1936

Montana Middle Cambrian brachiopoda

William Charles Bell

The University of Montana

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by

K. Charles Bell

Submitted in partial fulfillment of the requirement for the degree of Master of Arts

Montana State University

1936

Approved:

[Signature]
Chairman of examining Committee

[Signature]
Chairman of Graduate Committee
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The first carefully measured stratigraphic sections of Paleozoic rocks in northwestern Montana were published by Deiss in 1933. He divided the Cambrian rocks into 11 formations: Flotehead, Welsey, Darma- tion, Hamlin Basin, Bearborn, Steamboat, Paroda, Pentagon, Gordon Mountain, Switchback, and Devils Glen. In correlating these formations in his sections Deiss stated, "with a few exceptions the correlations suggested are purely tentative, and should be considered such until the complete faunal evidence is made available and understood". The writer intended originally to study only the brachiopods collected from Deiss' Cambrian sections in northwestern Montana in order to obtain evidence from these fossils for or against the original correlations of the Middle Cambrian formations in northwestern Montana. During the summer of 1933 a field-party of the Montana Bureau of Mines and Geology remeasured and collected fossils from the type sections of Cambrian rocks in central and south-central Montana, and northwestern Yellowstone Park. At least two faunal zones in the Middle Cambrian of northwestern Montana are present also in the central and southern areas. The writer extended his study to include the brachiopods from these two zones in the Middle Cambrian rocks of the central and southern part of

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the state. The fossils were collected from the Middle Cambrian rocks of
Montana by field parties of the Montana Bureau of Mines and Geology under
the direction of Dr. C. F. Deiss.

The purposes of this paper are to describe and figure the species of
Middle Cambrian brachiopods from Montana, and to record the stratigraphic
correlations suggested by them.

Acknowledgments

The writer is deeply indebted to Dr. C. F. Deiss for direction, en
couragement, and criticism during the course of this study; and for plac-
ing at the writer's disposal collections of brachiopods from the Middle
Cambrian formations of Montana. Dr. G. Arthur Cooper of the United States
National Museum very kindly answered questions, and commented upon specimens
sent to him for examination.

IDENTITY OF PREVIOUS WORK IN CAMBRIAN BRACHIOPODS FROM MONTANA

The first brachiopods from the Cambrian of Montana were described in
1873 by B. B. Peck who assigned them to the Potsdam, or Primordial zone, of
Silurian age. Peck proposed that a species of Acrotereia, should it prove
distinct from A. subserica Ruterms, be given the name attenuata. He also
described "Iphidea (?) aestivalis", and suggested for it the name Micro-
mitra in the event that it should prove to "belong to an undefined genus,
either of the Brachiopods, or of some other group". 3

pp. 463 and 479 (1873).

3 B. B. Peck: op. cit., p. 479.
C. D. Salcott described 12 new species of brachiopods from the Cambrian rocks of Montana during the period 1908-1912, thus bringing the total number to 14 originally described from Montana. In 1912 Salcott listed 22 other species which had been identified from the Cambrian rocks of the state. Additions of new or previously described species to the Cambrian brachiopod fauna of Montana are not known to have been published since 1912. Thus 38 species of brachiopods belonging to 17 genera had been reported from the Cambrian of Montana at the time this study was begun. Of these species, 21 occur in Middle, 7 in both Middle and Upper, and 6 in Upper Cambrian rocks.

Schuchert and Cooper in 1922 published a revision of several genera which occur in the Cambrian of Montana, and listed previously described valid species of each.

THE BRACHIOPOD MORPHOLOGY

The general anatomy of brachiopods is so well known to paleontologists that a detailed discussion in this paper would be superfluous. However, during the study of the morphology of the Montana Middle Cambrian Atremata and Neotramata the writer made several observations worthy of mention.


Also, certain adaptations and innovations in terminology used in this paper must be defined, and some concepts of morphology as applied to taxonomy must be stated.

The dorsal valves of Acrotrreta p. sp. 1 and A. u. sp. 3 possess an internal median septum which is expanded laterally and vertically into a broad strong plate extended into six or more finger-like processes. The function of this structure suggested tentatively at present is that the septum is a primitive brachial support. The writer hopes to study this peculiar feature more carefully.

The terminology applied to the Atremata and Neotremata in this paper is essentially that discussed by Walcott, and that applied to the Protremata is from the recent work of Schuchert and Cooper. The following quotation gives the definition of the pseudointerarea as used in this paper:

"According to Buckman, the word area should be retained for general use, but interarea might be used for 'the area lying between the apex and the posterior line of valve-junction --- the cardinal margin when there is a hinge, but at any rate the posterior margin'. Interareas, or what were formerly called cardinal areas, are usual in most of the members of the order Protremata.... True interareas are at times also well-developed in the Telotremata, but never in the Atremata or Neotremata. When a similar structure is present in the two last named orders it is due to holopheral growth or to subsequent thickenings of the posterior margins, and in both these instances it is termed a pseudointerarea."


8Schuchert and Cooper: op. cit., p. 20.
The line of valve-junction is that straight line which connects the lateral marginal extremities of the pseudointerarea.

The terms proposed by Schuchert and Cooper to describe the inclination of the interarea are applied in this paper to the pseudointerarea with the provision that the angle of inclination be measured between the plane of the commissures and a straight line from the apex to the center of the posterior margin, or, in those genera with a pseudodelthyrium or pseudonotothyrium, to the center of its base.

In many atracaces and nootracaceous genera the pseudointerarea is divided by a pedicle groove, false pedicle groove, pseudodelthyrium, or pseudonotothyrium into two more or less sharply defined lateral triangular parts. The name proparea (referring to its position beside the pedicle opening) is here proposed for each lateral part. The following letters refer to the sides and angles of the proparea. (see fig. 1)

1. Side m— that side along the posterolateral margin of the valve.
2. Side p— that side which borders the pedicle groove, false pedicle groove, pseudodelthyrium, or pseudonotothyrium.
3. Side y— that side which borders the visceral region of the valve, or extends from the apex of the valve to the lateral angle of the proparea.
4. Angle C—that angle formed by the junction of sides p and y.
5. Angle C—that angle formed by the junction of sides m and y.
6. Angle V—that angle formed by the junction of sides p and m.

Schuchert and Cooper: op. cit., p. 21.

*Lat. prope, nearby of area.
Fig. 1. Diagram of pseudointerarea in Liocolella, to illustrate application of letters to parts of propores.

In several genera of Cambrian inarticulate brachiopods the generic importance of surface ornamentation has been emphasized, particularly in Micromitra, Entirina, Laphidella, and Hastaria. This emphasis has led some authors to describe new species which, had they not possessed a peculiar ornamentation pattern, would have been considered too imperfectly preserved to be identified. In Acrotreta n. sp. 4 and Micromitra n. sp. 4 there is apparently parallel development of the same type of surface pattern. In both species concentric growth ridges are broken into regular segments in such a manner that narrow smooth tracts radiate from the apex to the anterior and lateral margins. The fact that this pattern is developed by two genera which in other characters distinctly differ much, indicates that specifically different members of the same genus may frequently possess similar surface ornamentation. For this reason surface ornamentation as a primary generic or specific character seems of doubtful value. Probable examples of such "species", to which specimens have been assigned only because of similar surface ornamentation, are Laphidella pumula (White) and Hastariaella (Hall and Whitfield). These species also have such long geologic ranges that they are useless as definite horizon markers.
Contrary to most former practice, surface ornamentation is considered subordinate to the characters of the pseudointerareas and shellform in the definitions of new species. For example, *Kromitra n. sp. 1*, includes specimens which have superficially different surface ornamentation patterns, although the patterns are similar near the apex of all the shells. The apex of the dorsal valve also has a peculiar petaloid callus which has never been described. The individuals of the species appear to be identical in all characters except the surface pattern, and none of the variations of that pattern are limited to any particular stratigraphic horizon.

**Material Preparation**

The rough cleaning of all specimens was done by means of a dental engine equipped with small abrasive wheels. The calcareo-cornaceous shells of the Atremata and Neotremata were not satisfactorily exposed by carefully chipping away the matrix with a sharpened needle fitted into a stylus. Calcareous shells in a limestone matrix were observed only on weathered surfaces because the embedded portions of the valves could not be separated from the matrix by grinding, chipping, or acid. Casts of the pseudointerareas in several specimens of *Sohla* and *Littulella* were exposed by carefully removing the shell with a needle honed to a sharp chisel-edge. The shell-material was most successfully removed from weathered specimens or ones strongly heated for several hours over a Bunsen burner flame. Unfortunately, the heated specimens became extremely fragile. Cleaning the interior of a dorsal valve of *Littulella n. sp. 1* or *K. n. sp. 3* to expose the expanded median septum was a slow, delicate process. Only complete, unweathered
valves preserved in a relatively soft shale could be satisfactorily cleaned. Such valves were partly embedded in plaster of Paris and the matrix chipped away with an extremely sharp needle.

All specimens were cleaned and studied under a binocular microscope. Magnifications of 15 and 30 diameters were sufficient for all examinations and micrometer measurements.

Artificial keys for identification of genera and species

The following keys were made from charts upon which were tabulated the characteristics of each genus or species. The earlier published descriptions are usually unsatisfactory. Walcott's diagnoses were accepted for nearly all species described before 1912. In constructing the generic keys the genotypic descriptions and figures were adhered to as closely as possible, and in the specific keys the figures of the type specimens were followed more closely than the descriptions.

The keys were constructed to indicate the characters which separated closely related genera and species. The keys are partly unsatisfactory because many species are vaguely described and badly figured. Consequently they had either to be omitted from the keys or placed as synonyms.

Specific keys were made for all streptostomous and neurostomous genera in the Montana collections, but usable keys for crathylothecina and Iphidella Walcott could not be constructed. Genera with five or fewer species were not keyed, because comparison with the descriptions and figures could

be made readily.

Based on character of the ventral valve

F. Pedicle opening a foramen

Fa. Foramen anterior to apex

Ca. Shell calcareous

Ca. Shell not calcareous

Cs. Growth lines simple

Cs. Growth lines complex

Ca. Shell not calcareous

co. Valve highly conical

co. Valve not conical; teeth intercalated

Fam. Foramen posterior to or through apex

C2-3. Pseudointerarea ortholine to 70° ortholine

Ca. Shell calcareous

Cs. Growth lines simple

Cs. Growth lines complex

Ca. Shell not calcareous

co. Valve highly conical

co. Valve not conical; teeth intercalated

C4-5. Pseudointerarea ortholine to procline

Ca. Shell calcareous

F. Interior surface punctate

Ff. Interior surface not punctate

Ca. Shell not calcareous

I. Pseudointerarea more or less differentiated from general surface of shell

Is. Pseudointerarea sunk below surface

Isa. Pseudointerarea not sunk below surface

at. Apex formed by two tubercles; false pedicle groove faint or absent

--- A. BIAZELLA

aat. Apex single; false pedicle groove well defined

--- A. BIAZELLA

II. Pseudointerarea not differentiated from general surface of shell

ac. Spines of both valves eccentric

C6. Posterior margin arched upward, leaving a narrow rim between margin and foramen

Ff. Pedicle opening not a foramen

C2. Pseudointerarea ortholine

Ca. Shell calcareous

V. Internal vascular markings strong

Vv. Internal vascular markings faint

Ca. Shell not calcareous

I. Pseudopodiumium present

II. Pseudopodiumium absent

Cs. Growth lines simple
Gi. Lines on pseudointerarea
interrupted by false pedicle groove —— FURNINIA
G11. Lines on pseudointerarea not
interrupted by false pedicle groove
Z. Shell subcircular to transverse —— CHAMPS
Z3. Shell elongate —— LINDSAYA
— HYSTENEA

Gen. Growth lines complex
G. Rectrices made by intersecting
growth lines and radiating striae —— BICIA
G2. Strong, sharp, elevated, concentric
ridges that merge into each other
toward postero-lateral edges of shell,
where they terminate on margin —— BICILICA
G4. Transverse, semi-inbrissatie,
"ripple embossed" lines —— THERULA
Description and figures inadequate;
characterized by "thick shell, spatulate form" —— BICILICA

C2. Pseudointerareas absent

D. Convex pseudodeltidium present
D2. Growth lines more or less simple —— EPITHELIA
D3. Strong elevated growth lines bifurcate
and anastomose irregularly —— EPITHELIA
D5. Raised oblique lines
form quinquemarial pattern —— PERILICA

DD. Convex pseudodeltidium absent
Dd. Growth lines simple
A. Cardinal process present —— PERILICA
AA. Cardinal process absent —— CURTICIA

Gen. Growth lines complex
G3. Concentric impressed striae with
flat bands between them —— CALCITHEA
G5. Surface papillosa; papillae perforated —— PERILICA
G6. Spine bases irregularly
scattered over surface —— PERILICA
G7. Rectangles made by intersecting
growth lines and radiating striae —— BICILICA
G8. Rows of hexagonal pits
radiating from apex —— R. H. GENUS 1

C5. Pseudointerarea procine —— BICILICA
C6. Pseudointerarea spaecline —— BICILICA

Based on characters of the ventral valve

D. Deltidium present
C2-3. Interarea orthocline or slightly spaecline —— CHAMPS

10.
CS-5. Interarea strongly apsacline or proclive
V. Muscle scars pronounced -------------- JAEHELIA
VII. Muscle scars not visible -------------- NIGGIA
IX. Daetidium absent
P. Lateral profile resupinate; free spondylium present -- LEPHIA
PP. Lateral profile convex
I. Surface distinctly costate or costellate
U. Sulcus present
Z. Outline transversely subquadrate ---------------- JAEHELIA
ZC. Outline more or less lobate

d. Sulcus deep; pseudospondylium present ------- JAEHELIA
dd. Sulcus shallow; spondylium absent ---------- JAEHELIA
UU. Fold present
Y. Cardinal extremities acute or mucronate ------ OTTERIA
YY. Cardinal extremities obtusely rounded or angular
Sp. Pseudospondylium present ----------------- OTTERIA
Sp. Pseudospondylium absent
K. Dental plates strong ------------------------ JAEHELIA
KK. Dental plates weak
Z. Outline transversely subquadrate;
adder track subtriangular ------------------- JAEHELIA
ZZ. Outline transversely suboval;
adder track not triangular ------------------- JAEHELIA
UUU. Sulcus and fold absent
G. Spondylium present
f. Free spondylium ------------------------ CLAULIA
ff. Pseudospondylium
XX. Bivalval cavity deep; teeth strong;
dental plates receding ------------------------ PROTOCenia
XX. Bivalval cavity shallow; teeth small;
dental plates divergent ----------------------- NIGGIA
CS. Spondylium absent ------------------------ CLAULIA
LI. Surface with concentric striae and obscure costellae;
early smooth or finely ribbed billingsellids
with interiors that approach Billingsella ---------- NIGGIA
LII. Surface with fine growth lines only
Sm. Spondylium simplex present
w. Spondylium supported by stout median septum
and two or more accessory lateral septa -------- Sillselia
ww. Spondylium supported by median septum only ---- SYRACUELLIA

Based on characters of the dorsal valve
K. Chilidium present
A. Cardinal process present; sulcus present ------- SILL. NIGGIA
AA. Cardinal process absent; fold present -------------- NIGGIA
Kk. Chilidium absent
F. Lateral profile resupinate; cardinal process absent -- LEPHIA
LFP. Lateral profile plane to concave
  U. Sulcus present; multicospillate ----------------- **BOLIVIARIA**
  UUU. Sulcus and fold absent; multicospillate, 
costellate covered by parvicosillate ----------------- **ULIGOSY**
LFP. Lateral profile convex
  L. Surface distinctly costate or costellate
  U. Sulcus present
    A. Cardinal process present
      Y. Cardinal extremities acute or mucronate ------- **URUGIA**
      YY. Cardinal extremities obtusely 
        rounded or angular
        I. Cardinal process linear --------------------- **JUNOSARIA**
        II. Cardinal process expanding anteriorly ------ **BOORPHOS**
      AA. Cardinal process absent --------------------- **URUGIA**
    UU. Fold present
      E. Outline transversely subquadrate;
        brachiophores divergent ---------------------- **JUNOSARIA**
      EE. Outline more or less lobate;
        brachiophores convergent --------------------- **ULIGOSY**
    UUU. Fold and sulcus absent
      A. Cardinal process present
        No. Brachiophores convergent -------------------- **FINKHINORUCIA**
        Nc. Brachiophores divergent -------------------- **ULIGOSY**
      AA. Cardinal process absent ---------------------
        RI. Brachiophores long and sharp ---------------- **URUGIA**
        RII. Brachiophores short and blunt
          No. Brachiophores convergent ------------------ **FINKHINORUCIA**
          Nc. Brachiophores divergent ------------------ **PROTORTHOS**
    LL. Surface with concentric striae and obscure costal-
      lases; nearly smooth or finely ribbed billingsellids
      with interiors that approach Billingsella ------------ **MINASILIA**
    LLL. Surface with fine growth lines only
      ff. Fold faint; brachiophore plates convergent ------ **SYNTHROPHOS**
      ff. Fold prominent; brachiophore plates divergent
        J. Brachiophore plates supported by
          two or more accessory lateral septa ------------ **ULIGOSY**
          JJ. Brachiophore plates unsupported ------------- **SYNTHROPHOS**

Note: Dorsal valve of **Swamptonia** is unknown.

**K Y. Y. L. U. T.** **C. C. C. C.** **C. C. C.** **C. C. C.** **C. C. C.** **C. C. C.** **C. C. C.** Based on characters of the ventral valve

C6. Pseudointersarea procline
  C. False pedicle groove present
    Psc. Propareas sharply concave -------------------- **claytoni**
    Psc. Propareas flattened
      Pd. Propareas demarcated by grooves
Gf. False pedicle groove faint
Gff. False pedicle groove strong

cf. Concentric strie fine
Sff. Concentric ridges lamellar, coarse

I dd. Propareas not demarcated by grooves

I65. Pseudointerarea 65° procline;
height approximately 1/3 length
---- baileyi
I65. Pseudointerarea 65° procline;
height approximately 1/5 length
---- bellatula

Fsco. Propareas rounded

As. Apex erect

G1. False pedicle groove sharply
indentated into pseudointerarea

Gtt. Sides of false pedicle groove form triangle
---- lisani
Gttt. Sides of false pedicle groove parallel

H4. Height equals 1/4 length
---- dopressa
H3. Height greater than 1/3 length

Gtt. Outline transversely ovoid
---- precia
Gttt. Outline subcircular

Ac. Apex subcircular

Acx. Apex in posterior third

Acx. Growth lines simple

170. Pseudointerarea 70° or
less procline
---- socialis
180. Pseudointerarea 60° or
more procline

G11. Growth strie cross false
pedicle groove

H2. Height equals 1/2 length
---- uplandica
H3. Height equals 1/3 length
---- uplandica

var. limensis

H5. Height and length subequal
---- subornana

G11. Growth strie do not
cross pedicle groove

Ssa. Minute Westonia ella-like pattern
near margin

C11i. False pedicle groove formed by depressing
of propareas along median line

H3. Height less than 1/3 length

170. Pseudointerarea 70° to 75° procline
Sf. Growth lines fine
Sff. Growth lines rugose

Pyxidicula

Ophiorensis

var. rugosa

I45. Pseudointerarea 65° procline
---- n. sp. 4
12. Height equals 1/2 to 3/4 length

Nx. Anterior slope convex in profile;

Westonia ella-like pattern on surface

Primaeva

Kxx. Anterior slope concave in profile near apex
175. Pseudointerarea 75° to 80° procline
   Cf. Concentric striae fine ------------------- attenuata
   Ch. Concentric ridges coarse, broken ------ n. sp. 2
165. Pseudointerarea 65° procline
   HL. Height and length subequal ------------------ microscopica
   var. missouri ensis

Aes. Apex pointing posteriorly
   Ct. Sides of false pedicle groove form triangle ---- signalis
   Ct. Sides of false pedicle groove parallel -------- belti
   ---------------- sagitallis
   ---------------- var. magna
   ---------------- var. taconica
   ---------------- var. transversa

CG. No groove or ridge present across pseudointerarea

If. Pseudointerarea flat or concave
   HL. Height and length subequal
   Lg. Pseudointerarea demarcated by grooves ---------- gemma
   Lgg. Pseudointerarea not demarcated by grooves ------ pacifica
   E2/3. Height approximately 2/3 length --------------- sabrinae
   ---------------- bisecta

E2. Height approximately 1/2 length
   1. Pseudointerarea slightly flattened -------------- shantungensis
   11. Pseudointerarea strongly flattened
       Ut. outline transversely ovoid;
           more than 75° procline ---------------------- seebachi
       Ut. outline subcircular; 60° procline ----------- sabrinaevar. ensis
   Hs. Height approximately 1/3 length --------------- pyxidica
   Iff. Pseudointerarea not flattened
       Ac. Apex subcentral ---------------------------- conula
       Acc. Apex in posterior third of shell
           Fr. Posterior margin rounded ------------------ microscopica
           Frr. Posterior margin straight ----------------- arcentea

CCG. Ridge present across pseudointerarea

Pf. Propareas flattened -------------------------- carinata
   Iff. Propareas rounded -------------------------- circularis

C4. Pseudointerarea catacline

As. Apex posterior to line of valve-junction

U. Highest point anterior to apex
   0. False pedicle groove present
      Ct. Sides of false pedicle groove form triangle ---- definita
      Ct. Sides of false pedicle groove parallel
          Ut. Outline transversely ovoid
              E2/3. Height approximately 2/3 length --------- ophirensis
              E2. Height approximately 1/2 length ---------- eggeri-rundensis
              Ut. Outline elements ovoid ------------------ rudis

CG. False pedicle groove absent

If. Pseudointerarea more or less flattened
   Is. Pseudointerarea sunk below surface
      of shell; distinctly outlined ------------------ marjusensis
   Isa. Pseudointerarea not sunk below surface
      of shell; indistinctly outlined ---------------- ophirensis
      var. descenden
Appendix. Shell 1 mm in length; ventral valve low; nipple-like apex; apparently smooth surface —- n. sp.

**KEY TO SPECIES OF GENUS OF LINGULILLA AND UBOLUS**

Based on characteristics of the ventral valve

These two genera are very closely related. In 1912 Salcott wrote:

"The memoir of Kickwitz gave the genus *Ubolus* a position that it had not held prior to his very thorough investigation. With his descriptions and plates and a fine suite of specimens..., I have been able to make a series of comparisons with *Lingulilla* that at times has led me almost to doubt the advisability of characterizing *Lingulilla* as distinct from *Ubolus*. This distinction is now based on the oval elongate form of most of the
species of *Linpulella*, and the greater thickness of the shell of the typical forms of *Lobus*.

The data for a clear distinction of the two, *Lobus* and *Linpulella*, are still too limited for more than an arbitrary reference of *Linpulella* to a generic place in relation to *Lobus*.

The species of *Linpulella* and *Lobus* could not be separated into two distinct groups. A key containing all the species of both genera was too cumbersome to be useful. The following key contains all the Middle Cambrian species of both genera, and the lower and upper Cambrian species of China and the western half of North America.

L. Shell definitely longer than wide
T. Outline of shell subtrigangular
  S. Shell small (length less than 5 mm)
    1. Visceral cavity deep and elongate ---------------- L. dubia
    2. Visceral cavity shallow
       P. Flexure line present on propsema ---------------- L. manticula
       P2. Flexure line absent on propsema ---------------- L. desiderata
  3. Shell medium sized (length 6-10 mm)
    22. Width approximately 1/3 length ------------------ L. potentassuta
    22. Width definitely greater than 1/2 length
      A90. Apical angle 60°
        00. Surface with growth lines
           and undulating striae ------------------------ L. lineolata
        000. Surface smooth ----------------------------- L. cuneola
      A75. Apical angle 75°----------------------------- O. rhea
      A60. Apical angle 60°---------------------------- O. tetonensis var. minus
      A90. Apical angle 60°
        U. Dorsal valve sulcate ------------------------ L. clarkei
        UU. Dorsal valve not sulcate ------------------- L. n. sp. 1
  33. Shell large (length greater than 10 mm)
    01. Surface with lamellose growth lines ------------ O. whymperi
    011. Surface with dull, minutely granular
           incrusting layer over growth lines ------------ L. issi

TT. Outline of shell more or less evenly elongate ovate
  S. Shell small (length less than 5 mm)
    s. Length of shell 2 mm or less

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<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC5</td>
<td>Apical angle 90°; apex acuminate</td>
<td>L. morcia</td>
</tr>
<tr>
<td>A100</td>
<td>Apical 100° or more; apex rounded</td>
<td>O. pharos</td>
</tr>
<tr>
<td>C0.</td>
<td>Surface with simple growth lines</td>
<td>O. parvus</td>
</tr>
<tr>
<td>C0c.</td>
<td>Surface with fine network of irregular interrupted concentric lines</td>
<td>O. parvus</td>
</tr>
<tr>
<td>ss.</td>
<td>Length of shell 3-5 mm</td>
<td></td>
</tr>
<tr>
<td>A70.</td>
<td>Apical angle 65°-75°</td>
<td>L. similis</td>
</tr>
<tr>
<td></td>
<td>Surface with distinct radiating striae</td>
<td>L. chinensis</td>
</tr>
<tr>
<td></td>
<td>ORR. Surface without radiating striae</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F. Flexure line present on propera</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ls. Shell only slightly longer than wide</td>
<td>L. manticula</td>
</tr>
<tr>
<td></td>
<td>Lss. Width equal to about 2/5 length</td>
<td>L. manchuriansis</td>
</tr>
<tr>
<td></td>
<td>ORF. Flexure line absent on propera</td>
<td>L. desiderata</td>
</tr>
<tr>
<td></td>
<td>A88. Apical angle 65°</td>
<td>L. narcia</td>
</tr>
<tr>
<td></td>
<td>A100. Apical angle 100° or more; rounded</td>
<td>O. discoideus</td>
</tr>
<tr>
<td></td>
<td>Ls. Shell only slightly longer than wide</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lss. Width approximately 3/5 length</td>
<td>L. liui</td>
</tr>
<tr>
<td>53.</td>
<td>Shell medium sized (length 5-9 mm)</td>
<td></td>
</tr>
<tr>
<td>A90p</td>
<td>Apical angle 90° or more</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ip. Postero-lateral margin straight; apex pointed</td>
<td>L. argyta</td>
</tr>
<tr>
<td></td>
<td>Lss. Postero-lateral margin convex; apex rounded</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ls. Width approximately 2/5 length</td>
<td>U. demesi</td>
</tr>
<tr>
<td></td>
<td>Lss. Width approximately 2/5 length</td>
<td>L. liui</td>
</tr>
<tr>
<td>A90m</td>
<td>Apical angle less than 90°</td>
<td></td>
</tr>
<tr>
<td>ur.</td>
<td>Surface with radiating striae</td>
<td>L. similis</td>
</tr>
<tr>
<td></td>
<td>Ip. Interior faintly punctate</td>
<td>L. similis</td>
</tr>
<tr>
<td></td>
<td>Ip. Interior not punctate</td>
<td>L. linsola</td>
</tr>
<tr>
<td>533.</td>
<td>Shell large (length greater than 9 mm)</td>
<td></td>
</tr>
<tr>
<td>A90p</td>
<td>Apical angle 90° or more</td>
<td>L. similica</td>
</tr>
<tr>
<td>A90m</td>
<td>Apical angle less than 90°</td>
<td></td>
</tr>
<tr>
<td>0c.</td>
<td>Surface with distinct growth lines</td>
<td>L. punctata</td>
</tr>
<tr>
<td>0c0.</td>
<td>Surface with shell minutely granular</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incrusting layer over growth lines</td>
<td>L. ise</td>
</tr>
</tbody>
</table>

**TTT. Outline of shell quadrate**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.</td>
<td>Sulcus present</td>
<td>L. dimorphha</td>
</tr>
<tr>
<td>UU.</td>
<td>Sulcus absent</td>
<td>L. keysleri</td>
</tr>
</tbody>
</table>

**LL. Shell with length and width subequal**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.</td>
<td>Outline of shell subtriangular</td>
<td></td>
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<tr>
<td>0.</td>
<td>Shell small (less than 5 mm)</td>
<td>O. mucorrelli</td>
</tr>
<tr>
<td>0S.</td>
<td>Shell medium to large (more than 6 mm)</td>
<td>L. linsola</td>
</tr>
<tr>
<td>A70.</td>
<td>Apical angle 70°</td>
<td>L. linsola</td>
</tr>
<tr>
<td>A90.</td>
<td>Apical angle 90° or more</td>
<td></td>
</tr>
<tr>
<td>Ys.</td>
<td>Anterior margin straight</td>
<td></td>
</tr>
<tr>
<td>ur.</td>
<td>Faint radiating striae present</td>
<td>O. lusanhsiensis</td>
</tr>
<tr>
<td>ORR.</td>
<td>Radiating striae absent</td>
<td>O. trigonellis</td>
</tr>
<tr>
<td>Yss.</td>
<td>Anterior margin rounded</td>
<td></td>
</tr>
</tbody>
</table>

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*Please note: The above text is a transcription of the content shown in the image. It may contain some errors or variations in formatting due to the nature of the handwritten text.*
or. Radiating ornamentation strongly developed

V. Radiating undulating costae
   at anterior margin ---------------------- O. maccnelli var. pelias

IV. Surface reticulate; strong concentric
   and radiating striae ------------------- L. reticulata

Cv. Radiating ornamentation very faint
   cv. Concentric ornamentation typical
   1. Strom concentric growth ridges ------ O. maccnelli var. decisions

2. Fine, irregular inoscillating
   concentric striae ---------------------- L. helena

3. More or less transverse
   irregular striae ---------------------- O. maccnelli

Oco. Concentric ornamentation
   simple and inconspicuous

Dtt. Dorsal valve transverse ---------------------- O. johni
    == O. myron
    == O. tetonensis
    == O. tetonensis var. leda

Dttt. Dorsal valve subcircular

II. Pseudointerareas short ---------------------- O. natinalis

II. Pseudointerareas long ---------------------- O. nactum

TT. Outline of shell subcircular, with acuminate beak

3. Shell small (length less than 5 mm)

Oco. Concentric ornamentation very distinct
   1. Broad, regular, evenly spaced
      concentric ridges --------------------- O. maccnella

4. Narrow, evenly spaced growth lines and fine striae
   Ns. Postero-lateral margin convex ----------------- O. minimis

Ns. Postero-lateral margin straight ----------------- O. lingula

5. Irregular, unevenly spaced lamellate growth lines = L. mixtens
   == L. n. sp. 2

Oco. Concentric ornamentation indistinct

Ip. Funnelae numerous on interior --------------------- O. rotundatus

Ip. Functae scattered on interior

F. Flexure line present on proparea --------------------- O. sinuata

FF. Flexure line absent on proparea --------------------- O. chinensis

3G. Shell medium sized (more than 6 mm)

A90m. Apical angle 90° or less

9u. Fine irregular, inoscillating concentric striae --- L. helena

Gnu. Regular growth lines and fine
   undulating striae ---------------------- L. lineolata

Gnuu. Irregular lamellate growth lines ------------------ L. hirka

A90p. Apical angle distinctly greater than 90°

IV. Postero-lateral margins slightly concave;
   strong, evenly spaced, regular growth ridges ------ O. obscuris
Pseudointerarea large and well-defined —— C. n. sp. 1

III. Pseudointerarea small and faint

or. Surface with low radiating ridges —— C. shaensiensis

crr. Surface without radiating ornamentation

or. Fine growth lines and finer

undulating concentric stripes —— C. anops

crr. Lamellose growth lines —— C. taeniensis

--- C. mollisonensis

TTT. Outline of shell evenly subcircular

3. Shell small (length less than 5 mm)

II. Pseudointerarea apsacline —— C. wortheni

III. Pseudointerarea orthoclone —— C. n. sp. 1

SS. Shell medium to large (length 10-11 mm);

radiating ribs on inner layer —— C. saera

TTT. Outline of shell subquadrate

3. Shell small (length less than 5 mm)

anterior margin straight, posterior margin acuminate —— C. zetus

SSS. Shell large (length 15-17 mm);

shell extremely thin —— C. membranaceous

III. Shell distinctly wider than long

TTT. Outline subquadrate

SSS. Shell large; extremely thin —— C. membranaceous

TT. Outline evenly ovate

6. Shells small (length less than 5 mm);

posterior margin flattened —— C. isenae

SS. Shell medium to large (length 6-11 mm)

t. Shell thick —— C. persone

tt. Shell thin —— C. saeniensis

KEY TO SPECIES OF THE GENUS PSEUDELITIDIUM

(Including those assigned to the subgenus Paterea)

Based on characters of the ventral valve.

D. Pseudodeltidium almost completely filling pseudodelthyrium

I. Pseudointerarea procline

X. Anterior slope convex in profile

II. Posterior half of shell hexagonal in outline —— P. kingi

III. Posterior half of shell rounded in outline

R. Postero-lateral slopes broadly rounded —— P. superba

RR. Postero-lateral slope sharply rounded —— P. major

IX. Anterior slope convex in profile

Xc. Growth lines scarce; radiating ridges present —— P. acotica

Xcc. Growth lines fine; radiating ridges absent —— P. willardi

II. Pseudointerarea eustacine to apsacline

sharply demarcated from general surface

ines cross propareas and pseudodeltidium —— C. pealei
CC. Growth lines do not cross propareas and pseudodeltidium

PP. Propareas not demarcated from general surface

OU. Concentric ornamentation sharp ridges and striae

OR. Concentric ridges and striae regular P. bella

ORr. Concentric ridges bifurcate and coalesce irregularly M. sculptilis

OUu. Concentric ornamentation low broad undulations M. n. sp. 2

DD. Pseudodeltidium filling about half pseudodelthyrium

TT. Posterior margin greater than greatest width of shell P. zonobia

EE. Posterior margin acute; growth

LL. Pseudodeltidium filling only apex of pseudodelthyrium

YY. Pseudodeltidium not covered by incurved apex P. lucina

YY. Pseudodeltidium not covered by incurved apex

CC. Vertical groove present across pseudodeltidium P. creniaria

PP. Propareas demarcated from general surface of shell

L. Obtusely conical form

S. Faint radial striae P. stissinia-genus

SS. Strong radial striae P. stissinia-genus var. ora

HH. Highly conical form

BB. Radiating ridges absent M. n. sp. 3

BB. Radiating ridges absent

PP. Propareas not demarcated from general surface of shell

V. Outline distinctly transverse ovoid P. logani

VV. Length and width subequal

II. Posterior margin rounded P. stuarti

I. Posterior margin straight P. mediocris

Note. The following species of Micromitra and Paterina are omitted from the key because they either are inadequately described or because their generic relationship with Micromitra sculptilis (Meek) is questionable: albensis, chiron, etheridzii, labradorica, labradorica orientalis, labradorica utchenensis, lata, nius, philippai,
prospectanaia, pusilla, unicae, and sepias.

PUBLICATIONS OF CITED WORKS

Published descriptions and figures of Cambrian genera and species are often unsatisfactory for comparison with the specimens. The identifications of genera and species in this paper must be considered provisional until the specimens from Montana can be checked against the types of related species. The same reason prevented giving new generic and specific names to some of the previously undescribed specimens.

Subgenera are listed in the same way as genera.

The type specimens of all species described in this paper are preserved in the Museum of Paleontology at Montana State University.

Genus ACROTHELE Linnaeus


1880. Arothela Linnaeusson, Mittel, Handbuch der Palaeontologie, Bd. 1, Abth. 1, p. 605.


1892. Arothela Linnaeusson, Hall and Clarke, Eleventh Ann. Rept. State


Revised description from this reference.

ORIGINAL DESCRIPTION. "Shell cornaceous, composed of several laminae, the inner smooth and polished, the outermost one rough and opaque. Ventral valve slightly conical, with excentric umbone, pierced by a minute foramen, in front of which are, at least in one species, two small wart-like protuberances; the field between the umbone and the posterior margin is usually a little flattened, thus forming a slight indication of a false area. Dorsal valve with marginal umbone, consisting of two wart-like protuberances. In the interior of the dorsal valve there are two oblong, diverging muscular scars close to the posterior margin, and two small, rounded scars near the middle. The muscular scars are separated by a longitudinal ridge."

EMENDED DESCRIPTION. "General form subcircular to transversely broad
oval in outline. Ventral valve moderately convex to subconical; a false area is usually more or less distinctly outlined on the ventral valve between the apex (beak) and the posterior margin; pedicle opening on the posterior slope of the apex (or beneath the beak). The only suggestion of a true cardinal area is in Acrothole bellula Walcott; and this appears to be a broadening and slight flattening of the posterior under edge of the shell. Dorsal valve gently convex, and sometimes nearly flat; beak minute, marginal; area known only in A. bellula Walcott, where it is short and divided midway by a small triangular false denticulum, very much as in Acrothela definita Walcott.

"Surface marked by concentric lines and striae of growth which cross the false area of the ventral valve; in some species, there are low, rounded, radiating ridges that are usually confined to the ventral valve; in addition, on some species, there is a series of more or less incisulating, irregular, fine ridges with tubercles on them, which gives a highly ornamented surface such as occurs on some forms of Nieromitra and Fastania."

"The shells of Acrothole rarely exceed 15 mm in diameter, and the average size of adult shells is from 6 to 8 mm. Substance of shell corneous. The shell is built up of several layers or lamellae that are usually more or less obliquely inclined to the outer surface, over the central and outer portions."

"The interior of the ventral valve has a small visceral area about the pedicle opening and extending a short distance in front of it; in several species an elongate depression occurs on each side and a little in advance of the pedicle opening that corresponds to the tubercle on each side of the apex of the outer surface; frequently the shell is thickened beneath the visceral
cavity and a short ridge of varying width are length results; the edge of the pedicle opening may be slightly thickened, which forms a callosity or apical swelling, but not to the same extent as in the ventral valve of *Acrotreta*. Nothing has been seen of an area in front of the visceral area corresponding to the trapezoidal areas of *Obolus*, *Acrotreta*, and *Tremato-bolus*, in which the central, outside lateral, and middle lateral muscles were attached; in fact, it is only very rarely that the impression of the visceral area is shown. The main vascular sinuses start from just back of the pedicle opening, and curve, one on each side, out and then forward into the body of the valve, usually within a line drawn halfway between the center and the outer margin of the valve; many branches from the main sinuses occur in some species. The transmedian and anterior lateral muscle scars appear to be merged in the cardinal muscle scar, situated on the outer postero-lateral slope, outside of the main vascular sinuses; on one shell what appear to be umbonal muscle scars are preserved."

"The interior of the dorsal valve has a median ridge of varying length and size, and main vascular sinuses that start near the posterior margin and extend directly outward for a short distance, and then obliquely forward in almost a direct line. The cardinal muscle scars are usually small and close to the postero-lateral margin, but larger scars occur and extend farther forward into the valve. The central and anterior lateral scars are situated essentially as in *Obolus*; the former on the slopes of the median ridge and the latter at the anterior end of the ridge."

**Acrothela matthesi cryx** Salcott

*Plate II, figs. 11-13.*


1912. *Acrothela matthesi cryx* Salcott, *U. S. Geol. Survey Mono.* 51, p. 61, pl. 61, fig. 2.


**DESCRIPTION.** "The first identification of this species in China was based on a single ventral valve 8 mm in diameter. In the J. W. Iddings collection from southern Manchuria there is a fine series of specimens showing many characters of both the ventral and dorsal valves. These, when compared with *Acrothela matthesi* (Hurtt), indicate only a varietal difference between the widely separated forms. In fact, if the Asiatic and American specimens were all from the same locality and layer of rock, it is doubtful if I could separate one from the other even as a variety. The illustrations of the American shells (*Salcott, Comb. Brach.,* pl. 61, figs. 1-11) and the Asiatic shells (plate 3 of this paper) afford the student the means of comparison of specimens from the two continents."

"The shell is built up of several layers of lamellae that are smooth and shiny on the interior, except where slightly roughened by slight vascular markings and obscure radiating striae. The outer surface is dull and marked by concentric striae and lines of growth, and numerous fine, irregular..."
often anastomosing, elevated lines that give the surface a rough appearance."

"Most of the valves are slightly broader than long. The largest ventral valve in a limestone matrix has a length of 7.5 mm; width, 6.8 mm; and the apex is 1.5 mm in advance of the posterior margin; a large dorsal valve has a length of 11 mm; width 13.5 mm."

**Observations.** Acrothela colleni Walcott from the Middle Cambrian of Montana apparently is closely allied to A. matthaei eryx, although Walcott made no mention of their similarity. In the absence of a satisfactory figure of the holotype of A. colleni, the specimens from Montana are assigned to A. matthaei eryx.

**Locality and Vitrification.** Two fragmental ventral, and four dorsal valves of this variety, are known from locality 26, zone 4; pentagon shale.

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**Acrothela of A. subsidua (White)**

**Plate II, Fig. 15**


1877. **Acrotratata subsidua White**, J. S. Geog. Surveys 7. 10th Ser., vol. 4, pt. 1, p. 54-56, pl. 1, figs. 3a-d.


1886. **Acrothela subsidua (White)**, Walcott (in part), Bull. U. S. Geol. Survey no. 35, pp. 100-109, pl. 9, figs. 4a-c.


1912. Acestina subliquid (Chile, Chile, P. E. Cool, Survey Memo. 51, pp. 638-669, pl. 60, figs. 1-16, 6. Description from this reference.

DESCRIPTION. "General form subcircular to transversely broad ovate in outline with the posterior margin broadly rounded to slightly transverse in the dorsal valve. Ventral valve slightly convex toward the apex, with the apex between the posterior one-fifth to one-third the distance from the front to the back margin. The apex then perfect is formed of two minute elongate tubercles with a narrow elongate depression between them; the size and form of the tubercles and depression between them varies; in some specimens the tubercles are united in front, and in others there is a third minute tubercle just back of the apical depression. A pedicle opening varying from a minute circular to a small elongate-ovate aperture, narrow in front, occurs at the posterior end of the apical depression; it may have its narrow end well between the elongate tubercles or in back of them. A triangular false area is well defined on some shells, and very obscure on others; it is often divided midway by an elevated line which in some examples is a narrow rounded ridge extending from just back of the pedicle opening to the posterior margin; the concentric striae of growth cross the area and its median ridge or lie without interruption; casts of the interior show the outline of the false area more or less distinctly. "The posterior margin is usually slightly arched beneath the false area."

"The dorsal valve is depressed convex, with the greatest elevation in front of the posterior margin; the beak is minute, marginal, and divided at the center by an elongate depression that leaves a very minute, slightly elevated, elongate tubercle on each side."
"The exterior surface is marked by concentric lines of growth that vary in prominence and strength, and some ventral valves have a few low, rounded, radiating costae; the costae differ distinctly in length and size, and are entirely absent on many shells. The epidermal layer is ornamented with a minute granulation formed of very minute granules distributed more or less irregularly on irregularly haired lines distinct from the concentric strie of growth, or apparently at times superimposed on the latter. The shiny inner layers of the shell are marked by fine, radiating strie and concentric lines and narrow radiating depressions corresponding to the external costae. The shell is corneous and built up of thin layers or lamellae that give it some thickness over the visceral portion; the inner lamellae are slightly oblique to the outer ones. The average size of the shell at the typical locality at Antelope Springs is from 5 to 6 mm in length by 6 to 7 mm in width; a few miles distant and a little higher in the strata, shells occur 8 to 10 mm in diameter. Near Montpelier, Idaho, shells from 10 mm in diameter to young shells 3 mm in diameter occur in the same bed of shale."

"In the interior of the ventral valve a narrow main vascular sinus arches outward from each side a little back of the pedicle opening, and then forward into the exterior half of the valve. The pedicle opening is elongate oval in outline, and has a slightly elevated rim about it and on each side a depression corresponding to the elongate tubercles on the exterior of the shell; the visceral cavity in front of the opening is short, and in some shells very minute pits along the most indicate muscle scars that are too imperfectly preserved to be identified."

"In the posterior half of the interior of the dorsal valve there is a
strong median ridge that bifurcates near the center; this ridge enlarges
where the central muscle scars occur on its outer slopes and contracts be-
fore bifurcating just in advance of the anterior lateral muscle scars. The
main vascular sinuses originate near the posterior margin at the end of the
median ridge and extend outward and then obliquely forward as narrow, nearly
straight sinuses that are most deeply impressed in the shell at the inner
and outer margins. The muscle scars have left very faint impressions on the
shell. The cardinal scars are small and situated at the sharp angle formed
by the main vascular sinuses and the posterior margin of the shell."

"I have been able to discover no trace of a true area in either valve;
the posterior margins of the valves show concentric striae and often the
under side is striated, the surface apparently not having been rubbed a sima
the edge of the opposite valve."

**DISCUSSION.** A single fragmental ventral valve is compared with this
species. Its size, outline, position and character of the apex, and radiating
furrows across the anterior slope indicate a close relationship to Acrothela
subsidus. The outer shell-layer is almost entirely exfoliated, and the re-
main ing fragments are so badly weathered that the presence of the granular
surface typical of Acrothela subsidus is not definitely known. The valve
is approximately 0.8 cm in diameter.

**FORMATION and LOCALITY.** Locality 6, loose; Pentagon shale.

Genus ACROTHELA Autorsa

for 1947, no. 12, pp. 259 and 260 (notes on genus), and p. 275 (described
in German as a new genus).


1887. Linnearesonia alcott, Schliort, Manuel de conchyliologie, by Fischer, p. 1288.


Emended description from this reference.

**ORIGINAL DESCRIPTION.** "Dorsal valve highly conical; the hinge surface of the cone flat, in the form of a high triangle, similar to an area, with a shallow gut or-shaped depression running from the tip as far as the middle point, which (depression) here appears as an indication of a deltium. At the upper end of this furrow, turned consequently to the hinge side, is found the obtusely oval external siphonal opening."

"Ventral valve flat, with a distinct marginal apex. on the surface of
the shell are seen only delicate growth wrinkles concentric to the apex of
the cone, which curve crescentially into the longitudinal furrow of the
surface of the shell; no tubercles and no spines; hinge border rectilinear."

"Ventral valve strongly convex to conical, with
the posterior face more or less flattened to form a false area that is
usually marked by a shallow median groove. Pedicle opening at the apex of
the cone and directed more or less backward. Apex usually anterior to the
posterior margin, but occasionally overhanging it. Dorsal valve slightly
convex, with very small beak; area short and divided by a small false delti-
dium.

"Surface marked by fine concentric striae and lines of growth which
cross the posterior face and median groove; in addition there are on five
species very fine, concentric, undulating, often inosculating, rounded
ridges that form a surface like that of Obolus (Nestoria) ella (Hall and
Whitfield). Acrotrreta prisma Valcott has this type of surface. A. clay-
toni Valcott has fine, undulating striae, A. spinosa Valcott fine short
spines, and A. ? cancellata Valcott a cancellated surface. The shell in
all species where it is preserved is calcareocornaceous and built up of sev-
eral thin layers or lamellae that are arranged more or less obliquely to the
outer surface toward the outer margin of the valves."

"The cast of the ventral valve shows that the interior of the shell has
a rather strong callosity or apical swelling penetrated by the foraminal
tube, and on each side of and back of the callosity near the posterior
margin the cardinal muscle scars, which usually take the form of a
projecting boss or tubercle corresponding to a depression in the shell in which the transmedian and middle lateral muscles were probably attached. In front of the apical callosity in A. argenta Salcott there are two trapezoidal areas corresponding to similar areas in Abalollia and Obolus, in which the central, outside, and middle lateral muscles were attached. The grooves of the main vascular sinuses pass around the apical swelling and extend forward, diverging toward the antero-lateral margins of the shell."

"The interior of the dorsal valve is almost invariably marked by a long, well-defined median ridge and a pair of strong cardinal tubercles near the margin of the area corresponding in position to the cardinal tubercles of the ventral valve. Smaller tubercles occur in advance of the posterior tubercles, one on each side of the median ridge; they are often replaced by elongate oval scars that correspond to the central scars of the dorsal valve of Obolus; the anterior lateral muscle scars are too minute to be clearly located, but they were undoubtedly close to the median line a little in advance of the central scars. The cardinal tubercles of both valves often have scars on them indicating the attachment of muscles."


DISCUSSION. Salcott stated in his discussion of Acrotrata serrula

Matthew:

"A minute foraminal aperture just beneath the apex. The position of the pedicle aperture causes it to open almost directly backward. The position of the pedicle aperture is similar to that of many species of Acrothale and is unusual for the genus, and may be of generic or subgeneric importance."

This condition is typical of all the new species of Acrotreta described in this paper. The foramen is round, approximately 0.03 mm in diameter, situated slightly below the apex, and opens at right angles to the plane of the pseudointerarea. In Acrotreta n. sp. 4 the foramen opens directly backward through a small subquadrate callosity on the posterior side of the apex. Whether this condition "may be of generic or subgeneric importance" the writer is not qualified to say. In all other respects, so far as observed, the Montana specimens seem to be generically related to the type species of Acrotreta.

Acrotreta ophiensis Salfcct
Plate II, figs. 5,6,10, 14.


1912. Acrotreta ophiensis Salcott, U. S. Geol. Survey Bzno. 51, pp. 687-698, pl. 74, figs. 1-1P. Description from this reference.

DESCRIPTION. "General outline transversely broad oval, sometimes nearly circular, with the posterior margin slightly indented midway on the ventral valve by incurring to the false pedicle furrow. The ventral valve is convex and moderately elevated, the highest point being in front of the pedicle aperture at about one-third the diameter of the shell. Pedicle aperture large for the size of the shell and opening either directly or obliquely backward; one specimen shows an obscure, short, narrow, triangular false area, with a vertical furrow crossing it; false area scarcely defined by the cardinal slopes, which incurve very gently; median furrow well defined, rather strong, and nearly flat on the bottom, the margins being sharply outlined in many specimens. Some of the shells curve
over the false area so that the depressed apex extends slightly beyond the posterior margin, but generally it is directly on the line of, or a little in front of, the posterior margin.

"Longitudinal diameter of average size ventral valve 3 mm, with a length of 2 to 2.5 mm; elevation, 1.5 mm. A few shells have nearly the same length and width. The convexity of the dorsal valve averages 0.75 mm. The minute beak of the dorsal valve curves down to the posterior margin from the somewhat swollen posterior third of the valve."

"Surface marked by fine concentric strie and lines of growth, some of which form concentric ridges. The shell is built up of a thin outer layer and numerous thin inner layers or lamellae that are oblique to the outer layer over the central and outer portions, the obliquity increasing toward the outer anterior and lateral margins."

"The interior of the ventral valve shows a rather strong apical callousity that extended nearly to the posterior inner margin of the shell; distinct, but relatively small cardinal scars, and narrow main vascular sinuses that may be traced nearly to the antero-lateral margins of the valve. The outlines of the visceral cavity are indicated on one well-preserved cast of the interior of the valve. The interior of the dorsal valve shows great variation in size and length of the median ridge and cardinal and central scars; these characters are fully shown in the numerous illustrations of the interior and casts of the interior of the dorsal valve."

LOCALITY and COLLECTION. Several badly crushed and usually fragmental disassociated dorsal and ventral valves of this species were collected from
locality 26, zones 2 and 3; Sagada formation.

*Amortecta n. sp. 1.*

Plate I, figs. 1-6, 8, 9.

Species known from numerous disassociated dorsal and ventral valves.

DESCRIPTION. **Ventral valve:** Outline in plane of commissure subcircular or slightly transverse; length three-quarters to almost equal width. Anterior margin rounded or slightly flattened; lateral margins rounded; posterior margin more or less abruptly incurved at midpoint to meet false pedicle groove. Lateral profile triangular: posterior slope approximately 60⁰ procline, and straight or slightly concave from apex to margin; anterior slope regularly or irregularly concave, marginal-half usually straight or slightly convex, but posterior-half always concave, becoming more concave near apex. Most specimens crushed, causing apex to appear subcentral. Height slightly greater than half length. Pseudointerarea undifferentiated from general surface of shell. False pedicle groove present; formed by abrupt inbending of shell on postero-lateral slopes; widens and deepens from foramen to indented posterior margin. Growth lines on sides of groove bend apically, thicken and fuse radially to form central, well-defined, flattened, granular area as much as 0.3 mm in width at margin. Foramen circular; 0.03 mm in diameter; situated slightly posterior to apex; opens at right angles to plane of pseudointerarea. Anterior commissure rectimarginate. Concentric striae on surface of shell relatively faint; ill-defined; irregular in size and spacing; bifurcate and coalesce. Several concentric ridges, stronger than striae, occur at irregular
intervals. Interior unknown.

**Dorsal valve:** outline subcircular lateral profile nearly flat. Apex marginal; minute; knob-like; sharply raised above surface on both sides; carries minute, median, longitudinal groove at summit. Posterior margin slightly depressed at midpoint; anterior commissure rectimarginate. Growth lines faint; discontinuous; evenly concentric. Striae may bend abruptly posteriorly along median line from apex to anterior margin, where they break and develop delicate "criss-cross" pattern. Interior like that of *Acrotreta n. sp. 3.* Shell-substance calcareo-corneous; composed of several thin laminae inclined obliquely to surface and dipping toward apex.

**Measurements:** (in millimeters)

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>L/W</th>
<th>H/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small ventral valve</td>
<td>1.26</td>
<td>1.35</td>
<td>0.8</td>
<td>.53</td>
<td>.64</td>
</tr>
<tr>
<td>Average ventral valve</td>
<td>1.9</td>
<td>2.23</td>
<td>1.17</td>
<td>.54</td>
<td>.6</td>
</tr>
<tr>
<td>Large ventral valve</td>
<td>2.6</td>
<td>3.1</td>
<td>1.55</td>
<td>.3</td>
<td>.52</td>
</tr>
<tr>
<td>Dorsal valve</td>
<td></td>
<td></td>
<td></td>
<td>Subcircular; flat.</td>
<td></td>
</tr>
</tbody>
</table>

Survey of many ventral valves indicates tendency for height to become less in proportion to length in larger valves; apparently same variation in relation of length to width occurs in valves of all sizes.

**DISCUSSION.** The ventral valve of *Acrotreta n. sp. 1* is characterized by its conical form, strongly procline pseudointerarea, shallow false pedicle groove with a distinct granular center, and minute circular foramen on the posterior side of the apex. The dorsal valve is characterized by its subcircular flattened form, prominent marginal apex bearing a minute median

*L/W signifies proportion of length to width; H/L that of height to length.*
groove, rectangular anterior commissure, and internal brachial support.

Acrotreta n. sp. 1 apparently is different from all described species, the following three being most similar to it. Acrotreta attenuatareek from the Middle Cambrian of Montana differs in the orientation of the ventral pseudointerarea; Acrotreta princeaevelcotti from the Lower Cambrian of Nevada differs in lateral profile and surface ornamentation; and Acrotreta idahoensis sulcata velcotti differs in the character of the false pedicle groove.

Acrotreta n. sp. 1 is most closely related to n. n. sp. 2, from which it differs in the inclination of the ventral pseudointerarea, and in the absence of a sulcate anterior commissure. Although the two species are readily separable by means of external characters, the presence of an anteriorly-extended median septum in the dorsal valves of each shows a close relationship.

LOCALITY AND POSITION. Locality 8, quarry; Locality 26, zone 4; Pentagon shale. Locality 45, zones 3 and 3 c; Locality 47, zone 5; Oathyurusus zone in lo or Chester formation.

Acrotreta n. sp. 2. Plate 1, figs. 7, 10-12.

Species known from numerous disassociated dorsal and ventral valves.

DESCRIPTION. Ventral valve: outline in plane of commissure subcircular or slightly transverse; length three-quarters to almost equal width. anterior margin rounded or slightly flattened; lateral margins rounded; posterior margin flattened for a distance that is equal half width of valve,
and slightly incurved at midpoint to meet false pedicle groove. Lateral profile triangular: posterior slope $75^\circ$ to $30^\circ$ procline, and straight from apex to margin; anterior slope approximately twice length of posterior slope and irregularly slightly convex except just anterior to apex, where it becomes concave. Height one-third to approximately half length. Pseudointerarea undifferentiated from general surface of shell. False pedicle groove present; formed by indenting of shell on postero-lateral slopes; widens and deepens from foramen to indented posterior margin. Growth lines on sides of crest: bend apically, thicken, and fuse medially to form central, well-defined, flattened, circular area as much as $0.3$ mm in width at margin. Foramen circular; $0.03$ mm in diameter; situated slightly posterior to apex; opens at right angles to plane of pseudointerarea. Interior commissure rectimarginate or slightly sulcate. Concentric ridges on surface strongly defined; round; regularly-spaced; slightly crenulated and irregularly segmented in marginal third. Distance between crests of ridges approximately $0.03$ mm on a shell $4$ mm in width; average length of segments approximately $0.1$ mm; gaps between segments of same ridge approximately $0.03$ mm. Interior unknown.

**Terminal valve:** Outline subcircular. Lateral profile slightly convex; greatest convexity near middle of valve. Apex marginal; minute; knob-like; sharply raised above surface on both sides. Posterior margin slightly depressed at midpoint; anterior commissure slightly or strongly sulcate. Sulcus becomes narrow and shallow posteriorly; disappears on elevated umbo. Spinal ridges strong; rounded; segmented; bent abruptly posteriorly along median line from apex to anterior margin, where they break and develop
distinct "criss-cross" pattern. Pseudointerareas imperfectly known. Prop-areas flat; approximately 30° anterior; raised above interior surface of valve by thickness of postero-lateral margins. Pedicle groove deep; wide; smooth. Narrow, low median septum extends anteriorly from pedicle groove for three-quarters length of valve. Shell-substance calcarse-cornaceous; composed of several thin laminae inclined obliquely to surface and dipping toward apex.

Measurements: (in millimeters)

<table>
<thead>
<tr>
<th>Valve Type</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>L/W</th>
<th>H/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small ventral valve</td>
<td>2.07</td>
<td>2.52</td>
<td>1.17</td>
<td>.9</td>
<td>.56</td>
</tr>
<tr>
<td>Average ventral valve</td>
<td>2.25</td>
<td>2.7</td>
<td>1.08</td>
<td>.63</td>
<td>.40</td>
</tr>
<tr>
<td>Large ventral valve</td>
<td>3.33</td>
<td>3.87</td>
<td>1.03</td>
<td>.36</td>
<td>.32</td>
</tr>
<tr>
<td>Dorsal valve</td>
<td>Subcircular; slightly convex.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Survey of many ventral valves indicates tendency for height to become less in proportion to length in larger valves; larger valves more nearly circular.

DISCUSSION: The ventral valve of Acrotreta n. sp. 2 is characterized by its obtusely conical form, very strongly procline pseudointerarea, shallow false pedicle groove with a distinct granular center, concave lateral profile of anterior slope near the apex, minute circular foramen on the posterior side of the erect apex, and strong "dashed-line" concentric growth ridges. The dorsal valve is characterized by its subcircular slightly convex form, sulcus with "criss-cross" pattern of growth ridges at its center, and "dashed-line" surface ornamentation.

Acrotreta n. sp. 2 apparently is identical in outline with some specimens
of _A. attenuata_ seem figured by Vallett, but differs considerably from the type specimen in the relation of length to height, and also in surface ornamentation. The type specimen of _A. pycnica_ and _A. pycnica_ have differ from _A. n. sp. 2_ in having the anterior slope convex in profile, and also in surface ornamentation. The type specimen of _A. pycnica_ has no false pedicle groove, but the specimens from the middle Cambrian of Montana assigned to the species by Vallett apparently have a groove like that in _A. n. sp. 2_.

_Aerostreta n. sp. 2_ is readily separated from others described in this paper by its elliptically-oval ventral valve with nearly vertical pseudo-interiors, and strong "etched-line" ornamentation.

.LOCALITY and STRATUM: Locality 66, zones 2 and 3; locality 22, zone 1; Pangua formation. Locality 20, zone 2; locality 45, zone 2; _Baculites_ zone at base of _Cambrian_.

_Aerostreta n. sp. 3._

_Plate 1, figs. 14-23._

Species known from maximum disassociated dorsal and ventral valves.

DESCRIPTION. Ventral valve: Outline in plane of commissure subtrapezoidal; length approximately four-fifths width. Anterior and posterior margins somewhat flattened; more or less strongly incurved at meeting, the anterior margin inward the least. Intero-lateral margins more strongly rounded than postero-lateral margins. Lateral profile roughly right-

triangular; posterior slope cataclinal, sometimes straight, usually slightly concave; anterior slope regularly or irregularly more or less strongly convex. Height three-fifths to four-fifths length. Pseudointerarea undifferentiated from general surface of shell. False pedicle groove present; formed by in-bending of shell on postero-lateral slopes; widens and deepens from foramen to indented posterior margin. Growth lines on sides of groove bend apically, thicken and fuse medially to form central, ill-defined, more or less flattened, granular area slightly wider at margin than at foramen. Foramen circular; 0.03 mm in diameter; situated slightly posterior to apex; opens at right angles to plane of pseudointerarea. Anterior commissure slightly and broadly sulcate. Concentric striae on surface of shell faint and regular on apical-half; course and irregular toward margins. Several strong growth ridges occur on anterior third of same shells. Striae and ridges on marginal third of median anterior slope bend toward apex to conform with flexure in commissure. A few growth striae, thickened by fusion, may cross false pedicle groove unchanged. Interior unknown.

Dorsal valve: outline transversely subcircular. Margin broadly rounded posteriorly; strongly-rounded antero-laterally; well-flattened anteriorly. Greatest width slightly anterior to center of shell. Posterior part of shell flat; anterior part more or less strongly convex. Convexity of shell apparently increases progressively with age, ranging from nearly flat in young individuals to 0.4 mm at center in a shell 3.5 mm in width. Apex marginal; minute; nub-like; sharply raised above surface on both sides; carries minute, median, longitudinal groove at summit. Posterior margin slightly depressed at midpoint; anterior commissure broadly and strongly
sulcate. Deep sulcus, with width at margin one-third that of shell, becomes narrow and shallow posteriorly, disappearing before reaching apex. Concentric striae similar in definition to those on ventral valve. Striae bend abruptly toward apex in bottom of sulcus, break, and develop delicate "criss-cross" pattern. Prepares flat; approximately 45° anacline; raised above interior surface of valve by thickening of postero-lateral margins. False pedicle groove wide, shallow; traversed medially by low, narrow ridge; sides diverge anteriorly from apex at angle of 90°. Line of valve-junction half width of valve; length of groove one-seventh to one-eighth length of valve. Strong median septum extends anteriorly from pedicle groove; expands laterally in anterior third of shell to a width approximately one-third that of valve; extends vertically into broad strong plate, from which six or more finger-like processes project beyond plane of commissure. Form of expanded septum not constant in different valves, but extent of variation unknown.

Shell-substance calcareum-corneous; composed of several thin laminae inclined obliquely to surface and dipping toward apex.

**Measurements:** (in millimeters)

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>L/W</th>
<th>H/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small ventral valve</td>
<td>1.6</td>
<td>2</td>
<td>1.25</td>
<td>.82</td>
<td>.6</td>
</tr>
<tr>
<td>Average ventral valve</td>
<td>2</td>
<td>2.3</td>
<td>1.25</td>
<td>.8</td>
<td>.52</td>
</tr>
<tr>
<td>Large ventral valve</td>
<td>2.5</td>
<td>3</td>
<td>1.3</td>
<td>.25</td>
<td>.72</td>
</tr>
<tr>
<td>Dorsal valve</td>
<td>Subcircular; convexity increases with size.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Survey of many ventral valves indicates that relationships of length, width, and height are subject to some variations in shells of all sizes.
DISCUSSION. The ventral valve of **Acrotreta n. sp. 3** is characterized by its highly conical form, ctenoline pseudointerarea, shallow false pedicle groove with an ill-defined granular center, strongly convex lateral profile of the anterior slope, slightly sulcate anterior commissure, and distinct apical flexing of growth lines on anterior median slope. The dorsal valve is characterized by a distinct sulcus and a peculiar brachial (?) support.

**Acrotreta neboensis** Salcott from the Middle Cambrian of Utah apparently is closely related to *A. n. sp. 3*, but the ventral valve of *A. neboensis* differs in being more transverse, lower in proportion to length, and in having the apex slightly posterior to the line of valve-junction. No apical flexing of the growth lines on the anterior median slope is described or indicated on Salcott's figure 15 of the type specimen. Both species possess a deep sulcus in the dorsal valve, but they differ in outline in the plane of the commissure. **Acrotreta intermedia** Salcott from the Middle and Upper Cambrian of Alabama is similar in lateral profile, but the character of the false pedicle groove, subcircular outline in plane of commissure, and rectimarginate anterior commissure readily separate the two species.

**Acrotreta n. sp. 3** differs distinctly from others described in this paper in its highly conical ventral valve with ctenoline pseudointerarea, and sulcate anterior commissure. (See *A. n. sp. 1* for a discussion of the dorsal valve of these two species).

**Locality and For. Time.** Locality 26, zone 4; Pentagon shale. Locality 45, zones 3 and 2a; locality 47, zone 3; Spathuriscus zone in lower Megheur.

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formation.

Coritreta n. sp. 4.
Plate II, figs. 1-4.

Species known from numerous disassociated dorsal and ventral valves.

DESCRIPTION. Ventral valve: Outline in plane of commissure transversely elliptical except for slight, shallow indentation of posterior margin; length approximately four-fifths width. Lateral profile flatly triangular; posterior slope 45° to 50° procline, and straight from apex to margin; anterior slope slightly und regularly concave in undeformed specimens, but concavity is accentuated by crushing. Height one-quarter to one-third length; average slightly less than one-third length. Pseudointerarea undifferentiated from general surface of shell. False pedicle groove shallow and distinct in undeformed specimens, usually flattened by compression; formed by slight inbending of shell on postero-lateral slopes. Growth lines on sides of groove may or may not bend slightly toward apex, but fuse medially to form central, distinct, flattened, granular area. Foramen circular, 0.03 mm. in diameter; opens backward through slight subquadrate callosity on posterior side of truncated apex. Interior commissure rectimarginate. Concentric striae on surface distinct; thread-like; regularly segmented in such a manner that numerous narrow areas uncrossed by stria radiate from apex. Flat radiating bands may be present over all or only part of surface. Interior unknown.

Dorsal valve: Outline subcircular. Apex marginal; minute; depressed below posterior margin of shell. Greatest convexity at swollen umbo in
posterior third of shell. Anterior commissure rectilinear, or slightly sulcate. Usually faint median sulcus extends from anterior margin to umbo; most distinct slightly anterior to summit of umbo. Growth lines as on ventral valve. Pseudointerarea and interior unknown. Shell-substance calcareo-corneous; composed of several thin laminae inclined obliquely to surface and dipping toward apex.

**Measurements: (in millimeters)**

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>L/W</th>
<th>W/H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small ventral valve</td>
<td>1.62</td>
<td>1.96</td>
<td>0.34</td>
<td>.83</td>
<td>.23</td>
</tr>
<tr>
<td>Average ventral valve</td>
<td>1.8</td>
<td>2.15</td>
<td>0.45</td>
<td>.83</td>
<td>.25</td>
</tr>
<tr>
<td>Large ventral valve</td>
<td>2.03</td>
<td>4.22</td>
<td>0.63</td>
<td>.83</td>
<td>.17</td>
</tr>
<tr>
<td>Dorsal valve</td>
<td>Subcircular; most convex in posterior third.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Survey of many valves indicates larger shells more subcircular and lower in proportion to width.

**DISCUSSION.** The ventral valve of *Acrotreta n. sp. 4* is characterized by its transversely elliptical outline in plane of commissure, flatly conical form, 45° procline pseudointerarea, circular foramen opening through a subquadrate callosity on the posterior side of the truncated apex, and "dashed-line" type of growth striae with radiating flat bands uncrossed by striae. The dorsal valve is characterized by its surface ornamentation, sulcus, and prominent umbo.

*Acrotreta n. sp. 4* differs from all described species of *Acrotreta* in its slight height, 45° procline ventral pseudointerarea, and callosity through which the foramen opens on the posterior side of the apex.

The specimens from the Escorza formation are somewhat larger than those
from the type locality in the Pentagen shale, but otherwise they appear to be specifically identical. This occurrence of the same species in both formations is unique among the species of Acrotrata.

**Locality and F.I.T.B.** Locality 26, zones 2 and 3; Paroda formation. Locality 6, quarry; locality 26, zone 4; Pentagen formation. Locality 45, zone 3a; locality 47, zone 3; *Aethuriscus* zone of lower longer formation.

**Acrotrata n. sp. 5.**

Plate II, figs. 7-9.

Species known from several well preserved ventral valves.

**Description.** Outline in plane of commissure quite similar to that of *Acrotrata n. sp. 3*; length four-fifths to almost equal width. Anterior margin flattened, and very slightly inflexed at midpoint. Lateral profile highly triangular: posterior slope 75° to 80° sparsely, and concave from apex to margin; anterior slope strongly convex, most abruptly convex near midpoint. Convexity of anterior slope and concavity of posterior slope always adjusted in such a way that apex is highest point of valve and distinctly posterior to line of valve-junction. Height slightly less than three-quarters length. Pseudointerarea similar to that of *Acrotrata n. sp. 2.* Growth lines on sides of groove bend slightly toward apex, and partly fuse medially to form ill-defined central granular area. Some striae may retain their identity across groove with little change. Anterior commissure very slightly sulcate. Concentric striae on surface faint except on sides of false pedicle groove; bend slightly toward apex on anterior median surface. Some parts of surface show faint "dashed-line" development of striae, similar to
that on _L. n. sp. 2._ Interior unknown.

Shell-substance calcareo-corneous; composed of several thin laminae inclined obliquely to surface and dipping toward apex.

**Measurements:** (in millimeters)

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>L/W</th>
<th>N/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventral valve</td>
<td>2.52</td>
<td>3.06</td>
<td>1.54</td>
<td>.82</td>
<td>.6</td>
</tr>
<tr>
<td>Ventral valve</td>
<td>2.7</td>
<td>3.33</td>
<td>1.3</td>
<td>.81</td>
<td>.7</td>
</tr>
</tbody>
</table>

**DESCRIPTION.** The ventral valve of _Acrotreta n. sp. 5_ is characterized by its conical form, erect apex, posteriorly curved pseudointerarea, and faint concentric striae which flex slightly toward apex near anterior margin.

_Acrotreta n. sp. 5_ closely resembles _A. n. sp. 3_ from which it differs most distinctly in lateral profile. _Acrotreta microscopica tetonensis_ Valcott from the Middle Cambrian of Wyoming apparently is the most closely related described species, but it differs in lateral profile and the character of the pseudointerarea.

**LOCALITY and DISTRIBUTION.** Locality 26, top; Pentargon formation. Locality 47, zone 3; Parathuricus zone of lower Beacher formation.

_Genus EUPHORIA_ Valcott


1907. _Iphidsea Sillings, Valcott (in part), Proc. U. S. Nat. Mus., vol. 19,
pp. 70-711.


Subgeneric diagnosis from this reference.

**DESCRIPTION:** "*Iphidella* was proposed to replace *Iphidene*, no species being given as the type. *Micromitra* Beck has priority as the generic name, but as *Iphidella* was intended to include the ornamental ornamented as well as plain type of surface, those species having the former type are now grouped under *Iphidella* as a subgenus of *Micromitra*.


*Iphidella* cf. *I. panculus* (White)  
Plate II, figs. 16-18


1886. *Antorquina panculus* (White), Salcott, *U. S. Geol. Survey Bull. 30*, p. 105, pl. 7, figs. 3-5a; pl. 8, figs. 2-2c.

p. 183, pl. 1, figs. 14-14b.

1881. **Lithocystis panula** (Cline), Walcott, Smith. U. S. Geol. Survey, p. 600, pl. 49, figs. 8-11.


1906. **Lithocystis panula** (White), Jack., Jour. Geol., vol. 14, no. 4, p. 233, pl. 2, figs. 1-10.


1908. **Micracantha (Lithocystis) panula** (Cline), Walcott, Canadian Alpino Journal, vol. 1, no. 2, p. 244, pl. 1, figs. 1-12.

1912. **Micracantha (Lithocystis) panula** (White), Walcott, U. S. Geol. Survey Memo. 51, pp. 361-363, pl. 4, figs. 1-18, 2-34, t. fig. 52.

Description from this reference.

DECR. L.V. "Central valve conical; each slightly incurving over the pseudodeltidium. Cardinal slopes rounded and flattens so as to form a not very strongly defined false area on each side of the wide, triangular opening, which is crossed toward the summit by a less, highly rounded pseudodeltidium; the latter projects directly outward at right angles to the false area and then curves abruptly, so as to be almost flat across the center. A narrow, slight median groove extends from beneath the apex to the posterior margin. Another specimen shows a portion of a pseudodeltidium that is somewhat less elevated than the one described. The apex of the valve just outside of the
extreme point of the beak is crossed by a very minute longitudinal depression that is visible only under a strong magnifier.

"Dorsal valve slightly convex, sloping regularly from the front margin to the small beak, which is slightly incurved at the margin of the valve. False area clearly defined; in a specimen 10 cm in width the area has a width of a little over 1 cm at the side, narrowing to a point at the apex. It is broken midway by a wide triangular opening, which is filled in by a depressed pseudo-deltidium. The sides of the deltidium (deltbyrium ?) turn in at nearly a right angle for a short distance to the general plane of the pseudo-deltidium, which extends across from side to side. Posterior margin slightly arched, and its general surface broken midway by a narrow, distinct groove, which extends from beneath the beak back to the posterior margin. Striae of growth extend across the false areas and pseudodeltidia in both valves; shell substance homogeneous."

"The surface ornamentation of this species is as highly ornamental as that of any Carabrian brechlopod. It appears to be formed of a very fine network of oblique raised lines, which divide it up into minute diamond-shaped pore-like pits, a surface which resembles, under a strong lens, the texture of finely woven cloth. A closer examination, however, of some of the larger shells shows, on the outer margin, cremaluted concentric lines, and a little further back on the shell more deeply cremaluted lines; still farther back the points of the cremalutions unite as to form a solid network that gives the appearance of oblique lines crossing at nearly right angles."

**Discussion.** A badly weathered ventral valve with a broken apex is the
only species closely related to this species in the collections studied.

However, it differs from *Linguella pamsula* (White) in possessing sharply-decortated shell, unstriated propersae; in the absence of a vertical groove across the pseudodelthyrium; and is that the apical angle of the pseudodelthyrium is approximately 100°, which is 20° greater than any figured by Balout. The surface ornamentation seems to have been like that described for *L. pamsula* but has been almost entirely removed by weathering. The fragmentary valve can be only tentatively referred to *L. pamsula* at present. Possibly it belongs to a new species.

**Locality and Fossiliferous.** Locality 22, zone 1; upper Velser shale.

Genus *LINGUELLA* Salter


*B. linguella*. "Valves subequal, equilateral; elonate ovate, broad ovate, or subtriangular in outline. Ventral valve usually subcuneate, with a distinct arc, pedicle groove, and flexure line. dorsal valve somewhat shorter, less acuminate, and with a less clearly marked pedicle groove on
the shorter arm. Seals bend just at the margin of the area, which are usually in the plane of the margins of the valves; the areas, which vary in size and shape in the different species, are usually oval or less triangular; in the ventral valve they may be as shortened and arched as to nearly lose this marked form; the areas of the dorsal valve also vary in their form, length, and extension with cardiac shapes.

"Shell substance calcareous; structure consists of a thin outer surface layer and numerous inner layers or lamellae that are subparallel to the surface over the posterior portions of the shell and more or less oblique to it over the central, natural, and anterior portions; the short oblique layers usually form the inner flattened rim of the valves which is frequently seen in the casts. Surface of shell marked by fine concentric striae and lines of growth, and in some species finely inoscillating, lamellose striae; also, insert if not all species, radiating striae and lines."

"The visceral area (splanchnocoele) is usually confined to the central and posterior portions of the ventral valves, but it may extend far into the brachial area (brachiocoele); in the dorsal valve it extends farther forward than in the ventral valve of the same species; in both valves it may range from the posterior third of the shell forward to the anterior third, and in the dorsal valve well into the latter; in both valves the visceral area extends back to the base of the area of the areas where it is bounded externally by the flexure lines (lines of folding of the area lamellae)."

"A narrow median ridge or septum is frequently observable in the dorsal valve, but with the exception of what may be considered as indicating its
probable presence in the adductor of a ventral valve of *Lingula davisi* ( McCoy), no traces of a Caroline vein observed in the ventral valve of any of the species that I have studied. The main vascular sinuses vary in size, direction, and length in the various species; in all they begin in front of the area of the median line and extend forward and outward across the parietal band into the central-lateral and anterior parts of the brachiocele. The impressions of the secondary vascular sinuses are rarely preserved, but the few traces observed indicate that they were numerous and extended toward the peripheral canal and into the middle of the shell in the direction necessitated by the arrangement of the main sinuses and the boundaries of the visceral area."

"In the anterior portion of the visceral area of the dorsal valve of some species the "heart-shaped pit" or sinus is distinctly marked. It is rarely so well shown, although its anterior outline is preserved in nearly all species whose interior characters are well marked. A median ridge may or may not be present in the interior of the dorsal valve."  

"The preservation of all vascular markings depends largely on the thickness of the shell, being rarely seen in thin shells and often found in thick ones."

The description of the muscle scars is omitted.


**Lingula cf. H. isse (alcott)**

_Late III, fig. 3_

1912. *Lingulella isse* (Walcott), U. S. Geol. Survey Imono. 61, p. 500-511, pl. 39, figs. 4-4b; t. figs. 43-7. Description from this reference.

**DESCRIPTION.** "This shell is rather strong and made up of several thin layers or lamellae. Its outer surface is marked by concentric lines of growth, sometimes grouped in more or less elevated bands, and over all there is a thin encrusting or scabrous layer that has a minutely granular, dull surface, somewhat like that of *Lingulella (Lingula) præna* (Matthew), but very much finer in its granulations or points. The inner layers of the shell are dark, shiny, and marked by concentric lines of growth and radiating striae."

**DISCUSSION.** A single badly weathered and exfoliated ventral valve in the collections studied is closely allied to *Lingulella isse* (Walcott) in size, outline, and surface characters. Unfortunately the interior of *L. isse* is unknown and no comparison of the pseudointerareas can be made. The following is a description of the pseudointerarea of the Montana specimen.

Propareae narrow, marginal, raised above interior on strongly thickened edges of shell; separated from each other by wide, deep pedicle groove, whose sides diverge slightly from apex. Approximate relationships of sides $\xi$, $\upsilon$, and $\mu$ (see fig. 1, p. 6) of each propareae are 3:6:11 respectively. Strong straight flexure line from angle $V$ intersects side $\upsilon$ near midpoint. Portion of proparea lateral to flexure line smooth; portion between flexure line and pedicle groove apparently coarsely striated, but badly preserved; smooth portion slightly larger than striated portion.

**LOCALITY and FORMATION.** Locality 10; Switchback formation.
Species known from numerous disassociated dorsal and ventral valves.

**Description.**

**Dorsal valve:** Outline elongate elliptical; width, a proximely three-quarters length, slightly anterior to middle valve. Anterior margin broadly rounded; postero-lateral margins straight, and meet at approximately 90°. Convexity slight near anterior margin; increases posteriorly along median axis to highest point in posterior third. Apex marginal and in plane of commissure. Growth ridges on surface faint; broad; flat; smoothly concentric; interspersed with irregularly-spaced coarse growth lamellae. Propeareas narrow, marginal; raised slightly above interior surface of shell; separated by sharply-defined wide, deep, pedicle groove, whose sides diverge slightly from apex. Groove crossed perpendicular to longitudinal axis by faint traces of striae; parallel to axis by coarse narrow ridge, which is bordered by fine striae. Approximate relationships of sides g, v, and m of each propearea are 1:2. 5:3 respectively. Distinct straight flexure line from angle V intersects side v near midpoint. Portion of propearea lateral to flexure line smooth; portion between flexure line and pedicle groove coarsely striated parallel to side m; smooth and striated area approximately equal in size. Interior of valve with scattered coarse punctae, which appear as distinct papillae on internal cast. Vascular markings and muscle scars unknown.

**Ventral valve:** Outline elongate elliptical; width four-fifths length. Convexity slight near anterior margin; increases to highest point in posterior one-fourth. Growth lines as on ventral valve. Pseudointerarea
narrow; marginal; widest at apex and narrows laterally; crossed by several coarse and fine ridges parallel to margin of valve. Broad, shallow pedicle groove vaguely indicated by slight anterior flexing of striae in median part of pseudointerarea. Interior of valve with scattered coarse punctae as in ventral valve. Vascular markings and muscle scars unknown.

**Measurements:** (in millimeters)

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average ventral valve</td>
<td>2.9</td>
<td>2.3</td>
<td>.75</td>
</tr>
<tr>
<td>Large ventral valve</td>
<td>7.7</td>
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<td>.74</td>
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<td>Average dorsal valve</td>
<td>4.5</td>
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<tr>
<td>Large dorsal valve</td>
<td>7.3</td>
<td>6.4</td>
<td>.81</td>
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</table>

**DISCUSSION.** *Lingulella n. sp. 1* is characterized by its elongate sub-acuminate ventral valve whose width approximates three-quarters length, elongate elliptical dorsal valve whose width approximates four-fifths length, long ventral processes that are divided by flexure lines into subequal smooth and striated portions, and scattered coarse punctae on the interior.

The ventral valve of *Lingulella n. sp. 1* is very similar in outline to that of *Lingulella clarkii* (Calcott) from the Middle Cambrian of Nevada, but the dorsal valve of that species has a distinct median sulcus. The internal characters of *L. clarkii* are unknown. *L. punctata* (Calcott) from the Middle and Upper Cambrian of Nevada has an interior with scattered coarse punctae and the ventral valve is similar in outline to that of *L. n. sp. 1*; however, the dorsal valve of *L. punctata* is much wider in proportion to length, and has a median sulcus and an internal median septum. *Lingulella n. sp. 1* is quite similar in some respects to *L. acutangula* (Wheeler, from the Upper
Cambrian of Texas, but differs from it distinctly in the character of the surface striation, and in details of the pseudointerareas.

_Linolella n._ sp. 1 is readily separated from other species described in this paper because of its elongate sub-acuminate ventral valve, and coarsely punctate interior.

**Locality and Formation.** Locality 20, zones 2 and 3; locality 26, zone 1; Pagoda formation. Locality 43, zone 3a; _Durania_ zone in basal Vehecher formation. Locality 26, zone 4; Pentagon shale. Locality 45, zone 3a; locality 47, zone 3; _Eothyrisites_ zone in lower Vehecher formation.

**Linolella n._ sp. 2**

Plate III, figs. 5, 7.

Species known from numerous disassociated dorsal and ventral valves.

**Description.** Ventral valve: outline elongate subtriangular; greatest width, approximately four-fifths the length, anterior to middle of valve. Anterior margin straight or obtusely rounded; postero-lateral margins straight, and meet at approximately 90°. Convexity flat near anterior margin; increases slightly to highest point in posterior third. Apex marginal and in plane of commissure. Growth striae on surface distinct; evenly-concentric; coarse and fine. Propareas narrow; marginal; raised slightly above interior surface of shell; separated by sharply-defined narrow, deep, pedicle groove, whose sides diverge strongly from apex. Striae absent in groove. Approximate relationships of sides _x_, _y_, and _m_ of each proparea are 1:2, 5:3 respectively. Distinct at sight flexure line from angle V intersects side _y_ approximately one-third length from groove. Portion of proparea lateral to flexure line smooth; portion between flexure line and pedicle
groove strictly parallel to side; smooth area approximately twice as large as striated area. Interior impunctate; smooth. Vascular markings and muscle scars unknown.

**Dorsal valve:** Normally slightly elongate elliptical; greatest width, approximately nine-tenths length, slightly anterior to middle of valve. Anterior half of shell rounded subquadrate; posterior half obtusely rounded. Convexity flat near anterior margin; increases slightly to greatest height in posterior half. Apex, marginal and in plane of commissure. Surface striae as on ventral valve. Caudal interarea imperfectly known, but apparently similar to that in *Lingulella* n. sp. 1. Interior impunctate; smooth. Vascular markings and muscle scars unknown.

**Measurements:** (in millimeters)

<table>
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<tr>
<th></th>
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</tr>
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<tr>
<td>Average ventral valves</td>
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<td>3.3</td>
<td>.83</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>3.3</td>
<td>.83</td>
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<tr>
<td>Average dorsal valves</td>
<td>4.3</td>
<td>4.0</td>
<td>.83</td>
</tr>
<tr>
<td></td>
<td>3.6</td>
<td>3.3</td>
<td>.82</td>
</tr>
</tbody>
</table>

**Discussion:** *Lingulella* n. sp. 2 is characterized by its slightly elongate subtriangular outline of the ventral valve, flattened or obtusely rounded anterior margin, straight postero-lateral margins of ventral valve that intersect at 90°, ventral准备 unequally divided by a straight flexure line into a smooth lateral portion twice the size of the medial striated portion, and impunctate interior.

No described species of *Lingulella* that approximates *L. n. sp. 2* in size and outline, and of which the interior is known, possess a ventral
pseudointerarea similar in form. Some specimens assigned by Sappott\(^16\) to \textit{Linculella wataensis} alcott from the Middle Cambrian Burgess shale of British Columbia are very similar to the Montana species in size and outline. However, Sappott's description is inadequate, no interiors are figured, and no type specimen is designated.

\textit{Linculella n. sp. 2} is readily separated from other species described in this paper because of its slightly elongate subtriangular ventral valve, impunctate interior, and unequal-sized striated and smooth portions of each ventral proparea.

**Locality and Formation.** Locality 43, zone 2; \textit{Phylacosa} zone in basal Deager formation. Locality 43, zones 3 and 3a; \textit{Dohuyris} zone in lower Deager formation.

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Genus 'ICHOITRA' Weck


1887. Iphidaea Billins, Schlof, Samuel de onchylologie, by Fischer, p. 1270.


Description from this reference.

DESCRIPTIVE. "Ventral valve conical to depressed conical, with the beak curving more or less over a false area which is divided midway by a triangular fissure that may be covered almost entirely or only in part by a convex pseudodeltidium.

Dorsal valve slightly to moderately convex. Beak small and usually curved a little over a low area that has a rather broad pseudodeltidium.

Surface marked by concentric lines of growth and fine radiating striae; crenulated concentric striae that give a more or less distinctly crenulated appearance to the surface; and strongly crenulated concentric striae forming a network of raised, obliquely arranged lines that divide the surface into minute pits. Shell substance corneous. Shell built up of thin layers or lamellae that are more or less oblique to the outer surface."
Very little is known of the interior of the valves."


**Leptochioceras**. There is a closely related group of species among those assigned at present to **Leptochioceras** Leek, **Isterina** seecheri, and **Iphidella** Walcott. Its members are characterized by a more or less strongly convex ventral valve, a strongly apsinale to procline ventral pseudointerarea, and, most characteristic, a convex pseudodeltidium that more or less closes the widely triangular pseudodeltidium. Walcott in 1913 considered **Isterina** and **Iphidella** to be subgenera of **Leptochioceras**. Those species "whose surface is formed of simple concentric striae and lines of growth" were to be assigned to **Isterina**; those "whose surface is formed by the union of the orenulated striae so as to form a fine network of raised obliquely arranged lines" were to be assigned to **Iphidella**; and those "with the intermediate type of surface" were to be assigned to **Leptochioceras**. The separation of three generic groups by means of a predational type of surface ornamentation created an unfortunate situation that has been further complicated since 1912.

Walcott classified **Isterina** under the **Streptega**. In 1927 Thomson included it in the **Heteromorpha** on the basis of holopertipheral growth. Then


in 1929 Schuchert and Le Vene\textsuperscript{20} accepted Thomson's order Palaeotremata, included *Paterina*, restricted to the Lower Cambrian, in it; and included *Micromitra* and *Levia* in the *Atemata*. Finally, under the date of February 11, 1936, Dr. G. Arthur Cooper writes\textsuperscript{21}, "The one genus which certainly belongs in the Palaeotremata is *Rustella*.

Inasmuch as the above-mentioned changes in classification of *Paterina* have been published without explanatory remarks, the writer is unfamiliar with the reasons for them. It is apparent that *Paterina* has been redefined to include only those Lower Cambrian species that are congeneric with *Paterina labradorica* (Billings) and *Paterina labradorica* cantonensis (Calcott). Judging from the disagreement among the authorities regarding how *Paterina* should be classified, the revised definition is not yet explicit. Probably most of the species formerly assigned to *Paterina* must now be assigned to *Micromitra*, as represented to *M. sculptilis* (Meek).

The writer has considered as congeneric with *Micromitra sculptilis* (Meek) only those species which have a similar form, and a triangular pseudodelthyrium more or less closed by a pseudodeltidium. This concept necessitates the disregard of several species, formerly assigned to *Micromitra* or *Paterina*, in which the ventral pseudointerareas are either unknown or inadequately described and figured. The surface ornamentation cannot be considered of more than specific value, and even then of less importance than the characters of the pseudointerarea. For the present the genus *Levia* Calcott is


\textsuperscript{21}Personal communication.
considered valid, although the species assigned to it appear to be vaguely differentiated.

* Micromitra n. sp. 1. *

Plate III, figs. 9-18.

Species known from numerous disassociated dorsal and ventral valves.

**DESCRIPTION.** Ventral valve: Outline transversely rounded; posterior margin truncated; side $m$ (see fig. 1, p. 6) of each proparea diverges approximately $45^\circ$ from line of valve-junction, which equals four-fifths greatest width of shell. Profile obtusely conical; highest point at umbo, vertically above or slightly anterior to line of valve-junction. Apex sharply pointed; strongly incurved over pseudodeltidium. Propararea flat; smooth or granular; unstriated. Concentric ridges of anterior surface bent sharply toward apex and fuse along side $v$ of each proparea. Pseudodelthyrium high; triangular ($60^\circ$ at apex); completely filled by strongly convex pseudodeltidium. Pseudodeltidium thin; differentiated from each proparea by abrupt, smooth bending of shell along side $g$; surface identical with that of propareas. Length of shell approximately four-fifths width; height approximately half length. Interior unknown.

Dorsal valve: Outline transversely rounded; posterior margin truncated; side $m$ of each proparea diverges approximately $30^\circ$ to $45^\circ$ from line of valve-junction, which equals four-fifths greatest width of valve. Profile slightly convex; highest point at umbo, vertically above or slightly anterior to line of valve-junction. Apex broadly rounded; slightly incurved over pseudochilidium; carries low smooth callosity which extends anteriorly into
four symmetrically-arranged lobes; two central lobes most prominent. Prop-areas flat; smooth or granular; crossed parallel to side m by several thick-ened ridges that do not reach pseudochilidium. Concentric ridges of anterior surface bend abruptly toward apex and fuse along side y. Pseudonotothyrium low; triangular (90° at apex); completely (?) filled by convex pseudochili-dium. Pseudochilidium differentiated from each proparea by abrupt, smooth bending of shell along side g; smooth or granular; unstriated. Interior unknown.

Surface ornamentation variable. Rectangular pattern, formed by inter-section of strong concentric with strong radiating ridges, present near apex of all valves, and over entire surface of some; usually modified anteriorly.

Apparently only three modifications relatively constant: rectangular pattern over entire surface; rectangular pattern on posterior two-thirds, and irreg-u lar, russet, concentric ridges on anterior one-third; rectangular pattern on posterior one-third, and strong, regular, concentric ridges on anterior two-thirds. Radiating and concentric ridges few or numerous; may or may not bifurcate and coalesce. Irregular radiating crenulations of shell present on some valves; rectangles modified into more or less round pits on others.

Measurements (in millimeters)

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>L/H</th>
<th>W/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncrushed ventral valve</td>
<td>2.9</td>
<td>3.6</td>
<td>1.44</td>
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<td>.5</td>
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<tr>
<td>Crushed ventral valve</td>
<td>5.05</td>
<td>7.05</td>
<td>----</td>
<td>.75</td>
<td>---</td>
</tr>
<tr>
<td>Crushed dorsal valve</td>
<td>3.73</td>
<td>5.04</td>
<td>----</td>
<td>.75</td>
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</table>

Discussion: Micromitra n. sp. 1 is characterized by its obtusely conical
ventral valve and slightly convex dorsal valve, pseudodeltidium and pseudochilidium that apparently completely close the pseudodelthyrium and pseudonotothyrium, petalloid callosity on the broadly-rounded apex of the dorsal valve, and a surface ornamentation consisting of intersecting concentric and radiating ridges best developed near apex of each valve and usually modified anteriorly.

No described species of Micromitra possesses a petalloid callosity on the apex of the dorsal valve. Unfortunately, most species of Micromitra have been based upon types of surface ornamentation, and the morphology of the pseudointerareas either is unknown or very imperfectly described. Only one species, *M. pellicci* (Salcott), is described as having clearly demarcated properae and a pseudodeltidium that completely fills the pseudodelthyrium. However, Salcott in his description of that species states, "The striae of growth cross the false area and arch over the delthyrium (pseudodeltidium?)."

Valves of several species, as figured by Salcott, apparently have surface ornamentation similar to that present in *M. n. sp. 1* but they either differ widely in other respects or are inadequately described.

**LOCALITY and FORAMS.** Localities 26, zone 2; locality 28, loose; Pagoda formation. Localities 45, zone 2; locality 47, zone 2; *Hermia* zone in basal Meagher formation. Localities 6, quarry; locality 26, zone 4; Pentagon shal. Localities 45, zones 3 and 2a; locality 47, zone 3; *Bathyuriscus* zone in lower Meagher formation.

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Hieromitra n. sp. 2
Plate IV, figs. 1, 2.

Species known from one uncrushed dorsal valve, and several badly crushed and incomplete disassociated dorsal and ventral valves.

DESCRIPTION. Ventral valve: Outline transversely rounded; posterior margin flattened and slightly shorter than greatest width of shell. Profile probably conical, with apex incurved over posterior margin. Pseudodelthyrium apparently a broad triangular gap below apex. Proporaeas undifferentiated.

Dorsal valve: outline transversely rounded; with posterior margin flattened in central third. Profile slightly convex; greatest height at umbo of broadly rounded, slightly incurved, marginal apex. Petalloid callus faintly visible on apex of holotype, but exact characteristics indeterminable. Pseudonotothyrium low; widely triangular (135° at apex). Proporaeas undifferentiated.

Concentric surface undulations broad; low; irregularly-spaced; interspersed with faint narrow undulations; crossed on anterior half of valve by regularly-spaced, broad, shallow, radiating grooves, which are 0.3 mm to 0.4 mm apart near margin; curve slightly toward apex at junction with radiating grooves; thicken on margins of pseudodelthyrium and pseudonotothyrium and bend abruptly toward apex. Surface of shell dark brown or black; extremely glossy.

Measurements: (in millimeters)

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Length</th>
<th>Width</th>
<th>1/3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncrushed dorsal valve (holotype)</td>
<td>3.0</td>
<td>5.0</td>
<td>.6</td>
</tr>
</tbody>
</table>
HILMITE. Micromitra n. sp. 2 is characterized by its widely-triangular pseudonotothorium; absence of demarcated preproareas; petaloid callosity on apex of dorsal valve; and broad concentric surface undulations crossed in the anterior half of the valve by regularly-spaced radiating grooves.

The assignment of this species to Micromitra is problematical in the absence of any knowledge of a pseudodeltidium. However, the general form and structure of the shell, and the presence of a petaloid callosity on the apex of the dorsal valve indicate a probably generic relationship with Micromitra n. sp. 1.

No described species of Micromitra has a petaloid callosity on the apex of the dorsal valve, nor a surface ornamentation similar to that of M. n. sp. 2. This species is readily separable from others described in this paper because of its surface ornamentation and the absence of demarcated preproareas.

FORMATION and LOCALITY. Locality 26, zone 4; pentagon shale. Locality 45, zones 3 and 3a; eothyarismsa zone in lower Peaugh formation.

Micromitra n. sp. 2
Plate IV, figs. 3-6.

Species known from one fragmental dorsal and two fragmental ventral valves.

LOCALITY. Ventral valve: outline transverse only rounded; posterior margin truncated; side x of each preproarea diverges approximately 30° from line of valve junction, which equals four-fifths width of valve. Profile
Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

conical; highest point at umbo, obtusely pointed apex, vertically above line of valve-junction. Proporaeas flat; smooth; crossed perpendicular to side m by several widely and irregularly-spaced distinct grooves. Concentric ridges of exterior surface bend abruptly toward apex and fuse to form sharp ridge along side x. Pseudodelthyrium high; triangular (90° at apex); covered in apical one-fifth by convex pseudodelthyrium. Pseudodelthyrium thick; rises vertically from side m of each proporae; flattened radially; coarsely striated parallel to strongly concave margin; has short lateral extremities. Length of valve approximately half width; height seven-tenths length. Interior unknown.

Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

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Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

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Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

conical; highest point at umbo, obtusely pointed apex, vertically above line of valve-junction. Proporaeas flat; smooth; crossed perpendicular to side m by several widely and irregularly-spaced distinct grooves. Concentric ridges of exterior surface bend abruptly toward apex and fuse to form sharp ridge along side x. Pseudodelthyrium high; triangular (90° at apex); covered in apical one-fifth by convex pseudodelthyrium. Pseudodelthyrium thick; rises vertically from side m of each proporae; flattened radially; coarsely striated parallel to strongly concave margin; has short lateral extremities. Length of valve approximately half width; height seven-tenths length. Interior unknown.

Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

Dorsal valve: Specimen incomplete, but outline in plane of commissure probably transverse ovoid, with posterior margin truncated. Profile slightly convex; highest point at umbo, vertically above line of valve-junction.

conical; highest point at umbo, obtusely pointed apex, vertically above line of valve-junction. Proporaeas flat; smooth; crossed perpendicular to side m by several widely and irregularly-spaced distinct grooves. Concentric ridges of exterior surface bend abruptly toward apex and fuse to form sharp ridge along side x. Pseudodelthyrium high; triangular (90° at apex); covered in apical one-fifth by convex pseudodelthyrium. Pseudodelthyrium thick; rises vertically from side m of each proporae; flattened radially; coarsely striated parallel to strongly concave margin; has short lateral extremities. Length of valve approximately half width; height seven-tenths length. Interior unknown.
concentric growth lines may or may not be obliterated, radiate from apex; extend approximately one-third distance to margin.

Measurements: (in millimeters)

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>W/H</th>
<th>H/L</th>
</tr>
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<tbody>
<tr>
<td>Uncrushed ventral valve</td>
<td>3.2</td>
<td>6.3</td>
<td>2.25</td>
<td>.5</td>
<td>.7</td>
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</table>

**Discussion.** *Micromitra n. sp. 3* is characterized by its conical ventral valve; short, thick pseudodeltidium and pseudochilidium, with the pseudodeltidium flattened medially; distinctly demarcated propaxes on both valves; strong, irregular concentric growth ridges; and extremely irregular, low, broad, radiating ridges on posterior one-third of each valve.

All described species of *Micromitra* which possess a small pseudodeltidium differ markedly from *n. n. sp. 3* in other characters, usually in having the concentric growth ridges continuous across the postero-lateral slopes, no propaxes being demarcated. *Micromitra (Caterina) labradorica orientalis* (Salcott) from the Middle Cambrian of China, known from a single dorsal valve, has a surface ornamentation apparently similar to that on the Montana species. However, the Chinese variety is so incompletely described that no accurate comparison of the two forms can be made.

*n. n. sp. 3* is most closely allied to *n. n. sp. 4*, but the two species differ distinctly in the characters of the pseudodeltidium and surface ornamentation.

**Locality and Rock Type.** Locality 33, zone 31; lenticular limestones in basal part of Holsey shale.
Micromitra n. sp. 4.
Plate IV, fig. 3-10.

Species known from a single ventral valve.

DESCRIPTION. Outline transversely rounded; posterior margin truncated; side m of each proporean diverges approximately 45° from line of valve-junction, which equals four-fifths width of valve. Profile conical; highest point at uwo, vertically above line of valve-junction. Apex sharply pointed; slightly curved over pseudodeltidium. Proporean flat; granular; unstriated. Centric growth rings of anterior surface bent abruptly toward apex at distinct narrow groove along side y. Pseudodelthyrium high; triangular (90° at apex); covered in apical one-fifth by convex pseudodeltidium. Pseudodeltidium thick; rises vertically from side of each proporean; slightly convex radially; unstriated; has strongly concave margin, and lateral extremities which extend one-third distance from apex of pseudodelthyrium to angle V of each proporean. Length slightly more than half width; height slightly less than length.

Growth ridges on surface round; distinct; regularly-spaced; smoothly concentric; increase gradually in size from apex to margin; never bifurcate or coalesce; approximately one-third width of shallow, flat-bottomed interspaces; regularly broken into segments in such a manner that numerous narrow areas, uncrossed by ridges, radiate from apex. Radiating tracts irregular in width and distribution; straight from apex to margin. Interior unknown.

DISCUSSION. Micromitra n. sp. 4 is characterized by its conical ventral valve; short, thick, slightly convex pseudodeltidium with long, lateral extremities; surface with distinct, regular, concentric ridges crossed by
numerous radiating, smooth, narrow tracts.

*Micromitra* n. sp. 4 differs from all described species of the genus in the same ways as *Micromitra* n. sp. 2. The two species are closely allied, but differ distinctly in the characters of the pseudodeltidium and surface ornamentation.

**Locality** and F.R. **Notes.** Locality 17, zone 2; Pagoda formation.

**Genera** *NISUSIA* S.alcott


**Description.** "Exterior subquadrate to semicircular, unequally biconvex, with the dorsal valve the more convex. Hinge-line straight, usually as great as, or greater than, the greatest width of the shell; cardinal extremities usually acute, anterior commissure faintly uniplicate; ventral sulcus shallow; ventral interarea broad, strongly appascellate to proclive; deltidium well developed, strongly convex, but only partially covering the delthyrium, perforated at the apex. Dorsal interarea ensasellate, notothyrium more or less well developed. Chilidium present. Surface costellate, crests of costellae provided with prominent spines in the genotype and other species. Micro-structure of the shell not definitely known, probably fibrous, impunctate."
"Ventral interior: Notothyrial cavity obsolete; teeth very rudimentary; dental plates absent, ventral muscle-scars not visible."

"Dorsal interior: Notothyrial cavity very shallow; notothyrial callosity confined, without a cardinal process, and not produce forward as an axial ridge or thickening. Brochiophores bladelike thickenings along margins of notothyrium. Adductor scars appearing as two divergent, elongate impressions anterior to the notothyrial callosity."


Schuchert and Cooper completely revised Walcott's list of species referred to Nisusia with the result that but four are left unquestionably by them in this genus.

Nisusia alberta (Walcott)

Plate V, figs. 1-3, 5.

1912. Nisusia alberta (Walcott), U. S. Geol. Survey Mon. 51, p. 726, pl. 100, figs. 3-3d. Description from this reference, emended slightly as indicated by Schuchert and Cooper.
1922. Nisusia alberta (Walcott), Schuchert and Cooper, Nat. Peabody Mus.
V. Albert as a valid species of the emended genus.

**DESCRIPTION.** "Shell transversely oval, front broadly rounded; the straight hinge line is shorter than the full width of the valves. Surface of shell with numerous radiating ribs that increase by interpolation; on a shell 19 mm in width there are four ribs near the front margin in a distance of 5 mm; the ribs are narrow and sharp created, the interspaces being wider than the ribs. Cost of the outer surface of a shell in siliceous shales shows numerous strong spines irregularly distributed on the ribs very much as in *N. restituta*."

"Ventral valve elevated at the umbo and apex in some shells, convex and rounded over toward the area in others; area varying in height in different shells, usually elevated and overhanging the hinge line; it is divided by a strong delthyrium that is covered by a convex deltidium of varying length, orched at its front margin and divided by low itudinal lines into three parts."

"Dorsal valve gently convex; area low, and a little inclined over the hinge line; delthyrium broad with a narrow chilidium. Cost of the interior show... adductor muscle scars."

**DISCUSSION.** The specimens studied, all ventral valves, unfortunately are fragmental and badly weathered. However, they indicate clearly that a large foramen is present at the apex above the deltidium. Dr. C. Arthur Cooper kindly examined some of the specimens, and wrote, "The large foramen cutting the apex is one of the striking features of the genus."
Schuchert and Cooper hinted at this but were not absolutely certain of its presence." The Montana specimens seem to agree closely with Calcutt's description and figures of \( N. \) alberta. Spines are absent on the costae, except for very faint indications on some specimens, but this may be the result of weathering.

**Locality and P. T. T.** Locality 20, zone 2; Lommation limestones.

**Nisusia ? sp. undet.**

Plate V, figs. 6, 8.

There are in the collection several dorsal valves, apparently belonging to the same species, whose relationships cannot be determined.

**Description.** Outline transverse subquadrate. Hinge line straight. Cardinal extremities obtusely rounded or angular. Convexity strong and regular. Anterior commissure sulcate; sulcus deep. Radiating costae on surface strong; intercalated and bifurcated; provided with prominent spines on crests. Perforate growth lamellae present, or absent near anterior and lateral margins. Intereare unknown. Internal expression of radiating costae only characters visible on two badly weathered interiors. Length of figured specimen 3 mm; width 18 mm.

**Discussion.** Dr. C. Arthur Cooper examined the valve shown in fig. 6, and stated that it is *Nisusia*. If this is true, the generic diagnosis of *Nisusia* must be revised to include species in which the anterior commissure is sulcate. The valves from Montana do not belong to any described species of *Nisusia*. The specimens are tentatively assigned to *Nisusia* upon Dr. Cooper's identification of them; but in the writer's opinion more should
be known of the interarea and interior before final specific, or even
generic designations can be given to these valves.

**LOCALITY and DISTRIBUTION.** Locality 56, loose and top; pentagon forma-
tion.

**Genus OBOLEUS Richwald**

ba-b.

17-55.

1921. Oboleus Richwald, Davidson, British Fossil Brachiopoda, vol. 1,
Introduction, p. 129, pl. 9, figs. 200-294, figs. 51-52.

1922. Oboleus Richwald, Hall and Clarke, Nat. Hist. New York, Paleontology,
vol. 6, pt. 1, pp. 89, 337, figs. 33, 34.

1926. Oboleus (Obobulus) Rickwitz, Mem. acad. imp. sci., St.-Petersburg,
6th ser., vol. 4, no. 2, pp. 129, 133.

Cambrian Rocks Cape Breton, p. 125, 136.

7, figs. 1-8, 16-17; pl. 14, figs. 6, 6a; t. figs. 4, 15. Des-
cription from this reference.

**DESCRIPTION.** "Shells nearly equivelv, equal-sided, moderately con-
 vex, subcircular, transversely or longitudinally ovate, in some species
subtriangular or subrectangular.

"Shell substance calcareocornaceous, structure foliated; the layers of
calcium phosphate alternating with homogeneous, horny lamellae are traversed by microscopic canals, which in their main direction are perpendicular to the plane of stratification; the inner layers and lamellae are more or less oblique to the thin outer layer over the central and posterior portions of the valves, and strongly so with the short lamellae of the anterior and lateral parts. Surface shining as if varnished, with concentric and usually radial striation, varying from bare visibility to deeply incised concentric folds and radial ribs. Color of shell dark grayish blue to black, when in a state of decomposition dark reddish brown to whitish. Front and side margins usually thin, sharpened, fragile, lying in the same plane with the hinge margin, which is greatly thickened inside. Area mainly in the plane of the edge of the valve, in the ventral valve triangular, owing to the somewhat projecting beak, in the dorsal valve rounded at the point, in both striated parallel to the base, and traversed, from the point of the beak on, by the more or less diverging lines of folding of the areal lamellae and a strongly marked pedicle furrow. 

"Visceral area (splanchnocoela) on the ventral valve restricted to the back part, in the dorsal valve drawn far forward into the vascular area (brachioceles) and strongly indented laterally; in both valves it extends backward up close to the base of the visceral (splanchnocoela) part of the area, which is bounded by the flexure line (folding of the area lamellae). The edge of the mantle of the back part is restricted to the side areas (pleurocoels), appearing between the flexure lines of the area lamellae."
"Interior part of the thickened posterior half of the valve slopes down to the middle of the valve, forming in the ventral valve a line concave to the bend, in the dorsal valve a sinus. The lateral parts of the thickening are drawn out into thin side edges. In front of the base of the area is a small median septum, which in the dorsal valve for the most part is less prominent, but in both is often hardly perceptible by reflected light as an almost invisible crest. Beginning at the median septum, there are in each valve two gradually deepening grooves for the main vascular canals, which intersect the thickened part parallel to the edge of the shell. In the dorsal valve these grooves combine with the sinus from the calcareous ridges in forming two projections pushing themselves like horns into the middle of the valve. The traces of the main vessels of the mantle lobes in the continuation of the visceral (splanchnocoelid) vascular grooves are subparallel and project into the vascular (brachiocoelid) parts of the valves, in the ventral valve terminating with their anterior ends in the peripheral vascular canal, in the dorsal valve, shortly before reaching the vascular canal, bending about into the interior of the shell, and vanishing at the scars of the anterior lateral muscles. The peripheral vascular canals in both valves run along their edge from one side area (pleurocoele) to the other. Traces of secondary vessels radiate in great number from the grooves of the main vessels toward the peripheral canals and into the middle of the shell."

"In the median line of the ventral valve, between the median septum and the anterior edge of the thickened part of the shell, there is a deep,
heart-shaped pit, with its point directed forward and having a shallow median groove. In the cavity of the dorsal valve there is a more or less pronounced median ridge, extending into the anterior part of the valve and divided longitudinally by a shallow median furrow."

Description of musculature omitted.

Genotype: Aplys aequilhina Richwol., Coccoidea specialis, vol. 1, p. 274, pl. 4, figs. 5a-b, 1899.

Aplys p. sp. 1.
Plate IV, figs. 11, 14.

Species known from numerous disassociated dorsal and ventral valves.

**Proparea**: Ventral valve: Outline subcircular, with obtusely acuminate apex; greatest width near half length. Postero-lateral margins straight or slightly convex; intersect at approximately 135°. Profile strongly convex; highest point at center of valve, from which surface slopes equally to all margins. Concentric growth ridges on surface fine to coarsely lanellar. Endodermal layer finely granular, giving dull, velvety appearance. Proparea marginal; sharply raised above interior surface; separated by clearly-defined, deep, narrow pedicle groove whose sides diverge slightly from apex. Groove crossed perpendicular to its length by numerous coarse striae which do not extend to bottom. Approximate relationships of sides X, Y, and Y of each proparea are 5:7:9 respectively. Straight flexure line from angle V intersects side Y approximately one-third length from groove. Portion of proparea lateral to flexure line smooth; portion between flexure line and pedicle groove coarsely striated.
parallel to side by smooth area approximately twice the size of restricted area. Minor secondary line diverges slightly but distinctly from primary flexure line on side nearest pedicle groove. Interior surface impunctate; smooth. Vascular markings and muscle scars unknown.

Dorsal valve: outline subcircular. Profile strongly convex; greatest convexity at midpoint, from which surface slopes equally to all margins. Surface of shell as on ventral valve. Pseudointerarea narrow; marginal; extended laterally almost halfway around valve. Pedicle groove broad; shallow; vaguely demarcated from properae by slight flexing of shell along two lines that diverge from apex at 30°; crossed by fine striae which bend slightly away from apex. Properae with coarse, irregular, undulating striae more or less parallel to margin of valve. Interior smooth, impunctate. Low, broad, median ridge across central third of valve. Vascular markings and muscle scars unknown. Average diameter of valve 5-7 mm.

DISTINCTIVE. *Abolus* n. sp. 1 is characterized by its subcircular outline, straight or slightly convex postero-lateral margins of the ventral valve that meet at 135°, dull velvety surface caused by a fine epidermal granulation, strong primary and faint secondary flexure lines which divide each ventral properae into a smooth and striated portion, the former being twice the size of the latter.

All described species of *Abolus* that approach to *n. sp. 1* in size and outline differ distinctly in surface features and character of the ventral pseudointerarea. *Abolus* worthani Walcott from the Upper Cambrian of Idaho, and *n. zetus* (Walcott) from the Middle Cambrian of Arizona appear ex-rectly most closely resemble the Montana species, but their interiors are quite
different.

**LOCALITY and FACIES.** Locality 11a, zone 3; locality 50, zone 3; locality 150b; Cordon Mountain formation.

**Genus:** STYLISTHECTON


1939. Obolus (Lestonia) alcott, Smithsonian Misc. Coll., vol. 53, no. 4, pp. 142, 144, pl. 11.


**DESCRIPTION.** "Vate, with ventral valve slightly acuminate; area of ventral valve strongly defined and divided by a relatively large pedicle groove. Surface marked by concentric and radiating striae that are crossed by transverse, semi-inbricated, "ripple-embossed" lines. So far as known, the muscle scars and vascular markings are essentially the same as in Obolus."

Linnellia ephippium (Hart and Whitfield) Plate V, figs. 4, 7.

1897. Linnellia ephippium (Hart and Whitfield), U. S. Geol. Expl. 43rd Par., vol. 4, p. 222, pl. 1, fig. 9.

1898. Linnellia ephippium (Hart and Whitfield), Selcott (in part), U. S. Geol. Survey Bull. 3, pp. 97-98, pl. 7, fig. 2; pl. 8, figs. 4, 4a, 4b, 4e.


1898. Linnellia ephippium (Hart and Whitfield), Ick, Jour. Geol., vol. 14, no. 4, p. 230, pl. 1, figs. 2, 2a.

1907. Linnellia (Castoria) ephippium (Hart and Whitfield), Grabau and Shimer, North American Index Fossils, vol. 1, p. 133, figs. 223a-b.

1912. Obolus (Castoria) ephippium (Hart and Whitfield), Selcott, U. S. Geol. Survey Memo. 51, pp. 455-458, pl. 53, figs. 3-3c; pl. 47, figs. 1-1p.
Description from this reference.

EOCICHI [23]. "General form broad ovate, with the dorsal valve sub-
quadrate or rounded quadrate and the ventral valve obtusely acuminate;
valves moderately convex, so far as can be determined from the crushed and
flattened specimens from the shales of Utah and Nevada. Surface of the
shell marked by concentric striae and lines of growth and, on the type
specimen, by very fine, irregular, lamelllose, more or less transverse
strias and fine radiating lines; the surface is much like that of _J. ( _a_)
surculus (Salcott); fine, clearly defined radiating lines occur on the
inner layer of the shell of partly exfoliated specimens. The cast of the
inner surface of the shell shows papillae that filled punctae in the shell;
they are rather large and are arranged in the central portion of the shell
in concentric lines, much as in Lingulella davisi. The shell is strong
and rather thick in old shells. It is made up of a thin outer layer and
several inner layers of lamellae that are well shown in the figure of the
type specimen."

"The largest ventral valve thus far examined has a length of 16 mm
and a width of 13 mm. A dorsal valve is 15 mm long by 12.5 mm in width."

"The area of the ventral valve is of the same type as that of _J. ( _a_)
surcula (Hall) and Lingulella appa (Swen). The closure line is nearer
the pedicle furrow than in Lingulella paratenucta (Whitfield), _L_ acutana-
pala (Roemer), Lingulella appa, and Obolus (West nia) aurora, which re-
sults in a wider outer lateral space on the area. The pedicle furrow is
strong and deeply rounded, and in one specimen referred to this species
the cast of the base of the undercut between the area and the outer shell is clearly shown on each side of the pedicle groove. The area of the dorsal valve is low and broad; the flexure lines cross it so as to form a broad, slightly elevated space in the cast corresponding to a broad, shallow furrow in the shell. The lines of growth cross the area parallel with its base, both in the ventral and dorsal valve."

"The cast of the interior of the ventral valve shows the visceral cavity and the median septum of the dorsal valve."

"The muscle scars are not distinctly shown on the ventral valve. In the dorsal valve the central scars are preserved in specimens from Nevada and Montana, ...."

**LOCALITY and DISTRIBUTION.** Shells with the surface ornamentation typical of this species are found at several different stratigraphic horizons in the Middle Cambrian rocks of Montana. Locality 42, zone 1; upper part of Flathead sandstone. Locality 33, zone 32; lenticular limestones in lower part of Welsey shale. Locality 43, zone 1; middle part of Welsey shale. Locality 11, zones 2 and 2a; locality 29; locality 30; zone 3; Pagoda formation.

**Genus Limanella Scllott**

1906. **Limanella Scllott**, *Smithsonian Misc. Coll.* vol. 53, p. 96, pl. 10, fig. 2.

1913. **Limanella Scllott**, *J. B. Geol. Survey Mon.* 51, p. 745, pl. 89, figs. 2-2b, t. fig. 64.

1924. **Limanella Scllott**, *Smithsonian Misc. Coll.* vol. 67, pl. 111, figs. 2-4.
Genoholotype: *Liminella similix* Slocott 1906, an almost characterless species. Schuchert's and Cooper's presentation is based on the genotype and *Billiarsella* (= *Liminella* highlandensis) (Slocott).

*Liminella similix* Slocott

*Plate V, figs. 9, 10.*


1912. *Liminella similix* Slocott, U. S. Geol. Survey. Cen. 51, p. 743, pl. 69, figs. 2–8, t. fig. 64. Description from this reference.

**DESCRIPTION:** "The general form of this species is much like that of *Billiarsella coloradensis*, except that the beak of the ventral valve rises
above the hinge line, such as in *L. richlandensis*. The surface of *Limnella simplex* appears to be smooth except for a few concentric lines of growth. Nothing is known of the interior except what is shown by the cast of the umbonal cavity. A crushed specimen with the two valves flattened out indicates that the back of the dorsal valve was slightly elevated above the hinge line.

**DISCUSSION.** Two internal casts of ventral valves in the collections studied apparently belong to *Limnella simplex*, which Schuchert and Cooper termed "an almost characterless shell". No vascular or muscle markings are visible on the casts, but they are very similar in form to the typical specimen figured by Salcott. The type material was collected from the Albertella zone in northwestern Montana, which Salcott designated as Lower Cambrian. That zone is Middle Cambrian in age, and is now known to occur in the upper part of the Solsey shales at approximately the horizon from which the specimens studied were collected.

**LOCALITY and FORMATION:** Locality 23, zone 1; upper part of Solsey shale.

*Limnella cf. L. richlandensis* (Salcott)

Plate V, figs. 11, 12.


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1912. **Billingsella highlandensis** (Gelcott), U. S. Geol. Survey Mem. 31, p. 756, pl. 67, figs. 4-4c. Description from this reference.

1932. **Billingsella highlandensis** (Gelcott), Schuchert and Cooper, U. S. Peabody Mus. Nat. Hist., vol. 4, pt. 1, p. 50. (Changia generic reference and bases an emended generic description partially on this species.)

**Description:** "Shell transversely oval or subrostrate. Front broadly rounded and nearly straight in the dorsal valve. In the ventral valve the cardinal line slopes toward the beak at an angle of about 20°, while in the dorsal valve it is less than 10°. The greatest width is about the middle of the shell. The ventral valve is moderately convex, being most elevated toward the beak, which is slightly arched over to the cardinal margin."

"A dorsal valve associated in the same hand specimen of limestone is more convex than the ventral valve. The cardinal line is shorter than the greatest width of the shell. The median fold is but slightly raised above the general surface, although the front margin has a low, broad arch for the reception of the fold of the ventral valve. A slight flattening in the central portion of the ventral valve in some specimens forms a low, broad resilial sinus toward the front margin."

"The surface is marked by concentric lines of growth and fine radiating ribs; on some specimens stronger ribs occur, very much as on **Billingsella coloradensis**. Interior casts of the valves show fine, radiating striae toward the front. In a number of partly exfoliated shells, the shell is shown to be thick and apparently solid, having been replaced by calcite. The average-sized ventral valve has a length of 13 mm, with a width of
16 mm. The dorsal valve is 17 mm in width.

"Cardinal area of the ventral valve unknown except that its plane extends backward at an angle of about 10° or 15° to the plane of the margin of the shell."

"Casts of the interior of the ventral valve show that the dental plates extend down to the bottom of the valve, supporting distinctly defined hinge teeth. The traces of a vascular system are limited to the main vascular trunks, which extend forward well toward the front margin, very much as in Billingsella coloradoensis. In one case there is a strong furrow extending from a median furrow obliquely outward to each main vascular sinus. The median furrow extends backward to the apex of the cast that filled the space beneath the umbus and the deltidium. This portion of the cast is also marked by fine vertical venation. In another case there is a very narrow median furrow. These median furrows probably indicate the beginning of a section that in later forms connected the deltidium with the shell. Nothing is known of the interior of the dorsal valve."

CONCLUSIONS. Schuchert and Cooper state in their discussion of the genus *Minnella*:

"The most important clue to the ventral morphology of these shells is furnished by a specimen referred to *M. simplex*, in which the ventral musculature consists of two large adductor tracks, closely adjacent at the posterior of the shell by convergent at the front. In the space between the antero-median margin of the adductor tracks is a low suboval elevation corresponding probably to the adductor impressions. This is exactly the same musculature as shown by the type of Billingsella highlandensis. This species also has prominent ventral palial trunks as in Billingsella, is likewise very finely ribbed, and seems to correspond well with the concept of *Minnella* described in this paper."24

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a ventral internal cost and two badly preserved dorsal and ventral exter-

eriors in the collections studied seem to agree closely with that it's

specific description and additional information about the

musculation. The ventral cardinal exteriors of the ventral specimens are

slightly concave.


47, zone 2; 

NEW GENUS 1

All that is known of the genus is included in the description of the

only known species.

New genus 1, n. sp. 1

Plate IV, figs. 12, 13, 15-17.

Species known from numerous dorsal and ventral valves; four specimens

with valve joined.

DESCRIPTION: Ventral valve: Shell broadly rounded anterior to line

of valve-junction, which is slightly less than greatest width; extended

posteriorly into elevated obtusely-escinate beak, the apex of which, in

a valve 6.75 mm from anterior margin to apex, lies 1.4 mm posterior to line

of valve-junction. Convexity slight near anterior margin; increases strong-

ly along median axis to highest point at umbo. Apex pointed; slightly in-

curved over pseudodeltium. Pseudointerarea 30° to 45° apicoline. Apical

gle of valve, as read parallel to plane of commissure, approximately

135°. Postero-lateral slopes strongly rounded. Truncares narrow; smooth

or granular; unstriated; sharply separated by distinct line from anterior
ornamented surface; border high, triangular, open pseudodelthyrium. Apical angle of pseudodelthyrium approximately 125°. Interior unknown.

Dorsal valve: outline transversely oval; median part of posterior margin slightly flattened for short distance. Fore gently convex: highest point at umb vertically above line of valve-junction. Apex rounded and slightly incurved over pseudonotothyrium. Postero-lateral slopes slightly rounded. Preparae narrow; smooth or granular; unstriated; sharply separated from ornamented anterior surface; border low, widely-triangular pseudonotothyrium, which lies in a plane perpendicular to plane of commissure. Apical angle of pseudonotothyrium approximately 125°. Interior unknown.

Surface covered by distinct, hexagonal pits separated from each other by narrow, sharply-defined ridges. Pits arranged in rows which radiate from apex. Hexagons of each row interlock alternately with hexagons of adjacent rows. Each row retains its identity from apex nearly to margin; no intercalation of new rows occurs. Pits minute and 1 distinct near apex; become progressively larger toward margin; regular hexagons on most of surface; become transverse in marginal third and replaced by irregular concentric ridges in same valves.

Measurements: (in millimeters)

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<td>7.3</td>
<td>1.7</td>
<td>.7</td>
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DISTRIBUTION: New Genus 1, p. 64, 1 is characterized by its ventral valve extended posteriorly into an elevated, atticly-constricted bell, the apex of which lies well beyond the line of valve-junction; high, widely-triangular, open pseudodelthyrium that lies in a plane 30° to 45° espaeial,
and is bordered by narrow, smooth, distinctly-decorated propareas; and surfaces with radiating rows of hexagonal pits, the hexagon of each row interlocking alternately with those of adjacent rows.

No described genus of brechiopod has this combination of characters. *New Genus 1, n. sp. 1* is most closely related to *Lobidella* saltott, and were it not that careful cleaning and sectioning of many well-preserved valves revealed no trace of a pseudodeltidium or pseudochilidium, would be assigned to a new species of that genus. The surface ornamentation is so exactly similar to that developed on *Lobidella commala* meladoras* saltott, but in that species the hexagonal pits are not arranged in radiating rows. The thick, glossy, ornamented, cornose shell and well-decorated smooth propareas of *New Genus 1, n. sp. 1* indicate affinities with those species of *Macromitra* described in this paper, but the general form of the ventral valve, the orientation of the pseudointerarea, and particularly the absence of a pseudodeltidium and pseudochilidium definitely exclude it from that genus. Whether the ornamentation pattern on the Montana specimen is of more than specific value cannot now be ascertained; an apparently identical pattern occurs on *Gyrotia illuminata* Hall as illustrated by Hall and Clarke.25

LOCALITY and Fossil Site. Locality 11, zone 2; locality 29, loose; locality 20, zone 2; Fagoda formation.

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95

II. LOCALITIES

Mountain Bureau of Mines and Geology localities

6. Continental divide, Lewis and Clark range, approximately two miles south-east of Pentagon Mt., in the NE^ sec. 24, T. 23 N., R. 12 W.
   Elevation approximately 7900 feet. Type locality of Pentagon shale.
   Quarry--34 feet above base.
   Loose--lower 75 feet.

10. Northeast spur of Pagoda Mt., in SW^ sec. 3, T. 22 N., R. 13 W.
    Switchback formation.

11. Lewis and Clark range, Coopers Lake quadrangle, canyon of North Fork of Dearborn River, in sec. 6, T. 17 N., R. 7 W.
    Zone 2--Pagoda formation, water's edge.
    Zone 2a--Pagoda formation, on hillside above zone 2.

11a. on north side of canyon above locality 11.
    Zone 3--Gordon Mountain formation.

20. Continental divide, crest of Lewis and Clark range, Coopers Lake quadrangle, west end of Scapagoat Basin at foot of cliffs. Approximately half mile south of Observation Point, in SW^ sec. 6, T. 18 N., R. 10 W. Elevation approximately 6250 feet.
    Zone 2--Formation limestone.

23. Continental divide, Lewis and Clark range, on the south side of Bench Park 6100 peak, head of Ahorn Creek, Ovando quadrangle in the SW^ sec. 15, T. 20 N., R. 12 W. Elevation approximately 7600 feet.
    Zone 1--upper part of Wolesey shale.

Zone 2 and 3—Pagoda shale and shaly limestone.

Zone 4, loose, and top—Pentagon shale and shaly limestone.

27. Lewis and Clark range, ridge between Rock and Baldy Bear Creeks, in sec. 17, T. 23 N., R. 11 W. Elevation approximately 6800 feet.

Zone 1 and loose—Pagoda formation.

28. Continental divide, Lewis and Clark range, above Chinese Wall, on south side of Belt Ft. in sec. 9, T. 22 N., R. 12 W. Elevation approximately 7000 feet. Pagoda formation.

29. Continental divide, Lewis and Clark range, Chinese Wall, Cliff Ft.

All zones in sec. 2, T. 22 N., R. 12 W.

Zone 2—Pagoda formation, northeast side Cliff Ft., above Chinese Wall. Elevation approximately 7000 feet.

Zone 3—Cordon Mountain formation, north side and near top of Cliff Ft. Elevation approximately 6025 feet.

30. Keegan Butte in Belt Park on south side of Belt Creek, approximately two miles east of Monarch, Little Belt Mountains. Locality is on south end of hill.

Zone 31—lenticular fossiliferous limestones in base of Dolsey Shale. Elevation approximately 6250 feet.

43. Crawford Ridge, Yellowstone National Park, first buff limestone cliffs north of Cambrian-Archean contact. Elevation approximately 9550 feet.

Zone 1—upper part of Flathead sandstone.
Zone 3a—small limestone concretions in thin bed of fissile green shale 40 feet above top of Holsey shale.

45. Nixon Gulch, approximately six miles north of Manhattan, in SW sec. 23, T. 2 S., R. 3 E.

Zone 1—middle part of chocolate and green Holsey shale on Trilobite Hill.

Zone 2—Zumaia zone at base of Meagher formation on Trilobite Hill.

Zone 3—Bathyuriscus zone in Meagher formation 20 feet above zone 2.

Zone 3a—Bathyuriscus zone in Meagher formation 1500 feet N. 12° from zone 3.

47. North side of Beaver Creek, opposite schoolhouse approximately two miles down stream from Nelson, Big Belt Mountains.

Zone 2—basal Meager limestone lying on Holsey shale.

Zone 2T—fossiliferous limestone layer eight feet above zone 2.

Zone 3—one-half to two inch layer of black fissile shales three feet above zone 2T. Bathyuriscus zone.

United States National Museum Localities

19z. Equivalent to Montana Bureau of Mines and Geology locality 45, zone 3a.

CONCLUSIONS

The Middle Cambrian brachiopods from Montana discussed in this paper are divided into 23 species belonging to 10 genera; 13 species are new, 9 either are assigned to or compared with known species, and one is indeterminate. Of the 9 previously known species, 7 were originally described from the Middle Cambrian of the Cordilleran region. *Aerthele matthewi* Eryx Walcott is from the Middle Cambrian of China, and *Cimarella highlandensis* (Walcott) is from the Lower Cambrian of Nevada. The new species also are most closely allied with Middle Cambrian forms. That over half the species in the faunas appear to be new may be more apparent than real. The writer has hesitated to assign his specimens to species that were inadequately described and figured, and consequently the new species described in this paper must be considered provisional until comparisons can be made with the type material of related forms.

The Middle Cambrian formations from which the brachiopods discussed in this paper were collected belong to two stratigraphic provinces: that of northwestern, and that of central and south-central Montana. Deiss recognized that, with the possible exception of the Flathead sandstone and Selley shale, the Cambrian formations in central and south-central Montana had no readily recognizable lithologic equivalents in the northwestern part of the state. Consequently, correlations between the two provinces must be based upon faunal evidence. The faunal chart (p. 93) shows that in

northwestern Montana only two formations, the Agoda and Pentagon, contain a significant new brachiopod fauna. Likewise, nearly all of the brachiopods collected in the south-central province occur in two zones in the lower part of the Meagher formation. The Ichnania zone is at the base of the formation, and is so designated because of the prolific occurrence of that trilobite. The Bathyuriscus zone, also named from its most characteristic trilobite, is 5 to 20 feet higher in the section than the Ichnania zone.

In northwestern Montana 9 species of brachiopods are known from the Agoda formation; 4 of these, or 44 percent, also occur in the Ichnania zone of the Meagher formation in central Montana. Of the 5 species from the Ichnania zone, 4, or 80 percent, occur in the Agoda formation. Ten species occur in the Pentagon formation; 7 of these, or 70 percent, occur in the Bathyuriscus zone of the Meagher formation. Of the 8 species from the Bathyuriscus zone, 7, or 87.5 percent, occur in the Pentagon formation. Of the 11 species present in the Pentagon-Bathyuriscus assemblage, 4, or 36 percent, are present also in the Agoda-Ichnania fauna. Acrotricha n. sp. 4 occurs in both the Agoda and Pentagon formations; Limulella n. sp. 2 is common to both the Ichnania and Bathyuriscus zones; and Limulella n. sp. 1 and Heteromitra n. sp. 1 are found at both horizons in both provinces.

These facts are the basis for the following conclusions. The Agoda and Pentagon formations of northwestern Montana are stratigraphically equivalent to the Ichnania and Bathyuriscus zones respectively of central and south-central Montana, and northwestern Yellowstone Park. Sedimentation during at least part of Middle Cambrian time was more rapid in north-
western than in south-central Montana, inasmuch as the thickness of beds between the Pagoda and Pentagon faunas is 60 feet, whereas the Hymenia and Bathyuriscus faunas are separated by a minimum of 5 feet. The Pentagon-Bathyuriscus fauna appears at least in part to be a recurrent Pagoda-Hymenia fauna.

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Original descriptions and figures of one new genus (Acrothale),
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Acrotreta n. sp. 1

Figs. 1-3. Apical, profile, and posterior views of slightly crushed ventral valve; apex more subcentral than is normal. Triangular granular central part of false pedicle groove clearly shown. Cotype. x 6.

4-6. Apical, profile, and posterior views of essentially undistorted ventral valve, showing foramen on posterior side of apex. Photograph not retouched. Cotype. x 7.

6-9. Apical and profile views of dorsal valve, showing median groove in knob-like apex, and anastomosis of pseudointerarea. Apex is to the right in fig. 9. Cotype. x 6.

Locality Z6, zone 4.

Acrotreta n. sp. 2

Figs. 7. Apical view of dorsal valve, showing median line made by interruption of growth ridges to form "criss-cross" pattern. Cotype. x 6.

10-12. Posterior, profile, and apical views of undistorted ventral valve, showing abrupt concavity of profile just anterior to apex. Cotype. x 6.

13. Enlarged view of "dashed-line" ornamentation near margin of specimen shown in figs. 10-12. x 20.
Acrotreta n. sp. 3

Figs. 14-16. Profile, posterior, and apical views of almost perfect ventral valve. Note foramen on posterior side of apex in fig. 15. Photograph not retouched.
Cotype. x 6.

17. Profile of dorsal valve in fig. 1, showing increase in convexity toward anterior margin (right side of figure).

18. Apical view of well preserved dorsal valve showing deep sulcus and line along bottom made by interruption of growth striae to form "criss-cross" pattern.
Cotype. x 6.

Locality 26, zone 4.

19. Drawing of interior of dorsal valve, showing peculiar expanded median septum. This valve apparently is identical with, but better preserved than, dorsal valves from type locality. Part of anterior margin restored from an associated specimen. Provisional allotype. x 10.

Locality 45, zone 3a.

20-23. Apical, posterior, profile, and anterior views of ventral valve with apex broken. Sub-trapezoidal outline in plane of commissure well shown in fig. 20. Note apical flexing of concentric striae and
ridges near anterior median margin in fig. 23.

Cyprae. x 5.

Locality 23, and 4.
Acrotrcta n. sp. 4 ——————————————————————————————————— 45

Figs. 1. Apical view of associated dorsal and ventral valves.

Note faintly developed sulcus in dorsal valve.

Holotype. x 6.

2. Profile of larger ventral valve illustrated in fig. 4, showing truncated apex with vertical posterior face.

3. Profile of dorsal valve illustrated in fig. 4, showing greatest convexity in posterior third of valve.

4. Apical view of associated ventral valve on same piece of shale with specimen shown in fig. 1.

Note shallow false pedicle groove. Holotype. x 6.

Locality 6, quarry.

Acrotrcta n. sp. 5 ——————————————————————————————————— 47

Figs. 7-9. Apical, profile, and posterior views of ventral valve, showing posteriorly curved apex, faint concentric growth stele, and faint false pedicle groove. Holotype. x 6.

Locality 47, zone 3.

Acrotrcta ophirensis sailco.t ——————————————————————————————————— 34

Figs. 5, 6, 10. Apical, profile, and posterior views of ventral valve. Note large apical foramen in fig. 10. x 6.

Locality 28, zone 3.

Acrothela matthewi emz. Calcott --- ----------------------------- 25

Figs. 11. Apical view of dorsal valve, showing apex formed of two tubercles. x 3.

12-13. Profile and apical views of fragmental ventral valve, showing apex formed of two tubercles.

Large elliptical foramen posterior to apex is not well shown in photograph. x 5.

Locality 29, zone 4.

Acrothela cf. A. subsidua (White) ------------------------------ 26

Fig. 15. Apical view of badly crushed and fragmental ventral valve. x 4.

Locality 6, loose.

Iphidella cf. I. parrula (White) ----------------------------- 49

Figs. 15-19. Posterior, apical, and profile views of incomplete ventral valve, showing distinct pappae and widely-triangular pseudodelthyrium. x 3.

Locality 23, zone 1.
Lingulella n. sp. 1
Figs. 1, 4. Interior views of ventral and dorsal valves.
Laratypes. x 6.

2, 3. Views of ventral and dorsal internal casts,
showing pseudointerareas and strong tubercles.
Cotypes. x 4.

Locality 28, zone 2.

Lingulella n. sp. 2
Fig. 5. View of partly exfoliated ventral valve, showing
internal cast of pseudointerarea. Cotype. x 5.

7. View of partly exfoliated dorsal valve, showing
internal cast of pseudointerarea. Cotype. x 6.

Locality 45, zone 3.

Lingulella cf. L. isae (Salcott)
Fig. 6. View of partly exfoliated ventral valve, showing
internal cast of pseudointerarea. x 2.5.

Locality 10.

Micromitra n. sp. 1
Figs. 8, 9. Typical and oblique posterior views of uncrushed
incomplete ventral valve, showing a variation in
surface pattern. Note distinct proporesae and
fragment of pseudodeltidium. x 6.

Locality 47, zone 27.
Figs. 10. Apical view of crushed ventral valve, showing strong evenly-concentric and faint radiating ridges. x 7.

Locality 6, quarry.

11-13. Oblique posterior, apical, and profile views of incomplete uncrushed ventral valve, showing pointed apex, distinct propareas, and rectangular surface pattern. x 5.

Locality 47, zone 2T.

14. Apical view of crushed ventral valve, showing a variation in surface pattern. x 3.

Locality 6, quarry.

15. Apical view of crushed dorsal valve, showing distinct propareas and pseudochilidium.

Cotype. x 4.

16. Apical view of crushed but relatively complete ventral valve, showing distinct propareas and large convex pseudodeltidium. Cotype. x 4.

17. Apical view of incomplete dorsal valve, showing characteristic petalloid callosity on apex.

Paratype. x 6.

18. Apical view of incomplete dorsal valve, showing extremely rugose concentric growth ridges on marginal half of valve. Paratype. x 4.

Locality 25, zone 3.
EXPLANATION OF PLATE IV

Micromitra n. sp. 2

Figs. 1. Apical view of well-preserved dorsal valve showing
concentric surface undulations and shallow
radiating grooves. Holotype. x 4.

Locality 26, zone 4.

Micromitra n. sp. 3

Figs. 3. Posterior view of fragmental dorsal valve, showing
distinct proporesae and trilobed pseudochilidium.
Cotype. x 6.

4-6. Apical, profile, and posterior views of incomplete
ventral valve, showing distinct proporesae, flattened
pseudodeltidium, and smooth concentric growth-ridges.
Cotype. x 6.
Locality 36, zone 32.

Micromitra n. sp. 4

Figs. 7-9. Apical, posterior, and profile views of incomplete
and somewhat weathered ventral valve, showing short,
thick pseudodeltidium. Holotype. x 4.

10. View of specimen illustrated in figs. 7-9, tilted to
show radiating smooth tracts. x 4.
Locality 11, zone 2.
Figs. 11. View of ventral internal cast, showing strong flexibility lines across each proporeus. Cotype. x 5.


Locality 11a, Zone 3.

New Genus 1, n. sp. 1

Figs. 12. Posterior view of ventral valve illustrated in fig. 15, showing distinctly-demarcated narrow proporeus and widely-triangular pseudodelthyrium. x 3.

13, 15. Profile and apical views of well-preserved ventral valve, showing radiating rows of hexagonal pits. Cotype. x 4.

16. Enlarged view of surface ornamentation on central part of valve shown in fig. 15. x 7.


Locality 11, Zone 2.
PLATE IV

1. [Image of a fossilized shell]
2. [Image of a fossilized shell]
3. [Image of a fossilized shell]
4. [Image of a fossilized shell]
5. [Diagram of a fossilized shell]
6. [Image of a fossilized shell]
7. [Image of a fossilized shell]
8. [Image of a fossilized shell]
9. [Diagram of a fossilized shell]
10. [Image of a fossilized shell]
11. [Image of a fossilized shell]
12. [Image of a fossilized shell]
13. [Diagram of a fossilized shell]
14. [Image of a fossilized shell]
15. [Image of a fossilized shell]
16. [Image of a fossilized shell]
17. [Image of a fossilized shell]
EXPLANATION OF PLATE V

**Misusia alberta (Calcott)** .................................. 74

*Figs. 1, 3. Apical and posterior views of ventral internal cast,*
showing cast of large foramen through apex. *x 3.*

*2, 5. Apical and posterior views of incomplete ventral*
value, showing foramen at apex, and short deltidium.
*x 3.*

**Locality: Gm. Zone 2.**

**Misusia sp. undet.** ............................................. 76

*Figs. 6. Apical view of dorsal exterior, showing deep sulcus*
and strong costae with spines on their crests. *x 3.*

*3. View of ventral interior, showing strong costae, and*
absence of muscle scars. *x 2.5.*

**Locality 20, top.**

**Pectonia ella (Hall et al. Hillfield)** ........................ 83

*Figs. 4, 7. Views of complete dorsal and partly exfoliated*
ventral valves, showing ornamentation pattern, and*
flexure lines on ventral pseudointerarea. *x 3.*

**Locality 90, Zone 1.**

**Vinuela simplex Calcott** .................................... 86

*Figs. 9, 10. Apical and profile views of ventral internal cast,*
showing absence of internal partitions. *x 3.*

**Locality 23, Zone 1.**

**Vinuela cf. E. highlandensis (Calcott)** ........................ 87

*Figs. 11, 12. Profile and apical views of ventral internal cast,*
showing strong adductor tracks diverging from apex, with small adductor scars between them. x 4.

Locality 47, zone 2.