THE

PENNSYLVANIAN MILL CREEK LIMESTONE IN PENNSYLVANIA

CHOW

PENNSYLVANIA
GEOLOGICAL SURVEY
FOURTH SERIES
BULLETIN G26

THE PENNSYLVANIAN MILL CREEK LIMESTONE IN PENNSYLVANIA

By
MINCHEN MING CHOW

A DISSERTATION
Presented to the Graduate Faculty
of Lehigh University
in candidacy for the degree of
Doctor of Philosophy

DEPARTMENT OF INTERNAL AFFAIRS
WILLIAM S. LIVENGOOD, JR., *Secretary*

TOPOGRAPHIC AND GEOLOGIC SURVEY
S. H. CATHCART, *Director*

1951

additional copies
of this publication may be purchased from
BUREAU OF PUBLICATIONS
DEPARTMENT OF PROPERTY AND SUPPLIES
HARRISBURG, PA.

CONTENTS

ILLUSTRATIONS

Figures

Plates

TABLES

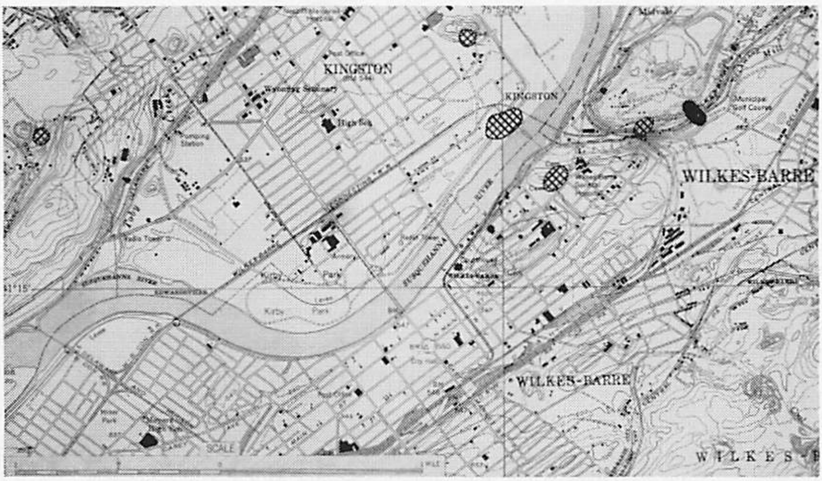


FIGURE 1. Map of Wilkes-Barre and vicinity. *Solid black:* area of known outcrop of the Mill Creek limestone today. *Crosshatched:* areas of approximate localities recorded in the literature but no longer available for study. Except for those along the lower end of Mill Creek, these lost localities are subsurface. See also Figure 3, p. 15.

THE PENNSYLVANIAN MILL CREEK LIMESTONE IN PENNSYLVANIA

BY

MINCHEN MING CHOW[1]

ABSTRACT

The Mill Creek limestone crops out in the vicinity of Wilkes-Barre, Pennsylvania. It is the only known marine limestone of Pennsylvanian age east of the bituminous fields in the United States. This limestone is less than two feet thick and is rich in marine fossils. An investigation of its fossils and faunal composition leads to the conclusion that it is assignable to the Conemaugh and can be closely correlated with the Ames limestone found in the bituminous fields of western Pennsylvania, West Virginia, and southern Ohio. Moreover, the faunas of the two limestones, in spite of their similarity, represent two penecontemporaneous but different organic phases reflecting unlike physical environments. The Mill Creek limestone fauna suggests a possible brackish water environment. A total of 36 species of fossils including 6 brachiopods, 24 pelecypods, 3 gastropods, 3 cephalopods, and 1 trilobite are described in the appendix to the report.

INTRODUCTION

LOCATION OF AREA

The Mill Creek limestone occurs, insofar as known, only in the vicinity of Wilkes-Barre in the Wyoming Valley of the Northern Anthracite Field of Pennsylvania (see fig. 1). The first record of the existence of limestone in this area is dated 1835 (Jones, 1934), when a farmer is known to have quarried and gathered loose pieces from the outcrop south of Mill Creek to burn for agricultural purposes.

Today, the Mill Creek limestone crops out in its type region on the north side of Mill Creek in the eastern part of the City of Wilkes-Barre. It was found at the creek bank, on the railroad and in a cut on the road above to the north. Figure 1 shows the present area of outcrop and places where the limestone has been reported but is no longer exposed. The localities are all within the area of the U. S. Geological Survey's Kingston and Pittston, Pennsylvania, 7½ minute quadrangle topographic maps, parts of which are reproduced in the figure.

HISTORICAL BACKGROUND

Limestones are generally reported to be rare in the anthracite fields of Pennsylvania. This is not true in the Northern Anthracite Field where thin beds of limestone are encountered in the mines. Most of

[1] Minchen M. Chow received the degree of Doctor of Philosophy from Lehigh University in January, 1951. Immediately thereafter it was necessary for him to return to his native land, China. In the meantime the dissertation was submitted for publication, but it was not until after he left that it was accepted by the Pennsylvania Topographic and Geologic Survey. In Mr. Chow's absence, the necessary revision and rearrangement of the dissertation for publication as a Survey bulletin has been done largely by Dr. Bradford Willard, Professor and Head, Department of Geology, Lehigh University, under whom Dr. Chow did most of the graduate work.

these beds are believed to be of fresh-water origin, because they are limited in horizontal distribution and barren of fossils. The only known exception is the Mill Creek limestone, a richly fossiliferous marine limestone, which is identified from a few surface exposures and has been found in mines.

The occurrence of fossils in the limestone beds in this area has long attracted the attention of local amateur collectors and mining engineers. Before 1880, members of the Wyoming Historical and Geological Society of Wilkes-Barre, founded in 1858, collected limestone fossils, considered to be Permian in age, along the New York and Pennsylvania Canal south of Mill Creek. The most prominent collectors were Dr. Charles F. Ingham, Messrs. C. H. Scharar, and Harrison Wright, and their collections of fossils were placed in the Society's building at Wilkes-Barre.

In 1886, studies on the limestones of the Wyoming valley were made by Charles A. Ashburner (1886b), a geologist of the Pennsylvania Second Geological Survey. He found that all the fossils in the area were from one bed of limestone to which he gave the name *Mill Creek* from Mill Creek, a small tributary that enters the Susquehanna River from the east after running southwest across part of the City of Wilkes-Barre.

In the same year, the fossils from the Wilkes-Barre area in the possession of the Wyoming Society, the State Survey, together with the privately held collection of Scharar were sent by the Survey to Professor Angelo Heilprin of the Philadelphia Academy of Natural Sciences for critical examination. This was the first time that the Mill Creek fossils were studied by a professional paleontologist, and the first time that the "Carboniferous" age of the fauna was recognized. The results of the investigations by Ashburner and Heilprin were published in both the Annual Report for 1885 of the Second Survey (Heilprin, 1886a) and the Bulletin of the Wyoming Historical and Geological Society in 1886 (Heilprin, 1886b).

Isaac Lea (1853) and E. W. Claypole (1886) also described a few marine limestone fossils from the Wilkes-Barre area. No further study of the Mill Creek limestone fauna has since been made. The total number of definitely known species recorded by all the previous authors does not exceed twenty. Most of their taxonomic terms have undergone considerable change.

As to the relationship between Mill Creek limestone and fossiliferous marine limestones in the bituminous fields of western Pennsylvania, West Virginia, and Ohio, I. C. White (1903) suggested its correlation with the Ames limestone, a correlation that a few subsequent writers have followed.

PRESENT STUDY

The author has taken up this problem at the suggestion of Professor Bradford Willard of Lehigh University. It was proposed that all the species from the collections that are accessible and new material gathered by the author be described and a correlation of this limestone with the related ones of other regions be attempted.

The result of the investigation shows that the Mill Creek limestone, besides being the only known fossil-bearing marine Pennsylvanian element in the United States east of the bituminous fields, contains a much larger fauna than suspected. More than fifty species have been recognized, and the richness of the fossil fauna in the bed suggests that more and new ones may be found if better exposures are produced by highway or other construction. No new species is established. Some probable new ones have been discussed under the most closely related forms, but they are represented only by fragmental remains or by not more than two poorly preserved specimens. Another reason for not establishing new species is that the Mill Creek limestone fauna is principally a pelecypod fauna, and the majority of the individuals within each group of Paleozoic pelecypods vary through a great morphological range. Under these conditions the establishment of new species based solely upon one or two imperfectly known specimens is risky and unwise.

Some of the materials on which the present study is based were collected by Professor Bradford Willard. Professor P. E. Raymond of Harvard kindly loaned his collection for examination. The rest was collected by the author and other graduate students at Lehigh University. Efforts were made to procure the old collections which were previously owned by the Wyoming Historical and Geological Society, Pennsylvania Second Geological Survey and the Philadelphia Academy of Natural Sciences, but none could be located.

ACKNOWLEDGMENTS

The writer acknowledges the aid and advice given by Dr. Bradford Willard, Professor and Head of the Department of Geology; Dr. Lawrence Whitcomb, Associate Professor of Geology; Dr. H. R. Gault, Associate Professor of Geology; Dr. Bradford B. Owen, Associate Professor of Biology; and Dr. F. J. Trembley, all of Lehigh University.

Although the work as initiated and completed at Lehigh University, a large portion of the systematic paleontology was carried out during the author's stay at Princeton University in 1950. The writer wishes to express his gratitude to Dr. Benjamin F. Howell of Princeton University and to Dr. Norman D. Newell of Columbia University for their council during that interval.

RESUME OF GEOLOGY AND STRATIGRAPHY

The geologic structure of the Northern Anthracite Field is a fusiform synclinorium with the axis of elongation extending southwest-northeast, more or less parallel to the course of the Susquehanna River in the Wyoming Valley. The northwestward dipping strata of the east flank of the basin are folded and crenulated, while those on the west side dip gently and more uniformly southeastward. The Pottsville conglomerate, which forms the basal part of the Pennsylvanian system in this area, overlies disconformably the Mauch Chunk red shale of Mississippian age. Above the Pottsville are beds assigned collectively to the "Coal Measures". These include strata belonging to the Allegheny and

Conemaugh "formations". The latter, the youngest recognized in the basin, includes the Mill Creek limestone. The maximum thickness of the Pennsylvanian system in the axial portion of the basin is about 2,400 feet. Figure 2, a generalized cross section of the area, shows the approximate horizon of the Mill Creek limestone.

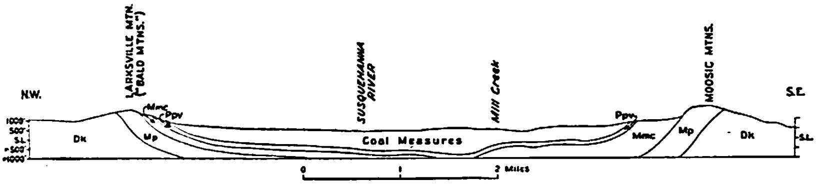


FIGURE 2. Generalized cross section showing the structure of the Northern Anthracite Field near Wilkes-Barre *(modified after Ashburner, Darton, Willard).*

Ashburner (1886, pp. 449-450) records the following section from a drill hole near the type locality of the Mill Creek limestone:

1	Slate	51′	5″
2	Coal and dirt	2′	10″
3	Slate	7′	2″
4	Sandstones, soft	2′	1″
5	Slate	21′	1″
6	Sandstone	5′	5″
7	Slate	3′	4″
8	Sandstone, hard	11′	1″
9	Slate	1′	10″
10	*Joe Gibbs* coal-bed	1′	10″
11	Sandstone	30′	0″
12	*MILL CREEK LIMESTONE*	1′	0″
13	Sandstone	25′	0″
14	*CANAL LIMESTONE*	2′	0″
15	Slate	14′	0″
16	Coal	1′	10″
17	Sandstone	11′	0″
18	Slate and sandstone	7′	5″
19	Sandstone	13′	1″
20	Slate and fire-clay	2′	2″
21	Sandstone	39′	4″
22	Slate	7′	6″
23	*Rock,* or *K* coal-bed	7′	2″
24	Slate	3′	2″
25	Coal	2′	6″
26	Slate and sandstone	25′	0″
27	*LIMESTONE*	2′±	0″
28	Conglomerate, sandstone, and slate	33′	0″
29	*Abbott,* or *J* coal-bed	5′	0″
30	Sandstone	51′	0″
31	Conglomerate	10′	0″
32	Sandstone	15′	0″
33	*Bowkley,* or *I* coal-bed	5′	0″
34	Slate	17′	0″
35	Conglomerate	20′±	0″
36	*HILLMAN LIMESTONE*	3′	0″
37	Slate	10′	0″
38	*Hillman,* or *H* coal-bed	16′	0″
39	Conglomerate and sandstone	150′	0″
40	*G* coal-bed	3′	0″
41	Sandstone	57′	0″
42	*5-Foot,* or *F* coal-bed	3′	0″
43	Fire-clay	12′	0″
44	Sandstone	116′	0″
45	*Baltimore,* or *E* coal-bed	16′	0″
46	Sandstone	106′	0″
47	Coal-bed	4′	0″
48	Sandstone	6′	0″
49	Coal-bed	1′	0″
50	Sandstone	87′	0″
51	*D* coal-bed	4′	0″

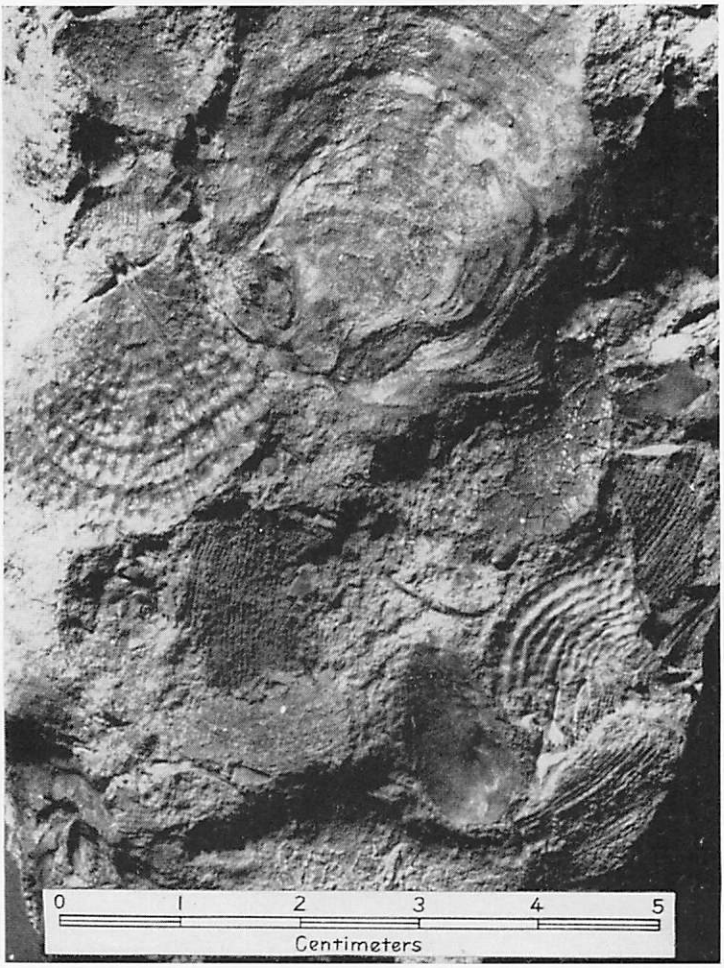


PLATE 1. Sample of Mill Creek limestone from type area showing preservation of abundant fossils.

52	Slate	6′	0″
53	Coal-bed	1′	0″
54	Slate	21′	0″
55	*Ross*, or *C* coal-bed	7′	0″
56	Sandstone	28′	0″
57	*Red Ash*, or *B* coal-bed	17′	0″
58	Slate	2′	0″
59	Coal-bed *A*	2′	0″
60	Slate and sandstone	11′	0″
61	*Pottsville Conglomerate*	96′	0″
	TOTAL THICKNESS OF SECTION	1,267 feet	

Several beds of limestone occur at different horizons in the Conemaugh in the basin. Their thickness varies from one to three feet. According to Ashburner's section, the Mill Creek limestone is the uppermost of all and lies about 1,100 feet above the base of the Pennsylvanian rocks although it seems probable that the interval as recorded by Ashburner is too small. The rest of the limestones, other than the Mill Creek, are all barren of fossils and are believed to be of fresh-water origin. They rarely crop out on the surface. The Hillman limestone, which resembles the Mill Creek lithologically, occurs ten feet above the Hillman coal bed. It is a tough, barren, siliceous limestone recorded 500 feet below the Mill Creek limestone.

Ashburner's original description (Ashburner 1886a, p. 443) runs:

> The Mill Creek limestone-bed outcrops along the north side of Mill Creek, near the breast of the old Hollenback dam, and about midway between the River Street bridge and a bridge of the Lehigh Valley railroad, which crosses the creek immediately at its mouth.
>
> The limestone is siliceous, ferruginous, and extremely hard, and from 1 foot to 15 inches thick.

All of the outcrops of the Mill Creek known today are restricted to the vicinity of Wilkes-Barre (fig. 1). As the limestone is one of the youngest in the Conemaugh strata in the region, it is expected that it should be found only in a limited area near the axis of the synclinorium in which Wilkes-Barre is located (fig. 2).

Lithologically, the Mill Creek limestone varies, but is generally siliceous, contains clay and silt and is extremely tough. The color ranges from dark gray to dark brownish-gray. It turns rusty yellow or limonite-brown and becomes quite soft on weathering. Loose pieces of layered, concretionary iron carbonate nodules were collected on the weathered outcrop. The limestone as a whole is rich in fossils (pl. 1, p. 5), but sometimes only a few cross sections of shells can be observed on the broken surfaces. The thickness of the limestone varies between one and three feet. A 50 gram sample of fresh rock digested in dilute hydrochloric acid gave an insoluble residue which weighed between 20 and 25 grams and consisted of clay, a few sand grains and mica flakes. Treatment with acetic acid gave no additional data. No microfossils were found among the insolubles.

The Mill Creek limestone appears to have been deposited in a small eastward-extending bay or lagoon of the Conemaugh sea to the west. The type of sediments indicates shallow water, an inference supported by the fauna which includes a number of neritic benthonic species.

The abundance of dwarfed forms, especially among the mollusks, suggests the possibility of brackish water. This possibility will be discussed under paleoecology.

FAUNA

So far as is known Angelo Heilprin (1886a, 1886b), Isaac Lea (1853), and E. W. Claypole (1886) are the only paleontologists who published on the Mill Creek limestone fauna. The following is a composite list of fossils reported by them:

Discina convexa Shumard
Chonetes (?) *millepunctata* Meek & Worthen
Productus cora D'Orbigny
P. nebrascensis ? Owen
Athyris subquadrata Hall
Spirifer lineatus ? Martin
Aviculopecten winchelli Meek
A. occidentalis Shumard
Eumicrotis hawni Meek & Worthen
Monopteria gibbosa Meek & Worthen
Pinna peracuta Shumard
Myalina subquadrata Shumard
M. wyomingensis Lea
Macrodon obsoletus Meek
Schizodus cuneatus ? Meek
S. wheeleri Swallow
Allorisma subcuneata Meek & Worthen
Macrocheilus primigenius Conrad
Bellerophon nodocrinatus Hall
Phillipsia sangamonensis Meek & Worthen

The present author recognizes about fifty species from the Mill Creek limestone. Besides those listed in this paper, there are a number of fossils of which, due to poor preservation of the fragmentary materials, even rough generic identification has been impossible. The following list records all the fossils that are known to date from the Mill Creek limestone at Wilkes-Barre. Their relative abundance is indicated (r = *rare*, c = *common*, cc = *very common*):

	RELATIVE ABUNDANCE (rare or common)
CRINOIDEA	(r)
Fragments	
BRACHIOPODA	
Lingula sp.	(r)
Orbiculoidea convexa (Shumard)	(r)
Meekella striatocostata (Cox)	(c)
Juresania nebrascensis (Owen)	(c)
J. symmetrica (McChesney)	(cc)
Echinoconchus semipunctatus (Shepard)	
Linoproductus cora (McChesney)	(r)
Isogramma millepunctata (Meek & Worthen)	(cc)
Squamularia perplexa (McChesney)	(r)
Composita (?) *ovata* Mather	(r)

Fauna

	RELATIVE ABUNDANCE (rare or common)
Pelecypoda	
Edmondia aspinwallensis Meek	(r)
E. sp.	(r)
Nucula parva McChesney	(cc)
Leda bellistriata Stevens	(c)
Yoldia glabra ? Beede & Rogers	(r)
Parallelodon tenuistriatus ? Meek & Worthen	(r)
P. obsoletus Meek	(cc)
P. oblongus Meek	(r)
Aviculopinna americana ? Meek	(r)
A. peracuta Shumard	(c)
Monopteria gibbosa Meek & Worthen	(r)
M. sp.	(r)
Aviculopecten occidentalis (Shumard)	(c)
Acanthopecten carboniferous (Stevens)	(c)
A. meeki Newell	(r)
Pseudomonotis hawni var. *sinuata* (Meek & Worthen)	(r)
P. sp.	(r)
Streblochondria sculptilis (Miller)	(r)
S. hertzeri (Meek)	(r)
Pernopecten (Entolium) ohioensis Newell	(r)
P. (E.) prosseri (Mark)	(r)
Myalina meeki Dunbar	(r)
M. wyomingensis (Lea)	(c)
M. subquadrata Shumard	
Schizodus cuneatus Meek	(r)
S. wheeleri Swallow	(c)
S. curtus Meek & Worthen	(cc)
Allorisma terminale Hall	(cc)
Pleurophorus tropidophorus Meek	(r)
P. oblongus Meek	(r)
P. subcostatus Meek & Worthen	(r)
Astartella concentrica Conrad	(r)
Gastropoda	
Pharkidonotus percarinatus (Conrad)	(cc)
P. tricarinatus (Shumard)	(c)
Euphemites nodocarinatus (Hall)	(r)
Bucanopsis meekiana ? Swallow	(c)
Unidentified microgastropods	(cc)
Cephalopoda	
Mooreoceras normale Miller, Dunbar & Condra	(r)
Temnocheilus sp.	(r)
Metacoceras sangamonense (Meek & Worthen)	(c)
Trilobita	
Ameura sangamonensis (Meek & Worthen)	(c)

An examination of the complete faunal list and the fossils from the Mill Creek limestone reveals some characteristics of the fauna. The total known species in the Mill Creek limestone is fifty-four, of which thirty-two or approximately three-fifths are pelecypods. Brachiopods with a total of ten come second.

The most common of all the Mill Creek limestone fossils are *Juresania symmetrica, Isogramma millepunctata, Leda bellistriata, Parallelodon obsoletus, Schizodus curtus, Pleurophorus tropidophorus,* and *Pharkidonotus percarinatus.* With the exception of one species of trilobite and a few fragments of crinoid stem columnels, brachiopods and mollusks, the pelecypods are the chief phyla represented in the Mill Creek limestone. No traces of "fusulinas", corals, or bryozoans, usually common in the Carboniferous limestones, were found. The gastropods, although represented by only a few species, are numerically plentiful. Most of them are almost microscopic and represented by only the internal fillings of the shell, so many cannot be identified. Hence, the actual number of species of gastropods in the fauna probably is higher than listed.

Comparatively few species of gastropods and pelecypods in the fauna reach the average adult size of their species. Most show dwarfing. In the case of the pelecypods, almost every one is under average size for the species. Some of the cephalopods are slightly dwarfed, the rest are normal. As they were free-swimming pseudoplankton, it seems possible that the normal-sized individuals drifted or were washed in from the open sea, the dwarfs were probably indigenous.

The number of species of brachiopods is not large, but some of them, as *Juresania symmetrica* and *Isogramma millepunctata,* are abundant and among the most common of the Mill Creek limestone fossils. Of particular interest is *Isogramma millepunctata,* abundant here, but reported from only a few localities outside the region, notably by C. O. Dunbar and G. E. Condra (1932) in the Pennsylvanian rocks of some western states.

CORRELATIONS

I. C. White was the first person to suggest correlating the Mill Creek limestone with the Ames limestone in western Pennsylvania, Ohio, and West Virginia. White, basing his conclusion upon his stratigraphic studies in the coal fields of West Virginia and Heilprin's (1886b) list of the Mill Creek fauna stated (1903, p. 259):

> . . . there can be little doubt that the fossiliferous Mill Creek limestone near the summit of the Pennsylvania anthracite coal series in the Wilkes-Barre basin, represents the same geological plane, since nearly every species described from it by Prof. Angelo Heilprin is found in the faunal list from the Crinoidal or Ames limestone in the vicinity of Morgantown, West Virginia.

This correlation has been generally accepted. It was adopted by M. Grace Wilmarth (1938). Harold R. Wanless (1937), and R. C. Moore (1944) use it in their correlation of the Pennsylvanian of North America.

There are five fossiliferous marine limestone beds in the Conemaugh formation of western Pennsylvania, southern Ohio, and West Virginia. Their sequence in descending order is:

Skelley limestone
Ames or "Crinoidal" limestone
Portersville
Cambridge or Pine Creek
Brush Creek

Fauna

The Skelley is the thin limy upper part of the Birmingham shale, which is directly above the Ames, and contains only a few sparsely scattered species. The Portersville is restricted to southern Ohio. The following table shows the occurrence of Mill Creek limestone fossils in the various limestones of the Conemaugh in western Pennsylvania, Ohio, and West Virginia.

Table 1. *Occurrence of Mill Creek Fossils in Limestones of Conemaugh Age*

	Mill Creek (Pa.)	Ames (Pa., Ohio, W. Va.)	Portersville (O.)	Cambridge (Pa., Ohio, W. Va.)	Brush Creek (Pa., Ohio, W. Va.)
Crinoidea					
Fragments of stems	x	x	x	x	x
Brachiopoda					
Lingula sp.	x	?	?	?	?
Orbiculoidea convexa (Shumard)	x	x	x	-	-
Meekella striatocostata (Cox)	x	-	-	-	-
Juresania nebrascensis (Owen)	x	x	x	x	x
J. symmetrica (McChesney)	x	-	-	-	-
Echinochonchus semipunctatus (Shepard)	x	-	-	x	-
Linoproductus cora (D'Orbigny)	x	x	x	x	-
Isogramma millepunctata (Meek & Worthen)	x	-	-	-	-
Squamularia perplexa (McChesney)	x	x	-	x	-
Composita ? ovata Mather	x	x	-	x	-
Pelecypoda					
Edmondia aspinwallensis Meek	x	x	x	x	-
Nucula parva McChesney	?	x	x	x	x
Leda bellistriata Stevens	x	x	x	-	-
Yoldia glabra ? Beede & Rogers	x	x	-	-	-
Parallelodon tenuistriatus ? Meek & Worthen	x	x	x	x	-
P. obsoletus Meek	x	x	x	x	-
P. oblongus Meek	x	-	-	-	-
Aviculopinna americana ? (Meek)	x	x	x	-	-
A. peracuta (Shumard)	x	x	-	-	-
Monopteria gibbosa Meek & Worthen	x	-	x	-	-
M. sp.	x	-	-	-	-
Aviculopecten occidentalis (Shumard)	x	x	x	x	x
Acanthopecten carboniferous (Stevens)	x	x	x	x	-
A. meeki Newell	x	-	-	-	-
Pseudomonotis hawni var. *sinuata* (Meek & Worthen)	x	?	-	-	-
P. sp.	x	-	-	-	-
Stroblochondria sculptilis (Miller)	x	-	-	-	-
S. hertzeri (Meek)	x	x	x	x	-
Pernopecten (Entolium) ohioensis Newell	x	-	x	-	-
P. (E.) prosseri (Mark)	x	x	-	-	-
Myalina wyomingensis (Lea)	x	-	-	-	-
M. meeki Newell	x	-	-	-	-
M. subquadrata Shumard	x	-	-	x	x
Schizodus cuneatus Meek	x	-	-	-	x
S. wheeleri Swallow	x	x	x	-	-
S. curtus Meek & Worthen	x	x	x	-	x
Allorisma terminale Hall	x	x	-	-	x
Pleurophorus tropidophorus Meek	x	x	x	-	-
P. oblongus Meek	x	x	x	x	-
P. subcostatus Meek & Worthen	x	x	x	x	-
Astartella concentrica Conrad	x	x	-	-	-

TABLE 1. *Continued*

	MILL CREEK (Pa.)	AMES (Pa., Ohio, W. Va.)	PORTERSVILLE (O.)	CAMBRIDGE (Pa., Ohio, W. Va.)	BRUSH CREEK (Pa., Ohio, W. Va.)
GASTROPODA					
Pharkidonotus percarinatus (Conrad)	x	x	x	x	x
P. tricarinatus (Shumard)	x	x	x	x	x
Euphemites nodocarinatus Hall	x	-	-	-	-
Bucanopsis meekiana Swallow	x	x	-	-	-
CEPHALOPODA					
Mooreoceras normale Miller, Dunbar, & Condra	x	-	-	-	-
Metacoceras sangamonense (Meek & Worthen)	x	-	x	-	-
Temnochellus sp.	x	-	-	-	-
TRILOBITA					
Ameura sangamonensis (Meek & Worthen)	x	-	-	-	-
TOTAL	50	30	24	19	11

For further comparison, the following, Table II, lists Ames fossils in the bituminous fields of western Pennsylvania, West Virginia and southern Ohio and fossils of the Mill Creek limestone.

TABLE 2. *Tabulation of Ames Limestone Faunas From Specific Areas*

	AMES			
	W. Pa.	West Va.	S. Ohio	MILL CREEK
PROTOZOA				
Fusulina secalica (Say)	-	-	x	-
ANNELIDA				
Serpula sp.	-	-	x	-
Spirorbis cf. *anthracosia* Whitfield	-	-	x	-
ANTHOZOA				
Lophophyllum profundum Milne-Edwards & Haime	x	x	x	-
CRINOIDEA				
Ceriocrinus hemisphericus Shumard	-	-	x	-
Delocrinus sp. ?	x	-	-	-
D. allegheniensis Burke	-	x	-	-
D. hemisphericus ? Shumard	x	x	-	-
D. harshbargeri (Beede)	-	-	x	-
Eupachycrinus sp. ?	-	-	x	-
E. magister Miller & Gurley	x	-	-	-
Hydreionocrinus sp. ?	-	x	-	-
H. discus (Meek & Worthen)	-	x	-	-
Graphiocrinus sp. ?	-	x	-	-
Ulocrinus sp. ?	-	x	-	-
Zeacrinus ?	x	-	-	-

TABLE 2. *Continued*

	Ames			
	W. Pa.	West Va.	S. Ohio	Mill Creek
Bryozoa				
Fenestella limbata Foerste	x	–	–	–
F. shumardi Prout	–	–	x	–
Fistulipora sp. ?	–	–	x	–
F. nodulifera Meek	–	?	x	–
Polypora sp. ?	–	x	–	–
P. submarginata Meek	–	x	–	–
Rhombopora lepidodendroides Meek	?	x	x	–
Septopora biserialis Swallow	–	–	x	–
Brachiopoda				
Ambocoelia expansa Dunbar & Condra	x	–	–	–
A. planoconvexa Shumard	x	x	x	–
Cancrinella boonensis (Swallow)	x	x	x	–
Chonetes choteauensis Mather	x	–	–	–
C. granulifer Owen	x	x	x	x
C. granulifer var. *transversalis* Dunbar & Condra	x	–	–	–
Chonetina flemingi (Norwood & Pratten)	–	–	x	–
Cleiothyridina orbicularis ? (McChesney)	x	–	–	–
Composita argentea (Shepard)	x	–	–	–
C. ovata Mather	x	–	–	–
C. subtilita Hall	x	x	x	?
Crania modesta White & St. John	x	x	–	–
Derbyia sp. ?	–	–	?	–
D. crassa (Meek & Worthen)	x	x	x	?
D. kansasensis ? Dunbar & Condra	?	–	–	–
D. robusta (Hall)	–	x	x	–
Dictyoclostus americanus Dunbar & Condra	x	x	x	–
D. portlockianus (Norwood & Pratten)	x	–	–	–
D. portlockianus var. *crassicostatus* Dunbar & Condra	–	–	x	–
Echinochonchus semipunctatus (Shepard)	–	–	–	x
Enteletes hemiplicatus (Hall)	–	x	x	–
Hustedia mormoni (Marcou)	x	x	x	–
Isogramma millepunctata (Meek & Worthen)	–	–	–	x
Juresania nebrascensis (Owen)	x	x	x	x
J. symmetrica (McChesney)	–	–	–	x
Leptalosia spondyliformis (White & St. John)	–	?	–	–
Lingula sp.	–	–	–	x
L. umbonata Cox	x	x	–	–
Linoproductus sp.	x	–	–	–
L. cora (D'Orbigny)	x	x	x	x
L. meniscus Dunbar & Condra	x	–	–	–
L. prattenianus (Norwood & Pratten)	x	–	–	–
Marginifera haydenensis Girty	x	–	–	–
M. missouriensis ? (Girty)	x	–	–	–
M. splendens (Norwood & Pratten)	–	–	x	–
M. wabashensis (Norwood & Pratten)	x	x	–	–
Meekella striatocostata (Cox)	–	–	–	x
Neospirifer cameratus (Morton)	–	x	x	–
N. triplicatus (Hall)	x	x	–	–
Orbiculoidea convexa (Shumard)	x	–	–	x
O. missouriensis (Shumard)	–	–	x	?
Productus sp. ?	–	–	x	–
Punctospirifer kentuckyensis (Shumard)	x	x	x	–
Rhipidomella carbonaria (Swallow)	x	x	x	?
Schizophoria resupinoides ? (Cox)	?	–	–	–
Schuchertella pratteni (McChesney)	x	–	–	–
Seminula argentia Shepard	–	–	–	x
Spirifer occidentalis Girty	x	–	–	–
S. rockymontanus Marcou	x	–	–	–
Squamularia perplexa (McChesney)	x	x	x	x
Strophalosia sp. ?	–	x	x	–
Wellerella delicatula Dunbar & Condra	x	–	–	–
W. osagensis (Swallow)	x	–	x	–
W. tetrahedra Dunbar & Condra	x	x	–	–

TABLE 2. *Continued*

	Ames			
	W. Pa.	West Va.	S. Ohio	MILL CREEK
PELECYPODA				
Acanthopecten carboniferous (Stevens)	x	x	x	x
A. meeki Newell	-	-	-	x
Allorisma sp. ?	-	-	x	-
A. terminale Hall	x	x	x	x
Astartella sp. ?	-	x	x	?
A. concentrica Conrad	x	?	-	x
A. vera Hall	x	-	x	-
Aviculopecten sp. ?	x	-	-	-
A. herzeri Meek	-	-	x	x
A. occidentalis (Shumard)	x	x	x	x
A. soror Herrick	-	-	x	-
Aviculopinna americana (Geinitz)	-	-	x	x
A. peracuta (Shumard)	-	-	x	x
Cardiomorpha missouriensis Shumard	-	-	x	x
Chaenomya leavenworthensis Meek & Hayden	-	-	x	-
Clinopistha radiata Hall	-	-	x	-
Edmondia sp.	-	-	-	x
E. aspinwallensis Meek	x	x	x	x
E. nebraskensis (Geinitz)	-	-	x	-
Entolium aviculatum (Swallow)	-	-	x	-
E. prosseri Condit	-	-	x	x
Euchondria neglecta (Geinitz)	-	-	x	-
Leda bellistriata Stevens	-	x	x	x
Lima retifera Shumard	-	-	x	-
Monopteria sp.	-	-	-	x
M. gibbosa Meek & Worthen	-	-	-	x
Myalina sp. ?	-	-	x	-
M. ampla Meek	-	?	x	-
M. subquadrata Shumard	-	?	-	x
M. wyomingensis (Lea)	-	-	-	x
Nucula anodontoides Meek	-	x	x	x
N. parva McChesney	-	x	x	?
N. wewokana Girty	x	-	-	-
Nuculopsis ventricosa (Hall)	x	x	x	?
Parallelodon obsoletus Meek	x	x	x	x
P. oblongus Meek	-	-	-	x
P. tenuistriatus Meek & Worthen	x	-	x	x
Placunopsis carbonaria Meek & Worthen	-	-	x	-
Pleurophorella costatus (Meek & Worthen)	-	-	x	-
P. geinitzi (Meek)	x	-	-	-
Pleurophorus immaturus Herrick	x	-	-	-
P. oblongus Meek	-	-	x	x
P. subcostatus Meek & Worthen	-	-	x	x
P. tropidophorus Meek	-	-	x	x
Posidonomya ? recurva Beede	-	-	x	-
P. pertenuis Beede	-	-	x	-
Pseudomonotis hawni (Meek & Hayden)	x	x	x	x
P. hawni var. *sinuata* (Meek & Worthen)	-	-	-	x
Schizodus cuneatus Meek	-	-	-	x
S. curtus Meek & Worthen	-	-	x	x
S. wheeleri (Swallow)	-	-	x	x
Solenomya radiata Meek & Worthen	-	-	x	-
Stroblochondria sculptilis (Miller)	-	-	-	x
Yoldia glabra Beede & Rogers	x	-	-	x
GASTROPODA				
Aclisina cf. *bellilinesta* Miller	-	-	x	-
A. stevensana (Meek & Worthen)	x	-	-	-
Bellerophon crassus Meek & Worthen	-	-	x	-

TABLE 2. *Continued*

	AMES			
	W. Pa.	West Va.	S. Ohio	MILL CREEK
B. stevansanus McChesney	x	-	x	-
Bucanopsis meekiana Swallow	x	x	x	x
B. meekiana var. *minuata* n. var.	x	-	-	-
B. montfortiana Norwood & Pratten	-	x	x	-
Euphemites blaneyanus (McChesney)	x	-	x	-
E. blaneyanus var. *minuta* n. var.	x	-	-	-
E. nodocarinatus (Hall)	-	-	-	x
Loxonema sp. ?	x	-	-	-
L. plicatum Whitfield	x	-	-	-
L. scitulum Meek & Worthen	-	-	x	-
L. rugosum Meek & Worthen	-	-	x	-
Macrocheilus sp. ?	-	?	x	-
M. primigenius Conrad	-	-	-	x
Orestes nodosus Girty	x	-	-	-
Orthonema bilineatum Condit	-	-	x	-
Patellostium montfortianum Norwood & Pratten	x	x	x	-
Phanerotrema grayvillense Norwood & Pratten	x	-	x	-
Pharkidonotus large sp.	x	-	-	-
P. percarinatus Conrad	x	x	x	x
P. tricarinatus (Shumard)	x	x	x	x
Platyceras parvum (Swallow)	x	-	-	-
P. petersoni Burke	-	-	x	-
Pleurotomaria sp. ?	x	x	x	-
P. carbonaria Norwood & Pratten	-	-	x	-
P. euglyphea ? Girty	x	-	-	-
P. euglyphea ? var. *minuta* n. var.	x	-	-	-
P. inornata Meek	-	-	x	-
P. watsoni n. sp.	x	-	-	-
Soleniscus aplatus Condit	-	-	x	-
S. fusiformis (Hall)	-	-	x	-
S. typicus Meek & Worthen	-	-	x	-
Schizostoma sp. ?	-	x	-	-
S. catilloides (Conrad)	x	-	-	-
Sphaerodoma brevis White	x	-	x	-
S. gracilis ? Cox	x	-	-	-
S. intercalaris Meek & Worthen	x	-	-	-
S. paludiniformis Hall	x	-	x	-
S. primigenia (Conrad)	x	-	x	-
S. primigenia var. *minuta* n. var.	x	-	-	-
S. ventricosa (Hall)	x	x	x	-
Trepospira depressa Cox	x	-	-	-
Worthenia beedei Condit	-	-	x	-
W. speciosa (Meek & Worthen)	-	-	x	-
CEPHALOPODA				
Moorecoceras normale Miller, Dunbar & Condra	-	-	-	x
Metacoceras sangamonense (Meek & Worthen)	-	-	-	x
M. subquadrangulare Whitfield	-	-	x	-
Nautilus sp. ?	-	x	-	-
N. winslowi Meek & Worthen	x	-	-	-
Orthoceras sp.	-	-	x	?
O. cribosum Geinitz	-	-	x	-
Pseudorthoceras knoxense (McChesney)	x	x	x	-
Tainoceras occidentale (Swallow)	x	-	x	-
Temnocheilus crassus Hyatt	x	-	-	-
T. sp.	-	-	-	x
TRILOBITA				
Ameura sangamonense (Meek & Worthen)	-	-	-	x
Griffithides parvulus Girty	x	?	-	-
G. scitulus Meek & Worthen	-	-	x	?

TABLE 2. *Continued*

	Ames W. Pa.	Ames West Va.	Ames S. Ohio	Mill Creek
VERTEBRATA				
Agassizodus variabilis (Newberry & Worthen)	x	-	-	-
Cladodus sp. ?	-	x	-	-
C. occidentalis Leidy	x	-	-	-
Deltodus angularis Newberry & Worthen	x	x	-	-
Fissodus inaequalis (St. John & Worthen)	x	x	-	-
Peripristis semicircularis (Newberry & Worthen)	-	x	x	-
Petalodus alleghaniensis Leidy	x	x	x	-
Sandalodus sp. ?	-	x	-	-
Unidentified jaw	x	-	-	-

The Mill Creek limestone of the anthracite fields may be correlated most closely with the Ames of western Pennsylvania, West Virginia and southern Ohio for a number of reasons. The Mill Creek is the only known marine limestone in the anthracite fields, and its stratigraphic position indicates that it is assignable to the Conemaugh. In western Pennsylvania, southern Ohio and West Virginia, marine limestones occur in the Conemaugh; presumably, the Mill Creek may be a correlative of one of these. Of the western limestones of Conemaugh age, the Ames has the widest areal distribution and extends farthest east in Pennsylvania. The probable equivalence of the fauna of the Ames and the Mill Creek, rather than the other Conemaugh limestones, is indicated in Table 1. Furthermore, in Table 2, the Mill Creek is shown to be allied with the Ames faunas from western Pennsylvania, southern Ohio and West Virginia. The relationship of the two faunas, Ames and Mill Creek, can be demonstrated by comparing the Brachiopoda and Pelecypoda graphically in Figure 3. This shows that the relationship is closer for the pelecypods than for the brachiopods. Such a distinction has ecologic significance which will be mentioned later.

Pennsylvanian sections in many parts of the world show cyclic sedimentary changes which some attribute to frequent, rhythmic fluctuations of sea level. The presence of a series of marine limestones in the Conemaugh "formation" indicates such changes. On a broad, flat coastal plain, such as presumably typified the physiography of most of Pennsylvania during the later Paleozoic, small positive changes of sea level might cause sweeping inundations of large areas in short intervals of time. The Ames has the greatest areal distribution of all the Conemaugh limestones and extends farthest east in Pennsylvania, hence it was most probably the expanded Ames sea which reached the region of the Northern Anthracite Field and brought about the deposition of the Mill Creek limestone.

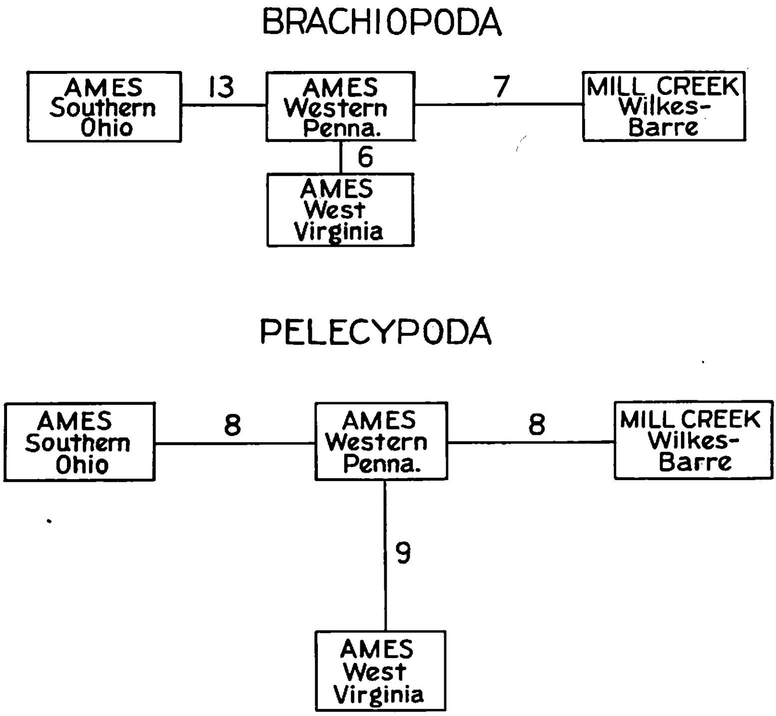


FIGURE 3. Comparison of faunas—brachiopoda and pelecypoda. *Explanation:* The relative lengths of lines connecting boxes indicates roughly faunal relations between several localities. The numbers beside the lines are the number of species common to the faunas which the corresponding lines connect.

PALEOECOLOGY

The existence of a brackish water environment during the deposition of the Mill Creek limestone is postulated to explain the peculiarities of its fauna as contrasted with that of the Ames. Shimer (1908) described among the fossil faunas of Carboniferous limestones in Nova Scotia certain peculiarities which are quite similar to those of the Mill Creek. In both, there is a dwarfing of the molusks, but the brachiopods are of normal size though depleted in species. Shimer attributed the abnormalities to brackish water. If a brackish environment prevailed when the Mill Creek limestone formed, the peculiarities of its fauna, as contrasted with the fossils from the Ames, can be similarly explained.

Comparison of the Mill Creek and Ames brachiopods and pelecypods suggests a more brackish environment for the Mill Creek fauna. Few brachiopods can stand brackish water without deterioration. Marine pelecypods tend to become more dwarfed under sub-saline conditions than do brachiopods, which may retain their normal size but suffer a reduction in the number of species. Among the marine mollusks, the pelecypods are more tolerant of environment than are the cephalopods.

A total of fifty species of brachiopods and forty-seven of pelecypods has been reported from the Ames limestone. This ratio of brachiopods to pelecypods is approximately one-to-one. In the Mill Creek fauna, the ratio between the same two groups is approximately one-to-three (*cf.* Table 2).

The pelecypods of the Mill Creek limestone are abundant in both species and individuals, but uniformly dwarfed. The gastropods are either dwarfed or represented by many nearly microscopic, immature individuals. The brachiopods are of normal size, but fewer in species than those from the Ames fauna.

The Ames fauna is more varied than that of the Mill Creek. Corals, crinoids, foraminifera, and bryozoa, present in considerable abundance in the Ames, are conspicuously absent from the Mill Creek. This difference further substantiates the supposition of the brackish condition of the Mill Creek sea.

The role of food supply in dwarfing and restriction of faunas is poorly understood. Marine micro-organisms and larger planktonic life, however, may have been sparse or lacking in brackish waters, thus reducing available food for the larger forms.

The climate and physiographic setting during Pennsylvanian time in the region discussed were conducive to local brackish water conditions (*cf.* Willard, 1948). The climate was relatively moist and cool. The great forests indicate abundant rainfall. Large quantities of peat and muck, typical of much of Pennsylvanian sediments, today are observed generally to accumulate not in tropical areas but in a relatively cool, moist climate. Excessive evaporation with accompanying high salinity of waters is not probable in a cool, moist climate; absence of evaporites, salines and red beds in the anthracite "coal measures" supports this conclusion. Seasonal changes in the Pennsylvanian climate have been accepted, since Turner and Randall (1923) demonstrated the presence of annual growth rings in plants from the Pennsylvania anthracite. The well-authenticated continental glaciation of the Permian period suggests that the climate was growing colder in late Paleozoic time. Professor B. F. Howell has suggested (personal communication) that cyclothems, recognized in many Pennsylvanian sedimentary sequences, may indicate intermittent, local glaciation in the highlands of Appalachia, as a forerunner of the Permian ice sheets.

Many of the embayments and lagoons of the low, flat coastal area would have been more or less separated from the open sea. With heavy rainfall, much fresh water would enter these bodies and decrease the salinity of completely or partially land-locked waters. If the Mill Creek limestone was deposited in such a constricted arm of the Conemaugh (Ames) sea, then its brackish environment seems likely.

Though the effect of a brackish water environment presents a likely and plausible explanation of the dwarfing and restrictions of the Mill Creek fauna, other possibilities should not be overlooked. The fauna and lithology of the Mill Creek indicate relatively shallow water conditions, so it is not likely that the dwarfing is due to poor water circulation, as is sometimes the case in deep water. Furthermore, the influx of fresh water would prevent stagnation.

Presumably, mineral matter in solution and mud in suspension may have caused or contributed to dwarfing and restricting the fauna. Streams flowing across low, flat, swampy coastal plain country would not carry much coarse debris, but might be heavily charged with silt.

Paleoecology

The Mill Creek limestone carries a high percentage of clay. Dissolved iron, common in swamp water, may have been carried into the basin of Mill Creek deposition, as may have been dissolved silica, found commonly in streams in cool, moist climates. Both silica and ferruginous material are present in the Mill Creek limestone.

SUMMARY

The Mill Creek limestone which crops out in the vicinity of Wilkes-Barre, Pennsylvania, is the only known marine Pennsylvanian limestone east of the bituminous coal fields in the United States. This limestone, with an average thickness of one foot, is richly fossiliferous. An investigation of its fossils and its faunal composition leads to the conclusion that it can be closely correlated with the Ames limestone found in the bituminous fields of western Pennsylvania, West Virginia, and southern Ohio. The faunas of these two limestones, despite their similarity, represent two penecontemporaneous but different organic phases reflecting unlike physical environments.

REFERENCES

Ashburner, C. A., (1883), *Atlas of anthracite fields; Northern anthracite field,* Pa. 2nd Geol. Survey, pts. 1-6, 1883-5.

——————, (1885), *Second report of progress in the anthracite coal region,* Pa. 2nd Geol. Survey, vol. AA, 1885.

——————, (1886a), *Second report of progress in the anthracite coal regions,* Pa. 2nd Geol. Survey, Ann. Rept. 1885, pp. 269-436.

——————, (1886b), *Report on the Wyoming Valley Carboniferous limestone beds,* Pa. 2nd Geol. Survey, Ann. Rept. 1885, pp. 437-450. Cf. also, Wyoming Hist. and Geol. Soc., Proc. and Coll. 2, pp. 254-264, 1886.

Beede, J. W., (1900), *Carboniferous invertebrates,* Kan. Geol. Survey, vol. 6, pp. 1-187, pls. 1-22.

Burke, J. J., (1930), *The fauna of the Ames limestone from Painters Hollow, Wellsburg, West Virginia,* Unpublished master's thesis, in the Graduate School of the Univ. of Pittsburgh.

Chao, Y. T., (1927), *Fauna of the Taiyuan formation of north China—Pelecypoda,* Palaeontologia Sinica, ser. B, vol. 9, fansc. 3, 64 pp., 4 pls.

Claypole, E. W., (1886), *Report on some fossils from the lower Coal Measures near Wilkes-Barre,* Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 2, pt. 2, pp. 275-286.

Condit, D. D., (1912), *The Conemaugh formation in southern Ohio,* Ohio Geol. Survey, 4th ser., Bull. 17, 318 pp., pls. 13-16.

Conrad, T. A., (1835),*Description of five new species of fossil shells,* Pa. Geol. Soc., Trans., vol. 1, pp. 267-270.

Cox, E. T., (1857), *Paleontological report of Coal Measure mollusca,* Ky. Geol. Survey, vol. 3, pp. 557-576.

Darton, N. H., (1940), *Some structural features of the northern anthracite coal basin, Pennsylvania,* U. S. Geol. Survey, Prof. Paper 193-D, pp. 69-81.

Dunbar, C. O., and G. E. Condra, (1932), *Brachiopoda of the Pennsylvanian system in Nebraska,* Neb. Geol. Survey, 2nd ser., Bull. 5.

Geinitz, Hans B., (1866), *Carbonformation und Dyas in Nebraska,* K. Leopoldino-Carolinische Deut. Akad. Naturf., Verh. 33, Abh. 4.

Girty, G. H., (1904a), *The Carboniferous formations and faunas of Colorado,* U. S. Geol. Survey, Prof. Paper 16.

——————, (1904b), *New molluscan genera from the Carboniferous,* U. S. Nat. Mus., Proc., vol. 27.

———, (1904c), *The type of Aviculopecten,* Am. Geol., vol. 34, pp. 332-333.

———, (1908), *The Guadalupian fauna,* U. S. Geol. Survey, Prof. Paper 58.

———, (1909), *Paleontology of the Manzano group of the Rio Grande Valley, New Mexico,* U. S. Geol. Survey, Bull. 389, pp. 41-136.

———, (1910), *The fauna of the phosphate beds of the Park City formation of Idaho, Wyoming, and Utah,* U. S. Geol. Survey, Bull. 436, pp. 1-82.

———, (1915), *Fauna of the Newoka formation of Oklahoma,* U. S. Geol. Survey, Bull. 544.

Hall, James, and J. M. Clarke, (1893), *An introduction to the study of the genera of Paleozoic brachiopoda,* N. Y. Geol. Survey, vol. 8, Paleontology, pt. 1.

———, (1894), *An introduction to the study of the genera of Paleozoic brachiopoda,* N. Y. Geol. Survey, vol 8, Paleontology, pt. 2.

Heilprin, Angelo, (1886a), *Report on the Wyoming Valley limestone bed and a description of the fossils contained in the same,* Pa. 2nd Geol. Survey, Ann. Rept. for 1885, pp. 437-460.

———, (1886b), *Fossils from the limestone beds of the Wyoming Valley,* Wyoming Valley Hist. and Geol. Soc., Proc. and Coll., vol. 2, pt. 2, pp. 266-275.

Herrick, C. L., (1887), *A sketch of the geological history of Licking County [Ohio],* Denison Univ., Sci. Lab., Bull., vol. 2, pp. 5-70.

Jäkowlew, N., (1903), *Die fauna der oberen Abtheilung der Palaeonzoischen Ablagerungen im Donez-Basin, I. Die Lamellibranchiaten,* Mem. du Com. Geol., ser. neu., liv. 4.

Jones, T. H., (1934), *A geologist abroad in Wyoming Valley—a brief outline of the geological history of the territory about Wyoming Valley,* Wyoming Hist. and Geol. Soc., Quart. Bull., vol. 1, no. 1.

Keyes, C. R., (1894), *Paleontology of Missouri, pt. 2,* Mo. Geol. Survey, vol. 5.

Knight, J. B., (1941), *Paleozoic gastropoda genotypes,* Geol. Soc. Am., Spec. Paper, no. 32.

Lea, Isaac, (1853), *On some new fossil mollusks in the Carboniferous slates of the anthracite seams of the Wilkesbarre coal formation,* Phila. Acad. Nat. Sci., Jour., 2nd ser., vol. 2, pp. 203-206.

Leighton, Henry, (1926), *The geology of Pittsburgh and its environs,* Carnegie Mus. Annals, vol. 17, no. 1, pp. 91-162.

Mark, Clara G., (1912), *The fossils of the Conemaugh formation in Ohio,* Ohio Geol. Survey, 4th ser., Bull. 17, pp. 261-318.

Mather, K. F., (1915), *Fauna of the Morrow group of Arkansas and Oklahoma,* Denison Univ., Sci. Lab., Bull., vol. 18, pp. 59-284.

McChesney, T. H., (1867), *Descriptions of new species of fossils from the Paleozoic rocks of the Western States,* Chicago Acad. Sci., Tr. 1, pp. 1-57.

Meek, F. B., (1864), *Remarks on the family Pteriidae with descriptions of some new fossil genera,* Am. Jour. Sci., 2nd ser., vol. 37, pp. 212-220.

———, (1871), *Descriptions of new species of invertebrate fossils from the Carboniferous and Devonian rocks of Ohio,* Phila. Acad. Nat. Sci., Proc., 1871, pp. 59-93.

———, (1872), *Report on the paleontology of eastern Nebraska,* U. S. Geol. Survey, Final Rept., pp. 85-239.

———, (1875), *A report on some of the invertebrate fossils of the Waverly group and Coal Measures of Ohio,* Ohio Geol. Survey, vol. 2, pt. 2, Paleontology, pp. 269-347.

Meek, F. B., and A. H. Worthen, (1860), *Description of new Carboniferous fossils from Illinois and other Western States,* Phila. Acad. Nat. Sci., Proc., 1860, pp. 447-472.

———, (1866), *Description of invertebrates from the Carboniferous system,* Ill. Geol. Survey, vol. 2, pp. 143-411.

Miller, A. K., C. O. Dunbar, and G. E. Condra, (1933), *The nautiloid cephalopods of the Pennsylvanian system in the mid-continent region,* Neb. Geol. Survey, 2nd ser., Bull. 9.

References

Moore, R. C., (1936), *Stratigraphic classification of the Pennsylvanian rocks of Kansas,* Kan. Geol. Survey, Bull. 22.

———, (1944), *Correlation of Pennsylvania formations of North America,* Geol. Soc. Am., Bull., vol. 55, no. 6, pp. 657-706.

Morningstar, Helen, (1922), *The Pottsville fauna,* Ohio Geol. Survey, Bull. 25.

Morse, W. C., (1931), *Pennsylvanian invertebrate fauna,* Ky. Geol. Survey, 6th ser., vol. 36, pp. 293-348.

Newell, N. D., (1937), *Late Paleozoic pelecypods: Pectinacea,* Kan. Geol. Survey, vol. 10, pt. 1.

———, (1942), *Late Paleozoic pelecypods: Mytilacea,* Kan. Geol. Survey, vol. 10, pt. 2.

Price, W. A., (1918), *Invertebrate fossils from the Conemaugh and Pottsville series,* W. Va. Geol. Survey, Rept. on Barbour and Upshur Counties, pp. 777-804.

———, (1920), *Notes on the paleontology of Webster County,* W. Va. Geol. Survey, Rept. on Webster County, pp. 544-615.

———, (1921), *Notes on the paleontology of Nicholas County,* W. Va. Geol. Survey, Rept. on Nicholas County, pp. 751-788.

Raymond, P. E., (1910), *A preliminary list of the fauna of the Allegheny and Conemaugh series in western Pennsylvania,* Carnegie Mus., Annals, vol. 7, no. 1, pp. 144-158.

Sayre, A. N., (1930), *The fauna of the Drum limestone of Kansas and western Missouri,* Kan. Geol. Survey, Bull. 17, pp. 144-158.

Shimer, H. W., (1908), *Dwarf faunas,* Am. Naturalist, 42, pp. 472-490.

Stevens, R. P., (1858), *Descriptions of new Carboniferous fossils,* Am. Jour. Sci., 2nd ser., vol. 25, pp. 258-260.

Swallow, G. C., and R. P. Shumard, (1858), *Descriptions of new fossils from the Coal Measures of Missouri and Kansas,* St. Louis Acad. Sci., Trans., vol. 1, pp. 198-227.

———, (1863), *Descriptions of some new fossils from the Carboniferous and Devonian rocks of Missouri,* St. Louis Acad. Sci., Trans., vol. 2, pp. 81-100.

Theiss, Mary E., (1940), *The fauna of the Ames limestone in the Pittsburgh Quadrangle,* Unpublished master's thesis, in the Graduate School of the Univ. of Pittsburgh.

Turner, H. G., and H. R. Randall, (1923), *Preliminary report on the microscopy of anthracite coal,* Jour. Geol., vol. 31, no. 4, pp. 306-313.

Wanless, H. R., (1937), *Pennsylvanian correlations in the eastern interior and Appalachian coal fields,* Geol. Soc. Am., Spec. Paper 17.

Wanless, H. R., and J. M. Weller, (1932), *Correlation and extent of Pennsylvanian cyclothems,* Geol. Soc. Am., Bull., vol. 43, no. 4, pp. 1003-1016.

White, C. A., (1884), *The fossils of the Indiana rocks,* Ind. Geol. Survey, Ann. Rept. 13, pt. 2, pp. 107-180.

White, I. C., (1883), *The geology of the Susquehanna River region, in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour and Northumberland,* Pa. 2nd Geol. Survey, Prog. Rept., G7.

———, (1903), *The Appalachian Coal Field; the Conemaugh series,* W. Va. Geol. Survey, Rept., vol. 2, pp. 225-332.

Willard, Bradford, (1946), *Origin of the Lackawanna Basin, Pennsylvania,* Jour. Geol., vol. 54, no. 4, pp. 246-251.

———, (1948), *Coal evolution in Pennsylvania,* Pa. Acad. Sci., Proc., vol. 22, pp. 117-121.

Wilmarth, M. G., (1938), *Lexicon of geologic names of the United States,* U. S. Geol. Survey, Bull. 896, pts. 1 and 2.

Worthen, A. H., (1884), *Description of fossil invertebrates,* Ill. Geol. Survey, vol. 8, pp. 69-154.

PLATE 2

Reduction one-sixth.

FIGURE

1 *Meekella striatocosta* (Cox)

1. Ventral valve of an average specimen.

2–3b *Juresania nebrascensis* (Owen)

2. Ventral view of a partly broken specimen.

3a,b. Ventral and dorsal views of a small specimen.

4–6 *J. symmetrica* (McChesney)

4. Dorsal valve of a large specimen with the cardinal process.
5. Dorsal valve of a small specimen.
6. Dorsal view of an incomplete specimen.

7–8 *Echinoconchus semipunctatus* (Shepard)

7. Ventral view of a small specimen.
8. Dorsal view of the umbonal part of a large ventral valve.

9 *Composita subtilita* ? (Hall)

9. Interior view of a ventral valve

10–11 *C. ovata* Mather

10. Interior view of a dorsal valve.
11. Interior view of a ventral valve of another specimen (?).

12a–13 *Isogramma millepunctata* (Meek & Worthen)

12a. A large ventral valve (x 1½).

12b. Enlargement (x 5) of the part of the above.

13. Interior view of an incomplete dorsal valve.

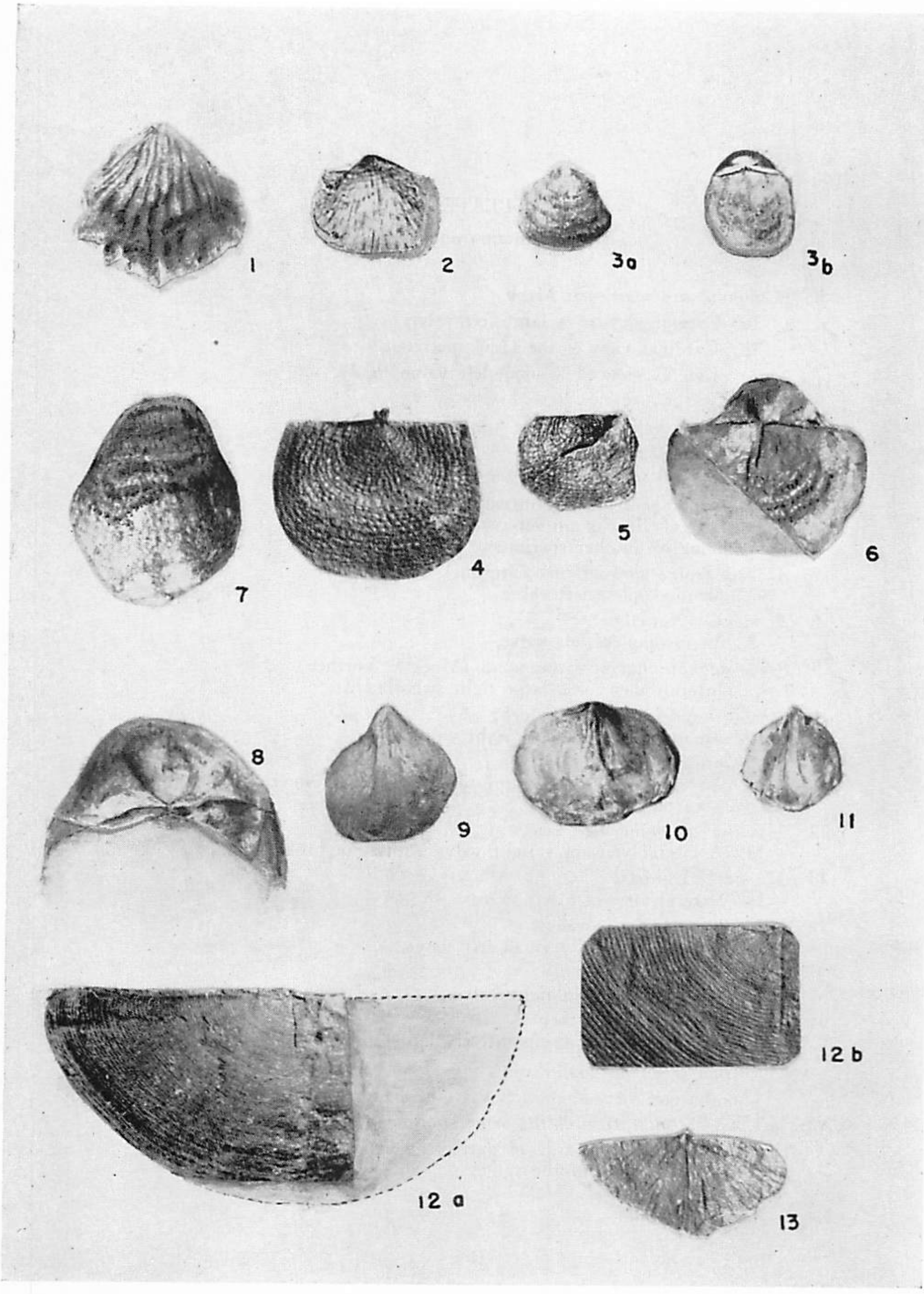

1
2
3a
3b
7
4
5
6
8
9
10
11
12 b
12 a
13

PLATE 3

Reduction one-sixth.

FIGURE

1a–2 *Edmondia aspinwallensis* Meek
- 1a. Lateral view of a large left valve.
- 1b. Cardinal view of the same specimen.
- 2. Lateral view of a small left valve (x 2).

3 *Leda bellistriata* Stevens
- 3. A left valve of average age.

4 *Parallelodon obsoletus* (Meek)
- 4. A small right valve.

5–6 *Aviculopinna peracuta* (Shumard)
- 5. Lateral view of an internal cast.
- 6. Same of another specimen.

7 *Acanthopecten carboniferus* (Stevens)
- 7. An incomplete left valve.

8 *A. meeki* (Newell)
- 8. An incomplete left valve.

9 *Pseudomonotis hawni* var. *sinuata* (Meek & Worthen)
- 9. Interior view of a large right valve (x 2).

10 *Stroblochondria hertzeri* (Meek)
- 10. An internal mold of a right valve.

11 *S. sculptilis* (Miller)
- 11. An enlarged (x 2) impression of a broken piece of a right valve.

12 *Myalina wyomingensis* Lea
- 12. A lateral view of a right valve with beak broken off.

13 *M. meeki* Dunbar
- 13. Lateral view of a left valve.

14 *Schizodus wheeleri* Swallow
- 14. Lateral view of a small left valve.

15 *S. cuneatus* Meek
- 15. Lateral view of a right valve.

16 *S. curtus* Meek & Worthen
- 16. Left valve of a comparatively large specimen.

17a–c *Allorisma terminale* Hall
- 17a. Lateral view of the left valve of a bivalved specimen.
- 17b. Cardinal view of the same specimen.
- 17c. Enlargement (x 2) of part of an external mold showing the impression of the spines.

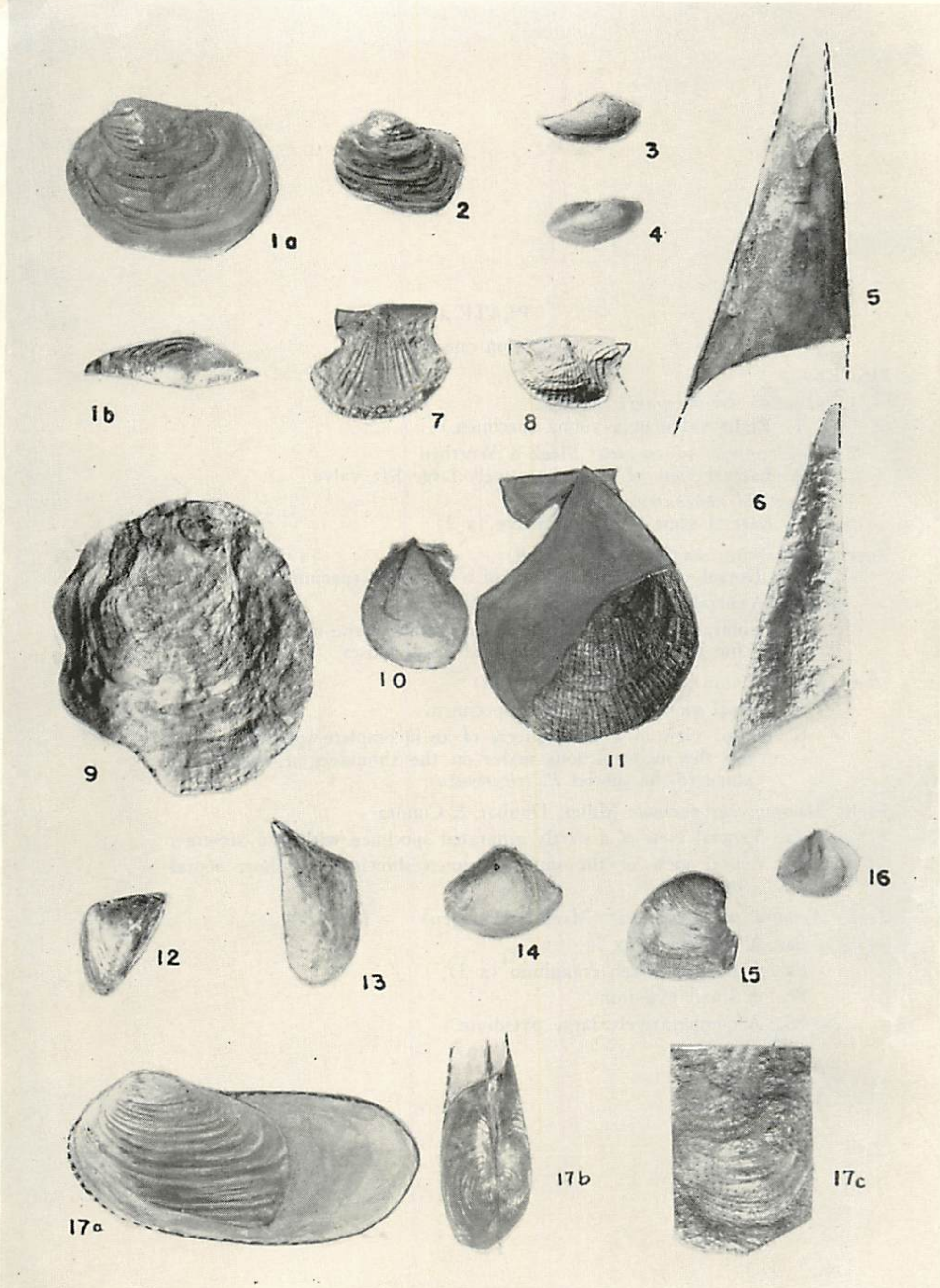

1a
1b
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17a
17b
17c

PLATE 4

Reduction one-sixth.

FIGURE

1 *Myalina wyomingensis* (Lea)
  1. Right valve of a young specimen.

2 *Pleurophorus subcostatus* Meek & Worthen
  2. Lateral view of a comparatively large left valve.

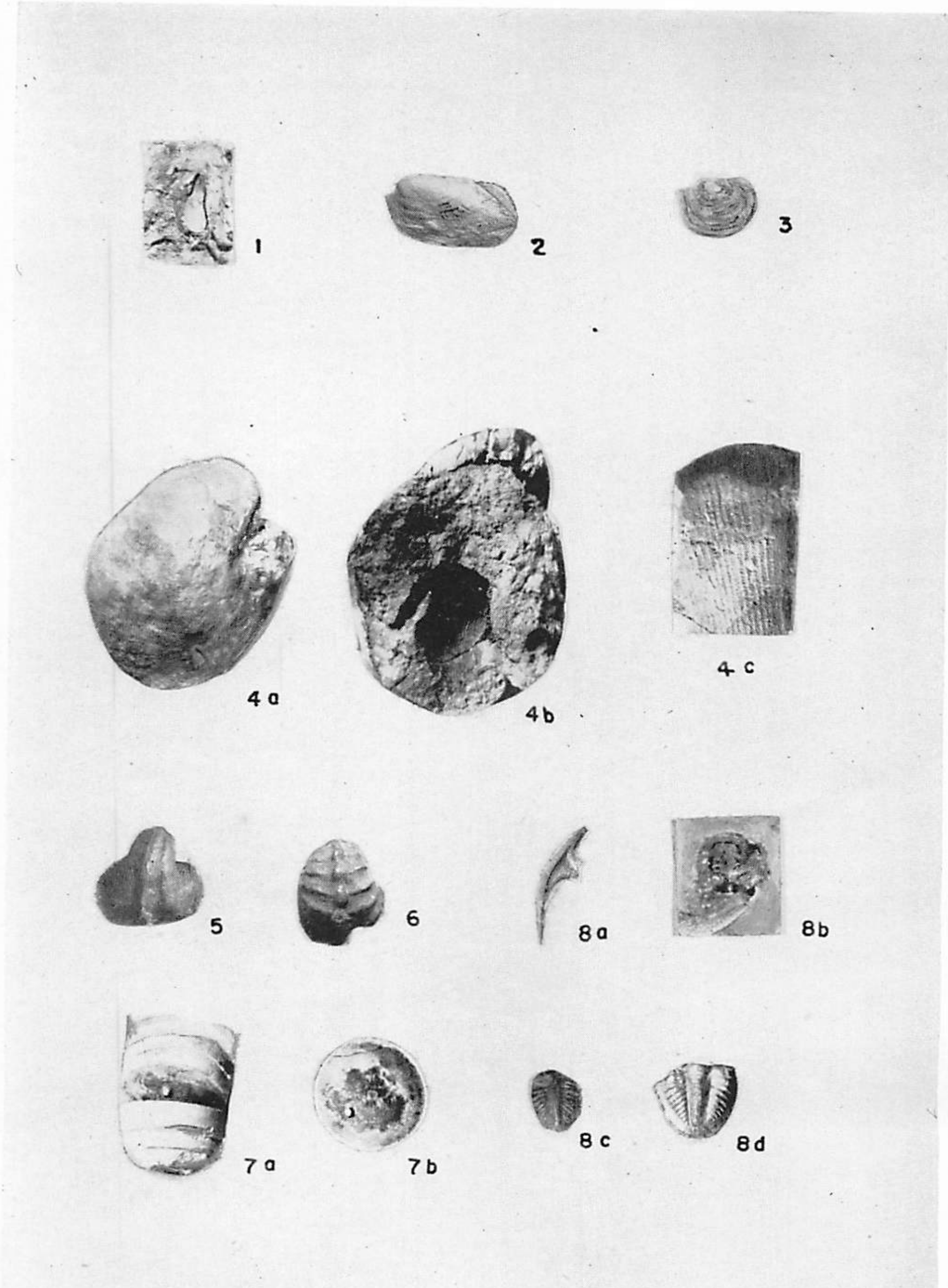
3 *Astartella concentrica* Conrad
  3. Lateral view of a right valve (x 2).

4a–c *Euphemites nodocarinatus* (Hall)
  4a. Dorsal view of the interior of a deformed specimen.
  4b. Ventral view of the same specimen.
  4c. Enlargement (x 8) of the inner surface of the last whorl showing the longitudinal lines and fine noduses.

5–6 *Pharkidonotus percarinatus* (Conrad)
  5. Dorsal view of an average specimen.
  6. Dorsal view of a wax squeeze of an incomplete specimen showing the inconspicuous nodes on the shoulders, a transitional stage to the species *P. tricarinatus.*

7a–b *Mooreoceras normale* Miller, Dunbar, & Condra
  7a. Ventral view of a partly separated specimen with five camerae.
  7b. Septal view of the same specimen showing the short septal neck.

8a–d *Ameura sangamonensis* (Meek & Worthen)
  8a. A free cheek (x 3).
  8b. A partly broken cranidium (x 3).
  8c. A small pygidium.
  8d. A comparatively large pygidium.


1
2
3
4 a
4 b
4 c
5
6
8 a
8 b
7 a
7 b
8 c
8 d

APPENDIX

SYSTEMATIC PALEONTOLOGY

BRACHIOPODA

Genus *Meekella* White & St. John

Meekella striatocostata (Cox)

Pl. 2, fig. 1

1857. *Plicatula striato-costata.* Coxe, Kentucky Geol. Surv., vol. 3, p. 568, pl. 8, fig. 7.
1858. *Orthisina shumardiana.* Swallow, St. Louis Acad. Sc., Trans., vol. 1, p. 183.
1858. *O. missouriensis.* Swallow, St. Louis Acad. Sc., Trans., vol. 1, p. 219.
1859. *O. shumardiana.* Meek & Hayden, Philadelphia Acad. Nat. Sci., Proc., p. 26.
1863. *O. occidentalis.* Swallow, St. Louis Acad. Sci., vol. 2, p. 82.
1866. *Orthis striato-costata.* Geinitz, Carb. und Dyas in Nebraska, p. 48, figs. 22-24.
1868. *Meekella striato-costata.* White & St. John, Chicago Acad. Sci., vol. 1, p. 120, figs. 4-6.
1872. *M. striato-costata.* Meek, U. S. Geol. Surv., Nebraska, p. 175, pl. 5, figs. 12a-c.
1877. *M. striatocostata.* White, U. S. Geol. Surv., W. of 100th Merid., vol. 4, p. 126, pl. 9, figs. 4a-e.
1883. *Streptorhynchus (Meekella) striatocostata.* Hall, New York State Geologist, 2nd Rept. for 1882, pl. 40, figs. 18-23.
1884. *Meekella striatocostata.* White, Indiana Geol. Surv., 13th Ann. Rept., p. 130, pl. 26, figs. 12-14.
1892. *M. striatocostata.* Hall & Clarke, New York Pal., vol. 8, pt. 1, pl. 10, figs. 18-23; pl. 11B, figs. 20-22.
1894. *M. striatocostata.* Keyes, Missouri Geol. Surv., vol. 5, p. 68, pl. 39, figs. 1a-e.
1900. *M. striatocostata.* Beede, Kansas Geol. Surv., vol. 5, p. 65, pl. 12, figs. 9-9c.
1903. *M. striatoccstata.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 150.
1909. *M. striatocostata.* Girty, U. S. Geol. Surv., Bull. 389, p. 54, pl. 6, fig. 6.
1932. *M. striatocostata.* Dunbar & Condra, Nebraska Geol. Surv., Bull. 5, 2nd ser., p. 125, pl. 16, figs. 1-10; pl. 12, figs. 3a-c.

The shell is subglobose and medium in size. Both valves are strongly convex, the greatest convexity is near the umbo. The outline of the shell varies considerably. The pointed beak of the ventral valve is highly elevated on the high and large triangular cardinal area. The beak of the dorsal valve is but slightly incurved over the hinge line, which is more or less straight and about half of the maximum width of the shell across the middle. The anterior margin is broad and subcircular in outline. The surfaces of the both valves bear coarse radial plications which are separated by sulci of about the same shape and strength. Both the plications and the sulci are finely striated. There are commonly 9 to 12 coarse plications on the ventral valve and 8 to 10 on the dorsal, but sometimes more plications may be present on either valve.

The measurement for a ventral valve of average size is about 28 mm. long from the apex to the anterior margin, 29 mm. wide and 18 mm. thick. The hinge line is about 17 mm. long.

This species is fairly common in the Mill Creek limestone, but in all the specimens the shell material is gone and only the internal mold or the cast of the shell is preserved.

Genus *Juresania* Fredericks

Juresania nebrascensis (Owen)

Pl. 2, figs. 2-3b

1852. *Productus nebrascensis.* Owen, Wisconsin, Iowa, and Minnesota Geol. Surv., Rept., p. 584, pl. 5, fig. 3.
1854. *P. nebrascensis.* Norwood & Pratten, Philadelphia Acad. Sci., Jour., 2nd ser., vol. 3, p. 9, pl. 1, figs. 3a-c.
1868. *P. nebrascensis.* McChesney, Chicago Acad. Sci., Trans., vol. 1, p. 24, pl. 1, figs. 7a-b.
1872. *P. nebrascensis.* Meek, U. S. Geol. Surv., Nebraska, Final Rept., p. 165, pl. 2, fig. 2; pl. 4, fig. 6; pl. 5, figs. 11a-c.
1873. *P. nebrascensis.* Meek & Worthen, Illinois Geol. Surv., vol. 5, p. 569, pl. 25, fig. 8.
1875. *P. nebrascensis.* White, U. S. Geol. Surv., W. of 100th Merid., Rept., pt. 1, vol. 4, p. 116. pl. 8, figs. 3a-d.
1876. *P. nebrascensis.* White, U. S. Geol. Surv., Terr., Powell's Rept., p. 90.
1883. *P. aspersus.* Hall, New York State Geologist, 2nd Ann. Rept. for 1882, pl. 50, figs. 5-7.
1884. *P. nebrascensis.* White, Indiana Geol. Surv., 13th Ann. Rept., pt. 2, p. 122, pl. 24, figs. 7-9.
1886. *P. nebrascensis.* Heilprin, Pennsylvania, 2nd Geol. Surv., Ann. Rept. for 1885, p. 453, fig. 4c; p. 440, figs. 4, 4b.

1886. *P. nebrascensis.* Heilprin, Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 2, pt. 2, p. 268, figs. 4, 4b.
1887. *P. nebrascensis.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 49, pl. 2, fig. 30.
1892. *P. nebrascensis.* Hall & Clarke, New York State Geologist, 11th Ann. Rept., p. 22, fig. 7.
1892. *P. nebrascensis.* Hall & Clarke, New York Geol. Surv., Paleontology, vol. 8, pt. 1, p. 19, figs. 5-7.
1895. *P. nebrascensis.* Keyes, Missouri Geol. Surv., vol. 5, p. 48, pl. 37, figs. 3a-c.
1900. *P. nebrascensis.* Beede, Kansas Geol. Surv., vol. 6, p. 84, pl. 9, figs. 7-7f.
1903. *P. nebrascensis.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 370, pl. 5, figs. 1, 2, 2a.
1904. *P. nebrascensis.* Girty, U. S. Geol. Surv., Prof. Paper 21, p. 53, pl. 11, figs. 7-9.
1906. *P. nebrascensis.* Woodruff, Nebraska Geol. Surv., vol. 2, pt. 2, p. 270, pl. 10, fig. 3.
1909. *P. nebrascensis.* Girty, U. S. Geol. Surv., Bull. 389, p. 62, pl. 7, figs. 5, 6.
1915. *P. nebrascensis.* Girty, U. S. Geol. Surv., Bull. 544, p. 65, pl. 10, figs. 6, 6a, 7.
1915. *Pustula nebrascensis.* Mather, Denison Univ., Sci. Lab., Bull. 18, p. 169, pl. 9, figs. 6, 7.
1922. *P. nebrascensis.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 182.
1924. *P. nebrascensis.* Morgan, Oklahoma Geol. Surv., Bull. 2, p. 218, pl. 44, fig. 10.
1930. *P. nebrascensis.* Sayre, Kansas Geol. Surv., Bull. 17, p. 96, pl. 6, figs. 3-3b.
1931. *Productus nebrascensis.* Morse, Kentucky Geol. Surv., vol. 36, p. 310, pl. 57, figs. 12-16.
1932. *Juresania nebrascensis.* Dunbar & Condra, Nebraska Geol. Surv., Bull. 5, p. 195, pl. 22, figs. 1-9, 13.

The shell is of moderate size. The ventral valve is strongly convex and has a semicircular profile. The umbo is broad and swollen with its beak overarching the straight hinge line which may be nearly equal or slightly shorter than the greatest width near the anterior of the shell. The posterolateral slopes descend almost vertically to the lateral margin and the ears. There is a shallow median sinus originating from the umbo. This sinus widens progressively toward the anterior margin. The subquadrangular dorsal valve is slightly convex, more pronounced in front and near the lateral margin.

The surfaces of the both valves are covered with spines which are roughly arranged into concentric belts. The size of the spines is not uniform, but they are of two types, heavy and small, the latter are more numerous. The differentiation of the spines into two sets becomes more pronounced anteriorly and anterolaterally. The heavy spines are more erect and the small ones are tangential to the shell surface. On all the specimens in the collections, the spines are broken off. According to Dunbar and Condra (1923) in specimens from the Jones Point shale of Iowa, the small spines reach a length of 5 to 8 mm. and the heavy ones over 22 mm.

On the interior of the dorsal valve there is a distinct median ridge extending forward to about two-thirds of the length of the shell and raised beyond the hinge line as the trifid cardinal process.

The measurement for a specimen of average size is about 23 mm. long, from the umbo to the anterior margin, 26 mm. wide near the anterior and 20 mm. along the hinge. The convexity of the ventral valve is about 10.5 mm.

Juresania symmetrica (McChesney)

Pl. 2, figs. 4-6

1860. *Productus symmetricus.* McChesney, Descr. New Species Pal. Foss., p. 35.
1867. *P. symmetricus.* McChesney, Chicago Acad. Sci., Trans., vol. 1, p. 25, pl. 1, figs. 9a, b.
1872. *P. symmetricus.* Meek, U. S. Geol. Surv., Nebraska, Final Rept., p. 167, pl. 5, figs. 6a-b; pl. 7, fig. 13.
1895. *P. symmetricus.* Keyes, Missouri Geol. Surv., vol. 5, p. 48, pl. 34, figs. 2a-b.
1915. *P. nebrascensis.* Girty, U. S. Geol. Surv., Bull. 544, pl. 10, figs. 6a, b.
1922. *Pustula symmetricus.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 183, pl. 8, fig. 7.
1930. *P. symmetrica.* Sayre, Kansas Geol. Surv., Bull. 17, p. 95, pl. 7, figs. 6-6b.
1932. *Juresania symmetrica.* Dunbar & Condra, p. 198, pl. 22, figs. 10-12.

The original description of the species by McChesney is:

> . . . Shell of medium size, depressed suborbicular; length and breadth about equal. Cardinal line considerably less than the greatest width of the shell below; extremities rounded; auriculate extensions small, but distinct from the vault of the shell, straight or slightly elevated. Ventral valve quite regularly convex, expanding at the front, and entirely destitute of a medial sinus; front regularly and broadly rounded; beak large, little incurved, barely passing beyond the hinge line. Dorsal valve regularly concave, of moderate depth.
>
> Surface marked much as in the preceding species *P. nebrascensis;* but the spines and broken rib-like striae of the ventral valve are much finer and more thickly set, and the concentric bands are narrower and more closely arranged, becoming crowded on the front of the shell.
>
> This shell, though closely related to the last described species, differs from its being a larger shell, less ventricose and much broader, entirely destitute of medial sinus, less enrolled and with the beak not projecting so far beyond the hinge line; in its dorsal valve being less concave, the nearly or quite destitute of the lateral ridges which pass obliquely from the beak to the sides of the valves in that species. Its spines are also smaller and more numerous.

This is one of the commonest of the Mill Creek brachiopods. Also, it is usually better preserved than most of the fossils in the limestone. The distinction of this species and *J. nebrascensis* is sometimes not clear and their separation is difficult. It is usually larger than the latter. A typical specimen is about 25 mm. long, 29 mm. wide, and 12.5 mm. thick. Its hinge line is about 26 mm. long.

Genus *Echinoconchus* Weller

Echinoconchus semipunctatus (Shepard)

Pl. 2, figs. 7-8

1836. *Productus punctatus?.* Morton, Am. Jour. Sci., 1st ser., vol. 29, p. 153, pl. 26, fig. 38.
1838. *P. semipunctata.* Shepard, Am. Jour. Sci., 1st ser., vol. 34, p. 153, fig. 9.
1854. *P. punctatus.* Shumard, Marcy's Expl. Red River of La., p. 175, pl. 1, fig. 5; pl. 2, fig. 1.
1855. *P. punctatus.* Norwood & Pratten, Philadelphia Acad. Nat. Sci., Jour., vol. 3, p. 19.
1858. *P. punctatus.* Marcou, Geol. N. Am., p. 48, pl. 6, fig. 2.
1860. *P. tubulospinus.* McChesney, Descr. New Pal. Foss., p. 37.
1868. *P. punctatus.* McChesney, Chicago Acad. Sci., Trans., vol. 1, p. 27, pl. 1, figs. 10, 11.
1872. *P. punctatus.* Meek, U. S. Geol. Surv., Nebraska, p. 169, pl. 2, fig. 6; pl. 4, fig. 5.
1873. *P. punctatus.* Meek & Worthen, Illinois Geol. Surv., vol. 5, p. 569, pl. 25, fig. 13.
1876. *P. punctatus.* White, Powell's Rept., Geol. Uinta Mts., p. 89.
1877. *P. punctatus.* White, U. S. Geol. Surv., W. of 100th Merid., vol. 4, p. 114, pl. 7, figs. 2a-c.
1878. *P.* sp. allied to *P. punctatus.* Etheridge, London Geol. Sci. Quart., vol. 34, p. 630.
1882. *P. punctatus.* White, Indiana Geol. Surv., 11th Rept., p. 373, pl. 42, figs. 1-3.
1883. *P. punctatus.* Hall, New York State Geologist, Rept. for 1882, pl. 50, figs. 14-16.
1884. *P. punctatus.* White, Indiana Geol. Surv., 13th Rept., p. 124, pl. 27, figs. 1-3.
1887. *P. punctatus.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 48, pl. 2, fig. 29.
1892. *P. punctatus.* Hall & Clarke, New York Pal., vol. 8, pt. 1, pl. 17A, fig. 21; pl. 19, figs. 14-17.
1894. *P. punctatus.* Keyes, Missouri Geol. Surv., vol. 5, p. 51, pl. 37, figs. 1a-c.
1897. *P. punctatus.* Smith, Am. Phil. Soc., Proc., vol. 35, p. 29, pl. 22, fig. 7.
1900. *P. punctatus.* Beede, Kansas Geol. Surv., vol. 6, p. 87, pl. 10, figs. 3-3c; pl. 11, fig. 3.
1903. *P. punctatus.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 368.
1912. *P. punctatus.* Mark, Ohio Geol. Surv., Bull. 17, p. 303, pl. 12, fig. 6.
1915. *Pustula punctata.* Mather, Denison Univ., Sci. Lab., vol. 18, p. 172, pl. 8, fig. 11.
1932. *Echinoconchus semipunctatus.* Dunbar & Condra, Nebraska Geol. Surv., Bull. 5, 2nd ser., p. 205, pl. 25, figs. 1-4.

This large and heavy productoid shell has a narrow umbo and broadly rounded anterior. The ventral valve is strongly convex. It is swollen on the umbonal region and descends gradually therefrom to the lateral slopes and the anterior margin, but curves sharply backward into the rather acute beak which is closely incurved over the hinge line and against the dorsal valve. The hinge line is comparatively short and only about two-thirds of the maximum width of the shell near the anterior margin. The ventral valve bears a shallow median sinus running from the umbo forward and becoming obsolete near the anterior margin. The dorsal valve is nearly flat or slightly concave and bears a low, round fold which becomes obscure near the anterior margin.

The surface of the shell is marked by the concentric, terrace-like bands which are more or less uniformly spaced throughout. There are numerous spines of different sizes arranged into rows which follow the contours of the concentric belts. Generally they are roughly differentiated into a set of coarse ones and finer ones, the latter are more numerous.

The measurement for a specimen of average size is 39 mm. long, 35 mm. for the maximum width near the anterior margin of the shell, the corresponding width along the hinge line is 25 mm. and the convexity of the ventral valve is 18.5 mm.

Genus *Isogramma* Meek & Worthen

Isogramma millepunctata (Meek & Worthen)

Pl. 2, figs. 12a-13

1870. *Chonetes* (?) *millepunctata.* Meek & Worthen, Philadelphia Acad. Nat. Sci., Proc., p. 35.
1873. *C.* ?? *millepunctata.* Meek & Worthen, Illinois Geol. Surv., vol. 5, p. 568, pl. 25, fig. 3.
1886. *C.* (?) *millepunctata.* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 452, fig. 3.
1886. *C.* (?) *millepunctata.* Heilprin, Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 2, pt. 2, p. 280, fig. 3.
1895. *C. millepunctata.* Keyes, Missouri Geol. Surv., vol. 5, p. 48, pl. 37, figs. 3a-c.
1900. *Aulacorhynchus millepunctatus.* Beede, Kansas Geol. Surv., vol. 6, pt. 2, p. 89, pl. 12, figs. 1, 1b.
1922. *A. millepunctatus.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 180, pl. 7, fig. 12.

1924. *A. millepunctatus.* Morgan, Oklahoma Geol. Surv., Bull. 2, p. 212, pl. 42, fig. 3.
1932. *Isogramma millepunctata.* Dunbar & Condra, p. 280, pl. 42, figs. 18-21.

The shell is transversely semi-elliptical in outline. It is almost twice as wide as long. The hinge line is straight and long, only slightly shorter than the greatest width located a little in front of the hinge line. There is no cardinal area observed on both valves. The cardinal extremities are slightly rounded. The lateral margins curve broadly forward into the broad round anterior margin.

The valves are nearly flat. The ventral valve has a low convexity and the dorsal one is slightly concave. The surfaces of both valves are ornamented with numerous fine concentric ribs or lirae. There are about 25 lirae in a space of 10 mm. They are more or less uniform in strength, evenly spaced throughout the surface and separated by broadly concave interspaces which are wider than the lirae. The lirae and interspaces are obscure near the beak.

The surface of the shell is coarsely punctate, which punctae can be observed under slight magnification.

Internally there is a narrow triangular area for muscular attachment on the ventral valve and a short cardinal process extending medially and forward as a low ridge to the mid-length of the dorsal shell.

The shell may attain large size, but complete specimens are lacking. A rather large specimen in the collection measures 30.2 mm. long, and 67 mm. wide next to the hinge line.

Genus Composita ovata Mather
Pl. 2, figs. 10-11

1915. *Composita ovata.* Mather, Denison Univ., Sci. Lab., Bull., vol. 18, p. 202, figs. 6-6c.
1932. *C. ovata.* Dunbar & Condra, Nebraska Geol. Surv., Bull. 5, 2nd ser., p. 370, pl. 43, figs. 14-19.

The shell is of medium size and suboval in outline. The two valves are moderate and subequal in convexity. The ventral umbo is curved apically and produced dorsally into the rather large beak which is terminated by a small oval foramen. The hinge line is short and poorly defined. A rounded ventral sinus originates in the umbonal region. It broadens and deepens progressively toward the anterior margin. This sinus and the corresponding similar but less pronounced fold on the dorsal valve gives the broad U-shaped front commissure of the shell. The lateral commissures are nearly straight and converge anteriorly and dorsally as the slopes of the median fold.

The surface of the shell is smooth or faintly marked by a few concentric growth-lines which tend to be more prominent at intervals indicating different stages of ontogenetic development.

The species is represented in the collection by several internal molds of the ventral valve and a dorsal valve. As this species resembles and is usually associated with *C. subtilita* (Hall), which is a more common form and widely distributed, the latter may be present in the Mill Creek limestone and been included with *C. ovata.*

PELECYPODA

Genus *Edmondia* Koninck
Edmondia aspinwallensis Meek
Pl. 3, figs. 1a-2

1871. *Edmondia aspinwallensis.* Meek, U. S. Geol. Surv., Prelim. Rept. Wyoming, p. 299.
1872. *E. aspinwallensis.* Meek, U. S. Geol. Surv., Final Rept. Nebraska, p. 216, pl. 4, figs. 2-2c.
1883. *E. aspinwallensis.* White, Indiana Dept. Geol. and Nat. Hist., 13th Ann. Rept., pt. 2, p. 148, pl. 31, figs. 4, 5.
1900. *E. aspinwallensis.* Beede, Kansas Geol. Surv., vol. 6, p. 166, pl. 22, figs. 3-3b.
1912. *E. aspinwallensis.* Mark, Ohio Geol. Surv., Bull. 17, p. 305, pl. 9, fig. 11.
1922. *E. aspinwallensis.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 197, pl. 10, fig. 7.
1924. *E. aspinwallensis.* Morgan. Oklahoma Geol. Surv., Bull. 2, pl. 46, fig. 6.
1930. *E. aspinwallensis.* Sayre, Kansas Geol. Surv., Bull. 17, p. 103, pl. 8, figs. 1-1a.

The shell is large, moderately convex and subovate in outline which measures 37 mm. wide and 26.7 mm. high. The umbo is moderately high and has a ridge extending from the beak to the posteroventral margin. The greatest convexity is on the ridge lateral to the cardinal margin which is much shorter than the length of the shell, the portion in front of the beak is short and curved, the portion behind is almost three times longer, straight for about half of the distance and declining gradually toward the posterior margin. The beak is depressed, pointed, incurved, moderately elevated above the hinge line and directed forward, and located near the anterior cardinal extremity. The posterior ligamental groove is lanceolate and extends from under the beak almost to the posterior end of the cardinal margin. Both the anterior and posterior borders of the shell are convex and round, the former is narrower and tends to square up slightly near the hinge. The external surface is marked by prominent sharp-crested concentric ridges which are separated by much broader grooves, some of which are finely striated with lines of growth.

This species differs from *Edmondia ovata* Meek and Worthen in its shorter shell, the beak is more elevated and less terminal, and being narrower posteriorly.

Pelecypoda

Genus *Leda* Schumacher

Leda bellistriata Stevens

Pl. 3, fig. 3

1858. *Leda bellistriata.* Stevens, Am. Jour. Sci., vol. 25, p. 261.
1858. *L. bellistriata.* Hall, Iowa Geol. Surv., Rept., vol. 1, pt. 2, p. 717, pl. 29, figs. 6a-d.
1884. *Nuculana bellistriata.* White, Indiana Dept. Geol. and Nat. Hist., 13th Ann. Rept, pt. 2, p. 146, p. 31, figs. 8, 9.
1887. *N. bellistriata.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 40, pl. 4, fig. 26.
1888. *N. bellistriata.* Keyes, Philadelphia Acad. Nat. Sci., Proc., p. 233.
1895. *N. bellistriata.* Keyes, Missouri Geol. Surv., vol. 5, p. 122, pl. 45, figs. 4a, 6b.
1896. *N.* aff. *bellistriata.* Smith, Am. Philos. Soc., Proc., vol. 35, p. 245.
1900. *N. bellistriata.* Beede, Kansas Geol. Surv., vol. 6, p. 148, pl. 20, figs. 14, 14b.
1903. *Leda bellistriata.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 442.
1915. *L. bellistriata.* Girty, U. S. Geol. Surv., Bull. 544, p. 122, pl. 14, figs. 1-9a.
1915. *L. bellistriata.* Mather, Denison Univ., Sci. Lab., Bull., vol. 18, p. 212, pl. 15, fig. 19.
1922. *L. bellistriata.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 204, pl. 10, fig. 27.
1924. *L. bellistriata.* Morgan, Oklahoma Geol. Surv., Bull. 2, pl. 48, figs. 7, 7a, 8.
1930. *L. bellistriata.* Sayre, Kansas Geol. Surv., Bull. 17, p. 106, pl. 8, figs. 7-7c.
1931. *L. bellistriata.* Morse, Kentucky Geol. Surv., Paleontology of Kentucky, p. 315, pl. 40, figs. 8-15.

The size of the shell varies greatly. Most of the specimens in the collection are small and have dimensions of about or less than 10 mm. long and 5.5 mm. high. An exceptionally large shell attains a length of about 33.4 mm. and a height of 11.8 mm. There are also variations in other characters, but only within a very limited range except the attenuation of the posterior end of the shell which may be so pronounced that it has been considered by some as a separated variety, *attenuata.*

The shell is equivalve and inequilateral. The anterior border is broadly rounded to give the front half of the shell a semicircular outline, but the posterior end is narrowly attenuated. In comparison with its size the shell is thick, especially at the anterior and middle portions. The posterior end is more or less compressed. The exterior surface is lined with fine, parallel, concentric striae, which are closely and regularly arranged, obsolete upon the umbonal ridge. They are separated by rounded grooves of about the same width or slightly wider. The umbo is prominent and has a ridge which runs backward to the end of the posterior border. The beaks are close together, raised, slightly incurved and pointed backward, located at one-third the distance from the anterior margin of the shell, but almost subcentral on the hinge line which is straight in front of the beak but curved downward posteriorly. The lunule is obscure and the escutcheon broad and well-defined. On the interior of the shell the pallial line is simple; and the muscle scars are deep and well-marked. The anterior one is much larger and near the anterior border; the posterior one is small and close to the cardinal margin dorsally.

Genus Parallelodon obsoletus (Meek)

Pl. 3, fig. 4

1871. *Macrodon obsoletus.* Meek, Regents Univ., West Virginia, Rept., (List of Carb. Foss.).
1875. *M. obsoletus.* Meek, Ohio Pal., vol. 2, p. 334, pl. 19, fig. 9.
1886. *M. obsoletus.* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 456, fig. 19.
1891. *M. obsoletus.* Keyes, Philadelphia Acad. Nat. Hist., Proc., p. 249.
1894. *M. obsoletus.* Keyes, Missouri Geol. Surv., vol. 5, p. 120, pd. 44, fig. 1.
1900. *M. obsoletus.* Beede, Kansas Geol. Surv., Rept., vol. 6, p. 147, pl. 20, fig. 13.
1903. *M. obsoletus.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 443.
1922. *Parallelodon obsoletus.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 109, pl. 11, figs. 1, 2.
1924. *P. obsoletus.* Morgan, Oklahoma Geol. Surv., Bull. 2, pl. 47, fig. 17.

Most of the individuals are very small, only about 10 mm. long, but one large specimen is 27 mm. long, 12 mm. high between the hinge line and ventral border, the left valve is about 4 mm. thick. The shell is equivalved, strongly inequilateral, and transversely elongated. The hinge line, which is straight and more or less parallel to the ventral margin, is about four-fifths of the length of the shell across the middle where it is the longest. The cardinal extremities are slightly projected at the anterior and rounded posteriorly. The beak is located at one-fifth the distance from the anterior end of the hinge line, flatly compressed, incurved, directed forward, and raised slightly above the dorsal margin. The umbo is only moderately convex and depressed dorsally toward the beak. The umbonal ridge runs obliquely from the beak backward and downward to the posteroventral corner and gives the shell a more or less truncated appearance. There is a depression on the ventral side extending from the umbonal region to the margin of the ventral border, causing a slight sinuation of the edge of the shell. The anterior of the shell turns gradually downward and backward. The posterior border turns more abruptly from the terminal of the umbonal ridge to meet the ventral margin which is more or less parallel to the hinge, but slightly divergent ventrally and posteriorly.

The surface is rather smooth, marked only with fine concentric growth lamellae, most prominent on the anterior umbonal slope. On most of the specimens the surface markings are gone or fail to show on the molds, thus making it difficult to distinguish from the other species of the genus.

Genus *Aviculopinna* Meek

Aviculopinna peracuta (Shumard)

Pl. 3, figs. 5-6

1858. *Pinna peracuta.* Shumard, St. Louis Acad. Sci., Trans., vol. 1, p. 214.
1872. *P. peracuta.* Meek, U. S. Geol. Surv., Fin. Rept., Nebraska, p. 198, pl. 4, figs. 11a-b.
1877. *P. peracuta.* White, U. S. Geol. Surv., West of 100th Merid. (IV), p. 151, pl. 19, fig. 5a.
1884. *P. peracuta.* White, Indiana Dept. Geol. and Nat. Hist., 13th Ann. Rept., pt. 2, p. 145, pl. 28, fig. 12.
1886. *P. peracuta.* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 454, fig. 12a.
1886. *P. peracuta.* Heilprin, Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 2, pt. 2, p. 272, fig. 12; p. 273, fig. 12a.
1892. *Aviculopinna peracuta.* Hyatt, Boston Soc. Nat. Hist., Proc., vol. 25, p. 338.
1895. *Pinna peracuta.* Keyes, Missouri Geol. Surv., vol. 35, p. 116, pl. 14, figs. 2a-b.
1899. *P. peracuta.* Girty, U. S. Geol. Surv., 19th Ann. Rept., pt. 3, p. 579.
1900. *P. peracuta.* Beede, Kansas Geol. Surv., Rept., vol. 6, p. 144, pl. 18, figs. 3, 3b.
1903. *Aviculopinna peracuta.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 432, pl. 9, figs. 1, 2.
1909. *A. peracuta.* Girty, U. S. Geol. Surv., Bull. 389, p. 77.

The shell is long and slender. The exact length is difficult to determine, due to incomplete preservation of the specimens. Heilprin gave an approximate length of 14 cm. for one of his specimens from the same locality from which the present material was collected; however, none of the specimens in the present collection exceeds 10 cm. The valves have very great convexity, which gives the shell a subcylindrical shape which is oval in cross section. Anteriorly the hinge line makes an angle of about 18° with the ventral margin of the shell and becomes more parallel posteriorly. The external surface as indicated on preserved thin fragments of shell is marked by fine lines of growth which curve gently backward ventrally. Two large and deep, elongate, anterior muscle scars are seen on the internal fillings and are longitudinally divided but not completely separated by a round ridge. The cardinal border is thickened, and the beak is pointed terminally. The shells are in certain cases slightly bent or distorted at the point just behind the muscle scars. This may be caused by the slight difference in the stress of the muscle attachments on the two sides.

Genus *Aviculopecten* McCoy

Aviculopecten occidentalis (Shumard)

1855. *Pecten occidentalis.* Shumard, Missouri Geol. Surv., Ann. Rept., p. 207, pl. c, fig. 18.
1861. *P. occidentalis.* Newberry, Ives's Colorado River Exped., p. 128.
1866. *Aviculopecten occidentalis.* Meek & Worthen, Illinois Geol. Surv., Rept., vol. 2, p. 331, pl. 27, figs. 4, 5, 5a.
1872. *A. occidentalis.* Meek, U. S. Geol. Surv., Nebraska, p. 191, pl. 9, fig. 10.
1876. *A. occidentalis.* White, Powell's Rept., Geol. Uinta Mountains, p. 90.
1877. *A. occidentalis.* White, U. S. Geol. Surv., West of 100th Merid., Rept., vol. 4, p. 146, pl. 12, figs. 8a, b.
1884. *A. occidentalis.* White, Indiana Geol. Surv., 13th Rept., p. 143, pl. 28, fig. 2.
1886. *A. occidentalis.* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 455, fig. 5a; p. 442, fig. 5.
1891. *A. occidentalis.* White, U. S. Geol. Surv., Bull. 77, p. 29, pl. 4, fig. 1.
1894. *A. occidentalis.* Keyes, Missouri Geol. Surv., vol. 5, p. 110, pl. 42, fig. 3.
1897. *A. occidentalis.* Smith, Am. Philos. Soc., Proc., vol. 35, p. 34.
1899. *A. occidentalis.* Girty, U. S. Geol. Surv., 19th Ann. Rept., pt. 3, p. 578.
1900. *A. occidentalis.* Beede, Kansas Geol. Surv., Rept., vol. 6, p. 114, pl. 13, fig. 7.
1900. *A. occidentalis.* Knight, Wyoming Univ., Bull. 45, pl. 3, fig. 3.
1903. *A. occidentalis.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 414, pl. 8, fig. 1.
1924. *A. occidentalis.* Morgan, Oklahoma Geol. Surv., Bull. 2, pl. 44, fig. 8.
1937. *A. occidentalis.* Newell, Kansas Geol. Surv., vol. 10, p. 51, pl. 4, figs. 4-9; pl. 5, fig. 7.

This is one of the commonest of the Pennsylvanian pectenids. The average length of specimens in the collection is about fifteen millimeters. The height usually slightly exceeds the length; in rare cases they are longer than high. The shell is acline, inequivalved, and inequilateral. The lateral and ventral margins are curved. The left valve is convex; the right one nearly flat. The former is more frequently found. The large auricles are broken off on almost all the specimens. They are marked with radial auricular costae. On one small, partly broken left valve, both auricles are preserved. They are triangular and have broad bases. The posterior one is longer, pointed and with 9 costae of subequal strength. The anterior auricle is rounded at the extremity and well-defined behind from the swell of the umbonal slope by a shallow sulcus. The pointed beak projects only slightly beyond the hinge line, which is nearly straight. The umbo is depressed and triangular and has an apical angle of about 80°. The sides are well-defined by the ears. The surface of the shell is ornamented with about 20 flat costae and with finer intercalated striae, usually prominent only on the parts ventral to the umbo. There are also a few widely spaced concentric fila which are more important at the anterior part of the valve.

Genus *Acanthopecten* Girty

Acanthopecten carboniferus (Stevens)

Pl. 3, fig. 7

1858. *Pecten carboniferus.* Stevens, Am. Jour. Sci., 2nd ser., vol. 25, p. 261.
1863. *P. broadheadii.* Swallow, St. Louis Acad. Sci., Trans., vol. 2, p. 97.
1866. *P. hawni.*. Geinitz, Carb. und Dyas in Nebraska, p. 36, pl. 2, figs. 19a, b.
1872. *Aviculopecten carboniferus.* Meek, U. S. Geol. Surv., Nebraska, p. 193, pl. 4, fig. 8; pl. 9, figs. 4a, b.
1873. *A. carboniferus.* Meek & Worthen, Illinois Geol. Surv., vol. 5, p. 26, fig. 8.
1874. *A. carboniferus.* Meek, Am. Jour. Sci., 3rd ser., vol. 7, p. 489.
1884. *A. carboniferus.* White, Indiana Geol. Surv., 13th Rept., pt. 2, p. 144, pl. 28, figs. 5-6.
1887. *A. carboniferus.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 67, pl. 3, fig. 13.
1894. *A. carboniferus.* Keyes, Missouri Geol. Surv., vol. 5, p. 111, pl. 43, figs. 4a, b.
1897. *A. carboniferus.* Smith, Am. Philos. Soc., Proc., vol. 35, p. 33.
1900. *A. carboniferus.* Beede, Kansas Geol. Surv., Rept., vol. 6, p. 117, pl. 13, fig. 9.
1903. *Acanthopecten carboniferus.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 418.
1906. *A. carboniferus.* Woodruff, Nebraska Geol. Surv., vol. pt. 2, p. 282, pl. 14, fig. 2.
1908. *A.* aff. *A. carboniferus.* Girty, U. S. Geol. Surv., Prof. Paper 58, p. 440.
1912. *A. carboniferus.* Mark, Ohio Geol. Surv., Bull. 17, p. 308, pl. 15, fig. 4.
1915. *A. carboniferus.* Girty, U. S. Geol. Surv., Bull. 544, p. 134, pl. 17, figs. 10, 10a.
1924. *A. carboniferus.* Morgan, Oklahoma, Bull. 2, pl. 44,, figs. 1, 1a.
1927. *A. carboniferus.* Chao, Pal. Sinica, ser. B, vol 9, p. 33, pl. 4, figs. 5-9.
1930. *A. carboniferus.* Sayre, Kansas Geol. Surv., Bull. 17, p. 121, pl. 12, figs. 5, 6.
1937. *A. carboniferus.* Newell, Kansas Geol. Surv., vol. 10, p. 72, pl. 12, figs. 8a-10.

Only relatively few specimens of this widespread species are found in the collection. The shells are usually small with broken ventral borders. The average specimen is about sixteen millimeters high and fifteen millimeters long. The inequilateral aclne shell has a circular ventral border with serrate edge. The left valve is more convex than the ventral one which is nearly flat. The hinge line is straight or slightly bent at the beak, which is at the same level with or barely raised above the hinge line, which is almost as long as the length of the valve across the middle where it is longest, and sometimes longer than the height of the shell. Of the two large auricles, the posterior one is longer on the dorsal margin and pointed at the extremity; the anterior auricle is rounded at the end and separated under the umbo by a rather deep auricular sulcus and defined ventrally by a marginal sinuosity. Both ears are lined with fine ridges which are a continuation of the first order fila on the valve. The umbo is triangular, slightly anterior, and vertically truncated at the anterior margin but merges imperceptibly toward the posterior border and the ear. The surface is marked with broad, round-topped costae, fifteen or sixteen on each valve. The costae are separated by comparatively narrow furrows. Both the costae as well as the furrows on the left valve are interrupted by coarse concentric fila which are more pronounced and at greater intervals toward the ventral border. Sometimes they form short points in the furrows and elevations on the costae to give the shell an overlapping appearance.

Acanthopecten meeki Newell

Pl. 3, fig. 8

1930. *Acanthopecten carboniferus.* Sayre, Kansas Geol. Surv., Bull. 17, p. 121, pl. 12, figs. 5, 6.
1937. *A. meeki.* Newell, Kansas Geol. Surv., vol. 10, p. 72, pl. 12, figs. 1a-5.

A partly broken specimen in the collection representing the dorsal two-thirds of a left valve seems to belong to this species. The shell is small and markedly convex. The hinge line is about 14 mm. long, straight, with the beak slightly anterior and scarcely extending beyond the hinge line. The posterior auricle is large and distinctly marked by the vaulted, auricular fila which are more or less parallel and concave apaxially. The anterior auricle is smaller, triangular and separated from the young parts of the shell on the umbo by a distinct auricular sulcus. The umbo swells but is depressed dorsally toward the beak. Its anterior end projects and overhangs the auricle sulcus. The surface of the shell is marked by 15 narrow costae and strong concentric vaulted fila with sharp-pointed imbrications. They are more prominent on the anterior part of the shell and quite distinct even on the juvenile parts of the shell on the umbo. The ventral border of the shell is broken but seems to be more broadly concave than that of *Acanthopecten carboniferus* as indicated by the concentric fila preserved on the earlier parts where they generally follow the outline of the shell.

Mill Creek Limestone

Genus *Pseudomonotus* Beyrich

Pseudomonotis hawni var. *sinuata* (Meek & Worthen)

Pl. 3, fig. 9

1864. *Eumicrotis hawni.* Meek, Am. Jour. Sci., 36, p. 216.
1866. *E. hawni* var. *sinuata.* Meek & Worthen, Illinois Geol. Surv., vol. 2, p. 338, pl. 27, figs. 12-14.
1937. *Pseudomonotis hawni* var. *sinuata.* Newell, Kansas Geol. Surv., vol. 10, p. 102, pl. 16, figs. 1a, b.

The single internal mold of a right valve in the collection coincides with this variety in every respect. The valve is flat and large, having a length of about 38 mm., and a slightly greater height. The beak is obsolete. The hinge line is only half as long as the length of the shell. The byssal sinus is very deep and narrow. The resilifer is broad and placed at the dorsal middle of the hinge directly under the beak. The anterior of the valve is slightly gaping and has a shoulder-like corner next to the hinge. The large subovate muscle impression is obliquely placed behind the midline of the valve. The interior surface is marked with more or less wavy undulations which are vaulted, and fine growth lines which are more distinct on the juvenile part of the shell. The contours of these lamellae indicate that the younger shell has proportionally much greater height than the adult one which is equally long and high.

Genus *Stroblochondria* Miller

Stroblochondria sculptilis (Miller)

Pl. 3, fig. 11

1892. *Aviculopecten sculptilis.* Miller, Indiana Geol. Surv., 17th Rept., p. 702, pl. 20, fig. 5.
1900. *A. sculptilis.* Beede, Kansas Geol. Surv., vol. 6, p. 122, pl. 13, figs. 3-3b.
1930. *A. sculptilis.* Sayre, Kansas Geol. Surv., Bull. 17, p. 119, pl. 9, figs. 9-10.
1937. *Stroblochondria sculptilis.* Newell, Kansas Geol. Surv., vol. 10, p. 82, pl. 16, figs. 5a-c, 7, 9a, b, 11.

This species is represented only by an external mold of a fragment of a fairly large right valve and an internal mold of a small left valve. The pattern of surface ornamentation and the outline of the shell are all quite characteristic of the species. The surface of the valve is marked by a network of numerous radial costae intersected by as many concentric fila. The latter are more closely spaced near the ventral margin and converge as they ascend the anterior border of the umbo. The pointed beak projects beyond the hinge line. The single preserved anterior auricle of the right valve is separated from the swell of the umbo by a broad transitional zone which is marked by fine growth lines and coarser auricular fila which become obsolete on the ear.

This species is distinguishable from *Stroblochondria hertzeri* (Meek) by its smaller umbonal angle and the deeply separated, low-positioned, and deep-notched anterior auricle of the right valve.

Stroblochondria hertzeri (Meek)

Pl. 3, fig. 10

1871. *Aviculopecten (Stroblopteria ?) hertzeri.* Meek, Philadelphia Acad. Nat. Sci., Proc., p. 61.
1875. *A. (Stroblopteria ?) hertzeri.* Meek, Ohio Pal., vol. 2, p. 330, pl. 19, figs. 13a-c.
1922. *A. hertzeri.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 226, pl. 13, fig. 4.
1937. *Stroblochondria hertzeri.* Newell, Kansas Geol. Surv., vol. 10, p. 81, pl. 16, figs. 6, 10, 12-15.

This is represented by a partly broken internal mold of a small right valve and a portion of the umbonal region of another one with the anterior auricle preserved. The valve is nearly flat. The beak is pointed and subcentral, directed forward and raised slightly above the straight hinge line. The smaller posterior auricle is broken at its extremity. The anterior ear is ornamented similarly to the surface of the shell body. It is relatively large and with a rather deep byssal notch. The position of this auricle is depressed in comparison with the general surface of the shell. The surface of the shell is decorated with a cancellated pattern of numerous regularly arranged radial costae and concentric fila. The same ornamentation extends with equal distinctness to the surface of the anterior auricle. The umbo is flat. The anterior margin is slightly concave, and the posterior gently convex. The two form an umbonal angle of about 90 degrees.

Genus *Pernopecten* Winchell

Pernopecten prosseri (Mark)

1858. *Pecten aviculites.* Swallow, St. Louis Acad. Sci., Trans., vol. 1, p. 213.
1912. *Entolium prosseri.* Mark, Ohio Geol. Surv., Bull. 17, p. 309, pl. 15, figs. 6-8.
1937. *Pernopecten prosseri.* Newell, Kansas Geol. Surv., vol. 10, p. 111, pl. 20, figs. 12, 13, 17, 18.

The shell is acline, large, subcircular in outline, and gaping in front and behind. The valves are only moderately convex in comparison with the size. The largest specimen has dimensions of about 30 millimeters in length and height. The hinge line is short, about one-third of the length of the shell body. The auricles are small, nearly equal, slightly convex, and very finely striated. The rather deep triangular resilifer is located at the middle of the hinge plate under the tip of the compressed beak. The umbo is flatly convex and has an umbonal angle of about 110 degrees. The interior of the shell has irregular broad concentric undulations, but the exterior is smooth or marked by fine concentric growth lamellae which are more distinct near the margin. The species is distinguishable from *Pernopecten clypeatus* and *P. ohioensis* usually by its large size, nonprojecting lateral margins, and shorter hinge line.

Genus *Myalina* Koninck

Myalina wyomingensis (Lea)

(= *Myalina recurvirostris* Meek & Worthen)

Pl. 3, fig. 12; Pl. 4, fig. 1

1853. *Modiola wyomingensis.* Lea, Philadelphia Acad. Nat. Sci., Jour. (2), vol. 2, p. 205, pl. 20, fig. 1a.

1866. *Myalina recurvirostris.* Meek & Worthen, Illinois Geol. Surv., vol. 2, p. 344, pl. 26, figs. 9a-c.

1884. *M. recurvirostris.* Keyes, Missouri Geol. Surv., vol. 5, pl. 45, figs. 1a, b.

1886. *M. wyomingensis.* Claypole, Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 2 pt. 2, p. 247.

1894. *M. recurvirostris.* White, Indiana Geol. Surv., 13th Ann. Rept., p. 140, pl. 29, figs. 3, 4.

1898. *M. wyomingensis.* Weller, U. S. Geol. Surv., Bull. 153, p. 365.

1903. *M. wyomingensis.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 422, pl. 8, figs. 8-13.

1915. *M. cuneiformis* ?. Mather, Denison Univ., Sci. Lab., Bull. 18, p. 220, pl. 15, fig. 3.

1942. *M. wyomingensis.* Newell, Kansas Geol. Surv., vol. 10, pt. 2, p. 49, pl. 3, figs. 1-4, 7, 10; pl. 7, fig. 6.

The shell is of medium size, subtriangular to subquadrangular in outline. The average specimen is about 15 mm. long from the extremity of the anterior lobe to the posterior margin of the shell, which varies considerably. The corresponding height is about 19 mm. or more. The cardinal margin is straight and long. The beak is pointed, not quite terminal, slightly twisted; the twisted portion projects slightly beyond the cardinal margin. The umbonal ridge is high, meeting the cardinal line at an angle of about 65 degrees (angle α of Newell). The anterior umbonal slope is narrow and steep; the posterior one, broad and does not reach the border. The anterior margin of the shell is more or less parallel to the umbonal ridge and slightly sinuous; the posterior is broadly convex. The two meet ventrally with a subtriangular or semicircular outline. The surface is marked by fine lamellose striae which are more distinct on the posterior border and the postero-ventrally convex curvature which follows the outline of the shell; the convexity increases peripherally, so the younger shells have a greater length-height proportion than the adult ones.

The length of the hinge axis and its effects on the outline of the posterior of the shell vary greatly within the species. The type specimen of this species described by Lea was from the same horizon as the present material and most probably the same locality.

The young individuals have a much narrower and comparatively higher umbonal ridge which is more oblique. The angle between the anterior umbonal ridge and the hinge axis is only about 50 degrees instead of about 70 degrees for the adult form. These differences can also be correlated by tracing the outline of the juvenile parts on the mature shells.

Myalina meeki (Dunbar)

Pl. 3, fig. 12

1857. *Myalina perniformis.* Cox, Kentucky Geol. Surv., vol. 3, p. 569, pl. 8, fig. 8.

1903. *M. perniformis.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 426, pl. 8, fig. 8.

1922. *M. perniformis.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 217, pl. 11, figs. 7-9.

1922. *M. perniformis* var. Morningstar, *ibid.*, p. 218, pl. 11, figs. 5, 6.

1924. *M. meeki.* Dunbar, Am. J. Sci., vol. 7, p. 201, fig. 3.

1942. *M. meeki.* Newell, Kansas Geol. Surv., p. 60, pl. 14, figs. 7-14.

The shell is elongate and subquadrate in outline exclusive of the beak. It has a height to length ratio of 2:3 or greater. A representative one has dimensions of 16 mm. high and 37 mm. long. The hinge axis is straight and shorter than the length of the shell. The beak is high, terminal, directed slightly forward. The umbonal ridge is high, straight vertically, truncated anteriorly but merges into the posterior margin. The anterior margin is straight; the posterior, slightly convex, meeting the hinge axis at a right angle. The posterodorsal corner is sometimes rounded. The lateral margins of the shell body are almost parallel for most of the length till they meet the semicircular ventral border. The surface of the shell is contoured by a few wide-spaced lamellae shown only on posterior and ventral peripheral regions following the general outline of the shell.

Genus *Schizodus* King

Schizodus cuneatus Meek

Pl. 3, fig. 16

1858. *Schizodus cuneatus.* Meek, Ohio Geol. Surv., Ohio Pal., vol. 2, p. 336, pl. 20, fig. 7.
1886. *S. cuneatus.* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 456, fig. 9a; p. 442, fig. 9.
1886. *S. cuneatus.* Heilprin, Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 2, pt. 2, p. 275, fig. 9.
1903. *S. cuneatus.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 439, pl. 9, fig. 10.
1918. *S. cuneatus.* Price, West Virginia Geol. Surv., Rept., Randolph County, p. 797, pl. 44, figs. 4, 4a.
1920. *S. cuneatus.* Price, West Virginia Geol. Surv., Rept., Webster County, p. 604, pl. 35, fig. 5.

Two incomplete specimens in the collection have been referred to this species. The shells are of large size, with length more than 25 mm. and height 23 mm. The posterior umbonal ridge is sharply defined. The beak is anterior, depressed, and incurved. The posterior margin is obliquely truncated on the dorsal side. The surface of the shell is marked with numerous fine growth lines.

This species has been described by Heilprin from the same horizon and locality. The incompleteness of the specimens makes the identification rather doubtful. Fragments of external molds that might be comparable to this form are occasionally found. Some small young specimens of this species might have been included in *S. wheeleri* Swallow.

Schizodus wheeleri Swallow

Pl. 3, fig. 14

1858. *Schizodus obscurus.* Swallow, St. Louis Acad. Sci., Trans., vol. 1, p. 193.
1863. *Cypricardia* (?) *wheeleri.* Swallow, St. Louis Acad. Sci., Trans., vol. 2, p. 96.
1866. *Schizodus obscurus.* Geinitz. Carb. und Dyas in Nebraska, p. 20, pl. 1, figs. 30, 31.
1872. *S. wheeleri.* Meek, U. S. Geol. Surv., Nebraska, Final Rept., p. 209, pl. 10, pgs. la-d.
1876. *S. wheeleri* White, U S. Geol. Surv., Terr., Sec. Div.; Powell's Rept., p. 91.
1877. *S. wheeleri* White, U. S. Geol. Surv., W. 100th Merid., Rept., vol. 4, p. 154, pl. 11, figs. 6a, b.
1884. *S. wheeleri.* White, Indiana Geol. Surv., 13th Ann. Rept., p. 147, pl. 30, figs. 3-5.
1886. *S. wheeleri.* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 456, p. 442, fig. 7.
1886. *S. wheeleri.* Heilprin, Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 2, pt. 2, p. 275; p. 270, fig. 7; p. 274, fig. 7a.
1887. *S. wheeleri.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 42, pl. 3, fig. 15.
1895. *S. wheeleri.* Keyes, Missouri Geol. Surv., Rept. 5, p. 123, pl. 46, fig. 3c.
1896. *S. wheeleri.* Smith, Stanford Univ. Pub., Cont. Biol. 9, p. 36, pl. 22, fig. 4.
1897. *S. wheeleri.* Smith, American Philos. Soc., Proc., vol. 35, p. 155, pl. 22, fig. 4.
1900. *S. wheeleri.* Beede, Kansas Geol. Surv., Rept., vol. 6, p. 155, pl. 22, figs. 1-1c.
1909. *S. wheeleri.* Girty, U. S. Geol. Surv., Bull. 389, p. 83, pl. 10, fig. 6.
1918. *S. wheeleri.* Price, West Virginia Geol. Surv., Rept., Randolph County, p. 797, pl. 44, figs. 4, 4a.
1922. *S. wheeleri.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 225.

This species is fairly abundant in the Mill Creek limestone. Some are rather well-preserved. The size is usually small, one considered to be quite large has the dimensions of about 18 mm. long, 12 mm. high from the beak to the ventral margin, and about 4 mm. thick. The description of this species by Meek is:

> . . . Shell attaining a medium size, longitudinally subovate, moderately convex; anterior side wider than the other, and regularly rounded; posterior side narrowed, and obliquely truncated; basal outline rather prominently rounded anteriorly, and straightened, or slightly sinuous between the middle, and sharply rounded or subangular posterior basal extremity; dorsal margin straight, and sloping from the beaks to the truncated posterior edge; beaks rather depressed, incurved, and placed about halfway between the middle and the front, or perhaps nearer the middle; posterior umbonal slope rather prominent, or usually forming a rather obtuse ridge near the posterior basal extremity; surface with merely fine lines and obscure marks of growth.

The fine lines and growth marks are only to be seen under magnification. They are more prominent on the borders of the shell.

Schizodus curtus Meek & Worthen

Pl. 3, fig. 16

1858. *Schizodus rossicus.* Swallow, St. Louis Acad. Sci., Trans., vol. 1, p. 193.
1865. *S. curtus.* Meek & Worthen, Chicago Acad. Sci., Trans., vol. 1, p. 18.
1866. *S. rossicus.* Geinitz, Carb. und Dyas in Nebraska, p. 18, pl. 1.

1872. *S. curtus.* Meek, U. S. Geol. Surv., Nebraska, p. 208, pl. 10, figs. 13a-e.

1873. *S. curtus.* Meek & Worthen, Illinois Geol. Surv., vol. 3, p. 382, pl. 26, fig. 16.

1877. *S. curtus.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, pp. 42, 145, pl. 14, fig. 20.

1922. *S. curtus.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 274.

This species is the commonest form of the *Schizodus* group in the Mill Creek limestone. The fossils are more or less of uniform size, about 11 mm. long, 8.5 mm. high between the beak and the ventral margin, and 2 mm. thick. The small shell is suborbicular in outline, thin, and compressed. The hinge line is nearly straight, more or less sloping behind the beak, about two-thirds as long as the length of the shell across the middle. The beak is slightly anterior, depressed, pointed, directed forward, incurved, and raised beyond the cardinal margin. The umbo is low or nearly flat. It is distinctly marked off on both sides by ridges meeting dorsally at an angle of 85 degrees. The anterior umbonal ridge is less prominent, merging imperceptibly downward into the anteroventral border. The posterior ridge is sharp, and extends from the beak all the way to the posteroventral corner and is a little concave axially. The anterior margin is well-rounded and turns uniformly to meet the ventral border which is broad and semicircular. The posteroventral corner is more or less angular and usually faintly sinuous on both sides. The posterior margin is truncated, nearly vertical or slanting backward. The flank behind the umbonal ridge is a rather steep and slightly concave surface. The surface marking of the shell is seen only on a few specimens. It consists of extremely fine concentric lines of growth, more prominent on the flank behind the ridge, or occasionally a few heavier ones near the ventral margin.

This species is similar to and has been considered by some early workers as identical with *Schizodus rossicus* from Permian and Carboniferous rocks of Russia and North China (Chao, 1927). According to Meek, the American form is distinguishable from the Asiatic form in having a more prominent beak, a more deeply rounded anteroventral margin, and a more nearly vertical truncated posterior margin. But, as the "species" has a long geological range and variations have been observed even among the American material, probably the two merely represent geographical subspecies.

Genus *Allorisma* King

Allorisma terminale Hall

Pl. 3, figs. 17a-c

1852. *Allorisma terminalis.* Hall, Stansbury's Exped. to Great Salt Lake, p. 413, pl. 2, figs. 4a, b.

1858. *A. subcuneata.* Meek & Hayden, Philadelphia Acad. Nat. Sci., Proc., p. 263.

1860. *A. ensiformis.* Swallow, St. Louis Acad. Sci., Trans., vol. 1, p. 656.

1864. *A. subcuneata.* Meek & Hayden, Smithsonian Cont. Knowledge, vol. 14, no. 172, p. 37, pl. 1, figs. 10a, b.

1866. *A. subcuneata.* Geinitz, Carb. und Dyas in Nebraska, p. 14.

1872. *A. subcuneata.* Meek, U. S. Geol. Surv., Nebraska, p. 221, pl. 2, figs. 10a, b.

1875. *A. subcuneata.* White, U. S. Geol. Surv., W. of 100th Merid., Rept., vol. 4, p. 155, pl. 12, figs. 7a, b.

1881. *A. subcuneata* ?. White, Indiana Stat. and Geol. Dept., 2nd Ann. Rept., p. 518, pl. 8, figs. 1, 2.

1884. *A. subcuneata.* White, Indiana Geol. Surv., 13th Rept., p. 148, pl. 31, figs. 1-3.

1886. *A. subcuneata.* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 457, fig. 10a, p. 444, fig. 10.

1887. *A. subcuneata.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 34, pl. 4, figs. 1, 2.

1895. *A. subcuneatum.* Keyes, Missouri Geol. Surv., vol. 5, p. 129, pl. 47, figs. 5a-c.

1900. *A. subcuneatum.* Beede, Kansas Geol. Surv., Rept., vol. 6, p. 169, pl. 20, figs. 1-1b.

1903. *A. terminale.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 437, pl. 9, figs. 4-6.

1909. *A. terminale.* Girty, U. S. Geol. Surv., Bull. 389, p. 90.

1921. *A. terminale.* Price, West Virginia Geol. Surv., Rept., Nicholas County, p. 784.

1922. *A. terminale.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 234, pl. 18, fig. 15.

1924. *A. terminale.* Morgan, Oklahoma Geol. Surv., Bull. 2, pl. 46, figs. 3, 3a.

1931. *A. terminale.* Morse, Kentucky Geol. Surv., Paleontology of Kentucky, p. 318, pl. 41, fig. 2.

This is one of the commonest pelecypods in the Mill Creek limestone. The shell is of fairly large size. The majority of the specimens have an average length of about 40 mm. and are about 15 mm. high between the dorsal and ventral margins. The shell is equivalved, inequilateral, and greatly elongated. It is narrow at the anterior end and broader and gaping posteriorly. The umbo is flat.

The beaks are close together, anterior, depressed and slightly incurved. The cardinal margin is long and straight behind the beak but is short and slightly concave in front of it. The ligamental groove is a narrow lanceolate slit. The exterior is strongly marked by broad, round, concentric ridges which are separated by narrower furrows which are finely striated by more irregular growth lines. The ridges converge anteriorly upward toward the cardinal margin; they broaden posteriorly and become obsolete when they reach the umbonal ridge, which is low and indistinct and disappears before reaching the border. The external surface of the shells also bears minute spines which are usually microscopic in size and only seen as minute pits on the external molds of the shells. They are arranged roughly in radial lines from the umbo outward.

A comparative study of the large number of the specimens seems to indicate that there is a bimodal variation within the species. In one group the ribs on the surface are greater in number, more numerous and more or less sharp-crested. Those beyond the umbo are much fewer in number, round and widely separated. The spines are also more regularly arranged and the beak is less terminal. This group is morphologically closer to the European and Asiatic species *Allorisma regularis* King. For the other group, there are uniformly distributed and fewer, broad, round-topped ribs separated by narrow furrows. The posterior are broader in comparison with the anterior than of the other group.

Genus *Pleurophorus* King

Pleurophorus oblongus Meek

1866. *Pleurophorus pallasi.* Geinitz, Carb. und Dyas in Nebraska, p. 23, pl. 2, fig. 4.
1872. *P. oblongus.* Meek, U. S. Geol. Surv., Nebraska, p. 212, pl. 10, figs. 4a-c.
1894. *P. oblongus.* Keyes, Missouri Geol. Surv., vol. 5, p. 125.
1912. *P. oblongus.* Mark, Ohio Geol. Surv., Bull. 17, p. 310, pl. 15, fig. 12.
1922. *P. oblongus.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 138.

Meek's description of the species:

> . . . Shell, longitudinally oblong, about twice as long as high, moderately convex, particularly along the umbonal slopes from the beaks to the posterior basal margin, but without any defined angle or ridge there; cardinal margin nearly straight, and subparallel to the base, about equaling two-thirds the entire length of the valves; basal margin more or less distinctly sinuous near the middle, at the termination of a broad, oblique impression or convexity extending from the anterior side of the beaks under the umbonal slopes to the lower margin; anterior margin narrowly rounded below; posterior side much wider, rounded or sometimes obliquely subtruncated above; beaks convex, very oblique, obtuse, located one-seventh to one-eighth the length of the valves behind the anterior extremity; surface with apparently only fine concentric marks of growth; muscular impressions faintly marked; ridge behind the anterior one small; posterior lateral tooth slender and elongated.
> Length of largest specimen, 0.44 inch; height, 0.24 inch; convexity, about 0.14 inch.

The single specimen found in the present collection not only fits perfectly the description by Meek for his Nebraska form, but it is identical with his figures and has exactly the same measurements as given by him to his largest specimen.

Pleurophorus subcostatus Meek & Worthen

Pl. 4, fig. 2

1865. *Pleurophorus subcostatus.* Meek & Worthen, Philadelphia Acad. Nat. Sci., Proc., p. 246.
1866. *P. subcostatus.* Meek & Worthen, Illinois Geol. Surv., Rept., vol. 2, p. 347, pl. 27, figs. 2, 2a.
1887. *P. subcostatus* ?. Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 35, pl. 4, figs. 16, 16a.
1900. *P. subcostatus.* Beede, Kansas Geol. Surv., Rept., vol. 6, p. 161, pl. 20, figs. 11-11b.
1903. *P. subcostatus.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 444, pl. 9, figs. 11, 12.
1924. *P. subcostatus.* Morgan, Oklahoma Geol. Surv., Bull. 2, pl. 48, fig. 1.

The original description of this species by Meek and Worthen is:

> . . . Shell elongate-oblong, moderated convex; umbonal ridges the most convex part of the valves, and extending obliquely from the beaks toward the postero-basal margin; anterior ventral region somewhat compressed; basal and cardinal margins very nearly straight and subparallel, the former being usually somewhat sinuous or arcuate along the middle; extremities rather narrowly rounded, the posterior being generally a little wider than the other, and sometimes faintly subtruncate obliquely. Hinge line long and nearly straight; posterior lateral tooth of each valve elongated parallel to the hinge margin, very remote from the cardinal teeth, and extending back a little beyond the posterior muscular impression. Beaks depressed upon a line with the dorsal margin, small, somewhat compressed, and placed about one-ninth the entire length of the shell behind the anterior margin. . . . Surface of casts showing traces of a few obscure concentric markings, crossed on the postero-dorsal region by traces of about three equal obscure radiating costae. . . . Length of a medium-sized specimen (internal cast), 0.88 inch; height of same, 0.37 inch; convexity, 0.26 inch. Some larger specimens, of same proportions, measure 1.33 inches in length.

The Mill Creek limestone forms usually are smaller than the type. With the exception of two doubtful and poorly preserved valves, the largest one has a length of only 17 mm. long. The surface markings, which are obscure on Meek and Worthen's specimens, are distinctly shown on one of the specimens as fine concentric striae, more numerous and distinct on the posterior side of the shell and crossed on the posterior by three prominent radiating costae. This species seems quite common in the Mill Creek limestone, but the generally poor preservation of the specimens makes the exact identification quite uncertain.

Pelecypoda

Genus *Astartella* Hall

Astartella concentrica Conrad

Pl. 4, fig. 3

1842. *Nuculites concentricus.* Conrad, Philadelphia Acad. Nat. Sci., Jour., vol. 8, pt. 2, p. 248.
1915. *Astartella concentrica.* Girty, U. S. Geol. Surv., Bull. 544, p. 142, pl. 18, figs. 2-9.
1922. *A. concentrica.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 240, pl. 13, figs. 20, 21.
1924. *A. concentrica.* Morgan, Oklahoma Geol. Surv., Bull. 2, p. 46, fig. 5.
1927. *A. adenticulata.* Chao, Pal. Sinica, ser. B, vol. 9, p. 14, pl. 1, figs. 18-20.
1931. *A. concentrica.* Morse, Kentucky Geol. Surv., Paleontology of Kentucky, p. 319, pl. 42, fig. 3.

This is a small shell with subquadrilateral outline. The maximum width is near the dorsal margin. The convexity is moderate and greatest at the middle of the umbonal region which slopes down evenly toward the anterior and ventral borders, more gently posteriorly.

The anteroventral corner tends to be more angular, while the posterior is rounded. The cardinal extremities are rounded, and the posterior more so. The cardinal margin is nearly straight and divided by the beak which is depressed and pointed forward. The surface is marked by concentric ridges which are fine and closely spaced on and near the umbo but coarser and more widely separated by broad concave furrows toward the borders.

This shell is similar to *Astartella adenticulata* Jakowlew from the Donez-Basin of Russia and from north China. The single specimen in the present collection, except for its slightly smaller size, is more like the Chinese specimens in its outline and surface ornamentations than any illustrated American forms. The Russian and Chinese species is supposed to be differentiated from the American forms in its greater convexity and more concentric ridges. This is not conclusive, because both these characteristics vary among the specimens within the species.

GASTROPODA

Genus Pharkidonotus Girty

Pharkidonotus percarinatus (Conrad)

Pl. 4, figs. 5-6

1842. *Bellerophon percarinatus.* Conrad, Philadelphia Acad. Sci., Jour., 1st ser., vol. 8, p. 268, pl. 16, fig. 5.
1872. *B. percarinatus.* Meek, U. S. Geol. Surv., Nebraska, p. 227, pl. 11, fig. 14.
1884. *B. percarinatus.* White, Indiana Geol. Surv., 13th Ann. Rept., pt. 2, p. 158, pl. 33, figs. 12-14.
1886. *B. percarinatus.* Heilprin, Pennsylvania Geol. Surv., Ann. Rept. for 1885, p. 451.
1887. *B. percarinatus.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 17, pl. 2, fig. 14.
1895. *B. percarinatus.* Keyes, Missouri Geol. Surv., vol. 5, p. 153, pl. 50, figs. 2a, 2c, 2e.
1897. *B. percarinatus.* Ulrich, Minnesota Geol. Surv., Final Rept., vol. 3, pt. 2, p. 853.
1899. *B. percarinatus.* Girty, U. S. Geol. Surv., 19th Ann. Rept., pt. 3, p. 592.
1903. *B. percarinatus.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 470.
1915. *Pharkidonotus percarinatus.* Girty, U. S. Geol. Surv., Bull. 544, p. 165, pl. 19, figs. 4-9c.
1922. *P. percarinatus.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 248, pl. 15, fig. 6.
1924. *P. percarinatus.* Morgan, Oklahoma Geol. Surv., Bull. 2, p. 228, pl. 49, fig. 15.
1941. *P. percarinatus.* Knight, Paleoz. Gastropod Genotypes, Geol. Soc. Am., Sp. Paper 32, p. 241, pl. 12, figs. 4a-f.

This is undoubtedly the commonest gastropod in the Mill Creek limestone. The specimens are usually small and preserved as the internal molds with the base of the lips broken. The largest specimen has a maximum width between the lateral edges of the aperture of less than 20 mm. The shell is globose, greatly expanded toward the aperture, which is twice as broad as the unexpanded part of the shell. The last whorl is marked by transverse folds, each of which has a prominent nodosity on the midline. The entire series resembles a prominent ridge. The nodes increase in size toward the aperture and disappear gradually apically. On each side of the noduse ridges, there develops a shoulder-like area on the edge of which there may be another series of nodes which vary from inconspicuous to prominent, the extremity of the latter stage leads to that of the species *Pharkidonotus tricarinatus* with which the present species intergrades. The original description of this species by Conrad (1842, p. 268) is very brief and not clear:

> . . . Subglobose; back with a sharp, elevated, waved carina; sides with distant transverse acute ribs and intermediate minute striae; volutions concealed.

Most specimens in the present collection have the lateral ridges faintly developed or entirely absent. The intermediate, minute striae between the ribs are only seen on a few specimens near the apertures.

Pharkidonotus tricarinatus (Shumard)

1855. *Bellerophon percarinatus.* Norwood & Pratten, Philadelphia Acad. Sci., Jour., vol. 3, p. 74, pl. 9, figs. 4a-c.

1858. *B. tricarinatus.* Shumard, St. Louis Acad. Sci., Trans., vol. 1, p. 204.
1884. *B. percarinatus.* White, Indiana Geol. Surv., 13th Ann. Rept., p. 158, pl. 33, figs. 9-13.
1922. *Pharkidonotus percarinatus* var. *tricarinatus.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 248.

This species is distinguished from the one described above in having lateral rows of well developed, prominent nodes on the ribs as well as those on the median carina. The original description by Shumard is:

> . . . Shell rather large, elongated, expanding rather gradually from beak to front; aperture elongate, sub-pentagonal; dorsum marked with three carinae, which are rather strong towards the front and become obsolete posteriorly; central one most prominent, rounded; lateral ones broad and sub-angular; sides descending obliquely from the carinae to the base, flattened or slightly concave before and rounded posteriorly.

As mentioned above, this characteristic ornamentation varies greatly from the type. That which may appear typical of one species may intergrade with the other. White did not differentiate those in his collection, but four of the six figures that he put under *Pharkidonotus percarinatus* apparently have the lateral nodes well developed and belong to this species. In the Mill Creek limestone only a few specimens have the lateral nodes developed, and they are usually not prominent.

Genus *Euphemites* Warthin
(= *Euphemus* McCoy)
Euphemites nodocarinatus (Hall)
Pl. 4, figs. 4a-c

1858. *Bellerophon nodocarinatus.* Hall, Iowa Geol. Surv., vol. 2, p. 723, pl. 29, figs. 15a-c.
1884. *B. nodocarinatus.* White, Indiana Geol. Surv., 13th Ann. Rept., p. 159, pl. 33, figs. 3-5.
1886. *B. nodocarinatus?* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 457, p. 446, fig. 7a.
1886. *B. nodocarinatus?* Heilprin, Wyoming Hist. and Geol. Soc., vol. 2, pt. 2, p. 277, fig. 13.
1887. *B. nodocarinatus.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 18, pl. 3, fig. 3.
1895. *B. nodocarinatus.* Keyes, Missouri Geol. Surv., vol. 5, p. 152, pl. 50, figs. 4a-c.
1897. *Euphemus nodocarinatus.* Ulrich, Minnesota Geol. Surv., Final Rept., vol. 3, pt. 2, p. 855.
1899. *E. nodocarinatus.* Girty, U. S. Geol. Surv., 19th Ann. Rept., pt. 3, p. 592.
1903. *E. nodocarinatus.* Girty, U. S. Geol. Surv., Prof. Paper 16, p. 475.
1922. *E. nodocarinatus.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 249, pl. 15, figs. 1-3.
1924. *E. nodocarinatus.* Morgan, Oklahoma Geol. Surv., Bull. 2, p. 228, pl. 49, fig. 8

The shell is large, heavy, subglobose, only slightly expanded toward the aperture. The umbilicus is closed. It has a broad subnodose median carina and a shallow furrow along its middle, and on each side of the median carina is a broad shallow depression. On the interior only a band or shallow depression of medium width is seen in the middle. The ventral side of the outer volution is marked with distinct longitudinal lines of moderate strength, uniformly spaced and parallel. The entire surface is densely covered with fine nodules which are also present on the sides of the whorl. The outer lip is thin. There is no callus on the inner lip. The sides of the aperture are thick and have rounded edges near the umbilicus and are crenulated. The shell attains large size. One large specimen has the sides of the aperture extending to a width of as much as 40 mm. The last whorl is more than 22 mm. wide on the apical end and 36 mm. near the aperture. The corresponding width for the inner whorl is only slightly over 10 mm. There are eight longitudinal lines on the inner surface of the last whorl in a transverse distance of 5 mm.

This species was recorded from the same locality and horizon by Heilprin. His figure illustrated in the Pennsylvania Geological Survey Annual Report for 1885 for the species *Schizodus wheeleri* was referred to this species, while his figure for the present species looks more like one of a *Pharkidonotus percarinatus,* both by its features and size. In a footnote he corrected the first error assigning it to *Bellerophon,* but made no note of the second mistake.

CEPHALOPODA

Genus *Mooreoceras* Miller, Dunbar & Condra
Mooreoceras normale Miller, Dunbar & Condra
Pl. 4, figs. 7a-b

1858. *Orthoceras occidentale.* Swallow, St. Louis Acad. Sci., vol. 1, p. 201.
1892. *O. colletti.* Miller, Indiana Geol. Surv., 18th Ann. Rept., p. 67, pl. 10, fig. 1.
1894. *O. occidentale.* Keyes, Missouri Geol. Surv., vol. 5, p. 226.
1930. *O. occidentale.* Sayre, Kansas Geol. Surv., Bull. 17, p. 152, pl. 19, figs. 1-2a.
1931. *O. colletti.* Morse, Kentucky Geol. Surv., vol. 36, p. 325, pl. 54, figs. 1, 2.
1933. *Mooreoceras normale.* Miller, Dunbar & Condra, Nebraska Geol. Surv., Bull. 9, p. 87, pl. 21, figs. 5-7.

This is the only orthoceroid shell in the collection. It is represented by the incomplete filling of four camerae of an adoral phragmacone. The conch is straight, conical, slightly flattened laterally, tapering regularly and very gradually, and expanding adorally. The average diameter of the known chambers is about 15 mm., and 16 mm. in the flattened direction. The average length for the four known chambers is 12 mm., e.g., about one-fifth of the diameter of the camera. The septum is gently convex, less than the height of the chamber. The septal neck is very short, more so ventrally. The siphuncle is located midway between the center and the well. It is very small, circular in cross section and has a diameter of only about one millimeter. The sutures are simple, not quite uniformly spaced, transversely straight except on the siphuncular side of the wall where they curve slightly upward adaperturally as a very broad saddle. No surface markings are seen except doubtful indication of few fine annulation-like impressions.

The specimen belongs undoubtedly to this species, in which, according to Miller, Dunbar and Condra, the adult conch may attain a maximum diameter of as much as 35 mm. The present specimen, less than one-half as long, is probably a young shell. These authors did not mention the relationship between this species and *Orthoceras occidentale* of Swallow whose original decription fits perfectly the present specimen. But as the type specimen described by Swallow is even more incomplete than that here described and was not illustrated, exact comparison is uncertain. It is rather doubtful whether the two names are synonymous. Sayre's specimen with its more eccentric siphuncle and lacking of surface marking is quite uncertain in its identity. Morse's description and illustration of the specimen are incomplete. The greater convexity of the septa, the shorter camerae, and large shell are closer to the description by Miller, which is probably different from the present species.

Genus *Metacoceras* Hyatt

Metacoceras sangamonense (Meek & Worthen)

1860. *Nautilus (Discus) sangamonensis.* Meek & Worthen, Philadelphia Acad. Nat. Sci., Proc., p. 470.

1866. *N. sangamonensis.* Meek & Worthen, Illinois Geol. Surv., vol. 2, p. 386, pl. 29, figs. 3-3b.

1883. *Metacoceras (Discus) sangamonense.* Hyatt, Boston Soc. Nat. Hist., Proc., vol. 22, p. 269.

1891. *Pleuronautilus sangamonensis.* Ford, Cat. fossil Ceph. in British Museum, pt. 2, p. 138.

1894. *Metacoceras sangamonensis.* Keyes, Missouri Geol. Surv., vol. 5, p. 225.

1898. *M. sangamonensis.* Weller, U. S. Geol. Surv., Bull. 153, p. 351.

1910. *M. sangamonense.* Raymond, Carnegie Museum Ann., vol. 7, p. 156.

1912. *M. sangamonense.* Mark, Ohio Geol. Surv., Bull. 17, p. 299.

1915. *M. sangamonense.* Girty, U. S. Geol. Surv., Bull. 544, p. 240.

1918. *M. sangamonense.* Price, West Virginia Geol. Surv., Rept., Barbour County, p. 801, pl. 44, fig. 6.

1933. *M. sangamonense.* Miller, Dunbar & Condra, Nebraska Geol. Surv., Bull. 9, p. 170, pl. 15, figs. 8, 9.

More than a half dozen specimens in the collection are referred to this species. The large tarphyceraconic shells are only imperfectly represented by internal fillings and external molds of less than half of the original two volutions. The conch has an hexagonal cross section. The measurements of the cast between the lateral walls of the last few camerae of the phragmaconch may be as wide as 30 mm., the corresponding width in the direction perpendicular to the former is about 25 mm. The inferred maximum and minimum diameters of the complete outer volution in the perpendicular dorsoventral direction are 65 mm. and 45 mm. respectively. The conch is flattened laterally, dorsally, ventrally and dorsolaterally. The ventrolateral edges are marked by prominent, large, bluntly rounded nodes which if on a complete conch would be more than twenty in number on each side. The septa are numerous, and, therefore, the camerae are many. On a fragment of a well-preserved specimen, there are three of them within a longitudinal distance of 10 mm. The sutures on the dorsal, ventral and lateral sides have a broad lobe separated from each other by a narrower subarcuate saddle. The siphuncle is ventrally subcentral. The septal neck is small and short.

The structures of the conchs are typical of the species, so that identification is quite certain. The only deviation from the norm is that the shell seems to have greater average size.

TRILOBITA

Genus *Ameura* Weller

Ameura sangamonensis (Meek & Worthen)

Pl. 4, figs. 8a-d

1858. *Phillipsia missouriensis.* Shumard, St. Louis Acad. Sci., Trans., vol. 1, p. 225.

1865. *P. sangamonensis.* Meek & Worthen, Philadelphia Acad. Nat. Sci., Proc., p. 225.

1873. *P. (Griffithides?) sangamonensis.* Meek & Worthen, Illinois Geol. Surv., vol. 5, p. 615, pl. 32, fig. 4.

1883. *P. (Griffithides?) sangamonensis.* White, Indiana Geol. Surv., Ann. Rept. 13, pt. 2, p. 174, pl. 39, figs. 4, 5.

1886. *P. sangamonensis.* Heilprin, Pennsylvania 2nd Geol. Surv., Ann. Rept. for 1885, p. 458, fig. 14a; p. 466, fig. 14.

1886. *P. sangamonensis.* Heilprin, Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 2, pt. 2, p. 247, fig. 14; p. 277, fig. 14a.

1887. *P. sangamonensis.* Herrick, Denison Univ., Sci. Lab., Bull., vol. 2, p. 61, pl. 5, fig. 13.
1915. *P. sangamonensis.* Girty, U. S. Geol. Surv., Bull. 544, p. 265, pl. 18, figs. 10-13a.
1922. *P. sangamonensis.* Morningstar, Ohio Geol. Surv., Bull. 25, p. 272.
1924. *P. sangamonensis.* Morgan, Oklahoma Geol. Surv., Bull. 2, pl. 43, fig. 11.
1936. *Ameura sangamonensis.* Weller, Jour. Paleon., vol. 10, no. 8, p. 713.

This species is represented in the collection by part of a cranidium, two pieces of free cheek and several pygidia and their external molds. The glabella is rounded, elevated, and defined in front by a narrow brim. The shape is subrectangular in outline, about 3.9 mm. long and 2 mm. wide in the front, expanding gradually and reaching its maximum width between the eyes. The basal lobe is large and separated in front by the deep third glabellar furrow which curves backward and divides the posterior margin of the glabella into three more or less equal parts. There are two less prominent lobes in front of the basal one. The first glabellar furrow that separates the frontal lobe is very shallow and obscure. The occipital segment is only half as wide as the posterior margin of the glabella and is constricted and separated from the latter by the deep occipital furrow. The large eyes have broken off but are indicated by the large broken surface which is lunate and separated in front from the frontal glabellar lobe by triangular depressions. The two detached free cheeks are triangular in shape produced posteriorly into rather long genal spines which are partly broken off on both specimens. The apaxial margin of the ocular platform, which bounds the eyes, has semicircular outline, is slightly elevated and slopes down laterally toward the more or less elevated rounded marginal border from which it is separated by the deep marginal furrow.

The largest pygidium is about 11.6 mm. wide anteriorly and half ellipsoidal, bluntly rounded posteriorly. The axial lobe is narrow and highly elevated. It has a nearly flat top which curves laterally and steeply on each side to the axial furrows which are only moderately defined. The pleural lobes are broader than the axial and also rather highly elevated above the relatively wide and flat border which is broadest at the posterior end. There are at least 18 segments on the axial lobe. They are nearly parallel and straight and become obsolete laterally near the furrows. There are 12 oblique segments on each lateral lobe, slanting posterolaterally. The last axial segment extends slightly beyond the posterior margin of the lateral lobes.

A fragment of an external mold of an unusually large pygidium in the collection is more than 16 mm. wide. The border is both flat and broad. The axis is low and its segments have become obsolete. It is quite doubtful that it should be included here.

Although this species is the only one found in the collection, and the material is fragmental, it is fairly abundant and rather well-preserved in comparison with most of the Carboniferous trilobites. It seems quite possible that some new and interesting finds may be made by more extensive search.