickness and ponderous appearance of this form, holotype, UCM No. 29352; 6-9, brachial, pedicle, and lateral views of a similar specimen from the same faunule, paratype, UCM No. 29353.

10-14. Cyrtospirifer horridus variant A, n. variant p. 259

10-14, Brachial, pedicle, anterior, lateral and posterior views of an exfoliated specimen from the Roystone coquinoid member of the Oswayo formation at locality 1, showing the inflated valves, and the distinctive outline, holotype, UCM No. 29365.

Note the many depressions and rugosities shown on the mold of the interior when the shell has completely exfoliated away as in figs. 1, 7, 8 and 12. These seem to represent healed internal irritations or lesions.

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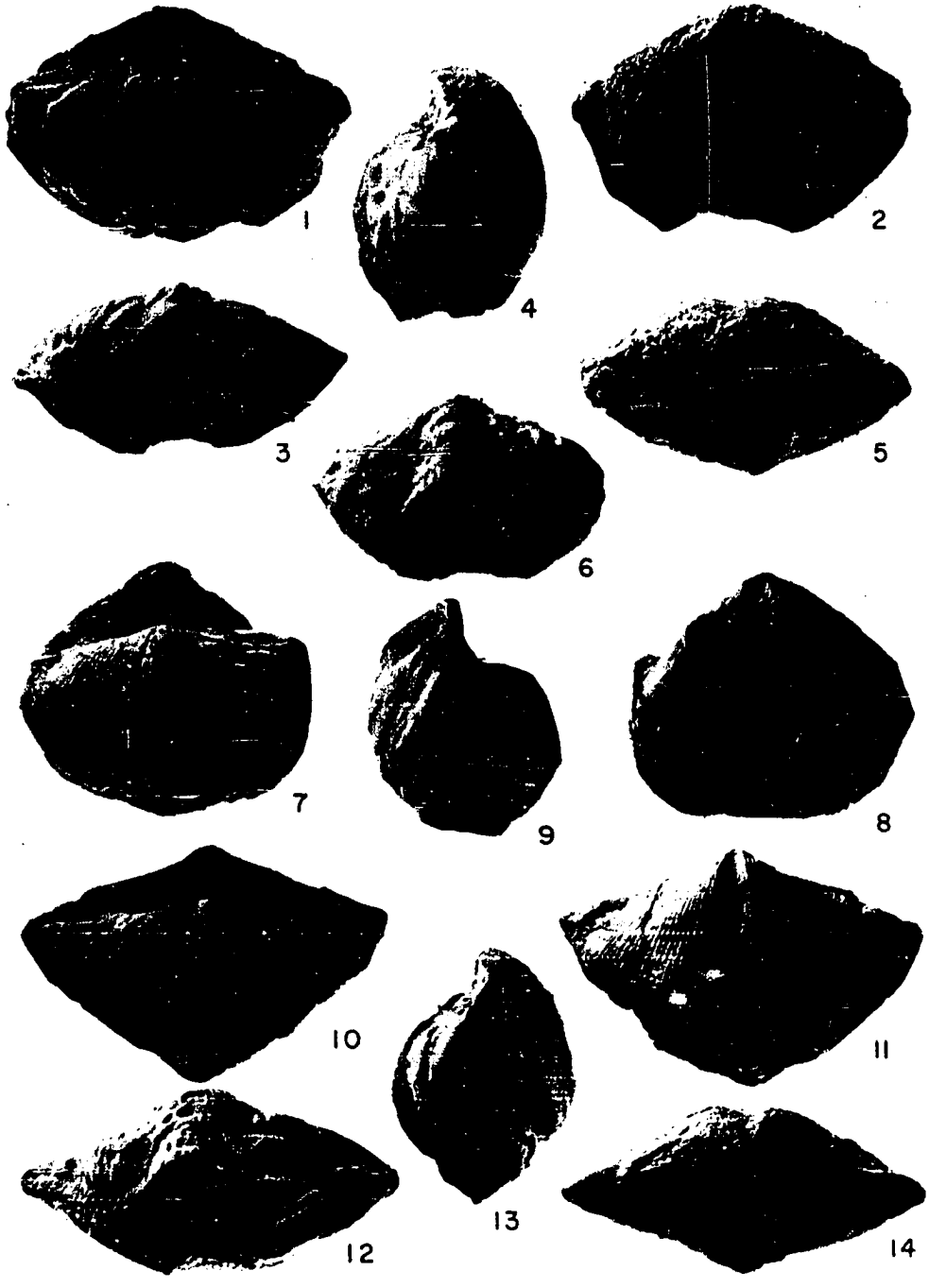
Plate 9



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Explanation of Plate 10

Figure

1 -12. Cyrtospirifer horridus strigosus, n. subsp. p. 262

Specimens from the Roystone coquinoid member of the Oswayo formation at locality 183. 1-5, Brachial pedicle, anterior, lateral and posterior views of an exfoliated specimen showing the length of the valves, the semicircular anterior outline and the characteristic broad low fold and reduced width of this form, holotype, UCM No. 29377; 6-9, anterior, brachial, lateral and pedicle views of an exfoliated specimen showing a subquadrate outline, broad, low fold, high, slightly curved nearly orthocline area and broad diductor and narrow adductor scars where the shell is exfoliated, paratype, UCM No. 29378; 10, brachial view of a small specimen with a high area and wide delthyrium characteristic of this fomr, but showing the similarity to other closely related Conewangoan species, UCM No. 29381; 11, brachial view of a mold of the interior of a specimen with the pedicle umbo slightly crushed up over the brachial valve showing the depression for the large cardinal process of the brachial valve and at the top of the large depression for the heavy adductor process of the pedicle valve, paratype, UCM No. 29388; 12, brachial view of a mold of the interior, UCM No. 29395.

Note the depressions and rugosities characteristic of the species in specimens where the shell has broken away.

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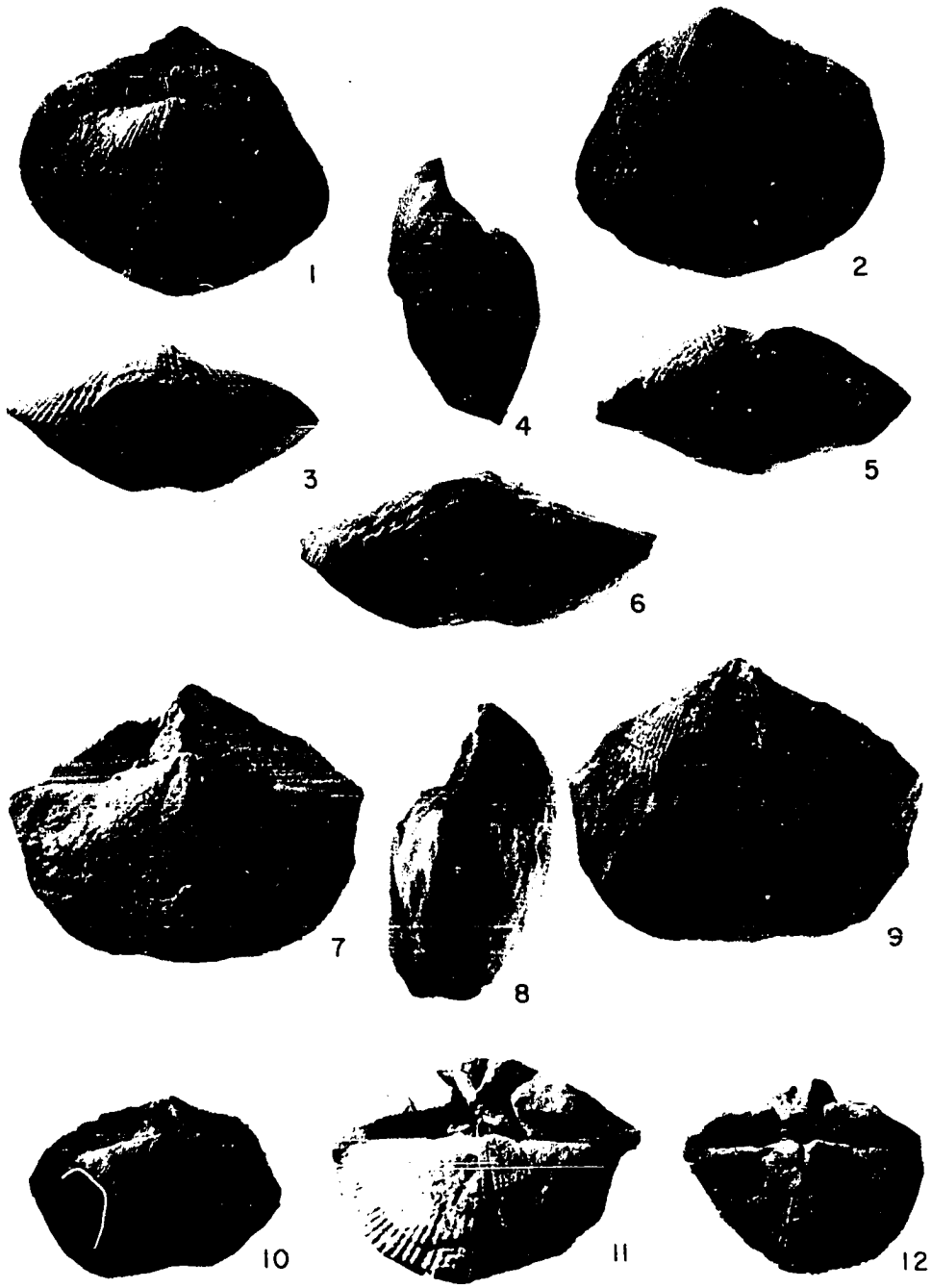
Plate 10



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Explanation of Plate 11

Figure

1 - 2. *Cyrtospirifer* sp. indeterminate p. 268

1, Mold of the interior of a brachial valve showing the attenuate hinge line characteristic of this form, sandstone in the Oswayo formation at locality 109, UCM No. 29525; 2, pedicle view of a mold of the interior from the same faunule showing laterally attenuate nature and the depressions for the thin dental lamellae, UCM No. 29523.

3. *Cyrtospirifer extentus* (?) n. sp. p. 241

Broken, exfoliated exterior from the Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at locality 97, UCM No. 29864.

4 - 9. *Cyrtospirifer lobatimusculus* Greiner p. 232

4, Mold of the interior of the pedicle valve shwoing the thin dental lamellae which bound the characteristic lobate muscle area, from the lower *Syringothyris* zone of the Knapp at locality 118, UCM No. 29870; 5-6, mold and rubber cast of the interior of a pedicle valve from the same faunule, UCM No. 29871; 7, mold of the interior of the pedicle valve from the same faunule, UCM No. 29872; 8-9, mold and rubber cast of the interior of a pedicle valve from the Kushequa member of the Knapp formation at locality 166, UCM No. 29881.

10-14. *Cyrtospirifer warrenensis* Greiner p. 229

Specimens from the Kushequa member of the Knapp formation. 10-11, Mold and rubber cast of the interior of a pedicle valve showing the large robust nature, widely divergent dental lamellae, large diamond-shaped muscle scar, characteristic of this species, at locality 51, UCM No. 29887; 12-13, same, UCM No. 29884; 14, mold of the interior of the pedicle valve of a broken specimen from locality 166, UCM No. 29890.

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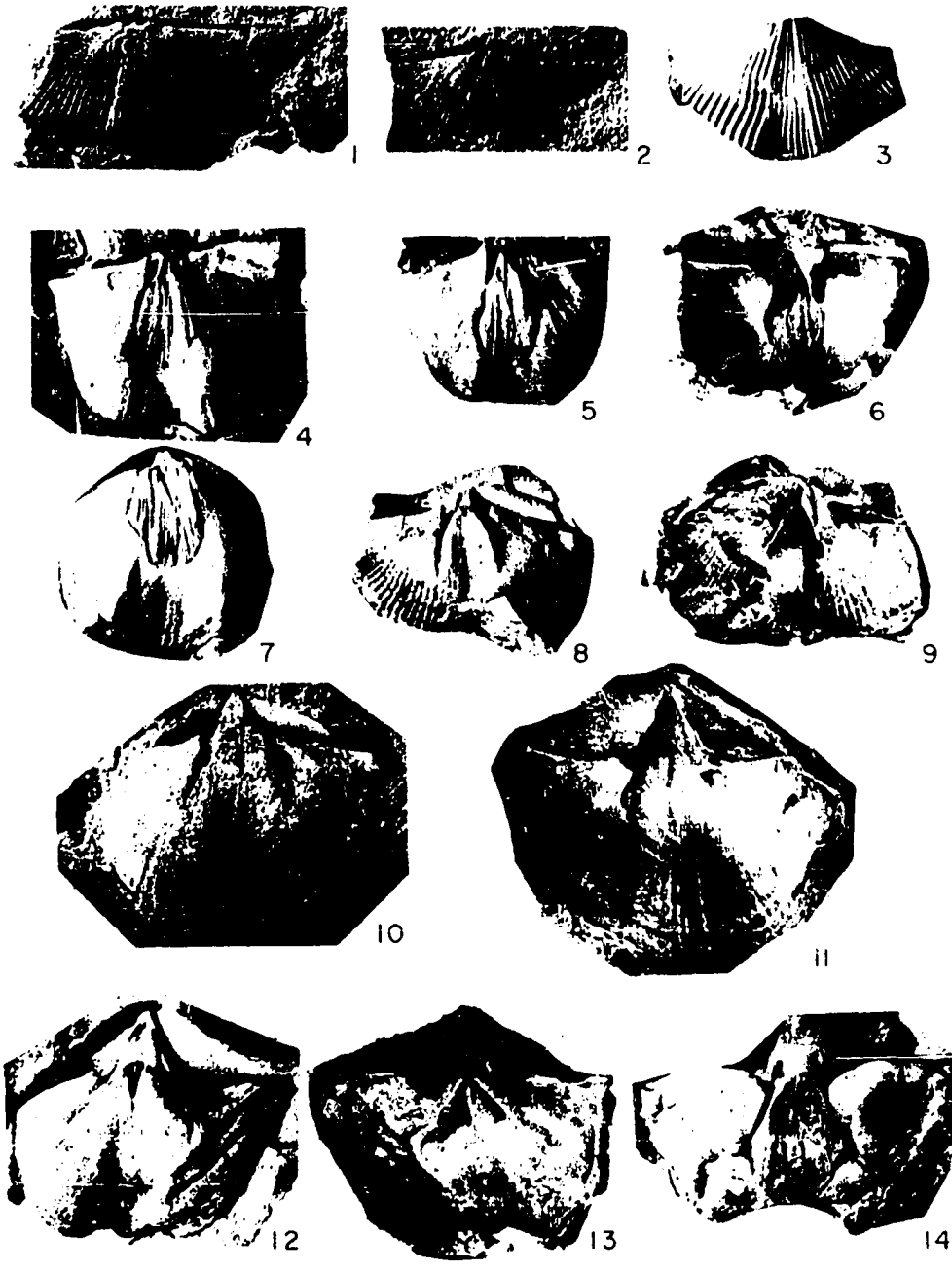
Plate II



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Explanation of Plate 12

Figure

1 - 4. Cyrtospirifer lobatimusculus parvus, n. subsp. p. 235

1, Mold of the interior of the pedicle valve showing the tendency of this form to develope mucrones, sandstone in the Kushequa member of the Knapp formation at locality 51, holotype, UCM No. 29900; 2-3, mold and rubber cast of the interior of the pedicle valve showing the fine plicae, attentuate outline, and thin dental lamellae from the Kushequa member of the Knapp formation at locality 166, paratype, UCM No. 29902; 4, rubber cast of the interior of a pedicle valve showing the thin dental lamellae and slight development of the subdelthyrial plate, lower Syringothyris zone of the Knapp formation at locality 118, UCM No. 29905.

5 -16. "Cyrtospirifer" plenellus, n. sp. p. 270

Specimens from sandstone in the Knapp formation at locality 118. 5, Mold of the interior of the pedicle valve showing the estreme development of the dental lamellae and the large diductor scar enclosing the narrow adductor scar, paratype, UCM No. 29929; 6-7, mold and rubber cast of the interior of the pedicle valve showing the estreme development of the dental lamellae and the distinctive, very long adductor process, UCM No. 29936; 8, rubber cast of the interior of a pedicle valve showing the same features and the development of the genital pits in the posterior part of the valve, UCM No. 29933; 9-13, brachial, pedicle, anterior, lateral, and posterior views of a mold of the interior showing the obese nature, huge muscle scar, faint but wide plicae, and large lingula extension of the sulcus, paratype, UCM No. 29928; 14, rubber cast of the preceeding; 15-16, mold and rubber cast of the interior showing the distinctive muscle scar and large adductor process, holotype, UCM No. 29927.

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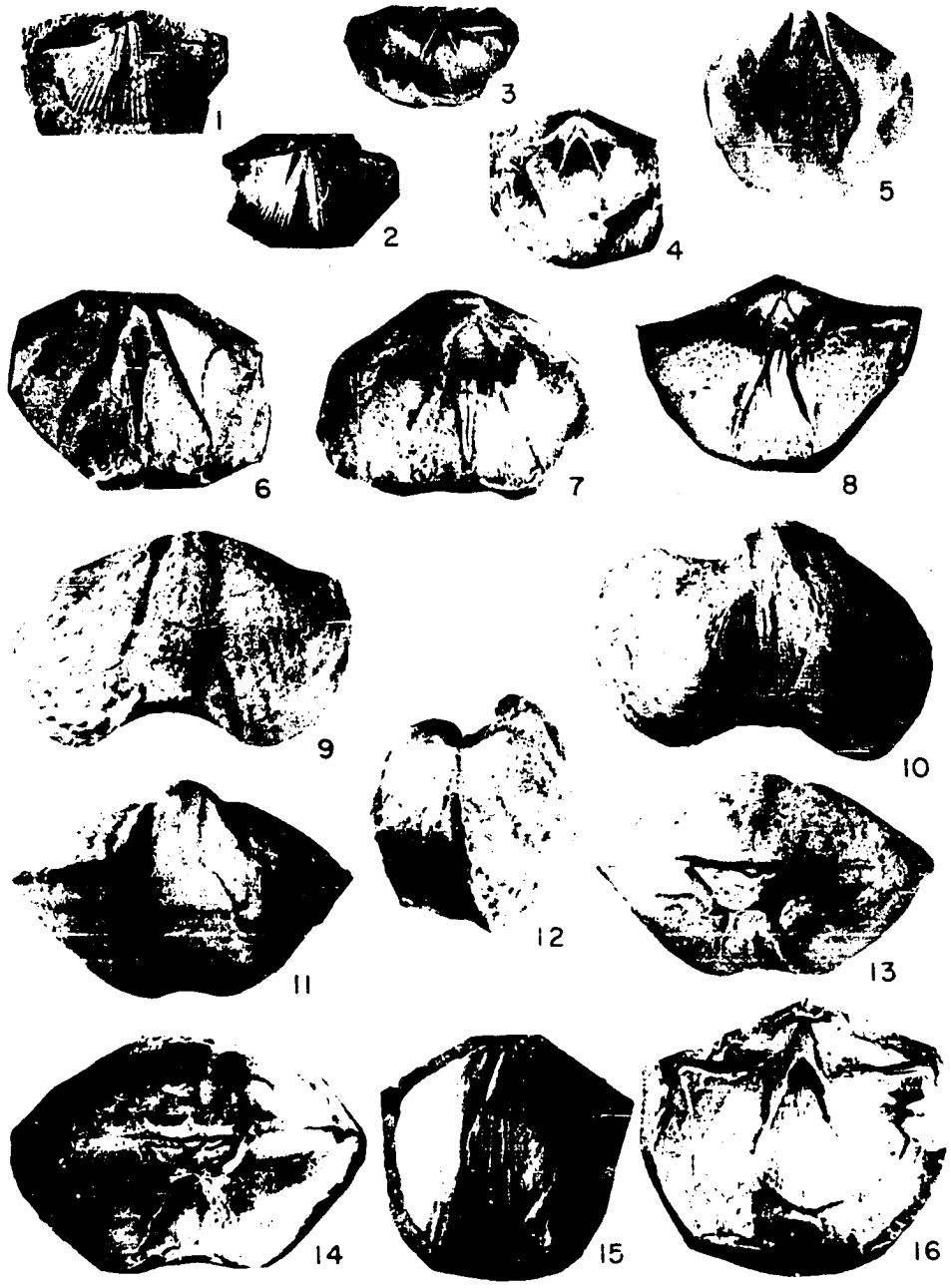
Plate 12



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Explanation of Plate 13

Figure

1 -15. Syringothyris angulata Simpson p. 295

1-2, Posterior and posteropedicle views of a mold of an interior of one of Simpson's cotypes, Philadelphia Academy of Natural Sciences No. 9533; 3-4, brachial and posterior views of a mold of the interior herein selected as the lectotype, Philadelphia Academy of Natural Sciences No. 9535; 5, posterior view of a mold of the interior of one of Simpson's cotypes, Philadelphia Academy of Natural Scineces No. 9538; 6-7, pedicle and posterobrachial views of a mold of the interior of another specimen with the type lot, Philadelphia Academy of Natural Scienes No. 9480; 8-9, brachial and pedicle views of a mold of the interior from the Kushequa shale member of the Knapp formation at locality 166, UCM No. 29923; 1-, posterobrachial view of a mold of the interior showing well preserved the position of the cardinal process and depression for the heavy vertical ridge below it, Kushequa member of the Knapp formation at locality 175, UCM No. 29535; 11-12, same from the Cobham conglomerate member of the Knapp formation at locality 91, UCM No. 29546; 13, brachial view of an exfoliated specimen from the Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at locality 97, UCM No. 29541; 14-15, mold of the interior and rubber cast of a pedicle valve from the Kushequa shale member of the Knapp formation at locality 166, UCM No. 29922.

The Philadelphia Academy of Natural Sciences specimens were studied by both Dr. Caster and the writer and no. 9533 is believed to be from the Lower Knapp or the Kushequa shale, the lectotype (no. 9535) and specimen no. 9480 are believed to be from the Kushequa, but no. 9538 is believed to be from the Tidioute formation.

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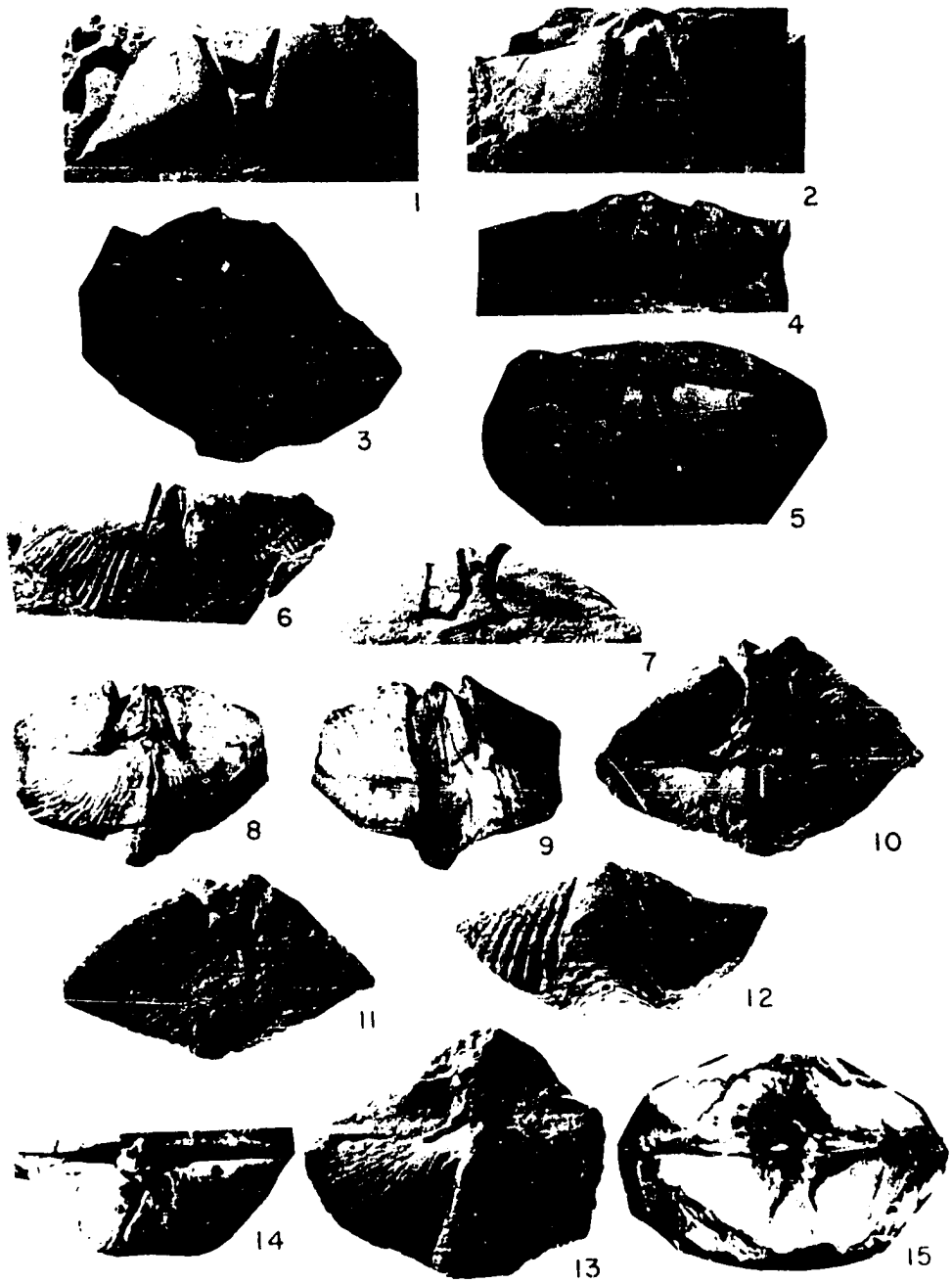
Plate 13



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Explanation of Plate 14

Figure

1 - 2. *Syringothyris angulata* Simpson p. 295

Mold and rubber cast of the interior of a specimen showing the cardinalia, teeth and extremely wide, flat syrinx, Kushequa shale member of the Knapp formation at locality 175, UCM No. 29531.

3 - 11. *Syringothyris warrenensis*, n. sp. p. 303

3-5, Pedicle, posterior views of a mold of the interior of a pedicle valve and interior view of a rubber cast showing the extremely wide muscle area and a divergent and recurved dental lamellae fig. 5 shows the heavy syrinx which was twisted, however, in the rubber cast during preparation, lower *Syringothyris* zone of the Knapp formation at locality 199, holotype, UCM No. 29621; 6-7, pedicle and lateral views of a mold of the interior of a specimen from the Kushequa member at locality 175, UCM No. 29534; 8, pedicle view of a mold of the interior of a specimen from the Kushequa member at locality 166, UCM No. 29916; 9-10, mold and cast of the interior of a broken specimen from the lower *Syringothyris* zone of the Knapp formation at locality 118, UCM No. 29917.

11-12. *Cyrtospirifer tionesta* Greiner p. 237

Brachial and pedicle views of two specimens from the Tidioute shale at locality 91 showing the distinctive broad flat plicae, UCM Nos. 29948 and 29944, respectively.

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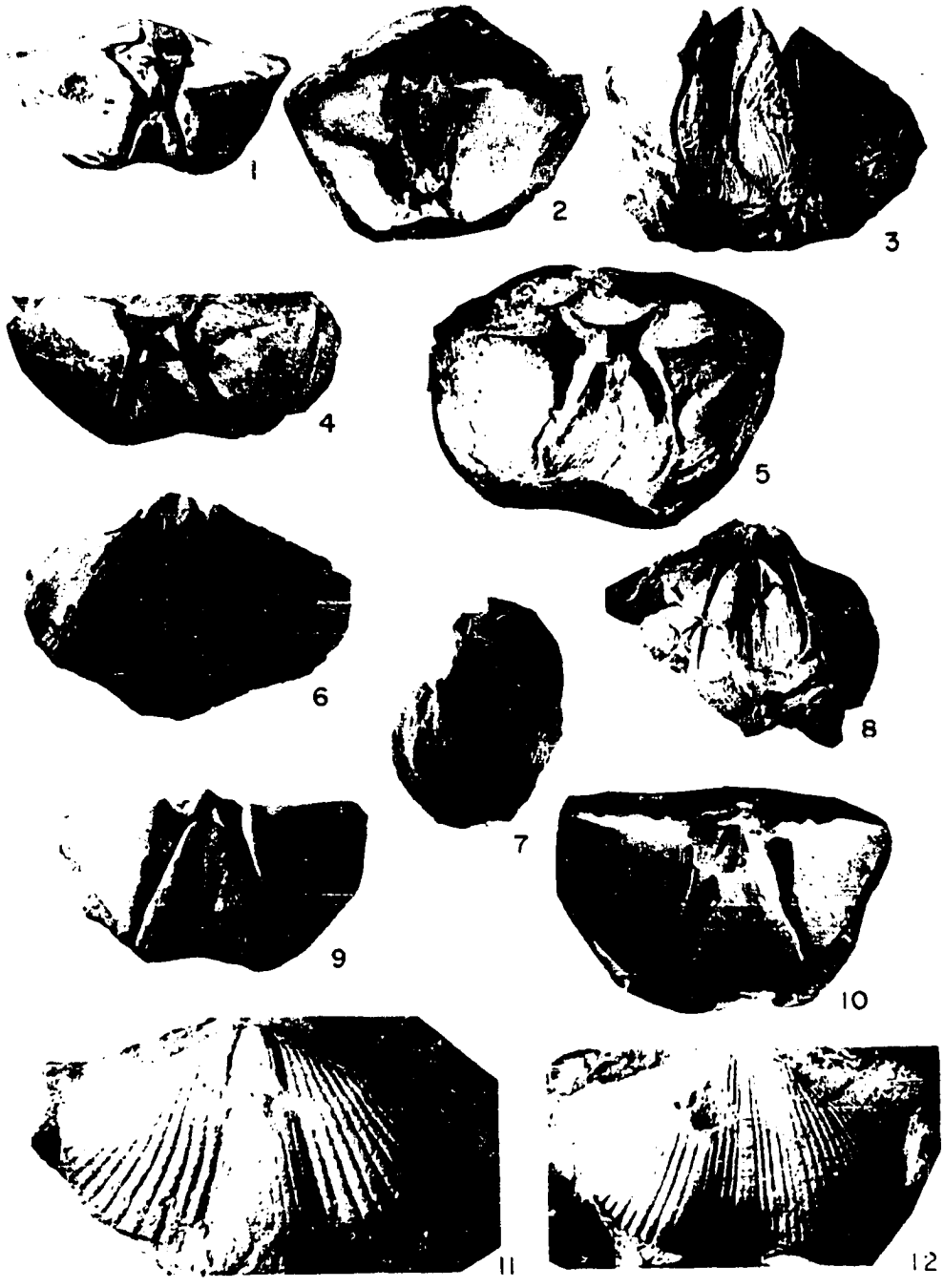
Plate 14



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Explanation of Plate 15

Figure

1 - 7. *Syringopleura casteri*, n. sp. p. 310

1-5, Brachial, pedicle, posterior, lateral and interior views of a mold of the interior and the posterior part of the interior of a rubber cast showing the relatively small muscle area and depression of the septum below the syrinx; fig. 5 shows the small narrow syrinx aligned with the median septum so that the latter does not show, Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97, holotype, UCM No. 29557; 6-7, mold and rubber cast of the interior of a pedicle valve from the same faunule, paratype, UCM No. 29558.

8 - 9. *Syringopleura randalli* (Simpson)

Pedicle and posterior views of the type specimen introduced for comparison and showing the depression for the median septum below the syrinx and the fuller development of the muscle scar, dental lamellae and other shell features than in *Syringopleura casteri*, n. sp., Philadelphia Academy of Natural Sciences No. 9532. Note the weak development of plicae on the lateral slopes of the sulcus. Photograph supplied by Dr. K. E. Caster. Dr Caster's notes say that the lithology indicates the specimen is from the Corry sandstone.

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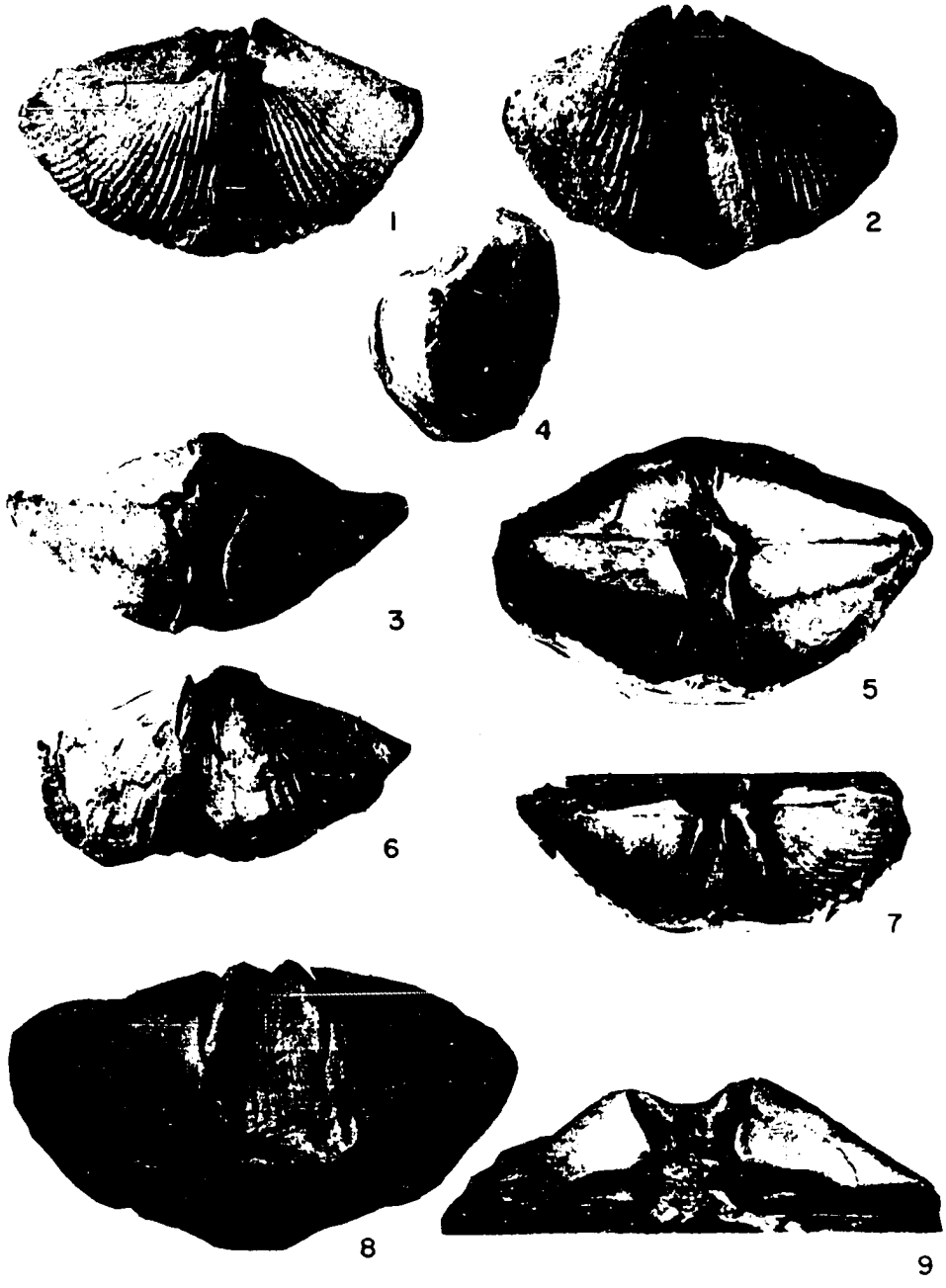
Plate 15



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Explanation of Plate 16

Figure

1 - 8. *Syringopleura casteri*, n. sp. p. 310

Specimens from the Marvin Creek coquinoid zone of the Kushequa shale member of the Knapp formation at locality 97. 1-3, Brachial, pedicle and anterior views of a large exfoliated specimen showing an usually high area, paratype, UCM No. 29549; 4-5, brachial, anterior, and pedicle views of an exfoliated specimen showing especially well the perideltidium in fig. 4, and the textile-like ornament in fig. 6, paratype, UCM No. 29572; 7-8, brachial and pedicle views of another specimen, UCM No. 29564.

9 -17. *Proeumetria acroria*, n. gen., n. sp. p. 353

9-11, Brachial, lateral and pedicle views of a specimen showing the typical shale and broad plicae, Marvin Creek coquinoid zone of the Kushequa member of the Knapp formation at locality 97, holotype, UCM No. 29650; 12-13, brachial and lateral views of a broken, partly exfoliated large specimen showing the typical form of the genus, from the same faunule, paratype, UCM No. 29651; 14, mold of the interior from the Kushequa member of the Knapp formation at locality 175, paratype, UCM No. 29664; 15-17, brachial, pedicle and lateral views of a mold of an interior of a crushed speciman, showing the position of a low median ridge in the brachial valve, same faunule, paratype, UCM No. 29661.

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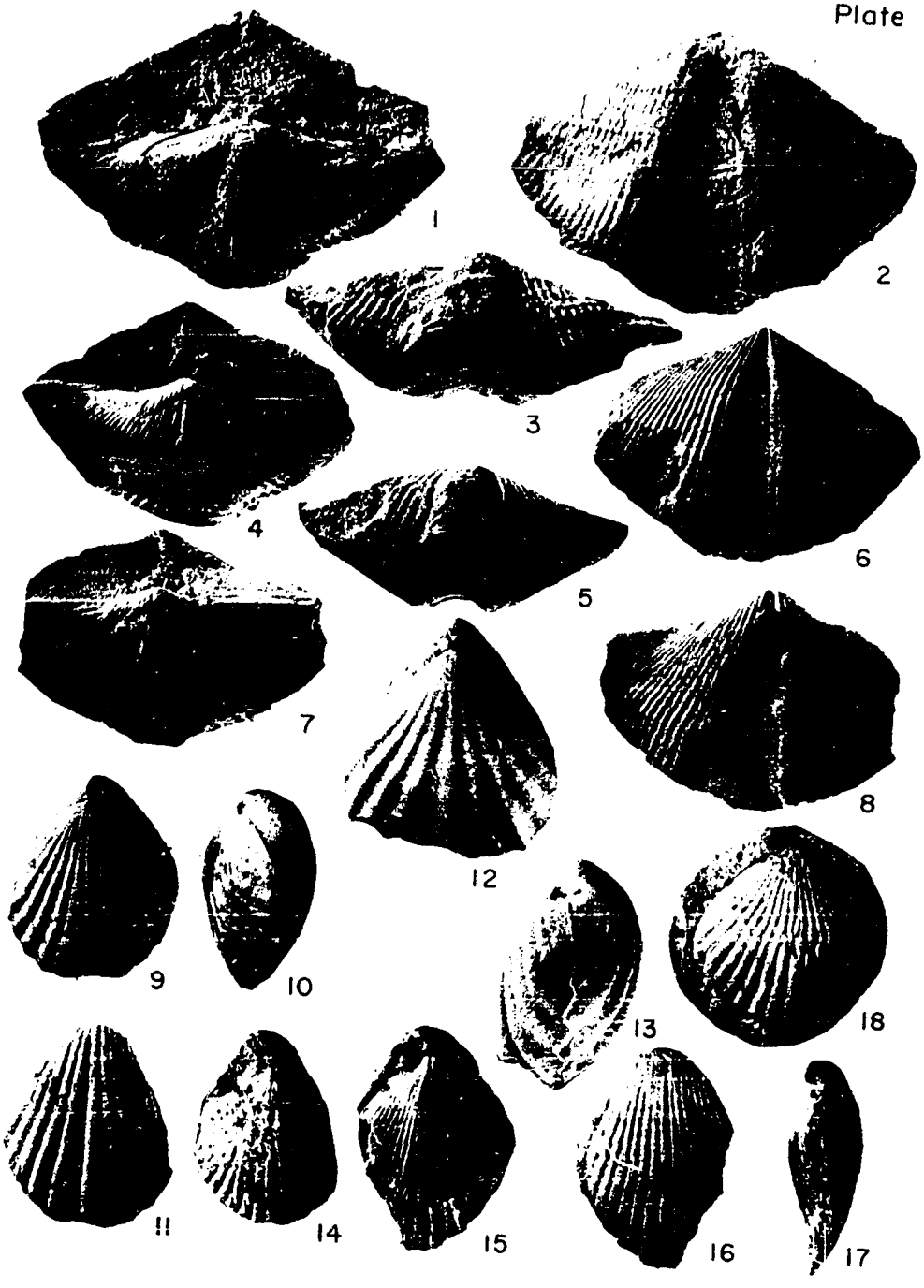
Plate 16



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Explanation of Plate 17

Figure

1 -12,
27-28. Athyris mardiae, n. sp. p. 325

All specimens from the Roystone coquinoid member of the Oswayo formation at locality 1. 1-4, Brachial, pedicle, lateral and anterior views of a specimen so exfoliated as to be nearly a mold of the interior, but which well shows the typical size and shape of this species, holotype, UCM No. 29016; 5-7, brachial, lateral and anterior views of a similar specimen, paratype, UCM No. 29017; 8-10, brachial, lateral and anterior views, paratype, UCM 29018; 11-12, brachial and lateral views of a similar specimen, paratype, UCM No. 29019; 27-28, posterior part of rubber casts of the interior (X2) showing the dental lamellae, cardinalia, and teeth in sockets, UCM Nos. 29059 and 29071 respectively.

13-18,
29. Athyris mardiae planaria, n. subsp. p. 333

All specimens from the Roystone coquinoid member of the Oswayo fromation at locality 1. 13-16, brachial, pedicle, lateral, and anterior views of an exfoliated specimen showing the characteristic, wide, flat, shape, holotype, UCM No. 29081; 17-18, brachial and lateral views of the same paratype, UCM No. 29084; 29, enlargement (X3.1) of a portion of the lateral flank of the pedicle valve shown in figure 20 to show the micro-ornament, holotype, UCM No. 29081.

19-26. Athyris mardiae sulcula, n. subsp. p. 336

All specimens from the Roystone coquinoid member of the Oswayo formation at locality 1. 19-22, brachial, pedicle, lateral and anterior views of an exfoliated specimen showing the characteristic sulcus, holotype, UCM No. 29089; 23, brachial view of same, paratype, UCM 29091; 24-26, brachial, anterior and lateral views of same, paratype, UCM No. 29090.

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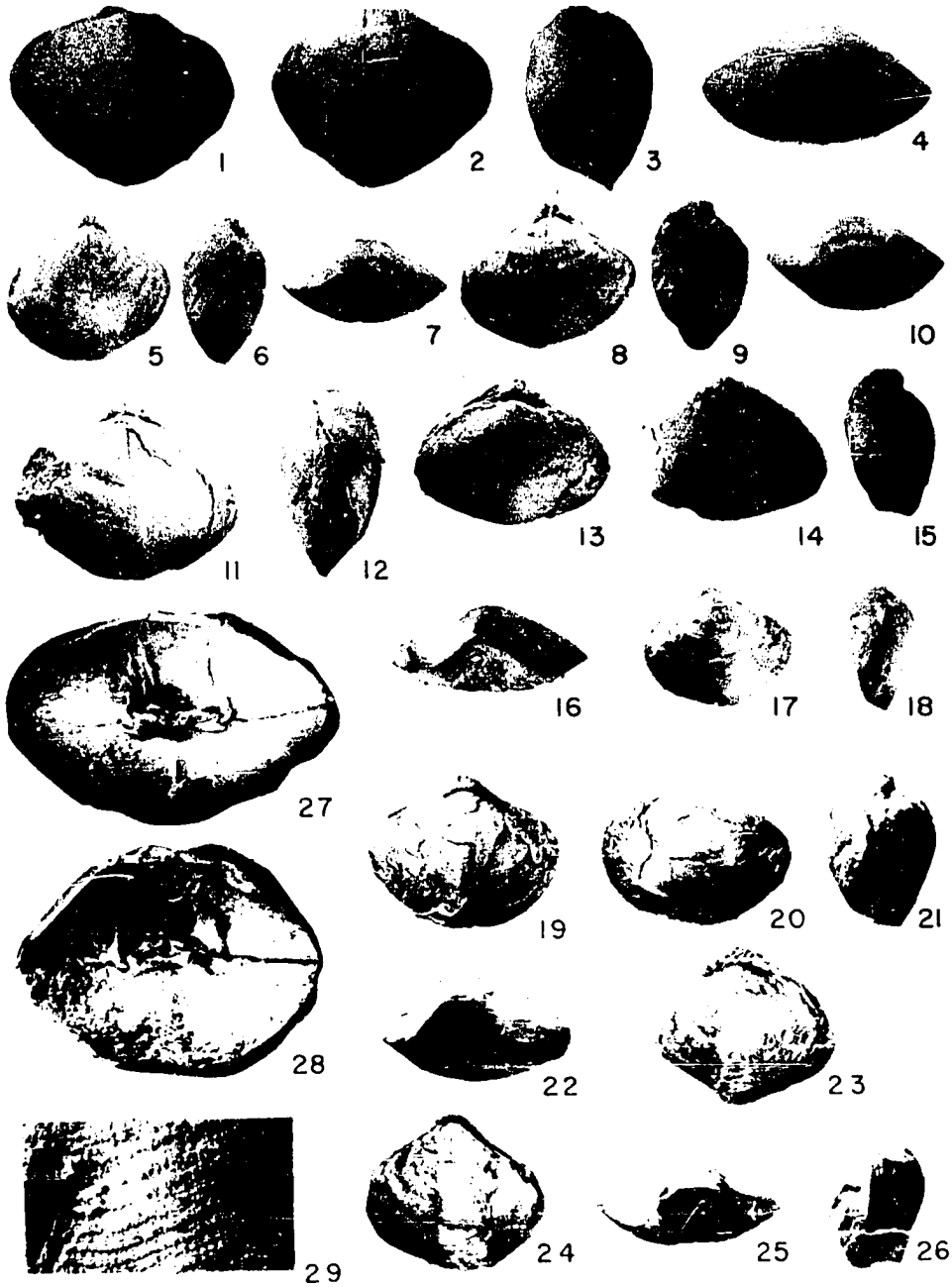
Plate 17



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Explanation of Plate 18

Figure

1. Athyris sp. indeterminate p. 347

   Rubber cast of the interior of a specimen showing the deeply impressed cordiform muscle scar, from the lower Syringothyris zone of the Knapp formation at locality 118, UCM No. 29964.

2 - 3. Cyrtina triplicata Simpson p. 319

   Molds of the interior of the brachial valve of two partial specimens from the Tidioute formation at locality 201, UCM No. 29853 and UCM No. 29854.

4 -14. Athyris minuta, n. sp. p. 342

   All specimens from the Marvin Creek zone of the Kushequa member of the Knapp formation at locality 97. 4-7, brachial, pedicle, lateral and anterior views of a partly exfoliated specimen showing the typical size and shape of this species, holotype, UCM No. 29760; 8-10, brachial, lateral and anterior views of same, paratype, UCM 29761; 11-13, same, UCM No. 29762; 14, brachial view of a small specimen, UCM No. 29824.

15. Brachiopod undetermined p. 362

   Pedicle valve with right and left reversed, from the Marvin Creek coquinoid zone of the Kushequa shall member of the Knapp formation at localtiy 97, UCM No. 29899.

16-26. Athyris thrasyangelica, n. sp. p. 337

   Specimens from the Roystone coquinoid member of the Oswayo formation at locality 1. 16-19, brachial, pedicle, lateral and anterior views of a mold of the interior with part of the shell remaining, showing the robust nature of this species, holotype, UCM No. 29094; 20, brachial view of a small specimen, UCM No. 29098; 21-24, brachial, pedicle, lateral and anterior views of another individual, paratype, UCM No. 29095; 26, rubber cast of posterior part of the interior of a shell showing the prominent crural processes, X2, paratype, UCM No. 29109.

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27-33. Athyris thrasyangelica magna, n. subsp. p. 340

All specimens from the Roystone coquinoid member of the Oswayo formation at locality 1. 27-29, Brachial, lateral and anterior views, paratype, UCM No. 29114; 30-33, brachial, pedicle, lateral, and anterior views of an exfoliated specimen showing the typical large square fold and robust nature of this form, holotype, UCM 29113.

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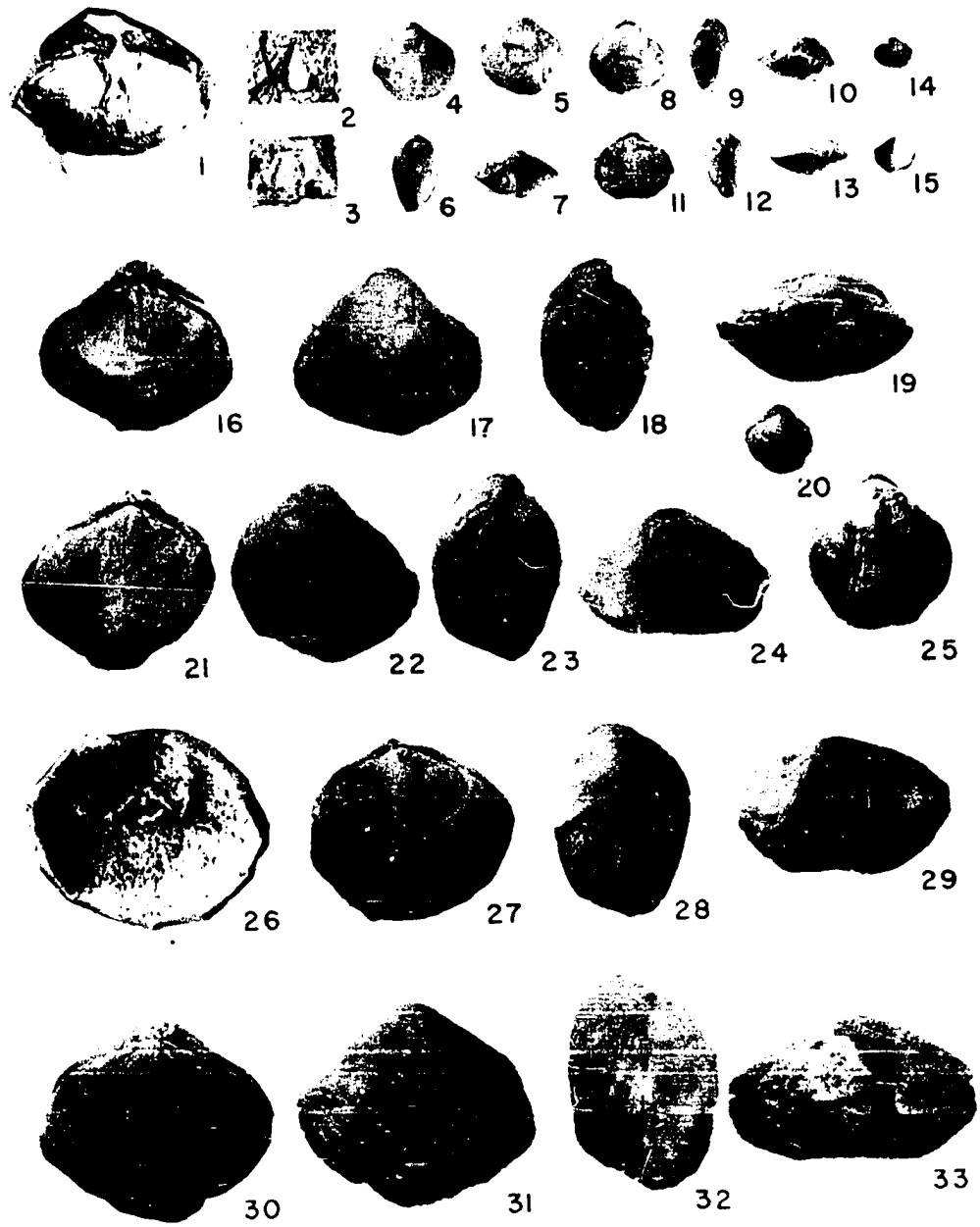
Plate 18



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