

BRACHIOPODS OF THE TRAVERSE  
GROUP (DEVONIAN)  
OF MICHIGAN

PART 1. DALMANELLACEA, PENTAMERACEA,  
STROPHOMENACEA, ORTHOTETACEA,  
CHONETACEA, AND PRODUCTACEA

JOHN IMBRIE

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## *PART 1. DALMANELLACEA, PENTAMERACEA, STROPHOMENACEA, ORTHOTETACEA, CHONETACEA, AND PRODUCTACEA*

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## INTRODUCTION

### ABSTRACT

THE TRAVERSE GROUP, of middle and late Devonian age, comprises about 600 feet of limestone, argillaceous limestone, and calcareous shale along its belt of outcrop in the northern part of the southern peninsula of Michigan.

The abundance and exquisite preservation of the invertebrate fauna make these beds one of the finest collecting grounds for Devonian fossils in North America, and many studies on the corals, mollusks, ostracods, and Bryozoa have been published. The present report begins the systematic study of Traverse brachiopods by an analysis of the superfamilies Dalmanellacea, Pentameracea, Strophomenacea, Orthotetacea, Chonetacea, and Productacea. Twenty-three genera, 98 species, and 11 subspecies are recognized. Fifty-four of the species are new. Five new genera (*Sphenophragmus*, *Orthopleura*, *Oligorhachis*, *Helaspis*, and *Truncalosia*) are proposed. Bivariate statistical techniques are employed as a means of characterizing the growth patterns of 70 species and subspecies.

Unusually abundant and stratigraphically complete collections of several genera from the lower four formations of the Traverse group in the Thunder Bay region involve continuous variation between extreme morphologic types. This is inter-

Along its belt of outcrop in the northern part of the southern peninsula of Michigan, the Traverse group comprises about 600 feet of limestone, argillaceous limestone, and calcareous shale of middle and late Devonian age. The abundance of the contained fauna and the high quality of its preservation make this one of the finest regions for studying Devonian fossils in North America.

Since the pioneer work of C. C. Douglass in 1841, many geologists have contributed to our knowledge of Traverse rocks and fossils. G. M. Ehlers and E. R. Stumm, in a series of papers published as Contributions from the Museum of Paleontology of the University of Michigan, are making known the coral fauna; the Bryozoa have been treated by

preted as a record of endemic evolution rather than migration. Theoretical difficulties in the compartmentation of a biologic continuum, ordinarily not encountered because of the incomplete nature of the paleontologic record, are here met in fact.

Significant differences are noted in the number of species of the genus *Strophodonta* found in different formations, with a maximum of taxonomic diversity and a minimum of morphologic variation characterizing collections from the Alpena limestone. This relationship is interpreted in terms of adaptive radiation into a diversity of habitats associated with Alpena reefs.

Ranges of species in the sections exposed on the shores of Little Traverse Bay and Thunder Bay are established. Faunal evidence documents the correlation of the Gravel Point formation with the Alpena limestone and part of the Four Mile Dam formation and the correlation of the middle Petoskey formation with the Potter Farm formation. Although the proportion of cosmopolitan species is small, identification of Traverse forms in collections from Illinois, Ohio, Indiana, Ontario, Missouri, and New York contributes to the regional correlation of Traverse strata.

Deiss (1932), Duncan (1939), and McNair (1937); the ostracods by Warthin (1934); and the mollusks by Foerste (1927) and La Rocque (1949).

The object of the present work is to begin the systematic study of Traverse brachiopods. Six superfamilies have been treated—the Dalmanellacea, Pentameracea, Strophomenacea, Orthotetacea, Chonetacea, and Productacea. Although it has been necessary to erect five new genera, attention has been focused principally on the delimitation and characterization of species and subspecies. The abundance and exquisite preservation of Traverse brachiopods make them ideally suited for taxonomic inquiries at these lower taxonomic levels.

### TECHNIQUES OF STUDY

The taxonomic investigations recorded in this paper have been carried out in three distinct phases. The first phase entailed field collecting and familiarization with Traverse

stratigraphy as exposed between Thunder and Little Traverse bays. The second or taxonomic phase, carried on largely at the United States National Museum in Washing-

ton, D. C., involved laboratory examination of Traverse collections. In this part of the work the writer has had the opportunity of studying collections representing the combined efforts of many paleontologists. The largest single collection, that in the United States National Museum, contains collections made by the University of Michigan and the Michigan Geological Survey, as well as the United States National Museum. In addition, the collections at Yale Peabody Museum, made by P. E. Cloud and T. Yang, and those made by the writer during the summer of 1949, were studied. It is important to note that the taxonomic arrangement of Traverse brachiopods proposed in this paper is entirely the result of this qualitative laboratory examination and that biometric techniques were *not* employed in the delimiting of species and subspecies.

The final phase of this study was the statistical characterization of groups of fossils judged to represent distinct species or subspecies. A simple bivariate system of statistical analysis was chosen as most suitable for the quantity and quality of materials at hand. The essence of this system, set forth in another paper (Imbrie, 1956), is the documentation of patterns of relative growth by means of paired measurements. The use of such a bivariate system has the great advantage that samples are characterized by growth trend rather than by statistics directly or indirectly related to size. Hence biased size distributions, which are the rule rather than the exception in paleontological work, do not affect the taxonomic usefulness of the statistical data. This fact is particularly important when one is dealing with brachiopods, where the objective identification of corresponding growth stages in two or more shells is notoriously difficult.

In order to provide an adequate statistical characterization of the numerous and abundantly represented Traverse species described in this report, it was necessary to select pairs of numerical characteristics that could be determined rapidly and with reasonable precision. For many of the species with costellate or costate ornamentation, some statistical measure of rib size or rib count would have been desirable, but such documentation would have been too tedious. This loss is not

so serious as it might seem, however, for the eye can detect quite readily subtle differences in ornamentation between two specimens. Moreover, with a few notable exceptions such as *Strophondonta erratica* and *S. proteus*, ornamentation characteristics prove to have rather a small variation range. Hence it is usually a simple matter to judge these subtle but consistent differences by eye and, what is equally important, to record these population characteristics adequately by means of a single photograph. In the matter of gross shape, however, the Michigan brachiopods treated in this paper usually display much greater infrapopulation variation. For this reason, and because gross shape may be conveniently approximated by the taking of linear dimensions, the statistical methods employed in this study are based on three measurements, as follows:

*W*, maximum width.

*L*, maximum length parallel to the plane of the commissure.

*T*, maximum thickness perpendicular to the plane of the commissure; in concavo-convex shells this is defined as the maximum distance from the plane of the commissure to the exterior of the pedicle valve.

In table 1 samples of 70 populations of Traverse brachiopods are characterized by statistics that describe the average trend of relative growth for these dimensions taken in pairs, *W-L* and *W-T*. The following statistics are given for each of these pairs: the number of pairs of observations, the standard deviation of each dimension in the pair, the arithmetic mean value of each dimension, the correlation coefficient, the coefficient of relative dispersion around the reduced major axis, and the observed range of width measurements.

With the above statistics at hand an investigator may perform the following operations (see Imbrie, 1956):

1. Plot a line on graph paper representing the average trend of relative growth for the two pairs of measurements.
2. Test for statistical significance observed differences in growth pattern between any pair of samples characterized in this way.
3. Judge the degree of morphological overlap among groups of samples treated in this



way. One may do this by simply noting values of  $D_d$ , a statistic that measures the degree of dispersion of values around the average growth trend, or by constructing a polygonal figure to represent for each sample an objective estimate of the amount of dispersion in the sampled population (see Colbert and Imbrie, 1956).

4. Employ the calculated value of  $D_d$  as an objective measure of relative shape variability.

Each collection characterized in this study is a homogeneous biostratigraphic sample, i.e., a group of shells from a single locality and zone which, upon critical laboratory examination, is judged to represent a local interbreeding population. Where available specimens numbered more than 50, a random sample of 50 was selected from the collections at hand. Empirical tests of Traverse materials have shown that the additional accuracy achieved by a consideration of samples larger than about 50 is small in compari-

son with the additional effort expended. Throughout the statistical part of this study the aim has been to employ a biometrical technique that could be carried out within a reasonable length of time and that would at the same time provide a useful and objective quantitative characterization of Traverse species and subspecies.

Although biometrical methods can be a useful adjunct to taxonomic work, it must be kept in mind that statistics characterize a sample, they do not describe it; they emphasize group characteristics, but they do not judge the biologic or stratigraphic significance of the features so emphasized; and, although they permit an investigator to place the essential features of a large group of samples on a single sheet of paper, they do not in themselves constitute a synthesis. Like the hand lens, the microscope, the geology hammer, and the camera, statistics are neither more nor less than instruments of an inquiring mind.

#### ACKNOWLEDGMENTS

Grateful acknowledgment is here made to Dr. G. A. Cooper of the United States National Museum, who made available the fine collections under his charge and, through stimulating criticism, gave the writer the benefit of his profound knowledge of brachiopods. Thanks are due to Prof. C. O. Dunbar, under whose guidance the dissertation was written. Dr. Helen M. Muir-Wood made suggestions and criticisms regarding the Productacea. Mr. Percy A. Morris of Yale Peabody Museum aided in many ways the preparation of the plates. Special mention

should be made of papers by Ehlers and Kline (1934) and Stumm (1951), which are invaluable aids to taxonomic work on Michigan fossils. I am indebted, finally, to my wife for constant encouragement and for assistance in the field and in preparation of the manuscript.

The major portion of this paper was presented as a dissertation for the degree of Doctor of Philosophy in Yale University.

The abbreviation U.S.N.M. indicates a catalogue number of the United States National Museum, Washington, D. C.

## STRATIGRAPHY

TRAVERSE ROCKS HAVE BEEN studied for more than a century. Following the pioneer work of Douglass (1841), many workers have added to our knowledge, notably A. Winchell (1866), C. Rominger (1877), A. C. Lane (1892), A. W. Grabau (1902), and W. A. Ver Wiebe (1927). Pohl (1930) summarized the knowledge of Traverse beds in the type area around Little Traverse Bay. Warthin and Cooper (1943) restudied the important Thunder Bay region along the eastern extremity of the outcrop. Kelly and Smith (1947), basing their work on that of Warthin and Cooper to the east, mapped the Afton-Onaway area of Cheboygan County. Cohee (1947), in a summary of the subsurface stratigraphy of the Traverse group of Michigan, extended the surface units throughout the Michigan basin. In the present work the concept of Traverse stratigraphy summarized and emended by Warthin, Cooper, Kelly, Smith, and Pohl is employed, and the discussion below is a summary statement of their views, supplemented by the writer's observations in the field.

The Traverse group comprises some 600 feet of limestone, argillaceous limestone, and calcareous shale. The lower boundary of the group is taken as the base of the Bell shale which rests disconformably on the eroded surface of the Rogers City limestone, or, where that is absent, on the Dundee limestone. The Rogers City and Dundee formations are considered to be the approximate equivalent of the Marcellus formation of New York. Its upper limit is the base of the early late Devonian Antrim black shale. The lithology of the Antrim contrasts sharply with the underlying Squaw Bay and Thunder Bay limestones.

The outcrop area of the Traverse group (fig. 1) occupies the northern portion of the Michigan basin. The structure is simple, the beds dipping gently towards the center of the basin about 40 feet per mile. The best exposures occur to the east in the Thunder Bay area along the shores of Lake Huron, and to the west along the shores of Little Traverse Bay. Glacial deposits cover the bedrock in most of the intervening area, so that in the central portion of the outcrop area exposures

are sparse and isolated. A major problem in Traverse stratigraphy, then, is the correlation of beds exposed in the shore areas. Conclusions from the present study on this problem are summarized below in the section on stratigraphic paleontology.

Although the type area of the group is along the shores of Little Traverse Bay, the composite section worked out by Warthin and Cooper in the Thunder Bay area has become the standard of comparison for Michigan. Figure 2 summarizes the section in this area. In ascending order the formations are: Bell shale, Rockport Quarry limestone, Ferron Point formation, Genshaw formation, Newton Creek limestone, Alpena limestone, Four Mile Dam formation, Norway Point formation, Potter Farm formation, Thunder Bay limestone, and Squaw Bay limestone.

The Bell shale comprises about 80 feet of soft, calcareous shale with local lenses of limestone. In outcrop it weathers quickly to a sticky blue mud. The overlying Rockport Quarry limestone includes gray, sublithographic limestone; brown, bituminous limestone; and thin beds of brown and black shale. The Ferron Point formation is composed of gray, calcareous shale, with some thin beds of argillaceous limestone. The Genshaw formation comprises mostly argillaceous and crystalline limestone, gray and brown in color, with many intercalated thin beds of gray, calcareous shale. Near the top of the formation, 23 feet of gray to black limestone and black shale have been separated as the Killians member. The overlying Newton Creek limestone contrasts sharply with the Genshaw formation, being a dark brown petroliferous limestone. Subsurface data indicate that this formation occurs only locally. The Alpena limestone is composed mostly of white or light gray limestone, with a few thin beds of black or gray shale. Here occur the famous biohermal masses composed largely of the remains of *Hexagonaria*, stromatoporoïds, and *Favosites*. Many of these attain a diameter of 150 feet. The overlying Four Mile Dam formation, at its type locality, comprises light gray, brecciated, biohermal limestone, with the interspaces filled with bluish green clay. The Dock Street clay,

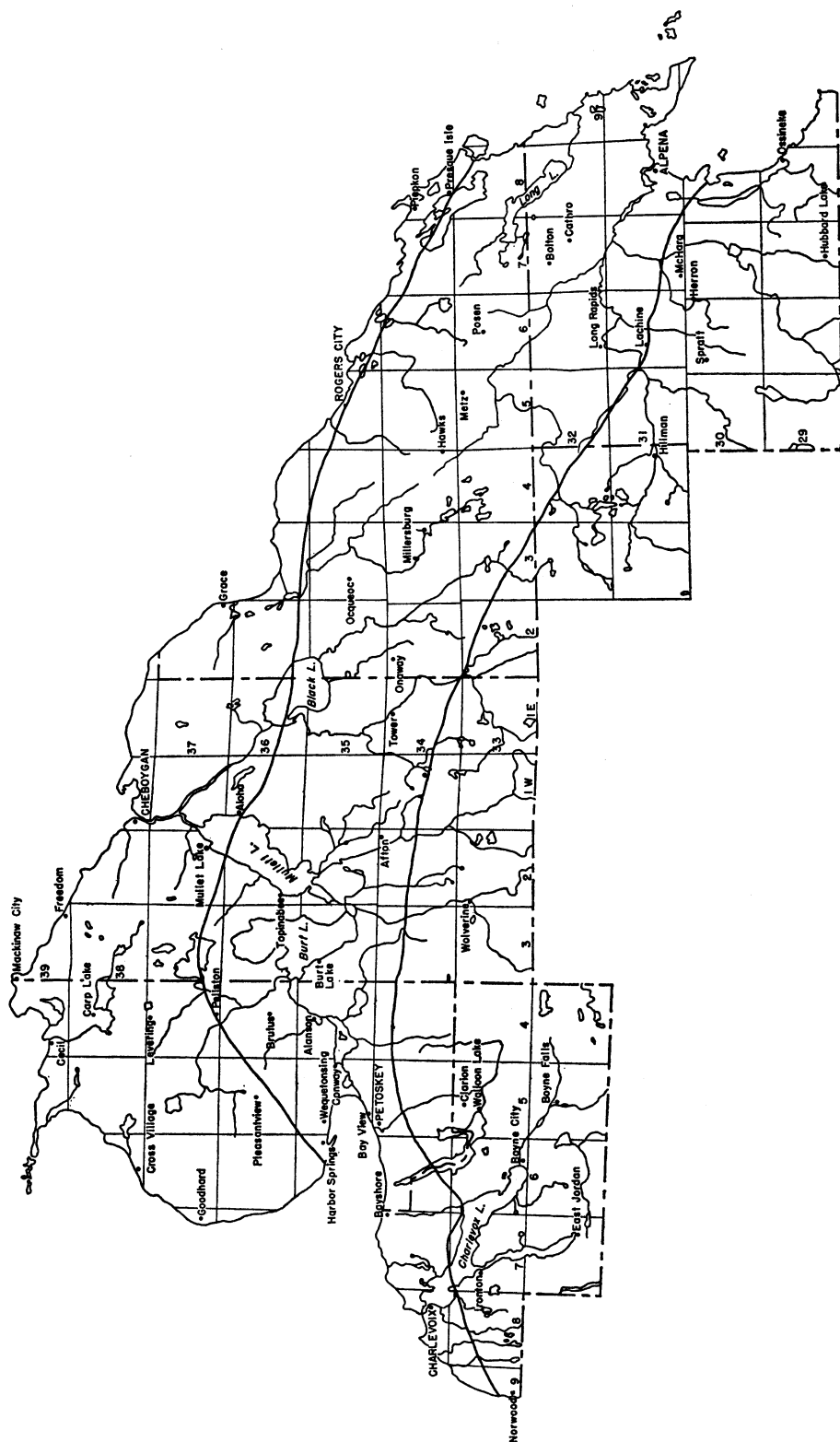


FIG. 1. Map showing the outcrop of the Traverse group in the northern part of the southern peninsula of Michigan. Heavy lines bound the area of Traverse outcrop. After Cohee, 1947.



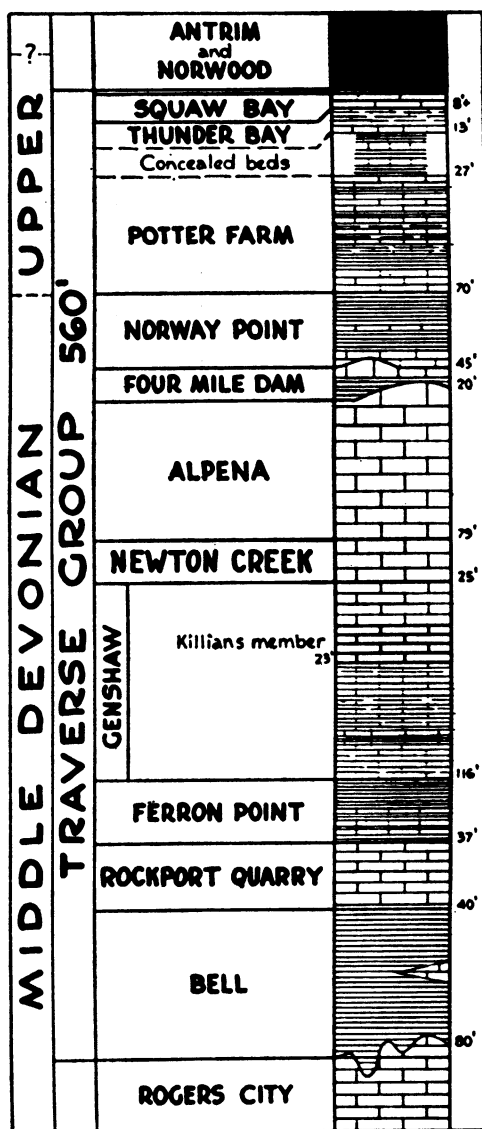


FIG. 2. Columnar section of Traverse rocks in the Thunder Bay region. After Warthin and Cooper, 1943.

which occurs locally in the Alpena region, is considered to be a member of the Four Mile Dam formation. The Norway Point formation is made up of alternate thin beds of gray, crystalline limestone and calcareous gray shale. The Potter Farm formation consists mostly of argillaceous and sublithographic limestone, with some thin beds of gray shale. The Thunder Bay limestone is composed of argillaceous limestone and gray,

calcareous shale. The Squaw Bay limestone comprises brown, crystalline, irregularly dolomitic limestone.

Subsurface studies have shown that the Traverse group varies considerably in thickness over the state of Michigan. In the eastern part of its outcrop, near Thunder Bay, it totals about 600 feet, but westward to Little Traverse Bay it thickens gradually to about 700 feet. Accompanying this change in thickness are lithologic changes. The entire section, with the exception of the Bell shale at the base, becomes more calcareous from east to west; the argillaceous limestones become purer and the shales more calcareous, so that the sequence exposed at Little Traverse Bay is largely pure limestone. Three named units comprise the rocks exposed in this area: in ascending order they are the Gravel Point formation, the Charlevoix formation, and the Petoskey formation. Biostratigraphic and subsurface stratigraphic data combine to indicate that these formations are the equivalent of only the upper part of the section exposed along Thunder Bay, the Gravel Point formation being the approximate equivalent of the Alpena limestone.

The Afton-Onaway area of Cheboygan County, in the central part of the peninsula, was studied and mapped by Kelly and Smith (1947). These workers extended Cooper and Warthin's formations into this area, but facies changes necessitated the introduction of three new units: the Koehler limestone, the Gorbut member of the Gravel Point formation, and the Beebe School formation. The Koehler limestone includes the sublithographic limestones overlying the Kilians member of the Genshaw formation and underlying the Gravel Point. Near the middle of the Gravel Point formation, a unit of black limestone and black shale 10 feet thick was named the Gorbut member of the Gravel Point formation. The limestone and shale beds overlying the Gravel Point and underlying the Antrim shale were recognized as the Beebe School formation.

The maximum thickness of the Traverse is to the south in the Saginaw Bay area, where it attains a total of 875 feet. From this maximum the group thins rapidly southward until, along the southern boundary of the state, it totals only about 100 feet. From

Saginaw Bay it thins gradually westward to about 400 feet along the Lake Michigan shore; northward it thins to about 600 feet in the outcrop area. In spite of the change in thickness from north to south, the surface

units of the standard section (except the Newton Creek) can be recognized southward to within 25 miles of the southern boundary of the state, where the section is thin and many of the units lose their identities.

## STRATIGRAPHIC PALEONTOLOGY

### GEOGRAPHIC DISTRIBUTION

OF THE 98 SPECIES AND SUBSPECIES treated in this work, about two-thirds have a rather restricted geographic range. Only 17 can be identified with certainty outside Michigan. In part this limitation of range is undoubtedly due to lack of detailed knowledge of equivalent beds in the surrounding areas, but the discrepancy is almost certainly too great to be accounted for by that factor alone. The occurrence of *Sieberella romingeri* is a case in point. This large, distinctive, sturdy shell (see pl. 50) is abundant throughout the outcrop of the Genshaw formation in Alpena, Presque Isle, and Cheboygan counties. It is so prominent and easy to identify that field work in surrounding areas would certainly have revealed its presence, if it did, in fact, range outside Michigan.

Differences in lithofacies between Traverse beds and equivalent strata may be called upon to explain part of the localization of the fauna, but even this explanation is inadequate. Many of the species, it is true, are restricted to one lithology: *Pentamerella alpenensis* to gray, calcareous shale; *Helaspis luma crista* to the dark gray and black shale of the Kilians member of the Genshaw formation; and *Hercostrophia alpenensis* to gray calcareous shale. Others, however, are not restricted to one lithology: *Sphenophragmus nanus* occurs both in the limestone beds of the Beebe School formation and in the soft calcareous shales of the Norway Point; *Pentamerella pericosta* occurs both in the pure, bioclastic limestones of the Four Mile Dam formation and in the soft calcareous gray shales of the overlying Norway Point formation; and *Strophodonta titan* is found in both the solid limestones and the soft shales of the Alpena limestone. The danger of taxonomic generalizations on the control of faunas by lithologic facies is evident.

There is positive as well as negative evidence that Traverse deposition was accompanied by the development of many endemic species, which is best illustrated by collections of *Strophodonta extenuata* from the lower four formations of the Traverse group exposed in the Thunder Bay area. Successive

populations referred to this species, although morphologically shifting in various directions, represent a continuously evolving biologic unit. Moreover, the only non-Traverse occurrence of the species is in the Arkona shale of southwest Ontario. It follows that the brachiopod faunas represented in these beds record evolution *in situ* rather than repeated migration.

### STRATIGRAPHIC DISTRIBUTION

Stratigraphic ranges of Traverse brachiopods treated in this study that are not restricted to a single area are summarized in figure 3. This chart documents the following faunal relationships between Michigan and non-Michigan sections:

1. *Chonetes mediolatus* is known only from the St. Laurent limestone of Missouri and the Bell, Rockport Quarry, and Ferron Point formations of Michigan.

2. *Strophodonta pentagonia* is known only from the Rapid limestone of Illinois and from the middle Petoskey formation of Michigan.

3. *Strophodonta proteus* is known only from the lower Centerfield formation of New York and the Alpena formation of Michigan.

4. *Sphenophragmus nanus* is known only from the Wanakah formation of New York and the Norway Point formation of Michigan.

5. *Rhipidomella trigona* is known only from the Enfield formation of the upper Devonian of New York and the uppermost Petoskey formation of Michigan. This occurrence would imply a younger age for the uppermost Petoskey formation than heretofore considered, namely, an equivalence with the Naples rather than the Genesee group.

6. The occurrence of the *Strophodonta extenuata* complex in the Arkona shale of Ontario and in the Bell, Rockport Quarry, Ferron Point, and Genshaw formations of Michigan is convincing evidence for their equivalence.

7. The occurrence of *Pholidostrophia ovata* and *Sphenophragmus nanus* in the Widder shale of Ontario and the Norway Point formation of Michigan suggests the equivalence of the Norway Point to the Widder shale of



	M I C H I G A N													SURROUNDING AREAS														
	Alpena and Presque Isle Cos.								Cheboygan Co.			Emmet and Charlevoix Cos.		Mo.	Ill.	N. Y.		Ont.	Ind.	Ohio								
	Bell	Rockport Quarry	Ferron Point	Genshaw	Newton Creek	Alpena	Four Mile Dam	Norway Point	Potter Farm	Ferron Point	Genshaw	Koshler	Gravel Point	Beebe School	Gravel Point	Middle Petoskey	Upper Petoskey	St. Laurent	Rapid	Centerfield	Ludlowville	Wanakah	Enfield	Arkona	Hungry Hollow	Widder	Logansport	Silica
<i>Chonetes ensicosta</i> <i>C. medialis</i> <i>Douvillina distans</i> <i>Longispina emmetensis</i> <i>L. lissohybus</i>	X	X	X						X	X				X				X							X		X	
<i>L. subcalva</i> <i>Megastrophia concava</i> <i>M. gibbosa</i> <i>Oligorhachis oligorhachis</i> <i>Pentamerella affonensis</i>		X				X				X											X				X		X	
<i>P. alpenensis</i> <i>P. lingua</i> <i>P. pericosta</i> <i>P. petoskeyensis</i> <i>P. tumida</i>			X			X	X			X			X		X										X	X	X	
<i>Pholidostrophia geniculata</i> <i>P. ovata</i> <i>Helaspis luma</i> <i>Protolapstrophia lirella</i> <i>Rhipidomella trigona</i>						X						X			X									X	X	X		
<i>Schizophoria ferronensis</i> <i>S. traversensis</i> <i>Schuchertella anomala</i> <i>S. crassa</i> <i>Siebertella romingeri</i>	X	X	X							X	X				X										X			X
<i>Sphenophragmus nanus</i> <i>Strophodonta crassa</i> <i>S. erratica</i> <i>S. extenuata</i> <i>S. extenuata extenuata</i>									X				X		X						X	X				X		
<i>S. extenuata ferronensis</i> <i>S. fissicosta</i> <i>S. nanus</i> <i>S. pentagonia</i> <i>S. proteus</i> <i>S. titan titan</i>		X													X									X				

FIG. 3. Stratigraphic ranges of widespread Traverse species. Only species treated in the present report are included.

the Ontario section, rather than to the Ipperwash limestone as now considered.

8. *Douvillina distans* and *Megastrophia gibbosa* occur together in the Logansport limestone of Indiana and the Four Mile Dam formation of Michigan.

9. *Schizophoria ferronensis* occurs in the Silica shale of Ohio and the Bell, Rockport Quarry, and Ferron Point formations of Michigan.

In addition, stratigraphic ranges of species established in this paper document certain correlations within the Traverse group, as follows:

1. Three distinctive species are associated in the Potter Farm formation and in the middle Petoskey formation: *Chonetes ensicosta*, *Pentamerella petoskeyensis*, and *Strophodonta crassa*. This association verifies the correlation of these two units made by Warthin and Cooper.

2. The Gravel Point formation is the

equivalent of the Alpena limestone and at least part of the Four Mile Dam formation. The following assemblage characterizes those formations: *Chonetes emmetensis*, *Pentamerella alpenensis*, *Pholidostrophia geniculata*, *Schuchertella anomala*, *Strophodonta erratica*, *Strophodonta fissicosta*, *Strophodonta nanus*, and *Strophodonta titan titan*. This is a good documentation of the correlation made by Warthin and Cooper.

3. Correlation of scattered outcrops of the Genshaw and Ferron Point formations in Cheboygan County with their type localities in the Thunder Bay area is aided by the occurrence of several distinctive species, as indicated in figure 3.

4. *Pentamerella aftonensis* provides one of the few faunal links between the Gravel Point formation in its type area along Little Traverse Bay and the beds mapped as Gravel Point by Kelly and Smith in Cheboygan County.

## LIST OF LOCALITIES

- 7b. One-half mile north of center, sect. 26, T. 33 N., R. 9 W., Cheboygan County. Lower Petoskey formation.
- 7c. Shore of Lake Michigan 1.3 miles north of Norwood, sect. 27, T. 33 N., R. 9 W., Charlevoix County. Uppermost Petoskey formation.
8. Pine River Point, shore of Lake Michigan, about 2 miles west of Charlevoix, NW.  $\frac{1}{4}$  sect. 28 and NE.  $\frac{1}{4}$  sect. 29, T. 34 N., R. 8 W., Charlevoix County. Gravel Point formation.
- 8a. Shore of Lake Michigan, sect. 29, T. 34 N., R. 8 W., Charlevoix County. Gravel Point formation.
9. Abandoned quarry Charlevoix Rock Products Co., 1 mile west of Charlevoix, near center SE.  $\frac{1}{4}$  sect. 28, T. 34 N., R. 8 W., Charlevoix County. Gravel Point formation.
10. Charlevoix City quarry (now a dump) immediately south of center point of east-west road on north line, north line sect. 33, T. 34 N., R. 8 W., Charlevoix County. Lower Petoskey formation.
11. Test pit  $\frac{3}{4}$  mile east of Charlevoix City quarry, sect. 33, T. 34 N., R. 8 W., Charlevoix County. Lower Petoskey formation.
12. Abandoned quarry near center sect. 28, T. 34 N., R. 8 W., Charlevoix County. Lower Petoskey formation.
13. Curtis quarry and shore, Bayshore, SW.  $\frac{1}{4}$  sect. 6, T. 34 N., R. 6 W., Emmet County. Petoskey formation.
- 13b. Curtis quarry, Bayshore, sect. 6, T. 34 N., R. 6 W., Emmet County. Petoskey formation.
14. Quarry of Petoskey Portland Cement Co., about 2 miles west-southwest of Petoskey, SW.  $\frac{1}{4}$  sect. 2, T. 34 N., R. 6 W., Emmet County. Gravel Point formation.
- 14c. Abandoned quarry 2.74 miles east of Bayshore, NE.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 8, T. 34 N., R. 6 W., Emmet County. Gravel Point (upper) formation.
- 14e. Abandoned Bell quarry 2.3 miles east of Bayshore, NW.  $\frac{1}{4}$  NW.  $\frac{1}{4}$  sect. 9, T. 34 N., R. 6 W., Emmet County. Gravel Point formation.
15. Superior quarry, about  $1\frac{1}{2}$  miles west northwest of Bayshore, SW.  $\frac{1}{4}$  sect. 2, T. 34 N., R. 7 W., Charlevoix County. Petoskey formation.
17. Antrim Lime Co. quarry, SE.  $\frac{1}{4}$  sect. 1, T. 34 N., R. 6 W., Emmet County. Upper Gravel Point formation.
18. Quarry of Northern Lime Co., just north of railroad station in Petoskey, NE.  $\frac{1}{4}$  sect. 32, T. 35 N., R. 5 W., Emmet County. Petoskey formation.
- 18a. Bluffs on shore of Little Traverse Bay at railroad station, Bay View, NW.  $\frac{1}{4}$  sect. 32, T. 35 N., R. 5 W., Emmet County. Gravel Point formation.
19. On the Lake Michigan shore, 1 mile west of Petoskey, sect. 1, T. 34 N., R. 5 W., Emmet County. Gravel Point formation.
21. Quarry in northeast Bay View, SE.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 27, T. 35 N., R. 5 W., Emmet County. Middle Petoskey formation.
- 21a. Junction of U. S. 31 and Michigan 131, about 1 mile east-northeast of Bay View, NW.  $\frac{1}{4}$  NW.  $\frac{1}{4}$  sect. 34, T. 35 N., R. 5 W., Emmet County. Middle Petoskey formation.
22. Sorenson quarry, on section line road  $\frac{3}{4}$  mile south of the northeast corner, sect. 1, T. 34 N., R. 2 W., Cheboygan County. Koehler limestone.
- 22a. Beebe School grounds, sect. 14, T. 34 N., R. 2 W., Cheboygan County. Beebe School formation.
- 24a. Pigeon River, about  $1\frac{1}{4}$  miles south-southwest of Afton, sect. 12, T. 34 N., R. 2 W., Cheboygan County. Genshaw formation.
- 24b. West side of road  $\frac{1}{4}$  mile north of Beebe School, NE.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 14, T. 34 N., R. 2 W., Cheboygan County. Beebe School formation.
25. Quarry  $\frac{3}{4}$  mile north of Afton, SW.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 36, T. 35 N., R. 2 W., Cheboygan County. Gravel Point formation.
- 25a. North line of section about 2 miles north-northeast of Afton, NE.  $\frac{1}{4}$  sect. 25, T. 35 N., R. 2 W. Genshaw formation (Killians member).
- 25b. North line of NW.  $\frac{1}{4}$  sect. 30, about  $1\frac{3}{4}$  miles due west of Legrand, T. 35 N., R. 1 W., Cheboygan County. Genshaw formation.
27. Marvin quarry, about  $1\frac{1}{2}$  miles east and  $1\frac{1}{2}$  miles south of Afton, SW.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 7, T. 34 N., R. 1 W., Cheboygan County. Koehler limestone and Gravel Point formation.
- 27a. Abandoned quarry about 1 mile southeast of Legrand, NW.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 28, T. 35 N., R. 1 W., Cheboygan County. Koehler limestone.
28. Below dam on Black River, about  $\frac{1}{4}$  mile

- east of rail station at Tower, NW.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 3, T. 34 N., R. 1 E., Cheboygan County. Upper Genshaw formation.
- 28a. On U. S. 23, about 1.1 miles due west of Tower, north line sect. 9, T. 34 N., R. 1 E., Cheboygan County. Genshaw formation (Killians member).
- 28b. On road at top of hill (north side), about  $1\frac{1}{2}$  miles north of U. S. 23 in Tower, north center of sect. 34, T. 35 N., R. 1 E., Cheboygan County. Genshaw formation.
29. Quarry at south end of Black Lake, NW.  $\frac{1}{4}$  SW.  $\frac{1}{4}$  sect. 7, T. 35 N., R. 2 E., Presque Isle County. Rockport Quarry limestone.
- 29a. Same locality as 29. Ferron Point formation.
- 29b. Same locality as 29. Genshaw formation.
- 29c. Shale thrown out basement, NE.  $\frac{1}{4}$  sect., 26, T. 34 N., R. 1 E., Cheboygan County. Ferron Point formation.
- 29d. On Rainy River, at junction of south line sect. 26, T. 35 N., R. 2 E., Presque Isle County. Genshaw formation.
- 29e. Branch of Rainy River and on roadside, SE.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 26, T. 35 N., R. 2 E., Presque Isle County. Genshaw formation.
30. Ocqueoc Falls, just below junction of Ocqueoc River and U.S. 23, Ocqueoc Township, NW.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 27, T. 35 N., R. 3 E., Presque Isle County. Rockport Quarry limestone.
- 30a. On U. S. 23, about 2 miles east of Ocqueoc Falls, south line sect. 24, T. 35 N., R. 3 E., Presque Isle County. Genshaw formation.
31. Quarry of Michigan Limestone and Chemical Co., about 1 mile southeast of Rogers City, Presque Isle County. Bell shale (lowest).
33. Road cut on Presque Isle 451, Belknap Township, southwest corner NW.  $\frac{1}{4}$  sect. 9, T. 34 N., R. 5 E., Presque Isle County. Genshaw formation.
- 33a. At Orchard, Posen Township, northwest corner sect. 4, T. 33 N., R. 6 E., Presque Isle County. Genshaw formation.
- 33b. Krakow Township, southeast corner sect. 4, T. 33 N., R. 7 E., Presque Isle County. Genshaw formation.
- 33c. Krakow Township north line NW.  $\frac{1}{4}$  sect. 7, T. 33 N., R. 7 E., Presque Isle County. Genshaw formation.
- 33d. Posen Township, northwest corner sect. 12, T. 33 N., R. 6 E. Presque Isle County. Upper Genshaw formation.
- 33e. Dirt thrown out of cellar, 1 mile north and 0.6 mile east of Posen, Posen Township, SW.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 3, T. 33 N., R. 6 E., Presque Isle County. Genshaw formation (Killians member).
- 33f. On west side U. S. 23 on south line of Posen village, east line sect. 16, T. 33 N., R. 6 E., Presque Isle County. Genshaw formation (Killians member).
- 33g. Two miles west of Posen, northeast corner sect. 18, T. 33 N., R. 6 E., Presque Isle County. Lower Alpena limestone.
35. Four miles south of Alpena, sect. 11, T. 30 N., R. 8 E., Alpena County. Thunder Bay limestone.
36. Abandoned quarry, SE.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 29, T. 31 N., R. 8 E., Alpena County. Potter Farm formation.
37. Abandoned quarry, southwest corner sect. 19, T. 31 N., R. 8 E., Alpena County. Potter Farm formation.
- 37a. Pit in northwest corner of Alpena Cemetery near Thunder Bay River, NW.  $\frac{1}{4}$  SW.  $\frac{1}{4}$  sect. 21, T. 31 N., R. 8 E., Alpena County. Potter Farm formation.
- 37b. Fields along section line fence, SE.  $\frac{1}{4}$  sect. 20, T. 31 N., R. 8 E., Alpena County. Potter Farm formation.
- 38a. Quarry of Kelly Island Lime and Transport Co., at Rockport, sect. 6, T. 32 N., R. 9 E., Alpena County. Upper (12 feet) Bell shale.
- 38b. Same locality as 38a. Basal 8 inches of Rockport Quarry limestone.
- 38d. Quarry of Kelly Island Lime and Transport Co., at Rockport, sect. 6, T. 32 N., R. 9 E., Alpena County. Rockport Quarry limestone.
- 38e. Same locality as 38d. Lower 10-foot shale portion of Ferron Point formation.
- 38f. Same locality as 38d. Ferron Point formation.
- 38g. Same locality as 38d. Ferron Point formation.
- 38h. Rabiteau Farm, NW.  $\frac{1}{4}$  sect. 35, T. 32 N., R. 8 E., Alpena County. Genshaw formation.
40. Quarry of Michigan Alkali Co., SW.  $\frac{1}{4}$  sect. 13, T. 31 N., R. 8 E., Alpena County. Alpena limestone and Newton Creek formation.
- 40i. Below dam at Ninth Avenue bridge over Thunder Bay River, just north of center sect. 22, T. 31 N., R. 8 E., Alpena County. Norway Point formation.
41. Four Mile Dam, Thunder Bay River, SW.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 7, T. 31 N., R. 8 E., Alpena County. Four Mile Dam formation.
- 41a. Same locality as 41. Lower Norway Point formation.

- 41c. One-half mile south of Four Mile Dam, just north of center sect. 18, T. 31 N., R. 8 E., Alpena County. Potter Farm formation.
- 41e. Six-tenths mile west of Four Mile Dam, NE.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 13, T. 31 N., R. 7 E., Alpena County. Potter Farm formation.
42. Orchard Hill on the Long Rapids road,  $4\frac{1}{2}$  miles east of Long Rapids, center sect. 31, T. 32 N., R. 7 E., Alpena County. Potter Farm formation.
- 42a. By roadside on section line road, north line NW.  $\frac{1}{4}$  sect. 31, T. 32 N., R. 7 E., Alpena County. Potter Farm formation.
- 44b. Stone piles, NW.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 17, T. 31 N., R. 7 E., Alpena County. Thunder Bay limestone.
46. South bank of Thunder Bay River,  $\frac{3}{4}$  mile downstream from Four Mile Dam, SE.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 18, T. 31 N., R. 8 E., Alpena County. Norway Point formation.
- 46a. Same locality as 41. Norway Point formation.
47. North bank of Thunder Bay River at Norway Point Dam, NW.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 12, T. 31 N., R. 7 E., Alpena County. Norway Point formation.
- 47a. South bank Thunder Bay River at Norway Point Dam, NW.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 12, T. 31 N., R. 7 E., Alpena County. Norway Point formation.
- 47b. Same as 47a.
48. Sink hole on shore of Misery Bay, sect. 15, T. 31 N., R. 8 E., Alpena County. Genshaw formation.
49. Abandoned quarry, north center NE.  $\frac{1}{4}$  sect. 10, T. 31 N., R. 9 E., Alpena County. Lower Genshaw formation.
- 49a. Same as 49.
50. On Wessel Road, 0.3 mile south of northwest corner sect. 25, T. 32 N., R. 8 E., Alpena County. Genshaw formation (upper).
- 50a. On Wessel Road, 0.4 mile south of northwest corner sect. 25, T. 32 N., R. 8 E., Alpena County. Genshaw formation (Killians member).
51. From lake and bank of lake in west end abandoned shale pit, Alpena Portland Cement Co., SE.  $\frac{1}{4}$  sect. 18, T. 32 N., R. 9 E., Alpena County. Upper Ferron Point formation.
- 51a. Abandoned shale pit of Alpena Portland Cement Co., SE.  $\frac{1}{4}$  sect. 18, T. 32 N., R. 9 E., Alpena County. Ferron Point formation.
- 51b. Same locality as 51a. Genshaw formation.
- 51c. Ditches on each side of section line road,  $\frac{1}{2}$  mile south of Genshaw School,  $\frac{1}{2}$  mile south of northwest corner sect. 19, T. 32 N., R. 9 E., Alpena County. Genshaw formation.
- 52a. On French Road, 0.3 mile south of northeast corner sect. 8, T. 32 N., R. 8 E., Alpena County. Genshaw formation.
- 52b. On French Road, 0.4 mile south of northeast corner sect. 8, T. 32 N., R. 8 E., Alpena County. Genshaw formation.
- 52c. On French Road, 0.5 mile south of northeast corner sect. 8, T. 32 N., R. 8 E., Alpena County. Genshaw formation.
- 52d. On French Road, 0.5–0.6 mile south of northeast corner sect. 8, T. 32 N., R. 8 E., Alpena County. Genshaw formation (Killians member).
- 52e. On French Road, 0.7 mile south of northeast corner sect. 8, T. 32 N., R. 8 E., Alpena County. Lower Alpena limestone.
- 52f. Road junction, northwest corner sect. 9, T. 31 N., R. 8 E., Alpena County. Norway Point formation.
- 52g. On Alpena City line about 0.4 mile north-northwest of the County Farm, NW.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 16, T. 31 N., R. 8 E., Alpena County. Norway Point formation.
- 52h. Roadside near center of NE.  $\frac{1}{4}$  sect. 22, T. 32 N., R. 8 E., Alpena County. Genshaw formation.
- 52k. Sink, 0.3 mile south of Polish School, SW.  $\frac{1}{4}$  NW.  $\frac{1}{4}$  sect. 11, T. 32 N., R. 7 E., Alpena County. Lower Alpena limestone.
- 52i. Falls of Long Lake Creek, under Grand Lake Road, south of center of NW.  $\frac{1}{4}$  sect. 23, T. 32 N., R. 8 E., Alpena County. Genshaw formation.
- 52j. Long Lake Road, about 0.6 mile north of Town Hall School, about 5 miles north of Alpena, sect. 26, T. 32 N., R. 8 E., Alpena County. Lower Alpena limestone.
- 52l. Quarry about  $1\frac{1}{2}$  miles northwest of Bolton, SE.  $\frac{1}{4}$  SW.  $\frac{1}{4}$  sect. 5, T. 32 N., R. 7 E., Alpena County. Middle Alpena limestone.
53. Quarry of Thunder Bay Quarries Co., SE.  $\frac{1}{4}$  sect. 14, T. 31 N., R. 8 E., Alpena County. Alpena limestone; Dock Street clay member of the Four Mile Dam formation.
100. Two miles west of Charlevoix City, SE.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 29, T. 34 N., R. 8 W., Charlevoix County. Gravel Point formation.
101. Shore of Little Traverse Bay,  $2\frac{1}{2}$  miles west of Nine Mile Point, sects. 1–4, T. 34 N., R. 7 W., Emmet County. Gravel Point formation.



102. Mud Lake,  $\frac{1}{2}$  mile north of junction of Routes 31 and 131, Bay View, sect. 27, T. 35 N., R. 5 W., Emmet County. Middle Petoskey formation.
103. Near Petoskey, Emmet County. Gravel Point formation.
104. Quarry in sect. 32, T. 34 N., R. 8 W., Charlevoix County. Petoskey formation.
105. Two miles north of Afton, center of south line of sect. 30, T. 35 N., R. 1 W., Cheboygan County. Koehler limestone.
106. Marvin quarry, sect. 7, T. 34 N., R. 2 W., Cheboygan County. Gravel Point formation.
107. One-half mile south and 1 mile east of Afton, sect. 6, T. 34 N., R. 1 W., Cheboygan County. Gravel Point formation.
108. One-quarter mile south of intersection of U. S. 23 and Long Lake Road, SE.  $\frac{1}{4}$  sect. 22, T. 32 N., R. 8 E., Alpena County. Genshaw formation.
109. Long Lake, Alpena County. Genshaw formation.
110. Eighty-five hundredths mile north of Alpena and Presque Isle county line, 0.85 mile north of southwest corner sect. 35, T. 33 N., R. 8 E., Presque Isle County. Genshaw formation.
111. Two and one-quarter miles south of Ocqueoc,  $\frac{1}{4}$  mile south of northwest corner sect. 33, T. 35 N., R. 3 E., Presque Isle County. Genshaw formation.
112. Fifty to 100 yards south of county line near northwest corner sect. 5, T. 32 N., R. 8 E., Presque Isle County. Genshaw formation.
113. U. S. 23,  $\frac{1}{4}$  mile east of bridge at Tower, near northwest corner sect. 11, T. 34 N., R. 1 E., Cheboygan County. Genshaw formation.
114. Four and forty-five hundredths miles east of rail crossing on U. S. 23, sect. 15, T. 34 N., R. 6 E., Presque Isle County. Rockport Quarry limestone.
115. Near Lake Augusta, sect. 36, T. 34 N., R. 6 E., Presque Isle County. Genshaw formation.
116. Just southwest of LeRoy, SW.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 36, T. 33 N., R. 7 E., Presque Isle County. Genshaw formation.
117. NE.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sect. 12, T. 33 N., R. 6 E., Presque Isle County. Genshaw formation.
118. NW.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  sect. 31, T. 33 N., R. 8 E., Presque Isle County. Genshaw formation.
119. Dump from limestone taken on cut on U. S. 23, 125 feet above cemetery, along south line of section, sect. 30, T. 31 N., R. 8 E., Alpena County. Potter Farm formation?
120. Four and seven-tenths miles east and 1 mile north of Posen, 0.3 miles west of corner of section, sect. 8, T. 33 N., R. 7 E., Presque Isle County. Genshaw formation.
121. Stony Point, sect. 27, T. 31 N., R. 8 E., Alpena County. Potter Farm formation.
122. Thirty-five hundredths of a mile west of northeast corner sect. 31, T. 32 N., R. 7 E., Alpena County. Potter Farm formation.
123. On county highway 634, 100 yards north of county line, sect. 31, T. 33 N., R. 8 E., Presque Isle County. Genshaw formation.
- 123a. One-quarter to  $\frac{1}{2}$  mile north of locality 123. Genshaw formation.
124. Highway 23 at city line of Alpena, just west of cemetery, sect. 16, T. 31 N., R. 8 E., Alpena County.
125. Long Lake road, 0.2 mile north of southwest corner sect. 35, T. 32 N., R. 8 E., Alpena County. Alpena limestone.
126. Thunder Bay Island, Alpena County.
127. French Road, 0.3 mile south of northeast corner sect. 8, T. 32 N., R. 8 E., Alpena County. Genshaw formation. Same locality as 52a.
128. French Road, 0.2 mile north of southwest corner sect. 9, T. 32 N., R. 8 E., Alpena County. Genshaw formation.
129. West side of Long Lake Road,  $\frac{1}{2}$  mile south of northwest corner sect. 2, T. 31 N., R. 8 E., Alpena County. Alpena limestone.
130. Three hundred yards west of bridge over Thunder Bay River near center of south line, sect. 17, T. 31 N., R. 8 E., Alpena County. Potter Farm formation.
131. Jarman quarry, near Petoskey, Emmet County. Gravel Point formation.

## SYSTEMATIC PALEONTOLOGY

SUPERFAMILY **DALMANELLACEA** SCHUCHERT  
AND COOPER, 1931

GENUS **SCHIZOPHORIA** KING, 1850

*Schizophoria* KING, 1850, The Permian fossils of England, pp. 105, 106. SCHUCHERT AND COOPER, 1932, Mem. Peabody Mus. Nat. Hist., vol. 4, pt. 1, pp. 143, 144, fig. 12, pl. 23, figs. 11, 16-18, 20-25. HALL AND CLARKE, 1892, Paleontology of New York, vol. 8, pt. 1, pp. 211-213.

**DIAGNOSIS:** Outline transversely elliptical; hinge line straight, narrower than the greatest width; lateral profile convexo-concave, the brachial valve always the deeper; anterior commissure rectimarginate to uniplicate; surface multicostellate. Pedicle interior with divergent or subparallel diductor scars separated by a median ridge. Brachial interior with widely divergent brachiophores supported by nearly vertical plates, quadripartite adductor field and a pair of oblique ridges separating the anterior and posterior adductor scars.

**DISCUSSION:** Samples of *S. ferronensis* and *S. traversensis*, taken in normal stratigraphic sequence from the Bell through the Genshaw, show a progressive increase in size. The progressive nature of this change makes it probable that the trend is genotypic; and gross size, in conjunction with ribbing and shape, has been used in separating two species.

***Schizophoria ferronensis*** Imbrie, new species

Plate 48, figures 1-7

*Schizophoria striatula* (Schlotheim), STEWART, 1927, Bull. Geol. Surv. Ohio, ser. 4, no. 32, p. 40, pl. 3, fig. 21.

*Schizophoria striatula* var. *parvum* STEWART, 1927, *ibid.*, ser. 4, no. 32, pp. 40, 41, pl. 3, figs. 22, 23.

**DISTINGUISHING CHARACTERS:** The following characters distinguish *S. ferronensis* from other Traverse *Schizophoria*: (1) small to moderate size, (2) a rib count of about 18 per 5 mm. 15 mm. from the pedicle beak, (3) a tendency for a fold and sulcus to develop in individuals over 25 mm. wide, and (4) the absence of an internal anteromedian ridge in the pedicle valve. The following characters, together with those just mentioned, combine to distinguish *S. ferronensis* from other known congeneric species: (1) a subelliptical

outline, (2) a subtruncate to gently convex anterior margin, and (3) an interarea inclined apsacline 45 degrees.

**DESCRIPTION:** Shell of small or medium size for the genus. Outline transversely subelliptical. Lateral and anterior profiles subequally biconvex. Multicostellate, ribs increasing by implantation and some bifurcation; costellae subangular to subround, about equal to striae in width; rib count about 18 per 5 mm. at a point 15 mm. from pedicle beak. Individuals over 25 mm. wide generally with pedicle sulcus and brachial fold.

**Pedicle Valve:** Greatest convexity in the umbonal region; anterior and lateral slopes gently and evenly convex, posterolateral slopes gently concave. Beak pointed, incurved, and projecting posteriorly slightly more than brachial beak; interarea moderately high, curved, apsacline 45 degrees. Muscle field obcordate in outline; diductor scars subparallel to gently divergent; median ridge variable in width, occasionally extending anteriorly from muscle field as a short, low ridge; adjustor scars obscure.

**Brachial Valve:** Greatest convexity in the umbonal region; anterior and lateral slopes gently and evenly convex, posterolateral slopes gently concave. Beak pointed, incurved; umbo slightly swollen; interarea curved, orthocline to gently apsacline.

**MEASUREMENTS OF HOLOTYPE:** Length of pedicle valve, 22 mm.; length of brachial valve, 21 mm.; width, 25 mm.; thickness, 16 mm.

**OCCURRENCE:** Bell shale (localities 31, 38), basal 8 inches of the Rockport Quarry limestone (locality 38), and Ferron Point formation (localities 29, 31, 38, 51) of Michigan. Silica shale of Ohio.

**HOLOTYPE:** U.S.N.M. No. 124322; Ferron Point formation, locality 38.

***Schizophoria traversensis*** Grabau, 1931

Plate 48, figures 8-14

*Schizophoria stratula traversensis* GRABAU, 1931, Pal. Sinica, ser. B., vol. 3, fasc. 3, p. 59, pl. 6, fig. 9. STUMM, 1951, Contrib. Mus. Paleont. Univ. Michigan, vol. 9, no. 1, p. 11.

**DISTINGUISHING CHARACTERS:** The following characters distinguish *S. traversensis*

from other conspecific Traverse forms: (1) large size, (2) a rib count of about 20 per 5 mm. 15 mm. from pedicle beak, (3) absence of internal anteromedian ridge in pedicle valve, and (4) a tendency for fold and sulcus to develop only in individuals wider than 35 mm. The following characters, combined with those enumerated above, distinguish *S. traversensis* from other known congeneric species: (1) a subelliptical outline, (2) a subtruncate to gently convex anterior margin, and (3) an interarea inclined apsacline 45 degrees.

**DESCRIPTION:** Shell large for the genus. Outline transversely subelliptical; front margin gently convex to subtruncate. Lateral profile with brachial valve considerably deeper than the pedicle valve. Fold and sulcus present in individuals wider than 35 mm. Ornamentation as in *S. ferrenensis* but with a corresponding rib count of about 20.

**Pedicle Valve:** Greatest convexity in umbonal region; lateral and anterior slopes evenly and gently convex; posterolateral slopes very gently concave. Beak pointed, slightly incurved, umbo not inflated; interarea curved, apsacline 45 degrees. Muscle field obcordate in outline; median ridge variable in width, not extending forward from muscle field.

**Brachial Valve:** Greatest convexity in the umbonal region; anterior and lateral slopes evenly and moderately convex; posterolateral slopes gently concave. Beak incurved, umbo slightly inflated; interarea strongly curved in large specimens, orthocline to apsacline 45 degrees.

**OCCURRENCE:** Genshaw formation of Michigan (localities 25a, 28b, 29c, 33c, 49, 51c, 105, 108, 109, 138).

***Schizophoria mesacarina* Imbrie, new species**

Plate 48, figures 15-21

**DISTINGUISHING CHARACTERS:** The following characters distinguish *S. mesacarina* from other Traverse species: (1) small to medium size, (2) a rib count of about 15 per 5 mm. 15 mm. from pedicle beak, (3) an internal anteromedian ridge in the pedicle valve, and (4) the absence of a fold and sulcus. The following characters, together with those just mentioned, combine to distinguish *S. mesacarina* from other known congeneric species: (1) a

subelliptical outline and (2) an interarea inclined apsacline 45 degrees.

**DESCRIPTION:** Shell medium in size for the genus. Outline transversely subelliptical. Lateral profile subequally biconvex. Fold and sulcus not developed. Ornamentation as in *S. ferrenensis*, but with a rib count of about 15.

**Pedicle Valve:** Exterior as in *S. traversensis* but lacking a well-defined sulcus. Internal median ridge extending forward from muscle field.

**Brachial Valve:** Exterior as in *S. traversensis* but lacking a well-defined fold.

**MEASUREMENTS OF HOLOTYPE:** Length of pedicle valve, 23 mm.; length of brachial valve, 23 mm.; width, 28 mm.; thickness, 14 mm.

**OCCURRENCE:** Uppermost Petoskey formation (locality 7c) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124250; uppermost Petoskey formation, locality 7c.

**REMARKS:** Samples of *Schizophoria* from the Cedar Valley limestone of Scott and Muscatine counties, Iowa (*S. lata* Stainbrook, 1940), Calhoun County, Illinois, and Pike County, Missouri, are identical with *S. mesacarina* except in size, the non-Traverse populations being (in a statistical sense) significantly larger than the Traverse species.

#### **SPHENOPHRAGMUS** IMBRIE, NEW GENUS

**TYPE SPECIES:** *Sphenophragmus nanus* Imbrie, new species.

**DISTINGUISHING CHARACTERS:** Several features combine to distinguish *Sphenophragmus* from other genera of the Schizophoriidae: (1) the nearly plano-convex lateral profile, a feature that distinguishes it from young *Schizophoria*; (2) cardinalia resembling those of *Schizophoria* but differing in having brachio-phore plates gently diverging anteriorly; (3) the lack of a medium septum in the brachial valve; and (4) a pedicle interior marked by strongly divergent dental plates and the lack of a median ridge separating the diductor muscles.

**DIAGNOSIS:** Shell small. Outline subcircular to transversely elliptical; hinge line straight, about equal to half of the greatest width; cardinal extremities rounded. Lateral profile plano-convex to unequally biconvex. Anterior commissure rectimarginate

to very gently sulcate. Pedicle valve subcarinate, brachial valve with shallow sulcus. Pedicle interarea gently curved, strongly apsacline; delthyrium open; beak small, pointed, incurved. Brachial interarea smaller than interarea of pedicle valve, slightly anacline; notothyrium more or less closed by cardinal process; beak obsolete. Surface multicostellate; costellae hollow, subangular, increasing by bifurcation and occasional trifurcation; commonly fascicostellate along posterolateral margins. Shell substance endopunctate.

*Pedicle Interior:* Delthyrial cavity deep; teeth strong, with oblique crural fossettes. Dental plates strong, strongly divergent anteriorly, gently divergent in the direction of the pedicle valve, slightly advancing, extended forward around the sides of the muscle area as a low ridge. Muscle field slightly impressed, obcordate in outline, occupying slightly over one-third of the length of the valve; adductor marks comprising an elongate, narrow, shallow groove; diductor marks divergent, extending beyond the adductors; adjustor scars indistinct, located along the base of the dental plates outside the diductors.

*Brachial Interior:* Notothyrial cavity confined, largely filled by cardinal process and notothyrial platform. Brachiophores long, extending about 45 degrees from the plane of the commissure into the pedicle valve; brachiophore plates strong, nearly vertical, diverging slightly anteriorly, extended forward around the outside of the muscle field as low ridges. Sockets defined by concave fulcral plates. Cardinal process variable; shaft rising perpendicular to the plane of the commissure, recurved posteriorly, and meeting a low median ridge extending anteriorly from the notothyrial platform; myophore either distinctly lobate, or indistinctly lobate, partially resorbed, and more or less dominated by a median crenulated ridge. Muscle field slightly impressed, bilobed in front, separated by a low median elevation which expands anteriorly and corresponds to the sulcus; anterior adductors larger than posterior pair; extending nearly to center of valve.

#### SPECIES ASSIGNED

*Rhipidomella cyclas* (Hall) HALL AND CLARKE,

1892, Paleontology of New York, vol. 8, pt. 1, p. 225.

*Sphenophragmus nanus* IMBRIE, new species.

DISCUSSION: Only one species of this genus, *Sphenophragmus nanus*, is known from the Traverse group. It occurs in the lower Beebe School and Norway Point formations. From collections in the United States National Museum the genus is known from the Arkona, Hungry Hollow, and Widder formations of southwest Ontario; from the Cardiff, Stafford, Mottville, Centerfield, Wanakah, Tichenor (probably *Sphenophragmus cyclas*), and Tully formations of the Hamilton group of New York; from Devonian rocks "3½ miles west of Charleston, Indiana" (U.S.N.M. No. 39198); and probably from Devonian rocks "near Lebanon, Kentucky" (U.S.N.M. No. 39197). According to present knowledge, therefore, the genus is restricted to the Cazenovia, Tioughnioga, and Taghanic stages of the Devonian.

Biologically, as well as stratigraphically, the genus is of considerable interest. The pattern of the cardinalia clearly places *Sphenophragmus* among the Schizophoriidae, but internal and external features combine to individualize it. Internally, the brachiophore supports are nearly vertical and diverge only slightly anteriorly, a feature that is characteristic of this genus and to which its name refers. In the pedicle valve, the pattern of the musculature differs from the other members of the family in lacking a median ridge separating the diductor scars. Externally, the profile of *Sphenophragmus* is unique among the Schizophoriidae.

The phenomenon of homeomorphy is interestingly displayed in *Monelasmina* Cooper from the Devonian of France. Externally, the French shells mimic *Sphenophragmus*, but the presence of a high median septum in the brachial interior of *Monelasmina* precludes a congeneric assignment.

*Sphenophragmus nanus* Imbrie, new species

Plate 49, figures 1-12

DISTINGUISHING CHARACTERS: A combination of several characters serves to distinguish *Sphenophragmus nanus* from congeneric species in Ontario, New York, and Indiana: (1) a subcircular outline, (2) a rib count of about 14 in the space of 5 mm. 8 mm.

from pedicle beak, (3) subequal costellae, and (4) the moderately high pedicle interarea. *Sphenophragmus nanus* is further distinguished from *S. cyclas* by its lower and less angular costellae and by its narrower striae.

**DESCRIPTION:** Shell small, mean width about 6 mm. Outline subcircular to transversely elliptical, slightly wider than long; hinge width slightly more than half of the greatest width. Lateral profile plano-convex to unequally biconvex, the pedicle valve always the deeper; lateral commissure very gently flexed brachial; anterior commissure slightly sulcate. Ornamentation multicostellate; costellae numbering about 14 in the space of 5 mm. at a distance 8 mm. from the pedicle beak, increasing by bifurcation and occasional trifurcation, subequal in size; surface commonly fascicostellate along posterolateral margins.

**Pedicle Valve:** Subcarinate. Greatest convexity in umbonal region; slopes gently and evenly convex laterally and anteriorly. Beak small, pointed, incurved, projecting posteriorly beyond brachial beak; umbo not inflated.

**Brachial Valve:** Greatest convexity at umbo; slopes very gently convex. Sulcus broad, shallow, developing just anterior to beak. Beak very small, pointed, incurved. Umbo not inflated.

**MEASUREMENTS OF HOLOTYPE:** Length of pedicle valve, 7.7 mm.; length of brachial valve, 7.5 mm.; width, 8.7 mm.

**OCCURRENCE:** Norway Point formation (locality 46) and Beebe School formation (localities 22a, 24b) of Michigan. Lower Ludlowville formation and Wanakah formation of New York. Widder formation of Ontario.

**HOLOTYPE:** U.S.N.M. No. 124355; Norway Point formation, locality 46.

#### GENUS RHIPIDOMELLA OEHLERT, 1890

*Rhipidomella* OEHLERT, 1890, Jour. Conchyl., vol. 38, p. 372. HALL AND CLARKE, 1892, Paleontology of New York, vol. 8, pt. 1, pp. 208-211. SCHUCHERT AND COOPER, 1932, Mem. Peabody Mus. Nat. Hist., vol. 4, pt. 1, pp. 133-135, pl. 19, fig. 3, pl. 20, figs. 22-24, 26, 27.

*Rhipidomys* OEHLERT, 1887, in Fischer, Manuel de conchyliologie, p. 1288.

**DIAGNOSIS:** Outline subcircular to sub-

trigonal; hinge line narrow. Profile unequally biconvex, the brachial valve always the deeper. Pedicle interior with large, flabellate, diductor scars completely enclosing the adductor scars in front. Brachial interior with ponderous cardinal process and bluntly pointed, widely divergent brachiophores.

**DISCUSSION:** *Rhipidomella* is extremely rare in the Traverse group. This is extraordinary, because in many horizons of the Hamilton group these shells are abundant.

Species are here distinguished primarily on the basis of outline, degree of inflation of the pedicle umbo, curvature of the pedicle interarea, and lateral profile. Ratios of hinge width to other major dimensions of the shells are taxonomically deceptive and cannot be employed (in Traverse species, at least) as independent characters, because these ratios are regularly related to the total size of the shell.

#### *Rhipidomella penelope traversensis*

Imbrie, new subspecies

Plate 48, figures 24-27

**DISTINGUISHING CHARACTERS:** This subspecies can be distinguished from other *Rhipidomella* by (1) its small size, (2) its transversely elliptical outline, (3) its inflated umbo, (4) the strongly curved pedicle interarea, and (5) the even convexity of the pedicle valve. There is a tendency for two adjacent bifurcations from a costella to occur more closely together than is the case with its Traverse congeners.

**DESCRIPTION:** Shell small. Outline transversely elliptical, hinge width less than half of the greatest width. Lateral profile subequally biconvex. Surface multicostellate; costellae subangular to subround, increasing by bifurcation. Fold and sulcus lacking.

**Pedicle Valve:** Greatest convexity in the umbonal region; slopes evenly and moderately convex anteriorly and laterally; umbonal region moderately inflated. Beak small, pointed, incurved, projecting forward of brachial beak; interarea low, strongly curved, moderately apsacline.

**Brachial Valve:** Greatest convexity in the umbonal region; slopes evenly and gently convex. Interarea small, orthocline to gently anacline.

**MEASUREMENTS OF HOLOTYPE:** Length of



pedicle valve, 10 mm.; width, 11 mm.; thickness, 4 mm.

**OCCURRENCE:** Four Mile Dam formation (locality 41) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124346; Four Mile Dam formation, locality 41.

**REMARKS:** *Rhipidomella penelope* (Hall), *sensu stricto*, is a large form with a markedly subcircular adult outline. *Rhipidomella penelope traversensis*, by contrast, is a small form with a transversely elliptical outline. However, a careful analysis of a series of growth stages of *R. penelope* available from the Hungry Hollow formation of Ontario demonstrates that the Four Mile Dam specimens are identical in size and shape with the younger growth stages of the Hungry Hollow *R. penelope*. When this morphological observation is joined with independent faunal evidence that the two formations in question are probably equivalent, there is a real basis for considering the Four Mile Dam population as a subspecies, using the term in a sense comparable to that of modern neontological taxonomists, of *R. penelope*.

***Rhipidomella trigona*** Imbrie, new species

Plate 49, figures 13–18

**DISTINGUISHING CHARACTERS:** *Rhipidomella trigona* is distinguished from known conspecific forms by (1) a subtrigonal outline, (2) the moderate inflation of the pedicle umbonal region, and (3) the lateral profile.

**DESCRIPTION:** Shell of medium size for the genus. Outline subtrigonal; hinge width less than one-half of the greatest width; length about equal to width. Lateral profile subequally biconvex in small individuals; the brachial valve deeper than pedicle valve in large individuals.

**Pedicle Valve:** Greatest convexity in the umbonal region; slopes evenly and moderately convex towards the lateral and anterior margins. Beak small, bluntly pointed, gently incurved; interarea curved, moderately high in proportion to width, gently to moderately apsacline.

**Brachial Valve:** Lateral profile strongly and evenly convex. Interarea greatly reduced in mature shells. Interior typical of the genus.

**MEASUREMENTS OF THE HOLOTYPE:** Length of the pedicle valve, 12.7 mm.; width, 12.7 mm.; thickness, 8.5 mm.

**OCCURRENCE:** Uppermost Petoskey formation (locality 7c) of Michigan. Enfield formation of the upper Devonian of New York.

**HOLOTYPE:** U.S.N.M. No. 124249; uppermost Petoskey formation, locality 7c.

***Rhipidomella* sp.**

Plate 48, figures 22, 23

This species is not here described, because it is known only from a single pedicle valve collected 50 feet below the top of the Alpena limestone at locality 40. This specimen compares favorably with shells usually identified as *R. vanuxemi* from the Wanakah and Centerfield formations of the Hamilton group and from the Hungry Hollow formation of Ontario, but it differs from other such shells in the uninflated nature of its umbo and the shallowness of the ventral valve.

#### SUPERFAMILY PENTAMERACEA

SCHUCHERT, 1896

GENUS **SIEBERELLA** OEHLERT, 1887

*Sieberella* OEHLERT, 1887, in Fischer, Manuel de conchyliologie, p. 1311. SCHUCHERT AND COOPER, 1932, Mem. Peabody Mus. Nat. Hist., vol. 4, pt. 1, p. 175. HALL AND CLARKE, 1893, Paleontology of New York, vol. 8, pt. 2, pp. 241–246.

**DIAGNOSIS:** Galeatiform. Pedicle valve deep, with inflated umbo and strongly incurved beak. Variably developed fold on the pedicle valve. Sulcate. Brachial valve with variably developed sulcus. Multicostate. Brachial interior with septal plates converging to meet at the floor of the valve or uniting with low median septum.

***Sieberella romingeri*** (Hall and Clarke), 1893

Plate 50, figures 1–12

*Gypidula romingeri* HALL AND CLARKE, 1893, Paleontology of New York, vol. 8, pt. 2, p. 248, pl. 72, figs. 27–33. SCHUCHERT, 1897, Bull. U. S. Geol. Surv., vol. 87, p. 227. SCHUCHERT AND COOPER, 1932, Mem. Peabody Mus. Nat. Hist., vol. 4, pt. 1, p. 174.

*Gypidula? romingeri* Hall and Clarke, COOPER, 1944, in Shimer and Shrock, Index fossils of North America, p. 305, pl. 115, figs. 8, 9.

**DISTINGUISHING CHARACTERS:** This species is easily distinguished from known congeneric forms by the following characters: (1) large size; (2) high pedicle valve bearing a poorly defined fold; (3) shallow brachial

valve, with a broad median sulcus; and (4) gently sulcate or rectimarginate anterior commissure.

**DESCRIPTION:** Shell very large. Pedicle valve as wide as long in large shells, wider than long in smaller. Umbo smooth; rest of shell coarsely multicostate, with broad, rounded costellae increasing by bifurcation, numbering seven to eight per 20 mm. at the front margin. Anterior commissure gently sulcate to rectimarginate.

**Pedicle Valve:** Lateral profile strongly convex, with greatest convexity at the umbo, sloping with even convexity to the front and side margins. Anterior fold faint or absent. Umbo inflated, beak bluntly pointed, strongly incurved, overhanging the brachial beak. Interarea low, commonly obscurely defined. False interarea prominent. Delthyrium wide, with incipient deltidial plates. Interior typical of the genus.

**Brachial Valve:** Shallow. Anterior and lateral profiles gently and evenly convex, with broad anterior median sulcus. Greatest convexity at the umbo. Interarea obsolete. Interior with septal plates convergent, uniting at the floor of the valve to yield a V-shaped sessile cruralium.

**OCCURRENCE:** Genshaw formation throughout the area of outcrop (localities 28, 29d, 32h, 49, 50, 50a, 51c, 52a, 52h, 108, 109, 110, 111, 115, 117).

**REMARKS:** The assignment of this species to *Sieberella*, rather than *Gypidula*, calls for some comment. Worn brachial beak regions display two longitudinal, narrowly separated tracks. Such marks are commonly found on *Gypidula* and indicate the union of the discrete septal plates with the floor of the valve. The septal plates of *S. romingeri*, however, actually converge to form a V-shaped sessile cruralium. Because the angle of convergence is quite obtuse, a slight exfoliation of the beak region will yield two distinct tracks.

The nature of the cruralium eliminates *Gypidula* from consideration, and *Pentamerella* has the opposite flexure of the commissure. *Sieberella*, then, among established genera, can receive the species. But even this association is anomalous: the genotype (*S. sieberi*) has a well-defined fold, whereas the fold in *S. romingeri* is faint or absent. Would it be desirable to erect another genus around

*S. romingeri*? If this were done, the distinction between the new genus and *Sieberella*, *sensu stricto*, would be based on the presence or absence of a fold, and the question resolves to an analysis of the character of folding as a generic character for this group of shells. An examination of this species and the genotype alone is not sufficient to establish the nature of the variation of the character of folding, and until *Sieberella* can be studied as a whole, the erection of another genus would be premature. Caution is also engendered by the extraordinary variation in the degree of folding and flexure in Traverse *Pentamerella*, described below.

***Sieberella newtonensis* Imbrie, new species**

Plate 51, figures 1-5

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) small size, (2) subglobular shape, and (3) faint anterior fold on the pedicle valve.

**DESCRIPTION:** Shell small. Outline subelliptical, elongate. Lateral profile subequally biconvex. Costae probably developed only on the anterior portion of the shell, about three per 5 mm. at the front margin, low, subround, narrower than striae. Lateral commissure gently flexed brachiad; anterior commissure gently sulcate. Marginal portions of both valves sharply geniculate.

**Pedicle Valve:** Lateral profile moderately convex, with greatest convexity at the umbo. Beak bluntly pointed, strongly incurved, projecting a little beyond the brachial beak. Anterior profile moderately and evenly convex. Low anterior fold faint or absent. Interareas low, obscurely set off.

**Brachial Valve:** Lateral profile moderately convex, with greatest convexity at the umbo. Sulcus not developed. Single track of cruralium extending to about the middle of the valve.

**MEASUREMENTS OF HOLOTYPE:** Length of pedicle valve, 15 mm.; width, 15 mm.; thickness, 13 mm.

**OCCURRENCE:** Newton Creek limestone (locality 40) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124339; Newton Creek limestone, locality 40.

**REMARKS:** The generally subglobular form of the shell, the lack of a sulcus, and the faint development of a fold are unusual for this

genus. Available specimens are exfoliated, and it is difficult to ascertain the nature and extent of the costae.

GENUS *GYPIDULA* HALL, 1867

*Gypidula* HALL, 1867, Ann. Rept. New York State Cabinet Nat. Hist., no. 20, p. 163. HALL AND CLARKE, 1893, Paleontology of New York, vol. 8, pt. 2, pp. 241, 247. SCHUCHERT AND COOPER, 1932, Mem. Peabody Mus. Nat. Hist., vol. 4, pt. 1, pp. 173-175.

DIAGNOSIS: Galeatiform pentamerids having the external form of *Sieberella*, but discrete septal plates in the brachial valve uniting directly with the floor of the valve.

*Gypidula* sp.

Plate 49, figures 19-22

A single complete specimen collected from the Genshaw formation (locality 49) is identified as *Gypidula*. Examination of the brachial beak region indicates that the septal plates are closely spaced but discrete. The shell is elongate in outline and carries a low sulcus on the brachial valve and a corresponding faint anterior pedicle fold. The rounded costae are broad and low, developed only towards the margin.

GENUS *PENTAMERELLA* HALL, 1867

*Pentamerella* HALL, 1867, Ann. Rept. New York State Cabinet Nat. Hist., no. 20, p. 163. HALL AND CLARKE, 1893, Paleontology of New York, vol. 8, pt. 2, pp. 242, 245. SCHUCHERT AND COOPER, 1932, Mem. Peabody Mus. Nat. Hist., vol. 4, pt. 1, p. 176.

DIAGNOSIS: Galeatiform pentamerids having a variably developed fold on the brachial valve, generally a sulcus on the pedicle valve, a uniplicate anterior commissure, and an interior like that of *Sieberella*.

DISCUSSION: The variable development of the fold and sulcus is of considerable interest in Traverse *Pentamerella*. On many species, such as *P. lingua*, *P. pericosta*, *P. aulax*, and *P. athyroides*, the fold is distinct and sharply set off. In others, notably *P. tumida*, *P. aftonensis*, and *P. petoskeyensis*, the fold as well as the sulcus is obscure or lacking, and the commissure is nearly rectimarginate. Flexure of the commissure when it is developed is almost always, but not invariably, in the direction of the brachial valve. Rare specimens of

*P. aftonensis* have a very slight reverse flexure. In such specimens the characteristics recognized as distinctive of *Pentamerella* do not apply. It is evident from Traverse species, however, that an attempt to separate from *Pentamerella* individuals or populations with a rectimarginate commissure would not succeed, for the intergradation between uniplicate, rectimarginate, and gently sulcate commissures is complete.

*Pentamerella lingua* Imbrie, new species

Plate 52, figures 6-10

DISTINGUISHING CHARACTERS: Several characters combine to distinguish this species: (1) medium size; (2) slightly incurved beak; (3) strong, broad costae developed on the anterior two-thirds of the valves only, rounded, numbering about 13 on mature shells; and (4) prominent fold and sulcus.

DESCRIPTION: Size moderate for the genus; largest individual observed, 30 mm. wide. Outline elongate, subelliptical to subtriangular. Middle portion of front margin corresponding to fold and sulcus projecting forward as a short tongue. Lateral profile subequally biconvex. Umbonal region smooth; costae confined to anterior two-thirds of the valves, broad, rounded, equal to or slightly wider than concave striae, rarely increasing by bifurcation, numbering about 13 on an individual of average size. Anterior commissure flexed strongly and sharply brachiad.

*Pedicle Valve*: Beak bluntly pointed, incurved, projecting beyond brachial beak. Interarea low and poorly defined. Sulcus narrow, commonly poorly defined, bearing two or three costae. Interior typical of the genus.

*Brachial Valve*: Single track of cruralium extending to about midlength.

MEASUREMENTS OF HOLOTYPE: Length of pedicle valve, 27 mm.; length of brachial valve, 25 mm.; width, 26 mm.; thickness, 16 mm.

OCCURRENCE: Ferron Point shale (localities 29, 29c, 38, 51) of Michigan.

HOLOTYPE: U.S.N.M. No. 124323; lower Ferron Point formation, locality 38.

*Pentamerella tumida* Imbrie, new species

Plate 52, figures 19-23

DISTINGUISHING CHARACTERS: Several characters combine to distinguish this species

from known congeneric forms: (1) large size, (2) deep pedicle valve bearing a high swollen umbo and strongly incurved beak, (3) strongly costate anterior portions of the shell, and (4) gently but consistently uniplicate anterior commissure. *Pentamerella tumida* resembles *P. aftonensis*, but the latter is smaller, more finely ribbed, and lacks the consistent and gentle uniplicate commissure. *Pentamerella* sp. D is similar in form but much more coarsely costate.

**DESCRIPTION:** Shell large for the genus. Lateral profile unequally biconvex, with a deep pedicle valve. Costae broad, low, rounded, wider than striae, increasing by bifurcation, numbering about five per 15 mm. along the front margin, covering only about the anterior two-thirds of the shell. Anterior commissure broadly and consistently uniplicate.

**Pedicle Valve:** Beak bluntly pointed, strongly incurved, overhanging the brachial beak. Interarea low and poorly defined. Sulcus not developed.

**Brachial Valve:** Median fold low and poorly defined when present, commonly absent. Single track of cruralium extending to about midlength.

**MEASUREMENTS OF HOLOTYPE:** Length of pedicle valve, 43 mm.; length of brachial valve, 37 mm.; width, 40 mm.; thickness, 29 mm.

**OCCURRENCE:** Genshaw formation (localities 28, 29e, 33d, 50, 52c, 107, 115, 117, 118, 123) and Newton Creek limestone (locality 40) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124293; Genshaw formation, locality 28.

**REMARKS:** Of interest in this species is the consistent development of a gently uniplicate commissure combined with the lack of a sulcus and the feeble and intermittent development of a brachial fold. The constancy of the uniplicate condition is taken as significant in the generic assignment.

***Pentamerella alpenensis* Imbrie, new species**

Plate 53, figures 9-13

**DISTINGUISHING CHARACTERS:** Several characters combine to distinguish this species: (1) moderate size; (2) moderately high, subangular costae covering the anterior two-thirds of the shell only, numbering about

eight per 15 mm. at the front margin; and (3) low but commonly distinct fold and sulcus.

**DESCRIPTION:** Shell of medium size; largest individual 30 mm. wide. Outline subtriangular, width about equal to length. Umbonal region smooth. Costae covering anterior two-thirds of shell, moderately high, subangular, about equal to striae in width, rarely increasing by bifurcation, numbering about eight per 15 mm. at the front margin. Anterior commissure with gentle but consistent uniplicate flexure.

**Pedicle Valve:** Interarea low and poorly defined. Anterior profile moderately and evenly convex. Anteromedian sulcus faint or absent.

**Brachial Valve:** Low fold commonly present. Single track of cruralium extending to about the middle of the valve.

**MEASUREMENTS OF HOLOTYPE:** Length of pedicle valve, 26 mm.; length of brachial valve, 23 mm.; width, 27 mm.; thickness, 18 mm.

**OCCURRENCE:** Alpena limestone (localities 40, 52 l), Gravel Point formation (localities 9, 14e, 18e), and Dock Street clay member of the Four Mile Dam formation (locality 53) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124279; Gravel Point formation, locality 14e.

***Pentamerella aftonensis* Imbrie, new species**

Plate 52, figures 11-18

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) large size; (2) elongate outline; (3) rectimarginate commissure; and (4) broad, low, rounded costae numbering about seven per 15 mm. at the front margin, occupying the anterior two-thirds of the valves only. This species resembles *P. tumida* in general form but differs in being more finely costate and rectimarginate. *Pentamerella* sp. D is much more coarsely costate.

**DESCRIPTION:** Size large for the genus; largest known individual, 31 mm. wide. Outline elongate. Lateral profile unequally biconvex, the pedicle valve being much deeper. Costae broad, low, rounded, equal to striae in width, numbering about seven per 15 mm. at the front margin, increasing rarely by bi-

furcation. Anterior commissure rectimarginate, rarely very slightly sulcate.

*Pedicle Valve*: Interarea low and poorly defined. Sulcus absent.

*Brachial Valve*: Fold lacking. Single track of cruralium extending to about the middle of the valve.

MEASUREMENTS OF HOLOTYPE: Length of pedicle valve, 31 mm.; length of brachial valve, 26 mm.; width, 27 mm.; thickness, 24 mm.

OCCURRENCE: Gravel point formation (localities 8a, 14, 25, 100), Gorbut member of the Gravel Point formation (localities 27a, 106, 107) of Michigan.

HOLOTYPE: U.S.N.M. No. 124292; Gravel Point formation, locality 25.

***Pentamerella pericosta* Imbrie, new species**

Plate 52, figures 1-5

DISTINGUISHING CHARACTERS: The following characters distinguish this species: (1) small size; (2) subtriangular outline; (3) broad, rounded, low costae occupying only the anterior one-third of the valves; and (4) low but distinct fold and sulcus.

DESCRIPTION: Shell small. Outline subtriangular. Surface paucicostate, with broad, rounded costae equal to striae in size, numbering about 13 or 14 at the front margin. Anterior commissure uniplicate, with a low distinct flexure.

*Pedicle Valve*: Interarea small but distinctly set off. Anterior sulcus low.

*Brachial Valve*: Anterior fold low. Interior with septal plates meeting at the floor of the valve to form a sessile cruralium.

MEASUREMENTS OF HOLOTYPE: Length of pedicle valve, 18 mm.; length of brachial valve, 16 mm.; width, 18 mm.; thickness, 11 mm.

OCCURRENCE: Norway Point formation (localities 46, 47) and Beebe School formation (localities 23, 24b) of Michigan. Widder and Hungry Hollow formations of Ontario. Logansport limestone of Indiana.

HOLOTYPE: U.S.N.M. No. 124398; Norway Point formation, locality 47.

***Pentamerella petoskeyensis* (Imlay), 1932**

Plate 51, figures 25-30

*Gypidula petoskeyensis* IMLAY, 1932, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, no. 5, pp. 101-104, pl. 1.

DISTINGUISHING CHARACTERS: The following characters distinguish this species: (1) large size; (2) subtrigonal outline; (3) subangular ribs occupying about two-thirds of the valve, numbering about five per 15 mm. at the front margin; and (4) rectimarginate anterior commissure.

DESCRIPTION: Size large for the genus. Outline subtrigonal. Costae occupying about two-thirds of the valve, subangular anteriorly, rounded posteriorly, equal to or a little wider than the striae in width, rarely increasing by bifurcation, numbering about five per 15 mm. at the front margin. Anterior commissure rectimarginate.

*Pedicle Valve*: Sulcus absent. Interarea small, poorly defined.

*Brachial Valve*: Fold lacking.

MEASUREMENTS OF HOLOTYPE: Length of pedicle valve, 22 mm.; length of brachial valve, 20 mm.; width, 24 mm.; thickness, 13 mm.

OCCURRENCE: Middle Petoskey formation (localities 21, 21a, 102) and Potter Farm formation (localities 41c, 42, 42a, 122) of Michigan.

***Pentamerella papilla* Imbrie, new species**

Plate 51, figures 18-24

DISTINGUISHING CHARACTERS: This species is easily distinguished by its small size and papillose surface.

DESCRIPTION: Outline elongate, subtriangular, narrow. Costae subangular, increasing by occasional bifurcation, about equal to striae in width, numbering about four per 5 mm. at the front margin. Surface covered with prominent lamellae and concentric lines composed of rows of tiny papillae. Commissure uniplicate.

*Pedicle Valve*: Sulcus absent. Interior typical of the genus, with spondylium duplex and short median septum.

*Brachial Valve*: Anterior fold faint. Interior typical of the genus, with septal plates converging to form a V-shaped, sessile cruralium.

MEASUREMENTS OF HOLOTYPE: Length of pedicle valve, 13 mm.; length of brachial valve, 11 mm.; width, 12 mm.; thickness, 19 mm.

OCCURRENCE: Potter Farm formation (localities 27, 42, 119) of Michigan.



**HOLOTYPE:** U.S.N.M. No. 124407; Potter Farm formation, locality 37b.

**REMARKS:** The papillose surface of this species is a striking feature. A similar ornamentation is known in *Gypidula dudleyensis* Schuchert from the Silurian Wenlock of England, and from specimens of *Pentamerella* from the lower Coralville of Iowa which are very close to *P. papilla* but differ in having wider costae. The papillae are visible only on well-preserved parts of the surface.

***Pentamerella proteus* Imbrie, new species**

Plate 53, figures 1-8

**DISTINGUISHING CHARACTERS:** Several characters distinguish this species: (1) small size; (2) subtrigonal outline; and (3) strong, subangular costae, equal to striae in width, and numbering about three per 5 mm. at the front margin. *Pentamerella proteus* suggests *P. liorhyncha*, but lacks the sharp fold and characteristic long, shallow sulcus of that species.

**DESCRIPTION:** Shell small. Outline subtrigonal. Ornamentation costate; costae subangular to subround, broad, moderately strong, numbering about three per 5 mm. at the front margin, and occupying about two-thirds of the valves. Uniplicate.

**Pedicle Valve:** Interarea narrow but distinctly set off. Sulcus absent.

**Brachial Valve:** Anterior fold low. Anterior profile gently convex, evenly so or with greatest convexity at the midline.

**MEASUREMENTS OF HOLOTYPE:** Length of pedicle valve, 14 mm.; length of brachial valve, 12 mm.; width, 17 mm.; thickness, 9 mm.

**OCCURRENCE:** Thunder Bay formation (locality 35) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124308; Thunder Bay formation, locality 35.

**REMARKS:** The species is remarkably variable in the depth of the pedicle valve, the height of the pedicle interarea, length-width ratio, number of costae, separation of beaks, and shape of costae. Intergrading forms occur, however, and valid subdivisions cannot be made.

***Pentamerella aulax* Imbrie, new species**

Plate 51, figures 11-17

**DISTINGUISHING CHARACTERS:** Several characters distinguish this species: (1) me-

dium size; (2) subtriangular outline; (3) high pedicle valve, with a strongly incurved projecting beak; (4) strong angular costae numbering about six per 10 mm. at the front margin; and (5) sharply defined fold and sulcus. *Pentamerella multicostata* Cleland is the most similar described species, differing in being more finely costate.

**DESCRIPTION:** Size moderate. Outline subtrigonal. Multicostate; costae strong, angular, equal to striae in width and shape, increasing rarely by implantation and bifurcation, extending from umbo to margin, numbering about six per 10 mm. at the front margin. Anterior commissure sharply uniplicate.

**Pedicle Valve:** Interarea relatively wide for the genus and well marked. Sulcus prominent, extending nearly to beak, flat-floored, bearing five or six costae, deeply impressed. Interior typical of the genus.

**Brachial Valve:** Fold high, prominent, sharply set off, extending to umbo, bearing about six costae. Track of cruralium extending to about midlength.

**MEASUREMENTS OF HOLOTYPE:** Length of pedicle valve, 32 mm.; length of brachial valve, 26 mm.; width, 32 mm.; thickness, 22 mm.

**OCCURRENCE:** Uppermost Petoskey formation (locality 7c) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124253; uppermost Petoskey formation, locality 7c.

***Pentamerella athyroides* (Winchell), 1866**

Plate 51, figures 6-10

*Martinia athyroides* WINCHELL, 1866, The Grand Traverse region, p. 94.

*Pentamerella athyroides* (Winchell), EHLERS AND KLINE, 1934, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, no. 10, pp. 159-161.

**DISTINGUISHING CHARACTERS:** Several characters distinguish this species: (1) medium size; (2) subtrigonal outline; (3) costae low, subround, extending from umbo to margin, numbering six per 10 mm.; and (4) commissure gently but distinctly uniplicate.

**DESCRIPTION:** Shell of medium size. Outline subtrigonal. Costae broad, low, rounded, wider than striae, increasing by bifurcation, extending from umbo to margin, numbering about six per 10 mm. at the front margin. Anterior commissure gently but distinctly uniplicate.

**Pedicle Valve:** Interarea rather wide and

distinct for the genus. Sulcus absent. Interior typical of the genus.

**Brachial Valve:** Fold low, distinct, extending from umbo to margin, bearing four or five costae. Interior with septal plates meeting to form a sessile cruralium.

**OCCURRENCE:** Lower Petoskey formation (localities 10, 12, 18, 104) of Michigan.

***Pentamerella* sp. A**

Plate 49, figures 23, 24

Three specimens from the lower Bell shale are here designated *Pentamerella* sp. A. The shells are large, averaging 32 mm. in width. Costae occupy only the anterior half of the valve, and are broad, subround, and equal to the striae in width.

***Pentamerella* sp. B**

Plate 53, figures 14-17

Two specimens from the Rockport Quarry limestone (basal 8 inches) are here designated *Pentamerella* sp. B. The shells are small, averaging 11 mm. in length, and subglobular in form.

***Pentamerella* sp. C**

Plate 49, figures 30-32

A complete and distinctive specimen from the Dock Street clay is here designated *Pentamerella* sp. C. In form it resembles most closely *P. alpenensis*, but it differs from that species in being much narrower and having much coarser and fewer costae.

***Pentamerella* sp. D**

Plate 49, figures 25-27

A small collection of specimens from the Gravel Point formation are so distinctive as to merit designation as *Pentamerella* sp. D. The shells are large, the largest being 38 mm. long. Large individuals are elongate and similar in shape and form to *P. tumida* and *P. aftonensis*, but differ from them both in being much more coarsely costate.

***Pentamerella* sp. E**

Plate 49, figures 28, 29

A small collection of shells from the Potter Farm formation is here designated *Pentamerella* sp. E. Their ornamentation is distinctive, the umbonal region being smooth and the anterior portions of the shell possess-

ing narrow, rounded ribs. The shell somewhat resembles that of *P. alpenensis*, but the costae originate farther from the beak and are lower and less angular. A specimen from the Mineola limestone of Missouri is smaller than the Traverse form but identical with the corresponding growth stage.

**SUPERFAMILY STROPHOMENACEA**  
SCHUCHERT, 1896

**GENUS STROPHODONTA HALL, 1850**

*Strophodonta* HALL, 1850, Proc. Amer. Assoc. Adv. Sci., vol. 2, pp. 348, 349.

*Stropheodonta* HALL, 1852, Paleontology of New York, vol. 2, p. 63.

*Strophodonta* HALL, 1858, Rept. Geol. Surv. Iowa, vol. 1, p. 491.

*Strophodonta* HALL, 1867, Paleontology of New York, vol. 4, p. 78.

*Stropheodonta* HALL AND CLARKE, 1892, Paleontology of New York, vol. 8, pt. 1, pp. 284-289.

**DIAGNOSIS:** Outline semicircular to elongate and elliptical; mucronate. Lateral profile concavo-convex. Pseudodeltidium flat. Ornamentation costellate to costate; ribs subequal and uninterrupted; corrugations lacking. Pedicle valve with a completely crenulated hinge; sealed apical foramen; broadly flabellate diductor and small lanceolate adductor scars. Brachial valve with large, bilobed, cardinal process and a quadripartite muscle field separated by a simple median septum and two sinuous ridges.

**DISCUSSION:** *Strophodonta* is one of the most abundant, ubiquitous, and stratigraphically important fossils in the Traverse group. It occurs in all but two of the named formations (Squaw Bay and Charlevoix), and, because it is generally available in quantities of well-preserved material, the genus provides unique opportunities for an inductive paleontologic study of speciation. The abundance of material is at once the bane and the blessing of the taxonomist, for many theoretical difficulties in the compartmentation of what was once a biologic continuum are here met in fact. In order to avoid on the one hand a fruitless overproduction of taxonomic divisions, and unmanageably inclusive units on the other, an attempt has been made to formulate a taxonomic scheme such that the boundaries of species are judged to enclose a group of local populations potentially capable of interbreeding. Geographic and chrono-

logic subspecies have been employed where infraspecific groupings were of sufficient stratigraphic importance to warrant formal designation. Simpson (1943) has pointed out that the practical means by which the paleontologist attempts to apply neontologic principles of this sort lie in a study of the *distribution* of selected characters within and between populations.

Specimens of Alpena *Strophodonta* have been assigned to eight species. Such subdivision of a genus from a single formation is amply justified by the fossils themselves: although the samples are small, the groups are quite distinct and the characteristics do not overlap those of neighboring groups. Individuals of Alpena *Strophodonta* form, in this, a contrast to those of underlying formations, particularly the Genshaw and Ferron Point, where the samples are very large and the species fewer. If we accept the collectable fossils as an index, however approximate, of the size of the living populations, we arrive at this conclusion: that during Genshaw and Ferron Point deposition, two or three contemporaneous species formed large and variable populations, but that Alpena deposition was marked by small and localized populations of eight species. Now the Alpena limestone is also remarkable for the presence in it of biohermal masses apparently representing ancient reefs. The coincidence of reefy lithology with maximum strophodont speciation involving small populations suggests strongly that the taxonomic diversity is a reflection of an environment marked by a diversity of ecologic niches. Such an environment, following more uniform conditions, would have been ideal for the splitting of large, variable populations into smaller isolated units, many of which could develop into distinct species.

A total of 24 species (and 11 subspecies) are here recognized in the Traverse fauna. Of this number, only two are identified with non-Michigan forms, which is undoubtedly owing in part to a lack of detailed knowledge of other equivalent sections, and in part to a certain degree of biologic isolation of the Michigan area. The two identifications that can be made, however, are susceptible of more precise biostratigraphic interpretation under the proposed classification than would otherwise be possible.

A nomenclatural problem arises in con-

nection with this genus. In 1850 Hall proposed the genus *Strophodonta*, giving a brief diagnosis, citing *Leptaena demissa* Conrad as type, and remarking that the name referred to the crenulated hinge. Etymologically he was in error on this point, for the derivation implied by the name would be "twisted tooth" (Greek *strophos*, twisted; *odous*, tooth). Two years later, apparently wishing to correct this etymology, he designated the genus *Stropheodonta*, giving the derivation as Greek *stropheus*, a hinge. In 1858 and 1867, however, he reverted to the 1850 usage as *Strophodonta*. In 1892 Hall and Clarke employed *Stropheodonta* once more, saying that this "original usage" should be retained as more appropriate. They are correct in considering *Stropheodonta* as more appropriate, but wrong in referring to it as the original usage. The proper form is the usage of 1850, 1858, and 1867. The statement of Hall and Clarke (1892, p. 284) clearly indicates that two separate etymologies are involved, so that the first usage cannot be corrected as a *lapsus calami* or incorrect transliteration.

#### MORPHOLOGY OF TRAVERSE *Strophodonta*

Specific and subspecific importance has been attached to the following characters: the coarseness and character of the ornamentation, convexity, outline, heights of interareas, size, configuration of the ventral process, and the relative length of the diductor and adductor impressions in the pedicle valve. Despite the great variability in these characters, the interiors are, with the exception of *S. heteromys*, nearly constant and match those of *S. demissa*, the genotype.

The pattern of the pedicle interior is remarkably uniform. The ventral process varies somewhat in shape, but is typically Y-shaped in cross section. The apex of the Y is contiguous with the pseudodeltidium and projects anteriorly as two bluntly rounded projections articulating with corresponding depressions in the back of the cardinal process; the structure is extended in the direction of the pedicle valve into two ridges or nodes running forward to meet the posterior ends of the adductor scars. Pits for the reception of the cardinal process lobes lie on each side. The quadripartite adductor field is lanceolate or elliptical in outline, medially divided by a shallow groove. The posterior adductors ex-

tend slightly laterally of the anterior pair. Two subflabellate, radially fluted diductor scars extend anterolaterally from the adductors, extending forward to midlength or beyond. Bounding ridges are variably developed but always low. The relative lengths of the adductor and diductor fields vary, but this character is rarely useful in specific definition. A subperipheral rim is variably developed in all species, generally correlated with the relative size of the shell. The inner surface of both valves is marked by tiny pustules, arranged in an obscure radiating pattern.

The pattern of the brachial interior is constant, except in *S. heteromys*. The cardinal process is a stout, erect structure with two distinct lobes directed posteriorly at an angle of about 45 degrees to the plane of the commissure. The myophore surfaces are vertical, or nearly so. Two shallow pits excavated behind the cardinal process receive blunt projections from the ventral process. Brachial processes, present in the form of low, widely diverging ridges, bound the denticulate area of the hinge medially. The muscle field is divided by a medium septum which extends forward from the base of the cardinal process to or beyond the midpoint, typically rising anteriorly. A sinuous adductor dividing ridge runs anterolaterally from a point just anterior to each brachial process, curving medially and rising to a point located at the anterior end of the posterior adductor. From this point it swings sharply posteriorly, dividing the adductor pairs, and terminates at the notothyrial platform near the median ridge. Each of the four adductor scars is divided again by a variably developed, generally low, inconspicuous, radial ridge. The area immediately in front of the adductor field is commonly elevated and more coarsely pustulose than the remainder of the floor of the valve. The posterior adductors are reniform areas bounding the elliptical anterior adductors laterally.

***Strophodonta extenuata* Imbrie, 1955**

Plate 54, figures 1-29

*Strophodonta extenuata* IMBRIE, 1955, Amer. Mus. Novitates, no. 1754, p. 2, figs. 1-20.

**DISTINGUISHING CHARACTERS:** Although this species exhibits an extraordinarily wide range of variation, several features combine

for one to distinguish it without difficulty from known congeneric forms. The outline, although variable, is always markedly wider than long and generally subsemicircular. The lateral profile is always moderately to strongly concavo-convex. Two extremes of ornamentation, with intermediate types, occur: some shells possess subequal and angular costellae, numbering about 13 per 5 mm. at midlength, and decreasing regularly and gradually in size as they increase in number from beak to margin; other forms have costellae markedly coarser umbonally and decreasing rapidly in size as they increase in number to about 13 per 5 mm. near the front margin.

**DESCRIPTION:** Shells of medium size. Outline variable, subsemicircular to transversely subelliptical; slightly mucronate. Slopes to cardinal extremities moderately concave; lateral profile moderately to deeply concavo-convex. Ornamentation varying between two extremes: some forms with costellae numbering about 13 per 5 mm. at midlength and increasing in number gradually from beak to front margin as they decrease in size; others with markedly larger umbonal costellae, decreasing in size rapidly marginally. Costellae low, subround to subangular, about equal to striae in width.

**Pedicle Valve:** Lateral profile varying from moderately to strongly convex, generally evenly convex. Anterior profile generally evenly and either moderately or strongly convex. Rarely subcarinate. Umbonal region gently to moderately inflated. Interarea low. Interior with adductor scar from one-third to one-half of the length of the muscle field; extremities of ventral process narrowly divergent and projecting as tiny bosses.

**Brachial Valve:** Anterior profile commonly evenly and moderately concave. Lateral profile either with greatest concavity between midlength and the front margin, or evenly and moderately concave. Interior typical of the genus.

**OCCURRENCE:** The species is known from the Bell, Rockport Quarry, Ferron Point, and Genshaw formations in Michigan, and from the Arkona shale of Ontario.

**REMARKS:** The abundance and great variability of this species make it one of the most interesting parts of the strophodont fauna. Important taxonomic characters are con-

sidered to be the ornamentation and shape of the shell. The shape varies from a wide, rather flat, subelliptical form (pl. 54, fig. 19) to a longer form with subsemicircular outline and subcarinate pedicle valve (pl. 54, fig. 14) to a subquadrate type with a rather low umbonal region (pl. 54, fig. 2). The ornamentation, as indicated above, varies between two extremes. The key to the interpretation of the data lies in an analysis of the distribution of these characters within the known stratigraphic framework. The available samples may be divided into five lots from the lower and upper Bell shale, lower and upper Ferron Point formation, and Genshaw formation. Within each lot the characters follow a normal distribution, i.e., the majority of individuals in the intergrading assemblage cluster around a morphologic mean, with fewer specimens representing divergences; and as this is the pattern within modern interbreeding populations, the samples cannot be validly subdivided. Any one of the five lots, however, shows a *mean* morphologic form which easily distinguishes it, but in each horizon there are extreme forms that may be identical with the mean individuals of other horizons. It is evident that paleontologic and stratigraphic precision demands the recognition of five taxonomic units. Simpson (1943, p. 175) has dealt effectively with any objections to such a course: "If two specimens cannot be distinguished, except by trivial variations admittedly less than can occur within a subspecies, how can one maintain that they are taxonomically distinct? . . . [The objection is] based on the fallacious tendency to compare *individuals* when the correct comparison is of *groups*. The groups as such [may be] readily distinguishable even though some individuals are not." The morphologic observations cited above clearly indicate that these groups are very closely allied. To consider each group as a separate species would, without the erection of a subgenus, obscure this close relationship. A far better taxonomic expression, it seems to me, is to consider the groups as comprising a single species with five subspecies.

***Strophodonta extenuata bellensis* Imbrie, 1955**

Plate 54, figures 1-7

*Strophodonta extenuata bellensis* IMBRIE, 1955, Amer. Mus. Novitates, no. 1754, p. 3, figs. 16-20.

**DISTINGUISHING CHARACTERS:** The following characteristics distinguish this subspecies from conspecific groups: (1) small size, (2) subquadrate outline, (3) deeply concavo-convex lateral profile, (4) gently inflated umbonal region, (5) subgeniculate profile, and (6) finely and rather uniformly multicostellate ornamentation.

**DESCRIPTION:** Shell small. Outline subquadrate, a little wider than long, slightly mucronate. Profile commonly strongly concavo-convex. Ornamentation uniformly and finely multicostellate; costellae low, rounded, subequal, numbering about 17 in a distance of 5 mm.

*Pedicle Valve:* Lateral profile moderately to strongly convex, with point of greatest convexity between midlength and front margin. Anterior profile evenly convex. Umbonal region gently inflated.

*Brachial Valve:* Lateral and anterior profiles gently and evenly concave. Umbonal region depressed.

**MEASUREMENTS OF HOLOTYPE:** Length, 21 mm.; width, 24 mm.; thickness, 8 mm.

**OCCURRENCE:** Bell shale (localities 31, 38) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124325, from the upper Bell shale, locality 38.

***Strophodonta extenuata rockportensis***

Imbrie, 1955

Plate 54, figures 8-12

*Strophodonta extenuata rockportensis* IMBRIE, 1955, Amer. Mus. Novitates, no. 1754, p. 3, figs. 6-10.

**DISTINGUISHING CHARACTERS:** This subspecies resembles *S. extenuata extenuata* in the character of its ornamentation, but differs in being larger and flatter. The ornamentation, large size, and relatively low convexity distinguish *S. extenuata rockportensis* from other conspecific groups.

**DESCRIPTION:** Shell large, commonly 30 mm. long. Outline transversely subelliptical. Lateral profile slightly or moderately convex. Ornamentation as in *S. extenuata extenuata*.

*Pedicle Valve:* Lateral and anterior profiles evenly convex. Umbonal region commonly slightly swollen.

*Brachial Valve:* Lateral and anterior profiles gently and evenly concave.

**MEASUREMENTS OF HOLOTYPE:** Length, 22 mm.; width, 26 mm.; thickness, 7 mm.

OCCURRENCE: Lower 8 inches of the Rockport Quarry limestone (locality 38) of Michigan.

HOLOTYPE: U.S.N.M. No. 124327; Rockport Quarry Limestone, locality 38.

***Strophodonta extenuata extenuata***  
Imbrie, 1955

Plate 54, figures 13-17

*Strophodonta extenuata extenuata* IMBRIE, 1955, Amer. Mus. Novitates, no. 1754, p. 5, figs. 11-15.

DISTINGUISHING CHARACTERS: The following characters distinguish this subspecies: (1) transversely subsemicircular outline, (2) moderately to strongly concavo-convex profile, (3) inflated umbo, and (4) the character of the ornamentation.

DESCRIPTION: Shell of medium size. Outline transversely subsemicircular. Lateral profile moderately to deeply concavo-convex. Ornamentation multicostellate; costellae rounded and coarse umbonally, rapidly increasing in number and decreasing in size towards the margin, where the rib count is about 13 in a distance of 5 mm.; costellae subangular to subround, narrower than striae; striae rounded.

*Pedicle Valve*: Lateral profile moderately to strongly and evenly convex. Anterior profile with greatest convexity along the midline, sloping with gentle convexity laterally. Umbonal region swollen.

*Brachial Valve*: Lateral profile moderately convex, shallower than the pedicle valve. Anterior profile with greatest concavity along the midline, corresponding to the low pedicle carina.

MEASUREMENTS OF HOLOTYPE: Length, 25 mm., width, 28 mm.; thickness, 8 mm.

OCCURRENCE: Lower Ferron Point formation (localities 29, 29c, 38) of Michigan, Arkona shale of Ontario.

HOLOTYPE: U.S.N.M. No. 124326; lower Ferron Point formation, locality 38.

***Strophodonta extenuata ferronensis***  
Imbrie, 1955

Plate 54, figures 18-22

*Strophodonta extenuata ferronensis* IMBRIE, 1955, Amer. Mus. Novitates, no. 1754, p. 6, figs. 1-5.

DISTINGUISHING CHARACTERS: In ornamentation the subspecies resembles *S. extenuata bellensis*, but it may be distinguished

by its larger size and the even convexity of the pedicle valve. In shape it resembles specimens of *S. extenuata rockportensis*, but it differs in ornamentation.

DESCRIPTION: Shell of a medium size. Outline transversely subelliptical to subquadrate, width a little greater than length. Lateral profile moderately concavo-convex. Ornamentation commonly as in *S. extenuata bellensis*, rarely with coarser umbonal costellae.

*Pedicle Valve*: Lateral and anterior profiles evenly and gently to moderately convex. Umbonal region gently inflated.

*Brachial Valve*: Lateral and anterior profiles evenly and gently concave, shallower than pedicle valve. Umbonal region slightly depressed.

MEASUREMENTS OF HOLOTYPE: Length, 26 mm.; width, 30 mm.; thickness, 8 mm.

OCCURRENCE: Upper Ferron Point formation (locality 51) of Michigan. Arkona shale of Ontario.

HOLOTYPE: U.S.N.M. No. 124333; upper Ferron Point formation, locality 51.

***Strophodonta extenuata genshawensis***  
Imbrie, new subspecies

Plate 54, figures 23-27

DISTINGUISHING CHARACTERS: The pattern of the ornamentation is like that of *S. extenuata bellensis* and *S. extenuata ferronensis*, although a little coarser, but many individuals tend to the *S. extenuata extenuata* pattern. The subspecies is distinguished from *S. extenuata bellensis* by its evenly convex lateral profile and tapering lateral margins; from *S. extenuata ferronensis* by its relatively greater width, greater convexity, and tapering lateral margins; from *S. extenuata extenuata* by its restriction of coarser costellae to the umbo, greater width, and more tapering lateral margins; and from *S. extenuata rockportensis* by its greater depth and more tapering lateral margins.

DESCRIPTION: Shell of medium size. Outline generally transverse, subsemicircular to subelliptical. Ornamentation variable, costellae either relatively constant in size from umbo to margin or slightly coarser umbonally and gradually decreasing in size anteriorly.

*Pedicle Valve*: Lateral profile moderately and evenly convex. Anterior profile with



greatest convexity along the midline. Umbonal region commonly slightly swollen.

*Brachial Valve*: Lateral profile slightly or moderately concave, shallower than pedicle valve, and with greatest concavity between midlength and front margin. Umbonal region not depressed.

MEASUREMENTS OF HOLOTYPE: Length, 28 mm.; width, 36 mm.; thickness, 10 mm.

OCCURRENCE: Genshaw formation (localities 32h, 38, 49, 51, 51c, 108, 109, 132) of Michigan.

HOLOTYPE: U.S.N.M. No. 124332; lower Genshaw formation, locality 51.

***Strophodonta fascis* Imbrie, new species**

Plate 53, figures 30–35

**DISTINGUISHING CHARACTERS**: This species is distinguished by a combination of the following characters: (1) medium size; (2) subquadrate to subelliptical outline; (3) strongly and evenly convex lateral profile; (4) swollen umbonal region; and (5) a rather coarse, unequal, sub-fasciculate ornamentation in which the costellae decrease in size anteriorly.

**DESCRIPTION**: Shell of medium size. Outline subelliptical to subquadrate; greatest width at midlength. Lateral profile deeply concavo-convex. Ornamentation coarsely multicostellate; costellae arranged in fascicles, becoming finer towards the margins.

MEASUREMENTS OF HOLOTYPE: Length, 20 mm.; width, 20 mm.; thickness, 9 mm.

OCCURRENCE: Ferron Point formation (localities 38, 51) of Michigan.

HOLOTYPE: U.S.N.M. No. 124330; lower Ferron Point shale, locality 38.

***Strophodonta titan* Imbrie, new species**

Plate 55, figures 1–6, 14–18

**DISTINGUISHING CHARACTERS**: This species is distinguished by its unusually large size, with individuals commonly 50 mm. long; its markedly transverse, subsemicircular outline; and its strongly concavo-convex lateral profile. The nearest described form is *S. calloveyensis* from the Snyder Creek shale of Missouri, which is easily distinguished by outline and profile.

**DESCRIPTION**: Shell large. Outline commonly subsemicircular, rarely transversely subelliptical. Lateral profile deeply concavo-convex. Ornamentation variable; costellae

commonly angular, subequal and either relatively constant in size or becoming finer anteriorly.

*Pedicle Valve*: Lateral profile evenly and strongly convex. Umbonal region moderately swollen. Interarea low. Interior with adductor scars extending forward over half of the length of the muscle field; adductor scars relatively large.

*Brachial Valve*: Lateral profile strongly and evenly concave. Posterolateral areas tending to be depressed as shallow troughs. Umbonal region not depressed. Interior typical of the genus.

OCCURRENCE: The species is known from the Genshaw, Alpena, and Gravel Point formations of Michigan.

REMARKS: Specimens assigned to this species fall naturally into two groups, the first confined to the Genshaw, and the second to the Alpena and Gravel Point formations. Although their morphologic means differ markedly, both groups contain extreme individuals that duplicate the normal condition of the other. Subspecific categories have been chosen to express this close stratigraphic and biologic relationship.

***Strophodonta titan costella* Imbrie, new species and subspecies**

Plate 55, figures 14–18

**DISTINGUISHING CHARACTERS**: This subspecies is distinguished from *S. titan titan* by the following characters: (1) smaller size and (2) finer and more numerous costellae.

**DESCRIPTION**: Size large, with the largest individual known 40 mm. in length. Costellae numbering about 14 per 10 mm. at the front margin. Otherwise as described for the species.

MEASUREMENTS OF HOLOTYPE: Length, 26 mm.; width, 31 mm.; thickness, 10 mm.

OCCURRENCE: Genshaw formation (localities 49, 123, 127, 138) of Michigan.

HOLOTYPE: U.S.N.M. No. 124371; Genshaw formation, locality 123a.

***Strophodonta titan titan* Imbrie, new species and subspecies**

Plate 55, figures 1–6

**DISTINGUISHING CHARACTERS**: *Strophodonta titan titan* is distinguished from *S. titan costella* in being more coarsely ribbed and larger.

**DESCRIPTION:** Shell very large for the genus, with many shells exceeding 40 mm. in length. Ornamentation coarsely multicostellate; costellae numbering eight to 10 in a distance of 10 mm. Otherwise as described for the species.

**MEASUREMENTS OF HOLOTYPE:** Length, 53 mm.; width, 65 mm.; thickness, 18 mm.

**OCCURRENCE:** Gravel Point formation (localities 14, 14e, 15a, 18a) and Alpena limestone (locality 40) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124267; Gravel Point formation, locality 14.

***Strophodonta paula* Imbrie, new species**

Plate 56, figures 23-26

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) small size; (2) subquadrate to subelliptical outline; and (3) low, rounded costellae numbering about eight in a distance of 5 mm.

**DESCRIPTION:** Shell of small to medium size, largest individual 25 mm. long. Outline subquadrate to subelliptical. Ornamentation multicostellate, costellae subequal, low, rounded, numbering about eight in a distance of 5 mm.; rarely coarser umbonally.

**Pedicle Valve:** Lateral profile evenly and generally moderately convex, or with middle portion somewhat flattened. Anterior profile with even and low or moderate convexity. Umbonal region generally slightly swollen.

**Brachial Valve:** Anterior and lateral profiles gently and evenly convex. Posterolateral areas somewhat flattened. Umbonal region not depressed. Interior typical of the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 18 mm.; width, 21 mm.; thickness, 6.3 mm.

**OCCURRENCE:** Alpena limestone (locality 521) and Dock Street clay member of the Four Mile Dam formation (locality 53) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124368; Alpena limestone, locality 521.

***Strophodonta leptoidema* Imbrie, new species**

Plate 53, figures 18-21

**DISTINGUISHING CHARACTERS:** Several characters distinguish this species: (1) large size, (2) subsemicircular to subelliptical outline, (3) gently convex lateral profile, and (4) coarse subangular costellae.

**DESCRIPTION:** Shell large. Outline subsemicircular to subelliptical, transverse, markedly wider than long. Ornamentation coarsely multicostellate, costellae subangular, constant, subequal, numbering about 10 to 13 in a distance of 10 mm.

**Pedicle Valve:** Interior with adductor field extending about one-half of the length of the muscle field; diductors separated in front.

**Brachial Valve:** Interior typical of the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 35 mm.; width, 43 mm.; thickness, 9 mm.

**OCCURRENCE:** Alpena limestone (locality 40) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124342; Alpena limestone, locality 40.

***Strophodonta nanus* Imbrie, new species**

Plate 53, figures 25-29

**DISTINGUISHING CHARACTERS:** Although this species resembles young growth stages of *Strophodonta leptoidema*, the closely spaced growth lines and subgeniculate condition of the shell near the margins are indications of maturity.

**DESCRIPTION:** Shell small; greatest known length, 17 mm. Ornamentation as in *Strophodonta leptoidema*.

**MEASUREMENTS OF HOLOTYPE:** Length, 16 mm.; width, 19 mm.; thickness, 5 mm.

**OCCURRENCE:** Alpena limestone (localities 40, 521), Gravel Point formation (locality 14), and Dock Street clay member of the Four Mile Dam formation (locality 53) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124344; Alpena limestone, locality 40.

***Strophodonta acris* Imbrie, new species**

Plate 57, figures 28-32

**DISTINGUISHING CHARACTERS:** Several characters distinguish this species: (1) medium size, (2) transverse outline, (3) strongly concavo-convex lateral profile, (4) swollen umbonal region, and (5) unequal costellae.

**DESCRIPTION:** Shell of medium size for the genus, maximum length about 20 mm. Outline subsemicircular to subelliptical, transverse, hinge width equal to greatest width. Costellae unequal to subequal in size, high, varying in number from about 12 to 16 in a

distance of 10 mm.; commonly slightly fasciculate.

*Pedicle Valve*: Interior with adductor scar about one-half of the length of the muscle field; diductors nearly enclosing adductors.

*Brachial Valve*: Interior typical of the genus.

MEASUREMENTS OF HOLOTYPE: Length, 17 mm.; width, 20 mm.; thickness, 7 mm.

OCCURRENCE: Genshaw formation (localities 49, 52, 52h, 108, 118, 138) of Michigan.

HOLOTYPE: U.S.N.M. No. 124372; Genshaw formation, locality 123a.

***Strophodonta erratica* Winchell, 1866**

Plate 57, figures 33–43

*Strophodonta erratica* WINCHELL, 1866, The Grand Traverse region, p. 93. EHLERS AND KLINE, 1934, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, p. 150, pl. 1, figs. 4–9.

*Strophodonta erratica* var. *solidicosta* WINCHELL, 1866, The Grand Traverse region, p. 93. EHLERS AND KLINE, 1934, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, pp. 153, 154, pl. 1, figs. 14–19.

*Strophodonta cincta* WINCHELL, 1866, The Grand Traverse region, p. 93. EHLERS AND KLINE, 1934, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, pp. 149, 150, pl. 1, figs. 1–3.

DISTINGUISHING CHARACTERS: The following characters distinguish this species: (1) evenly and strongly concavo-convex lateral profile; (2) swollen umbonal region; and (3) unequal, strong, angular costellae numbering from eight to 16 in a distance of 10 mm. near the front margin.

DESCRIPTION: Shell small to large, commonly 14 to 20 mm. long, with extreme individuals reaching 29 mm. Outline variable. Hinge width equal to the greatest width. Lateral profile strongly and evenly convex. Ornamentation coarsely multicostellate; costellae strong, angular, unequal, numbering eight to 16 in a distance of 10 mm. near the front margin.

*Pedicle Valve*: Lateral and anterior profiles strongly and evenly convex. Umbonal region moderately to strongly swollen.

*Brachial Valve*: Anterior and lateral profiles moderately and evenly concave. Interior typical of the genus.

OCCURRENCE: Alpena limestone (localities 40, 521, 53), Dock Street clay member of the Four Mile Dam formation (locality 53), and

Gravel Point formation (localities 8, 9, 14, 14c, 14e, 15a, 17) of Michigan.

REMARKS: The abundant collections of this species suggest that the species was widespread and prolific. Great variation is exhibited in size, shape, and ornamentation. The recurrence of identical forms at different localities and horizons, together with the complete intergradation in morphology exhibited, indicates that the whole assemblage should be treated as a single species.

***Strophodonta fissicosta* (Winchell), 1866**

Plate 57, figures 17–22

*Strophodonta erratica* var. *fissicosta* WINCHELL, 1866, The Grand Traverse region, p. 93. EHLERS AND KLINE, 1934, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, no. 10, pp. 151, 152, pl. 1, figs. 10–13.

DISTINGUISHING CHARACTERS: Several characters distinguish this species: (1) medium size, (2) low length-width ratio, and (3) subfasciculate ornamentation.

DESCRIPTION: Largest known individual, 24 mm. long. Outline transversely subelliptical. Ornamentation multicostellate, increasing by implantation and bifurcation; costellae thin, angular, subfasciculate.

*Pedicle Valve*: Interior with adductor field rather broad, occupying about one-half of the length of the muscle field.

*Brachial Valve*: Interior typical of the genus.

OCCURRENCE: Upper Gravel Point formation (localities 9, 13, 14, 14e, 18, 18a) and Dock Street clay member of the Four Mile Dam formation (locality 53) of Michigan.

***Strophodonta proteus* Imbrie, new species**

Plate 57, figures 1–6

DISTINGUISHING CHARACTERS: The following characters distinguish this species: (1) medium size; (2) moderately and evenly concavo-convex lateral profile; and (3) coarsely multicostellate ornamentation, with the costellae subequal, not fasciculate, strong, variable in width, subangular, equal to striae in width and shape and numbering about 11 or 12 per 10 mm. near the front margin.

DESCRIPTION: Outline transversely subelliptical. Lateral profile uniformly and moderately concavo-convex. Ornamentation coarse-

ly multicostellate; costellae variable in width, strong, subangular, equal to striae in width and shape, subequal, not fasciculate, numbering about 11 or 12 in a distance of 10 mm. near the front margin.

*Pedicle Valve*: Interior with adductor field about one-half of the length of the muscle field.

MEASUREMENTS OF HOLOTYPE: Length, 15 mm.; width, 17 mm.; thickness, 6.5 mm.

OCCURRENCE: Alpena limestone (locality 521) of Michigan. Lower Centerfield formation,  $2\frac{1}{2}$  miles west of East Bethany, New York.

HOLOTYPE: U.S.N.M. No. 124369; Alpena limestone, locality 521.

REMARKS: The small sample at hand exhibits a considerable variation in the strength and number of ribs, but, because this variation is continuous and the size and general shape are uniform, the collection is interpreted as a single species. The high variability of this species stands in contrast to the general uniformity displayed by most of its Alpena congeners.

*Strophodonta proteus* is one of the few Michigan strophodonts here recognized that have been identified outside the state.

***Strophodonta micropleura* Imbrie, new species**

Plate 56, figures 11-17

DISTINGUISHING CHARACTERS: Several characters distinguish this species: (1) large size; (2) low and evenly concavo-convex lateral profile; and (3) rounded, subequal costellae numbering about 20 in a distance of 10 mm. near the front margin.

DESCRIPTION: Shell large. Lateral profile shallow and rather evenly concavo-convex. Ornamentation finely multicostellate; costellae subequal, low subangular to subround, wider than striae, increasing by bifurcation and some trifurcation, and numbering about 20 in a distance of 10 mm. near the front margin.

MEASUREMENTS OF HOLOTYPE: Length, 25 mm.; width, 32 mm.; thickness, 6 mm.

OCCURRENCE: Alpena limestone (localities 40, 521) of Michigan.

HOLOTYPE: U.S.N.M. No. 124366; Alpena limestone, locality 521.

REMARKS: This species is known from only

a few individuals, but its features are so different from any other known form that it deserves specific recognition.

***Strophodonta discus* Imbrie, new species**

Plate 58, figures 7-11

DISTINGUISHING CHARACTERS: The following characters distinguish this species: (1) large size; (2) subplanate lateral profile; and (3) broad, subangular costae numbering about 10 in a distance of 10 mm. near the front margin.

DESCRIPTION: Large. Lateral profile subplanate to very gently concavo-convex. Interareas low. Costae broad, subangular, subequal, constant in strength, numbering about 10 in a distance of 10 mm. near the front margin, equal to striae in width and shape.

*Pedicle Valve*: Interior with adductor field about one-half of the length of the muscle field.

*Brachial Valve*: Interior typical of the genus.

MEASUREMENTS OF HOLOTYPE: Length, 21 mm.; width, 25 mm.; thickness, 3 mm.

OCCURRENCE: Alpena limestone (locality 521) of Michigan.

HOLOTYPE: U.S.N.M. No. 124367; Alpena limestone, locality 521.

***Strophodonta alpenensis* Grabau, 1913**

Plate 57, figures 7-11

*Stropheodonta alpenensis* GRABAU, 1913, Publ. Michigan Geol. Biol. Surv., no. 12, geol. ser. no. 9, p. 338. STUMM, 1951, Contrib. Mus. Paleont. Univ. Michigan, vol. 9, no. 1, p. 19.

DISTINGUISHING CHARACTERS: The following characters distinguish this species: (1) medium size, (2) subquadrate outline, and (3) finely multicostellate ornamentation.

DESCRIPTION: Outline subquadrate. Ornamentation finely multicostellate; costellae subequal, subangular to subround, nearly constant in size, numbering about 22 per 10 mm. near the front margin.

*Pedicle Valve*: Interior with adductor field a little over one-half of the length of the muscle field.

*Brachial Valve*: Interior typical of the genus.

OCCURRENCE: Norway Point formation (localities 41, 46, 47) of Michigan.

***Strophodonta elongata* Imbrie, new species**

Plate 56, figures 27-31

**DISTINGUISHING CHARACTERS:** Several characters distinguish this species: (1) small size, (2) elongate outline, and (3) finely multicostellate ornamentation. *Strophodonta parva* Owen, described by Stainbrook from the Cedar Valley limestone, is very close to this species in size and ornamentation, but the constant difference in outline renders them distinct. *Strophodonta parva* is a markedly transverse form, with acute cardinal extremities.

**DESCRIPTION:** Outline subelliptical, elongate; hinge width less than the greatest width. Costellae subequal, subround to subangular, constant in size from umbo to margin, equal to striae in width, numbering 13 or 14 in a distance of 5 mm. near the front margin.

**Pedicle Valve:** Adductor field wider than normal for the genus, occupying over one-half of the length of the muscle field.

**Brachial Valve:** Interior typical of the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 15 mm.; width, 14 mm.; thickness, 4.4 mm.

**OCCURRENCE:** Potter Farm formation (locality 41e) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124352; Potter Farm formation, locality 41e.

***Strophodonta crassa* Imbrie, new species**

Plate 55, figures 7-13

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) large size; (2) flattened umbonal region; and (3) wide, high ribs. *Strophodonta costata* Owen, described by Stainbrook from the Cedar Valley limestone of Iowa, is closely allied to this species but differs in having a flatter pedicle valve.

**DESCRIPTION:** Individuals 20 mm. long common. Surface multicostate; costae high, wide, varying in number between 13 and 20 in a distance of 10 mm. along the front margin but commonly about 12 at midlength.

**MEASUREMENTS OF HOLOTYPE:** Length, 20 mm.; width, 23 mm.; thickness, 6.9 mm.

**OCCURRENCE:** Potter Farm formation (localities 37a, 41c) and middle Petoskey formation (localities 21, 21a) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124311; Potter Farm formation, locality 37a.

***Strophodonta potterensis* Imbrie, new species**

Plate 56, figures 1-5

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) small size, (2) finely multicostellate ornamentation, and (3) evenly convex lateral profile. It further differs from *S. crassa*, with which it occurs, in the more even convexity of its lateral profile and in its greater umbonal inflation.

**DESCRIPTION:** Large individuals 16 mm. long. Ornamentation multicostellate; costellae subequal, constant in size from umbo to margin, subround to subangular, numbering from 13 to 23 per 10 mm. near the front margin.

**MEASUREMENTS OF HOLOTYPE:** Length, 12.5 mm.; width, 15.6 mm.; thickness, 3.7 mm.

**OCCURRENCE:** Potter Farm formation (localities 37a, 42) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124310; Potter Farm formation, locality 37a.

***Strophodonta tenuicosta* Imbrie, new species**

Plate 57, figures 12-16

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) medium size; (2) broadly and gently inflated umbonal region; (3) high, thin, angular costellae; and (4) high pedicle interarea. The species differs from *S. pentagonia* in being much narrower and in lacking a pentagonal outline, and from *S. fissicosta* in being narrower and lacking imbrication of the ribs.

**DESCRIPTION:** Large individuals 28 mm. long. Outline subelliptical. Costellae high, thin, angular, constant, subequal, equal to striae in width, numbering about 21 per 10 mm. near the front margin.

**Pedicle Valve:** Interior with adductor field one-half of the length of the muscle field.

**Brachial Valve:** Interior typical of the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 19 mm.; width, 21 mm.; thickness, 5.9 mm.

**OCCURRENCE:** Middle Petoskey formation (localities 21, 21a, 102) of Michigan.

HOLOTYPE: U.S.N.M. No. 124283; middle Petoskey formation, locality 21.

***Strophodonta pentagonia* Imbrie, new species**

Plate 57, figures 23-27

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) medium size; (2) pentagonal outline; and (3) high, thin, angular, subequal costellae. The quality of the ribbing resembles that of *S. tenuicosta*, but *S. pentagonia* has slightly lower ribs, a distinct pentagonal outline, and higher interareas. *Strophodonta pentagonia* differs from *S. fissicosta* by its lack of imbricating ribs.

**DESCRIPTION:** Outline pentagonal, transverse, with acute cardinal extremities. Interareas low. Costellae high, thin, angular, subequal, constant, numbering about 16 in a distance of 10 mm. near the front margin.

**MEASUREMENTS OF HOLOTYPE:** Length, 19 mm.; width, 24 mm.; thickness, 6 mm.

**OCCURRENCE:** Middle Petoskey formation (localities 21, 21a) of Michigan. Rapid limestone of Calhoun County, Illinois.

**HOLOTYPE:** U.S.N.M. No. 124286; middle Petoskey formation, locality 21a.

***Strophodonta rhabdosis* Imbrie, new species**

Plate 56, figures 18-22

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) medium size; (2) subsemicircular outline; (3) closely appressed valves; and (4) narrow, angular costellae on the pedicle valve separated by wide, trough-like striae.

**DESCRIPTION:** Large individuals 19 mm. long. Ornamentation on the pedicle valve giving a fluted appearance; costellae narrow, low, subequal, much narrower than the rounded striae, numbering about 18 in a distance of 10 mm. near the front margin.

**Brachial Valve:** Interior typical of the genus, except for a greater development of the radial ridges dividing each of the anterior adductor scars.

**MEASUREMENTS OF HOLOTYPE:** Length, 14 mm.; width, 18 mm.; thickness, 3 mm.

**OCCURRENCE:** Petoskey formation (locality 7c) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124246; uppermost Petoskey formation, locality 7c.

***Strophodonta levidensa* Imbrie, new species**

Plate 56, figures 6-10

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) medium size, (2) finely multicostellate ornamentation, and (3) closely appressed thin valves. Small specimens suggest finely ribbed individuals of *S. potterensis*, but *S. levidensa* has narrower costae and relatively wider striae.

**DESCRIPTION:** Large individuals 25 mm. long. Valves thin and closely appressed. Ornamentation finely multicostellate; costellae high, narrow, angular, about equal to striae in width, constant, equal, numbering about 22 in a distance of 10 mm. near the front margin. Interareas low.

**Brachial Valve:** Interior typical of the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 17 mm.; width, 20 mm.; thickness, 4.2 mm.

**OCCURRENCE:** Uppermost Petoskey formation (locality 7c) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124240; uppermost Petoskey formation, locality 7c.

**REMARKS:** The species is abundant at locality 7c (relative to other studied brachiopods), and collections are large enough to exhibit the character of intraspecific variation. The ornamentation and lateral profile are remarkably constant, in strong contrast to many of the other Traverse strophodonts. Its outline, however, shows considerable variation, with cardinal extremities ranging from acute and extended to nearly rectangular and restricted.

***Strophodonta heteromys* Imbrie, new species**

Plate 58, figures 1-6

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) medium size; (2) strongly concavo-convex lateral profile, with the pedicle valve much deeper than the brachial; and (3) adductor field diverging from the typical generic pattern.

**DESCRIPTION:** Hinge width equal to or a little less than greatest width. Interareas high for the genus. Costellae strong umbonally, decreasing in size marginally, subangular, subequal, a little narrower than striae,

numbering about 16 in a distance of 10 mm. at midlength.

*Pedicle Valve*: Interior typical of the genus.

*Brachial Valve*: Adductor scars subelliptical, the posterior pair situated posteriorly to the anterior pair instead of laterally, and separated by a very low, sinuous ridge, exhibiting the typical generic pattern. The inner and anterior part of the muscle scars elevated to form two parallel, straight, crenulated ridges.

MEASUREMENTS OF HOLOTYPE: Length, 22 mm.; width, 23 mm.; thickness, 10 mm.

OCCURRENCE: Uppermost Petoskey formation (locality 7c) of Michigan.

HOLOTYPE: U.S.N.M. No. 124248; uppermost Petoskey formation, locality 7c.

REMARKS: The peculiar muscle pattern, described from a single brachial valve, differs from other strophodont musculature, although it is clearly allied to that of *Strophodonta*.

***Strophodonta* sp. A**

Plate 53, figures 22-24

A single specimen from the lower Bell shale at locality 31 (U.S.N.M. No. 124296) represents a species unique in the Traverse.

***Strophodonta* sp. B**

Plate 58, figures 15, 16

Several specimens of a distinctive form are known from the Four Mile Dam formation at locality 53. They occur in the Dock Street clay member and in the overlying crystalline limestone bed. Plate 58 illustrates their external morphology. They are most nearly allied to *S. paula* from the Alpena limestone and *S. alpenensis* from the Norway Point formation, but are easily distinguished from them by ornamentation, outline, and shape.

***Strophodonta* sp. C**

Plate 58, figures 12-14

Three specimens from the uppermost Petoskey beds at locality 7c form a group distinct from other known *Strophodonta*, but the material is too poor to permit formal specific designation. The brachial interior is typical of the genus.

**GENUS PHOLIDOSTROPHIA**

HALL AND CLARKE, 1892

*Pholidostrophia* HALL AND CLARKE, 1892, Pale-

ontology of New York, vol. 8, pt. 1, p. 287. HALL, 1892, Ann. Rept. New York State Geol., no. 11, p. 281.

*Pholidostrophia* (*Pholidostrophia*) WILLIAMS, 1950, Jour. Washington Acad. Sci., vol. 40, no. 9, p. 280.

DIAGNOSIS: Strophodontids with a semi-circular outline, concavo-convex profile, narrow interareas, pearly shells, and musculature as in *Strophodonta*.

DISCUSSION: Williams (1950, p. 281), in his analysis of the genus *Pholidostrophia*, erected two subgenera on the basis of differences in development of the pseudodeltidium, chilidium, cardinal process, brachial bases, and musculature. Traverse species belong to *P. (Pholidostrophia)* because they have a flat pseudodeltidium, no brachial bases, and a strongly impressed musculature.

The very nature of the pholidostrophid shell, with its lack of distinct ornamentation, renders specific distinctions more difficult than in other strophodontid genera. Young shells of different species commonly resemble one another so closely that it is imperative that classification and identification be made with entire populations in mind.

An exceptionally well-preserved specimen from the Four Mile Dam formation (illustrated on pl. 61, fig. 15, as *Pholidostrophia* sp. B) shows a phenomenon of growth ordinarily not observed. The cardinal extremities are widely extended laterally as narrowly tapering points, bearing on their anterior edges regularly spaced, curving, tooth-like projections, producing a comb-like structure. On each side of the beak, about midway to the cardinal extremities, a pair of similarly alate extensions from a younger growth stage are directed posterolaterally at about 25 degrees to the hinge, somewhat in the manner of chonetid spines. Stainbrook (1943, p. 44) has observed similar features in *P. iowensis*.

Internally the resemblance to *Strophodonta* is remarkable. The chief difference in the pedicle valve is the lack of the bilobed anterior projections from the distal portion of the ventral process. In the brachial valve, *Pholidostrophia* lacks both the brachial bases and the pits behind the cardinal process for the articulation of the ventral process. *Pholidostrophia* has, commonly, two knob-like, more or less isolated projections from the



floor of the valve, situated anterolaterally to the ends of the posterior adductors.

***Pholidostrophia gracilis* Imbrie, 1955**

Plate 61, figures 1-12

*Pholidostrophia gracilis* IMBRIE, 1955, Amer. Mus. Novitates, no. 1754, pp. 6-7, figs. 21-25.

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) narrow outline, with lateral margins tapering continuously anteriorly from the cardinal extremities; (2) very low and even profile; and (3) thin, closely appressed valves.

**DESCRIPTION:** Size variable, commonly large. Outline transversely subelliptical to subquadrate; length-width ratio high for the genus, about 0.85; hinge width the greatest width; cardinal extremities acute, lateral margins tapering continuously forward from the cardinal extremities. Lateral profile gently and evenly concavo-convex.

*Pedicle Valve:* Lateral and anterior profiles very gently and evenly convex. Umbonal region slightly swollen. Interior with diductors extending to or beyond the midpoint of the valve.

*Brachial Valve:* Lateral and anterior profiles gently and evenly concave. Adductor field typical of the genus.

**OCCURRENCE:** The species is known from the Bell, Rockport Quarry, Ferron Point, and Genshaw formations of Michigan.

**REMARKS:** Population samples included in this species are closely allied in the characters enumerated above, but they differ markedly in size. Populations studied from the lower Bell, Ferron Point, and Rockport Quarry formations have mean lengths of about 14 mm., with large individuals 18 mm. long. Genshaw specimens average the same size, but contain a few very large individuals up to 26 mm. long. By contrast, a large sample of this species from the upper Bell shale comprises individuals significantly smaller than collections stratigraphically above and below, although in other respects the populations are identical. This stratigraphic intercalation of a population of small individuals between populations of large ones poses a taxonomic problem. At least three interpretations are possible. First, the entire assemblage may represent a single species varying in size with

time; second, two species may be involved, with migration accounting for the vertical change; and third, a single species may be represented, with the observed size differences an artifact of current sorting or other processes. The second hypothesis is held to be unlikely in view of the evidence that indicates that the Traverse is essentially an endemic fauna. The third interpretation is tentatively eliminated, because there is no certain indication in the mode of preservation or lithology of the enclosing sediments that the observed size differences are due to differential sorting, solution, or preservation. Although present knowledge does not permit critical discrimination of these hypotheses, the first is here chosen as the most probable, and subspecies are established to provide a taxonomic framework for further study.

***Pholidostrophia gracilis gracilis* Imbrie, 1955**

Plate 61, figures 1-10

*Pholidostrophia gracilis gracilis* IMBRIE, 1955, Amer. Mus. Novitates, no. 1754, p. 7, figs. 21-23.

**DESCRIPTION:** Mean length about 16 mm., with a few individuals 25 mm. long. Otherwise as described for the species.

**MEASUREMENTS OF HOLOTYPE:** Length, 16 mm.; width, 19 mm.; thickness, 3.6 mm.

**OCCURRENCE:** Lower Bell shale (locality 31), Rockport Quarry limestone (locality 38), Ferron Point formation (localities 38, 51), and Genshaw formation (localities 49, 50, 51, 51c, 105, 128, 138, 132) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124318; Rockport Quarry limestone, locality 38.

***Pholidostrophia gracilis nanus* Imbrie, 1955**

Plate 61, figures 11, 12

*Pholidostrophia gracilis nanus* IMBRIE, 1955, Amer. Mus. Novitates, no. 1754, p. 7, figs. 24, 25.

**DESCRIPTION:** Mean length about 11 mm., with largest individual about 13 mm. long. Otherwise as described for the species.

**MEASUREMENTS OF HOLOTYPE:** Length, 10.3 mm.; width, 12.8 mm.; thickness, 2.0 mm.

**OCCURRENCE:** Upper 12 feet of the Bell shale (locality 38) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124320; upper Bell shale, locality 38.

***Pholidostrophia geniculata* Imbrie, new species**

Plate 60, figures 1-7

**DISTINGUISHING CHARACTERS:** The following characters distinguish the species: (1) medium to large size; (2) geniculate lateral profile, with a flattened umbonal region; and (3) distinct, rounded ridges running anterolaterally from the base of the cardinal process. The most similar described species is *P. nacrea* Hall, which is smaller and has a more inflated umbonal region. *Pholidostrophia fragilis* is narrower, lacks the geniculate profile, and differs internally.

**DESCRIPTION:** Large individuals 18 mm. long. Lateral margins tapering regularly forward. Interareas high for the genus. Lateral profile concavo-convex, geniculate.

**Pedicle Valve:** Lateral profile geniculate. Umbonal and posterior portion of valve tending to be nearly flat. Reflexed portion of valve very gently convex. Diductor field obcordate in outline, extending to or beyond the midpoint.

**Brachial Valve:** Umbonal region nearly flat or gently and evenly concave. Interior with low, rounded ridges extending anterolaterally from the base of the cardinal process and bounding the adductor field posteriorly. Adductors expanded laterally more than is usual in the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 14 mm.; width, 16 mm.

**OCCURRENCE:** The species is known from the Gravel Point formation (localities 8, 8a, 14, 14c, 14e, 17, 18a, 19) and Alpena limestone (locality 40) of Michigan, and from the Widder and Hungry Hollow formations of Ontario.

**HOLOTYPE:** U.S.N.M. No. 124378; lower Gravel Point formation, locality 100.

**REMARKS:** In order to give *Pholidostrophia nacrea* Hall a more precise meaning, the specimen illustrated by Hall (1867) in his plate 18, figures 1c, 1d, and 1e is here designated as lectotype. Specimens conforming to this figure are in hand from the Ludlowville formation of New York.

***Pholidostrophia ovata* Imbrie, new species**

Plate 60, figures 8-11

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1)

medium size, (2) suboval outline, and (3) deeply and evenly concavo-convex lateral profile.

**DESCRIPTION:** Large individuals 14 mm. long. Outline transversely suboval, with the sides expanding anteriorly from the cardinal extremities to midlength.

**Pedicle Valve:** Lateral and anterior profiles strongly convex. Umbonal region moderately swollen. Cardinal extremities distinctly marked, acute, deflected.

**Brachial Valve:** Lateral and anterior profiles gently concave. Interior resembling that of *P. geniculata*.

**MEASUREMENTS OF HOLOTYPE:** Length, 14 mm.; width, 18 mm.; thickness, 7 mm.

**OCCURRENCE:** Norway Point formation (localities 46, 47) of Michigan. Upper Widder formation of Ontario.

**HOLOTYPE:** U.S.N.M. No. 124385; Norway Point formation, locality 47.

***Pholidostrophia* sp. A**

Plate 61, figures 13, 14

Several specimens from the uppermost Petoskey formation (locality 7c) are distinct from known species but are inadequate to warrant formal specific designation.

**GENUS *PROTOLEPTOSTROPHIA* CASTER, 1939**

*Protoleptostrophia* CASTER, 1939, Bull. Amer. Paleont., vol. 24, no. 83, pp. 29, 75-78.

**DIAGNOSIS:** Lateral profile gently concavo-convex to subplanate. Outline subcircular. Ornamentation finely multicostellate; costellae subequal. Triangular diductor field enclosing the elliptical adductors and bounded by more or less straight, low ridges. Brachial interior with diverging, more or less straight ridges bounding the adductors posterolaterally; brachial bases absent.

**DISCUSSION:** Characteristics useful in specific distinction are: the character of the ornamentation, the shape of the pedicle muscle field, and the presence or absence of a convex pseudodeltidium.

***Protoleptostrophia lirella* Imbrie, new species**

Plate 60, figures 12-21

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) convex, narrow pseudodeltidium; and (2)

narrow, subequal, serrated costellae. *Protoleptostrophia fragilis* and *P. occidentalis* from the Cedar Valley limestone resemble this species in general form, but both have a flat pseudodeltidium.

**DESCRIPTION:** Ribs subequal, much narrower than the rounded striae, bearing conspicuous tooth-like projections and numbering about 27 per 10 mm. 15 mm. from the pedicle beak.

**Pedicle Valve:** Pseudodeltidium narrow and strongly convex. Interior with diductor field completely enclosing adductors in front.

**Brachial Valve:** Interior with stout cardinal process comprising two distinct, distally diverging lobes, with myophore surfaces directed about 45 degrees to the plane of the commissure.

**MEASUREMENTS OF HOLOTYPE:** Length, 30 mm.; width, 34 mm.; thickness, 3 mm.

**OCCURRENCE:** Dock Street clay member of the Four Mile Dam formation (locality 53), Norway Point formation (localities 40i, 41e, 46, 47), and Alpena limestone (localities 521, 53) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124384; Norway Point formation, locality 47.

#### GENUS *MEGASTROPHIA* CASTER, 1939

*Megastrophia* CASTER, 1939, Bull. Amer. Paleont., vol. 24, no. 83, pp. 37-38.

**DIAGNOSIS:** Large strophodontids having a deeply concavo-convex profile; a prominent, convex pseudodeltidium; uninterrupted, unequal costellae in two sizes cancelled by concentric fila; and a pedicle interior as in *Strophodonta*.

**REMARKS:** *Megastrophia* is rare in the Traverse. None are known higher than the Four Mile Dam formation.

#### *Megastrophia concava* (Hall), 1857

Plate 59, figures 10-13

*Strophomena* (*Strophodonta*) *concava* HALL, 1857, Ann. Rept. State Cabinet Nat. Hist., no. 10, pp. 115, 140, fig. 1.

*Strophodonta concava* (Hall), HALL, 1867, Paleontology of New York, vol. 4, p. 96, figs. 1a-1h, pl. 16.

*Megastrophia concava* (Hall), COOPER, 1944, in Shimer and Shrock, Index fossils of North America, p. 339, pl. 131, figs. 1-4.

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1)

large size, (2) transversely subelliptical outline, and (3) moderately to strongly concavo-convex lateral profile. *Megastrophia gibbosa* is smaller, relatively more strongly concavo-convex, with a more swollen umbonal region.

**DESCRIPTION:** Individuals over 55 mm. long common. Lateral profile concavo-convex, moderately deep for the genus. Ornamentation with narrowly rounded, uninterrupted costellae numbering about nine per 10 mm., separated by groups of from two to seven parvicostellae, both cancellated by prominent fila.

**Pedicle Valve:** Lateral profile subgeniculate, with points of maximum convexity at the umbo and midlength. Umbonal region moderately inflated.

**Brachial Valve:** Lateral and anterior profiles evenly concave. Interior with ponderous, bilobed, cardinal process. Brachial bases in the form of low, distinct, widely divergent ridges. Adductor field small, occupying only about one-fourth of the length of the shell.

**OCCURRENCE:** Alpena limestone (localities 40, 521) of Michigan. Ludlowville formation of New York.

**REMARKS:** The specimen illustrated by Hall (1867) in figures 1b and 1c of plate 16 is hereby designated as lectotype.

#### *Megastrophia gibbosa* Imbrie, new species

Plate 59, figures 1-7

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) small size, (2) strongly and evenly concavo-convex lateral profile, (3) swollen umbonal region, and (4) relatively few parvicostellae between costellae. The species differs from *M. concava* in being relatively deeper, smaller, and wider, and in having fewer parvicostellae.

**DESCRIPTION:** Largest known individual 35 mm. long. Outline transversely subsemicircular. Lateral profile deeply and evenly concavo-convex. Ornamentation like that of *M. concava*, but commonly with fewer than five parvicostellae between costellae on the pedicle valve.

**Pedicle Valve:** Interarea high. Pseudodeltidium narrow, convex. Interior unknown.

**Brachial Valve:** Chilidium vestigial. Interior as in *M. concava*.

**MEASUREMENTS OF HOLOTYPE:** Length, 35 mm.; width, 40 mm.; thickness, 14 mm.

**OCCURRENCE:** Four Mile Dam formation (locality 41) of Michigan. Hungry Hollow formation of Ontario. Logansport formation of Indiana.

**HOLOTYPE:** U.S.N.M. No. 124391; Hungry Hollow formation at Aux Sables River north of Arkona, Ontario.

**Megastrophia** sp.

Plate 59, figures 8, 9

Two incomplete specimens from the lower Bell shale (locality 31) are designated *Megastrophia* sp. U.S.N.M. No. 124297 is illustrated.

**GENUS HERCOSTROPHIA WILLIAMS, 1950**

*Hercostrophia* WILLIAMS, 1950, Jour. Washington Acad. Sci., vol. 40, no. 9, pp. 277-278.

**DIAGNOSIS:** Hinge line denticulate. Lateral profile subplanate. Pseudodeltidium with a narrow, median fold. Surface parvicostellate, with accentuated primary ribs. Pedicle interior with small, elongate, widely divergent diductor scars situated anterolaterally to the adductor field and each bounded laterally by a pair of ridges which join posteriorly. Brachial interior with a small, transversely subsemicircular adductor field divided by a median ridge and four discrete, narrowly divergent, radiating ridges.

**Hercostrophia alpenensis** Williams, 1950

Plate 58, figures 24-26

*Hercostrophia alpenensis* WILLIAMS, 1950, Jour. Washington Acad. Sci., vol. 40, no. 9, p. 278, figs. 2, 4.

**DISTINGUISHING CHARACTERS:** The species is distinguished from congeneric forms by its small size, its subplanate lateral profile, and the delicacy of its valves.

**DESCRIPTION:** Largest known individual 14 mm. long. Ornamentation unequally and finely parvicostellate, with primary ribs tending to be larger than groups of smaller ribs lying between.

**Pedicle Valve:** Laterally profile gently convex, with greatest convexity in the umbonal region. Anterior profile very gently and evenly convex. Umbo slightly inflated. Beak nearly obsolete, with sealed apical foramen. Interior with strongly impressed diductor scars.

**Brachial Valve:** Lateral and anterior pro-

files very gently and evenly concave. Interior unknown.

**MEASUREMENTS OF HOLOTYPE:** Length, 11 mm.; width, 13 mm.; no thickness measurement possible.

**OCCURRENCE:** Alpena limestone (localities 40, 521) of Michigan.

**GENUS DOUVILLINA OEHLERT, 1887**

*Douvillina* OEHLERT, 1887, in Fischer, Manuel de conchyliologie, p. 1282.

*Douvillina* (*Douvillina*) WILLIAMS, 1950, Jour. Washington Acad. Sci., vol. 40, no. 9, p. 281.

**DIAGNOSIS:** Size medium or small. Hinge line denticulate. Outline transverse. Profile commonly deeply concavo-convex. Ornamentation as in *Megastrophia*. Brachial interior with small, elliptical, adductor field divided by a median ridge which rises and bifurcates anteriorly.

**DISCUSSION:** The median fold in the pseudodeltidium and the strongly developed bifurcating septum in the brachial valve of Traverse *Douvillina* indicate that they belong to *Douvillina* (*Douvillina*) Williams.

The genus is rare in the Traverse group.

**Douvillina distans** Imbrie, new species

Plate 58, figures 17-20

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) small size; (2) transversely subelliptical outline, with acute cardinal extremities; and (3) widely and evenly separated costellae. *Douvillina inequistriata*, the most similar species, lacks the distinctly set-off cardinal extremities and has more closely spaced costellae. *Douvillina bellistriata* differs in being smaller, and in having intercostellar spaces relatively wider and provided with more parvicostellae.

**DESCRIPTION:** Ornamentation with costellae evenly and widely spaced for the genus, numbering about five per 5 mm. at the front margin; intercostellar spaces commonly concave on the pedicle valve, bearing from two to seven parvicostellae.

**Pedicle Valve:** Lateral profile moderately convex, with greatest convexity at the umbo. Anterior profile moderately and evenly convex. Umbo slightly swollen. Pseudodeltidium with narrow median fold. Interior typical of the genus.

**Brachial Valve:** Brachial valve gently concave. Interior unknown.

MEASUREMENTS OF HOLOTYPE: Length, 12 mm.; width, 15 mm.; thickness, 4 mm.

OCCURRENCE: The species is known from the Four Mile Dam formation (locality 41) of Michigan, the Hungry Hollow formation of Ontario, and the Logansport formation of Indiana.

HOLOTYPE: U.S.N.M. No. 124349; Four Mile Dam formation, locality 41.

REMARKS: Details of *D. inequistriata* Conrad are impossible to determine from the original description and figure, and the present concept of the species is based on material from the type locality (Moscow, New York) which matches Conrad's figure in size and outline. Conrad's species is a little larger than *D. distans* and has more closely spaced, larger ribs, as well as a flatter umbonal region.

*Douvillina* sp.

Plate 58, figures 21-23

Two specimens from the lower Gravel Point formation (locality 14) represent a unique type of *Douvillina*. They differ from known congeneric forms in having (1) a gently concavo-convex, subgeniculate profile, and (2) the larger costellae irregularly spaced, with the distinction between costellae and parvicostellae not so clear as is typical of the genus. U.S.N.M. No. 124269 is illustrated.

GENUS *LEPTAENA* DALMAN, 1828

*Leptaena* DALMAN, 1828, Svenska Vetensk. Akad. Handl., for 1827, pp. 94, 106, 147. COOPER, 1944, in Shimer and Shrock, Index fossils of North America, p. 341.

DIAGNOSIS: Profile concavo-convex, commonly geniculate in front. Outline transverse. Surface costellate, commonly rugose. Pedicle interior with strong hinge teeth and thickened margins of the elliptical muscle field. Brachial interior with large, bilobed, cardinal process, thickened adductor field, and an elevated subperipheral rim.

*Leptaena* sp.

Plate 63, figures 7, 8

A few poorly preserved specimens from the uppermost Petoskey formation (locality 7c) are the only known representatives of the genus in the Traverse. One of these specimens (U.S.N.M. No. 124251) is illustrated.

SUPERFAMILY ORTHOTETACEA

WILLIAMS, 1953

GENUS *SCHUCHERTELLA* GIRTY, 1904

*Schuchertella* GIRTY, 1904, Proc. U. S. Natl. Mus., vol. 27, p. 734. WELLER, 1914, Monogr. Illinois Geol. Surv., no. 1, pp. 53, 54. DUNBAR AND CONDRA, 1932, Bull. Nebraska Geol. Surv., ser. 2, vol. 5, pp. 70-73. STEHLI, 1954, Bull. Amer. Mus. Nat. Hist., vol. 105, p. 298.

DIAGNOSIS: Profile unequally biconvex to convexo-concave. Ornamentation multicos-tellate. Shell of irregular shape consequent on its attachment by parts of the pedicle valve. Interior with neither dental plates nor median septum in the pedicle valve.

DISCUSSION: *Schuchertella* is not a common fossil in the Traverse, and collections from several formations (Alpena, Potter Farm, Thunder Bay, and uppermost Petoskey) are too inadequate to be named or described.

*Schuchertella crassa* Imbrie, new species

Plate 63, figures 1-6

DISTINGUISHING CHARACTERS: The following characters distinguish this species: (1) medium size, (2) subequally biconvex profile, (3) transversely subelliptical outline, and (4) moderately strong costellae. *Schuchertella cornucopia* differs by its more elongate outline and higher pedicle valve; *S. lirella* has finer costellae; *S. anomala* has coarser ribs.

DESCRIPTION: Largest known individual 38 mm. wide. Costellae equal, rounded, equal to or a little wider than striae, moderately strong, constant in size, increasing by numerous implantations, numbering about 11 per 5 mm. 15 mm. from the brachial beak.

*Pedicle Valve*: Irregular in shape, commonly irregularly rugose. Lateral profile irregularly and gently concave or convex. Interarea moderately high for the genus.

*Brachial Valve*: Lateral profile moderately and evenly convex in smaller individuals, becoming strongly convex in large. Umbonal region gently to strongly inflated. Interarea very narrow. Interior typical of the genus.

MEASUREMENTS OF HOLOTYPE: Length, 19 mm.; width, 24 mm.; thickness, 10 mm.

OCCURRENCE: Lower Bell shale (locality 31), Rockport Quarry limestone (locality 38), and Ferron Point formation (localities 29, 38) of Michigan. Arkona shale of Ontario.

HOLOTYPE: U.S.N.M. No. 124316; Ferron Point formation, locality 38.

**Schuchertella cornucopia** Imbrie, new species

Plate 62, figures 5-8

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) medium size, (2) elongate outline, and (3) high pedicle interarea.

**DESCRIPTION:** Largest known individual 37 mm. wide. Costellae rounded, subequal, equal to or slightly greater than striae in width, constant, numbering about 10 per 5 mm. 15 mm. from the brachial beak.

**Pedicle Valve:** Shape irregularly subconical. Interarea high for the genus.

**Brachial Valve:** Interior typical of the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 33 mm.; width, 37 mm.; thickness, 18 mm.

**OCCURRENCE:** Genshaw formation (localities 51, 52h) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124373; Genshaw formation, locality 52h.

**Schuchertella lirella** Imbrie, new species

Plate 62, figures 9-12

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) large size, (2) very finely multicostellate ornamentation, and (3) moderately high interarea.

**DESCRIPTION:** Lateral profile subequally biconvex. Costellae subequal, rounded, much wider than angular striae, crowded, constant, numbering about 17 per 5 mm. 15 mm. from the brachial beak.

**Pedicle Valve:** Interarea moderately high for the genus. Interior unknown.

**Brachial Valve:** Umbo swollen. Interior typical of the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 30 mm.; width, 42 mm.; thickness, 19 mm.

**OCCURRENCE:** Norway Point formation (Thunder Bay River, probably locality 46 or 47) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 124393; Norway Point formation at Thunder Bay River.

**REMARKS:** This species is rare.

**Schuchertella** sp.

Plate 62, figures 16-18

A small collection of *Schuchertella* from the Four Mile Dam formation (locality 41) is inadequate for formal description. A representative specimen (U.S.N.M. No. 124351) is

illustrated because of the stratigraphic interest of the Four Mile Dam fauna.

**Schuchertella anomala** (Winchell), 1866

Plate 62, figures 1-4

*Crania* (*Pseudocrania*) *anomala* WINCHELL, 1866, The Grand Traverse region, p. 92.

*Orthotetes anomalus* (Winchell), SCHUCHERT, 1897, Bull. U. S. Geol. Surv., vol. 87, p. 295.

*Schuchertella anomala* (Winchell), EHLERS AND KLINE, 1934, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, no. 10, pp. 154-156.

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) large size, (2) low pedicle interarea, and (3) coarsely multicostellate surface.

**DESCRIPTION:** Shells 30 mm. wide are common. Costellae strong, high, rounded, equal, constant, wider than angular striae, numbering about 14 per 5 mm. 15 mm. from brachial beak.

**Pedicle Valve:** Shape irregular, flattened or gently concave. Interarea low, with the height-width ratio in large individuals about 0.20. Interior typical of the genus.

**Brachial Valve:** Lateral and anterior profiles moderately and evenly convex. Umbonal region gently inflated. Interior typical of the genus.

**MEASUREMENT:** Width of holotype, 28 mm. (Ehlers and Kline, 1934, p. 155).

**OCCURRENCE:** Gravel Point formation (localities 9, 14, 14e, 18a) and possibly Dock Street clay member of the Four Mile Dam formation (locality 53) of Michigan.

**ORTHOPLEURA** IMBRIE, NEW GENUS

**TYPE SPECIES:** *Orthopleura rhipis* Imbrie, new species.

**DISTINGUISHING CHARACTERS:** *Orthopleura* is a small orthotetid having an interior identical with that of *Schuchertella* but with paucicostate ornamentation, shallow valves, low interareas, and the pedicle valve deeper than the brachial. *Schuchertella*, *Orthotetes*, *Schellwienella*, and *Derbyia* are multicostellate and brachi-biconvex.

**DIAGNOSIS:** Small in size. Outline subsemicircular to transversely subelliptical. Profile subequally biconvex to plano-convex, the pedicle valve always being the deeper. Pedicle interarea low. Ornamentation paucicostate. Fold and sulcus lacking. Rectimarginate. Pseudopunctate.

*Pedicle Interior*: As in *Schuchertella*. Teeth stout, supported only by thickenings of the delthyrial margins.

*Brachial Interior*: As in *Schuchertella*. Cardinal process relatively short, curved sharply posteriorly, and fused with widely divergent brachiophores and a low chilidium in the orthotetid manner. Adductor field restricted, transversely elliptical, comprising two reniform scars separated by broad median ridges and divided again by two indistinct radial ridges.

#### SPECIES ASSIGNED

*Streptorhynchus flabellum* WHITFIELD, 1882, Ann. New York Acad. Sci., vol. 2, pp. 200–201. WHITFIELD, 1891, Ann. New York Acad. Sci., p. 521, pl. 6, figs. 2–9.

*Schuchertella? orthoplicata* STAINBROOK, 1943, Jour. Paleont., vol. 17, no. 1, pp. 43, 44, pl. 6, figs. 19–22, 24–28.

*Orthopleura rhipis* IMBRIE, new species.

DISCUSSION: Small collections from the Gravel Point formation exhibit such great variation that, with the small number of individuals available, specific limits cannot be defined. Instead, two complete and distinctive individuals are illustrated and designated *Orthopleura* sp. A and *Orthopleura* sp. B. Traverse collections also include fragmentary material from the Alpena, Norway Point, and Potter Farm formations. Undescribed non-Michigan species are known in United States National Museum collections from the Grand Tower, Logansport, and Skaneateles formations. *Orthopleura orthoplicata* is from the Cedar Valley limestone; *O. flabellum*, from the Columbus limestone (Stauffer, 1909, p. 164). Thus the known range of the genus is from the top of the Onesquethaw through the Taghanic stages of the Devonian.

*Orthopleura rhipis* Imbrie, new species

Plate 61, figures 19–26

DISTINGUISHING CHARACTERS: This species is distinguished from known congeneric forms by the following characters: (1) medium size; (2) transversely subsemicircular outline; and (3) subround, moderately broad costae. *Orthopleura orthoplicata* and *O. flabellum* are larger, with fewer and broader costae.

DESCRIPTION: Largest known individual 16

mm. wide. Costae subround, equal, equal to striae in width, numbering about 10 per 5 mm. at a distance 5 mm. from brachial beak.

*Pedicle Valve*: Interarea curved, moderately low. Interior as described for the genus.

*Brachial Valve*: Interior as described for the genus.

MEASUREMENTS: Of the holotype (a pedicle valve): length, 9.3 mm.; width, 12.0 mm.; thickness, 3 mm. Of a paratype (a brachial valve): length, 14 mm.; width, 19 mm.; thickness, 2.5 mm.

OCCURRENCE: Genshaw formation (locality 105) of Michigan.

HOLOTYPE: U.S.N.M. No. 124382; Genshaw formation, locality 105.

#### *Orthopleura* sp. A

Plate 62, figures 13–15

This specimen (U.S.N.M. No. 124258) comes from the "large *Atrypa* zone" of the Gravel Point formation (locality 14).

#### *Orthopleura* sp. B

Plate 61, figures 16–18

This specimen (U.S.N.M. No. 124280) comes from the "upper Blue shale" of the Gravel Point formation (locality 14e).

#### SUPERFAMILY CHONETACEA SHROCK AND TWENHOFEL, 1953

##### GENUS CHONETES DE KONINCK, 1844

Not *Chonetes* Fischer, 1837, Oryctographie du Gouvernement de Moscow, p. 134, pl. 26, figs. 8, 9.

*Chonetes* DE KONINCK, 1844 (*partim*), Description des animaux fossiles qui se trouvent dans le terrain carbonifère de Belgique, pp. 206–213.

TYPE SPECIES: *Terebratulites sarcinulatus* Schlotheim (1820, p. 256, pl. 29, figs. 3a, 3b; by subsequent designation of de Verneuil, 1845, p. 238).

DISTINGUISHING CHARACTERS: *Chonetes* may be distinguished from other chonetids by a combination of the following characters: (1) concavo-convex lateral profile, (2) rectimarginate anterior commissure, (3) multicostellate surface with straight ribs, (4) hollow spines directed obliquely backward, (5) edentate hinge line, (6) broad teeth, and (7) oblique prosocket ridges. *Longispina* is distinguished by its laterally directed spines,



deeper valves, and parallel prosocket ridges.

**DESCRIPTION OF TRAVERSE *Chonetes*:** The outline of these shells varies from subquadri-lateral to semicircular, with the hinge width about equal to the greatest width of the shell; the cardinal extremities may be acute, rectangular, or obtuse; the lateral margins, anterolateral angles, and anterior margins are rounded. The hinge line is straight. In lateral profile the shells are concavo-convex, the depth of the shells varying from small to moderate. The anterior commissure is rectimarginate. Uncommonly there is a very shallow pedicle sulcus. The pedicle interarea is low, higher than the brachial interarea, gently ap-sacine, and slightly curved. The delthyrium is incompletely closed by a convex pseudo-deltidium, the front margin of which is concave anteriorly. The brachial interarea is very low and slightly hypercline. The beaks are obsolete. The pedicle umbo is commonly slightly inflated. The notothyrium is partly filled by the cardinal process which is covered along its posterobasal portion by a low, convex chilidium. The surface is multicostellate, the costellae being generally straight, sub-round to subangular, and increasing commonly by bifurcation, rarely by implantation or trifurcation. Radial ornamentation comprises fine fila and commonly several lamellae. Ten or more hollow round spines adorn the pedicle cardinal margin; the basal portions of the spines project posteriorly, laterally, and brachiad; the distal portions (when they can be seen) are commonly twisted in various directions. The shell substance is pseudopunctate.

**Pedicle Interior:** The delthyrial cavity is shallow, but the teeth are broad and strong, with brachial surfaces marked by fine ridges and grooves running perpendicular to the long axis of the tooth. The teeth are broad, flat, unsupported, shelf-like projections situated under the palintrope and bounding the delthyrial cavity. They are continued antero-laterally as very low, broad, straight ridges or elevations which make an angle of about 30 degrees with the cardinal margin and extend about one-half of the distance to the margin, bounding the muscle field posterolaterally. These ridges are here referred to as prodental ridges. The floor of the apical portion of the delthyrial cavity is flat and higher

than the adductor muscle field bounding it anteriorly. Just anterior to this small apical platform, a low but distinct median septum develops. This septum is thin and high posteriorly where it divides the posterior adductors; its middle portion lowers and broadens abruptly where it divides the smaller anterior adductors; and it rises again to form a moderately broad ridge of variable height as it runs forward to about the middle of the valve or beyond, dividing the diductor scars.

Two pairs of adductor scars can usually be distinguished. The posterior adductors comprise two narrow elongate scars separated by the median septum; the anterior pair form a subelliptical scar divided longitudinally by the low portion of the median septum. The adductors occupy about one-third of the length of the valve and are completely enclosed in front by the diductor field. The diductors are large, subflabellate, and bounded posterolaterally by the prodental ridges. The diductor field is broadly bilobed in front, separated by the low anterior portion of the median ridge, and extends to about mid-length. The diductor marks are composed of a distinctive dendritic pattern of low ridges. The remaining surface of the valve is ornamented by radially arranged rows of papillae.

**Brachial Interior:** The notothyrial cavity is nearly filled by the notothyrial platform and the cardinal process. The cardinal process is a large structure commonly expanding distally and projecting from the notothyrial platform at a low angle to the plane of the commissure. Anteriorly the shaft is bilobed, with a sharply developed median furrow. The myophore surface, which lies roughly perpendicular to the plane of the commissure, has a furrow in each lobe of the shaft, yielding four narrow, crenulated ridges separated by three grooves, the whole surface narrowing towards the brachial beak. The low posterior portion of the shaft is covered by a small convex chilidium.

The sockets are large, flat-floored excavations along the sides of the notothyrial platform. They are bounded on the outside by low, broadly flaring ridges which are intimately joined to the notothyrial margin of the palintrope, but which are deflected from the palintrope and do not share its horizontal striations. These structures, here called the

outer socket ridges, in fact appear to be continuous with the chilidium. The inner, or median, side of the socket is bounded by a narrow, low, elongate, ridge-like structure which lies close to the base of the cardinal process. Callus is commonly deposited between this structure and the cardinal process, and the structure may suggest a rod or plate but generally has the form of a ridge. These structures, evidently homologous with orthoid brachiophores, are here called brachial bases. Compared with true brachiophores they are small, inconspicuous structures, and it is possible that they were non-functional or performed the same function in a different manner. Moreover, although the brachial bases retain the same relations to the sockets as brachiophores, they have migrated inward relative to the notothyrial margin.

Five ridges are produced from the notothyrial platform along the floor of the valve. One pair, variable in width, projects anterolaterally at an angle of about 30 degrees to the cardinal margin, bounding the sockets along their anterior margin and extending beyond them about halfway to the margin as a low, straight ridge. These structures, here called prosocket ridges, appear to be of importance in the classification of shells now passing under the name *Chonetes*. Another pair of ridges, low and narrow, proceeds a short distance anterolaterally from the notothyrial platform, making an angle of about 25 degrees with the midline. These ridges divide the two pairs of adductors and are here called the adductor dividing ridges. Finally, a low median ridge, round or subangular in cross section, extends from the notothyrial platform to a point between one-half and two-thirds of the distance to the anterior margin.

The adductor musculature is rather restricted, extending forward about one-fourth of the distance to the front margin. The posterior adductor scars are small, subtriangular, and bounded by the prosocket and adductor dividing ridges. The anterior adductor scars are smaller, subtriangular in outline, and lie inside and slightly forward of the posterior pair between the median ridge and the adductor dividing ridges. The remaining inner surface of the valve is covered with radially arranged rows of papillae.

**DISCUSSION:** The name *Chonetes* was first published by Fischer de Waldheim (1837, p. 134, figs. 8, 9), and the great majority of works dealing with the genus attribute it to him. Fischer described and figured a fragment of a brachial valve for which he proposed the generic name *Chonetes*, but no trivial name. No named species were assigned by him to the genus. A careful examination of Fischer's figure (see the present paper, pl. 67, fig. 20) and description reveals that his fragment is not what we now consider as *Chonetes* at all, but is instead one of the Schizophoriidae! He describes the interior as having "straight inner apophyses" and a pair of rounded "outer apophyses" which diverge and form funnel-shaped cavities. It is evident that Fischer was describing the worn brachial interior of a schizophoriid, and that his "inner apophyses" are in fact brachiophore plates, the "outer apophyses" fulcral plates, and the funnel-shaped cavities the sockets.<sup>1</sup> In any case, this fragment is not specifically recognizable.

As noted by Ramsbottom (1952, p. 11), de Koninck should be considered the author of the genus. Its type species, *Terebratulites sarcinulatus* Schlotheim, 1820, was fixed by subsequent designation of de Verneuil (1845, p. 238).

Fortunately, the age, type locality, and essential morphology of the type species can be determined. Schlotheim's original description (1820, p. 256, pl. 29, fig. 3) includes (1) a poor figure (see the present paper, pl. 67, fig. 19); (2) a statement that the material employed in the description of the species comprised three specimens collected in earthy brown ironstone ("Brauneisenstein") from the Rammelsberg near Goslar and in the neighborhood of Coblenz; and (3) a statement (pp. 247-249) that *Hysterolithes vulvarius* occurs with *C. sarcinulatus* in the ironstone beds in the neighborhood of Coblenz. Schlotheim's figure for *Hysterolithes vulvarius* includes two forms recognizable as *Schizophoria vulvaria* and *Eodevonaria dilatata*.

From these data several conclusions can be drawn with complete confidence: (1) That the type specimen of *C. sarcinulatus* is early

<sup>1</sup> Fischer states that the word *Chonetes* is an allusion to the form of these sockets (Greek *chone*, a funnel).

Devonian (Coblenzian) in age. This follows from the known restriction of *Eodevonaria* to the Coblenzian stage, which has Coblenz as its type locality, and from the fact that the combination *Eodevonaria dilatata* and *C. sarcinulatus* has been frequently reported from lower Devonian beds by such early workers as de Koninck (1847) and Sandberger and Sandberger (1856) and by such modern workers as Solle (1950, p. 331, 332). (2) That the type locality is either the Rammelsberg near Gosslar (in the Harz) or Coblenz.

British Museum collections contain a block of sandstone with specimens of *Chonetes* considered by H. M. Muir-Wood to be the type material of *C. sarcinulatus* (Schlotheim). Through her courtesy, a photograph of this block is here reproduced (pl. 67, figs. 21, 22). Two brachial valves are represented, one by an internal, and one by an external, mold. Examination of this material, supplemented by study of nearly identical specimens from lower Devonian localities near Gosslar in the Harz (Yale Peabody Museum No. 1999), indicates that *C. sarcinulatus* is a concavo-convex form with rectimarginate commissure, multicostellate ornamentation, and internal features as described for Traverse *Chonetes*. It is, in short, a species closely allied with the American *Chonetes coronatus* suite.

*Chonetes* is a common fossil in many of the Traverse formations, occurring in the Bell, Rockport Quarry, Ferron Point, Genshaw, Norway Point, Potter Farm, Gravel Point, Petoskey, and Beebe School formations. It is especially abundant in the Bell and Ferron Point formations.

#### ***Chonetes mediolatus* Cooper, 1945**

Plate, 63, figures 9-15

*Chonetes mediolatus* COOPER, 1945, Jour. Paleont., vol. 19, no. 5, pp. 480, 481, pl. 63, figs. 32-34.

**DISTINGUISHING CHARACTERS:** *Chonetes mediolatus* can be distinguished from known congeneric forms by the following characters: (1) very low, rounded ribs; (2) moderate size; (3) transversely quadrilateral outline; (4) shallow convexity of the valves; and (5) slightly inflated pedicle umbonal region. *Chonetes fragilis* Stewart, a closely allied species, is longer in proportion to its width and differs in its greater inflation of the umbo.

**DESCRIPTION:** Shell of medium size for the genus. Outline transversely subquadrilateral; cardinal extremities acute to rectangular, commonly slightly deflected; sides, anterolateral angles, and front margin rounded, greatest width at the hinge. Surface finely multicostellate, about 12 costellae in a distance of 5 mm. at the front margin; ribs very low, rounded, about equal to striae in width, increasing by bifurcation and implantation, obscure towards the front margin; lamellae rare. Rectimarginate.

**Pedicle Valve:** Lateral profile gently but evenly convex. Anterior profile broad and low, with greatest convexity along the midline, the sides with gentle but even convexity. Umbo very slightly inflated. Posterolateral slopes gently concave. Six to nine spines on each side of the beak along the cardinal margin.

**Brachial Valve:** Lateral profile very shallow, slightly shallower than ventral valve, evenly convex. Anterior profile very gently but evenly convex. Greatest convexity forward of midlength. Umbonal and posterolateral regions nearly flat.

**OCCURRENCE:** This species is known from the Bell (localities 31, 38), Rockport Quarry (locality 38), and Ferron Point (localities 29, 38, 51) formations in Michigan, and the St. Laurent limestone of Perry County, Missouri.

**REMARKS:** The species exhibits a considerable variation in its length-width ratio which is independent of gross size. It is worthy of note that this species occurs in the contrasting lithofacies of the St. Laurent limestone and the shaly beds of the Traverse.

#### ***Chonetes nateforma* Imbrie, new species**

Plate 64, figures 1-5

**DISTINGUISHING CHARACTERS:** This species can be distinguished by the relatively great depth of the pedicle valve; the distinct, moderately strong ribs; the gentle inflation of the umbo; the moderate size; and the generally acute cardinal extremities. It is evidently closely allied to *C. coronatus* but differs from that species in the markedly slighter inflation of its umbo.

**DESCRIPTION:** Outline transversely subelliptical to subquadrilateral; cardinal extremities acute, slightly deflected; margins and

anterolateral angles rounded. Ornamentation multicostellate; costellae subround to subangular, about equal to striae in width, moderately strong, increasing by bifurcation and implantation; concentric ornamentation consisting of fine fila, with lamellae absent; rib count about 10 in a distance of 5 mm. along the front margin.

*Pedicle Valve*: Lateral profile moderately and evenly convex; anterior profile moderately convex. Shallow sulcus common. Umbonal region moderately inflated. Five to six spines on each side of pedicle beak.

*Brachial Valve*: Lateral and anterior profiles gently and evenly convex. Posterolateral regions nearly plane. Very slight fold present rarely near the front margin.

MEASUREMENTS OF HOLOTYPE: Length, 16 mm.; width, 23 mm.; thickness, 4.6 mm.

OCCURRENCE: Ferron Point formation (localities 38, 51) of Michigan.

HOLOTYPE: U.S.N.M. No. 125536; upper Ferron Point formation, locality 51.

***Chonetes pachyactis* Imbrie, new species**

Plate 63, figures 16–21

DISTINGUISHING CHARACTERS: This species is distinguished by its low length-width ratio; by its strong, wide, rounded ribs; by the moderate and equal depth of its valves; and by its large size. *Chonetes pachyactis* is most closely allied with *C. macleurea* Norwood and Pratten from the St. Laurent limestone of Illinois, but the latter differs in the shallower brachial valve and a greater inflation of the umbo.

DESCRIPTION: Large shell; width of mature individuals commonly 30 mm. Outline transversely semicircular to subquadrilateral. Costellae strong, broad, rounded, about equal to the striae in width and shape, increasing by bifurcation and some implantation; rib count about seven in a distance of 5 mm. at the front margin.

*Pedicle Valve*: Six to eight spines on each side of the beak along the cardinal margin.

*Brachial Valve*: Lateral and anterior profiles moderately and evenly concave, about equal in depth to pedicle valve. Posterolateral regions slightly less concave than the general surface of the valve.

MEASUREMENTS OF HOLOTYPE: Length, 20 mm.; width, 31 mm.; thickness, 5.7 mm.

OCCURRENCE: Norway Point formation (localities 41, 46, 47) of Michigan.

HOLOTYPE: U.S.N.M. No. 124397; Norway Point formation, locality 47.

REMARKS: Analysis of growth stages of this species indicates that its major proportions change regularly with growth, so that larger individuals are relatively wider and thicker than smaller individuals.

***Chonetes ensicosta* Imbrie, new species**

Plate 63, figures 22–29

DISTINGUISHING CHARACTERS: *Chonetes ensicosta* is distinguished by a combination of the following characters: (1) subgeniculate lateral profile; (2) nearly flat umbonal region; (3) strong costellae in the umbonal region, becoming narrow, more angular, and more numerous anteriorly; and (4) vertically striated pedicle interarea.

DESCRIPTION: Costellae strong, about equal to striae in width, increasing by bifurcation and implantation, low and subangular towards the beak, tending to be higher, subangular, and thinner near the front margin; rib count 13 or 14 in a distance of 5 mm. near the front margin, smaller near the umbo.

*Pedicle Valve*: Interarea faintly or strongly striated vertically. Five to six spines on each side of the beak along the cardinal margin.

MEASUREMENTS OF HOLOTYPE: Length, 11 mm.; width, 18 mm.; thickness, 3.5 mm.

OCCURRENCE: Potter Farm (locality 37a) and lower Petoskey (localities 10, 12) formations of Michigan.

HOLOTYPE: U.S.N.M. No. 124265; lower Petoskey formation, locality 12.

***Chonetes hybus* Imbrie, new species**

Plate 64, figures 11–14

DISTINGUISHING CHARACTERS: This species can be distinguished from other congeneric forms by its deep pedicle valve; its swollen pedicle umbonal region; its small size; and its strong costellae. *Chonetes hybus* is closely related to *C. schucherti* Cleland, but differs in being slightly larger, more coarsely ornamented, and in having a more inflated umbonal region.

**DESCRIPTION:** Largest specimen observed 17 mm. in midwidth. Costellae moderately strong, subangular to subround, increasing chiefly by bifurcation, equal to striae in width, numbering about 13 in a distance of 5 mm. along the front margin.

**Pedicle Valve:** About five spines on each side of the beak.

**MEASUREMENTS OF HOLOTYPE:** Length, 9 mm.; width, 12 mm.; thickness, 3.5 mm.

**OCCURRENCE:** Uppermost Petoskey formation (locality 7c) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 125538; uppermost Petoskey formation, locality 7c.

**REMARKS:** Only a few specimens of this species are known. Complete interiors could not be obtained, but a combination of evidence makes the generic identification secure. A pedicle median septum is present, and the prosocket ridges of the brachial valve are oblique, as in *Chonetes*. Moreover, interiors available from the closely related *C. schucherti* from the Rapid limestone of Illinois place that species with *Chonetes* as diagnosed in the present study.

GENUS **LONGISPINA** COOPER, 1942,  
NEW EMENDATION

*Longispina* COOPER, 1942, Jour. Washington Acad. Sci., vol. 32, no. 8, p. 230; 1944, in Shimer and Shrock, Index fossils of North America, p. 347, pl. 135, figs. 1, 2.

**DIAGNOSIS:** Size small. General form as in *Chonetes*. Hinge edentate. Ornamentation costate to costellate. Spines directed laterally at low angles to the hinge line. Interior with pointed teeth and parallel prosocket ridges.

**DISCUSSION:** As originally proposed, *Longispina* embraced long-spined, costate forms centering around the genotype, *Chonetes emmetensis*. As here emended, the genus is broadened in scope to include multicostellate forms with shorter spines, a change necessitated by a study of new Traverse species in conjunction with other known congeneric forms. The species assigned to *Longispina* above have, in addition to identical interior characters clearly distinguishing them from *Chonetes*, laterally directed spines. If *L. lissohybus* and *L. emmetensis* are studied alone, the difference in ornamentation is so great as to suggest generic distinction, the former be-

ing multicostellate with low ribs, the latter strongly costate. However, these extremes are completely bridged by a grading series, as follows: *L. lissohybus*, *L. pelta*, *L. vicinus*, *L. mucronata*, and *L. emmetensis*. Such a distribution of characters is best treated as a single genus, and the genus has been so emended. Species can then be distinguished on the length and number of spines, size, coarseness of ornamentation, convexity, and outline. So far as known, the genus is restricted to middle Devonian rocks.

Species assigned include: *Strophomena mucronatus* Hall; *Chonetes emmetensis* Winchell; *Leptaena vicinus* Castelnau; *Longispina leionanus* Imbrie, new species; *Longispina subcalva* Imbrie, new species; *Longispina lissohybus* Imbrie, new species; and *Longispina pelta* Imbrie, new species.

**Longispina emmetensis** (Winchell), 1866

Plate 64, figures 23–26

*Chonetes emmetensis* WINCHELL, 1866, The Grand Traverse region, pp. 92, 93. EHLERS AND KLINE, 1934, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, no. 10, pp. 156–158, pl. 2, figs. 2, 3, 6, 8–10.

*Longispina emmetensis* (Winchell), COOPER, 1944, in Shimer and Shrock, Index fossils of North America, p. 347, pl. 135, figs. 1, 2.

**DISTINGUISHING CHARACTERS:** *Longispina emmetensis* is distinguished by a combination of the following characters: (1) subquadrate outline; (2) strongly concavo-convex lateral profile; (3) strong costae; and (4) spines on each side of the beak, four in number, the outer pairs being very long.

**DESCRIPTION:** Costae rounded, strong, equal to or narrower than striae in width, increasing rarely by implantation and bifurcation; rib count variable, about five or six in a distance of 4 mm. 7 mm. from the pedicle beak.

**Pedicle Valve:** Lateral and anterior profiles strongly and evenly convex. About four spines on each side of the beak, the outer pair being very long and stout. Interior typical of the genus.

**Brachial Valves:** Lateral and anterior profiles moderately and evenly concave. Posterolateral areas nearly plane. Umbonal region depressed. Interior typical of the genus.

**OCCURRENCE:** Alpena limestone (localities 40, 125, 129), Dock Street clay member of the Four Mile Dam formation (locality 40) and Gravel Point formation (localities 8, 14, 101) of Michigan.

***Longispina pelta* Imbrie, new species**

Plate 64, figures 27-30

**DISTINGUISHING CHARACTERS:** *Longispina pelta* can be distinguished by its shield-shaped outline; high length-width ratio; strongly concavo-convex lateral profile; and low ribs.

**DESCRIPTION:** Rib count about eight or nine in a distance of 4 mm. 7 mm. from the pedicle beak; costellae rounded, distinct, about equal to striae in width, increasing by bifurcation and implantation.

**Pedicle Valve:** Three to four spines on each side of the beak.

**MEASUREMENTS OF HOLOTYPE:** Length, 13.6 mm.; width, 12.5 mm.; thickness, 5.6 mm.

**OCCURRENCE:** Rockport Quarry limestone (locality 114) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 125544; Rockport Quarry limestone, locality 114.

**REMARKS:** Growth series indicate that larger specimens are relatively deeper and narrower than smaller ones.

***Longispina lissohybus* Imbrie, new species**

Plate 64, figures 15-22

**DISTINGUISHING CHARACTERS:** This species can be distinguished from known congeneric forms by its large size, its strongly concavo-convex profile, and its low, fine, obscure costellae.

**DESCRIPTION:** Costellae numbering about 11 per 5 mm. along the front margin, and very low, rounded, commonly obsolete on parts of the pedicle valve.

**Pedicle Valve:** Interior typical of the genus.

**Brachial Valve:** Interior typical of the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 13 mm.; width, 15.6 mm.; thickness, 4.7 mm.

**OCCURRENCE:** Lower Ferron Point formation (locality 38) of Michigan. Silica shale of Ohio.

**HOLOTYPE:** U.S.N.M. No. 125540; lower Ferron Point formation, locality 38.

**REMARKS:** Proportions change regularly with growth, so that larger individuals are relatively larger and thicker.

***Longispina subcalva* Imbrie, new species**

Plate 65, figures 1-4, 7-11

**DISTINGUISHING CHARACTERS:** This species can be distinguished from known congeneric forms by its moderate size; very low, small costellae; and by the shallowness of the valves.

**DESCRIPTION:** Rib count 13 or 14 in a distance of 5 mm. at the front margin; costellae very low, commonly obsolete, rounded, increasing mostly by bifurcation.

**Pedicle Valve:** About four spines on each side of the beak.

**Brachial Valve:** Umbonal region commonly depressed.

**MEASUREMENTS OF HOLOTYPE:** Length, 10.5 mm.; width, 14.0 mm.; thickness, 2.8 mm.

**OCCURRENCE:** Ferron Point formation (localities 29, 29c, 38, 51) and Genshaw formation (localities 28b, 32h, 33c, 49, 51, 51c, 52h, 127, 132, 138) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 125545; upper Ferron Point formation, locality 51.

***Longispina leionanus* Imbrie, new species**

Plate 64, figures 6-10; plate 65, figures 5, 6

**DISTINGUISHING CHARACTERS:** *Longispina leionanus* is identical with *Longispina subcalva* in every way except for its small size.

**MEASUREMENTS OF HOLOTYPE:** Length, 7.2 mm.; width, 9.2 mm.; thickness, 2.2 mm.

**OCCURRENCE:** Lower Bell shale (locality 31) of Michigan.

**HOLOTYPE:** U.S.N.M. No. 125539; lower Bell shale, locality 31.

**SUPERFAMILY PRODUCTACEA WAAGEN, 1883**

GENUS **LEPTALOSIA** DUNBAR AND CONDRA, 1932

*Leptalosia* DUNBAR AND CONDRA, 1932, Bull. Nebraska Geol. Surv., ser. 2, vol. 57, pp. 260-264.

**DIAGNOSIS:** Shell small, attached to substrate by most of the surface of the pedicle valve and by long, procumbent spines. Brachial valve smooth. Pseudodeltidium narrow, long, convex. Interareas narrow but distinct. Pedicle interior with stout teeth.

***Leptalosia radicans* (Winchell), 1866**

Plate 66, figures 24-27

*Crania radicans* WINCHELL, 1866, The Grand Traverse region, p. 92.*Strophalosia radicans* (Winchell), BEECHER, 1890, Amer. Jour. Sci., ser. 3, vol. 40, pp. 240, 243, pl. 9, figs. 14-17.*Leptalosia radicans* (Winchell), DUNBAR AND CONDRA, 1932, Bull. Nebraska Geol. Surv., ser. 2, vol. 5, p. 260. EHLERS AND KLINE, 1934, Contrib. Mus. Paleont. Univ. Michigan, vol. 4, no. 10, pp. 158, 159, pl. 2, figs. 1, 4-5, 7.

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1) large size; (2) outline transversely subelliptical; and (3) spines stout, long, commonly numbering about 40.

**DESCRIPTION:** Large individuals commonly 9 mm. wide. Outline transversely subelliptical; cardinal extremities slightly acute to subrectangular. Lateral profile irregularly concavo-convex. Shape of both valves irregular, conforming more or less to the configuration of the substrate. Ornamentation, except for pedicle spines, confined to fine fila.

**Pedicle Valve:** Marginal area geniculate, thickened, upturned from the substrate. Spines attaining length of 7 mm., tapering, procumbent, hollow, marked with annular growth lines, and more or less radially arranged. Interarea high for the genus, with a narrowly triangular, convex pseudodeltidium. Interior with strong, bluntly pointed teeth supported by callus beneath the delthyrial margins. Muscle field weakly impressed, obcordate in outline, expanding rapidly anteriorly, extending to about the middle of the valve. Diductor scars elongate, with teardrop outlines, extending well beyond the adductors and bounded by low ridges. Adductor field small, elongate-obcordate in outline, extending forward between the diductors about one-half of their length; slightly elevated.

**Brachial Valve:** Irregular in shape, subplanate to geniculate. Surface of valve lacking spines. Interior with stout cardinal process projecting generally at a high angle to the plane of the commissure; cardinal process bilobed anteriorly, each lobe furrowed posteriorly, yielding a quadrilobate myophore. Base of the process extended laterally as short, distinct ridges bounding the deep sock-

ets. Strong median ridge. Adductor field strongly impressed, restricted. Adductor pairs separated by obscure, low, radiating ridges. Brachial ridges extending anterolaterally from the adductor scars.

**OCCURRENCE:** Norway Point (locality 47), Gravel Point (localities 14, 14e), Alpena (localities 40, 53), Four Mile Dam (locality 41), and Genshaw (locality 52h) formations of Michigan. Arkona and Hungry Hollow formations of Ontario.

**GENUS *SPINULICOSTA* NALIVKIN, 1937,  
NEW EMENDATION**

*Spinulicosta* NALIVKIN, 1937, Trans. Central Geol. and Prospecting Inst. U.S.S.R., fasc. 99, pp. 49, 140.

**DIAGNOSIS:** Shell of medium size. Outline elongate. Pedicle valve gibbous. Interareas narrow on both valves. Pseudodeltidium obsolete or nearly so. Cicatrix lacking. Pedicle valve with long spines developing either from a smooth surface or from costae on the anterior portions of the valve. Brachial valve lacking spines. Hinge teeth in pedicle valve.

**REMARKS:** Nalivkin's genus<sup>1</sup> was originally briefly diagnosed as comprising forms like the genotype, *Productus spinulicosta* Hall, which had irregularly developed spiniferous ridges anteriorly. Certain Traverse specimens have the same size and characteristic form as the genotype. Moreover, brachial interiors of Traverse *Spinulicosta* are identical with specimens of *S. spinulicosta* in the United States National Museum. Exteriors of Traverse *Spinulicosta*, however, differ from the genotype in that the costae are developed sporadically and in various degrees. With the identity in general form and interior characters in mind, it seems wise to expand the scope of Nalivkin's genus to include species in which the character of costation is only partly established.

***Spinulicosta mutocosta* Imbrie, new species**

Plate 66, figures 1-14

**DISTINGUISHING CHARACTERS:** The following characters distinguish this species: (1)

<sup>1</sup> Thanks are due to Dr. Muir-Wood who brought this genus to my attention.



medium size; (2) elongate outline; (3) high, inflated, umbonal region on pedicle valve with incurved beak; and (4) spine bases varying from tiny, discrete, circular nodes to elongate ridges.

DESCRIPTION: Large individuals 14 mm. wide.

*Pedicle Valve*: Pseudodeltidium tiny, apical, convex. Spines long, delicate, gently curved, irregularly directed. Spine bases varying from small, circular nodes to elongate spiniferous ridges. Interior with strong, bluntly pointed, unsupported teeth.

*Brachial Valve*: Adductor dividing ridges short, low, running anterolaterally from the base of the process. Adductor field constricted, comprising four subequal, triangular scars. Interior surface covered with tiny spines.

MEASUREMENTS OF HOLOTYPE: Length, 12 mm.; width, 11 mm.; thickness, 6.4 mm.

OCCURRENCE: Bell (locality 31), Rockport Quarry (locality 38), Ferron Point (localities 29, 29c, 38, 51), Four Mile Dam (locality 41), Beebe School (locality 22a, 24b), Thunder Bay (locality 35), and Potter Farm (locality 37a) formations of Michigan.

HOLOTYPE: U.S.N.M. No. 125561; Beebe School formation, locality 22a.

REMARKS: This species is variable and long-ranging. In general form the species is quite constant. The ornamentation, however, varies strikingly from forms with the anterior portion of the pedicle valve bearing spinose costae to forms lacking such costae completely. Four observations may be cited to justify the inclusion in a single species of such diverse individuals: (1) Individuals are known that are partly costate and partly non-costate. (2) Intermediate forms are known in which the spiniferous ridges are short and do not form continuous costae. (3) Intermediate forms are found to link extreme forms within collections from one locality and horizon. (4) Identical extreme forms are found throughout the range of the species.

*Productella linnensis* Stainbrook from the Cedar Valley limestone is very similar to this species and may, in fact, with the study of more material, prove to be identical. It is considered distinct here because it is consistently smaller than the Traverse form.

#### HELASPIS IMBRIE, NEW GENUS

TYPE SPECIES: *Helaspis luma* Imbrie, new species.

DISTINGUISHING CHARACTERS: The type species of *Productella* Hall (*Productus subaculeatus* Murchison) differs from *Helaspis* in possessing widely scattered, circular spine bases. *Spinulicosta* lacks the characteristic transverse outline of the genus under discussion.

DIAGNOSIS: This genus is erected to include Productacea having (1) strong hinge teeth, (2) interareas on both valves, (3) spines on the pedicle valve only, (4) a transversely subsemicircular outline, (5) gibbous form, and (6) closely crowded spine bases either in the form of small elliptical ridges or elongated as spiniferous ridges.

#### *Helaspis luma* Imbrie, new species

Plate 65, figures 12-25

DISTINGUISHING CHARACTERS: A combination of characters easily distinguishes this species: (1) medium size; (2) subsemicircular outline; (3) gibbous form; and (4) closely crowded spine bases in the form of either small, elliptical mounds or elongate spiniferous ridges.

DESCRIPTION: Large individuals 20 mm. wide. Spine bases closely packed, variable in form, either small elliptical mounds or spiniferous ridges. Brachial valve lacking spines, ornamented with closely crowded, irregularly shaped, shallow depressions.

*Pedicle Valve*: Delthyrium partially closed by a small, apical, convex pseudodeltidium. Interior with strong, bluntly pointed teeth.

*Brachial Valve*: Adductor dividing ridges low. Muscle field quadripartite, restricted, subsemicircular in outline. Brachial ridges variably developed, bounding two reniform areas.

OCCURRENCE: Ferron Point, Genshaw, and Koehler formations of Michigan. The species is abundant in the Genshaw and rare in the Ferron Point.

REMARKS: Two extremes of ornamentation are found within the species. One, typical of *H. luma luma*, is marked by discrete, subelliptical spine bases. The other, found in *H. luma crista*, has the spine bases elongated

into spiniferous ridges, giving the shell a furrowed appearance. Although a complete intergrading series of specimens occurs, a preponderance of the *H. luma crista* type is found in and just below the Killians member of the Genshaw formation, and for this reason formal subspecific categories are erected.

Considerable stratigraphic interest attaches to specimens of *H. luma* from the Koehler limestone at locality 27 (pl. 65, figs. 23–25).

***Helaspis luma luma* Imbrie, new species and subspecies**

Plate 65, figures 12–16, 22

**DESCRIPTION:** Spine bases tending to be discrete, elliptical mounds not extended as spiniferous ridges. Otherwise as described for the species.

**MEASUREMENTS OF HOLOTYPE:** Length, 16 mm.; width, 17 mm.; thickness, 8.2 mm.

**OCCURRENCE:** Genshaw formation (localities 28b, 32h, 33, 33c, 49, 50, 52h, 108, 116); rare specimens from the Ferron Point formation (localities 38, 51); Michigan.

**HOLOTYPE:** U.S.N.M. No. 125554; upper Genshaw formation, locality 50.

***Helaspis luma crista* Imbrie, new species and subspecies**

Plate 65, figures 17–21

**DESCRIPTION:** Spine bases tending to be elongated into spiniferous ridges, giving the pedicle valve a furrowed appearance. Otherwise as described for the species.

**MEASUREMENTS OF HOLOTYPE:** Length, 17 mm.; width, 17 mm.; thickness, 9.0 mm.

**OCCURRENCE:** Genshaw formation, in and just below the Killians member (localities 33e, 52, 109, 112, 118, 138), of Michigan.

**HOLOTYPE:** U.S.N.M. No. 125556; Killians member of Genshaw formation, locality 52.

***Helaspis* sp.**

Plate 65, figures 26–29

A single, perfect specimen of *Helaspis* is known from the lower Bell shale (locality 31). It is illustrated for its stratigraphic interest.

**TRUNCALOSIA IMBRIE, NEW GENUS**

**TYPE SPECIES:** *Truncalosia gibbosa* Imbrie, new species.

**DISTINGUISHING CHARACTERS:** The following characters distinguish this genus: (1) small size; (2) distinct interareas on both valves; (3) narrowly triangular, slightly convex pseudodeltidium; (4) large umbonal cicatrix; (5) spines on pedicle valve only; and (6) strong hinge teeth. The genus differs from *Heteralosia* in its gibbous form, large cicatrix, more delicate spines, and smaller cardinal process; from *Productellana* in possessing a cicatrix and lacking brachial spines; and from *Eostrophalosia* in lacking brachial spines.

**DIAGNOSIS:** Shape and size as in the genotype. Interareas on both valves. Interareas and pseudodeltidium variably developed, depending on configuration of the cicatrix. Spine bases tiny, discrete, mound-like; spines delicate. Surface of brachial valve covered with small, irregular, shallow depressions.

**Pedicle Interior:** Hinge teeth moderately strong. Muscle scars faintly impressed, restricted, situated mainly on the flattened umbonal area.

**Brachial Interior:** Cardinal process small, tapering distally, with a median furrow in front producing two rounded, conjunct ridges in anterior view, each furrowed again posteriorly; basal portion produced into two widely flaring, short ridges bounding the narrow sockets in front (see pl. 66, fig. 23). Musculature faintly impressed. Adductor scars subelliptical in outline, the anterior pair the larger, situated in front of the posterior pair.

**DISCUSSION:** The group of shells for which this genus is proposed has been widely recognized in the middle Devonian, commonly identified as *Strophalosia truncata* (Hall). *Strophalosia* cannot receive this species, however, because its genotype, *Orthis excavata* Geinitz, differs in possessing a narrow hinge line, triangular outline, and a spinose brachial valve. King recognized this, and erected the genus *Heteralosia* for flattish productids with a small cicatrix and a smooth brachial valve. The cardinal process of King's genus, however, is a tall structure, completely lacking the anterior median groove typical of *Truncalosia*; moreover, the short spines and broad form of *Heteralosia* preclude the admission of *Strophalosia truncata*. Dunbar and

Condra (1932, p. 260) considered *S. truncata* as the earliest representative of *Leptalosia*. Although such a relation is possible, the co-existence in the Traverse of *Leptalosia* and *Truncalosia* with markedly different cardinal processes, habit, spination, and form makes it desirable to establish a generic category to express the differences. It is important to note that young of Traverse *Truncalosia* cannot be mistaken for *Leptalosia radicans*.

Two species are included in this new genus: *Truncalosia gibbosa* Imbrie, new species, and *Productus truncatus* Hall, 1867. The specimen from the Marcellus shale illustrated by Hall (1867, pl. 23, figs. 18–20) is hereby chosen as lectotype of the species *Productus truncatus* Hall.

The name *Truncalosia* is to be considered an arbitrary combination of letters.

***Truncalosia gibbosa* Imbrie, new species**

Plate 66, figures 15–23

**DISTINGUISHING CHARACTERS:** *Truncalosia gibbosa* differs from *T. truncata* in being considerably larger and in having a relatively much smaller cicatrix which is elliptical rather than subcircular in outline. The Traverse species also has more delicate spine bases.

**DESCRIPTION:** Large individuals 10 mm. long. Shape variable.

**Pedicle Valve:** Spines numerous, thin, extending backward at moderate angles to the shell. Spine bases tiny, discrete mounds, more closely spaced umbonally. Interior as for the genus.

**Brachial Valve:** Surface of the valve with irregular, small depressions. Posterolateral areas with strong wrinkles. Interior as for the genus.

**MEASUREMENTS OF HOLOTYPE:** Length, 9.7 mm.; width, 8.5 mm.; thickness, 4.9 mm.

**OCCURRENCE:** Genshaw (localities 32h, 49, 52h), Alpena (locality 40), Gravel Point (localities 9, 14, 14e, 18a, 131), Norway Point (locality 47), lower Petoskey (locality 10), Potter Farm (localities 37a, 41c) formations of Michigan. Arkona shale (?) of Ontario. Hamilton group, Canandaigua Lake, New York.

**HOLOTYPE:** U.S.N.M. No. 125568; Gravel Point formation, locality 14e.

**REMARKS:** The species is long-ranging and

variable. Varieties from the Alpena are unusually wide, and some from the Gravel Point have a less convex anterior profile than is usual in the species.

**GENUS HETERALOSIA KING, 1938**

*Heteralosia* R. H. KING, 1938, Jour. Paleont., vol. 12, no. 3, pp. 278–279.

**DIAGNOSIS:** Both valves with interareas. Pseudodeltidium narrowly triangular, gently convex. Umbo with cicatrix. Spines on the pedicle valve only. Profile low. Interior with hinge teeth and sockets.

**Group of *Heteralosia caperata* Imbrie, new species**

**DISTINGUISHING CHARACTERS:** Proposed for species resembling the genotype, *H. slocomi*, in the characters outlined above, but differing in possessing a cardinal process which is low and reflexed posteriorly instead of being high and perpendicular to the plane of the commissure. An evaluation of this difference would demand a survey of all strophalosids and is beyond the scope of this report.

***Heteralosia caperata* Imbrie, new species**

Plate 67, figures 13–17

**DISTINGUISHING CHARACTERS:** This species is distinguished by its small size; generally low profile, wide hinge line; numerous short, thick spines set on mound-like spine bases; and a wrinkled surface on the brachial valve.

**Pedicle Valve:** Pseudodeltidium prominent, narrowly triangular. Umbonal cicatrix very small and irregular. Spines short, tapering, stout, directed backward at low angles to the valve. Spine bases concentrically arranged, in the form of prominent, irregularly subconical, coalescing mounds. Interior with bluntly pointed hinge teeth; other details unknown.

**Brachial Valve:** Chilidium a continuation of the surface layers of the palintrope, covering the base of the cardinal process. Cardinal process with short, stout, anteriorly rounded shaft; distal portion sharply reflexed posteriorly and grooved anteriorly to yield two closely appressed and contiguous ridges, each cleft again posteriorly. Other interior details shown on plate 67, figure 13.

MEASUREMENTS OF HOLOTYPE: Length, 10.2 mm.; width, 11.5 mm.; thickness, 2.4 mm.

OCCURRENCE: Upper Genshaw formation (localities 25a, 105) of Michigan.

HOLOTYPE: U.S.N.M. No. 125580; upper Genshaw formation, locality 25a.

REMARKS: The species is rare.

**Heteralosia sp. A**

Plate 67, figures 8, 9

A single specimen from the Genshaw formation (locality 52h) can be identified as an undescribed species of this species group occurring in the Arkona shale. It is illustrated as *Heteralosia* sp. A.

**Heteralosia sp. B**

Plate 67, figure 18

Two pedicle valves from the Gravel Point formation (locality 17) are unique in collections from the Traverse studied by the writer. One of them is illustrated as *Heteralosia* sp. B.

**OLIGORHACHIS IMBRIE, NEW GENUS**

TYPE SPECIES: *Oligorhachis oligorhachis* Imbrie, new species.

DISTINGUISHING CHARACTERS: The genus is distinguished from other strophalosids by several characters: (1) stout, widely scattered spines; (2) spineless brachial valve; (3) small umbonal cicatrix; and (4) narrow hinge. The genus differs from *Heteralosia* in its narrower hinge, distinct cicatrix, fewer and more widely scattered spines, and deeper pedicle valve. *Truncalosia* is much deeper, has a larger cicatrix, and finer, more numerous spines. The general form and ornamentation resemble those of *Productellana*, but the latter has spines on the brachial valve and lacks a cicatrix. *Eostrophalosia* has spines on the brachial valve.

DIAGNOSIS: Shell small. Outline subelliptical, length about equal to width. Pedicle valve with swollen umbonal region, small cicatrix, and a narrow, convex pseudodeltidium. Brachial valve with hummocky sur-

face. Spines on pedicle valve only, coarse, widely scattered.

*Pedicle Interior*: Strong, bluntly pointed hinge teeth and deep delthyrial cavity. Musculature faintly impressed.

*Brachial Interior*: Cardinal process small, evenly recurved posteriorly, with shallow, median, distal groove in front. Adductor field subelliptical, transverse in outline.

DISCUSSION: Two species are assigned to this genus: *Oligorhachis oligorhachis* Imbrie, new species, and *Strophalosia? litteltonensis* Stainbrook.

**Oligorhachis oligorhachis** Imbrie, new species

Plate 67, figures 1-7

DISTINGUISHING CHARACTERS: This species has more widely scattered spine bases than *Oligorhachis litteltonensis*.

DESCRIPTION: Large individuals 10 mm. long.

*Pedicle Valve*: Interarea low but distinct, variably developed according to the configuration of the cicatrix. Pseudodeltidium narrowly triangular, gently convex. Interior as described for the genus.

*Brachial Valve*: Interior as described for the genus.

MEASUREMENTS OF HOLOTYPE: Length, 9.0 mm.; width, 9.8 mm.; thickness, 4.3 mm.

OCCURRENCE: Gravel Point (localities 14, 14e, 103) and Four Mile Dam (locality 41) formations of Michigan.

HOLOTYPE: U.S.N.M. No. 125574; Gravel Point formation, locality 103.

**Oligorhachis litteltonensis?** (Stainbrook), 1943

Plate 67, figures 10-12

(?) *Strophalosia litteltonensis* STAINBROOK, 1943, Jour. Paleont., vol. 17, no. 1, p. 58, pl. 7, figs. 32-37.

Two small lots of specimens from the middle Petoskey formation (locality 21) resemble *O. oligorhachis* except in the possession of more closely spaced spine bases. The material is too poor for certain identification, but the specimens are probably *O. litteltonensis* (Stainbrook).

TABLE 1

STATISTICAL CHARACTERIZATION OF SAMPLES OF TRAVERSE BRACHIOPODS BASED ON MEASUREMENTS IN MILLIMETERS  
(CALCULATIONS ON GROUPED DATA)

Species	Horizon	Locality	N	L	$\bar{W}$	$\bar{T}$	$s_l$	$s_w$	$s_t$	$r_{w1}$	$r_{wt}$	OR <sub>w</sub>	D <sub>w1</sub>
<i>Chonetes ensicosta</i>	LP	12	8	13.5	20.4	—	1.41	2.00	—	.988	—	17-23	1.52
<i>Chonetes mediolatus</i>	FP	51	50	—	21.8	3.4	—	3.17	.80	—	.687	17-27	11.7
<i>Chonetes mediolatus</i>	FP	51	49	15.4	21.9	—	2.26	3.12	—	.854	—	17-27	—
<i>Chonetes naleforma</i>	FP	38	10	12.2	15.2	—	3.19	3.58	—	.596	—	9-20	22.1
<i>Chonetes naleforma</i>	FP	38	6	—	14.3	2.9	—	3.45	.73	—	.693	9-19	—
<i>Chonetes pachyactis</i>	NP	46	18	12.0	17.3	—	2.22	3.76	—	.986	—	9-22	3.46
<i>Chonetes pachyactis</i>	NP	46	14	—	16.8	2.5	—	3.70	.62	—	.848	9-21	—
<i>Douvillina distans</i>	FM	41	5	10.4	13.0	—	1.82	2.55	—	.971	—	10-17	4.53
<i>Helaspis luma crista</i>	G	52h	13	14.1	15.6	—	2.18	2.40	—	.947	—	10-19	5.01
<i>Helaspis luma crista</i>	G	52h	13	—	15.6	6.3	—	2.40	1.46	—	.705	10-19	—
<i>Helaspis luma luma</i>	G	52h	36	14.5	15.8	—	1.96	1.61	—	.714	—	13-20	8.94
<i>Helaspis luma luma</i>	G	52h	35	—	15.9	7.0	—	1.56	1.26	—	.543	13-20	—
<i>Helaspis luma luma</i>	A	40	38	11.0	13.0	—	1.97	2.35	—	.665	—	7-18	14.7
<i>Hercostrophia alpenensis</i>	A	40	4	—	13.5	2.5	—	1.73	.58	—	—	11-15	—
<i>Hercostrophia alpenensis</i>	A	40	38	11.0	13.0	—	1.95	2.35	—	.659	—	7-18	14.8
<i>Hercostrophia alpenensis</i>	GP	14	50	8.7	9.9	—	1.40	1.56	—	.821	—	6-13	9.51
<i>Longispina emmetensis</i>	GP	14	50	—	9.9	3.9	—	1.56	.86	—	.746	6-13	—
<i>Longispina emmetensis</i>	GP	38	50	11.9	15.0	—	1.40	1.43	—	.733	—	11-18	7.63
<i>Longispina lissohybus</i>	FP	38	50	—	15.0	4.1	—	1.43	.87	—	.554	11-18	—
<i>Longispina leionanus</i>	FP	31	7	6.9	9.0	—	1.07	1.29	—	.965	—	7-11	3.90
<i>Longispina leionanus</i>	B	31	6	—	8.8	2.0	—	1.33	.16	—	.687	7-11	—
<i>Longispina pella</i>	RQ	114	8	9.1	9.8	—	2.30	1.49	—	.846	—	8-13	11.36
<i>Longispina pella</i>	RQ	114	5	—	9.8	3.8	—	1.92	1.38	—	.796	8-13	—
<i>Longispina subcalva</i>	FP	51	50	9.2	12.6	—	.82	1.09	—	.783	—	10-15	5.75
<i>Longispina subcalva</i>	FP	51	50	—	12.6	2.5	—	1.09	.57	—	.574	10-15	—
<i>Megastrophia concava</i>	A	40, 521	5	54.9	57.7	—	.89	14.96	—	—	—	54-69	—
<i>Megastrophia concava</i>	A	40, 521	3	—	63.2	17.3	—	1.16	.58	—	—	62-65	—
<i>Oligorhachis oligorhachis</i>	GP	14	19	8.4	9.3	—	1.54	1.77	—	.868	—	5-12	9.61
<i>Oligorhachis oligorhachis</i>	GP	14	16	—	9.1	3.8	—	1.81	.72	—	.656	5-12	—
<i>Orthopleura rhipis</i>	G	105	4	10.3	14.0	—	2.22	2.18	—	.905	—	11-16	7.80
<i>Pentamerella aftonensis</i>	GP	8	19	20.6	20.4	—	4.78	3.86	—	.796	—	14-27	42.78
<i>Pentamerella aftonensis</i>	GP	8	19	—	20.4	13.5	—	3.86	2.88	—	.827	14-27	—
<i>Pentamerella alpenensis</i>	GP	18a	16	26.4	25.5	—	3.18	3.18	—	.869	—	17-30	6.25
<i>Pentamerella alpenensis</i>	GP	18a	8	—	24.8	16.4	—	3.54	2.39	—	.986	17-30	—
<i>Pentamerella althyroides</i>	LP	10	7	17.4	17.7	—	3.99	3.73	—	.871	—	12-22	11.14

TABLE 1—(Continued)

Species	Horizon	Locality	N	L	W	T	S <sub>1</sub>	S <sub>w</sub>	S <sub>t</sub>	r <sub>w1</sub>	r <sub>wt</sub>	OR <sub>w</sub>	D <sub>w1</sub>
<i>Pentamerella althyroides</i>	LP	10	4	—	18.0	11.0	—	4.97	3.27	—	.905	11-22	—
<i>Pentamerella aulax</i>	UP	7c	16	21.0	21.1	—	4.60	4.77	—	.952	—	15-32	6.89
<i>Pentamerella aulax</i>	UP	7c	11	—	20.4	12.9	—	4.55	2.91	—	.811	15-26	—
<i>Pentamerella lingua</i>	FP	38	50	24.8	24.3	—	3.71	3.43	—	.839	—	16-31	8.25
<i>Pentamerella lingua</i>	FP	38	50	—	24.3	15.6	—	3.43	2.43	—	.736	16-31	—
<i>Pentamerella papilla</i>	PF	37a	8	9.0	7.9	—	1.31	1.36	—	.885	—	6-9	7.56
<i>Pentamerella papilla</i>	PF	37a	6	—	7.5	6.8	—	1.38	1.05	—	.770	6-9	—
<i>Pentamerella pericosta</i>	NP	47	21	15.3	15.8	—	3.35	3.16	—	.914	—	9-21	8.68
<i>Pentamerella pericosta</i>	NP	47	21	—	15.8	9.6	—	3.16	2.32	—	.887	9-21	—
<i>Pentamerella petoskeyensis</i>	MP	21	22	26.9	27.3	—	3.06	2.36	—	.378	—	22-33	11.22
<i>Pentamerella petoskeyensis</i>	MP	21	15	—	26.8	14.1	—	2.37	1.30	—	.173	22-31	—
<i>Pentamerella proteus</i>	TB	35	21	12.1	12.2	—	2.89	2.71	—	.930	—	8-18	8.63
<i>Pentamerella proteus</i>	TB	35	19	—	12.1	8.6	—	2.66	1.77	—	.642	8-18	—
<i>Pentamerella tumida</i>	G	28	13	32.8	32.0	—	3.66	4.53	—	.876	—	24-41	6.33
<i>Pentamerella tumida</i>	G	28	11	—	31.0	22.8	—	3.87	3.06	—	.886	24-37	—
<i>Pholidostrophia geniculata</i>	GP	14, 8a	50	12.6	16.4	—	1.87	2.15	—	.800	—	13-24	8.71
<i>Pholidostrophia geniculata</i>	GP	14, 8a	30	—	16.3	3.7	—	2.25	.95	—	.531	13-24	—
<i>Pholidostrophia geniculata</i>	GP	14	46	12.2	16.0	—	1.22	1.38	—	.547	—	13-18	8.71
<i>Pholidostrophia geniculata</i>	GP	14	28	—	15.9	3.8	—	1.50	.82	—	.370	13-18	—
<i>Pholidostrophia gracilis gracilis</i>	FP	38	50	15.1	18.7	—	1.91	1.90	—	.802	—	14-23	7.05
<i>Pholidostrophia gracilis gracilis</i>	FP	38	50	—	18.7	4.0	—	1.90	1.01	—	.546	14-23	—
<i>Pholidostrophia gracilis nanus</i>	B	38	50	11.1	14.1	—	1.21	1.41	.47	.796	—	11-16	6.61
<i>Pholidostrophia gracilis nanus</i>	B	38	50	—	14.2	2.2	—	1.41	.47	—	.383	11-16	—
<i>Pholidostrophia ovata</i>	NP	47	21	13.0	16.8	—	1.32	2.05	—	.827	—	13-20	6.75
<i>Pholidostrophia ovata</i>	NP	47	9	—	16.0	4.9	—	1.87	2.03	—	.824	13-18	—
<i>Protoliptostrophia lirella</i>	NP	47	18	29.6	32.4	—	6.40	7.49	—	.770	—	20-50	15.2
<i>Protoliptostrophia lirella</i>	NP	47	6	—	30.2	3.8	—	4.85	.98	—	.868	23-36	—
<i>Rhipidomella penelope</i>	FM	41	4	9.3	10.8	—	1.87	2.99	—	.985	—	9-16	4.27
<i>Rhipidomella trigona</i>	UP	7c	5	10.4	11.0	—	2.30	3.00	—	.977	—	8-16	5.35
<i>Schizophoria ferronensis</i>	RQ	38	5	20.0	23.8	—	4.53	5.36	—	.979	—	16-29	4.63
<i>Schizophoria ferronensis</i>	RQ	38	5	—	23.8	13.0	—	5.36	3.67	—	.951	16-29	7.50
<i>Schizophoria ferronensis</i>	FP	38	12	18.2	21.0	—	5.49	6.21	—	.984	—	9-33	5.33
<i>Schizophoria ferronensis</i>	FP	38	7	—	20.7	12.4	—	4.35	3.99	—	.872	14-26	12.37
<i>Schizophoria ferronensis</i>	B	31	7	12.6	15.7	—	6.24	7.11	—	.995	—	7-27	4.70
<i>Schizophoria mesacarina</i>	UP	7c	3	20.3	24.3	—	1.53	1.16	—	.756	—	23-25	4.23
<i>Schizophoria mesacarina</i>	UP	7c	3	—	24.3	12.3	—	1.16	1.53	—	.756	23-25	4.92
<i>Schizophoria traversensis</i>	G	109	12	26.2	31.0	—	10.6	12.5	—	.992	—	11-46	5.10
<i>Schizophoria traversensis</i>	G	109	8	—	30.3	16.0	—	12.0	7.9	—	.976	15-46	9.18

TABLE 1—(Continued)

Species	Horizon	Locality	N	Z	$\bar{W}$	$\bar{T}$	$s_1$	$s_w$	$s_t$	$r_{w1}$	$r_{wt}$	OR <sub>w</sub>	D <sub>w1</sub>
<i>Schuchertella anomala</i>	GP	9, 14, 14e, 18a	4	24.3	28.5	—	10.49	12.37	—	.998	—	15-39	2.74
<i>Schuchertella anomala</i>	GP	9, 14, 14e, 18a	4	24.3	28.5	—	10.49	14.10	—	.875	—	15-39	23.5
<i>Schuchertella crassa</i>	FP	38	9	21.2	26.2	—	6.24	6.52	—	.893	—	18-37	39.12
<i>Schuchertella crassa</i>	FP	38	10	—	26.0	10.9	—	6.18	3.54	.842	.842	18-37	—
<i>Schuchertella cornucopia</i>	G	51-52h	5	26.0	28.4	—	4.12	4.98	—	.998	—	25-37	1.05
<i>Schuchertella cornucopia</i>	G	51-52h	4	—	29.3	17.3	—	5.32	1.50	—	.366	25-37	—
<i>Schuchertella lirella</i>	NP	46	2	30.5	41.5	—	0	1.41	—	—	—	41-42	—
<i>Sieberella newtonensis</i>	NC	40	25	10.7	11.3	—	4.95	4.42	—	.959	—	5-18	12.21
<i>Sieberella newtonensis</i>	NC	40	17	—	9.9	7.0	—	4.53	4.45	—	.942	5-18	—
<i>Sieberella romingeri</i>	G	52h	36	30.4	30.8	7.0	7.47	6.64	—	.960	—	19-43	6.53
<i>Sieberella romingeri</i>	G	52h	23	—	30.3	17.1	—	7.27	4.00	—	.921	19-43	—
<i>Sphenophragmus nanus</i>	BS	24b	28	4.8	5.5	—	1.27	1.35	—	.945	—	3-8	8.42
<i>Sphenophragmus nanus</i>	BS	24b	26	—	5.4	2.4	—	1.36	.53	—	.962	3-8	—
<i>Spinulicosta multocosta</i>	BS	24b	27	10.4	10.6	—	1.39	1.60	—	.883	—	7-14	6.90
<i>Spinulicosta multocosta</i>	BS	24b	26	—	10.6	5.8	—	1.63	1.18	—	.883	7-14	—
<i>Strophodonta acris</i>	G	123a	50	13.4	14.8	—	3.58	3.62	—	.968	—	5-22	6.45
<i>Strophodonta acris</i>	G	123a	50	—	14.8	5.2	—	3.62	1.73	—	.907	5-22	—
<i>Strophodonta alpenensis</i>	NP	47	50	13.5	16.8	—	4.20	4.04	—	.959	—	8-24	7.74
<i>Strophodonta alpenensis</i>	NP	47	50	—	16.8	4.2	—	4.04	1.54	—	.910	8-24	—
<i>Strophodonta crassa</i>	PF	37a	50	15.8	18.6	—	3.11	3.44	—	.944	—	8-25	6.36
<i>Strophodonta crassa</i>	PF	37a	50	—	18.6	5.2	—	3.44	1.73	—	.777	8-25	—
<i>Strophodonta discus</i>	A	521	8	21.4	25.9	—	5.53	7.10	—	.978	—	18-36	5.61
<i>Strophodonta discus</i>	A	521	5	—	27.6	4.6	—	6.95	1.34	—	.863	21-36	—
<i>Strophodonta elongata</i>	PF	41e	13	15.5	15.5	—	2.99	2.96	—	.972	—	12-21	4.54
<i>Strophodonta elongata</i>	PF	41e	10	—	16.1	5.5	—	2.92	1.27	—	.914	12-21	—
<i>Strophodonta erratica</i>	GP	14	50	12.7	14.2	—	1.93	2.45	—	.751	—	8-22	11.58
<i>Strophodonta erratica</i>	GP	14	48	—	14.2	5.8	—	2.46	2.70	—	.597	8-22	—
<i>Strophodonta extenuata bellensis</i>	B	38	50	16.5	20.5	—	3.46	3.39	—	.864	—	12-28	9.60
<i>Strophodonta extenuata bellensis</i>	B	38	51	—	20.6	6.0	—	3.38	2.10	—	.841	12-28	—
<i>Strophodonta extenuata extenuata</i>	FP	38	49	15.9	18.2	—	3.77	4.09	—	.953	—	12-30	7.05
<i>Strophodonta extenuata extenuata</i>	FP	38	49	—	18.2	5.7	—	4.09	1.96	—	.805	12-30	—
<i>Strophodonta extenuata ferronensis</i>	FP	51	49	20.5	25.2	—	3.75	3.64	—	.905	—	16-36	7.01
<i>Strophodonta extenuata ferronensis</i>	FP	51	50	—	25.3	6.6	—	3.79	1.61	—	.774	16-36	—
<i>Strophodonta extenuata genschawensis</i>	G	109	39	17.7	19.9	—	7.46	8.66	—	.983	—	10-38	7.91
<i>Strophodonta extenuata genschawensis</i>	G	109	39	—	20.0	6.7	—	8.63	3.84	—	.894	10-38	—
<i>Strophodonta extenuata rockportensis</i>	RQ	38	40	18.8	21.1	—	4.95	4.53	—	.899	—	14-40	10.68
<i>Strophodonta extenuata rockportensis</i>	RQ	38	32	—	20.6	6.6	—	4.54	2.92	—	.576	14-26	—
<i>Strophodonta fuscis</i>	FP	38	51	12.8	13.5	—	3.12	3.41	—	.936	—	4-20	8.88
<i>Strophodonta fuscis</i>	FP	38	51	—	13.5	4.7	—	3.41	1.72	—	.865	4-20	—



TABLE 1—(Continued)

Species	Horizon	Locality	N	$\bar{L}$	$\bar{W}$	$\bar{T}$	$s_L$	$s_W$	$s_t$	$r_{wL}$	$r_{wt}$	$OR_w$	$D_{wL}$
<i>Strophodonta fissicosta</i>	GP	18a	49	10.4	12.5	—	3.49	4.55	—	.926	—	8-23	13.56
<i>Strophodonta fissicosta</i>	GP	18a	48	—	12.6	3.6	—	4.54	1.38	—	.885	8-24	—
<i>Strophodonta heteromys</i>	UP	7c	8	18.4	20.3	—	5.01	5.15	—	.987	—	10-25	4.22
<i>Strophodonta heteromys</i>	UP	7c	5	—	23.4	9.0	—	0.89	1.41	—	.971	23-25	—
<i>Strophodonta leptoidema</i>	A	40	11	23.0	28.6	—	6.21	6.96	—	.985	—	18-37	4.39
<i>Strophodonta leptoidema</i>	A	40	11	—	28.1	6.0	—	7.57	2.00	—	.898	17-37	—
<i>Strophodonta levidensa</i>	UP	7c	34	11.2	13.4	—	4.06	4.39	—	.942	—	6-23	11.66
<i>Strophodonta levidensa</i>	UP	7c	33	—	12.9	2.6	—	4.09	.859	—	.883	6-23	—
<i>Strophodonta nanus</i>	A	40	45	12.6	14.6	—	2.88	3.70	—	.975	—	7-21	5.43
<i>Strophodonta nanus</i>	A	40	37	—	14.7	4.4	—	3.69	1.21	—	.784	7-21	—
<i>Strophodonta paula</i>	A	521	12	17.3	19.8	—	3.24	3.60	—	.909	—	14-24	7.86
<i>Strophodonta paula</i>	A	521	9	—	20.8	6.3	—	3.32	2.06	—	.805	14-24	—
<i>Strophodonta potterensis</i>	PF	37a	50	10.8	12.9	—	3.20	3.93	—	.932	—	4-21	11.09
<i>Strophodonta potterensis</i>	PF	37a	50	—	12.9	2.8	—	3.93	1.05	—	.890	4-21	—
<i>Strophodonta proteus</i>	A	521	13	15.1	16.3	—	1.38	1.70	—	.875	—	14-19	4.92
<i>Strophodonta proteus</i>	A	521	10	—	16.2	5.9	—	1.62	1.10	—	.324	14-19	—
<i>Strophodonta rhabdosis</i>	UP	7c	4	12.8	16.3	—	4.86	6.13	—	.999	—	10-24	1.67
<i>Strophodonta rhabdosis</i>	UP	7c	3	—	17.3	33	—	7.02	1.53	—	.963	10-24	—
<i>Strophodonta tenuicosta</i>	MP	21	51	18.0	19.9	—	3.89	3.81	—	.917	—	10-32	8.26
<i>Strophodonta tenuicosta</i>	MP	21	51	—	19.9	5.8	—	3.81	1.80	—	.817	10-32	—
<i>Strophodonta titan costella</i>	G	114, 123	36	27.3	30.3	—	8.16	7.77	—	.928	—	4-28	10.49
<i>Strophodonta titan costella</i>	G	114, 123	32	—	31.3	9.9	—	8.03	4.01	—	.893	20-49	—
<i>Strophodonta titan costella</i>	G	123	22	29.7	32.7	—	9.21	8.21	—	.942	—	21-44	9.51
<i>Strophodonta titan costella</i>	G	123	23	—	33.4	10.7	—	8.48	4.26	—	.915	21-48	—
<i>Strophodonta titan costella</i>	G	114	14	23.6	26.6	—	4.82	5.84	—	.846	—	20-44	11.82
<i>Strophodonta titan costella</i>	G	114	9	—	26.1	7.7	—	2.79	2.18	—	.342	22-31	—
<i>Strophodonta titan titan</i>	GP	14	46	38.7	42.5	—	8.25	7.85	—	.992	—	24-57	2.49
<i>Strophodonta titan titan</i>	GP	14	41	—	42.7	16.2	—	8.20	5.07	—	.748	25-56	—
<i>Truncalostia gibbosa</i>	PF	37a	26	5.7	6.6	—	1.08	9.19	—	.569	—	4.1-8.5	98.49
<i>Truncalostia gibbosa</i>	PF	37a	22	—	6.4	3.3	—	.82	.79	—	.591	4.1-8.0	—
A Alpena limestone	NC	Newton Creek limestone				$\bar{W}$	Mean width						
B Bell shale	NP	Norway Point formation				$\bar{T}$	Mean thickness						
BS Beebe School formation	PF	Potter Farm formation				$s_L$	Standard deviation of length						
FM Four Mile Dam formation	RQ	Rockport Quarry limestone				$s_W$	Standard deviation of width						
FP Ferron Point formation	SB	Squaw Bay limestone				$s_t$	Standard deviation of thickness						
G Genshaw formation	TB	Thunder Bay limestone				$r_{wL}$	Coefficient of correlation of width and length						
GP Gravel Point formation	UP	Upper Petoskey formation				$r_{wt}$	Coefficient of correlation of width and thickness						
LP Lower Petoskey formation	N	Number of specimens in sample				$OR_w$	Observed range of width						
MP Middle Petoskey formation	$\bar{L}$	Mean length											
$D_{wL}$ Coefficient of relative dispersion of width and length measurements around the reduced major axis													

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**PLATES 48-67**

#### PLATE 48

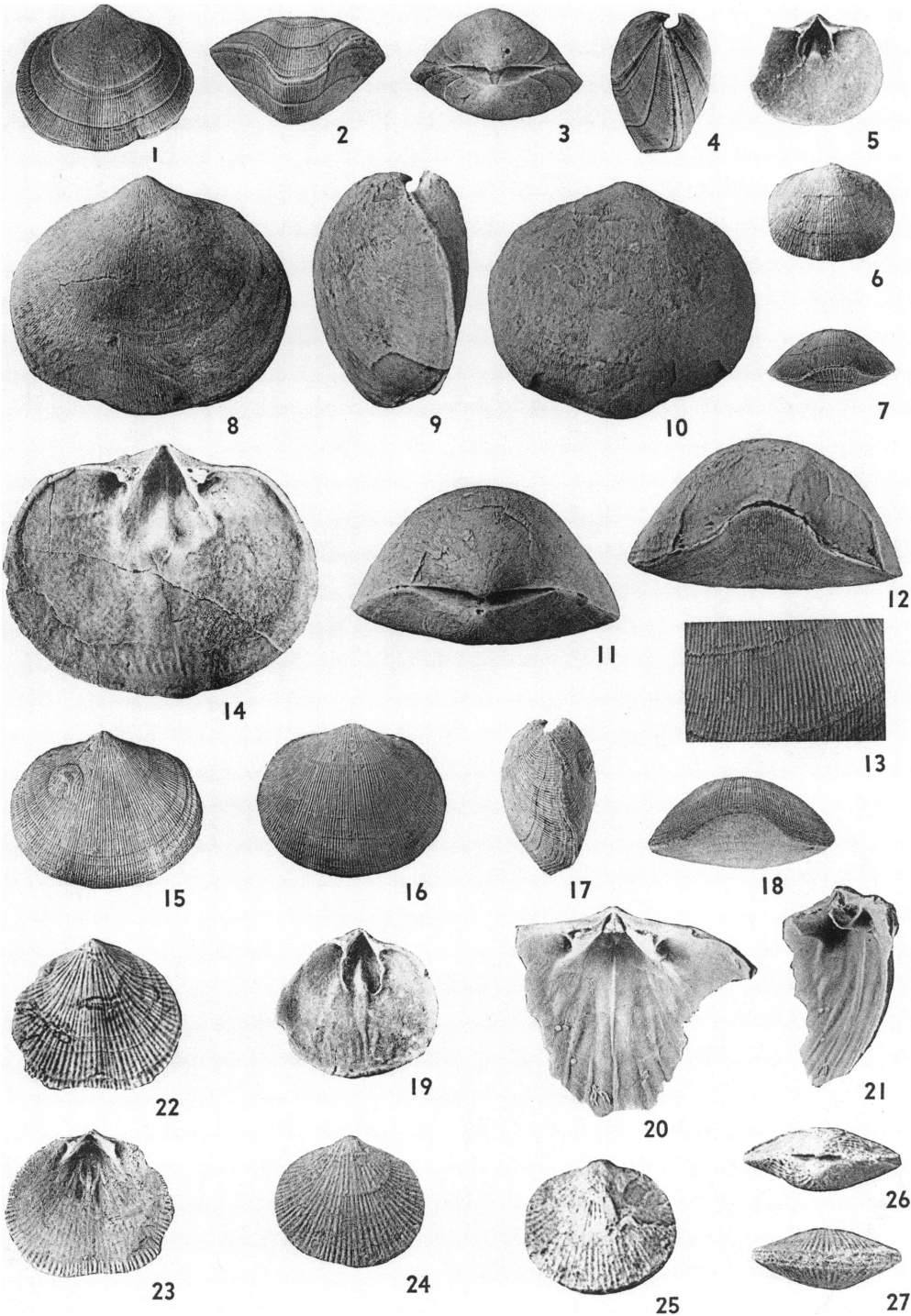
1-7. *Schizophoria ferronensis* Imbrie, new species. 1-4. Pedicle, anterior, posterior, and lateral views of the holotype; lower 10 feet of Ferron Point formation, locality 38; U.S.N.M. No. 124322;  $\times 1$ . 5. Pedicle interior; lower Bell shale, locality 31; U.S.N.M. No. 124314;  $\times 1$ . 6, 7. Brachial and anterior views; lower Ferron Point formation, locality 38; U.S.N.M. No. 124294;  $\times 1$ .

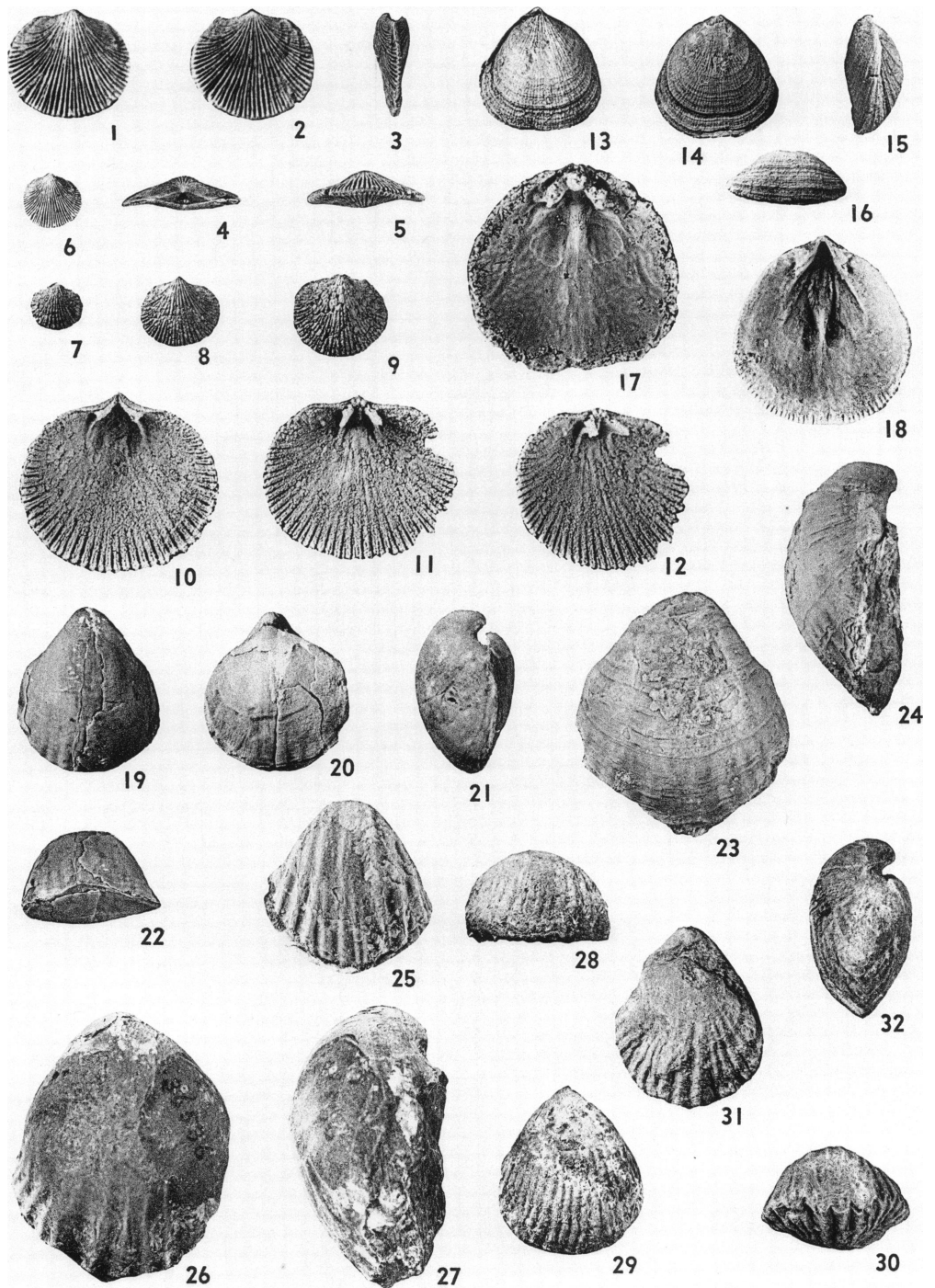
8-14. *Schizophoria traversensis* (Grabau). 8-12. Pedicle, lateral, brachial, posterior, and anterior views; Genshaw formation, locality 109; U.S.N.M. No. 124394;  $\times 1$ . 13. Portion of pedicle valve near the front margin of another individual; Genshaw formation, locality 109; U.S.N.M. No. 124395;  $\times 2$ . 14. Pedicle interior; Genshaw formation, locality 51; U.S.N.M. No. 124335;  $\times 1$ .

15-21. *Schizophoria mesacarina* Imbrie, new species. 15-18. Pedicle, brachial, lateral, and anterior views of holotype; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124250;  $\times 1$ . 19. Pedicle interior; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124261;  $\times 1$ . 20, 21. Brachial interior; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124262;  $\times 2$ .

22, 23. *Rhipidomella* sp. 22. Pedicle view; Alpena limestone (50 feet below top), locality 40; U.S.N.M. No. 124345;  $\times 2$ . 23. Pedicle interior of the same specimen;  $\times 2$ .

24-27. *Rhipidomella penelope traversensis* Imbrie, new subspecies. Pedicle, brachial, posterior, and anterior views of holotype; Four Mile Dam formation, locality 41; U.S.N.M. No. 124346;  $\times 2$ .







#### PLATE 49

1-12. *Sphenophragmus nanus* Imbrie, new genus and species. 1-5. Pedicle, brachial, lateral, posterior, and anterior views of holotype; Norway Point formation, locality 46; U.S.N.M. No. 124355;  $\times 2$ . 6. Pedicle view of the same specimen;  $\times 1$ . 7-9. Pedicle view of three individuals; U.S.N.M. Nos. 124289, 124290, and 124291, respectively; Beebe School formation, locality 24b;  $\times 2$ . 10. Pedicle interior; Beebe School formation, locality 22a; U.S.N.M. No. 124287;  $\times 4$ . 11, 12. Two views of the brachial interior of an individual; Beebe School formation, locality 22a; U.S.N.M. No. 124288;  $\times 4$ .

13-18. *Rhipidomella trigona* Imbrie, new species. 13-16. Brachial, pedicle, lateral, and anterior views of holotype; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124249;  $\times 1$ . 17, 18. Brachial and ventral interior views of two specimens from the same horizon and locality; U.S.N.M. Nos. 124260 and 124259, respectively;  $\times 2$ .

19-22. *Gypidula* sp. Pedicle, brachial, lateral, and anterior views of a specimen; Genshaw formation, locality 49; U.S.N.M. No. 124405;  $\times 1$ .

23, 24. *Pentamerella* sp. A. Pedicle and lateral views of a specimen; lower Bell shale, locality 31; U.S.N.M. No. 124295;  $\times 1$ .

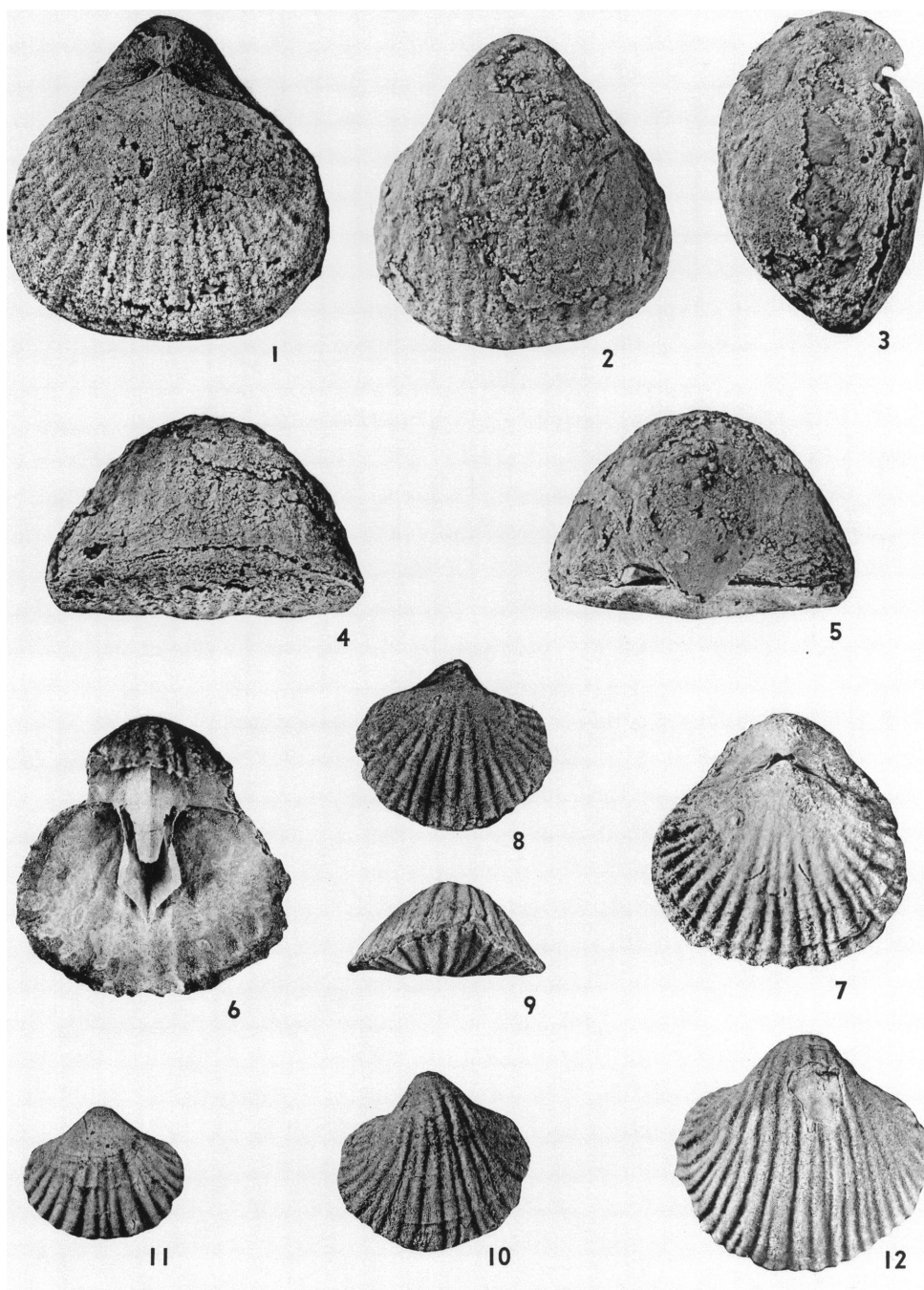
25-27. *Pentamerella* sp. D. 25. Pedicle view of a specimen; Gravel Point formation, locality 8a;  $\times 1$ . 26, 27. Pedicle and lateral views of another individual; Gravel Point formation, locality 103; U.S.N.M. No. 124403;  $\times 1$ .

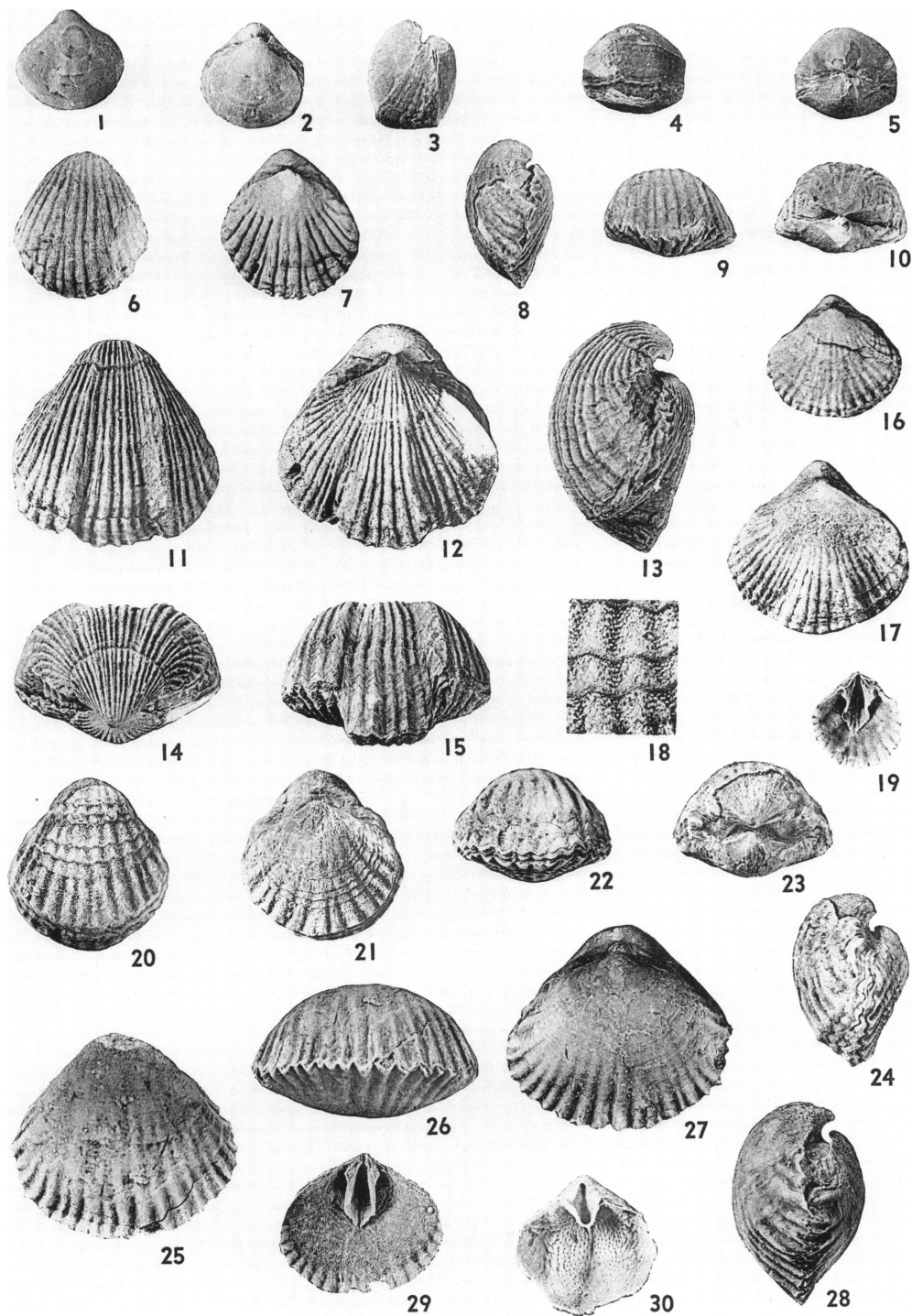
28, 29. *Pentamerella* sp. E. Anterior and pedicle views of a specimen; Potter Farm formation, locality 37b; U.S.N.M. No. 124406;  $\times 1$ .

30-32. *Pentamerella* sp. C. Anterior, brachial, and lateral views of a specimen; Dock Street clay member of Four Mile Dam formation, locality 53; U.S.N.M. No. 124404;  $\times 1$ .

PLATE 50

*Sieberella romingeri* (Hall and Clarke). 1-5. Brachial, pedicle, lateral, anterior, and posterior views of a large individual; Genshaw formation, locality 52a; U.S.N.M. No. 124334;  $\times 1.6$ . Interior view of a specimen with part of the pedicle valve removed, No. 124334;  $\times 1$ . 6. Interior view of a specimen with part of the pedicle valve removed, showing sessile cruralium and spondylium; Genshaw formation, locality 52h; U.S.N.M. No. 124401;  $\times 1$ . 7. Brachial view of the same specimen;  $\times 1$ . 8-10. Brachial, anterior, and pedicle views of a specimen; Genshaw formation, locality 52h; U.S.N.M. No. 124400;  $\times 1$ . 11. Pedicle view of small individual; same horizon and locality; U.S.N.M. No. 124399;  $\times 1$ . 12. Pedicle view of another individual; Genshaw formation, locality 38h; U.S.N.M. No. 124338;  $\times 1$ .





## PLATE 51

1-5. *Sieberella newtonensis* Imbrie, new species. Pedicle, brachial, lateral, anterior, and posterior views of holotype; Newton Creek limestone, locality 40; U.S.N.M. No. 124339;  $\times 1$ .

6-10. *Pentamerella athyroides* (Winchell). Pedicle, brachial, lateral, anterior, and posterior views; lower Petoskey formation, locality 10; U.S.N.M. No. 124257;  $\times 1$ .

11-17. *Pentamerella aulax* Imbrie, new species. 11-15. Pedicle, brachial, lateral, posterior, and anterior views of holotype; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124253;  $\times 1$ . 16, 17. Brachial views of two specimens, U.S.N.M. Nos. 124254 and 124255, from the same horizon and locality;  $\times 1$ .

18-24. *Pentamerella papilla* Imbrie, new species. 18. Enlargement of a portion of the surface of the pedicle valve of the holotype, showing the papillose surface;  $\times 5$ . 19. Pedicle interior of another individual; Potter Farm formation, locality 130; U.S.N.M. No. 124402;  $\times 1$ . 20-24. Pedicle, brachial, anterior, posterior, and lateral views of holotype; Potter Farm formation, locality 37b; U.S.N.M. 124407;  $\times 2$ .

25-30. *Pentamerella petoskeyensis* (Imlay). 25-28. Pedicle, anterior, brachial, and lateral views of a topotype specimen; middle Petoskey formation, locality 21; U.S.N.M. No. 124284;  $\times 1$ . 29. Brachial interior of a specimen; Potter Farm formation, locality 42a; U.S.N.M. No. 124353;  $\times 1$ . 30. Pedicle interior; middle Petoskey formation, locality 21a; U.S.N.M. No. 124285;  $\times 1$ .

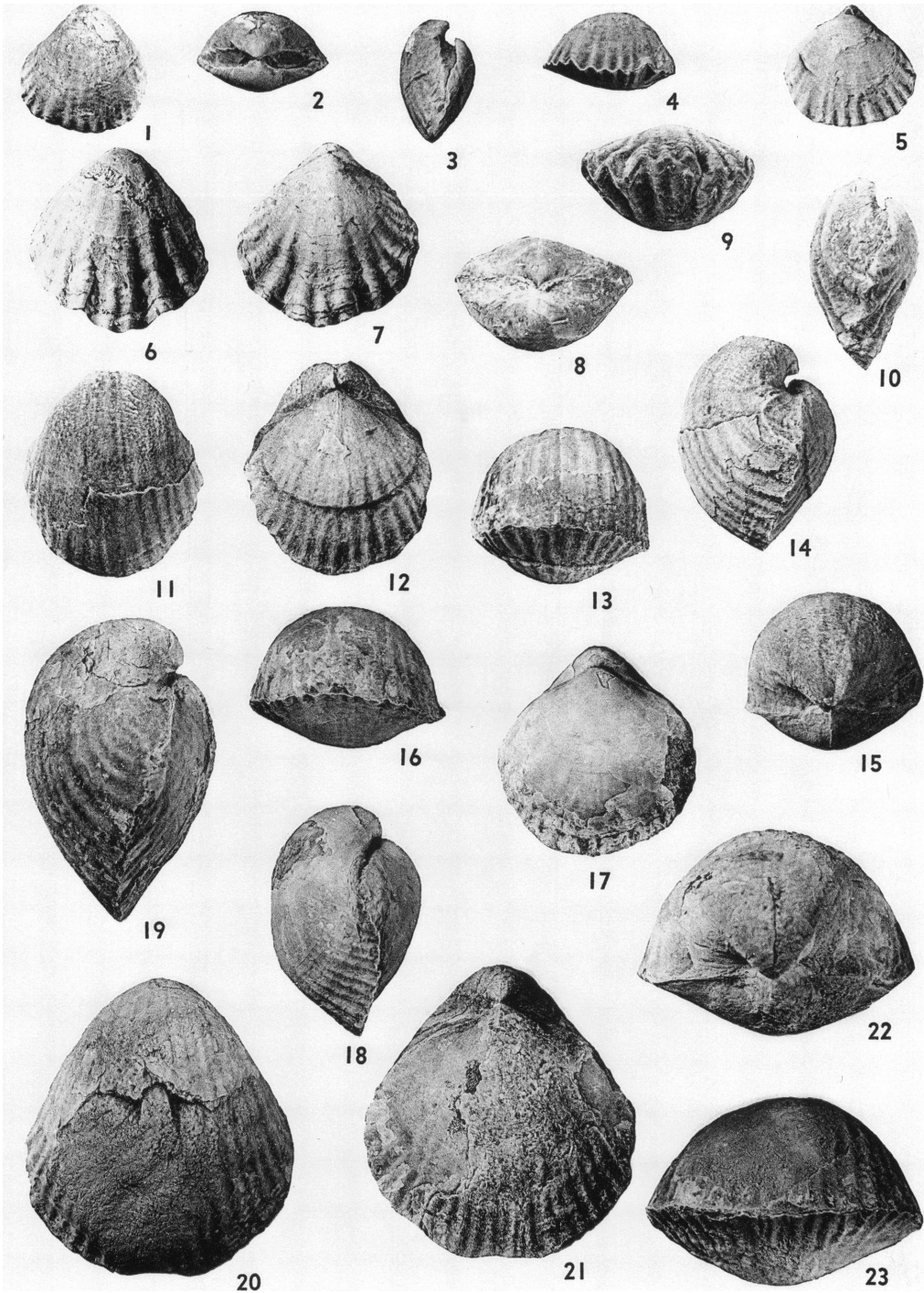
PLATE 52

1-5. *Pentamerella pericosta* Imbrie, new species. Pedicle, posterior, lateral, anterior, and brachial views of holotype; Norway Point formation, locality 47; U.S.N.M. No. 124398;  $\times 1$ .

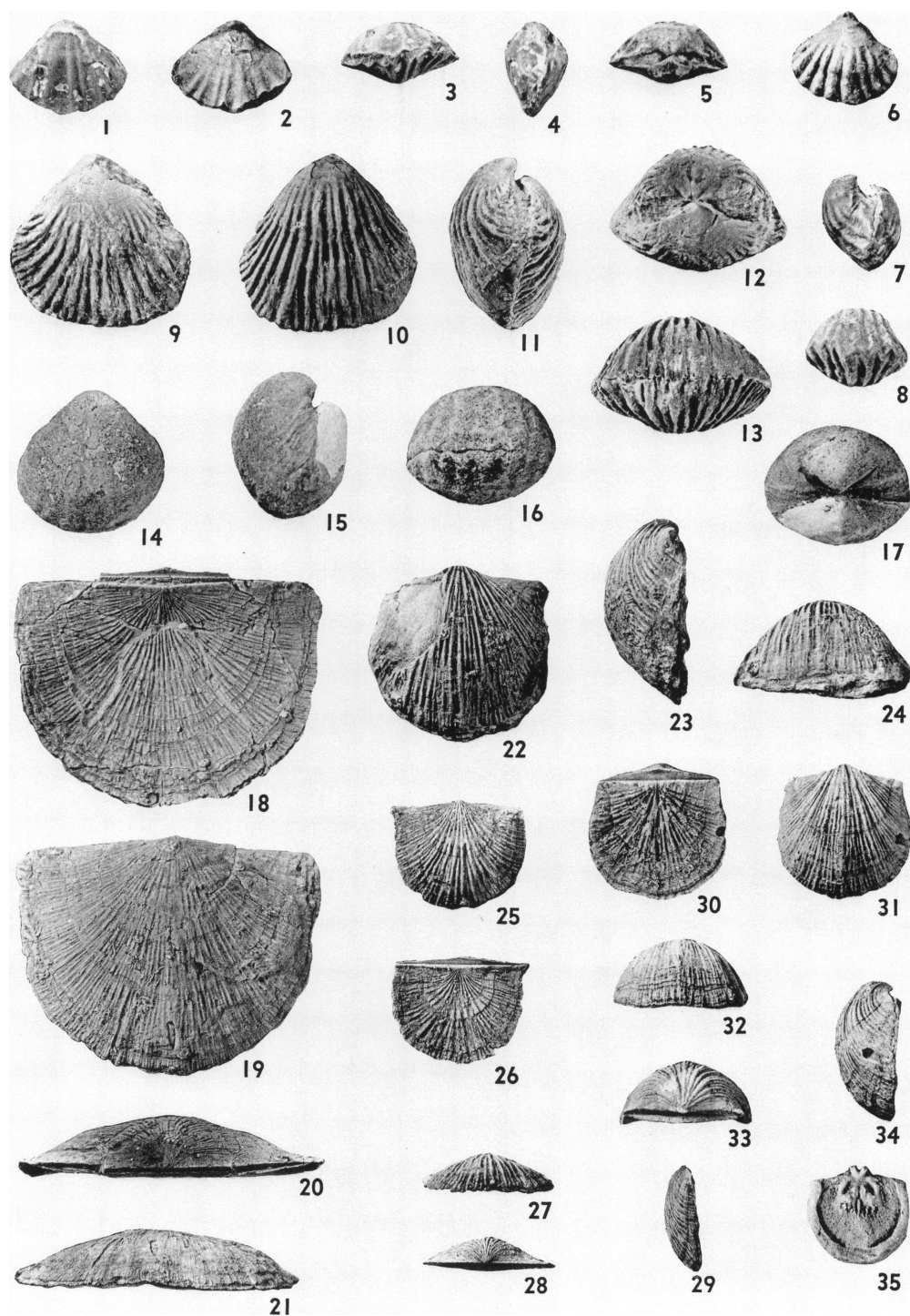
6-10. *Pentamerella lingua* Imbrie, new species. Pedicle, brachial, posterior, anterior, and lateral views of holotype; lower Ferron Point formation, locality 38; U.S.N.M. No. 124323;  $\times 1$ .

11-18. *Pentamerella aftonensis* Imbrie, new species. 11-15. Pedicle, brachial, anterior, lateral, and posterior views of holotype; Gravel Point formation, locality 25; U.S.N.M. No. 124292;  $\times 1$ . 16-18. Anterior, brachial, and lateral views of a specimen; Gravel Point formation, locality 8; U.S.N.M. No. 124256;  $\times 1$ .

19-23. *Pentamerella tumida* Imbrie, new species. Lateral, pedicle, brachial, posterior, and anterior views of holotype; Genshaw formation, locality 28; U.S.N.M. No. 124293;  $\times 1$ .









### PLATE 53

1-8. *Pentamerella proteus* Imbrie, new species. 1-5. Pedicle, brachial, anterior, lateral, and posterior views of holotype; Thunder Bay formation, locality 35; U.S.N.M. No. 124308;  $\times 1$ . 6-8. Brachial, lateral, and anterior views of another individual from the same horizon and locality; U.S.N.M. No. 124307;  $\times 1$ .

9-13. *Pentamerella alpenensis* Imbrie, new species. Brachial, pedicle, lateral, posterior, and anterior views of holotype; "Upper Blue shale" of Gravel Point formation, locality 14e; U.S.N.M. No. 124279;  $\times 1$ .

14-17. *Pentamerella* sp. B. Pedicle, lateral, anterior, and posterior views of a partially restored specimen; basal 8 inches of Rockport Quarry limestone, locality 38; U.S.N.M. No. 124324;  $\times 2$ .

18-21. *Strophodonta leptoidema* Imbrie, new species. Pedicle, brachial, posterior, and anterior views of holotype; Alpena limestone (shale seam 30 feet below top), locality 40; U.S.N.M. No. 124342;  $\times 1$ .

22-24. *Strophodonta* sp. A. Pedicle, lateral, and anterior views of a specimen; lower Bell shale, locality 31; U.S.N.M. No. 124296;  $\times 1$ .

25-29. *Strophodonta nanus* Imbrie, new species. Pedicle, brachial, anterior, posterior, and lateral views of holotype; Alpena limestone, locality 40; U.S.N.M. No. 124344;  $\times 1$ .

30-35. *Strophodonta fascis* Imbrie, new species. 30-34. Brachial, pedicle, anterior, posterior, and lateral views of holotype; lower Ferron Point shale, locality 38; U.S.N.M. No. 124330;  $\times 1$ . 35. Brachial interior; Genshaw formation, locality 52h; U.S.N.M. No. 124374;  $\times 1$ .

PLATE 54

1-7. *Strophodonta extenuata bellensis* Imbrie. 1-5. Brachial, pedicle, lateral, posterior, and anterior views of holotype; upper Bell shale, locality 38; U.S.N.M. No. 124325;  $\times 1$ . 6. Pedicle interior; lower Bell shale, locality 31; U.S.N.M. No. 124298;  $\times 1$ . 7. Brachial interior; lower Bell shale, locality 31; U.S.N.M. No. 124299;  $\times 1$ .

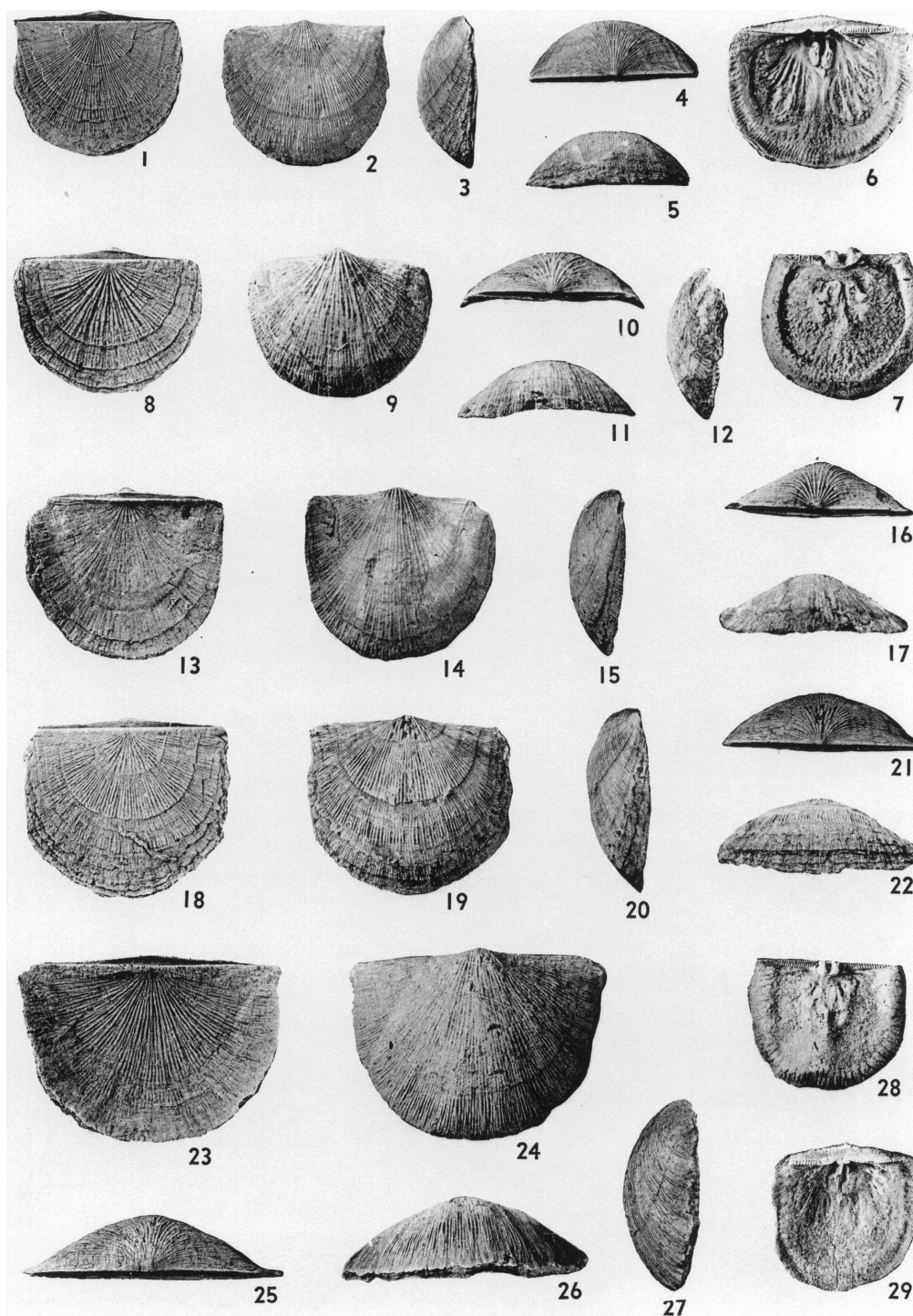
8-12. *Strophodonta extenuata rockportensis* Imbrie. Brachial, pedicle, posterior, anterior, and lateral views of holotype; basal 8 inches of Rockport Quarry limestone, locality 38; U.S.N.M. No. 124327;  $\times 1$ .

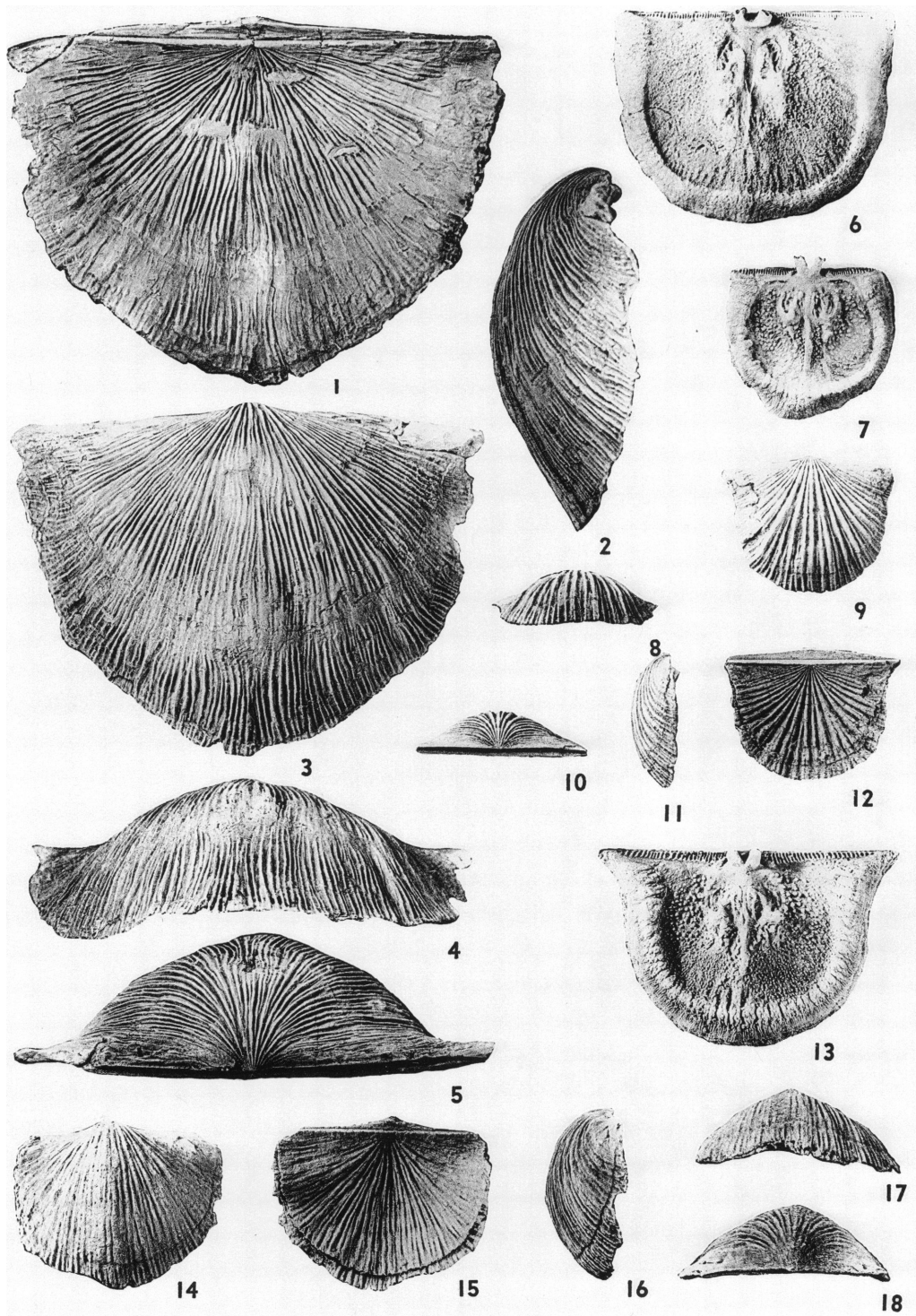
13-17. *Strophodonta extenuata extenuata* Imbrie. Brachial, pedicle, lateral, posterior, and anterior views of holotype; lower Ferron Point formation, locality 38; U.S.N.M. No. 124326;  $\times 1$ .

18-22. *Strophodonta extenuata ferronensis* Imbrie. Brachial, pedicle, lateral, posterior, and anterior views of holotype; upper Ferron Point formation, locality 51; U.S.N.M. No. 124333;  $\times 1$ .

23-27. *Strophodonta extenuata genshawensis* Imbrie, new subspecies. Brachial, pedicle, posterior, anterior, and lateral views of holotype; lower Genshaw formation, locality 51; U.S.N.M. No. 124332;  $\times 1$ .

28, 29. *Strophodonta extenuata rockportensis* Imbrie. Brachial and pedicle interior views; U.S.N.M. Nos. 124329 and 124328; Rockport Quarry limestone, locality 38;  $\times 1$ .





## PLATE 55

1-6. *Strophodonta titan titan* Imbrie, new species and subspecies. 1-5. Brachial, lateral, pedicle, anterior, and posterior views of the holotype; Gravel Point formation, locality 14; U.S.N.M. No. 124267;  $\times 1$ . 6. Brachial interior; Alpena limestone (shale bed 50 feet below top), locality 40; U.S.N.M. No. 124341;  $\times 1$ .

7-13. *Strophodonta crassa* Imbrie, new species. 7. Brachial interior; middle Petoskey formation, locality 21; U.S.N.M. No. 124282;  $\times 1$ . 8-12. Anterior, pedicle, posterior, lateral, and brachial views of holotype; Potter Farm formation, locality 37a; U.S.N.M. No. 124311;  $\times 1$ . 13. Brachial interior; Potter Farm formation, locality 37a; U.S.N.M. No. 124312;  $\times 1$ .

14-18. *Strophodonta titan costella* Imbrie, new species and subspecies. Pedicle, brachial, lateral, anterior, and posterior views of holotype; basal Killians member of Genshaw formation, locality 123a; U.S.N.M. No. 124371;  $\times 1$ .

PLATE 56

1-5. *Strophodonta potterensis* Imbrie, new species. Brachial, pedicle, posterior, anterior, and lateral views of holotype; Potter Farm formation, locality 37a; U.S.N.M. No. 124310;  $\times 1$ .

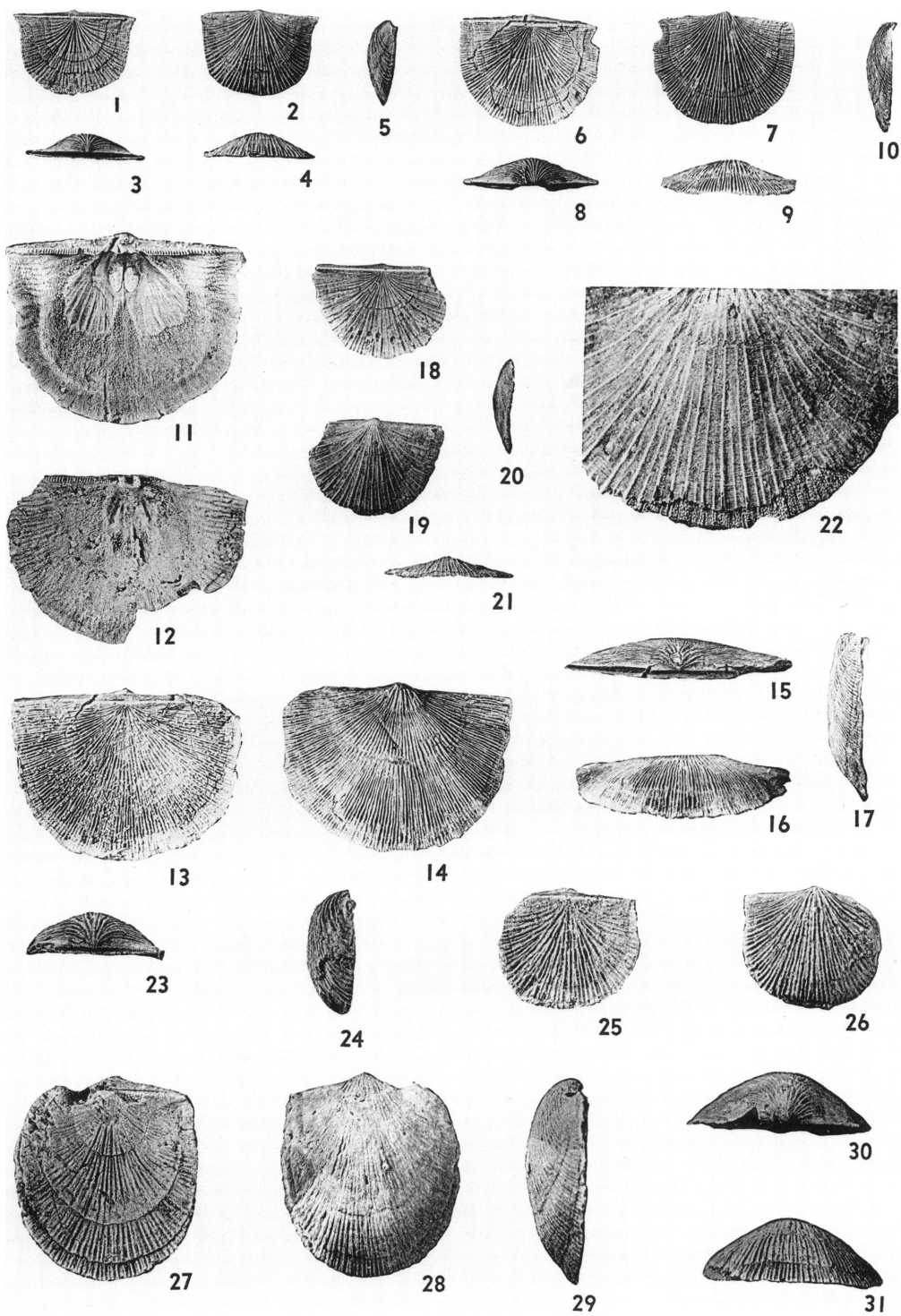
6-10. *Strophodonta levidensa* Imbrie, new species. Brachial, pedicle, posterior, anterior, and lateral views of holotype; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124240;  $\times 1$ .

11-17. *Strophodonta micropleura* Imbrie, new species. 11, 12. Pedicle and brachial interiors; U.S.N.M. Nos. 124340 and 124343; Alpena limestone (shale bed 50 feet below top), locality 40;  $\times 1$ . 13-17. Brachial, pedicle, posterior, anterior, and lateral views of holotype; Alpena limestone, locality 52 l; U.S.N.M. No. 124366;  $\times 1$ .

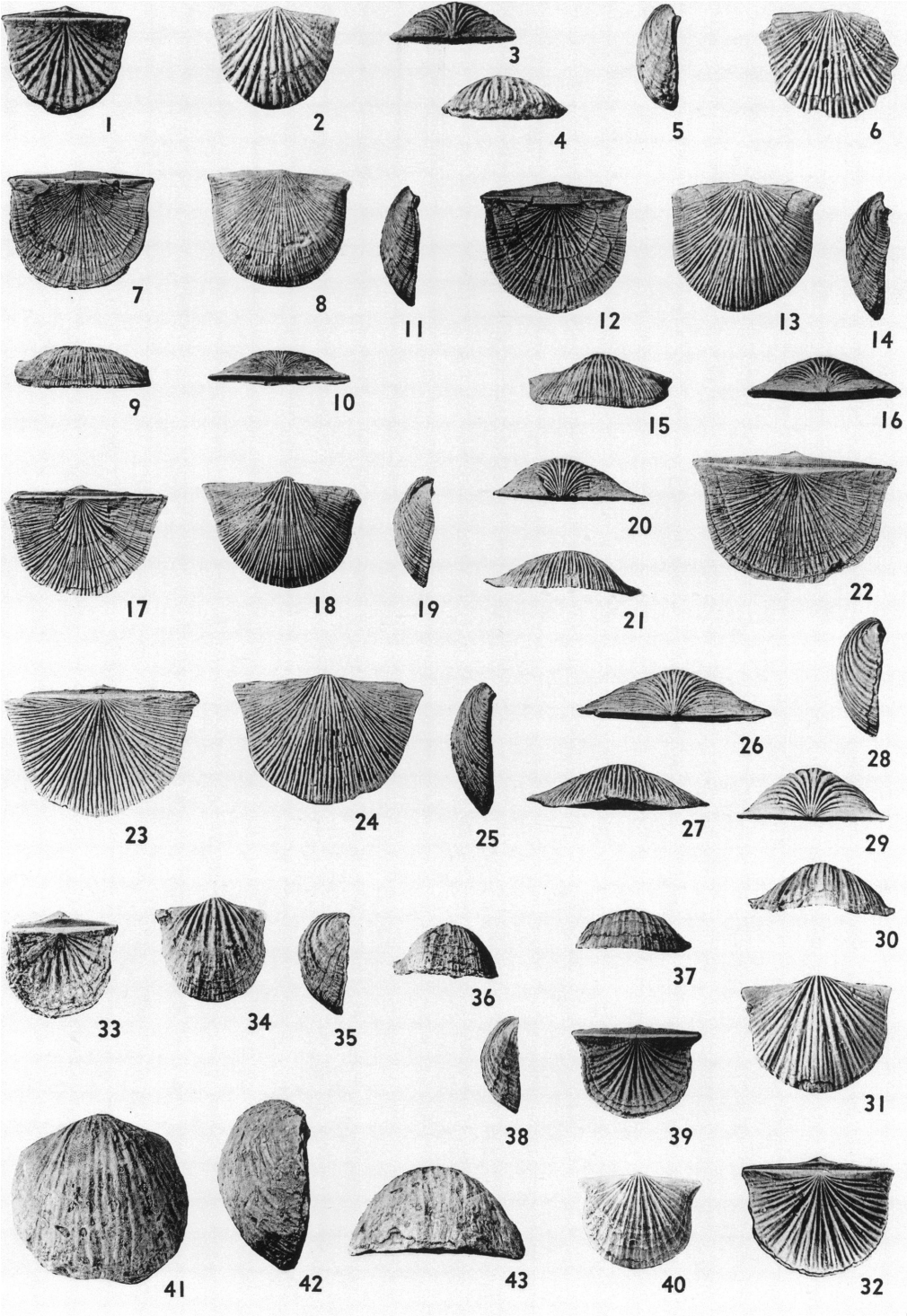
18-22. *Strophodonta rhabdosis* Imbrie, new species. 18-21. Brachial, pedicle, lateral, and anterior views of holotype; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124246;  $\times 1$ . 22. Enlargement of a portion of the pedicle valve of the same specimen;  $\times 3$ .

23-26. *Strophodonta paula* Imbrie, new species. Posterior, lateral, brachial, and pedicle views of holotype; Alpena limestone, locality 52 l; U.S.N.M. No. 124368;  $\times 1$ .

27-31. *Strophodonta elongata* Imbrie, new species. Brachial, pedicle, lateral, posterior, and anterior views of holotype; Potter Farm formation, locality 41e; U.S.N.M. No. 124352;  $\times 2$ .









## PLATE 57

1-6. *Strophodonta proteus* Imbrie, new species. 1-5. Brachial, pedicle, posterior, anterior, and lateral views of holotype; Alpena limestone, locality 52 1; U.S.N.M. No. 124369;  $\times 1$ . 6. Pedicle view of another specimen from the same horizon and locality; U.S.N.M. No. 124370;  $\times 1$ .

7-11. *Strophodonta alpenensis* Grabau. Brachial, pedicle, anterior, posterior, and lateral views; Norway Point formation, locality 46; U.S.N.M. No. 124354;  $\times 1$ .

12-16. *Strophodonta tenuicosta* Imbrie, new species. Brachial, pedicle, lateral, anterior, and posterior views of holotype; middle Petoskey formation, locality 21; U.S.N.M. No. 124283;  $\times 1$ .

17-22. *Strophodonta fissicosta* Winchell. 17-21. Brachial, pedicle, lateral, posterior, and anterior views of a specimen; Gravel Point formation, locality 18a; U.S.N.M. No. 124277;  $\times 1$ . 22. Brachial view of another specimen from the same formation and locality; U.S.N.M. No. 124278;  $\times 1$ .

23-27. *Strophodonta pentagonia* Imbrie, new species. Brachial, pedicle, lateral, posterior, and anterior views of the holotype; middle Petoskey formation, locality 21a; U.S.N.M. No. 124286;  $\times 1$ .

28-32. *Strophodonta acris* Imbrie, new species. Lateral, posterior, anterior, pedicle, and brachial views of the holotype; Genshaw formation (basal Killians member), locality 123a; U.S.N.M. No. 124372;  $\times 1$ .

33-43. *Strophodonta erratica* Winchell. 33-36. Brachial, pedicle, lateral, and anterior views; "large *Atrypa* zone" of Gravel Point formation, locality 14; U.S.N.M. No. 124309;  $\times 1$ . 37-40. Anterior, lateral, brachial, and pedicle view; same horizon and locality; U.S.N.M. No. 124268;  $\times 1$ . 41-43. Pedicle, lateral, and anterior views; Gravel Point formation, locality 103; U.S.N.M. No. 124376;  $\times 1$ .

PLATE 58

1-6. *Strophodonta heteromys* Imbrie, new species. 1-5. Brachial, pedicle, posterior, anterior, and lateral views of holotype; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124248;  $\times 1$ . 6. Brachial interior; same locality and horizon; U.S.N.M. No. 124247;  $\times 1$ .

7-11. *Strophodonta discus* Imbrie, new species. Brachial, pedicle, lateral, posterior, and anterior views of holotype; Alpena limestone, locality 52 l; U.S.N.M. No. 124367;  $\times 1$ .

12-14. *Strophodonta* sp. C. Brachial, pedicle, and lateral views of a specimen; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124263;  $\times 1$ .

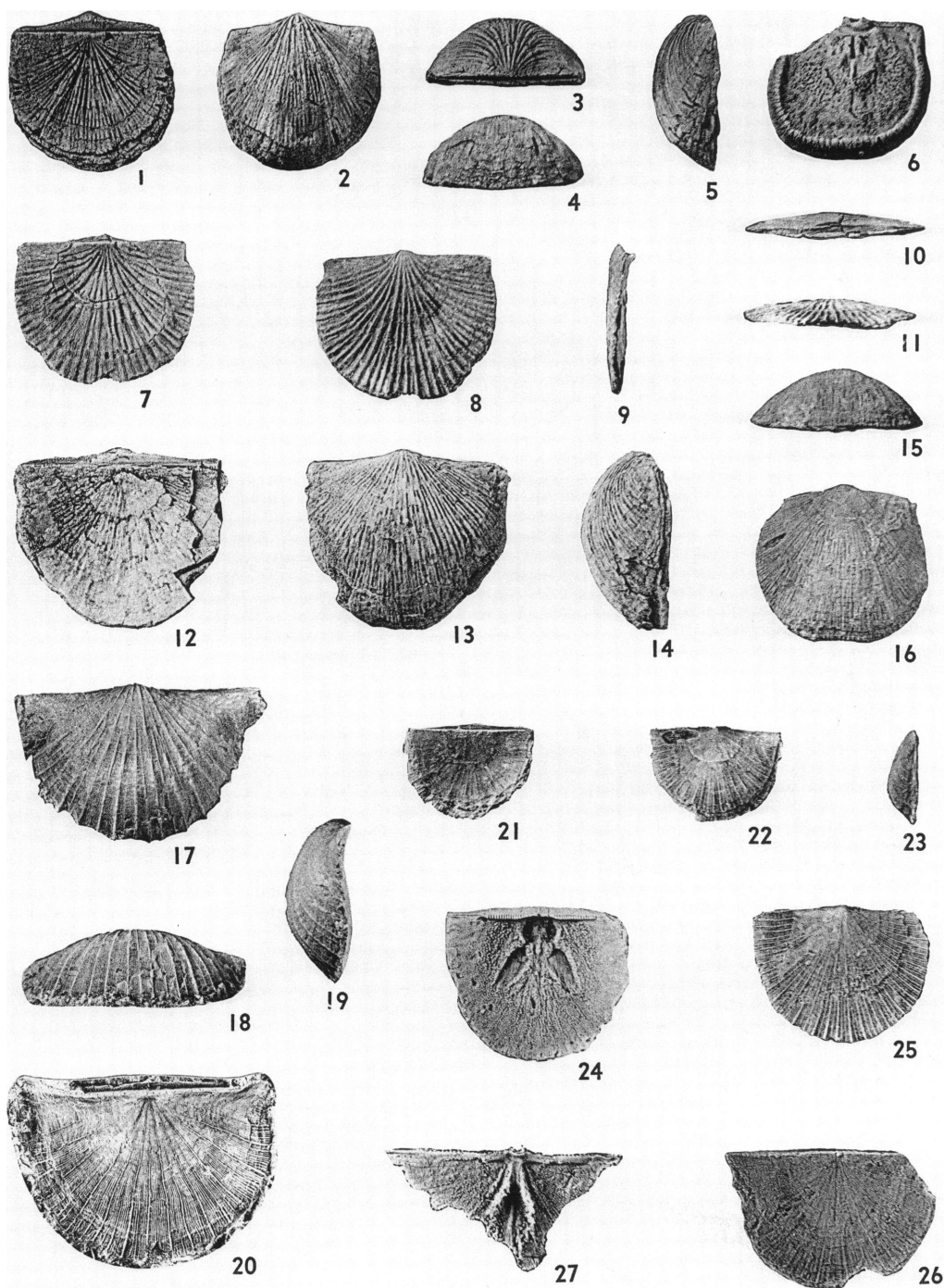
15, 16. *Strophodonta* sp. B. Anterior and pedicle views of a specimen; Dock Street clay member of the Four Mile Dam formation, locality 53; U.S.N.M. No. 124364;  $\times 1$ .

17-20. *Douvillina distans* Imbrie, new species. 17-19. Pedicle, anterior, and lateral views of holotype; Four Mile Dam formation, locality 41; U.S.N.M. No. 124349;  $\times 2$ . 20. Brachial view of another specimen from the same horizon and locality; U.S.N.M. No. 124348;  $\times 2$ .

21-23. *Douvillina* sp. Brachial, pedicle, and lateral views of a specimen; "large *Atrypa* zone" of Gravel Point formation, locality 14; U.S.N.M. No. 124269;  $\times 1$ .

24-26. *Hercostrophia alpenensis* Williams. 24. Pedicle interior of holotype; Alpena limestone, 30 to 40 feet below top, locality 40; U.S.N.M. No. 116017;  $\times 2$ . 25, 26. Pedicle and brachial views of different specimens from the same horizon and locality; U.S.N.M. No. 116018;  $\times 2$ .

27. *Hercostrophia* sp. Brachial interior; Hamilton group at Canandaigua Lake, New York, U.S.N.M. No. 116034b;  $\times 2$ .



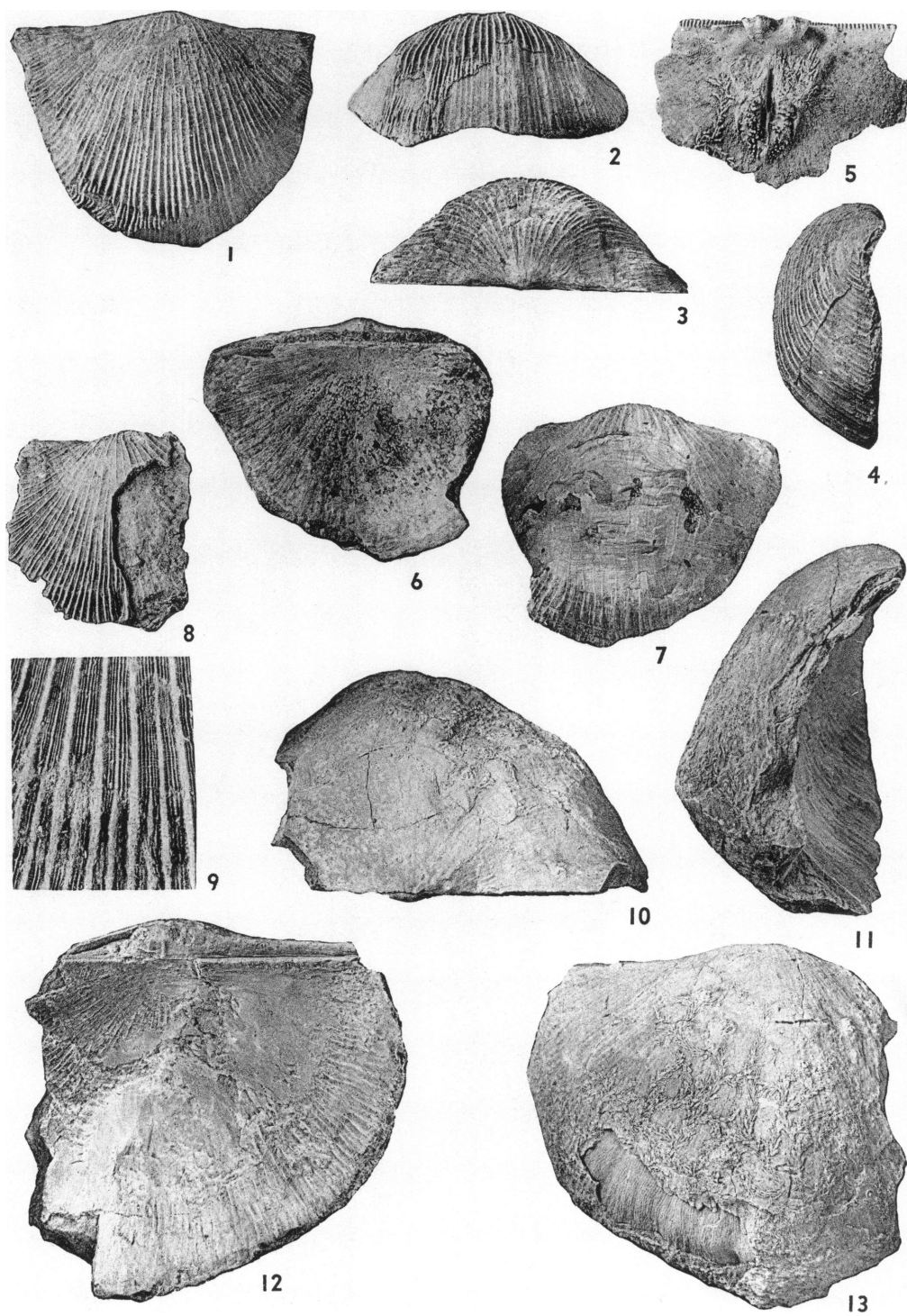


PLATE 59

1-7. *Megastrophia gibbosa* Imbrie, new species. 1-4. Pedicle, anterior, posterior, and lateral views of holotype; Hungry Hollow formation at the Aux Sables River north of Arkona, Ontario; U.S.N.M. No. 124391;  $\times 1$ . 5. Brachial interior; Hungry Hollow formation, tile yard at Thedford, Ontario; U.S.N.M. No. 124392;  $\times 1$ . 6, 7. Brachial and pedicle views of a specimen; Four Mile Dam formation, locality 41; U.S.N.M. No. 124347;  $\times 1$ .

8, 9. *Megastrophia* sp. 8. Pedicle view of an incomplete specimen; lower Bell shale, locality 31; U.S.N.M. No. 124297;  $\times 1$ . 9. Enlargement of a portion of the pedicle valve of the same specimen;  $\times 4$ .

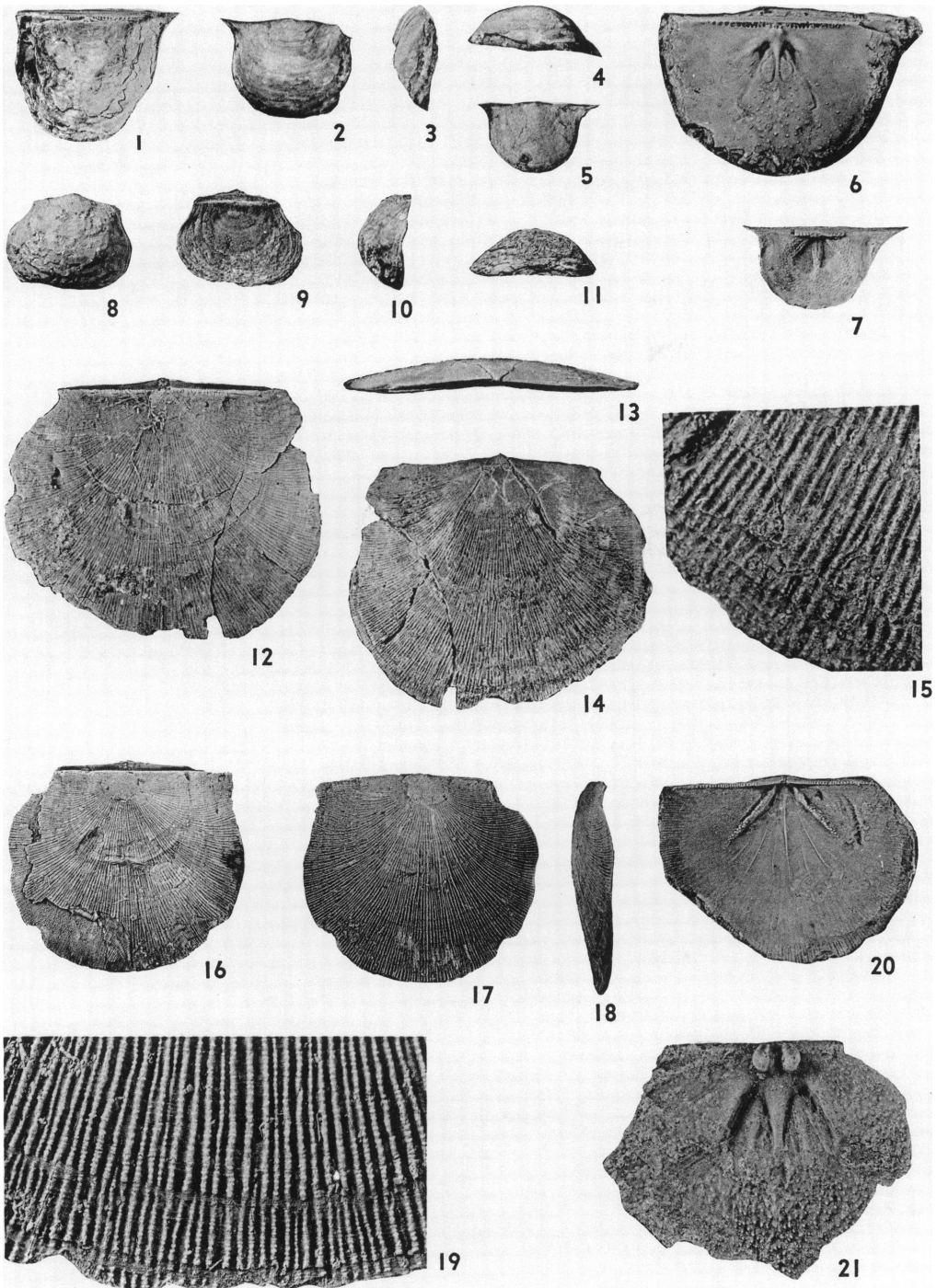
10-13. *Megastrophia concava* (Hall). Posterior, lateral, brachial, and pedicle views of an incomplete specimen; Alpena limestone, locality 52 1; U.S.N.M. No. 124365;  $\times 1$ .

PLATE 60

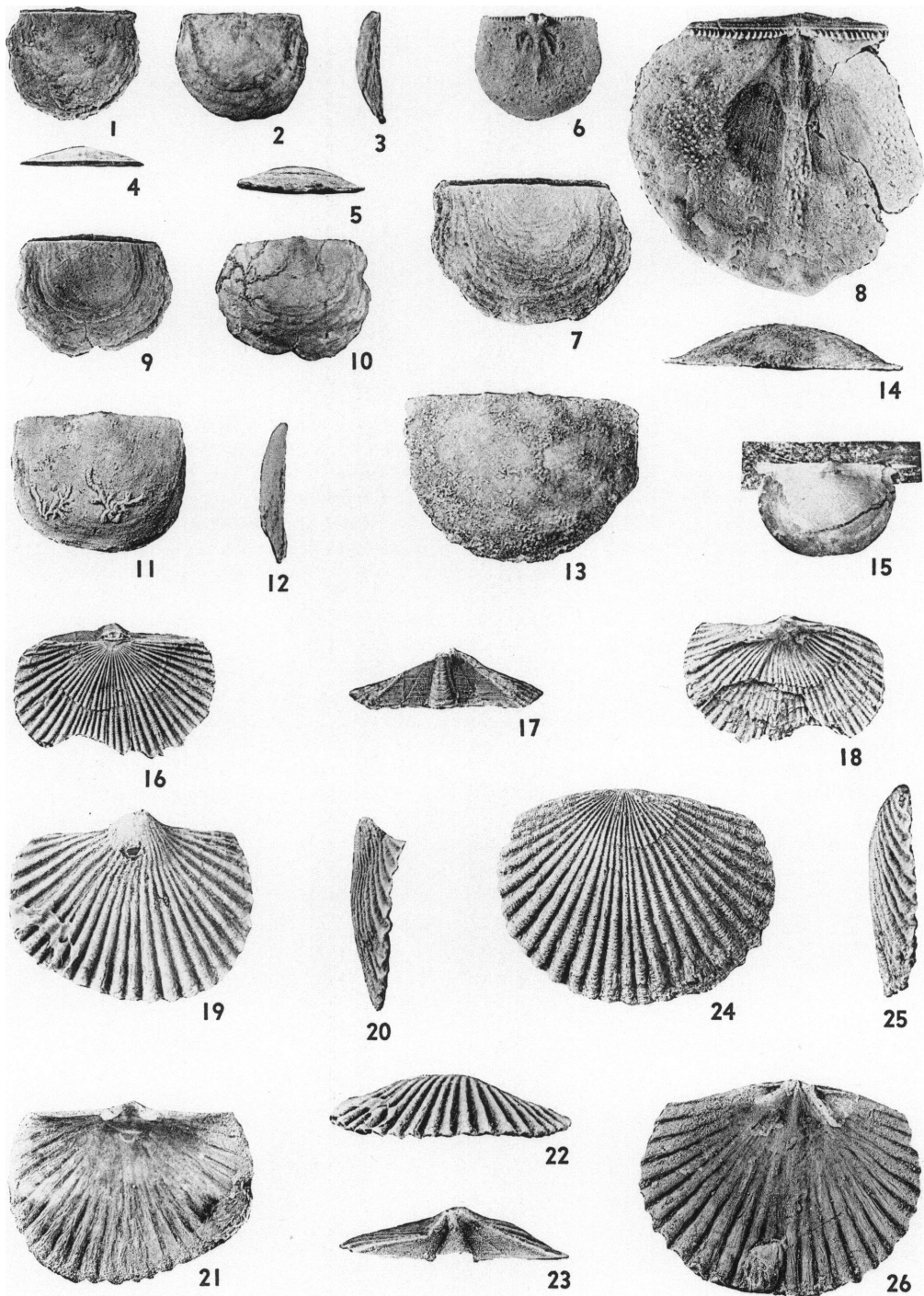
1-7. *Pholidostrophia geniculata* Imbrie, new species. 1. Brachial view of holotype; lower Gravel Point formation, locality 100; U.S.N.M. No. 124378;  $\times 1$ . 2-4. Pedicle, lateral, and anterior views of another specimen from the same horizon and locality; U.S.N.M. No. 124381;  $\times 1$ . 5. Pedicle view of an immature specimen from the same horizon and locality; U.S.N.M. No. 124379;  $\times 1$ . 6. Brachial interior; "*Longispina emmetensis* zone" of Gravel Point formation, locality 19; U.S.N.M. No. 124281;  $\times 2$ . 7. Pedicle interior; lower Gravel Point formation, locality 100; U.S.N.M. No. 124380;  $\times 1$ .

8-11. *Pholidostrophia ovata* Imbrie, new species. Pedicle, brachial, lateral, and anterior views of holotype; Norway Point formation, locality 47; U.S.N.M. No. 124383;  $\times 1$ .

12-21. *Protoleptostrophia lirella* Imbrie, new species. 12-14. Brachial, posterior, and pedicle views; Alpena limestone, locality 53; U.S.N.M. No. 124363;  $\times 1$ . 15. Detail of surface of pedicle valve of the same specimen;  $\times 5$ . 16-18. Brachial, pedicle, and lateral views of holotype; Norway Point formation, locality 47; U.S.N.M. No. 124384;  $\times 1$ . 19. Detail of surface of pedicle valve of the same specimen;  $\times 5$ . 20. Pedicle interior; Dock Street clay member of Four Mile Dam formation, locality 53; U.S.N.M. No. 124361;  $\times 1$ . 21. Brachial interior; same formation and locality; U.S.N.M. No. 124362;  $\times 2$ .









## PLATE 61

1-10. *Pholidostrophia gracilis gracilis* Imbrie. 1-5. Brachial, pedicle, lateral, posterior, and anterior views of holotype; basal 8 inches of Rockport Quarry limestone, locality 38; U.S.N.M. No. 124318;  $\times 1$ . 6. Brachial interior; lower Ferron Point formation, locality 38; U.S.N.M. No. 124319;  $\times 1$ . 7. Brachial view; basal 8 inches of Rockport Quarry limestone, locality 38; U.S.N.M. No. 124317;  $\times 1$ . 8. Pedicle interior; same horizon and locality; U.S.N.M. No. 124313;  $\times 2$ . 9, 10. Brachial and pedicle views of a specimen; lower Ferron Point formation, locality 38; U.S.N.M. No. 124321;  $\times 1$ .

11, 12. *Pholidostrophia gracilis nanus* Imbrie. Pedicle and lateral views of holotype; upper 12 feet of Bell shale, locality 38; U.S.N.M. No. 124320;  $\times 2$ .

13, 14. *Pholidostrophia* sp. A. Pedicle and posterior views of a specimen; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 124258;  $\times 2$ .

15. *Pholidostrophia* sp. B. Pedicle view; Four Mile Dam formation, locality 41; U.S.N.M. No. 124350;  $\times 15$ .

16-18. *Orthopleura* sp. B. Brachial, posterior, and pedicle views of a specimen; "upper Blue shale" of Gravel Point formation, locality 14e; U.S.N.M. No. 124280;  $\times 2$ .

19-26. *Orthopleura rhipis* Imbrie, new genus and species. 19-23. Pedicle, lateral, interior, anterior, and posterior views of the holotype, a pedicle valve; Genshaw formation, locality 105; U.S.N.M. No. 124382;  $\times 3$ . 24-26. Brachial, lateral, and interior views of a brachial valve from the same horizon and locality; U.S.N.M. No. 124383;  $\times 3$ .

## PLATE 62

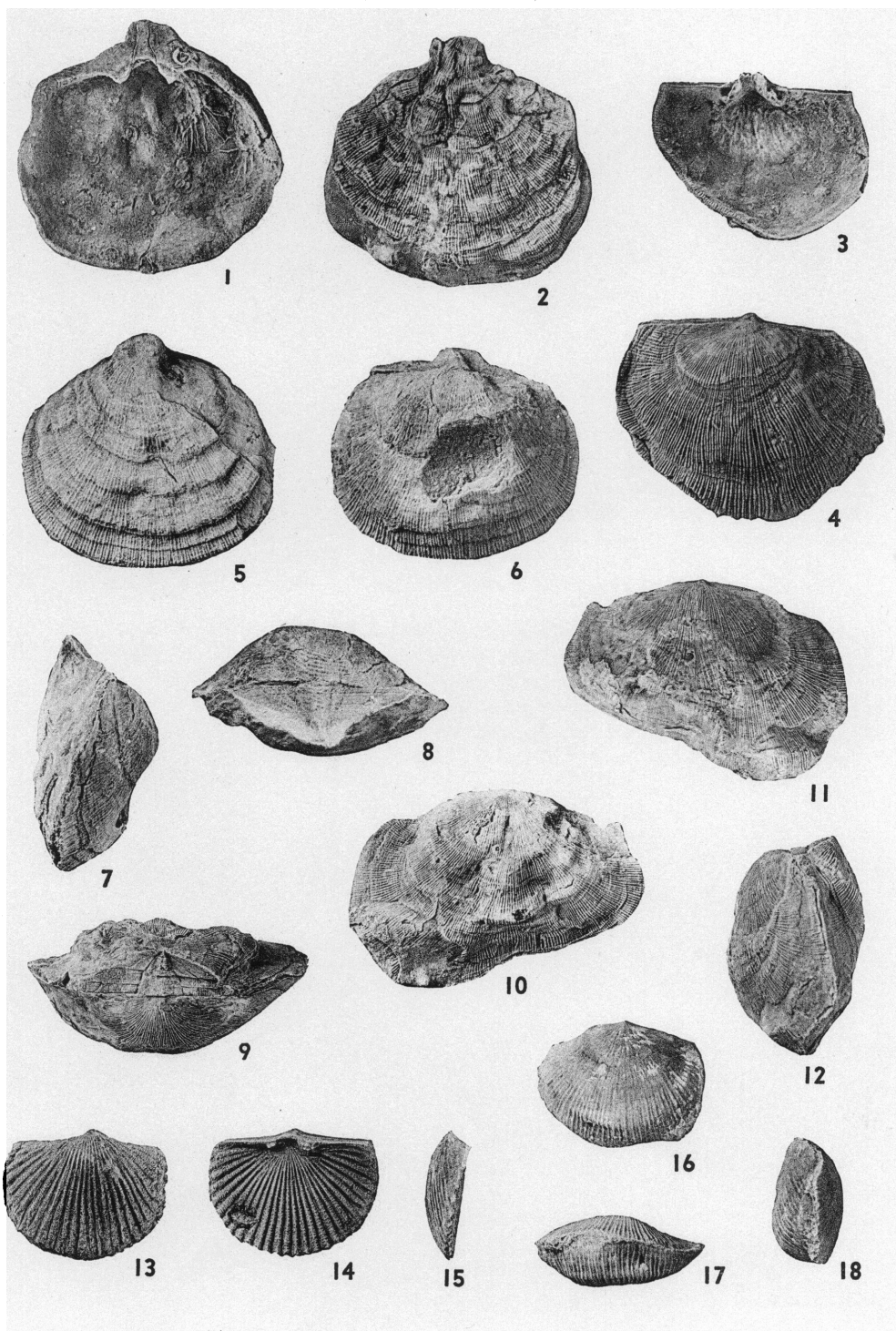
1-4. *Schuchertella anomala* (Winchell). 1, 2. Interior and exterior of pedicle valve; Gravel Point formation, locality 14; U.S.N.M. No. 124270;  $\times 1$ . 3. Brachial interior; Gravel Point formation, locality 103; U.S.N.M. No. 124377;  $\times 1$ . 4. Brachial view of another specimen; same formation and locality; U.S.N.M. No. 124375;  $\times 1$ .

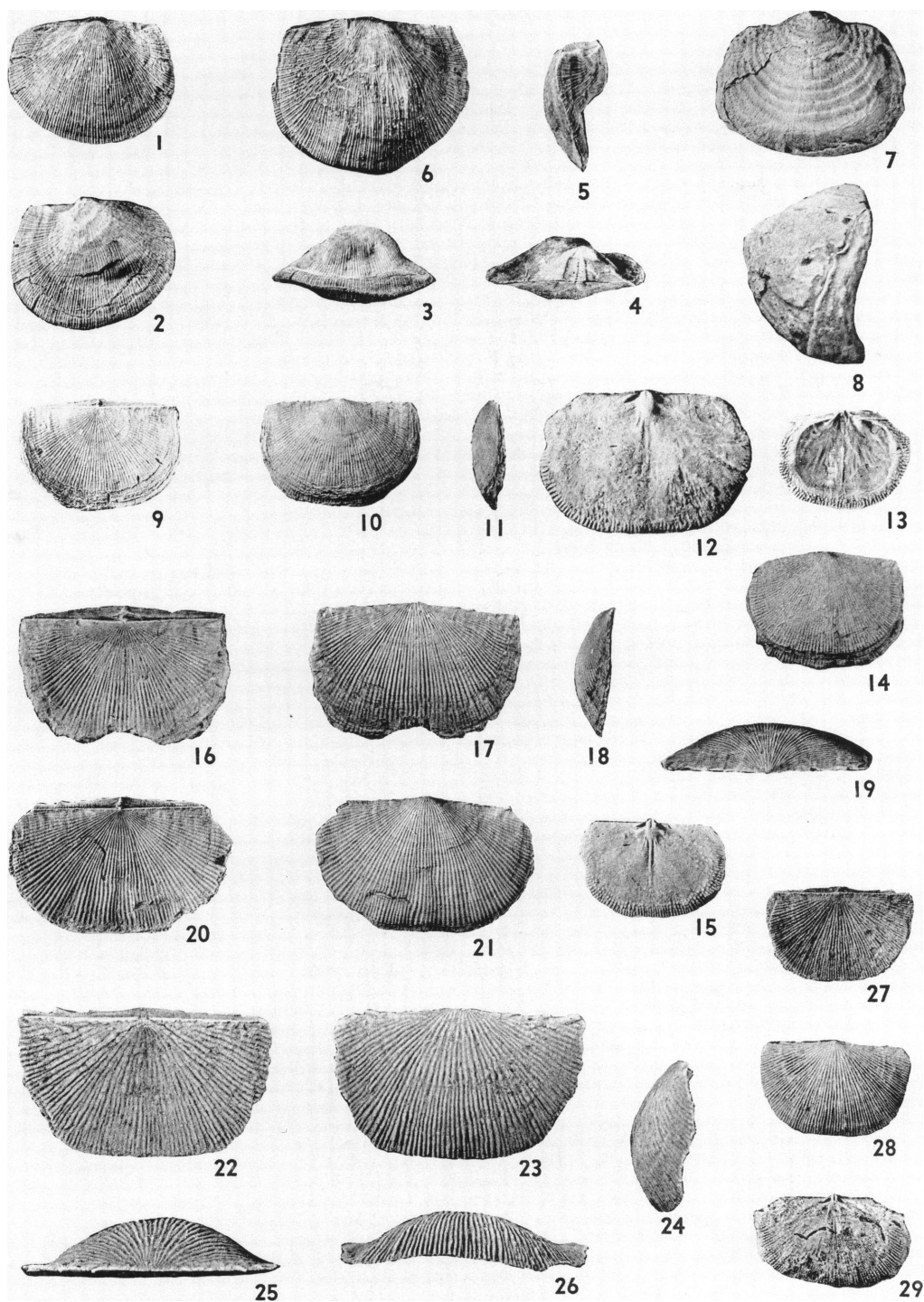
5-8. *Schuchertella cornucopia* Imbrie, new species. Pedicle, brachial, lateral, and posterior views of the holotype; Genshaw formation, locality 52h; U.S.N.M. No. 124373;  $\times 1$ .

9-12. *Schuchertella lirella* Imbrie, new species. Posterior, pedicle, brachial, and lateral views of the holotype; Norway Point formation, locality 46; U.S.N.M. No. 124393;  $\times 1$ .

13-15. *Orthopleura* sp. A. Pedicle, brachial, and lateral views of a specimen; "large *Atrypa* zone" of Gravel Point formation, locality 14; U.S.N.M. No. 124276;  $\times 2$ .

16-18. *Schuchertella* sp. Pedicle, anterior, and lateral views of a specimen; Four Mile Dam formation, locality 41; U.S.N.M. No. 124351;  $\times 2$ .





## PLATE 63

1-6. *Schuchertella crassa* Imbrie, new species. 1-5. Brachial, pedicle, anterior, posterior, and lateral views of holotype; lower 10 feet of Ferron Point formation, locality 38; U.S.N.M. No. 124316;  $\times 1$ . 6. Brachial view of another individual; upper Ferron Point formation, locality 51; U.S.N.M. No. 124366;  $\times 1$ . 7, 8. *Leptaena* sp. Pedicle and lateral views of two specimens; U.S.N.M. Nos. 124251 and 124252; uppermost Petoskey formation, locality 7c;  $\times 1$ .

9-15. *Chonetes mediolatus* Cooper. 9-11. Brachial, pedicle, and lateral views of a specimen; upper Ferron Point formation, locality 51; U.S.N.M. No. 124377;  $\times 1$ . 12, 13. Brachial and pedicle interiors of two specimens, U.S.N.M. Nos. 124300 and 124306; lower Bell shale, locality 31;  $\times 1$ . 14. Pedicle view of another specimen; upper Bell shale, locality 38; U.S.N.M. No. 124331.  $\times 1$ . 15. Brachial interior; lower Bell shale, locality 38; U.S.N.M. No. 124315;  $\times 1$ .

16-21. *Chonetes pachyactis* Imbrie, new species. 16-19. Brachial, pedicle, lateral, and posterior views of the holotype; Norway Point formation, locality 47; U.S.N.M. No. 124397;  $\times 1$ . 20, 21. Brachial and pedicle views of another specimen from the same horizon and locality; U.S.N.M. No. 124396;  $\times 1$ .

22-29. *Chonetes ensicosta* Imbrie, new species. 22-26. Brachial, pedicle, lateral, posterior, and anterior views of holotype; lower Petoskey formation, locality 12; U.S.N.M. No. 124265;  $\times 2$ . 27, 28. Brachial and pedicle views of another specimen from the same horizon and locality; U.S.N.M. No. 124264;  $\times 1$ . 29. Brachial interior of a specimen from the same horizon and locality; U.S.N.M. No. 124266;  $\times 1$ .

## PLATE 64

1-5. *Chonetes nateforma* Imbrie, new species. 1-4. Brachial, pedicle, posterior, and anterior views of the holotype; upper Ferron Point formation, locality 51. U.S.N.M. No. 125536;  $\times 1$ . 5. Brachial interior; lower Ferron Point formation, locality 38; U.S.N.M. No. 125537;  $\times 2$ .

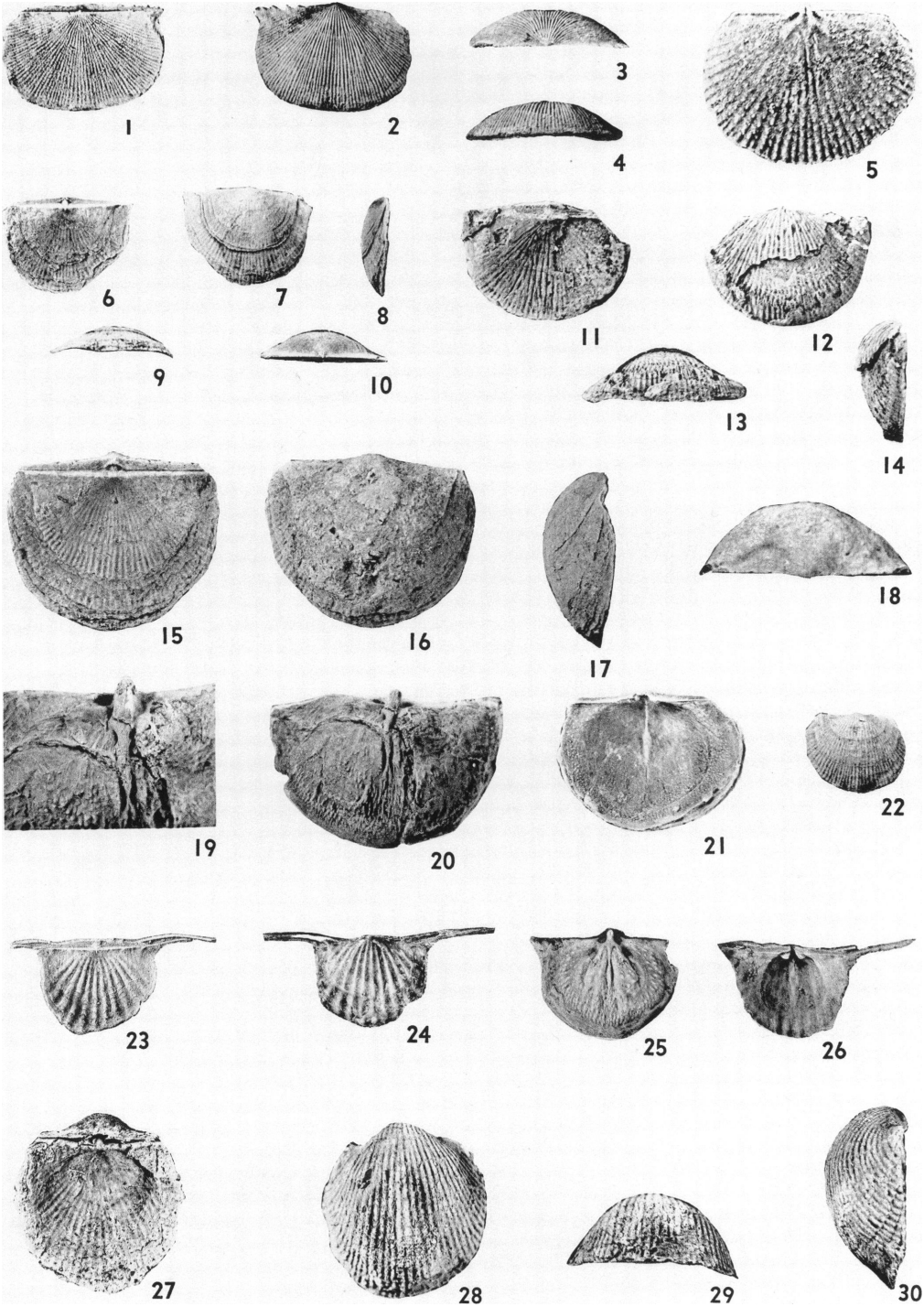
6-10. *Longispina leionanus* Imbrie, new species. Brachial, pedicle, lateral, anterior, and posterior views of the holotype; lower Bell shale, locality 31; U.S.N.M. No. 125539;  $\times 2$ .

11-14. *Chonetes hybus* Imbrie, new species. Brachial, pedicle, anterior, and lateral views of the holotype; uppermost Petoskey formation, locality 7c; U.S.N.M. No. 125538;  $\times 2$ .

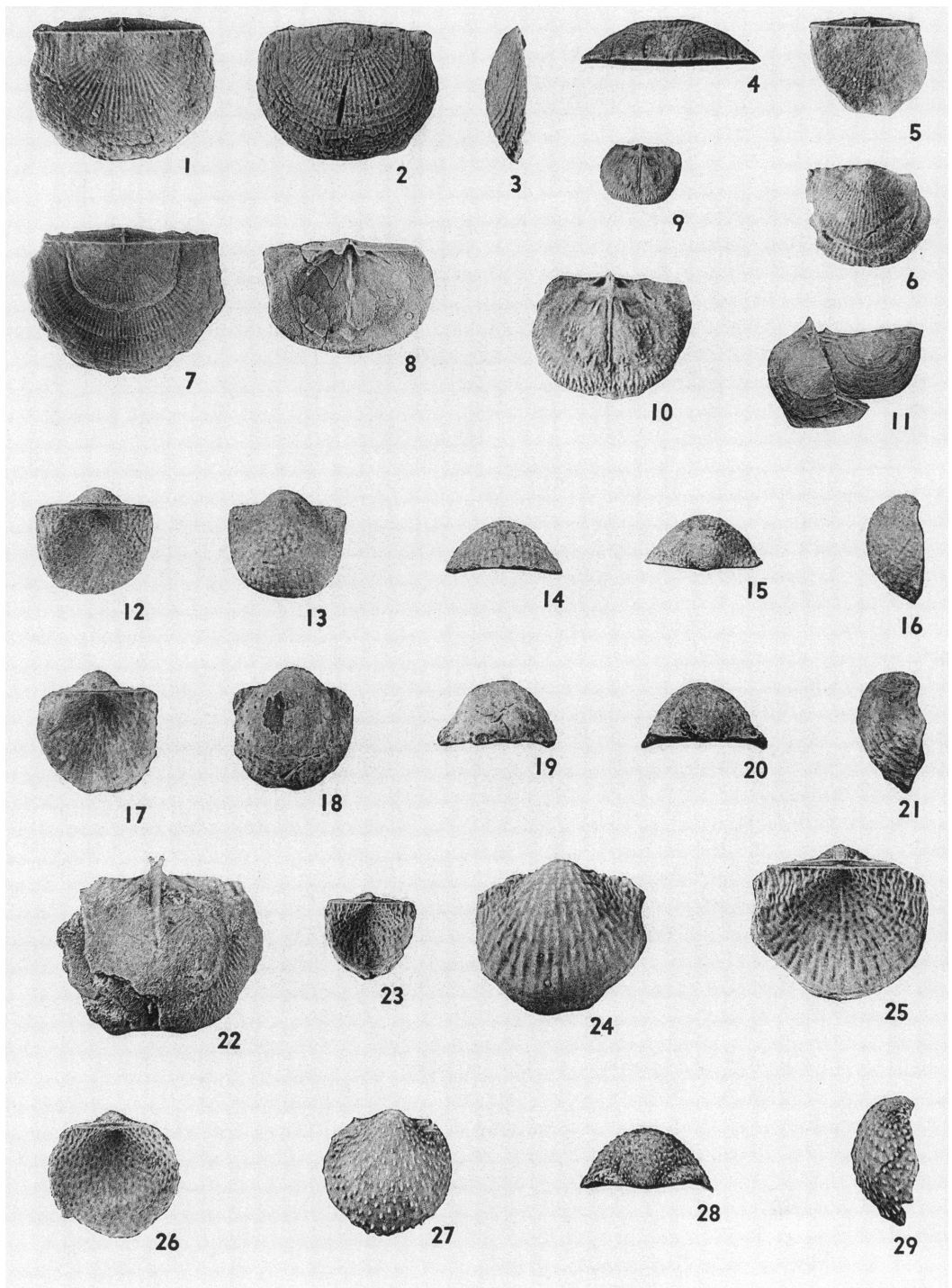
15-22. *Longispina lissohybus* Imbrie, new species. 15-18. Brachial, pedicle, lateral, and posterior views of the holotype; lower Ferron Point formation, locality 38; U.S.N.M. No. 125540;  $\times 2$ . 19. Detail of the cardinalia of a specimen; lower Ferron Point formation, locality 38; U.S.N.M. No. 125541;  $\times 3$ . 20. Brachial interior of the same specimen;  $\times 2$ . 21. Pedicle interior of another specimen from the same horizon and locality; U.S.N.M. No. 125542;  $\times 2$ . 22. Pedicle view of another specimen from the same horizon and locality; U.S.N.M. No. 125543;  $\times 1$ .

23-26. *Longispina emmetensis* (Winchell). 23, 24. Brachial and pedicle views of two specimens; "Longispina emmetensis zone" of the Gravel Point formation, locality 8; U.S.N.M. Nos. 108206a, 108206b;  $\times 2$ . 25, 26. Brachial and pedicle interiors of two specimens from the same horizon and locality; U.S.N.M. Nos. 108206c, 108206d;  $\times 2$ .

27-30. *Longispina pelta* Imbrie, new species. Brachial, pedicle, anterior, and lateral views of holotype; Rockport Quarry formation, locality 114; U.S.N.M. No. 125544;  $\times 2$ .









## PLATE 65

1-4, 7-11. *Longispina subcalva* Imbrie, new species. 1-4. Brachial, pedicle, lateral, and posterior views of the holotype; upper Ferron Point formation, locality 51; U.S.N.M. No. 125545;  $\times 2$ . 7. Brachial view of another individual; upper Ferron Point formation, locality 51; U.S.N.M. No. 125548;  $\times 2$ . 8. Pedicle interior; Genshaw formation, locality 49; U.S.N.M. No. 125581;  $\times 2$ . 9, 10. Two views of the brachial interior of a specimen; same horizon and locality; U.S.N.M. No. 125549;  $\times 1$  and  $\times 2$ . 11. Pedicle views of two specimens; Genshaw formation, locality 49;  $\times 1$ . Note the direction of the spines.

5, 6. *Longispina leionanus* Imbrie, new species. Brachial and pedicle views; lower Bell shale, locality 31; U.S.N.M. Nos. 125546 and 125547;  $\times 1$ .

12-16, 22. *Helaspis luma luma* Imbrie, new genus, species, and subspecies. 12-16. Brachial, pedicle, anterior, posterior, and lateral views of the holotype; upper Genshaw formation, locality 50; U.S.N.M. No. 125554;  $\times 1$ . 22. Brachial interior; Genshaw formation, locality 108; U.S.N.M. No. 125555;  $\times 2$ .

17-21. *Helaspis luma crista* Imbrie, new genus, species, and subspecies. Brachial, pedicle, anterior, posterior, and lateral views of the holotype; Killians member of Genshaw formation, locality 52; U.S.N.M. No. 125556;  $\times 1$ .

23-25. *Helaspis luma* Imbrie, new genus and species. 23. Brachial view of a specimen; Koehler limestone, locality 27; U.S.N.M. No. 125557;  $\times 1$ . 24, 25. Pedicle and brachial views of another specimen from the same formation and locality; U.S.N.M. No. 125558;  $\times 2$ .

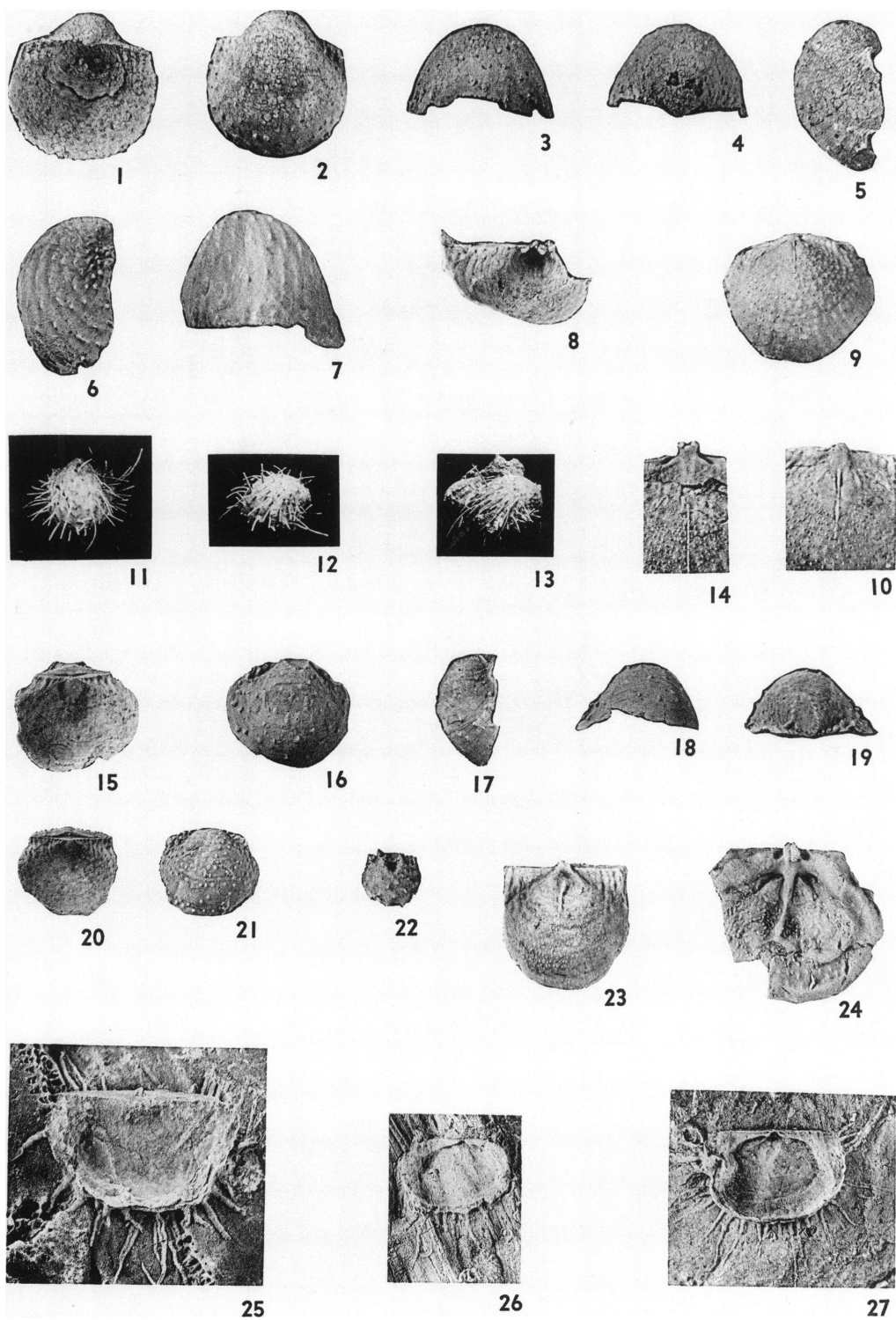
26-29. *Helaspis* sp. Brachial, pedicle, posterior, and lateral views of a specimen; lower Bell shale, locality 31; U.S.N.M. No. 125559;  $\times 2$ .

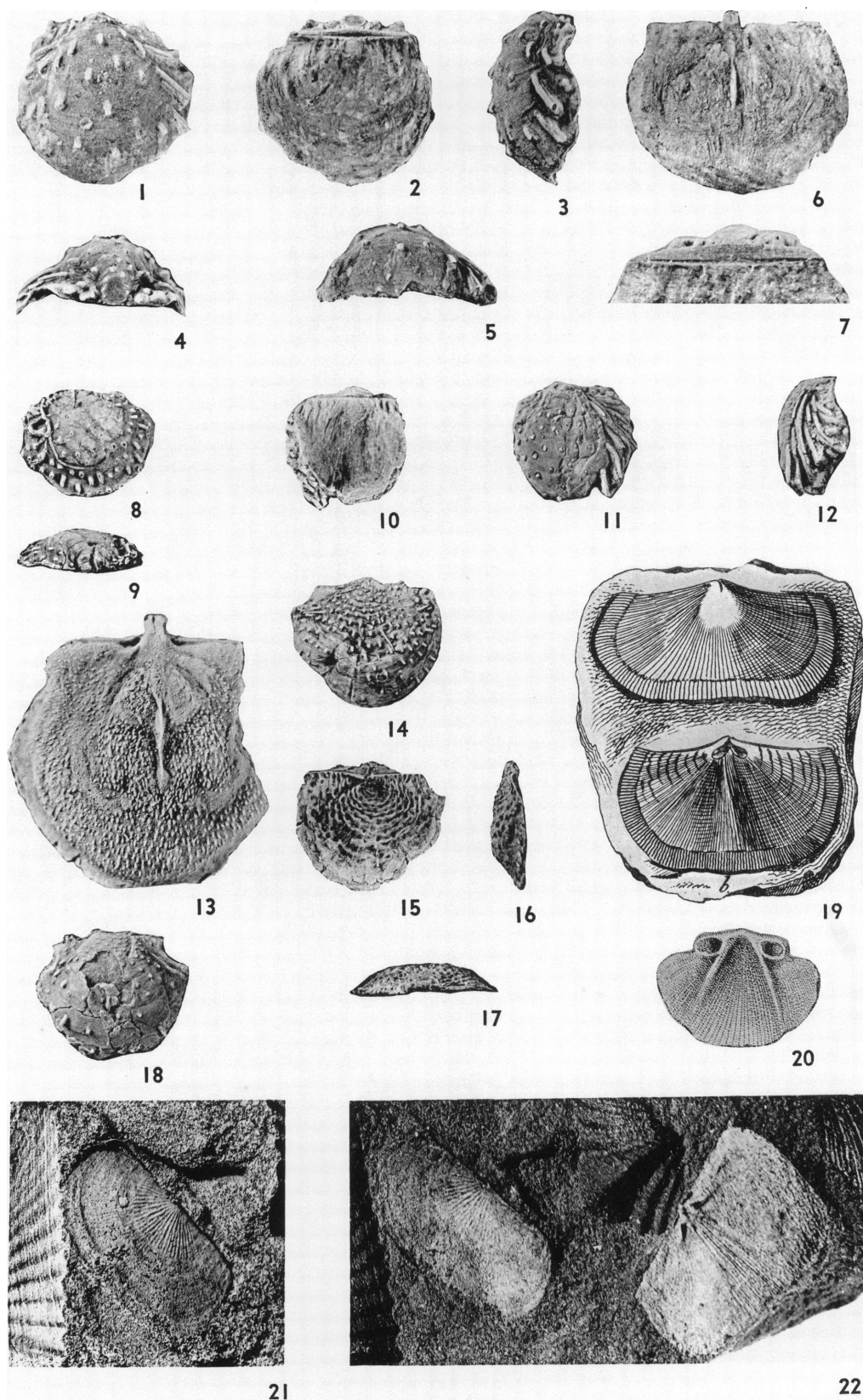
## PLATE 66

1-14. *Spinulicosta mutocosta* Imbrie, new species. 1-5. Brachial, pedicle, anterior, posterior, and lateral views of holotype; Beebe School formation, locality 22a; U.S.N.M. No. 125561;  $\times 2$ . 6, 7. Lateral and anterior views of a specimen; lower Ferron Point formation, locality 38; U.S.N.M. No. 125562;  $\times 2$ . 8. Pedicle interior; Beebe School formation, locality 22a; U.S.N.M. No. 125563;  $\times 2$ . 9. Brachial interior of a specimen; Beebe School formation, locality 24b; U.S.N.M. No. 125564;  $\times 2$ . 10, 14. Details of cardinalia of different individuals from the same horizon and locality; U.S.N.M. No. 125565;  $\times 3$  and  $\times 4$ . 11, 12. Pedicle and lateral views of a specimen from the same horizon and locality; U.S.N.M. No. 125566;  $\times 1$ . 13. Lateral view of another specimen from the same horizon and locality; U.S.N.M. No. 125567;  $\times 1$ .

15-23. *Truncalosia gibbosa* Imbrie, new genus and species. 15-19. Brachial, pedicle, lateral, anterior, and posterior views of the holotype; "upper Blue shale" of the Gravel Point formation, locality 14e; U.S.N.M. No. 125568;  $\times 2$ . 20, 21. Brachial and pedicle views of a specimen; "upper Blue shale" of Gravel Point formation, locality 9; U.S.N.M. No. 125569;  $\times 2$ . 22. Pedicle view of a specimen; Potter Farm formation, locality 41c; U.S.N.M. No. 125570;  $\times 1$ . 23. Brachial interior; "upper Blue shale" of the Gravel Point formation, locality 131; U.S.N.M. No. 125571;  $\times 3$ .

24-27. *Leptollosia radicans* (Winchell). 24. Brachial interior; "lower Blue shale" of Gravel Point formation, locality 14; U.S.N.M. No. 123887d;  $\times 4$ . 25. Brachial view of a specimen; same horizon and locality; U.S.N.M. No. 123887a;  $\times 4$ . 26. Pedicle interior; same horizon and locality; U.S.N.M. No. 125572;  $\times 2$ . 27. Pedicle interior; Alpena formation, locality 53; U.S.N.M. No. 125573;  $\times 2$ .





## PLATE 67

1-7. *Oligorhachis oligorhachis* Imbrie, new genus and species. 1-5. Pedicle, brachial, lateral, posterior, and anterior views of the holotype; Gravel Point formation, locality 103; U.S.N.M. No. 125574;  $\times 3$ . 6. Brachial interior; "large *Atrypa* zone" of Gravel Point formation, locality 14; U.S.N.M. No. 125575;  $\times 4$ . 7. Detail of hinge margin in brachial aspect; Gravel Point formation, locality 14; U.S.N.M. No. 125576;  $\times 4$ . 8, 9. *Heteralosia* sp. A. Pedicle and posterior views of a specimen; Genshaw formation, locality 52h; U.S.N.M. No. 125577;  $\times 2$ .

10-12. *Oligorhachis littletonensis?* (Stainbrook). Brachial, pedicle, and lateral views of a specimen; middle Petoskey formation, locality 21; U.S.N.M. No. 125582;  $\times 2$ .

13-17. *Heteralosia caperata* Imbrie, new species. 13. Brachial interior; Genshaw formation, locality 105; U.S.N.M. No. 125579;  $\times 4$ . 14-17. Pedicle, brachial, lateral, and posterior views of the holotype; upper Genshaw formation, locality 25a; U.S.N.M. No. 125580;  $\times 2$ .

18. *Heteralosia* sp. B. Pedicle view of a specimen; upper Gravel Point formation, locality 17; U.S.N.M. No. 125578;  $\times 2$ .

19. *Chonetes sarcinulatus* (Schlotheim). After Schlotheim (1820, pl. 29, figs. 3a and 3b).

20. "*Chonetes*" Fischer. After Fischer (1837, pl. 26, fig. 8).

21, 22. *Chonetes sarcinulatus* (Schlotheim). Photographs of Schlotheim's types courtesy of Dr. Helen M. Muir-Wood, British Museum (Natural History). 21. Mold of brachial exterior; specimen sprayed; illumination from the northwest;  $\times 2$ . 22. *Left*: Mold of brachial exterior. *Right*: Mold of brachial interior; specimens not sprayed. illumination from the southeast;  $\times 2$ .









