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REVISION OF THE FAUNA OF THE CANNONBALL
FORMATION (PALEOCENE) OF NORTH AND
SOUTH DAKOTA

BY
ALAN M. CVANCARA



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MUSEUM OF PALEONTOLOGY
THE UNIVERSITY OF MICHIGAN
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REVISION OF THE FAUNA OF THE CANNONBALL FORMATION (PALEOCENE) OF NORTH AND SOUTH DAKOTA

PART 1. BIVALVIA

BY

ALAN M. CVANCARA

ABSTRACT

Thirty species of bivalves are recognized from the Cannonball Formation (Paleocene) of the Dakotas. One species is considered new, *Caestocorbula sinistrirostellata* sp. nov. Approximately 40 per cent of the bivalves indicate a post-Cretaceous or Paleocene age. Seemingly, few similarities exist between the bivalve fauna of the Cannonball Formation and that of the Midway Group (Paleocene) of the American Gulf Coast. Several Cannonball bivalves show closer similarities with those of northern Europe (London and Paris basins), and suggest a Thanetian age.

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INTRODUCTION

THE CANNONBALL FORMATION and its marine fauna has been of interest to geologists since its naming by E. R. Lloyd in 1914. This interest has resulted primarily because of two reasons: (1) a controversy on account of its position at the Cretaceous boundary has existed regarding its age; and (2) it is seemingly restricted to the center of North America.

Stanton (1920) first studied the Cannonball fauna and concluded a Late Cretaceous age, although he realized certain Early Tertiary affili-

ations. In 1942, Fox and Ross, using Foraminifera, assigned to the Cannonball a Paleocene age, which has generally been accepted.

The Cannonball is presently known to crop out only in the Dakotas, mainly in western North Dakota. Up to about 300 feet thick, the Cannonball is a clastic deposit of primarily poorly consolidated, light grayish green sandstone, and medium to very dark gray mudstone. Distinct, well indurated, lenticular beds occur in the sandstone, and "cannonball" concretions occur in both the sandstone and mudstone. I have discussed recently the stratigraphy of the Cannonball Formation (Cvancara, 1965).

The purpose of this paper is to revise the taxonomy of the bivalves, to reillustrate them, and to re-examine their use as age indicators.

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CANNONBALL FAUNA

The Cannonball fauna consists of Foraminifera, Coelenterata, Bryozoa, Mollusca, Arthropoda, Vertebrata, and the supposed crustacean burrow, *Halymenites*. Mollusks are by far the most abundant of the macrofossils, in terms of both numbers of species and numbers of specimens. I have newly discovered Bryozoa, represented by a single specimen, shipworm

pallets, and meager evidence of skates or rays, gars, crocodiles or alligators, and turtles.

Macrofossils are known from 115 localities in North Dakota, 39 of which I have newly discovered (Fig. 1). Fossils are not generally abundant but may be so locally. They presumably occur throughout the formation, and more frequently in sandstone than in mudstone.

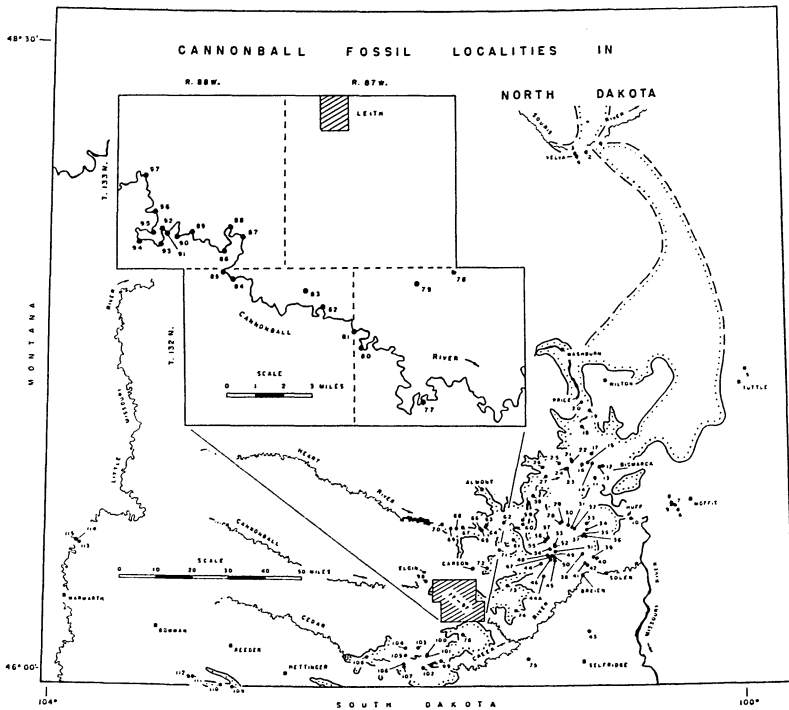


FIG. 1. Map of western North Dakota showing macrofossil localities and distribution of Cannonball Formation. Formation contacts, emphasized by dots, are after Hansen (1956) and North Dakota Geological Survey (1965); small areas of outcrop near Moffit and Selfridge are not shown. Diagonally-ruled area shown enlarged is type area of Cannonball Formation. Fossil locality numbers correspond to numbered descriptions of localities in the text.

At least a generalized macrofossil zonation appears to be present in the Cannonball Formation. Mollusks occur most frequently in a sandstone unit in the lower middle or lower part of the formation; and crabs occur most frequently in a sandstone unit in the upper middle or upper part.

CANNONBALL BIVALVES

Thirty species of bivalves are recognized as occurring in the Cannonball Formation, one species less than originally reported by Stanton (1920). I have placed eight of Stanton's species in synonymy, recognized one species (*Caestocorbula sinistrirostellata*) as new, and described three forms under the generic name only because incomplete material does not permit comparison of specific characters with known species of the same genus. The three forms thus described are *Nucula* sp., *Adula* sp., and *Periploma* sp. Three species, known earlier but neither described nor figured for the Cannonball, are also included: *Crassostrea glabra* (Meek and Hayden), *Corbicula* cf. *C. berthoudi* White, and *Bicorbula subtrigonalis* (Meek and Hayden).

The following thirteen species are considered characteristic of the Cannonball, but are not necessarily restricted to it:

- Nuculana mansfieldi* (Stanton)
- Cucullaea solenensis* (Stanton)
- Glycymeris subimbricata* (Meek and Hayden)
- Arcuatula schallerensis* (Stanton)
- Adula* sp.
- Isognomon lloydi* (Stanton)
- Arctica ovata* (Meek and Hayden)
- Miltha* (*Plastomiltha*) *cedrensensis* (Stanton)
- Bicorbula mactriiformis* (Meek and Hayden)
- Caestocorbula sinistrirostellata* sp. nov.
- Nototeredo globosa* (Meek and Hayden)
- Phenacomya haresi* (Stanton)
- Periploma* sp.

Bicorbula mactriiformis (Meek and Hayden) apparently ranges up into the overlying Tongue River Formation (Stanton, 1920, p. 12, 32), and *Arctica ovata* (Meek and Hayden) possibly occurs in Upper Cretaceous rocks (Stanton, 1920, p. 11, 27). The six most common bivalves in the Cannonball are *Arctica ovata*, *Dosiniopsis deweyi*, *Nucula* (*Nucula*) *planimarginata*, *Noteredo globosa*, *Crasstella evansi* and *Glycymeris subimbricata*, about in that order.

The seventeen bivalves not characteristic of the Cannonball are mainly assigned to species occurring in Cretaceous rocks of the western interior. However, because of few and/or poor specimens representing certain Cannonball species, comparisons are uncertain. It is, therefore, difficult to quantitatively evaluate Cannonball bivalves as age determinators. Approximately 40 per cent of the Cannonball bivalves, however, do not occur in Cretaceous rocks, and suggest a post-Cretaceous or Paleocene age.

Few similarities appear to exist between Cannonball bivalves and those of the Paleocene Midway Group (Harris, 1896; Gardner, 1933; Gardner, 1945) of the American Gulf Coast. The only rather closely similar species appear to be the Cannonball *Phenacomya haresi* (Stanton) and *Pholadomya mauryi* Harris from the Tennessee Midway.

Comparing the Cannonball fauna with Tertiary faunas of northern Europe, closest similarities seem to exist with Thanetian forms of the London and Paris basins. The following bivalves are morphologically similar:

Cannonball	Thanetian of London and Paris basins (names as used by various authors)
<i>Nuculana mansfieldi</i> (Stanton)	<i>Leda substriata</i> Morris
<i>Glycymeris subimbricata</i> (Meek and Hayden)	<i>Pectunculus terebratularis</i> Lamarck
<i>Arctica ovata</i> (Meek and Hayden)	<i>Cyprina scutellaria</i> Lamarck
<i>Miltha</i> (<i>Plastomiltha</i>) <i>cedrensis</i> (Stanton)	<i>Phacoides uncinatus</i> Defrance
<i>Dosinioopsis deweyi</i> (Meek and Hayden)	<i>Dosinioopsis orbicularis</i> (Edwards)
<i>Caestocorbula sinistrirostellata</i> sp. nov.	<i>Corbula regulbiensis</i> Morris
<i>Phenacomya haresi</i> (Stanton)	<i>Pholadomya cuneata</i> Sowerby

The four Cannonball bivalves, *Glycymeris subimbricata*, *Miltha* (*Plastomiltha*) *cedrensis*, *Dosinioopsis deweyi* and *Caestocorbula sinistrirostellata* appear to be especially similar to their probable European Thanetian counterparts.

COLLECTING LOCALITIES

All localities are shown in Figure 1. Several localities are those of the U. S. Geological Survey (USGS 9143), which have been modified somewhat for clarity and consistency and included here.

Localities:

1. North road cut, NE $\frac{1}{4}$ sec. 2, T. 153 N., R. 79 W., about 6 $\frac{1}{2}$ miles northeast of Velva, southern McHenry Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-33}}$, A. Cvan-
cara, 8 Sept. 1962. Fossils from well-indurated, very finegrained sandstone at top of road cut.
2. Southeast road cut, 0.35 mile northeast of southwest corner sec. 18, T. 153 N., R. 79 W., about 2.6 miles east-northeast of Velva, southern McHenry Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-32}}$, A. Cvan-
cara, 7 Sept. 1962. Fossils from light green to tan-gray clayey, poorly consolidated sandstone, top of which is about 2 ft. above road surface.

3. North (left) bank of Souris River, SW $\frac{1}{4}$ sec. 16, T. 153 N., R. 80 W., about 1 $\frac{3}{4}$ miles northwest of Velva, southern McHenry Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-37}}$, A. Cvancara, 6 Sept. 1962. Scaphopod from light tan to medium tan-gray, silty mudstone near top of exposure.
4. Northwest road cut, SE $\frac{1}{4}$ sec. 21, T. 153 N., R. 80 W., about 1 mile west of Velva, southern McHenry Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-31}}$, A. Cvancara, 7 Sept. 1962. Fossils from light tan to dark gray, poorly consolidated, silty mudstone 3 to 4 ft. above base of exposure.
5. West road cut, N. Dak. Highway 3, 0.35 mile north of southeast corner sec. 18, T. 143 N., R. 73 W., about 4 $\frac{1}{2}$ miles north-northeast of Tuttle, northern Kidder Co., N. Dak. Univ. of N. Dak. collection and Univ. of Mich., accession $\frac{1962}{\text{Tpa-34}}$, A. Cvancara, 5 Sept. 1962. Fossils from light grayish tan to sandy mudstone, about at level with top of road and also about 5 ft. above road level.
6. East road cut, about on east-west half-section line, west edge sec. 35, T. 137 N., R. 77 W., about 4 $\frac{3}{4}$ miles southwest of Moffit, southern Burleigh Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-30}}$, A. Cvancara, 4 Sept. 1962. Fossils as float on light grayish green, poorly consolidated, medium to very finegrained sandstone; Cannonball?
7. West road cut (sand blowout), northeast corner sec. 28, T. 137 N., R. 77 W., 5 miles west and 1.1 miles south of Moffit, southern Burleigh Co., N. Dak. (crab locality 1, Holland and Cvancara, 1958, p. 496). Univ. of N. Dak. collection. Fossils from light greenish gray, poorly consolidated, finegrained sandstone in upper part of exposure.
8. Road cuts on both sides of road, on sec. line common to secs. 20 and 21, T. 137 N., R. 77 W., 6 miles west and 0.7 mile south of Moffit, southern Burleigh Co., N. Dak. Univ. of N. Dak. collection and Univ. of Mich., accession $\frac{1961}{\text{Tpa-13}}$, A. Cvancara, 5 Aug. 1961. Fossils from surface of light greenish gray, poorly consolidated, finegrained sandstone.
9. Road cuts on both sides of road, on sec. line common to secs. 28 and 29, T. 137 N., R. 77 W., 6 miles west and 1.1 miles south of Moffit, southern Burleigh Co., N. Dak. (crab locality 1a, Holland and Cvancara, 1958, p. 496). Univ. of N. Dak. collection and Univ. of Mich., accession $\frac{1961}{\text{Tpa-14}}$, A. Cvancara, 7 Aug. 1961. Fossils from surface of light greenish gray, poorly consolidated, finegrained sandstone.
10. Northwest road cut, SW $\frac{1}{4}$ sec. 8, T. 136 N., R. 79 W., about 1 mile south of Huff, southern Morton Co., N. Dak. Univ. of N. Dak. collection. Fossils from light grayish green, poorly consolidated, very fine to finegrained sandstone, top of which is 41 ft. below top of section.
11. West road cut, NW $\frac{1}{4}$ sec. 13, T. 138 N., R. 81 W., about 4 $\frac{1}{4}$ miles south-southeast of center of Mandan (about one-half mile northwest of mouth of Heart River and 0.1 mile north of north boundary Fort Lincoln State Park), northeastern Morton Co., N. Dak.; considered about the same as USGS 8390. Univ. of N. Dak. collection and Univ. of Mich., accession $\frac{1962}{\text{Tpa-25}}$, A. Cvancara, 15 Aug. 1962. Fossils from light grayish green, poorly consolidated finegrained sandstone at top of exposure.

12. South road cut, NW $\frac{1}{4}$ sec. 32, T. 139 N., R. 80 W., about 1.6 miles northwest of junction U. S. highways 10 and 83 (0.4 mile east of Bismarck Junior College), southern Burleigh Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-19}}$, A. Cvancara, 31 July 1962. Fossils from surface of light grayish green, poorly consolidated, finegrained sandstone.
13. North side of small gully, NE $\frac{1}{4}$ sec. 31, T. 139 N., R. 80 W., 2.1 miles northwest of junction of U. S. highways 10 and 83 (about $\frac{1}{4}$ mile west-northwest of Bismarck Junior College), southern Burleigh Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-18}}$, A. Cvancara, 30 July 1962. Fossils from surface of light grayish green, poorly consolidated, finegrained sandstone.
14. South-facing hillside, NW $\frac{1}{4}$ sec. 26, T. 139 N., R. 81 W., northwest edge of Mandan Boundary, off north end of 12th Avenue northeast, northeastern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-23}}$, A. Cvancara, 30 Aug. 1961. Fossils from light buff-gray, poorly consolidated, sandy mudstone or clayey sandstone above concretionary, well-indurated sandy mudstone.
15. Near top of hill, just west of courthouse, Mandan, northeastern Morton Co., N. Dak. (USGS 9121).
16. Bluff on north side of Heart River (125 ft. above river level), $\frac{3}{4}$ mile west of Mandan, northeastern Morton Co., N. Dak. (USGS 9122; considered also about the same as USGS 9120).
17. Bluff on east (left) bank of Missouri River, about 5 miles north of Bismarck, southern Burleigh Co., N. Dak. (USGS 15991).
18. East (left) bank of Missouri River, opposite and about 1 mile north Harmon (about 10 $\frac{1}{2}$ miles north of center of Mandan), northeastern Morton Co., N. Dak. (USGS 16011; also considered about the same as USGS 16012).
19. East (left) bank of Missouri River (just south of east-west trending gully), SE $\frac{1}{4}$ sec. 12, T. 141 N., R. 81 W., about 9 miles southwest of Wilton, northern Burleigh Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-20}}$, A. Cvancara, 3 Aug. 1962. Fossils from light grayish green, poorly consolidated, finegrained, 20.9-ft. sandstone in lower middle part of section.
20. West (right) bank of Missouri River, SE $\frac{1}{4}$ sec. 34, T. 142 N., R. 81 W., about 1 mile south of Price, Oliver Co., N. Dak. (same as USGS 9126 and USGS 15996). Univ. of N. Dak. collection.
21. On gas line, east side of valley, NE $\frac{1}{4}$ sec. 23, T. 139 N., R. 82 W., about 5 miles west-northwest of center of Mandan, northeastern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-12}}$, A. Cvancara, 16 July 1962. Fossils from surface of light grayish green, poorly consolidated, finegrained sandstone.
22. North road cut (slide area), U. S. Highway 10, SE $\frac{1}{4}$ sec. 23, T. 139 N., R. 82 W., 4.65 miles west of railway station, center of Mandan, northeastern Morton Co., N. Dak. (crab locality 3, Holland and Cvancara, 1958, p. 498). Univ. of N. Dak. collection and Univ. of Mich. accession, $\frac{1961}{\text{Tpa-22}}$, A. Cvancara, 29 Aug. 1961. Fossils in poorly consolidated, light greenish gray, finegrained sandstone in upper part of section and dark gray, silty to sandy mudstone in lower part of section.

23. Small (about 7 by 10 yards) blowout on north side of gully, about on east-west half section line, E $\frac{1}{2}$ sec. 34, T. 139 N., R. 82 W., about 5 $\frac{3}{4}$ miles west-southwest of center of Mandan, northeastern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-16}}$, A. Cvancara, 26 July 1962. Fossils from surface of light grayish green, poorly consolidated, finegrained sandstone.
24. East (right) bank of Heart River, SW $\frac{1}{4}$ sec. 34, T. 139 N., R. 82 W., about 6 $\frac{1}{2}$ miles west-southwest of center of Mandan, northeastern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-17}}$, A. Cvancara, 26 July 1962. Fossils from upper part of exposure from very fine to finegrained, poorly consolidated sandstone with well-indurated lenticular sandstone; corals most common 4 to 5 ft. below base of lenticular, well-indurated sandstone.
25. Section 20 or 29, T. 139 N., R. 82 W., probably about 8 miles west of Mandan, northeastern Morton Co., N. Dak. (USGS 9144).
26. West (right) bank of Sweet Briar Creek, NE $\frac{1}{4}$ sec. 23, T. 139 N., R. 83 W., about $\frac{1}{2}$ mile south of Sweet Briar (about 11 $\frac{1}{2}$ miles west of Mandan), northeastern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-11}}$, A. Cvancara, 14 July 1962. Fossils from mottled (dark gray and grayish tan), poorly consolidated, silty to sandy mudstone about 8 $\frac{1}{2}$ ft. below top of exposure.
27. North (left) bank of Heart River, SE $\frac{1}{4}$ sec. 10 (and SW $\frac{1}{4}$ sec. 11), T. 138 N., R. 83 W., about 12 miles west-southwest of Mandan, northeastern Morton Co., N. Dak. (about the same as USGS 9143). Univ. of Mich. accession, $\frac{1962}{\text{Tpa-10}}$, A. Cvancara, 11 July 1962. Fossils as float on 50.2-ft., dark gray sandy mudstone in upper part of section, from 19.6-ft., light grayish green, finegrained sandstone underlying 50.2-ft. mudstone, and in upper part of 53.9-ft., poorly consolidated sandstone near middle part of section.
28. Sand blowout in pasture, east side of gully, SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 13, T. 136 N., R. 83 W., about 7 miles west-southwest of St. Anthony, southern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-33}}$, A. Cvancara, 21 Aug. 1961. Fossils from surface of light grayish green, poorly consolidated, finegrained sandstone.
29. East road cut, NW $\frac{1}{4}$ sec. 18 (0.25 mile south of northwest corner sec. 18), T. 136 N., R. 82 W., about 6 $\frac{3}{4}$ miles west-southwest of St. Anthony, southern Morton Co., N. Dak. Univ. of Mich. accessions, $\frac{1961}{\text{Tpa-19}}$, and $\frac{1962}{\text{Tpa-7}}$, A. Cvancara, 20 Aug. 1961 and 14 Aug. 1962. Fossils from light grayish green, poorly consolidated, very finegrained sandstone.
30. NE $\frac{1}{4}$ sec. 20, T. 136 N., R. 82 W., 3 miles southeast of Old Strain (5 $\frac{1}{2}$ miles west-southwest of St. Anthony), southern Morton Co., N. Dak. (USGS 8454).
31. SE $\frac{1}{4}$ sec. 21, T. 136 N., R. 82 W., 5 miles southeast of Old Strain Post Office (about 4 $\frac{3}{4}$ miles southwest of St. Anthony), southern Morton Co., N. Dak. (USGS 8455, and considered the same as USGS 8456).
32. East side of NW $\frac{1}{4}$ sec. 27, T. 136 N., R. 82 W., 5 miles southeast of Old Strain (about 4 $\frac{1}{2}$ miles southwest of St. Anthony), southern Morton Co., N. Dak. (USGS 8458).
33. East road cut, N. Dak. Highway 6, SW $\frac{1}{4}$ sec. 17, T. 136 N., R. 81 W., 1.8 mile south of St. Anthony, southern Morton Co., N. Dak. Univ. of N. Dak. collection.

34. Road cuts on both sides of N. Dak. Highway 6, on section line common to secs. 29 and 30 and on east-west half section line (secs. 29 and 30), T. 136 N., R. 81 W., 3.5 miles south of St. Anthony, southern Morton Co., N. Dak. Univ. of N. Dak. collection and Univ. of Mich., accession, $\frac{1961}{\text{Tpa-30}}$, A. Cvancara, 19 July 1961. Fossils from light grayish green, poorly consolidated, finegrained sandstone.
35. North-northwest-west-facing hillside near top of flat upland in pasture, SW $\frac{1}{4}$ sec. 31, T. 136 N., R. 81 W., about 5 miles south of St. Anthony, southern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-24}}$, A. Cvancara, 1 Sept. 1961. Fossils from light grayish green, poorly consolidated, finegrained sandstone.
36. East road cut, N. Dak. Highway 6, east edge SE $\frac{1}{4}$ sec. 6, T. 135 N., R. 81 W., about 5 $\frac{1}{2}$ miles south of St. Anthony, southern Morton Co., N. Dak. Univ. of N. Dak. collection.
37. Small hill on west side of road, NE $\frac{1}{4}$ sec. 1 (0.25 mile south of northeast corner sec. 1), T. 135 N., R. 82 W., about 5 $\frac{1}{4}$ miles south of St. Anthony, southern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-25}}$, A. Cvancara, 1 Sept. 1961.
38. Northeast-facing hillside in pasture, south side of N. Dak. Highway 21, NE $\frac{1}{4}$ sec. 36, T. 135 N., R. 82 W., 0.2 mile west of junction N. Dak. highways 6 and 21, about 6 $\frac{1}{4}$ miles north of Breien, southern Morton Co., N. Dak. Univ. of Mich. accessions, $\frac{1961}{\text{Tpa-8}}$ and $\frac{1962}{\text{Tpa-4}}$, A. Cvancara, 19 July 1961 and 15 Aug. 1962. Fossils from medium greenish gray, poorly consolidated, very fine to finegrained sandstone.
39. Top of flat-topped butte, T. 134 N., R. 81 W., about 6 miles northwest of Solen, southern Morton Co., N. Dak. (USGS 9129).
40. Near top of elongate, north-northeast-trending, flat-topped hill, N $\frac{1}{2}$ S $\frac{1}{2}$ sec. 3 (about on north-south center line of sec. 3), T. 134 N., R. 81 W., about 5 miles northwest of Solen, southern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-9}}$, A. Cvancara, 20 July 1961. Fossils collected light greenish gray, poorly consolidated, finegrained sandstone in upper part of exposed section.
41. T. 134 N., R. 81 W., about 8 miles northwest of Solen, southern Morton Co., N. Dak. (USGS 8448).
42. Around border of high plateau, NW $\frac{1}{4}$ sec. 17, T. 134 N., R. 81 W., about 7 miles northwest of Solen, southern Morton Co., N. Dak. (USGS 8446).
43. East-facing landslide, SW $\frac{1}{4}$ sec. 13, T. 131 N., R. 82 W., about 8 $\frac{1}{2}$ miles north-northeast of Selfridge, eastern Sioux Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-29}}$, A. Cvancara, 2 Sept. 1962. Fossils from light grayish green, poorly consolidated, finegrained sandstone in upper part of section, and from dark gray, sandy mudstone concretions in poorly consolidated sandy mudstone directly below.
44. Mitchell Butte, SW $\frac{1}{4}$ sec. 7, T. 134 N., R. 83 W., about 3 $\frac{1}{4}$ miles east-southeast of Flasher, southern Morton Co., N. Dak. Univ. of N. Dak. collection and Univ. of Mich. accession, $\frac{1961}{\text{Tpa-10}}$, A. Cvancara, 22 July 1961. Fossils from light greenish gray, poorly consolidated, finegrained sandstone in upper part of section.
- 44a. NE $\frac{1}{4}$ sec. 31, T. 134 N., R. 83 W., about 6 miles southeast of Flasher, southern Morton Co., Dak. (USGS 8387).

45. Southeast corner of sec. 3, T. 134 N., R. 83 W., about 6 miles east of Flasher, southern Morton Co., N. Dak. (USGS 8445).
46. SE $\frac{1}{4}$ sec. 4, T. 134 N. (originally given as T. 132 N.), R. 83 W., about 5 miles east of Flasher, southern Morton Co., N. Dak. (USGS 8443).
47. South-facing hillside, north side of N. Dak Highway 21, NW $\frac{1}{4}$ sec. 4, T. 134 N., R. 83 W., about 5 miles east of Flasher, southern Morton Co., N. Dak. (crab locality 2, Holland and Cvancara, 1958, p. 496). Univ. of N. Dak. collection. Fossils from small, light grayish brown sandstone concretions mainly on upper part of hillside.
48. South and southwest-facing hillside, north side of N. Dak. Highway 21, SE $\frac{1}{4}$ sec. 32 and SW $\frac{1}{4}$ sec. 33, T. 135 N., R. 83 W., about 4 $\frac{3}{4}$ miles east of Flasher, southern Morton Co., N. Dak. Univ. of Mich. accessions, $\frac{1961}{\text{Tpa-21}}$, and $\frac{1962}{\text{Tpa-8}}$, A. Cvancara, 26 Aug. 1961 and 20 July 1962. Fossils from small, light grayish brown sandstone concretions mainly in upper part of hillside exposure.
49. Two south road cuts N. Dak. Highway 21, SW $\frac{1}{4}$ sec. 34, T. 135 N., R. 83 W., about 6 miles east of Flasher, southern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-20}}$, A. Cvancara, 23 Aug. 1961. Fossils from surface of light grayish green, poorly consolidated, finegrained sandstone.
50. NE $\frac{1}{4}$ sec. 3, T. 134 N. (originally given as T. 132 N.), R. 83 W., about 6 miles east of Flasher, southern Morton Co., N. Dak. (USGS 8444).
51. Six road cuts on both sides of road along section line common to secs. 26 and 27, T. 135 N., R. 83 W., about 2 $\frac{1}{2}$ miles south of Fallon (about 7 miles east-northeast of Flasher), southern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-11}}$, A. Cvancara, 28 July 1961. Fossils from light greenish gray, poorly consolidated, very fine to finegrained sandstone in upper part of section.
52. West road cut, NE $\frac{1}{4}$ sec. 22 (0.2 mile south of northeast corner sec. 22), T. 135 N., R. 83 W., 1.2 miles south of Fallon (about 7 $\frac{1}{4}$ miles east-northeast of Flasher), southern Morton Co., N. Dak. Univ. of Mich. accessions, $\frac{1961}{\text{Tpa-12}}$ and $\frac{1962}{\text{Tpa-5}}$, A. Cvancara, 29 Aug. 1961 and 18 July 1962. Fossils from light greenish gray poorly consolidated, very fine to finegrained sandstone.
53. Two road cuts on both sides of road, on section line common to secs. 14 and 15 (also about on east-west half section line common to both sections), T. 135 N., R. 83 W., about $\frac{1}{2}$ mile south of Fallon (about 7 $\frac{1}{2}$ miles northeast of Flasher), southern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-14}}$, A. Cvancara, 18 July 1962. Fossils from small, light grayish brown sandstone concretions in light grayish green, poorly consolidated, finegrained sandstone in upper part of exposures.
54. South-southwest facing hillside, SE $\frac{1}{4}$ sec. 21, T. 135 N., R. 83 W., about 2 miles southwest of Fallon (about 6 miles east-northeast of Flasher), southern Morton Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-13}}$, A. Cvancara, 17 July 1962. Fossils from small, light grayish brown sandstone concretions, mainly in light grayish green, poorly consolidated, finegrained sandstone in upper part of exposure.

55. SW $\frac{1}{4}$ sec. 8, T. 135 N., R. 83 W., about 6 miles northeast of Flasher, southern Morton Co., N. Dak. (USGS 8442).
56. Gravel pit, NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 8, T. 135 N., R. 83 W., about 2 $\frac{1}{4}$ miles west-northwest of Fallon, southern Morton Co., N. Dak. Univ. of N. Dak. collection.
57. Field blowout, NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 4, T. 135 N., R. 83 W., about 2 $\frac{2}{3}$ miles northwest of Fallon, southern Morton Co., N. Dak. Univ. of N. Dak. collection.
58. SW $\frac{1}{4}$ SW $\frac{1}{4}$ (NW $\frac{1}{4}$?) sec. 6, T. 137 N., R. 83 W., about 7 $\frac{1}{2}$ miles southwest of center of Mandan, northeastern Morton Co., N. Dak. (USGS 9141).
59. West bluff of Heart River, center of sec. 8, T. 136 N., R. 84 W., about 11 miles north of Flasher, southern Morton Co., N. Dak. (USGS 8450).
60. SW $\frac{1}{4}$ sec. 16, T. 136 N., R. 84 W., about 10 miles north of Flasher, southern Morton Co., N. Dak. (USGS 8451).
61. South road cut, about on north-south half section line of sec. 11, T. 135 N., R. 85 W., about 6 $\frac{1}{4}$ miles northeast of Lark, northern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-34}}$, A. Cvancara, 2 Sept. 1961. Fossils from surface of light grayish green, poorly consolidated, finegrained sandstone.
62. Road cuts on both sides of road, on north one-half of section line common to secs. 16 and 17, T. 136 N., R. 85 W. (about $\frac{3}{4}$ mile south of where road crosses Heart River), about 10 miles north of Lark, northern Grant Co., N. Dak. (USGS 15992).
63. East (right) bank of Heart River, NE $\frac{1}{4}$ sec. 21, T. 136 N., R. 86 W., about 10 miles south of Almont (northwestern Morton Co.) or about 12 miles north-northeast of Carson, northern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-27}}$, A. Cvancara, 28 Aug. 1962. Fossils from dark gray to dark green, poorly consolidated, clayey, very finegrained sandstone near base of section.
64. East (right) bank of Heart River, near center of sec. 21, T. 136 N., R. 86 W., about 10 $\frac{1}{2}$ miles south of Almont (northwestern Morton Co.), or about 11 $\frac{1}{2}$ miles north-northeast of Carson, northern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-28}}$, A. Cvancara, 30 Aug. 1962. Fossils from dark gray to green, poorly consolidated, clayey, very finegrained sandstone near base of exposure.
65. East bluff of Heart River, sec. 29, T. 136 N., R. 86 W., about 12 miles south of Almont, northern Grant Co., N. Dak. (USGS 8459).
66. Northwest bluff of Heart River, south line of SW $\frac{1}{4}$ sec. 20, T. 136 N., R. 86 W., about 12 miles south of Almont, northern Grant Co., N. Dak. (USGS 8460).
67. North (left) bank of Heart River, A. A. Stegmeier farm, center of sec. 21, T. 136 N., R. 87 W., about 11 $\frac{1}{2}$ miles north-northwest of Carson, northern Grant Co., N. Dak. Univ. of N. Dak. collection and Univ. of Mich. accession, $\frac{1961}{\text{Tpa-31}}$, A. Cvancara, 17 July 1961. Fossils mainly from dark gray, poorly consolidated, sandy mudstone in lower part of exposure.
68. North bluff of Heart River, SE $\frac{1}{4}$ sec. 19, T. 136 N., R. 87 W., about 17 miles southwest of Almont (northwestern Morton Co.), northern Grant Co., N. Dak. (USGS 8463).
69. Heart River, SW $\frac{1}{4}$ sec. 24, T. 136 N., R. 88 W., about 19 miles southwest of Almont (northwestern Morton Co.), northern Grant Co., N. Dak. (USGS 8464).

70. East (left) bank of Heart Butte Creek, just above where it enters Heart River, SE $\frac{1}{4}$ sec. 16, T. 136 N., R. 88 W., about 14 miles north-northeast of Elgin, northern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-24}}$, A. Cvancara, 12 Aug. 1962. Tongue River vertebrate fossils from conglomeratic bed in upper part of section; Cannonball fossils from dark gray, poorly consolidated, sandy mudstone in lower part of section.
71. SE $\frac{1}{4}$ sec. 19, T. 135 N., R. 85 W., about 2 $\frac{1}{2}$ miles north of Lark, northern Grant Co., N. Dak. (USGS 8447).
72. Railroad cut on Northern Pacific Railway, SW $\frac{1}{4}$ sec. 15, T. 134 N., R. 86 W., about 4 miles southwest of Lark, northern Grant Co., N. Dak. (USGS 8388).
73. Railroad cut, SE $\frac{1}{4}$ sec. 9, T. 133 N., R. 85 W., about 3 miles west-southwest of Raleigh, southern Grant Co., N. Dak. (USGS 8385; probably about the same as USGS 8386).
74. NW $\frac{1}{4}$ sec. 22, T. 132 N., R. 85 W., 1 mile west of site of former Schaller Post Office, about 7 $\frac{1}{2}$ miles south of Raleigh, southern Grant Co., N. Dak. (USGS 8384).
75. Old road cut, mainly SW $\frac{1}{4}$ sec. 30, T. 130 N., R. 84 W., about 10 miles northeast of McIntosh (Corson Co., S. Dak.), western Sioux Co., N. Dak. Univ. of N. Dak. collection.
76. Road cut on top of hill, west side of sec. 19, T. 131 N., R. 87 W., about 14 miles south of Leith, southern Grant Co., N. Dak. Univ. of N. Dak. collection.
77. East (right) bank of Cannonball River, NW $\frac{1}{4}$ sec. 33, T. 132 N., R. 87 W., about 10 miles south-southeast of Leith, southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-29}}$, A. Cvancara, 8 July 1961. Fossils as float; here, from top to bottom, is gravel, poorly consolidated sandstone, and poorly consolidated sandy mudstone with lignite.
78. East road cut at top of hill, SE $\frac{1}{4}$ sec. 3, T. 132 N., R. 87 W., about 6 $\frac{1}{2}$ miles southeast of Leith, southern Grant Co., N. Dak. Univ. of N. Dak. collection.
79. Isolated, sandstone-capped hill, north edge of NW $\frac{1}{4}$ sec. 9, T. 132 N., R. 87 W., about 6 miles south-southeast of Leith, southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-9}}$, A. Cvancara, 28 June 1962. Fossils from light grayish green, poorly consolidated, very finegrained sandstone, 2 to 3 ft. above a 2-ft., lenticular, well-indurated sandstone bed.
80. West (right) bank of former channel of Cannonball River, NW $\frac{1}{4}$ sec. 19, T. 132 N., R. 87 W., about 7 $\frac{3}{4}$ miles south of Leith (about $\frac{1}{4}$ mile south of site of former Janesburg), southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-35}}$, A. Cvancara, 24 Aug. 1962. Fossils from 4 ft., medium grayish brown, poorly consolidated, sandy mudstone, 85 ft. below top of section.
81. South (right) bank of Cannonball River, SW $\frac{1}{4}$ sec. 18, T. 132 N., R. 87 W., about 7 $\frac{1}{4}$ miles south of Leith (about $\frac{1}{2}$ mile northwest of site of former Janesburg), southern Grant Co., N. Dak. (probably about the same as USGS 7968 and USGS 8378). Univ. of Mich. accession, $\frac{1962}{\text{Tpa-36}}$, A. Cvancara, 25 Aug. 1962.

82. East of bridge across Cannonball River on road south of Leith, southern Grant Co., N. Dak. (USGS 15998; quite probably on north (left) bank of Cannonball River, SE $\frac{1}{4}$ sec. 11, T. 132 N., R. 88 W., about 6 $\frac{1}{2}$ miles south of Leith).
83. Bluff on north side of Cannonball River (about $\frac{1}{2}$ mile north of the river), NW $\frac{1}{4}$ sec. 11, T. 132 N., R. 88 W., about 6 miles south of Leith, southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-5}}$, 30 June 1961. Fossils from dark gray, poorly consolidated, sandy mudstone and its contained dark gray limestone concretions in middle of section, and from poorly consolidated, very fine to finegrained sandstone and its contained concretions in lower part of section.
84. South (right) bank of Cannonball River, E $\frac{1}{2}$ sec. 5, T. 132 N., R. 88 W., about 6 $\frac{1}{2}$ miles south-southwest of Leith, southern Grant Co., N. Dak. Univ. of N. Dak. Collection and Univ. of Mich. accession, $\frac{1961}{\text{Tpa-28}}$, A. Cvancara, 6 July 1961. Fossils from dark gray, poorly consolidated, sandy mudstone in lower part of exposure.
85. West bank of Cannonball River, NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 5, T. 132 N., R. 88 W., about 9 miles southwest of Leith, southern Grant Co., N. Dak. (USGS 7961).
86. East (right) bank of Cannonball River, NE $\frac{1}{4}$ sec. 34, T. 133 N., R. 88 W., about 6 miles southwest of Leith, southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-6}}$, A. Cvancara, 7 July 1961. Fossils from lower part of light grayish green, poorly consolidated, very fine to finegrained, clayey sandstone in upper part of section, and from medium greenish gray concretions below in dark gray, poorly consolidated, sandy mudstone.
87. East (left) bank of Cannonball River, SE $\frac{1}{4}$ sec. 26, T. 133 N., R. 88 W., about 5 $\frac{1}{4}$ miles southwest of Leith, southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-32}}$, A. Cvancara, 11 July 1961. Fossils from light grayish green, poorly consolidated, finegrained sandstone near top of exposure.
88. East (left) bank of Cannonball River, NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26, T. 133 N., R. 88 W., about 5 $\frac{1}{4}$ miles southwest of Leith, southern Grant Co., N. Dak. (same as USGS 15993?). Univ. of Mich. accession, $\frac{1961}{\text{Tpa-7}}$, A. Cvancara, 11 July 1961. Fossils mainly from light grayish green, poorly consolidated finegrained sandstone and its contained indurated lenticular sandstone, in upper part of exposure; fossils also from dark gray, poorly consolidated, sandy mudstone directly below.
89. North (left) bank of Cannonball River, SE $\frac{1}{4}$ sec. 28, T. 133 N., R. 88 W., about 6 $\frac{1}{2}$ miles southwest of Leith, southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-15}}$, A. Cvancara, 19 July 1962. Fossils from medium to dark greenish-gray, poorly consolidated, clayey sandstone in lower part of exposure.
90. South (right) bank of Cannonball River, SW $\frac{1}{4}$ sec. 28, T. 133 N., R. 88 W., about 6 miles southwest of Leith, southern Grant Co., N. Dak. (same as USGS 7966?). Univ. of Mich. accessions, $\frac{1961}{\text{Tpa-4}}$ and $\frac{1962}{\text{Tpa-3}}$, A. Cvancara, 28 June 1961 and 26 Aug. 1962. Fossils from almost throughout section, but mainly from dark grayish green, poorly consolidated, clayey, finegrained sandstone in lower middle part of section.

91. South (right) bank of Cannonball River, SE $\frac{1}{4}$ sec. 29, T. 133 N., R. 88 W., about $6\frac{1}{4}$ miles southwest of Leith, southern Grant Co., N. Dak. Univ. of Mich. accessions, $\frac{1961}{\text{Tpa-3}}$ and $\frac{1962}{\text{Tpa-2}}$, A. Cvancara, 27 June 1961 and 5 July 1962. Fossils mainly from dark grayish green, poorly consolidated, clayey, finegrained sandstone in lower part of exposure; several corals from float, probably from dark gray, poorly consolidated, silty to sandy mudstone directly above.
92. North (left) bank of Cannonball River, SE $\frac{1}{4}$ sec. 29, T. 133 N., R. 88 W., about $6\frac{1}{4}$ miles southwest of Leith, southern Grant Co., N. Dak. Univ. of Mich. accessions, $\frac{1961}{\text{Tpa-1}}$ and $\frac{1962}{\text{Tpa-1}}$, A. Cvancara, 24 June 1961 and 5 July 1962. Fossils from dark grayish green, poorly consolidated, clayey, finegrained sandstone at about middle of section.
93. T. 133 N., R. 88 W., about 6 miles south of former Kayser or probably about 7 miles southwest of Leith, southern Grant Co., N. Dak. (USGS 7965; southeast bank of Cannonball River, NE $\frac{1}{4}$ sec. 32?; same as USGS 8377?).
94. Sec. 31, T. 133 N., R. 88 W., about 6 miles south of former Kayser or about 8 miles southwest of Leith, southern Grant Co., N. Dak. (USGS 7964).
95. SW $\frac{1}{4}$ sec. 29, T. 133 N., R. 88 W., about 6 miles south of former Kayser or about $7\frac{3}{4}$ miles southwest of Leith, southern Grant Co., N. Dak. (USGS 8382).
96. East (left) bank of Cannonball River, about on sec. line common to secs. 20 and 29, T. 133 N., R. 88 W., about 6 miles southwest of Leith, southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-2}}$, A. Cvancara, 22 June 1961. Fossils from mottled (light grayish green and dark gray), silty mudstone or siltstone in upper part of section.
97. Bluff on Cannonball River, SW $\frac{1}{4}$ sec. 17, T. 133 N., R. 88 W., about 5 miles southeast of former Kayser or about 7 miles west-southwest of Leith, southern Grant Co., N. Dak. (USGS 7962).
98. Northeast road cut, NW $\frac{1}{4}$ sec. 2, T. 133 N., R. 89 W., about $2\frac{1}{2}$ miles south of Elgin (or about $\frac{1}{4}$ mile north of Cannonball River), southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-26}}$, A. Cvancara, 21 Aug. 1962. *Haly-menites* from light grayish green, poorly consolidated, very fine to finegrained sandstone in upper middle part of section; shark teeth from float in lowest part of section.
99. Top of bluff, SW $\frac{1}{4}$ sec. 30, T. 130 N., R. 88 W., about 7 miles north of Morristown (Corson Co., S. Dak.), southern Grant Co., N. Dak. (USGS 8468).
100. East road cut, SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 16, T. 130 N., R. 89 W., about 23 miles south of Elgin (about 2 miles north of Cedar Creek), southern Grant Co., N. Dak. Univ. of N. Dak. collection.
101. East road cut, west edge SW $\frac{1}{4}$ sec. 21, T. 130 N., R. 89 W., about 23 miles south of Elgin (about 2 miles north of Cedar Creek, southern Grant Co., N. Dak. Univ. of N. Dak. collection.
102. High bluff south of Cedar Creek, SW $\frac{1}{4}$ sec. 5, T. 129 N., R. 89 W., about 11 miles northwest of Morristown (Corson Co., S. Dak.), western Sioux Co., N. Dak. (USGS 8467).

103. NE $\frac{1}{4}$ sec. 12, T. 130 N., R. 90 W., about 21 miles south of Elgin (also about 4 miles southwest of Pretty Rock Butte and about 2 miles north of Cedar Creek), southern Grant Co., N. Dak. (USGS 7970).
104. East (left) bank of Timber Creek, NW $\frac{1}{4}$ sec. 9 (0.2 mile southeast of northwest corner of sec. 9), T. 130 N., R. 90 W., about 11 $\frac{1}{4}$ miles north of Thunderhawk (Corson Co., S. Dak.), southern Grant Co., N. Dak. (considered same as USGS 7969). Univ. of Mich. accessions, $\frac{1961}{\text{Tpa-16}}$ and $\frac{1962}{\text{Tpa-6}}$, A. Cvanara, 11 Aug. 1961 and 22 Aug. 1962. Fossils from medium grayish green, poorly consolidated, very fine to finegrained sandstone.
105. East road cut and hill, NW $\frac{1}{4}$ sec. 21 (0.25 mile south of northwest corner of sec. 21), T. 130 N., R. 90 W., 9 $\frac{1}{4}$ miles north of Thunderhawk (Corson Co., S. Dak.), southern Grant Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-15}}$, A. Cvanara, 9 Aug. 1961. Fossils from both poorly consolidated and well-indurated, gray, sandy mudstone and underlying medium grayish green, poorly consolidated, finegrained sandstone.
106. Road cuts on both sides of road, on section line common to secs. 32 and 33, T. 130 N., R. 90 W., about 7 miles north of Thunderhawk (Corson Co., S. Dak.), western Sioux Co., N. Dak. Univ. of N. Dak. collection.
107. Continuous west road cuts, east edge of sec. 5, T. 129 N., R. 90 W., about 6 miles north of Thunderhawk (Corson Co., S. Dak.), western Sioux Co., N. Dak. Univ. of N. Dak. collection.
108. Northeast (left) bank of Cedar Creek, NE $\frac{1}{4}$ sec. 22, T. 130 N., R. 92 W., about 8 $\frac{3}{4}$ miles north of North Lemmon, Adams Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-23}}$, A. Cvanara, 10 Aug. 1962. Fossils from surface of dark gray, poorly consolidated, silty to sandy mudstone.
109. South (right) bank of North Fork Grand River, about on north-south half section line of sec. 24, T. 23 N., R. 9 E., about 11 miles south of Reeder (Adams Co., N. Dak.), northern Harding Co., S. Dak. (considered same as USGS 7976). Univ. of Mich. accession, $\frac{1961}{\text{Tpa-18}}$, A. Cvanara, 14 Aug. 1961. Fossils from poorly consolidated, very finegrained sandstone (interbedded with dark gray mudstone), about 35 ft. above river level.
110. North bank of North Fork Grand River, SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 36, T. 129 N., R. 99 W., about 5 miles east-southeast of Haley, Bowman Co., N. Dak. (USGS 7974).
111. South-facing hillside, NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 22, T. 129 N., R. 100 W., about 3 miles west-northwest of Haley, Bowman Co., N. Dak. Univ. of Mich. accession, $\frac{1961}{\text{Tpa-17}}$, A. Cvanara, 13 Aug. 1961. Fossils from light greenish tan (probably weathered), poorly consolidated, very fine to finegrained sandstone, about 6 feet below top of hill.
112. At quarter corner common to secs. 21 and 28, T. 129 N., R. 100 W., 12 miles south and 3 $\frac{1}{2}$ (2 $\frac{1}{2}$?) miles west of Scranton (or about 4 miles west of Haley), Bowman Co., N. Dak. (USGS 7975).
113. East (right) bank of Little Missouri River, sec. 14, T. 135 N., R. 105 W., Phelan Ranch, about 4 miles south-southwest of former Yule (or about 15 miles north-northeast of Marmarth), Slope Co., N. Dak. (USGS 16000).

114. Southwest-facing hillside, west side of Little Missouri River (about $\frac{1}{2}$ mile west of river) and east side of auto trail, SW $\frac{1}{4}$ sec. 10, T. 135 N., R. 105 W., about 15 miles north-northeast of Marmarth, Slope Co., N. Dak. (probably about the same as USGS 15999). Univ. of Mich. accession, $\frac{1962}{\text{Tpa-22}}$, A. Cvancara, 8 Aug. 1962. Fossils from brownish black shale directly above 2-ft. thick lignite in lower part of section and also from brownish gray shale about 9.5 ft. above the same lignite.
115. Southwest-facing hillside, west side of Little Missouri River (about $\frac{1}{2}$ mile west of river), SE $\frac{1}{4}$ sec. 9, T. 135 N., R. 105 W., about 15 $\frac{1}{4}$ miles north-northeast of Marmarth, Slope Co., N. Dak. Univ. of Mich. accession, $\frac{1962}{\text{Tpa-21}}$, A. Cvancara, 7 Aug. 1962. Fossils from brownish black shale directly above 2-ft. thick lignite in lower part of exposure and also from brownish shale about 9.5 ft. above the same lignite.

SYSTEMATIC DESCRIPTIONS

The classification of the bivalves used here is that of Thiele (1934), with slight modification for a few genera. The term "Bivalvia" is accepted here because it was used by Thiele (1934) and also because it has priority. Examples of others preferring this term are Wood (1861, p. 3), and Cox (1960, p. 60).

Measurements are prefixed with *ca.* (Latin *circa*, about or approximately) where only slight allowance was made for an incomplete shell or structure. A measurement prefixed with *ca.* and followed by (est.), meaning estimated, represents only a reasonable approximation.

Locality numbers under *Occurrence* of a species correspond to those localities shown on Figure 1 and described in detail above.

Repositories for specimens are as follows: UMMP—University of Michigan Museum of Paleontology; UND—University of North Dakota; USNM—United States National Museum.

Phylum Mollusca
Class Bivalvia
Order Taxodonta
Superfamily Nuculacea
Family Nuculidae
Genus *Nucula* Lamarck, 1799

Original reference.—Lamarck, J. B. P. A. de M. de, 1799, "Prodrome d'une nouvelle classification des coquilles," *Soc. Hist. Nat. Paris Mém.*, p. 87 (not seen).

Type species.—By monotypy, *Arca nucleus* Linné, 1758; Recent, European seas from Norway to Algeria and also in the Mediterranean (Stenzel, Krause, and Twining, 1957, p. 45).

Diagnosis.—Characteristics of the genus and subgenus *Nucula* that I followed are those given by Stenzel, Krause, and Twining, 1957, p. 43.

Remarks.—The diagnosis of Stenzel, Krause and Twining (1957) is somewhat restrictive compared to that conceived by Schenck (1934, p. 46), who included five subgenera. He included in *Nucula* those forms which have both crenulate and non-crenulate inner margins. Van de Poel (1955, p. 4–5) arranged all nuculids into two genera: *Nucula* Lamarck, 1799 and *Nuculoma* Cossmann, 1907 (both with several subgenera) on the basis of shell structure. He included six subgenera under *Nucula* (three subgenera the same as those given by Schenck and two proposed since Schenck, 1934), all of which are said to have crenulated or denticulated inner margins (Schenck, 1934, 1944, and Eames, 1951, p. 319).

Gardner (1943, p. 19) said *Nucula* today is characteristic of boreal and temperate oceans, and has only a meager representation in tropical seas. It is found in both shallow and deep water on both sandy and muddy bottoms. Allen (1954) studied five living British species of *Nucula*, and found (pp. 465, 471) that differences in shell form can be correlated with differences in bottom habitat, this occurring both between and within species.

The subgenus *Nucula sensu stricto* ranges from the early Cretaceous to the Recent (Stenzel, Krause, and Twining, 1957, p. 43).

Nucula (Nucula) planimarginata Meek and Hayden

Pl. I, Figs. 1–8

Nucula planomarginata Meek and Hayden, 1856b, p. 85.

Nucula planimarginata Meek and Hayden. Meek, 1876, p. 101–102, Pl. 15, Figs. 8a–b and Pl. 28, Fig. 16. Stanton, 1920, p. 19–20, Pl. 1, Fig. 2, 3.

?*Nucula subplana* Meek and Hayden? Stanton, 1920, p. 20, Pl. 1, Figs. 4–7.

Description.—Shell transversely subovate; posterior extremity very narrowly rounded to subangular, anterior extremity narrowly rounded; beaks small, low, about midway between mid-length of shell and posterior margin; lunule ill-defined as for genus, escutcheon lanceolate-ovate, bordered by low, rounded ridges and with raised central part; external ornamentation of fine, radial lines (ridges) and growth striae. Angle formed by anterior and posterior rows of teeth about 110 degrees; about 26 or 27

teeth in anterior row and about 10 teeth in posterior row; inner margin smooth (after Meek, 1876, p. 101).

Types.—Hypotypes, UND 9526 (locality 106), UMMP 47362 (locality 11) and UMMP 47363 (locality 2). The original type specimens (USNM 436 and 437) are from the Fox Hills Sandstone (Upper Cretaceous) on the Moreau River, South Dakota, and near Long Lake, North Dakota.

Material.—Two specimens with both valves (one poorly exposed), one right valve and one left valve, UND; seven complete or nearly complete specimens with both valves, six left valves, six right valves, and few external and internal molds and fragments, UMMP.

Measurements (in millimeters).—

Valve	Length	Height	Width
Right	ca. 24.5	ca. 19.0 (est.)	...
Left	ca. 21.0	ca. 16.0	...
Left	19.2	ca. 15.0 (est.)	...
Right	ca. 17.5	ca. 14.5	...
Right	ca. 15.5	13.3	ca. 8.0 (4.0)
Left	ca. 13.0 (est.)	10.2	...
Double	12.8	10.3	ca. 6.0
Double	10.6	9.0	ca. 5.5
Right	8.8	7.0	ca. 4.2 (2.1)
Right	8.6	ca. 7.0	...

Remarks.—This species is placed, with some reservation, in *Nucula sensu stricto*, the chief objections being the lack of a crenulate inner margin and the probable absence of true external radial ornamentation. I have observed weak wrinkles on the inner margins of a few Cannonball specimens, but these can hardly be called crenulations. Schenck (1934, p. 21) considered at least one species with a smooth ventral margin as belonging to *Nucula sensu stricto*.

The existence of external radial ornamentation is in doubt. The type specimens from near Long Lake, North Dakota (USNM 437) show numerous, subdued radial ridges, but it is uncertain if the true exterior is present. Meek (1876, p. 102) said “. . . that the radiating striae are probably not always readily seen on the outer surface-layer of well-preserved specimens.” There is no radial ornamentation on the external surface of the Cannonball specimens, but there is a radial element to the shell structure.

Following Schenck's (1934) classification of the nuculids, this species

could possibly be considered a member of the Australian subgenus *Ennucula* Iredale, 1931, which has a smooth ventral margin and is similar in shape. The tooth rows, however, are rather arched in this subgenus instead of being angulated as in the present species. The Cannonball specimens also show a chondrophore which appears much less oblique than that found in *Ennucula*.

In addition to the scars of the adductor muscles, the Cannonball specimens show other smaller, clearly discernible scars. On the underside of the anterior part of the hinge plate is a relatively long and broad pedal muscle scar, which is separated from the anterior adductor scar. Dorsad of the mid-height of the shell are several smaller pairs of accessory scars (many accessory scars also discernible on Fox Hills type specimens). Slightly posterior to the mid-length of the shell are paired, dorsoventrally elongate scars, followed slightly ventrally and anteriorly by a pair of small, rounded scars. Between the latter and the anterior adductor scars are other small, rounded scars, four pairs of which are discernible on those few specimens observed with distinct scars (Pl. I, Fig. 5). The names *median muscle scars* (elongate scars), *central muscle scars* (small rounded scars near elongate scars) and *punctiform scars* (four pairs of small, rounded scars) have been suggested by Nils Odhner (Schenck, 1934, p. 21) for these accessory scars. Heath (1937, pp. 12, 14) has discussed the functions of the muscles producing these scars.

The Cannonball specimens are doubtfully referred to this species because of uncertain true radial ornamentation, as stated above. Stanton's (1920, Pl. 1) Figure 2 is somewhat inaccurate and is based on an incorrectly made cast. The ventral margin has been retouched on the figure, as it is not present on the external mold. Prior to making the cast, all the shell material had not been removed from the external mold. Consequently, most of the cast shows a radial ornamentation which does not represent the true exterior but shows the radial internal structure of the shell. Only at the postero-ventral part of the mold has all the shell been removed; it is here that the cast shows the true exterior, which is smooth except for growth lines.

The specimens referred to *Nucula subplana* Meek and Hayden? by Stanton (1920, p. 20, Pl. 1, Figs. 4-7) are questionably placed in synonymy here, for they seem so indistinct as to not warrant a separate name. The characters ". . . relatively higher, more compressed, and with the posterior end more obliquely truncate . . ." do not appear to be constant. Reference of Stanton's specimens to *N. subplana* is a doubtful identification as the type specimens of that species are all internal molds (USNM 352).

Nucula proava Wood (1864, p. 117, Pl. 20, Figs. 3a, 3b) from the Eocene of England seems to be a closely similar species. It, too, has a smooth ventral margin.

Occurrence.—Cannonball Formation, localities 2, 5, 11, 12, 16, 18, 20, 29, 31, 43, 51, 52, 58, 62, 63, 66, 67, 69, 70, 86, 89, 92, 99, 104, 106 and 112.

Nucula sp.

Pl. I, Figs. 9, 10

Remarks.—A few small incomplete specimens from three localities are here given separate notation from the previous species as they appear to be specifically different. They differ chiefly in having crenulate inner margins and a slight, but noticeable, radial ornamentation appearing as lightly impressed striae. In specimens with parts of the shell broken away, the radial component of the shell structure is quite pronounced (Pl. I, Fig. 10).

These specimens could possibly represent immature forms of the previous species. A few considerably larger specimens from one of the same localities yielding the crenulate *Nuculas* appear, however, to be non-crenulate and the radial component of the shell structure is not at all pronounced as seen on the broken shell. Also, a few small specimens, believed to be immature *N. planimarginata* and about the size of the crenulate specimens, lack crenulate inner margins.

It seems unwise to assign specific terminology to this so-called species until more and better specimens are collected and studied.

Types.—Hypotypes, UMMP 47378 (locality 4) and UMMP 47349 (locality 4).

Material.—One incomplete specimen with both valves, one right valve and few fragments and incomplete internal and external molds, UMMP.

Measurements (in millimeters).—

Valve	Length	Height	Width
Double	ca. 3.2	ca. 2.6	ca. 1.4
Left	ca. 4.5	ca. 3.5	...
Right	ca. 4.3	ca. 3.4	...

Occurrence.—Cannonball Formation, localities 1, 2, and 4.

Family Nuculanidae

Genus *Neilonella* Dall, 1881

Original reference.—Dall, W. H., 1881, "Preliminary Report on the Mollusca XV. No. 2—Report on the Results of Dredging, under the Supervision of Alexander Agassiz, in the Gulf of Mexico, and in the Caribbean Sea, 1887–79, . . . ,” *Harvard Mus. Comp. Zool. Bull.*, Vol. 9, pp. 125–26.

Type species.—By monotypy (?), *Leda (Neilonella) corpulenta* Dall, 1881; Recent, in the West Indies.

Diagnosis.—Characters of the genus which I followed are those given by Verrill and Bush, 1897, p. 57.

Remarks.—Yonge (1939), from a study of various living protobranch mollusks, recognized three families, Nuculidae, Solenomyidae and Nuculanidae. He believed (p. 81) *Malletia* a genus of the Nuculanidae, and disregarded Thiele's (1934, p. 787) family Mallettiidae. Following Yonge, *Neilonella* would also be placed in the Nuculanidae.

The geologic range of *Neilonella* is unknown to me. Amano (1957, p. 55) has reported a species of *Neilonella*, *N. obliquistriata*, from the Upper Cretaceous of Kyushu, Japan. However, he said that the “. . . anterior taxodont teeth are linked continuously with [the] posterior taxodont teeth through [*sic*] under the beak” This creates doubt as to whether his species is a *Neilonella*, for in this genus there is said to be a gap in the hinge teeth, dividing them into an anterior and posterior series (Dall, 1898, p. 582).

Neilonella evansi (Meek and Hayden)?

Pl. I, Figs. 13–17

Nucula Evansi Meek and Hayden, 1856*b*, p. 84.

Leda Evansi Meek and Hayden, 1860*a*, page 185 (name change only).

Leda (Yoldia) Evansi Meek and Hayden, 1860*b*, p. 429 (listed only).

Yoldia Evansi Meek and Hayden. Meek, 1876, p. 111, Pl. 28, Figs. 10 *a-c*.

Yoldia evansi Meek and Hayden. Stanton, 1920, p. 21, Pl. 1, Fig. 11.

?*Yoldia scitula* Meek and Hayden. Stanton, 1920, p. 21, Pl. 1, Fig. 10.

Description.—Shell transversely elongate-subelliptical, both anterior and posterior extremities rather narrowly rounded; slightly to moderately convex; dorsal margin with shallow groove posterior to beaks in each valve; beaks low, slightly anterior to mid-length of shell; external surface smooth except for fine growth lines (after Meek, 1876, p. 111).

Types.—Hypotypes, UMMP 47366, 47410 (locality 91) and UMMP 47371 (locality 89). The original type specimens (USNM 307) are from the Fox Hills Sandstone (Upper Cretaceous), Moreau River, South Dakota.

Material.—One small specimen with both valves, two left valves, one right valve, five internal molds, two incomplete external molds and few fragments, UMMP.

Measurements (in millimeters).—

Valve	Length	Height	Width
Left	9.9	6.0	ca. 4.2 (2.1)
Left	9.4	5.6	ca. 4.0 (2.0)
Right	ca. 7.5	ca. 4.3	ca. 3.4 (1.7)
Left	ca. 7.0	3.9	...
Left	5.4	ca. 3.4	...

Remarks.—As is characteristic of *Neilonella*, the Cannonball specimens have a groove under the beaks for the reception of an external ligament. This groove is longer and more prominent posterior to the beaks. At the position of the beaks on the hinge line is the usual notch separating the two rows of hinge teeth. It is possible that a small "internal" ligament was housed in a pit directly beneath the beaks. In each valve, the Cannonball specimens have about 18 and 25 teeth in the anterior and posterior rows, respectively. Adductor muscle scar impressions are extremely faint and indistinct, but the posterior scars appear to be the longer. The pallial sinus was observed indistinctly on only one specimen and appears to be rather deeply inset and narrowly rounded (Pl. I, Fig. 13).

The Cannonball specimens do not differ appreciably internally from those of the Fox Hills Sandstone referred to this species. My examination of the original type specimens failed to reveal the presence of a chondrophore. Also, Ian Speden, Yale University (written communication, 28 March 1963), studying the fauna of the Fox Hills in South Dakota, maintained that, "The Fox Hills specimens of '*Yoldia*' *evansi* . . . possess only an external ligament." It is evident that this species can no longer be retained in the genus *Yoldia*, for species of this genus are characterized by the presence of a chondrophore bearing an internal ligament. The species is, therefore, herein assigned to the genus *Neilonella*.

Differences in the external ornamentation of the Cannonball material appear to exist. Published descriptions of this species (Meek and Hayden, 1856*b*, p. 84 and Meek, 1876, p. 111), and the writer's examination of the

type specimens, reveal that this species appears to lack external ornamentation except for fine growth lines. This differs from that of the Cannonball specimens which have an external ornamentation very similar to that of *Nuculana mansfieldi* (Stanton) (Pl. I, Figs. 18–21 of this paper). The ornamentation consists of low, narrow concentric bands, having the appearance of overlapping strips, so that the dorsal part of each band is a ridge and the ventral part a groove. As in *N. mansfieldi*, the concentric bands give way, anteriorly and posteriorly, to fine, concentric growth lines.

The specimen referred to *Yoldia scitula* (Meek and Hayden) by Stanton (1920, p. 21, Pl. 1, Fig. 10) is questionably synonymized here. Little can be learned from this specimen as it is a single valve imbedded in matrix with much of the shell missing. I prefer to place this specimen in synonymy until it can be established that "*Yoldia*" *scitula* occurs in the Cannonball Formation.

Occurrence.—Cannonball Formation, localities 2, 16(?), 31(?), 63, 64, 70, 89 and 91.

Genus *Nuculana* Link, 1807

Original reference.—Link, H. F., 1807, *Beschreibung der Naturalien-Sammlung der Universität zu Rostock*, p. 155.

Type species.—By monotypy, *Arca rostrata* Chemnitz, 1784 = *Arca pernula* Müller, 1779; Recent in the North Polar seas and in the North Atlantic (*vide* Stewart, 1930, p. 48 and Gardner, 1945, p. 43).

Diagnosis.—I have followed Gardner's (1926a, p. 10) diagnosis of *Nuculana*.

Remarks.—*Nuculana* Link, 1807 replaces *Leda* Schumacher, 1817. Discussions involving this change can be found in Iredale (1915, p. 483) and Stewart (1930, p. 48–50). In addition to the characters discussed by Gardner (1926a), Stewart (1930, p. 51–52) stressed the importance of the internal ligament pit (chondrophore), which he said is narrow and asymmetrical, curving posteriorly away from the umbo in *Nuculana*.

Gardner (1926a, p. 10) gave the geologic range of this genus as Silurian to the Recent, but under Stewart's restricted usage *Nuculana* was not in existence in the Eocene, at least in the Gulf Coast material he studied.

Nuculanids, in general, occur mainly in cool waters today (Morris, 1951, p. 7 and Keen, 1958, p. 17).

Nuculana mansfieldi (Stanton)

Pl. I, Figs. 18-21

Leda mansfieldi Stanton, 1920, p. 20-21, Pl. 1, Fig. 8.

Description.—Shell transversely sublanceolate to transversely suboval, compressed; anterior margin rather narrowly subangular; dorsal margin nearly straight anterior to beaks and gently concave posterior to beaks; beaks low and about central; lunule area weak, with two low, subparallel ridges; escutcheonal area wider and more prominent, with two low, arched ridges that diverge laterally from the beaks and converge gradually before reaching the posterior extremity; external ornamentation of low, narrow concentric bands, having the appearance of overlapping strips, so that dorsal part of each band is a ridge and ventral part a groove; concentric bands less prominent dorsally; at anterior and posterior parts of shell bands give way to fine growth lines.

Types.—Holotype, USNM 32385 (Stanton, 1920, Pl. 1, Fig. 8; also refigured here, Pl. 1, Fig. 21), Cannonball Formation, USGS 8388; hypotypes, UMMP 47332 (locality 109) and UMMP 47365 and 47368 (locality 2).

Material.—Two small, incomplete specimens with conjoined valves, five internal molds of single valves (two right valves and three left valves), and few incomplete valves and fragments.

Measurements (in millimeters).—

Valve	Length	Height	Width
Right	16.0	ca. 8.5	...
Right	15.5	ca. 8.5	...
Right	ca. 15.0	ca. 8.5	...
Left	11.5	ca. 6.0	...
Double	ca. 8.4	ca. 4.0	ca. 2.4

Remarks.—It is assumed that Stanton's holotype (1920, Pl. 1, Fig. 8) is an immature specimen. Considerably large specimens from my material are considered conspecific with Stanton's species although they lack the narrow, produced, posterior extremity. From observations of the growth lines of a few incomplete exteriors, it appears that the posterior extremity is pointed in the earlier stages and becomes blunt with age.

This species is placed somewhat provisionally in *Nuculana* until certain characters have been verified. The sinus has not been seen in this species.

The chondrophore appears to be asymmetric where it was observed on internal molds and incomplete shells. A slight posterior gape appears to be present, whereas no anterior gape appears to be present.

Leda substriata Morris (Wood, 1864, p. 130, Pl. 17, Fig. 5) from the Thanetian of England appears to be a similar species, but differs in its more elevated beaks.

Occurrence.—Cannonball Formation, localities 1, 2, 39, 72, 83, 90, 91, and 109.

Nuculana thomi (Stanton)

Pl. I, Figs. 22–24

Yoldia thomi Stanton 1920, p. 21–22, Pl. 1, Figs. 12a–c.

Description.—Shell transversely elongate-subovate; anterior margin narrowly rounded, posterior margin more narrowly rounded to nearly subangular; anterodorsal margin very slightly convex, posterodorsal margin very slightly concave; ventral margin broadly rounded; moderately convex, maximum convexity at about mid-length of shell; beaks moderately prominent, just slightly anterior to mid-length of shell; poorly defined, shallow, escutcheon-like depression present, bounded by low, obscure ridges; external ornamentation weak, of low, narrow, concentric bands having the appearance of overlapping strips, so that dorsal part of each band is a ridge and ventral part a groove; concentric bands gradually disappear dorsally, giving way to fine growth lines; adductor muscle scars very faintly impressed, anterior scars subovate, posterior scars not clearly discernible.

Types.—Holotype, USNM 32388 (Stanton, 1920, Pl. 1, Figs. 12 a–c; also refigured here, Pl. I, Figs. 22–24, USGS 7966.

Material.—One specimen with both valves (holotype); right valve incomplete, with part of anterior hinge and postero-ventral margin missing, USNM.

Measurements (in millimeters).—

Length	Height	Width
13.0	8.0	6.0

Remarks.—This species is probably a true *Nuculana* and not *Yoldia*. A chondrophore, although incomplete on the type, is present; no distinct or readily apparent gape of the valves is present and the pallial sinus, although indistinctly seen, appears to be relatively shallow.

This species is similar to the Upper Cretaceous species, *Yoldia scitula* (Meek and Hayden). Four type specimens (USNM 302) of *Y. scitula* have the following measurements (in millimeters):

Length	Height	Width
ca. 10.2	5.7	ca. 5.0
ca. 9.5	ca. 5.5	ca. 5.0
ca. 8.0	4.8	ca. 4.0
7.0	4.5	3.6

Although it is difficult and inaccurate to make comparisons with only a few specimens, *Nuculana thomi* appears to differ from *Yoldia scitula* in being less convex (wide), having more centrally placed beaks and finer external ornamentation. Also, the escutcheon-like depression is less well defined in *Nuculana thomi*, set off by low, inconspicuous ridges.

Occurrence.—Cannonball Formation, USGS 7966.

Family Solenomyidae

Genus *Solemya* Lamarck, 1818

Original reference.—Lamarck, J. B. P. A. de M. de, 1818, *Histoire naturelle des Animaux sans vertèbres* . . . , Vol. 5, p. 488 (not seen).

Type species.—By subsequent designation, Children, 1823: "*Solenomya*" *mediterranea* Lamarck = *Solemya mediterranea* Lamarck = *Tellina togata* Poli, 1791; Recent, Mediterranean Sea and adjacent areas of Atlantic Ocean (Vokes, 1955, p. 534, 535).

Diagnosis.—I have followed the characteristics for this genus given by Olsson (1961, p. 52).

Remarks.—On the basis of characters of the ligament (whether amphidetic or opisthodontic and internal or external) and its relationship to the chondrophore, which may be variously supported, Dall (1908) proposed three subgenera: *Solemya sensu stricto*, *Petrasma* and *Acharax*.

Chavan and Cailleux (1957, p. 222) gave the geologic range of *Solemya* as Triassic to Recent.

Solemya bilix White

Pl. I, Figs. 11-12

Solemya bilix White, 1880, p. 158; 1881, p. 137, 139 (no description), Pl. (not numbered, follows p. 534), Fig. 9. Stanton, 1920, p. 19, Pl. 1, Figs. 1*a-b*.

Description.—Shell length about two and one-half times height; anterior and posterior margins narrowly rounded, posterior more so than the anterior; moderately convex, maximum convexity near the dorsal margin; external ornamentation of growth lines and faint radiating lines, nearly uniformly distributed, and arranged in pairs on middle part of shell (after White, 1880, p. 158 and White, 1881, Pl. ?, Fig. 9).

Types.—Hypotype, USNM 32380 (Stanton, 1920, Pl. 1, Figs. 1*a-b*; also refigured here, Pl. I, Figs. 11-12), USGS 9121. The holotype (USNM 8913) is from the Fox Hills Sandstone or upper part of the Pierre Shale (Upper Cretaceous) (Stanton, 1920, p. 19), four miles north of Golden, Colorado.

Material.—Four internal molds of both valves and one exterior of left valve, USNM.

Measurements (in millimeters).—

Length	Height	Width
ca. 26.0 (est.)	ca. 9.0	ca. 6.0
ca. 21.0	ca. 8.5	ca. 6.0
ca. 17.0	ca. 7.0	ca. 5.0
Ca. 15.5	ca. 6.0	ca. 3.5

Remarks.—The Cannonball specimens are, with uncertainty, placed in *Solemya* because the internal characters are inadequately known. The posterior adductor muscle scars appear to be elongate-subtrigonal; evidence of a distinct, anteriorly-bordering ridge is not apparent. There appears to be an elongate-subovate escutcheon-like depression present.

It seems reasonable to assign the Cannonball specimens to *S. bilix*. The shape and proportion of the shells are similar. A radial ornamentation is evident on the internal molds of the Cannonball specimens, although the slightly raised, radial lines are not readily discernible into pairs as seen in *S. bilix* (holotype, USNM 8913).

Occurrence.—Cannonball Formation, localities 15, 20 and 59.

Superfamily Arcacea
 Family Cucullaeidae
 Genus *Cucullaea* Lamarck, 1801

Original reference.—Lamarck, J. B. P. A. de M. de, 1801, *Système des animaux sans vertèbres . . .*, p. 116 (not seen).

Type species.—By subsequent designation (Children, 1823, p. 318) *Cucullaea auriculifera* Lamarck, 1801 = *Arca cucullata* Röding, 1798 = *Arca cucullus* Gmelin, 1791 = *Arca labiata* Solander, 1786; Recent, Indian and western Pacific Oceans (Nicol, 1954, p. 97).

Diagnosis.—I follow Gardner (1933, p. 125) in the diagnosis of this genus.

Remarks.—Divergent ligamental grooves are present on fossil, but not on living species of *Cucullaea*. Nicol (1950*b*, p. 340, 342), said the ligament has only fine lines parallel to its long axis in the sole living and type species, *Cucullaea labiata* (Solander).

Living cucullaeids prefer fine sand or mud bottoms, are most common at depths of 15 to 150 meters and have not been reported from depths greater than 252 meters (Nicol, 1950*b*, p. 343).

I prefer to accept *Cucullaea* in the family Cucullaeidae (e.g., Finlay and Marwick, 1937, p. 18 and Nicol 1950*a* and 1954) rather than Arcidae (Thiele, 1934). This follows Reinhart's (1935, p. 6) definition of the Arcidae which excludes forms with taxodont teeth parallel to the hinge line. *Cucullaea* has also been assigned to the Parallelodontidae (e.g. Gardner, 1933, p. 125).

The geologic range of *Cucullaea* (*sensu lato*) is Early Jurassic to Recent (Finlay and Marwick, 1937, p. 18).

Cucullaea solenensis Stanton

Pl. II, Figs. 1–6, 9–13

Cucullaea solenensis Stanton, 1920, p. 22–23, Pl. 2, Figs. 2*a*, 2*b* and 3.

?*Cucullaea shumardi* Meek and Hayden. Stanton, 1920, p. 22, Pl. 2, Figs. 1*a*–*b*.

?*Cucullaea nebrascensis* Owen? Stanton, 1920, p. 22.

?*Trigonarca*? *hancocki* Stanton, 1920, p. 23, Pl. 2, Figs. 4, 5.

Description.—Shell transversely subovate to subquadrate or subrhomboidal; anterior margin forms nearly right angle with hinge margin and is rather broadly rounded ventrally; posterior margin subtruncate and rather narrowly rounded ventrally; moderately convex; beaks slightly anterior to

mid-length of shell and slightly prosogyral; external ornamentation of concentric growth lines and low, flattened obscure radiating ribs with relatively narrow interspaces; posterior adductor scars supported by a relatively weak ridge; crenulate marginally.

Types.—Lectotype (here designated), USNM 32392 (Stanton, 1920, Pl. 2, Fig. 3; also refigured here, Pl. II, Figs. 2, 3, Cannonball Formation, USGS 8446; hypotypes, USNM 32391 (Stanton, 1920, Pl. 2, Figs. 2*a*–*b*, USGS 9129 (also refigured here, Pl. II, Fig. 6), UMMP 47351 (locality 29), UMMP 47359 (locality 29) and UMMP 47360 (locality 67).

Material.—One incomplete double-valved specimen (holotype) with most of shell missing, and one incomplete, distorted, double-valved specimen (hypotype) with most of shell missing, USNM; one small, incomplete double-valved specimen, two left valves (one very small, the other incomplete), and fragment of a right valve, UMMP.

Measurements (in millimeters).—

Length	Height	Width
ca. 43.0 (lectotype)	ca. 34.0 (est.)	ca. 32.0 (16.0)
ca. 39.0	ca. 35.0	ca. 32.0 (16.0)
4.0	3.4	ca. 3.0 (1.5)

Remarks.—The larger left valve of the University of Michigan Museum of Paleontology material shows a slight difference from the three divaricating ligamental grooves mentioned by Stanton (1920, p. 22). Considering the ligamental grooves disjunct, three grooves are present on the posterior, and four grooves on the anterior part of the ligamental area. The University of Michigan Museum of Paleontology material also shows about five medial teeth and three subparallel lateral teeth on each side of the hinge line.

A very small specimen (Pl. II, Figs. 9, 11) is considered to be an immature form of this species, although it differs somewhat from the larger specimens. The hinge teeth are divergent as from an imaginary point in the central part of the shell and, especially, the lateral teeth are not subparallel to the hinge line. Internally, the margin of the shell is distinctly crenulated. On the ligamental area there appear to be only two oblique grooves, posterior to the beak. The external ornamentation is reticulate, of rounded concentric ridges and more prominent radial ribs. The radial ribs are separated by interspaces about twice their width, the latter usually containing a secondary, less prominent rib. The ornamentation becomes obscure at

the anterodorsal and posterodorsal parts of the valve. A shallow sulcus is present on the umbo and gradually disappears ventrally.

These differences possessed by the very small specimen are probably not so great as to prevent inclusion of this specimen within the present species. Nicol (1950a, p. 94, Pl. 21, Figs. 5-7) cited a species of *Cucullaea* in which the hinge teeth, in the early stages, are subequal and dorsally divergent. Later, the outer teeth become elongate and parallel to the hinge margin. As for the seemingly discordant external ornamentation, this can too, be resolved. Nicol (1950b, p. 340) said this concerning the external ornamentation in *Cucullaea labiata* (Solander):

"... In young shells the radial ribs are raised and tend to split, and new ribs form in the interspaces. The radial ribs are usually broader than the interspaces. There are concentric raised threads at regular intervals. In mature specimens the radial ribs tend to flatten and widen; less splitting occurs."

The external ornamentation as shown on certain weathered parts of the shell is distinctive. The radial ribs are separated by very narrow grooves and have low, secondary ribs. The crossing of these ribs by concentric growth lines results in a semi-scalloped appearance of the weathered, outer surface (Pl. II, Fig. 12).

Three bivalves discussed by Stanton (1920, p. 22-23) as occurring in the Cannonball Formation are questionably considered synonymous with *Cucullaea solenensis*. *Trigonalca? hancocki* Stanton (1920, p. 23, Pl. 2, Figs. 4, 5) is considered as the possible young of *C. solenensis*. It is refigured here (Pl. II, Figs. 10, 13) and can be compared with the small specimen (Pl. II, Figs. 9, 11) discussed earlier under Remarks. Similar ornamentation appears to be present in the two sets of specimens, as well as the similar presence of a shallow, medial sulcus. It is noted that subsequent to my consideration of *Trigonalca? hancocki* as immature *C. solenensis*, Alfred Rosenkrantz, Universitetets, Mineralogisk-Geologiske Institut, Copenhagen (written communication, 7 June 1963) informed me that he thought "... that *Trigonalca? hancocki* Stanton [Pl. II], Fig. 4-4 is a young of a *Cucullaea*."

Two incomplete specimens (partial hinges and beaks of right? and left valves, USGS 7969) were questionably assigned by Stanton (1920, p. 22) to *Cucullaea nebrascensis* Owen, and are considered here as assignable to *C. solenensis*. The external ornamentation of these specimens is of low, bifurcating, flattened ribs which are separated by much narrower grooves. These specimens differ from the type of *C. nebrascensis* (Upper Cretaceous Fox Hills Sandstone, USNM 20245) in having a much thinner shell, pos-

sessing radial ornamentation, and lacking numerous ligamental grooves. The Cannonball specimens show one main groove and two other short, curved grooves at the hinge line; the Fox Hills specimen has eight ligamental grooves.

The single specimen referred by Stanton (1920, p. 22, Pl. 2, Figs. 1a-b) to *C. shumardi* is also considered as probably belonging to *C. solenensis*, until it can be established that *C. shumardi* occurs in the Cannonball. This specimen was probably assigned to *C. shumardi* because of its apparent lack of marginal crenulations and radial ornamentation. Most of the margin, however, is missing on this specimen (right internal mold), making it difficult to determine whether crenulations were present. Only a small fragment of shell exists at the posterodorsal extremity of the mold; although no distinct radial ornamentation is apparent here (shell appears weathered) this is not proof of the lack of it. On more complete Cannonball specimens, the radial ornamentation is much less prominent on the antero- and posterodorsal extremities than over the central part of the shell and would be even less prominent upon weathering. This specimen appears similar to *C. solenensis* in general form and prominence of the ridge bordering the posterior adductor muscle scar.

Ligamental grooves of the *C. shumardi* specimen appear subparallel to the hinge and are wavy, and so differ from those of *C. solenensis*. This is shown in Stanton's figure 1b (1920, Pl. 2). In this figure the plane of commissure of the valve is not parallel to the surface of the plate of illustration; the dorsal area of the shell has been rotated slightly upward. Consequently, only the lower four, more prominent ridges are teeth, whereas, the upper finer ridges are the raised spaces between ligamental grooves.

Occurrence.—Cannonball Formation, localities 29, 39, 42, 67 and 104.

Family Glycymeridae

Genus *Glycymeris* Da Costa, 1778

Original reference.—Da Costa, E. M., 1778, *Historia naturalis Testaceorum Britanniae, or the British Conchology . . .*, p. 168-70 (not seen).

Type species.—By tautonymy, *Arca glycymeris* Linné, 1758 = *Glycymeris orbicularis* Da Costa, 1778; Recent, Island of Guernsey (Nicol, 1945, p. 616).

Diagnosis.—I followed Lamy's (1911, p. 81-82) diagnosis of this genus.

Remarks.—Disagreement as to the generic name for forms typified by *Arca glycymeris* Linné has involved mainly *Glycymeris* Da Costa, 1778, and *Pectunculus* Lamarck, 1799, with the latter name favored by earlier workers. Examples of discussions on *Glycymeris* versus *Pectunculus* are Dall (1898, p. 571–72) and Dautzenberg and Dollfus (1904). A generic synonymy for *Glycymeris* Da Costa was given by Dall (1898, p. 607).

The anterior and posterior parts of a *Glycymeris* are very similar but the following characters appear to be constant and are useful in making the distinction:

1) Shape of adductor muscle scars; anterior scar subtrigonal, the posterior scar subtrapezoidal (or somewhat rounded).

2) Ridge or flange bordering inner margins of adductor scars; ridge bordering posterior scar is more prominent.

3) Shape of anterior and posterior margins; if anterior and posterior margins are noticeably different in shape, posterior is subangular or somewhat truncated, whereas anterior is always rounded.

4) Inflection of beaks; if beaks are inflected (*i.e.*, not orthogyral), inflection is usually towards the posterior.

The above characteristics are verified by anatomical observations (Chavan, 1943, p. 91). Recent species show interiorly a darker coloration at the posterior part of the shell.

Glycymeris ranges from the Cretaceous to the Recent (maximum in the Miocene) and today about 80 species inhabit warm and temperate seas (Gardner, 1926a, p. 35). This is a shallow water genus, found usually at depths of 8 to 60 fathoms, rarely to 120 fathoms (Marwick, 1923, p. 63).

Glycymeris subimbricata (Meek and Hayden)

Fig. 2; Pl. II, Figs. 7, 8, 14–16; Pl. III, Figs. 1, 2, 5, 8, 19, 20

Pectunculus subimbricatus Meek and Hayden, 1857, p. 146.

Axinaea subimbricata Meek and Hayden, 1860a, p. 185 (name change only). Meek, 1876, p. 95–96, Pl. 28, Figs. 14a–d.

Glycymeris subimbricata (Meek and Hayden). Stanton, 1920, p. 23, Pl. 2, Figs. 6a–b, 7.

Description.—Shell suborbicular, slightly longer than high, anterior margin quite regularly rounded, posterior margin obtusely subangular to slightly truncate; external surface ornament of low, flattened radial ribs, about twice as wide as separating furrows and crossed by distinct growth lines; radial ribs four to six per 10 millimeters at central part of

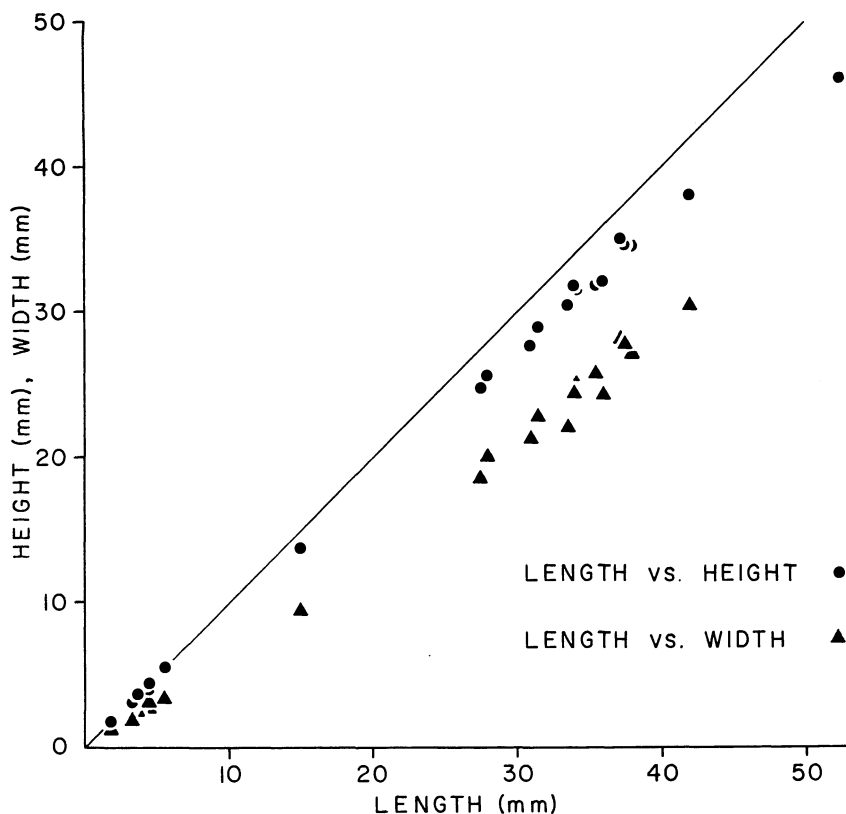


FIG. 2. Scatter diagram of length versus height and length versus width of valves of *Glycymeris subimbricata* (Meek and Hayden) from Cannonball Formation of North Dakota. Width refers to total width of both valves, obtained by doubling measurement of single valve.

ventral margin. Beaks orthogyral, moderately elevated, and slightly posterior to mid-length. Ligamental area with five to seven chevron-shaped grooves, and inequilateral, with posterior part of area the shorter. Main oblique, transverse teeth, five to eight on either side of beak.

Types.—Hypotypes, UND 9527, 9528, 9529 (locality 34) and UND 9530 (locality 33); hypotypes UMMP 47329 and 47361 (locality 37). The source of the original types is uncertain, but it may be the Cannonball Formation, North Dakota (Stanton, 1920, p. 24).

Material.—Four double-valved specimens (all immature), 14 single valves, and several incomplete shells and fragments, UMMP; one complete

double-valved specimen, seven single valves and many incomplete valves and fragments, UND.

Shell measurements for this species are plotted in Figure 2.

Remarks.—Besides the criteria for distinguishing the anterior and posterior parts of the shell in *Glycymeris*, given under Remarks for the genus, additional criteria are afforded by the present species. These are as follows:

1) Anterior adductor scars are larger; this character has been given by Abbott (1954, p. 348) for *Glycymeris*. It does not seem, however, to be a constant generic character; of 22 living species of *Glycymeris* which I examined, five have subequal adductor scars, of which it is not readily apparent which is the larger.

2) Posterior position of beaks; the beaks are slightly posterior to the mid-length of the shell.

3) Inequilateral ligamental area; the posterior part of the ligamental area is the shorter.

4) Unequal number of ligamental grooves in anterior and posterior parts of ligamental area; in specimens with an unequal number of ligamental grooves in the anterior and posterior parts of the ligamental area (in about one-half of those specimens observed), the posterior part has one *less* groove. This same character was noted in four living species; it may occur in other species but could not be determined in several species for the chevron grooves in the ligamental area are variable in strength, from very weak to not apparent.

Another character which may be useful is the relative length of anterior and posterior pedal scars on the under surface of the hinge plate. In the present species, the posterior pedal scar always appears to be the shorter. This same condition also seems to occur in at least two living species which I examined. The difference in relative length of pedal scars is probably a generic character; their use in orienting *Glycymeris* has previously been pointed out by Chavan (1943, p. 91-92).

Scatter plots of length versus height and length versus width of this species suggest certain ontogenetic trends (Fig. 2). The length-height plot implies that during growth shell shape becomes less orbicular, that is, larger shells are longer for a corresponding height (plots shifted from 1:1 ratio line). The length-width plot also shows a more rapid increase of length than width during growth. A plot of height versus width (not shown) appears to indicate a trend for older shells to become more swollen, for

larger specimens are wider for a corresponding height (plots shifted from 1:1 ratio line).

In the earlier stages of this species the external surface is essentially smooth with little or no radial ornamentation. Not until a later stage is reached (about 20 to 25 mm) does the radial ornamentation appear distinctly. Radial ribs often appear deceptively. As the shells weather, the grooves are commonly excavated more rapidly, and so they accentuate the ribs. Commonly, lines of growth also are accentuated on weathered specimens, forming distinct concentric ridges. Fine, very low radial lirae are present on the ribs on essentially unweathered parts of the shell. The beaks are lower in the earlier stages, and the ligamental area is relatively short with a correspondingly lesser number of ligamental grooves. The youngest specimens show but a small pit or single groove for the reception of the ligament.

Teeth must appear very early, for they can be distinguished on the youngest specimen at hand, which is 1.8 mm in length and height. Characteristic of the genus, the teeth are continuous in immature individuals but later commonly become obliterated at the central part of the hinge. On unweathered specimens, the contact surfaces of the hinge teeth are seen to be striated. Internal marginal crenulations do not appear to be present on the smallest specimen, but are evident on the next larger one (2.0 by 2.0 mm). Adductor muscle scars are subequal in the very young stages but are notably unequal (anterior adductor scar larger) at a stage represented by a length and height of 15 mm and 13.7 mm, respectively.

Pectunculus terebratularis Lamarck (Farchad, 1963, Pl. 21, Figs. 1a, 1b) from the Thanetian of the London basin seems to be closely similar to the Cannonball species. It may differ by having a bluntly terminated posterior margin, and more symmetrically placed beaks with respect to the ligamental area.

Glycymeris (Glycymerita) concava Marshall (Finlay and Marwick, 1937, p. 23, Pl. 2, Figs. 1, 6) from the Wangaloan (Danian) of New Zealand appears to be similar to *G. subimbricata* in its ornamentation, its somewhat subangulated posterior margin and the position of its beaks which appears slightly posterior to the mid-length.

Occurrence.—Cannonball Formation, localities 1, 8, 11, 29, 30, 31, 33, 34, 35, 36(?), 37, 45, 52, 68, 82(?), and 101.

Order Anisomyaria
 Superfamily Mytilacea
 Family Mytilidae
 Genus *Crenella* Brown, 1827

Original reference.—Brown, Thomas, 1827, *Illustrations of the Conchology of Great Britain and Ireland*, Pl. 31, Figs. 12–14 (not seen).

Type species.—By monotypy, *Mytilus decussatus* Montagu, 1808; Recent, North Atlantic and North Pacific (Soot-Ryen, 1955, p. 79, 81).

Diagnosis.—Characteristics of the genus which I followed are those given by Olsson (1961, p. 130).

Remarks.—This genus ranges geologically from the Cretaceous to the Recent. It is characteristic of cooler waters (Gardner, 1926a, p. 60).

Crenella cedrensis Stanton
 Pl. III, Figs. 3, 4

Crenella cedrensis Stanton, 1920, p. 25, Pl. 2, Figs. 9a–c.

Description.—Shell shortened subovate, strongly convex; beaks moderately prominent; dorsal margin slightly convex, ventral margin rather narrowly rounded; anterior margin broadly rounded, posterior margin more convex, joining dorsal margin with subangular outline; radial external ornamentation inadequately known, of fine (about 7 mm) low, flattened ridges wider than the interspaces at posteroventral margin; concentric growth lines fine and irregular.

Types.—Holotype, USNM 32397 (Stanton, 1920, Pl. 2, Figs. 9a–c; also refigured here, Pl. III, Figs. 3, 4 Cannonball Formation), USGS 8468.

Material.—Mainly two incomplete molds of both valves (some shell adheres), and one incomplete external mold of both valves, USNM.

Measurements (in millimeters).—

Length	Height	Width
ca. 13.0 (Holotype)	ca. 14.5	ca. 9.5

Remarks.—Judging from shape and external ornamentation, this species seems to be a *Crenella*. This assignment can only be confirmed when the internal characters are known because the holotype is merely an internal

mold of both valves (beak of left valve missing) with only a small area of adhering shell material. Only on the posterior and posteroventral margin of the left valve are there small fragments of the true exterior. Therefore, Stanton's (1920) Figure 9c (Pl. 2) does not show true external "sculpture," as one might be led to believe, but a remnant of the radial structure as seen on the exfoliated shell.

Stanton (1920, p. 25) implied having a specimen or specimens in addition to the holotype. The only other specimen of this species from the same locality as the holotype (USGS locality, 8468), which I observed at the United States National Museum, is an incomplete external mold of both valves.

Occurrence.—Cannonball Formation, localities 16 and 99.

Crenella stantoni Finlay

Pl. III, Figs. 9–11

Crenella elongata Stanton, 1920, p. 25–26, Pl. 2, Figs. 9a–c.

Crenella stantoni (nom. nov.) Finlay, 1927, p. 525.

Description.—Shell large, elongate-subovate, moderately convex; beaks rather prominent; dorsal margin curved, ventral margin probably narrowly rounded; anterior margin broadly rounded, posterior margin more convex; ornamentation of irregular growth lines, and possibly also fine radial element.

Types.—Holotype, USNM 32396 (Stanton, 1920, Pl. 2, Figs. 8a–8b; refigured here, Pl. III, Figs. 9, 10); Cannonball Formation, USGS 9126.

Material.—One right (?) valve (holotype) with much of shell missing, and few small, immature (?) specimens, USNM; one left valve probably of this species, UMMP.

Measurements (in millimeters).—

Length	Height	Width
ca. 15.0 (holotype)	ca. 25.0	ca. 14.0 (est.)

Remarks.—The selection of the holotype for this species is unfortunate. As Stanton (1920, p. 25) noted, this specimen is distorted. Part of the anterior margin is "tucked under" the specimen as shown by an irregular line of bending (Pl. III, Fig. 10). The distorted beaks appear to point toward the lateral margin which is less convex. A true external surface

does not appear to be present; a radial element of the shell structure is faintly seen on a small area of shell at the umbo.

In addition to the holotype, a few small specimens from USGS locality 8476 were also originally (questionably) assigned to this species. One of these specimens has internal crenulations along the posterodorsal margin. A radial element occurs on the shells of these specimens, but it is uncertain if the true exterior is present. One other small specimen (left valve), collected by the author (Pl. III, Fig. 11), is questionably assigned to this species. The exterior surface appears to be present, and a distinct radial ornamentation is not evident.

Because the internal characters are unknown and the external characters are generally uncertain, this species is doubtfully assigned to *Crenella*. For the same reason, one has no justification for changing the allocation and placing this species in any other genus.

The name change of this species from *Crenella elongata* to *C. stantoni* was necessitated because of preoccupation of the former name (Finlay, 1927, p. 525).

Occurrence.—Cannonball Formation, localities 20, 99, and 109.

Family Mytilidae

Genus *Arcuatula* (Jousseume) Lamy, 1919

Original reference.—Lamy, Edouard, 1919, "Les Moules et les Modioles de la Mer Rouge (d'après les matériaux recueillis par M. le Dr Jousseume) (Fin)," *Mus. Nat. d'Hist. Nat. Paris Bull.*, Vol. 25, No. 3, p. 173-74.

Type species.—By original designation, *Modiola plicatula* Lamarck 1819 = *Mytilus demissus* Dillwyn, 1817; Recent, east and west coasts of United States (Soot-Ryen, 1955, p. 56).

Diagnosis.—I follow Soot-Ryen's (1955, p. 55-56) diagnosis of this genus.

Arcuatula schallerensis (Stanton)

Pl. III, Figs. 6, 12-14

Modiolus schallerensis Stanton, 1920, p. 25, Pl. 3, Fig. 6.

Description.—Shell small, elongate-subovate; moderately convex, greatest width at about mid-length of shell; dorsal margin slightly convex, ventral margin (concave) medially; anterior margin very narrowly rounded, posterior margin narrowly rounded; beaks low, slightly posterior to the anterior extremity; external ornamentation of growth lines and low, flat-

tened to rounded ribs which are coarser on dorsoposterior and posterior parts of shell and at anterior extremity; ribs very faint on anteromedial part of shell, bifurcate dorsally and posteriorly; inner margin crenulate.

Types.—Holotype, USNM 32402 (Stanton, 1920, Pl. 3, Fig. 6, also refigured here Pl. III, Fig. 14), Cannonball Formation; hypotypes (here designated), USNM 132596 to 132598; all types from USGS 8384.

Material.—Four incomplete double-valved specimens (internal molds or with little shell remaining), one left valve (holotype, considerable shell absent), one right valve (little shell material remaining), and few other associated fragments questionably allied with this species, USNM.

Measurements (in millimeters).—

Length	Height	Width
ca. 15.0 (holotype)	ca. 7.5	ca. 6 (ca. 3.0)

Remarks.—The material shows few internal characters. I did not discern muscle scars. One specimen (Pl. III, Fig. 6, internal mold) shows a low, flattened, narrow ridge, with growth lines along the hinge which most probably represents a groove in the shell for the ligament.

Generally, there seems to be agreement that various *Modiolus*-like mytilids with radial ornamentation are not to be included under *Modiolus s. s.* (e.g., Olsson, 1961, p. 125, and Soot-Ryen, 1955, p. 57). Consequently, the present species can no longer be retained in this genus, and it seems reasonable to place this species in *Arcuatula*, although the characters of the hinge and muscle scars are incompletely known.

Occurrence.—Cannonball Formation, locality 74.

Family Mytilidae

Genus *Adula* H. and A. Adams, 1857

Original reference.—Adams, Henry, and Adams, Arthur, 1857, *The Genera of Recent Mollusca*, Vol. 2, p. 517.

Type species.—By monotypy, *Mytilus soleniformis* d'Orbigny, 1846; Recent, Panama to northern Peru (Olsson, 1961, p. 132).

Diagnosis.—Shell elongate, not cylindrical, usually (?) with ridge extending from beaks to posteroventral margin; beaks slightly anterior to mid-length to near anterior margin; external ornamentation smooth,

wrinkled, or radial; posterior adductor scars above mid-height of shell, confluent with posterior retractor scars mainly anterior to posterior adductor scars; ventral to posterior adductor scars are scars of retractors of siphonal mantle prolongations; crenulations on inner margins variable, being anterior, anterior and dorsal, or entirely smooth (modified after Soot-Ryen, 1955, p. 88 and Olsson, 1961, p. 132).

Remarks.—*Adula* has been treated variously as a subgenus of different genera. Examples are *Botula* Mörch (Franc, 1960, p. 2080; Abbott, 1954, p. 356), *Lithophaga* Röding (Dall, 1898, p. 799; Thiele, 1934, p. 800) and originally of *Perna* Adanson = *Modiolus* Lamarck (Adams and Adams, 1857, p. 517).

Living species of *Adula* occur from Peru to British Columbia and Japan and are generally borers, penetrating clay or soft shale (Soot-Ryen, 1955, p. 90–91) and rock (Olsson, 1961, p. 132).

Adula sp.

Pl. III, Figs. 15–18

Description.—Shell moderately elongate (height/length ratio .28 to .34) and convex (width/height ratio .67 to .81), with maximum width at about four-tenths of length of shell measured from anterior margin; dorsal margin slightly arched, ventral margin very slightly impressed; anterior and posterior margins rather narrowly rounded; beaks very near to anterior margin, at one-twentieth or less of total length of shell; posterior ridge extending from beaks to posteroventral margin, low and rounded; surface ornamentation smooth except for growth lines. Internally, dorsal margin with transverse crenulations, about eight per 0.5 mm; muscle scars and pallial line unknown.

Types.—Hypotype, UMMP 47330, locality 64.

Material.—One complete internal mold with fragments of shell, one internal mold of left valve, and few small fragments of shell and internal and external molds, UMMP.

Measurements (in millimeters).—

Length	Height	Width
13.1	3.7	3.0
7.0	2.4	ca. 1.6 (.8)

The boring habit of this bivalve is somewhat puzzling. Borings of this mollusk are closely associated with those of the teredinid, *Nototeredo*

globosa. In one specimen, the borings of these two species are directly adjacent. In two other specimens, the shells of both species are adjacent and occupy the same sediment-filled burrow. It seems most unlikely that both species could have occupied the same boring at the same time, and if this were not the case, did *Adula* sp. actually form its own boring and, in fact, was it truly a borer? It would seem that this species was a borer or an inhabitant of borings, but its position in a boring may not be normal. An abnormal occurrence is suggested in Pl. III, Fig. 15, in which a small gastropod and what appears to be a teredinid pallet occur in the same boring with *Adula* sp. and on the anterior side of the latter.

This species is considered new for the Cannonball, but it seems inadvisable to propose a formal name here, having to base it on two specimens and a few fragments.

Occurrence.—Cannonball Formation, localities 64 and 90.

Superfamily Pteriacea

Family Isognomonidae

Genus *Isognomon* [Humphrey, *ex* Solander MS.] 1786

Original reference.—Anonymous, 1786, *A Catalogue of the Portland Museum* . . . , p. 9, 41, 52, 115, 137 (not seen).

Type species.—By tautonymy, *Ostrea isognomon* Linné = *Isognomon lignea* Solander, 1786; Recent, Indo-Pacific (Olsson, 1961, p. 149).

Diagnosis.—I have followed Olsson's (1961, p. 149) diagnosis of this genus.

Remarks.—This bivalve has been variously and inconsistently referred to as *Pedalion*, *Perna*, *Melina*, and *Isognomon*. *Isognomon* is a relatively later usage, the citation of this name as used above is as noted by Cox (1954, p. 47), who followed the recommendations of the 1948 International Congress of Zoology.

Chavan and Cailleux (1957, p. 227) gave the range of *Isognomon* as Triassic to Recent.

Isognomon lloydi (Stanton)

Pl. IV, Figs. 1, 2

Perna sp. Stanton, 1914, p. 352.

Pedalion lloydi Stanton, 1920, p. 24, Pl. 4, Figs. 1a, 1b, and 2.

Description.—Shell elongate, thick (up to about 15 mm near middle of hinge); cardinal area with ligamental grooves usually slightly wider than

raised, flattened spaces between them; width of grooves may be up to three times the width of interspaces.

Types.—Lectotype (here designated) USNM 32408*a* (Stanton, 1920, Pl. IV, Figs. 1*a*, 1*b*; also refigured here, Pl. IV, Fig. 2); hypotypes, USNM 32408*b* (Stanton, 1920, Pl. IV, Fig. 2 and refigured here, Pl. IV, Fig. 1), 32408*c* and 32408*d*; all types from USGS 7968.

Material.—Several fragments, UMMP and USNM.

Measurements.—Because of fragmentary material, no measurements were attempted. An idea of size can be gained partly from the illustrations.

Remarks.—This species occurs at two localities (80 and 81) and possibly at a third (locality 74). I examined those specimens from locality 74, presumably seen by Stanton and cannot, with certainty, assign them to the present species.

This species, where its shells occur along the Cannonball River, is very fragile and difficult to collect. Until improved collecting techniques are devised to collect this species so all its characters can be seen, comparisons with other known species cannot be made.

Occurrence.—Cannonball Formation, localities 74(?), 80 and 81.

Family Pteriidae

Genus *Pteria* Scopoli, 1777

Original reference.—Scopoli, J. A., 1777, *Introductio ad Historiam naturalem* . . . , p. 397, Prague (not seen).

Type species.—By monotypy, *Mytilus hirundo* Linné, 1758; Recent, Mediterranean Sea and French Atlantic Coast (Dodge, 1952, p. 220–21).

Diagnosis.—Characteristics of this genus that I followed are those given by Stenzel, Krause, and Twining (1957, p. 80–81).

Remarks.—The name previously used for this genus is *Avicula* Klein, 1753. Gardner (1926*a*, p. 40) has indicated that the genus *Pteria* first appeared in the Silurian; various authors disagree with this, however.

Pteria linguaeformis (Evans and Shumard)

Pl. III, Fig. 7

Avicula linguaeformis Evans and Shumard, 1854, p. 163. Meek, 1859, p. 183, Pl. 1, Fig. 6.*Pteria linguiformis* (Evans and Shumard). Meek, 1864, p. 9. Meek, 1876, p. 32-33, Pl. 16, Figs. 1a-d. Whitfield, 1880, p. 384-85, Pl. 7, Figs. 2, 3.*Pteria linguaeformis* (Evans and Shumard). Stanton, 1920, p. 24-25, Pl. 3, Fig. 1.

Description.—Shell obliquely ovate-subtrigonal or linguiform, moderately convex, slightly inequivalved; hinge line nearly equal to maximum length in young specimens, proportionally shorter in adult specimens, may have narrow, marginal, posterior ridge on right valve; posterior auricle moderately long, pointed, compressed; anterior auricle narrow, pointed, somewhat produced, but less so than posterior auricle, defined by shallow, broad, marginal sinus, little, if any, deeper in right than in left valve; in right valve auricle separated from umbo by shallow groove extending from sinus to anterior side of beak. Beaks subequal, raised slightly above hinge line, at about one-fourth of length measured from anterior extremity; external ornamentation smooth, except for growth lines (after Meek, 1876, p. 32).

Types.—Hypotype, USNM 32398 (Stanton, 1920, Pl. 3, Fig. 1; also refigured here Pl. III, Fig 7, USGS 8468). The original types are presumably from the Pierre Formation (Upper Cretaceous), Sage Creek, Nebraska.

Material.—Left valve with some shell missing (USNM 32398) and incomplete right internal mold (USGS 9122); two small specimens (with radial shell structure?) tentatively referred to this species, UND.

Measurements.—The measurements, in millimeters, of the hypotype are:

Length	Height	Width
ca. 18.5	12.5	ca. 7.0 (ca. 3.5)

Remarks.—Stanton's (1920, p. 24-25) remark that this species is very rare in the Cannonball fauna is still true, for only two additional specimens, questionably referred to this species, have been discovered.

Occurrence.—Cannonball Formation, localities 5, 7, 16, and 99.

Superfamily Ostreacea
Family Ostreidae
Genus *Crassostrea* Sacco, 1897

Original reference.—Sacco, Federico, 1897, *I molluschi dei terreni terziarii del Piemonte e della Liguria*: Clausen, Torino, Vol. 23, p. 15 (not seen).

Type species.—By original designation, *Ostrea virginica* Gmelin; Recent, east and south coast of North America from Canada to Mexico (Stenzel, 1947, p. 172).

Remarks.—Besides occurring along the east coast of North America, living species of *Crassostrea* are found in the East Indies, and along the coasts of Japan and Australia (Gunter, 1950, p. 446). The geologic range of *Crassostrea* is presumably Cretaceous to Recent (Sohl and Kauffman, 1964, p. H7).

Crassostrea glabra (Meek and Hayden)
Pl. IV, Figs. 3–6; Pl. V, Figs. 10–12

Ostrea glabra Meek and Hayden, 1857, p. 146–47. Meek, 1876, p. 509–10, Pl. 40, Figs., 2a–d. White, 1883b, p. 421, Pl. 9, Figs. 1–4; Pl. 10, Figs. 1–5; Pl. 11, Figs. 1–4; Pl. 12, Fig. 1. White, 1884, p. 307–8, Pl. 58, Figs. 1–4; Pl. 59, Figs. 1–5; Pl. 60, Figs. 1–4; Pl. 61, Figs. 1–3. Stanton, 1917, p. 311, Pl. 79, Figs. 1–3.

?*Ostrea glabra* Meek and Hayden. Böse, 1906, p. 41–42, Pl. 2, Fig. 5. Böse, 1913, p. 43–45, Pl. 5, Figs. 5–14, Pl. 6, Figs. 1–10 and Pl. 7, Figs. 1–5.

Description.—Shell elongate-subovate, slightly arcuate laterally; left valve moderately convex, right valve flattened or slightly concave; beaks angular, may be pointed, generally abruptly curved (usually posteriorly); hinge line rather short; external ornamentation of growth lines or wrinkles (after Meek, 1876, p. 509–10).

Types.—Hypotypes, UMMP 47336 (locality 114), 47339 (locality 115), 47342 (locality 114), 47343 (locality 115), and 47344 (locality 114). The holotype (USNM 2165) is from the Clagett or Judith River Formation of Late Cretaceous age (Stanton and Hatcher, 1905, p. 105) at the mouth of the Judith River, Montana.

Material.—Five incomplete specimens with both valves, 43 incomplete left valves, 11 incomplete right valves and few fragments, UMMP.

Description of Cannonball material.—The shape of the shell is extremely variable and probably of little, if any, taxonomic importance;

it is generally elongate-subovate. The left valve is moderately convex and the right valve is flattened to slightly convex. On the margins of the shell, the valves are straight or not appreciably folded. The external ornamentation of the right valve consists of growth lines or wrinkles, whereas the left valve has growth lines or lamellae and possibly low, radial folds. The beaks are usually long and rather narrow, and they may be straight, curved posteriorly (more common) or anteriorly, and even show a tendency to being spiral; they may also be directed laterally toward the exterior of the left valve.

Internally, the recess under the hinge characteristic of the genus is usually present, but is not apparent on some specimens. The hinge line is usually moderately long, and the ligamental areas of both valves are high and subacutely tapering. The central part of the ligamental area (which bears the resilium) of the right valve is variable, flat to gently convex. A suggestion of crenulations on the valve margins lateral to the hinge is evident on a few incomplete specimens. The adductor muscle scars are near the posterior margin and ventral to the mid-height of the shell. The shape of the adductor scars is not known with certainty, but is probably subovate to curved, subteardrop-shaped.

Measurements.—No attempt was made to measure specimens because of the general incompleteness of the valves. One of the larger and more complete specimens of my material is shown on Pl. IV, Figure 6.

Remarks.—I believe that this species should be placed in the genus *Crassostrea*, because of the elongate shape, relatively deep left valve, recess under the hinge, and the laterally and distally positioned adductor muscle scars. Because of the wide variation in shell characters as affected and implemented by the environment, specific characters, as well as generic characters of members of the Ostreidae, are difficult to ascertain. Characters considered specific by Thomson (1954) are: (1) presence or absence of denticles or crenulations, (2) convexity of the valves, (3) external ornamentation, and possibly (4) position and outline of the adductor scars. In addition, McLean (1941) has considered the degree of folding of the valve margins and form of the beaks as of specific importance.

Keeping these characters in mind, it seems reasonable to assign the Cannonball species to "*Ostrea*" *glabra* Meek and Hayden. This appears to be a variable species, judging from the forms assigned to it by White (1883*b*, Pls. 9–12; 1884, Pls. 58–61). The type specimen (USNM 2165), examined by myself and figured by Meek (1876, Pl. 40, Figs. 2*a*–*b*)

is from near the mouth of the Judith River, Montana, and was collected from the Judith River or Clagett Formation (Stanton and Hatcher, 1905, p. 105). This specimen is an incomplete left valve and the true exterior is not present (therefore, the smoothness as suggested by the trivial name is not real); it has the following measurements (no allowances made for incompleteness):

Length	Height	Width (Valve)
45.1	75.6	ca. 21.0

Oysters, from what is now considered to be a tongue of the Cannonball Formation, were first discovered in southwestern North Dakota by Leonard (1908, p. 49), who described the locality as five miles southwest of Yule, in sec. 16, T. 135 N., R. 105 W. Yule is no longer in existence but was on the west side of the Little Missouri River at the present site of the Three V Ranch buildings in the SE $\frac{1}{4}$ sec. 25, T. 136 N., R. 105 W., Golden Valley County, North Dakota. My material is from two localities which are very near (probably 1 mile or less) to the place where Leonard first discovered oysters. The oysters occur in about 4 feet of brownish-black carbonaceous shale that overlies a lignite bed 2 feet thick. A main zone of oysters up to about 6 inches thick, has its base about 2.5 feet above the top of the 2-foot lignite. Thin oyster beds, 1 to 2 inches thick occur just above the main zone; oysters also occur at the extreme base of the carbonaceous shale in clusters more than 1 foot thick and up to about 10 feet wide. T. W. Stanton first referred the oysters to a single species, *Ostrea subtrigonalis* Evans and Shumard (Leonard, 1908, p. 49). In 1909 (p. 249) Stanton still believed all the oysters from near Yule belong to *O. subtrigonalis*, but in 1910 (p. 183) he said the oysters are referable to two species, *O. subtrigonalis* and *O. glabra*. It appears that the original types of *O. subtrigonalis* were never figured, and it is uncertain that the forms described and figured by Meek (1876, p. 509-10, Pl. 40, Figs. 1a-d) are of this species. If Meek's forms are considered representative of *O. subtrigonalis*, the present writer feels that this species is unrepresented in the Cannonball Formation. The types (USNM 2172) figured by Meek (1876) seem to differ from the Cannonball specimens in being generally smaller, more arcuate and in having a less convex left valve. Some question even exists as to whether *O. subtrigonalis* is a distinct species. Discussing the invertebrate fauna of the Judith River beds, Stanton (Stanton and Hatcher, 1905, p. 105) said this species, at two localities, is "... associated with *O. glabra*, with which it seems to be connected by intermediate forms."

The only other marine or brackish invertebrate in rather close proximity to the oysters appears to be *Corbicula* cf. *C. berthoudi* White. This species occurs about 6 feet above the top of the main oyster zone.

Occurrence.—Cannonball Formation, localities 114 and 115.

Order Eulamellibranchiata

Suborder Heterodonta

Superfamily Astartacea

Family Crassatellidae

Genus *Crassatella* Lamarck, 1799

Original reference.—Lamarck, J. B. P. A. de M. de, 1799, "Prodrome d'une nouvelle classification des coquilles," *Soc. Hist. Nat. Paris Mém.*, p. 85 (not seen).

Type species.—By monotypy (?), *Crassatella gibba* Lamarck, 1801 = *C. tumida* Lamarck, 1807, (*vide* Stewart, 1930, p. 135–35); Eocene of the Paris basin.

Diagnosis.—Shell thick, subtrigonal or subquadrangular, equivalve or slightly inequivalve; inequilateral, posterior region longer, posterior margin may be attenuate, rostrate, subangular or truncate. External surface smooth, or with concentric ridges and furrows, restricted or more prominent at the umbo. Lunule and escutcheon present. Ligament internal, received in a resilifer. Right valve with three cardinal teeth; *3a* (Fig. 3) weak, *3b* strong, *5b* weak, may be more or less effaced by the resilium (terminology of teeth after Bernard, 1895, p. 121 and Lamy, 1917, p. 199–200); anterior lateral (AI) slightly projecting, posterior lateral (PI) weak, at dorsal margin. Left valve with two cardinal teeth, *2* and *4b*; two slightly projecting laterals, AII (at dorsal margin) and PII. Adductor muscle scars distinct, with small distinct pedal scar above anterior adductor scar. Pallial line simple. Internal margins smooth or crenulate (after Gardner, 1943, p. 61–62 and Lamy, 1917, p. 198–200).

Remarks.—The anterior lateral of the left valve (AII) and the posterior lateral of the right valve (PI) are usually indistinct. Gardner (1943, p. 62) has treated these two teeth as merely beveled edges of the dorsal margin.

Two generic names have been used inconsistently for certain crassatellid bivalves; these names are *Crassatella* Lamarck, 1799 (or 1801) and *Crassatellites* Krüger, 1823. Lamy (1917, p. 197), Gardner (1943, p. 61) and Shuto (1957, p. 69–70) have discussed the use of these names.

Treating *Crassatella* in the broad sense, the geologic range is Late Cretaceous to Recent. Gardner (1943, p. 62) said there occur about 40 living species, most of which are tropical.

Crassatella evansi Hall and Meek

Fig. 3; Pl. V, Figs. 1-9

Crassatella Evansii Hall and Meek, 1855, p. 383, Pl. 1, Figs. 9a-e.*Crassatella (Pachythaerus) Evansi* Hall and Meek. Meek, 1876, p. 117-18, Pl. 17, Figs. 6a-d.*Crassatellites evansi* (Hall and Meek). Stanton, 1920, p. 28, Pl. 3, Figs. 7a-b, 8, 9.*?Eriphyla? mandanensis* Stanton, 1920, p. 28, Pl. 4, Fig. 3.

Description.—Shell ovate-subtrigonal, moderately thick and swollen; anterior margin rather narrowly rounded, posterior bluntly subtruncate; posterodorsal margin very slightly convex to nearly straight, anterodorsal margin noticeably concave; very slight, subdued ridge on posterior slope, extending from beaks to postero-ventral extremity. Beaks prosogyral, much elevated, and about half way between mid-length and anterior margin. Lunule oval and distinct; escutcheon narrow-lanceolate and indistinctly defined by obscure ridge on either side. External surface smooth except for fine, regular lines of growth. Resilifer extends to about two-thirds of distance to ventral border of hinge plate. Adductor muscle scars moderately well impressed; internal margin crenulate (after Meek, 1876, p. 117).

Types.—Hypotypes, UMMP 47344, 47347 and 47348 (locality 90) and UMMP 47350 (locality 89). The original types are from the upper part of the Pierre Shale (Upper Cretaceous) on the Cheyenne River at the mouth of Sage Creek, South Dakota (Stanton, 1920, p. 28).

Material.—Four complete specimens with both valves, five incomplete double-valved specimens, 10 left valves, three right valves and several fragments, UMMP; few fragments, UND.

Measurements (in millimeters).—

Valve	Length	Height	Width
Left	46.0	ca. 39.0	ca. 27.6 (13.8)
Left	40.1	33.7	ca. 24.8 (12.4)
Left	ca. 38.5	ca. 34.0	ca. 24.6 (12.3)
Double	37.0	ca. 34.0	ca. 25.0 (est.)
Double	33.0	28.1	ca. 21.0 (est.)
Double	31.3	28.0	ca. 17.5
Left	26.0	ca. 22.0	ca. 16.0 (8.0)
Right	25.2	22.2	ca. 15.4 (7.7)
Right	19.0	16.4	ca. 11.2 (5.6)
Right	16.0	ca. 13.5 (est.)	ca. 9.0 (4.5)
Left	ca. 14.0	ca. 13.0	ca. 9.0 (4.5)
Left	4.6	4.3	...
Left	2.8	2.6	ca. 1.6 (.8)

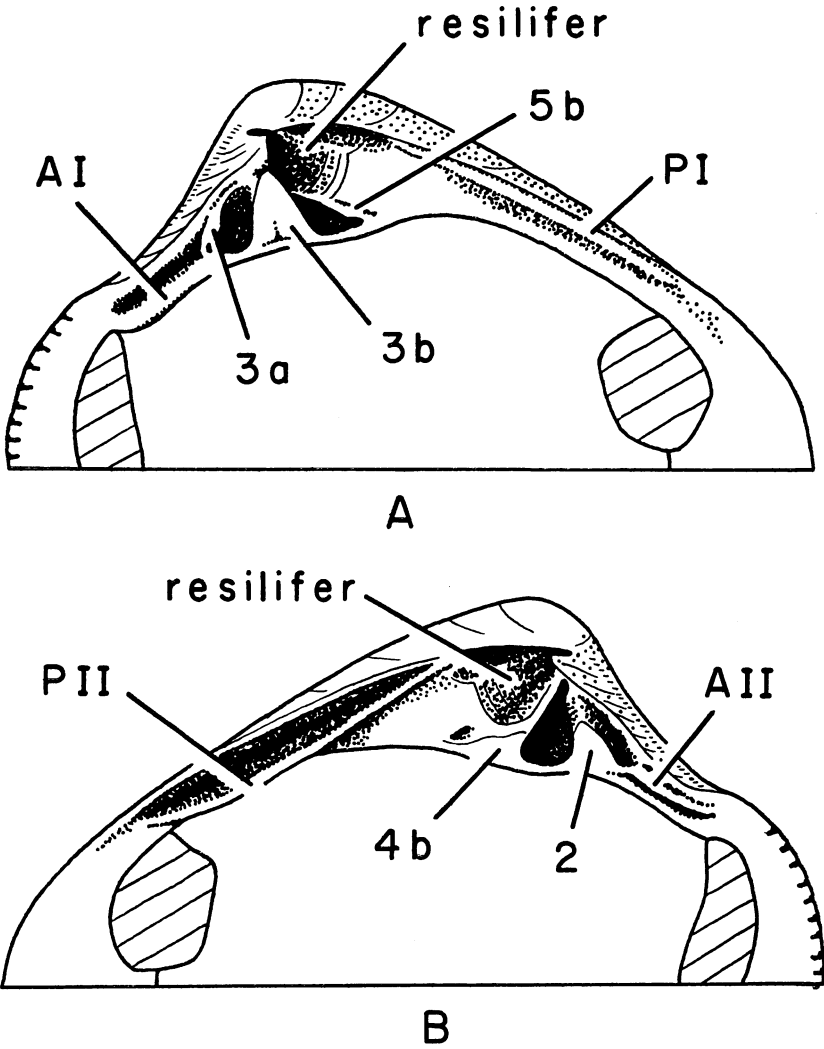


FIG. 3. Hinge characteristics of right (A) and left (B) valves of *Crassatella evansi* Hall and Meek, UMMP 47344, from Cannonball Formation, about six miles south-west of Leith (locality 90), Grant County, North Dakota. $\times 2.0$.

Remarks.—Young individuals of this species appear to be somewhat shorter and have a higher posterior truncation. The extension of the resifer on the hinge plate does not seem to vary appreciably with age. This is in contrast to certain species of *Crassatella* in which the resifer

extends to the ventral margin of the hinge plate in the young individuals, but fails to do so in the adults (Bernard, 1895, p. 121 and Stewart, 1930, p. 138). The crenulated internal margin does not seem to appear very early in this species; the smallest specimen on which it was observed measures about 31.0 mm by 27.5 mm in length and height, respectively.

Eriphyla? *mandanensis* Stanton is questionably placed in synonymy with this species because the type may be an immature specimen of *Crassatella evansi*. Young individuals of the latter species possess relatively pronounced concentric ridges, which are similarly present on *Eriphyla?* *mandanensis*, especially near the umbo. The type specimen of *Eriphyla?* *mandanensis* (USNM 32409, locality USGS 9120) is possibly a left valve. The margin is incomplete and no internal characters are observable.

Crassatella excelsa Cossman (1908, p. 50–51, Pl. 4, Fig. 68 and Pl. 5, Figs. 5–11) from the Montian of Belgium has a few similarities (e.g., general shape, and relative thinness and similar components of hinge plate) but differs noticeably in the beaks, which are less elevated and not directed so far forward as in the Cannonball species. Externally, the concentric ornamentation is more pronounced, consisting of very narrow lamellae over parts of the shell.

Occurrence.—Cannonball Formation, localities 5, 12, 13, 16(?), 19(?), 38, 50(?), 51, 78, 84, 85, 89, 90, 91, 92, 93, 94, 101(?), 103, 104 and 106.

Superfamily Sphaeriacea
Family Corbiculidae

Original reference.—Megerle von Mühlfeldt, J. K., 1811, "Entwurf eines neuen Systems der Schalthiergehäuse," *Magazin der Gesellschaft Naturforschender Freunde*, 5ter Jahrgang, Berlin, p. 56 (not seen).

Type species.—By monotypy, *Tellina fluminea* Müller 1774; Recent, southeastern Asia.

Diagnosis.—I followed Gardner's (1933, p. 154) diagnosis of this genus.

Remarks.—*Corbicula* is found in both fresh and brackish waters today. This genus ranges from the Cretaceous to the Recent.

Corbicula berthoudi White
Pl. VI, Figs. 3–6

Corbicula berthoudi White, 1882, p. 94, Pl. 4, Figs. 1–3; 1883b, p. 438, Pl. 21, Figs. 1–3. Stanton, 1920, p. 29–30, Pl. 5, Figs. 1a–b, 2–3.

Description.—Shell large, subtrigonal, moderately convex; beaks moderately to rather highly elevated; anterior margin rather broadly rounded,

posterior margin abruptly to rather narrowly rounded; dorsal margin slightly convex posteriorly, slightly concave anteriorly, ventral margin very broadly rounded; hinge plate heavy; external ornamentation smooth except for growth lines (after White, 1882, p. 94-95, Pl. 4, Figs. 1-3).

Types.—Hypotypes, USNM 32411 (Stanton, 1920, Pl. 5, Fig. 1a-b; also refigured here, Pl. VI, Figs. 3, 5, 6), USGS 7963 and USNM 32412 (Stanton, 1920, Pl. 5, Fig. 2 also refigured here, Pl. VI, Fig. 4), USGS 8439. The original types (USNM 11556) are from 15 miles north of Fremonts Orchard, Valley of the South Platte, Colorado.

Material.—Incomplete left and right valve (hypotypes), USNM.

Measurements.—Because of the incompleteness of specimens, measurements have not been attempted; a partial idea of size can be gained from the illustration.

Remarks.—In addition to the hypotypes mentioned above, Stanton (1920, Pl. 5, Fig. 3, USNM 32413) also figured an internal mold of a right valve as belonging to this species. Upon cleaning away the shell adhering to the hinge area, I found that not three, but *two* grooves are present in the sandstone, thereby indicating two cardinal teeth. Judging also by the size and convexity of this specimen, it, with little doubt, belongs to the species *Arctica ovata*, not *Corbicula berthoudi*. A partial case of the hinge of this specimen shows cardinal teeth identical with those of *A. ovata*.

Upon removal of poorly consolidated sandstone from the cavities of the hypotypes, two other features were revealed. The left valve shows an ovate anterior adductor scar with which is continued a short pedal (?) muscle scar on the under surface of the anterior part of the hinge plate. Medially, an assymetrical, rounded furrow extends ventrally from under the hinge plate; this medial groove is also weakly present on the incomplete right valve. The Cannonball specimens appear to differ from the types of this species (1) in having shorter anterior lateral teeth that do not "drape" to such an extent over the anterior adductor scars, and (2) in having longer and higher nymphs which do not appear granulose as do those on the types. Also, the Cannonball specimens appear to have their beaks less inflated and possess an internal, medial furrow.

Three of the four original types of *Corbicula berthoudi* White have the following measurements (in millimeters):

Valve	Length	Height	Width
Double	53.8	47.0	31.1
Left	ca. 62.0	54.1	...
Left	53.2	47.2	...

Occurrence.—Cannonball Formation, localities 20, and USGS 7963, 8439 and 8471.

Corbicula cf. *C. berthoudi* White
Pl. VI, Figs. 7–12; Pl. VII, Fig. 5

Types.—Hypotypes, UMMP 47333, 47335, 47337, 47338, 47340 and 47345 (locality 115).

Material.—Twenty-four incomplete specimens with conjoined valves, 9 incomplete right valves (three with discernible cardinal teeth), 7 incomplete left valves (six with cardinal teeth, of which four specimens have teeth which are only partly discernible), and 2 undetermined, incomplete valves. Most of the specimens are weathered. All specimens are characteristically light brown, which may not be due to weathering, and distorted, and many have only the dorsal parts remaining; also, most specimens are partially encrusted with selenite; UMMP.

Measurements.—No measurements were made because of the incompleteness and distortion of the material. An idea of size and proportion can be gained from the illustrations.

Remarks.—The specimens under study are placed with reasonable assurance in the genus *Corbicula*, although they are generally incomplete and not all morphological characters can be seen. Three cardinals occur in each valve, but the lateral teeth are somewhat doubtful. Shape and ornamentation (and coloration), however, are affected remarkably in living species by the environment (Sinclair and Isom, 1963, summary of literature) and these characters are generally unreliable. An incomplete posterior lateral is present on one left valve and what appears to be an elongate anterior lateral exists on another. The laterals appear to be crenulated transversely as is true of the anterior lateral socket of a right valve.

The Cannonball specimens are tentatively compared with *C. berthoudi*, because size and proportion suggest affinities with this species. It is desirable to know the true shape and exact external ornamentation of the shells before making final specific assignment.

This species from the Cannonball was first discovered by R. W. Brown of the United States Geological Survey in 1931 (Brown, 1962, p. 8) at fossil locality 113 (USGS 16000) on the east bank of the Little Missouri River; this corbiculid was found associated with *Bicorbula subtrigonalis* (Meek and Hayden). Unaware of Brown's discovery, I discovered inde-

pendently, this same species at fossil locality 115 (about 1½ miles west-northwest of locality 113). At this locality *Corbicula* cf. *C. berthoudi* occurs about six feet above the main oyster zone of *Crassostrea glabra* (Meek and Hayden), which is about 2.5 feet above a two-foot thick lignite. The occurrence of *Corbicula* cf. *C. berthoudi* in a very dark gray to black, carbonaceous shale, and separated but little vertically from *Crassostrea glabra* and lignite, suggests this to be a brackish water species.

Occurrence.—Cannonball Formation, localities 113, 114, 115, and USGS 15999.

Corbicula cytheriformis (Meek and Hayden)

Pl. VI, Figs. 1, 2

Cyrena (*Corbicula*?) *cytheriformis* Meek and Hayden, 1860a, p. 176.

Corbicula cytheriformis Meek and Hayden. Meek and Hayden, 1860b, p. 432. Meek, 1876, p. 520–21, Pl. 40, Figs. 5a–e. White, 1883a, p. 74, Pl. 21, Figs. 4a–d; 1883b, p. 437, Pl. 22, Figs. 1–6. Stanton, 1917, p. 316, Pl. 82, Fig. 4; 1920, p. 29, Pl. 5, Figs. 4a–b.

Description.—Shell medium to large, transversely ovate-subtrigonal to subcircular, moderately convex, rather thick; margins of shell generally rounded, or posterior may be slightly subtruncate, dorsal margin slightly concave anteriorly, slightly convex posteriorly. Beaks moderately prominent, anterior to the mid-length of the shell; external ornamentation smooth except for growth lines (after Meek, 1876, p. 520).

Types.—Hypotype, USNM 32414 (Stanton, 1920, Pl. 5, Figs. 4a–b; also refigured here, Pl. VI, Figs. 1, 2), USGS 8384. The original types are from the Judith River Formation near the mouth of the Judith River, Montana.

Material.—One nearly complete left valve (hypotype given above) and several incomplete valves, mainly only hinges, USNM.

Measurements (in millimeters).—

Length	Height	One-half Width
(Hypotype USNM 32414) ca. 28.0	ca. 25.5	ca. 10.0

Remarks.—I examined the type specimens (USNM 2133) of this species which were collected from the Judith River Formation near the mouth of Judith River, Montana. The type material consists of nine double-valved, mostly incomplete specimens and two fragments. These

specimens generally lack internal characters; only two specimens exhibit teeth and these indistinctly. Three of the type specimens have the following measurements in millimeters (most of the specimens are larger):

Length	Height	Width
30.2	ca. 27.5	ca. 19.5
25.0	ca. 23.0	15.2
ca. 34.0	31.0	ca. 20.5

Since the internal characters of *C. cytheriformis* are generally lacking, some doubt exists that the Cannonball specimens are of this species, for shape and proportion are the only criteria available. It seems best, however, to retain Stanton's (1920) original assignment until more Cannonball material can be compared with this species. The Cannonball specimens seem to differ from those assigned to *C. berthoudi* in being smaller and having shorter and lower ligamental nymphs.

Occurrence.—Cannonball Formation, localities 25(?), 74 and USGS 8390(?).

Superfamily Arcticea

Family Arctidae

Genus *Arctica* Schumacher, 1817

Original reference.—Schumacher, C. F., 1817, *Essai d'un nouveau système des habitations des vers testacés*, p. 145–46.

Type species.—*Venus islandicus* Linné, 1767 = *Arctica vulgaris* [*nomen vanum*] Schumacher, 1817; by subsequent designation of Children 1823, (*vide* Kennard *et al.*, 1931, p. 9).

Diagnosis.—Shell equivalve, oval-cordiform to suborbicular, moderately convex, inequilateral, concentrically striated. Beaks prosogyral; no lunule; ligament opisthodontic, borne on flattened nymphs. Hinge formula AI : AIII 3a : 3b : (5b) PI (numerical assignment of teeth after

AI 2a : 4b PII

Bernard, 1895, p. 130; this paper, Figure 4; right valve with two cardinals, a short and projecting anterior (3a) and an oblique and bifid posterior (3b); supplementary tooth 5b may be present, extending up to one-half of length of ligamental nymph; two weak anterior laterals, the dorsal AIII in continuity with 3a, ventral to which is AI; projecting posterior lateral PI isolated. Left valve with two cardinals, a strong, nearly perpendicular

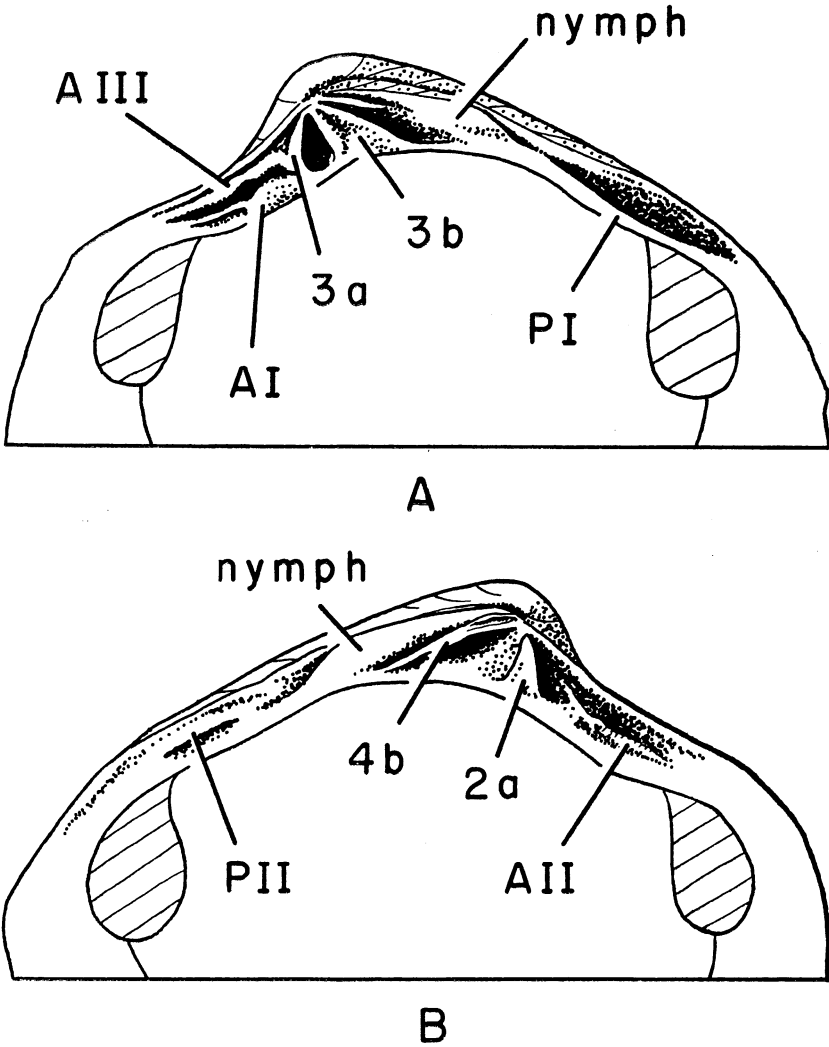


FIG. 4. Hinge characteristics of right (A) and left (B) valves of *Arctica ovata* (Meek and Hayden), UMMP 47341, from Cannonball Formation, 1.2 miles south of Fallon (locality 52), Morton County, North Dakota; small tooth (may be labelled 5b) is dorsal to 3b in right valve. $\times 1.2$.

anterior (2a) and an oblique and elongate posterior (4b); anterior lateral AII projecting and crenulated, posterior lateral PII very weak. Adductor muscle scars oval, subequal, anterior adductor scar continuous with scar

of pedal muscle on under surface of anterior part of hinge plate. No pallial sinus; interior of ventral margins smooth (mainly after Lamy, 1920a, p. 261–62; with consideration to Cossmann and Peyrot, 1912, p. 456, and Nicol, 1951, p. 103).

Remarks.—Considerable disagreement has resulted as to the generic name for the marine bivalve originally designated *Venus islandicus*. Names most commonly advocated are *Cyprina* Lamarck, 1812 (e.g., Lamy, 1920a, p. 260), *Cyprina* Lamarck, 1818 (Thiele, 1934, p. 856) and *Arctica* Schumacher 1817 (e.g., Nicol, 1951, p. 102–6). *Arctica* Schumacher 1817 has been established as the proper name (Hemming, 1944, Opinion 5, Vol. 1, Pt. 15, pp. 115–26). A much later synonym is *Cypriniadea* Rovereto 1900. Lengthy generic synonymies were given by Dall (1903, p. 1500), Smith (1912, p. 106) and Nicol (1951, p. 102). It is noted that *Cyclas* Link 1807 was supported by Dall (1903, p. 1500–1501), who was shown to have erred (Smith, 1912, p. 105; Dall, 1913, p. 286).

The geologic range of *Arctica* is early Cretaceous to the Recent. It is represented today by the single, type species, *A. islandica*, which is boreal and occurs in the North Atlantic. Distribution of this species is: off the coasts of northeastern United States, Newfoundland, Labrador, Greenland, Iceland, and Europe. *Arctica islandica* is usually found on sandy mud or mud bottoms, most commonly at depths of 10 to 280 meters (Nicol, 1951, p. 104–6).

Arctica ovata (Meek and Hayden)

Fig. 4; Pl. VII, Figs. 1, 4, 6, 7; Pl. VIII, Figs. 6, 7

Cyprina ovata Meek and Hayden, 1857, p. 144. Meek, 1876, p. 146–47, Pl. 29, Figs. 7a–c, text Fig. 8.

Cyprina compressa Meek and Hayden, 1857, p. 144.

Cyprina ovata var. *compressa* Meek, 1876, p. 147, Pl. 30, Fig. 11.

Cyprina ovata var. *alta* Whiteaves, 1885, p. 40, Pl. 5, Fig. 3.

Arctica ovata (Meek and Hayden). Stanton, 1920, p. 27–28, Pl. 4, Figs. 4, 6a–b.

Arctica ovata var. *compressa* (Meek). Stanton, 1920, Pl. 4, Fig. 5.

Description.—Shell ovate to transversely ovate, relatively compressed to moderately convex; anterior and posterior margins rather narrowly rounded, dorsal margin very slightly convex as traced posteriorly; beaks slightly to moderately elevated, more than one-fourth to one-third the length of the shell from the anterior margin.

Types.—Hypotypes, UMMP 47328 (locality 12) and 47341 (locality 52) and UND 953 (locality 34). The holotype (USNM 306) is from the Cannonball Formation at the mouth of Heart River, North Dakota.

Material.—Two matched specimens with both valves, five right valves,

two left valves and numerous fragments and a few internal molds, UMMP; one matched specimen with both valves, two right valves, three left valves and numerous fragments and few internal molds, UND.

Measurements (in millimeters).—

Valve	Length	Height	Width
Left	ca. 83.0	70.5	...
Right	ca. 75.0	64.0	...
Double	72.1	58.7	35.7
Double	ca. 70.0	59.6	32.5
Left	ca. 68.0 (est.)	53.4	...
Right	67.5	55.0	...
Right	66.8	ca. 53.0	...
Double	ca. 59.5	51.8	29.0
Left	53.2	42.1	...
Left	29.0	ca. 25.0	...

Remarks.—I have examined eighteen specimens of *A. islandica* housed at the University of Michigan Museum of Zoology. These specimens were collected from Norway, Iceland, Massachusetts, and Maine. The hinge of the living species is remarkably similar to that of *A. ovata*, as pointed out earlier (Meek, 1876, p. 146). Tooth 5b (Fig. 4) of the right valve in the living species is variably present, as is true of *A. ovata*. Both species show a variable amount of callus below the dorsal part of tooth 4b in the left valve. Specimens of *A. islandica* show a very narrow extension of the posterior adductor scar passing along the under surface of the posterior part of the hinge plate, directly below the posterior lateral teeth. This narrow scar, possibly a place for attachment of pedal muscles, is also present in *A. ovata* and very probably is a generic character. *Arctica ovata* differs from *A. islandica* in being generally more elongate (i.e.; ovate), less swollen and is perhaps smaller (no specimens have been seen which attain the size of those of *A. islandica*). Internally, the anterior part of the hinge plate is longer, resulting in longer anterior laterals than those in the living species.

In the original description of *A. ovata*, Meek and Hayden (1857, p. 144) mentioned the resemblance of this species to *Cyprina oblonga* d'Orbigny from the Cretaceous of France (d'Orbigny, 1847-1849, p. 105-6, Pl. 277, Figs. 1-4). Other differences than those cited by Meek and Hayden seem to be present and this is possibly not a closely allied species. The beaks of *C. oblonga* are situated more anteriorly and d'Orbigny's figures also indicate a slight oblique truncation at the dorsoposterior margin which is not present in *A. ovata*.

No species known to the writer closely resembles *A. ovata*. *Cyprina scutellaria* Lamarck (Cossmann and Pissarro, 1904–1906, Pl. 16, Fig. 68–1 from the Thanetian of the Paris basin is somewhat similar in its ovate shape, but is a higher shell, has more elevated beaks, and appears to possess a heavier hinge plate.

Occurrence.—Cannonball Formation, localities 7, 8, 11, 12, 13, 16, 19, 20, 22, 24, 25, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 41, 42, 43, 45, 49, 52, 55, 60(?), 62(?), 70, 73, 88, 89, 95, 100, 101(?), 104 and 106.

Superfamily Lucinacea

Family Lucinidae

Genus *Miltha* H. and A. Adams, 1857

Original reference.—Adams, Henry, and Adams, Arthur, 1857, *The Genera of Recent Mollusca . . .*, Vol. 2, p. 468.

Type species.—By monotypy, *Lucina childreni* Gray, 1825; Recent, coast of Brazil.

Diagnosis.—I followed Chavan's (1938, p. 65) diagnosis of this genus.

Remarks.—*Miltha sensu stricto* appears to range from the Paleocene (Montian) to the Recent (Chavan, 1938, p. 66).

Subgenus *Plastomiltha* Stewart, 1930

Original reference.—Stewart R. B., 1930, pp. 191–92.

Type species.—By original designation, *Cyclas claibornensis* Conrad, 1865; early Eocene of eastern and southern United States.

Diagnosis.—Chavan (1938, p. 75–76) has given a diagnosis of this subgenus.

Remarks.—The geologic range of *Plastomiltha* is tentatively given as early Eocene to Pliocene (Stewart, 1930, p. 191). Chavan (1938, p. 77) said it is probable that Recent representatives of this subgenus may exist.

Miltha (Plastomiltha) cedrensis (Stanton)

Fig. 5; Pl. VIII, Figs. 8, 9, 12

Lucina occidentalis (Morton). Stanton, 1914, p. 352.

Lucina cedrensis Stanton, 1920, p. 30, Pl. 3, Figs. 10a–b, 11a–b.

Description.—Shell subcircular with height about equal to length; dorsal areas faintly marked; lunule approximately symmetrical, relatively

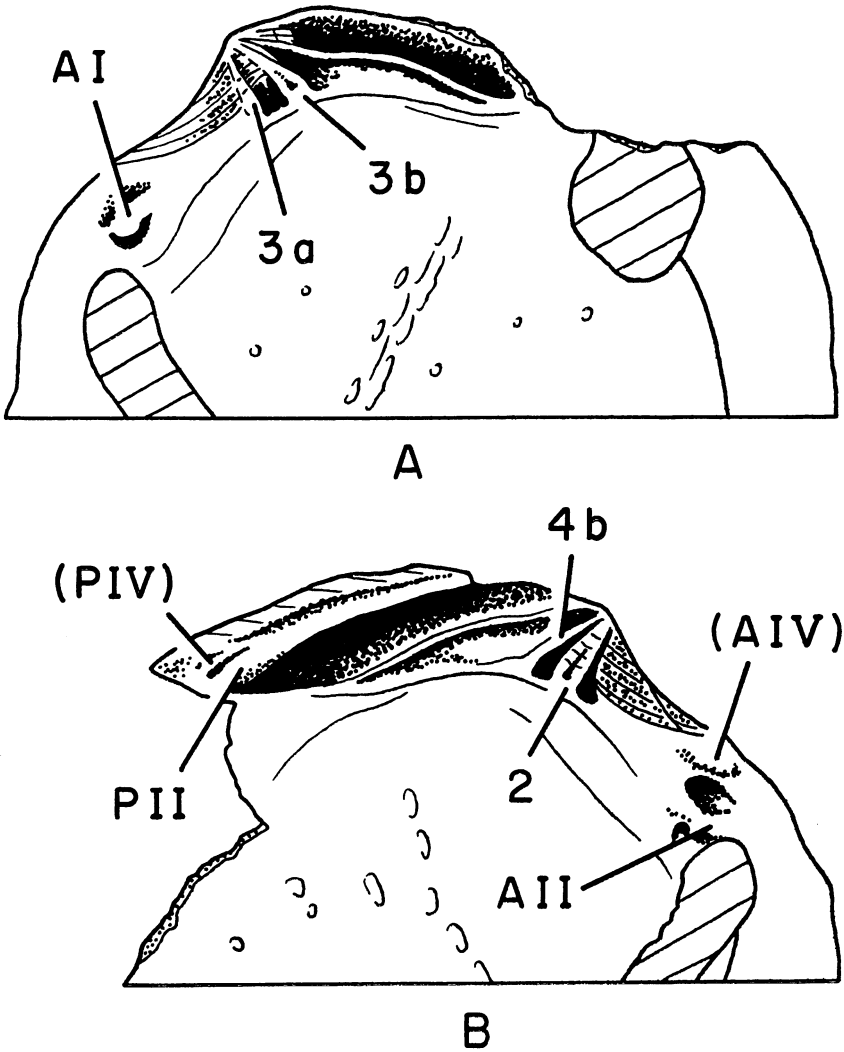


FIG. 5. Hinge characteristics of right (A) and left (B) valves of *Miltha (Plastomiltha) cedrensis* (Stanton), UMMP 47357, from Cannonball Formation, about six miles southwest of Leith (locality 90), Grant County, North Dakota. $\times 1.9$.

long and deep, invading hinge area; ligamental area deeply sunken; external ornamentation of very fine, closely set, concentric lines (ridges and striae; upon exfoliation shell shows slight radial structure); besides distinct cardinal teeth 3a, 3b, 2, and 4b, relatively weak lateral teeth are present (Fig. 5); AI bluntly subconical; AII bluntly subconical and less projecting

than AI, a suggestion of AIV; PII very weak, dorsal to which is a short ridge that may be PIV; anterior adductor muscle scars straight, somewhat shortened; series of scars under umbones and anterior part of hinge plate; linear belt of short, elongate scars extends from near middle of posterior part of hinge anteroventrally to about two-thirds of distance to margin of shell; also small, subcircular scars scattered over central part of shell.

Types.—Hypotype UMMP 47375 (locality 90). The holotype (USNM 32406) is from the Cannonball Formation, USGS 7969.

Material.—One nearly complete double-valved specimen and one incomplete right valve, UMMP; one small, incomplete right valve, two incomplete internal molds and one incomplete external mold of right valve, UND.

Measurements (in millimeters).—

Valve	Length	Height	Width
Right	ca. 37.0	ca. 35.5	...
Double	ca. 36.0	33.5	ca. 13.0

Remarks.—Chavan (1937, 1938) has critically studied the Lucinidae and suggested a scheme of evolution of this group. I was not able to fit the Cannonball species, with certainty, into any member of Chavan's classification. Therefore, this species is placed provisionally in *Plastomiltha*. The most obvious difference is the presence of lateral teeth, although they are generally relatively weak. Chavan (1938, p. 76) said lateral teeth are missing in this subgenus except for a slight, elongate protruberance in the type species. Another difference appears to be the more deeply sunken ligamental area in the Cannonball species. If these and other more minor characters are subgenerically valid, the Cannonball species may belong to a distinct group.

Whatever the true generic (and subgeneric) assignment of this species, it is clear that it can no longer be retained in *Lucina*. Chavan (1952, p. 119–20) has discussed what species should be the type of *Lucina*, a question of *Venus pennsylvanica* Linné or *Venus jamaicensis* (Spengler). If *L. pennsylvanica* were the type, the Cannonball species would differ from a typical *Lucina* in lacking well-defined dorsal areas, having a sunken ligamental groove, being much less convex (swollen), and having a much differently oriented lunule. Using *L. jamaicensis* as type, the Cannonball species would differ from a *Lucina* in lacking well-defined dorsal areas, having a sunken

ligamental groove, and possessing cardinal tooth *3a*, which is said to be lacking in *Lucina* (Chavan, 1937, p. 238). Concerning the last point, Lamy (1920*a*, p. 169), using *L. jamaicensis* as the type species for *Phacoides* Blainville 1825, gave a diagnosis which indicated the presence of tooth *3a*, but said, “. . . *3a* parfois peu visible sur le bord lunulaire, . . .” *Phacoides* is considered to be a vernacular name and has no status (Chavan, 1952, p. 120–21).

Phacoides ambiguus Defrance from the Eocene of Cotentin (Cossmann and Pissarro, 1904, p. 14–15, Pl. 6, Figs. 12, 14, 24 and 25) is generally similar but has notable differences. It is higher, has a somewhat less sunken ligamental groove, a slightly truncated posterior margin, and more pronounced growth lines.

Phacoides uncinatus Defrance (Cossmann and Pissarro, 1904–1906, Pl. 26, Fig. 82–37 and Farchad, 1936, Pl. 21, Figs. 5*a*, 5*b*) from the Thanetian of the Paris basin resembles the Cannonball species in having a deeply sunken ligamental groove and a relatively short anterior adductor scar. The Paris basin species, however, differs noticeably in having its beaks farther posteriorly and does not appear to possess anterior lateral teeth.

Occurrence.—Cannonball Formation, localities 16, 44, 90, 92 and 106.

Superfamily Veneracea

Family Veneridae

Genus *Dosiniopsis* Conrad, 1864

Original reference.—Conrad, T. A., 1864, “Notes on shells with descriptions of new fossil genera and species,” *Phila. Acad. Nat. Sci. Proc.*, p. 213, 2 figs.

Type species.—By monotypy (?) *Cytheria lenticularis* Rogers and Rogers, 1839; *Dosiniopsis meeki* Conrad, 1864, originally given as type, is a variety of this species (Clark, 1896, p. 78); Eocene of eastern United States.

Diagnosis.—I followed Tremlett (1935, p. 7) for characters of this genus.

Remarks.—In addition to the characters discussed by Tremlett (1953, p. 7), AII (Fig. 6) has been described as rugose, the nymphs as finely granulated, and the pallial sinus as “. . . ascending, rounded or subangular” (Jukes-Browne, 1914, p. 65). Palmer (1927, p. 214) gave the geologic range of *Dosiniopsis* as Cretaceous to Eocene.

Dosiniopsis deweyi (Meek and Hayden)

Fig. 6; Pl. VII, Figs. 2, 3; Pl. 1, Figs. 13, 14, 16-18

Cytherea Deweyi Meek and Hayden, 1856*b*, p. 83.*Meretrix Deweyi* (Meek and Hayden). Meek and Hayden, 1860*a*, p. 185 [name change only].*Callista Deweyi* (Meek and Hayden). Meek and Hayden, 1861, p. 443.*Dione Deweyi* (Meek and Hayden). Meek, 1864, p. 13 [name listed only].*Callista (Dosiniopsis?) Deweyi* (Meek and Hayden). Meek, 1876, p. 182-83, Pl. 17, Figs. 15*a-e*.*Callista (Dosiniopsis?) deweyi* (Meek and Hayden). Stanton, 1920, p. 31, Pl. 5, Figs. 11, 12.*Callista (Dosiniopsis) nebrascensis* (Meek and Hayden). Stanton, 1920, p. 30-31, Pl. 5, Figs. 9, 10.*Trigonocallista deweyi* (Meek and Hayden). Shimer and Shrock, 1944, p. 427, Pl. 170, Figs. 6, 7.

Description.—Shell subcircular or bluntly subovate, relatively thin, moderately convex; beaks not very prominent, slightly anterior to the mid-length of shell; external ornamentation smooth except for fine, regular, prominent growth lines; adductor muscle scars shallow, anterior scar narrow-ovate, posterior scar broad-ovate; pallial sinus broad, angular, forming an angle of about 35 degrees (after Meek, 1876, p. 182).

Types.—Hypotypes, UND 9532 (locality 33) and 9533, 9534, 9535, 9536 (all locality 34). The holotype (USNM 341) is from the Fox Hills Sandstone (Upper Cretaceous), Moreau River, South Dakota.

Material.—One small right valve, a small left valve, a few incomplete valves and several fragments, UMMP; nine incomplete matched valves, two nearly complete left valves, two nearly complete right valves, and several incomplete valves and fragments, UND.

Measurements (in millimeters.—

Valve	Length	Height	Width
Left	39.3	ca. 37.0	20.0 (ca. 10.0)
Double	ca. 37.5	ca. 33.5	36.0 (ca. 18.0 est.)
Left	ca. 32.5	31.6	18.0 (9.0)
Left	ca. 31.5 (est.)	ca. 29.0	17.0 (ca. 8.5)
Right	28.9	25.9	15.6 (7.8)
Right	28.0	ca. 26.0	15.4 (7.7)
Right	ca. 22.0 (est.)	ca. 20.0 (est.)	11.0 (ca. 5.5 est.)
Right	20.5	20.1	13.8 (6.9)

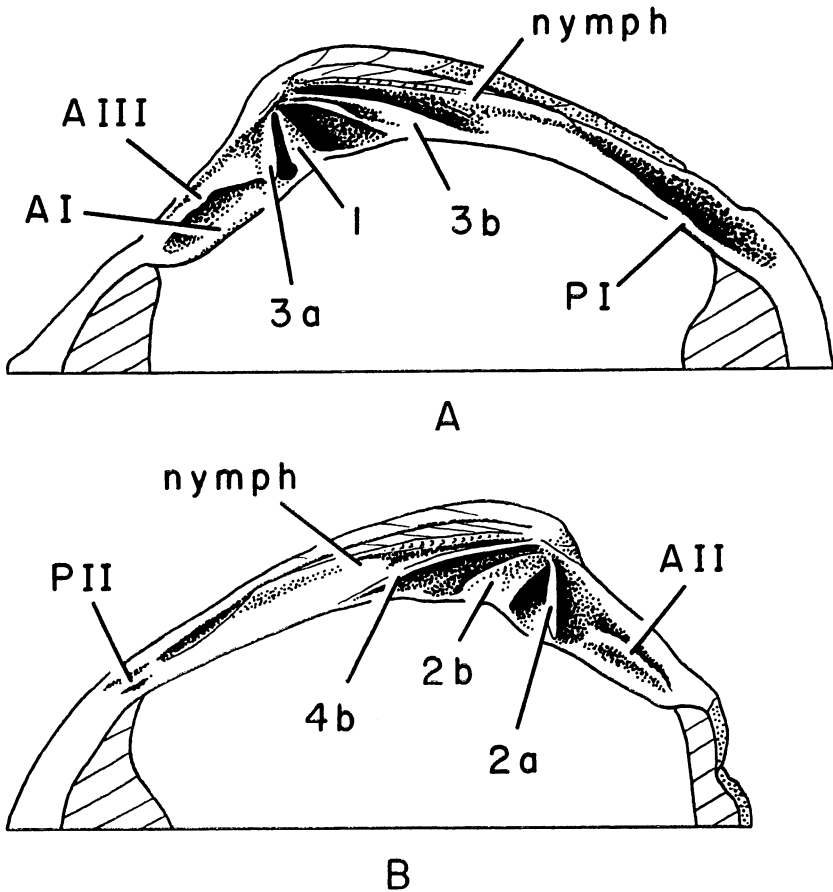


FIG. 6. Hinge characteristics of right (A) and left (B) valves of *Dosiniopsis deweyi* (Meek and Hayden), UND 9532, from Cannonball Formation, 1.8 miles south of St. Anthony (locality 33), Morton County, North Dakota. $\times 2.4$.

Remarks.—This species was placed in the genus *Trigonocallista* by Shimer and Shrock (1944, p. 427). *Trigonocallista* includes those forms which are trigonal and have a well-marked escutcheon (among other characters), neither of which are characteristic of *Dosiniopsis deweyi*. Earlier, Meek (1876, p. 182), followed by Stanton (1920, p. 31) placed the species in the section *Dosiniopsis* of the genus *Callista*. Meek (1876, p. 179), however, doubtfully proposed this arrangement. Some characteristics of *Callista* which distinguish it from *Dosiniopsis* are the oval or elongate shape of the

shell, the often, subsurface radial ornamentation and the absence of posterior laterals except for occasional vestiges of PII and PIII (Tremlett, 1953, p. 14).

Stanton (1920, p. 30–31) said two species of *Dosiniopsis* occur in the Cannonball, *D. nebrascensis* and *D. deweyi*. Originally, *D. deweyi* was said to be more convex (inflated) than *D. nebrascensis*. Examination of the type specimens (USNM 341 and 343, latter *D. nebrascensis*) failed to show any added differences. Also, Meek (1876, p. 185–86) stated that *D. nebrascensis* “. . . was founded upon young, or less developed, and slightly more compressed individuals . . .” and based his description on “. . . large, fully-developed specimens . . .” There appears to be doubt as to the validity of both of these species.

I prefer to place all the Cannonball specimens in one species of *Dosiniopsis*. There appear to be no valid and consistent differences upon which to separate the material into two groups. Several specimens from one locality are variable in shape and width of shell, and the variations appear to be interconnected and indistinct. The Cannonball specimens are assigned to *D. deweyi* rather than *D. nebrascensis* mainly because the original types of the former species are more complete and show the morphological characters better.

Some morphological details of the Cannonball specimens are to be noted. The lunule is subovate and faintly circumscribed. The lateral teeth PI and PII are short and rather weakly developed with PI the more projecting (Fig. 6). Scars of the adductor muscles are subovate and subequal, the posterior scar being slightly larger. A pedal (?) scar, relatively short and broad, on the under anterior part of the hinge plate, is continuous with the anterior adductor scar. The posterior adductor scar continues on the under surface of the posterior part of the hinge plate, where it is relatively long and narrow. The disposition and shape of muscle scars on the under surface of the anterior and posterior sides of the hinge plate is essentially the same as for *Arctica ovata* (Meek and Hayden).

Dosiniopsis subrotunda (Sowerby) (Woods, 1908, p. 181, Pl. 28, Figs. 1–6) from the Cretaceous of England is a rather closely similar species which differs from the Cannonball bivalve in possessing a depressed escutcheon with a sharp border. *Dosiniopsis orbicularis* (Edwards) (Cossmann and Pissarro, 1904–1906, Pl. 12, especially the two interiors of Figure 52–3) from the Thanetian of the Paris basin, seems to be very similar, differing in that the beaks appear to be slightly more anteriorly directed (especially as seen on the right exterior view). *Dosiniopsis bellowacina* (Deshayes) from the Thanetian of the London and Paris basins (Tremlett, 1953, p.

7-9, Pl. 1, Figs. 1-3) also appears to be very similar, differing mainly in having the anterior end of the shell somewhat produced. *Dosiniopsis fallax* Deshayes (Farchad, 1936, Pl. 20, Fig. 3) from the Thanetian of the Paris basin is generally similar but seems to differ in having a higher shell which is possibly also heavier, especially in the area of the hinge and beaks.

Occurrence.—Cannonball Formation, localities 11, 12, 15, 16, 17, 19, 20, 24, 25, 29, 31, 32, 33, 34, 36, 37, 39(?), 42, 45, 51, 52, 64, 74, 86, 89, 91, 92, 95, 104, 106, 107 and 110(?).

Suborder Adapedonta
Superfamily Saxicavacea
Family Saxicavidae
Genus *Panopea* Ménéard, 1807

Original reference.—Ménéard de la Groye, F. J. G., 1807, Sur un nouveau genre de coquille de la famille de Solénoïdes (*Panopea*),” Paris, *Mus. Hist. Nat. Annal.*, IX, p. 135; *Journ. de Phys.*, Vol. 65, 1807, p. 114 (not seen).

Type species.—By monotypy, *P. aldrovandi* Ménéard = *Mya glycymeris* Born; Recent, Mediterranean Sea (Oyama, Mizuno, and Sakamoto, 1960, p. 207).

Diagnosis.—I follow Olsson and Harbison (1953, p. 150) for a diagnosis of this genus.

Remarks.—Considerable disagreement exists regarding the correct spelling of the generic name and the type species. I make no attempt to discuss or resolve these difficulties. Gardner (1928, p. 237) gave the geologic range of *Panopea* (spelled *Panope*) as Cretaceous to Recent. Some writers have extended the range of this genus back to the Triassic.

Panopea? cf. *P. simulatrix* Whiteaves
Pl. VIII, Fig. 15

Panopaea simulatrix Whiteaves, 1885, p. 11-12, Pl. 2, Figs. 2, 2a.

Tellina? sp. Stanton, 1914, p. 352.

Panope simulatrix Whiteaves? Stanton, 1920, pp. 32-33, Pl. 6, Fig. 3.

Description.—The original description (Whiteaves, 1885, p. 11) is as follows:

Shell slightly inequivalve, the umbo of the right valve being a little larger and more tumid than that of the left: valves compressed at the sides, thickest on the anterior umbonal slopes and narrowing very gradually to the posterior end but more

rapidly to the anterior: posterior termination gaping: lateral outline elliptic ovate, the length being fully twice the maximum height inclusive of the beaks, and the posterior side a little longer, narrower and more pointed than the anterior. Umbones broad, obtuse and depressed: beaks small, subcentral but placed a little in advance of the middle, that of the right valve curved inwards and downwards with a slight inclination forwards, that of the left valve curved inwards and a little forwards but not downwards: ligament apparently short and external.

Surface concentrically striated: inner layer of the test not nacreous: hinge teeth and muscular impressions unknown.

Length of the most perfect example collected, (the one figured) fifty-two millimeters: greatest height of the same, twenty-five mm.: thickness of the same, sixteen and a half.

Types.—Hypotype, USNM 32420 (Stanton, 1920, Pl. 6, Fig. 3; also refigured here, Pl. VIII, Fig. 15), USGS locality 9122. The holotype is presumably from the Edmonton Formation (Upper Cretaceous) of Alberta.

Material.—Left valve with part of corresponding right valve (hypotype, USNM 32420), one incomplete internal mold of both valves, three incomplete molds of single valves, and one incomplete external mold, USNM; one internal mold of single valve questionably referred to this species, UMMP.

Measurements (in millimeters).—

Length	Height	Width
35.2 (Hypotype)	ca. 17.0	ca. 7.0 (ca. 3.5)
ca. 26.0 (est.)	ca. 13.5	...
ca. 21.0	ca. 11.5	...

Remarks.—Probably a useful concept of the species cannot be gained from the original description and figures, for they are of a single specimen. Warren (1926, p. 3) said, "It would appear Whiteaves had been a little unfortunate in the selection of his type as, though considerable variation occurs among the specimens in our collections, only one specimen approximates his type as shown by his figures."

This species is questionably referred to *Panopea* as the hinge is presumably still unknown. In 1926 Warren questioned (p. 3) the generic assignment and said, "As the hinge-line of this species is still unknown, its reference to the genus *Panopea* is provisional." The Cannonball specimens, as well, can only be questionably assigned to *Panopea* (or any genus) as the hinge and other internal characters are virtually unknown. On the internal molds there appear to be narrow grooves on both sides of the beak,

parallel to the dorsal margin. These grooves correspond to a slight thickening of the shell in the vicinity of the hinge line. Externally, the Cannonball specimens differ from *Panopea* in seeming to lack a prominent posterior gape. Also, the thin shell is generally not characteristic of *Panopea*.

Stanton (1920, p. 32) questionably referred the Cannonball specimens to this species; I prefer to merely indicate a comparison with *P. simulatrix*. Judging from Whiteaves' figures (1885, Pl. 2, Figs. 2, 2a), the Cannonball specimens appear to differ from this species in possessing two rather distinct ridges radiating out from the beaks. The anterior ridge is subangular and extends from the beaks to the anteroventral margin. The posterior ridge is much less prominent, rounded, and is on the dorso-posterior slope, extending from the beak to the posterior margin.

This species is abundant locally in the Edmonton Formation (Upper Cretaceous) of Canada (Warren, 1933, p. 118).

Occurrence.—Cannonball Formation, localities 16, 20, 83(?) and USGS 8474.

Superfamily Myacea

Family Corbulidae

Genus *Bicorbula* Fischer, 1887

Original reference.—Fischer, Paul, 1887, *Manuel de Conchyliologie et de Paléontologie Conchyliologique*, Vol. 3, p. 1123.

Type species.—By monotypy, *Corbula gallica* Lamarck; Eocene of the Paris basin.

Diagnosis.—I follow Gardner's (1962c, p. 47) diagnosis of this genus.

Remarks.—*Bicorbula* is used as a generic name here but it could as well have been treated as a subgenus of *Corbula*. The generic or subgeneric status of the many names for various corbulids is not yet established as are the limits and variation of morphological characters for these taxa. Vokes (1945), in his study of the supraspecific groups of corbulids, did not concern himself with the generic or subgeneric status of the names he discussed. Olsson (1961, pp. 433–35) has discussed two genera of corbulids (one described as new in that study), proposed after Vokes' revision.

The geologic range of *Bicorbula* is presumably unknown. Placing this genus in the Carycorbulinae, Vokes (1945, p. 5) gave the geologic range of that subfamily as "Cretaceous (probably Jurassic)—Recent."

Bicorbula subtrigonalis (Meek and Hayden)

Pl. VIII, Figs. 4, 5, 10, 11

Corbula subtrigonalis Meek and Hayden, 1856c, p. 116. White, 1883a, p. 80, Pl. 25, Fig. 6a-f; 1883b, p. 442, Pl. 19, Figs. 10-17. Stanton, 1893, p. 123-24, Pl. 27, Figs. 7, 8.

Corbula (Potamomya) subtrigonalis Meek and Hayden. Meek and Hayden, 1860b, p. 432.

Corbula (Pachyodon) subtrigonalis Meek and Hayden. Meek, 1876, p. 529-30, Pl. 40, Figs. 3a-b.

Description.—(Mainly after Meek, 1876, pp. 529-30, with reference to figures in White, 1883a and 1883b). Shell subtrigonal, left valve more convex than right; anterior margin abruptly rounded as it meets ventral margin, posterior margin subangular or narrowly rounded; dorsal and ventral margins very slightly convex, the ventral margin more convex anteriorly. Beaks moderately prominent, incurved, gibbous, anterior to the mid-length; posterior umbonal ridge variable in prominence, rounded to subangular; external ornamentation of fine growth lines and/or concentric wrinkles.

Types.—Hypotypes, USNM 132599, 132600 and 132601, USGS 16000.

Material.—One nearly complete specimen (both valves) showing hinge of right valve, two right valves, and few incomplete specimens and fragments, USNM.

Measurements (in millimeters).—

Length	Height	Width
ca. 30.0	ca. 25.5	$\frac{1}{2}$ = ca. 11.5
...	ca. 25.5	18.0
ca. 35.5	ca. 29.5	$\frac{1}{2}$ = ca. 12.0
34.0	ca. 27.0	$\frac{1}{2}$ = ca. 9.5

Remarks.—Most of the Cannonball material is preserved similarly to *Corbicula* cf. *C. berthoudi* (shells of both species light brown) and is associated with this species at the one locality known to date (locality 113). This corbulid was discovered in the Cannonball Formation by R. W. Brown of the United States Geological Survey in 1931 (Brown, 1962, p. 8).

Only two fragments show the chondrophore (and incompletely) which appears to be directed somewhat posteriorly. One specimen, preserved differently from most of the material in calcareous claystone, is an incomplete internal mold of the right valve. This specimen shows a somewhat ovate anterior adductor scar and a slightly larger, subcircular posterior

adductor scar. There appears to be a slight, narrowly rounded to sub-angular pallial sinus present.

Other characters of the Cannonball specimens may not necessarily be diagnostic. The hinge plate is heavy; the right valve has a strong, triangular cardinal tooth (3*b*) and a large resilial pit; the left valve, likewise, has a large socket for the reception of tooth 3*b*. The beaks are considerably in advance of the mid-length, about one-fourth of the total length as measured from the anterior end.

Attempting to follow Vokes' (1945) treatment of the corbulids, one finds it difficult to ascertain which characters are generic (or subgeneric) in the many groups discussed. The Cannonball species differs from *Bicorbula*, as represented by the type species, in that the hinge plate and generally the entire shell is much heavier. Whether or not this is of generic significance is unknown to the writer. It is also not improbable that the Cannonball species could be referred to *Ursirivus* (new name proposed by Vokes, 1945, p. 15), which has *Corbula* (*Potamomya*?) *pyriformis* Meek as its type species, for there are similarities in the large size, heavy hinge plate and thick shell. However, the pyriform shape and deep lunule and escutcheon, if diagnostic, would prevent assignment to this group. The Cannonball specimens differ from true *Corbula* in lacking a posterior lateral tooth on the right valve and apparently a posterior cardinal tooth on the left, and in possessing a chondrophore (Vokes, 1945, p. 10).

Occurrence.—Cannonball Formation, locality 113.

Bicorbula mactriiformis (Meek and Hayden)

Pl. VIII, Figs. 1–3

Corbula mactriiformis Meek and Hayden, 1856*c*, p. 117.

Corbula (*Potamomya*) *mactriiformis* Meek and Hayden. Meek and Hayden, 1860*b*, p. 432.

Corbula (*Pachyodon*) *mactriiformis* Meek and Hayden. Meek, 1876, pp. 528–29, Pl. 43, Figs. 7*a–f*.

Corbula mactriiformis Meek and Hayden. White, 1883*a*, p. 80; 1883*b*, p. 442, Pl. 18, Figs. 12–15. Stanton, 1920, p. 32, Pl. 6, Figs. 1, 2*a–b*.

Description.—Shell small, ovate-subtrigonal, moderately convex; anterior margin narrowly rounded, posterior margin narrowly rounded or obscurely subtruncate; beaks rather elevated, anterior to the mid-length of shell; obscure posterior umbonal ridge extends from beaks to postero-ventral margin; external ornamentation smooth except for growth lines. Internally, right valve with small obtuse cardinal tooth (3*b*) and rather large, deep resilial pit; left valve with oblique, compressed chondrophore;

adductor muscle scars faint, anterior scar narrow-ovate, posterior scar larger and broader; pallial sinus broad and shallow (after Meek, 1876, pp. 528-29).

Types.—Hypotypes, USNM 32419 (Stanton, 1920, Pl. 6, Figs. 1, 2*a-b*; also refigured here, Pl. VIII, Figs. 1-3), USGS 8384. The original types are from the Cannonball (?) Formation, at Fort Clark, North Dakota (Stanton, 1920, p. 32).

Material.—Five specimens, two internal molds of both valves, two left valves and one right valve, USNM (other material at USNM but I do not consider it referable to this species); one internal mold of both valves, UND; few incomplete specimens, UMMP.

Measurements (in millimeters; all specimens from USGS 8384).—

Valve	Length	Height	Width
Double	ca. 15.0	ca. 11.5	ca. 6.5
Double	ca. 13.0	ca. 9.5	ca. 5.5
Left	ca. 12.5	ca. 10.5	ca. 6.8 (3.4)
Left	11.0	7.8	ca. 4.8 (2.4)

Remarks.—Following Vokes' (1945) revision of the corbulids, it appears that this species can be placed in *Bicorbula*. This species differs from true *Corbula* in possessing a chondrophore and apparently lacking a posterior cardinal tooth on the left valve and a posterior lateral tooth on the right valve.

The original types of this species were not examined, but it appears as if the Cannonball specimens at hand are referable to this species. One difference, if comparison is made with Meek's illustrations (1876, Pl. 43, Figs. 7*a-f*), is that the Cannonball specimens generally have less elevated beaks.

Occurrence.—Cannonball Formation localities 1, 16(?), 74, and 76 and USGS 8474(?) and 8476(?).

Superfamily Myacea

Family Corbulidae

Genus *Caestocorbula* Vincent, 1910

Original reference.—Vincent, E., 1910, "Presence d'une plaque siphonal chez *Corbula regulbiensis* Morris," *Soc. Roy. Zool. Malac. Belgique Annales*, Vol. 44 (for 1909), pp. 141-42.

Type species.—By original designation, *C. henckeliusiana* Nyst (erroneously given as *C. henckeliusi* Nyst); Eocene, sables de Wemmél, Belgium (Vokes, 1945, p. 20).

Diagnosis.—I followed Vokes' (1944, p. 619) characterization of this genus.

Remarks.—The geologic range of this genus is Cretaceous (Aptian) to the upper Eocene (Vokes, 1944, p. 619).

Caestocorbula sinistrirostellata sp. nov.

Fig. 7; Pl. IX, Figs. 1–11, 13

Description.—Shell about medium-sized for genus, moderately convex (average width/height ratio for four specimens, .73); umbones low; beaks low, prosogyral, approximately central. Ornamentation of two kinds, very low, subdistinct, concentric ribs separated by intervening spaces of equal size on neanic parts of valves, growth lines and wrinkles of unequal prominence on remaining parts of valves. Neanic parts of each valve also with prominent, angular, posterior ridge and posterior truncation.

Right valve subovate to subtrigonal (height/length ratio .58 to .75), moderately convex (width/height ratio .36 to .58); during growth, valve changes from trigonal to ovate-subtrigonal with prominent rostral "snout"; hinge as for genus, with posterior lateral (PI?) at posterior side of resilial pit (Fig. 7). Left valve subtrigonal (height/length ratio .59 to .75), moderately convex (width/height ratio .30 to .50), posterior extremity slightly extended; projecting chondrophore with low ridge that is medial or slightly anterior.

Adductor scars slightly impressed, anterior scars subequilaterally subtrigonal, posterior scars arched, elongate-tear-drop shaped; pallial sinus broad and rounded as for genus.

Types.—Holotype UMMP 47369; paratypes UMMP 47352, 47355, 47358 and 47367 (all figured) and 9 paratypes not illustrated bearing the number UMMP 47346; all types from locality 37.

Type Locality.—Small isolated hill exposure, west side of road, NE¼ sec. 1, T. 135 N., R. 82 W., 0.25 miles south of northeast corner of section 1, about 5¼ miles south of St. Anthony, southern Morton County, North Dakota (locality 37).

Material.—Five double-valved individuals, 19 left valves and 10 right valves, and many incomplete valves and fragments, UMMP.

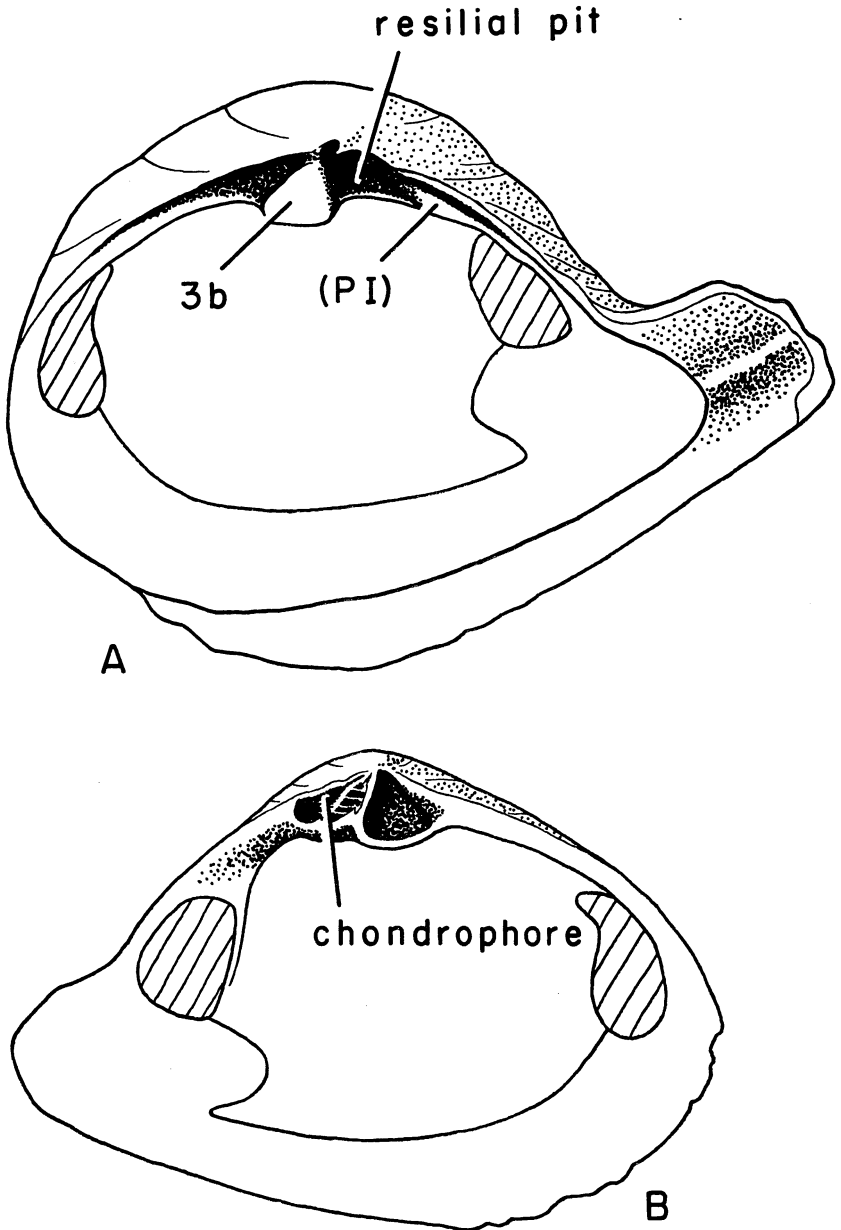


FIG. 7. Hinge characteristics of right (A) and left (B) valves of holotype of *Caestocorbula sinistrirostellata* sp. nov., UMMP 47369, from Cannonball Formation, about $5\frac{1}{4}$ miles south of St. Anthony (locality 37), Morton County, North Dakota. $\times 8.5$.

Measurements (in millimeters).—

Valve	Length	Height	Width or One-half Width
Right	ca. 9.3	ca. 6.0 est.	ca. 3.5
Double	9.2	6.2	4.5
Right	8.7	6.0	ca. 2.5
Double	ca. 8.4	5.8	4.3
(Holotype)			
Double	7.1	5.0	3.7
Right	ca. 6.6	4.7	2.3
Double	6.1	3.9	2.6
Right	5.7	4.1	1.5
Double	ca. 5.0	2.9	2.2
Left	8.5	5.9	2.1
Left	8.0	ca. 5.2	2.3
Left	7.6	4.5	2.2
Left	6.7	4.6	1.8
Left	6.2	4.4	1.8
Left	5.2	3.4	1.1
Left	4.2	2.7	.8

Remarks.—This species cannot, with complete certainty, be assigned to *Caestocorbula*, since this genus, as well as the allied genus *Parmicorbula* Vokes 1944, is characterized by a siphonal plate opposing the rostral “snout” of the right valve. No siphonal plate was observed in the Cannonball material. General form, rostral extension, and hinge teeth, however, indicate placement of this species in the *Caestocorbula-Parmicorbula* group. Lacking siphonal plates, which are distinctly different for each group (Vokes, 1944, pp. 620–21), general shape and proportion seem to be essentially the only characters that can be used to distinguish the two genera, for ornamentation, hinge and other internal characters are said to be generally similar.

This species differs from members of *Corbula sensu stricto* which possess a posterior cardinal tooth and lack a chondrophore on the left valve, according to Vokes (1945, pp. 8–10) who examined topotypes of the Recent type species, *C. sulcata* Lamarck, from the coast of Senegal. Lamy (1941, pp. 9–10), however, described *C. sulcata* Lamarck as possessing a chondrophore and a posterior lateral on the left valve.

Caestocorbula henckeliusiana (Nyst) from the upper Eocene (Lucian; sables de Wemmel) of Belgium, the type species (Vokes, 1945, Pl. 4, Figs. 1–4), is rather similar to the Cannonball species, differing in having a higher umbo and a left posterior extremity which is not produced. The

latter is judged from Vokes' Figure 3 of a right interior in which the interior is grooved for the reception of the left valve.

Corbula regulbiensis Morris (Cossmann and Pissarro, 1904-1906, Pl. 3, Fig. 20-19) from the Thanetian of the London and Paris basins appears also to be quite similar, with a greater length with respect to height in the right valve and a less produced posterior extremity in the left valve. Vokes (1944, p. 621-23) said siphonal plates of the type characteristic of *Parmicorbula* have been seen in this species.

The trivial name *sinistrirostellata* is from the Latin *sinister* "left" and *rostellum* "little bill, snout, beak," referring to the slightly drawn out or produced posterior extremity of the left valve.

Occurrence.—Cannonball Formation, localities 1, 16, 24, 29, 37, 64, 69(?), 71, 86, 89, 92, 104 and 106.

Superfamily Adesmacea

Family Teredinidae

Genus *Nototeredo* Bartsch, 1923

Original reference.—Bartsch, Paul, 1923, Biol. Soc. Washington Proc., Vol. 36, p. 100 (not seen).

Type species.—By original designation, *Teredo edax* Hedley; Recent, Australia and New Zealand (Turner, 1966, p. 259).

Diagnosis.—I have followed the diagnosis given by Turner (1966, p. 78).

Remarks.—*Nototeredo* is presently world-wide in distribution and occurs in tropical to cold temperate seas. Its geologic range is Paleocene to Recent (Turner, 1966, p. 16, 58, 78).

Nototeredo globosa (Meek and Hayden)

Pl. IX, Figs. 12, 28

Teredo globosa Meek and Hayden, 1858, p. 53. Meek, 1876, pp. 264-65, Figs. 31, 32 and Pl. 30, Fig. 13. Stanton, 1920, pp. 33-34, Pl. 6, Figs. 5a-b.

Teredo selliformis Meek and Hayden, 1860a, p. 178-79. Meek, 1876, p. 262-63, Pl. 17 Figs. 19a-d. Stanton, 1920, p. 33, Pl. 6, Fig. 4.

Description.—Shell globular, with length about equal to height; anterior slope (terminology of Turner, 1966, pp. 61-63) with 7-11 denticulated ridges per 0.5 mm at right-angled notch of anterior slope; auricle, when present, indistinctly marked by shallow groove; posterior margin of

auricle very slightly curved to nearly straight; internally, indistinct demarcation of auricle gives rise to slight, indistinctly-marked shelf; apophysis relatively narrow, slightly wider and flattened distally and bluntly terminated; apophysis extends ventrally to about 0.6 of height of shell.

Pallels generally with characters as for genus; detailed description withheld as mentioned under remarks of species.

Types.—Hypotypes, UMMP 47353 (locality 27) and UMMP 47370 (locality 14). The original types are from the Cannonball Formation, near Fort Clark, North Dakota.

Material.—Four relatively complete double-valved specimens, three right valves, five left valves and many incomplete valves and fragments; 22 incomplete pallels (a few covered with calcium carbonate) and many borings; UMMP. Few incomplete shells and borings, UND.

Measurements (in millimeters).—

Valve	Length	Height	Width
Right	ca. 7.1
Left	ca. 6.7	7.1	ca. 8.0 (4.0)
Right	ca. 6.5	ca. 6.4	ca. 6.8 (3.4)
Double	ca. 5.5	6.0	ca. 5.6
Double	ca. 5.2	5.7	5.5
Left	ca. 4.7	ca. 4.7	...
Double	ca. 4.0	4.4	ca. 4.7
Left	ca. 3.0	3.5	ca. 2.2 (1.1)

Remarks.—Descriptions of the shells of species of teredinids seem to have little taxonomic use, as is also true for generic descriptions. Therefore, only a few characters of the shell are mentioned in the description of the species, and these may not necessarily be specifically diagnostic.

This species was said to differ from *Teredo selliformis* Meek and Hayden (Meek, 1876, p. 265) by lacking a posterior notch in the ventral margin and a posterior groove or sulcus on internal molds, and having a regularly rounded posterodorsal margin instead of being "horizontal." Meek (1876) also said *Teredo globosa* has annular or ringed tubes which are larger than those of *T. selliformis*. *Teredo selliformis* is here placed in synonymy with *T. globosa* for it is believed that those differences cited by Meek are not valid, as they were based mainly on the shell, and differences based on borings seem to have less, if any, value.

The presence of a posterior notch in the ventral margin and a rounded or "horizontal" posterodorsal margin depends upon the presence of an

auricle. I noted an auricle on a few specimens, but most specimens lacked it; in the latter, the posterior margin usually appears irregular as if an auricle were present but had been broken or dissolved. In a few specimens, a very slight vestige of an auricle is present. This structure appears to be extremely variable, even where it can be consistently seen on living specimens. Miller (1922, p. 301, 309-11) found that in *Teredo navalis* the auricle may vary, from being reduced to very prominent; also during growth, the position of this structure changes from posterodorsal to posterior as it is gradually resorbed at its dorsal edge. Calman (1920, pp. 391-92, 396), studying living forms, also mentioned the resorption of the posterior margin, and said the rapidity and extent of this resorption appears to differ in different species. Citing *Teredo mannii* (Wright) from Australia, he also stated that the auricle and nearly all of the postero-median area (posterior slope) had been removed secondarily in many specimens. If this concept of secondary removal of the auricle can be applied to the Cannonball material, it would seem that the shape and extent of this structure cannot be used as a differentiating character.

As for the posterior groove or sulcus mentioned by Meek (1876), it is undoubtedly produced by the slight shelf on the interior of the shell. This shelf was present in varying degree on the specimens examined.

Shell characters, therefore, seem to indicate that one, and not two, species of shipworms occur in the Cannonball. This conservative approach necessitates the proving of occurrence of additional species by means other than shells, that is, by pallets.

Pallets, which I discovered from two localities (27 and 64), have not been reported previously from the Cannonball. Pallets are quite rare, and the association of pallets with shells is perhaps even rarer, so I feel that the Cannonball occurrence deserves special notice. They have been but briefly mentioned (Cvancara, 1964). A detailed description of the pallets, together with an account of their significance and several illustrations will appear separately in a forthcoming paper.

The assignment of Cannonball shipworms to *Nototeredo* is, therefore, based essentially on pallets, a few associated directly with shells, from the two localities. The occurrence of shipworms from several other localities in the Cannonball is evidenced by shells and/or borings. Consequently, one may assume that all Cannonball shipworms belong to the genus *Nototeredo* until pallets are found at other localities.

Borings occur in various kinds of material, well-preserved petrified wood, very finegrained sandstone, and sandy claystone in which little, if

any, of the structure of the wood remains. The calcite-lined borings are entirely empty (except for shells and pallets) or are variously filled with sediment or calcite. As a result, the shells may be loose in the borings, lightly or firmly attached to the base or sides of the borings, devoid or partially covered with calcium carbonate, or completely imbedded in sediment or calcium carbonate.

Two other objects were found associated with the Cannonball teredinids. What appear to be fecal pellets in a partially-filled teredinid boring were discovered at locality 27. These pellets are subcylindrical, smooth and approximately circular in cross-section. Each pellet is about 1.3 mm long and .8 mm in diameter. At locality 44 were found partially "septate" or concamerate borings. Observing the borings from the "septate" end, the "septa" are arched cross-partitions enclosing an oblong opening, which conforms to the two opposing pallets, which are convex on their outer faces. Wrigley (1929, p. 381) reported "septate" tubes as rare in the fossil state, whereas Turner (1966, p. 65, 78) inferred that these characteristic tubes are found in several species of Recent teredinids and aid in classification.

Occurrence.—Cannonball Formation, localities 7(?), 14, 15(?), 16(?), 18(?), 20(?), 22, 24(?), 27, 28(?), 34, 38(?), 39(?), 40(?), 43, 44, 47, 51, 54(?), 62(?), 64, 65, 74, 82(?), 83, 88, 89(?), and 90.

Suborder Anomalodesmata
Superfamily Pandoracea
Family Pholadomyidae
Genus *Phenacomya* Dall, 1898

Original reference.—Dall, W. H., 1898, p. 823.

Type species.—By original designation *Pholadomya cuneata* Sowerby, in Deshayes, 1860, Vol. I, p. 277, Pl. 9, Figs. 6–8.

Diagnosis.—I follow the original diagnosis given by Dall (1898, p. 823).

Remarks.—All of Deshayes' figures (1860, Pl. 9, Figs. 6–8) are views of the exterior, and nothing was said by Dall of the hinge line of *Phenacomya*. Dall included two American species, *Pholas petrosa* Conrad (Eocene) and *Pholadomya mauryi* Harris (Paleocene) in this genus. The type species, *Pholadomya cuneata* Sowerby is from the Thanetian of the London and Paris basins of Europe.

Phenacomya haresi (Stanton)

Pl. IX, Figs. 14-16, 21, 22, 24, 25, 27

Pholadomya haresi Stanton, 1920, p. 26, Pl. 3, Figs. 2a-b, 3.

Description.—Shell elongate, transversely subovate, with height about one-half that of length; anterior margin broadly rounded, posterior margin narrowly rounded with slight gape; greatest convexity at about anterior one-third of total length; beaks at slightly less than one-third of total length from anterior margin. Anterior surface of each valve with about 11 low, narrow, radiating ribs, the more anterior six relatively widely spaced and the remaining ones, on medioanterior part of shell, closely spaced and becoming fainter posteriorly; concentric growth lines irregular in spacing and prominence.

Types.—Hypotypes UMMP 47331 (locality 88) and 47354 (locality 104). The original type (USNM 32399) is from the Cannonball Formation, USGS 7975.

Material.—Two relatively complete specimens, the larger lacking much of the left exterior, UMMP.

Measurements (in millimeters).—

Length	Height	Width
ca. 55.0	ca. 27.0	ca. 23.5
ca. 30.0	ca. 21.0	ca. 19.5

Remarks.—Stanton's type is an immature specimen. Of my material, the small specimen is but slightly larger than the type specimen and generally agrees with the original description. The larger specimen is proportionally much longer, has finer radiating ribs, and lacks the subangular umbonal ridge of the type specimen. Both specimens differ from the type as figured in having a pronounced anterior gape which is wider on the smaller specimen. Also, my specimens differ in appearing to be inequivalved, the left valve being slightly smaller.

A cast of the dorsal part of the internal mold of the larger specimen (Pl. IX, Fig. 22) shows the absence of hinge teeth and the presence of a chondrophore for the reception of an internal ligament. It is not known if any external ligament was also present. The internal mold seems to lack muscle scars or a pallial sinus.

The internal morphology of *Phenacomya* is unknown to me, but the rather pronounced anterior gape and especially the dorsal reflection of the

anterodorsal margin prohibits retaining of this species in *Pholadomya*, and *Phenacomya* seems to be a reasonable assignment.

Pholadomya mauryi Harris (1896, p. 71–72, Pl. 6, Figs. 17, 17a) from the Paleocene Midway Group of Tennessee appears to be quite closely similar, both in form and external ornamentation. This species also appears to be inequivalved, the left valve being slightly smaller (Harris, 1896, Pl. 6, Fig. 17a). The radial ribs are perhaps slightly more numerous than in the Cannonball species and the anterior gape is not apparent. Harris (1896, p. 72) has pointed out the general similarities of *P. mauryi* with *Pholadomya cuneata* Sowerby, with the Thanetian type species of *Phenacomya*. Both the Midway and Cannonball species differ from the type species in being less high in relation to length and less swollen.

Occurrence.—Cannonball Formation, localities 88, 103, 104 and 112.

Family Laternulidae

Genus *Periploma* Schumacher, 1817

Original reference.—Schumacher, F. C., 1817, *Essai d'un nouveau système des habitations des vers testacés*, pp. 115–16, Pl. 5, Fig. 1a–b.

Type species.—By monotypy, *Periploma inaequivalvis* Schumacher, 1817; Recent, West Indies.

Diagnosis.—Olsson's (1961), pp. 460–61) diagnosis of *Periploma* is followed here.

Remarks.—Besides Thiele's (1934) assignment of *Periploma* to the Laternulidae, this genus has been included under the Periplomatidae by various workers (e.g., Olsson, 1961, p. 460, and Abbott, 1964, p. 472).

Periploma apparently ranges throughout the Tertiary to the Recent, and possibly extends back to the Late Cretaceous. Chavan and Cailleux (1957, p. 252) gave the range of *Periploma* as Senonian to Recent.

Periploma sp.

Pl. IX, Figs. 17, 18, 23, 26

Description.—Shell elliptic-ovate (height/length ratio of one specimen, .69), anterior margin narrowly rounded, posterior margin seemingly bluntly rounded; slightly inequivalve, left valve only slightly larger and slightly more convex; slightly to moderately convex, (width/height ratio of one specimen, .43), maximum width just anterior to beaks, which are at about

two-thirds of length of shell from anterior margin; external ornamentation of irregular growth lines or wrinkles, some of which are minute and appear secondary. Internally, chondrophores heavy and directed anteroventrally, posterodorsal to lithodesma. Posterior adductor scars subcircular, slightly impressed, anterior adductor scars indistinct, possibly elongate and slightly impressed; pallial sinus shallow, flattened to broadly rounded.

Types.—Hypotype, UMMP 47364 (locality 92).

Material.—Two internal molds, one nearly complete with some shell material, the other flattened and essentially bare, two fragments of external molds (from same specimen, also included fragment of internal mold), and few shell fragments, UMMP.

Measurements (in millimeters).—

Length	Height	Width
33.5	ca. 23.0	9.8

Remarks.—One character is seemingly discordant with the assignment of this species to *Periploma*. This genus is said to be inequivalve, with the right valve the more convex (e.g., Olsson, 1961, p. 460 and Abbott, 1954, p. 472), whereas in the present species the left valve is slightly more convex. A few species of living *Periploma* which I examined at the University of Michigan Museum of Zoology all had more convex right valves.

This species is considered new. A new name is withheld, however, so types need not be based on meager and incomplete material.

Occurrence.—Cannonball Formation, localities 5, 90, 92 and USGS 15994(?).

Genus *Laternula* Bolten, 1798

Original reference.—Bolten, J. F., 1798, *Museum Baltenianum* . . . *Pars secunda continens Conchyliis* . . ., ed. P. F. Röding, Hamburg, p. 155 (not seen).

Type species.—By subsequent designation, *Solen anatinus* Linné = *Anatina subrostrata* Lamarck. Recent, East Indies (Marwick, 1948, p. 27).

Diagnosis.—I followed Lamy's (1934, pp. 145–47) diagnosis of this genus.

Remarks.—This genus has also been called *Anatina* Lamarck (*non* *Anatina* Schumacher). Living species of *Laternula* are Oriental in their

distribution and fossil species were said not to be present in the Tertiary of North America (Dall, 1903, p. 1530). Chavan and Cailleux (1957, p. 252) gave the range of this genus as Triassic to Recent.

Laternula? subgracilis (Whitfield)

Pl. IX, Figs. 19, 20

Thracia subgracilis Whitfield, 1877, p. 36 (*vide* Stanton, 1920, p. 26); 1880, p. 419-20, Pl. 11, Figs. 29, 30.

Anatina subgracilis (Whitfield). Stanton, 1920, pp. 26-27, Pl. 3, Figs. 4a-b, 5a-b.

Description.—Shell small, transversely subovate; dorsal margin slightly convex anteriorly, slightly concave posteriorly; ventral margin broadly rounded anteriorly, abrupt and nearly straight on posterior one-third of shell; anterior margin broadly rounded, posterior margin subtruncate; moderately convex, greatest convexity at or about mid-length of shell, relatively compressed posterior to beaks. Beaks relatively prominent; external ornamentation of growth lines and irregular undulations (after Stanton, 1920, p. 26).

Types.—Hypotype, USNM 32401 (Stanton, 1920, Pl. 3, Figs. 5a-b; also refigured here, Pl. IX, Figs. 19, 20), USGS 8475. The holotype (USNM 12253), refigured by Stanton (1920, Pl. 3, Figs. 4a-b), is from the Pierre Shale (Upper Cretaceous), on Cheyenne River near French Creek, South Dakota.

Material.—Stanton (1920, p. 24) mentioned having six specimens of this species from the Cannonball Formation for study. At the U. S. National Museum, I saw only the hypotype (USNM 32401, an internal mold of both valves with little adhering shell) and two other incomplete specimens, which are questionably referred to this species.

Measurements (in millimeters).—

Length	Height	Width
ca. 24.0 (hypotype)	ca. 18.5	ca. 9.5

Remarks.—I agree with Stanton (1920, p. 27) that this species is probably a member of the genus *Anatina* Lamarck, or *Laternula* as used here. The fissured beaks, represented on each valve of the internal mold of the hypotype by a low, narrow ridge adjacent to which is a slight groove, and general form are suggestive of this genus; a definite assignment, however, cannot be made until all the internal characters are known. Only the right

posterior adductor muscle scar is well shown. It is elongate-subtrigonal and well impressed for such a thin-shelled bivalve.

The gape of the Cannonball shell is difficult to determine. Since the posterior extremity of the hypotype is broken, the amount of gape is uncertain, if it is present at all. The apparent slight separation along the posterodorsal margin, however, indicates the presence of a slight gape.

Stanton (1920, p. 27) remarked on Whitfield's (1880, p. 419) statement that the posteroventral margin is ". . . constricted or sinuate . . .", believing that this was caused by an accidental break. Upon examining the holotype, I agree that Stanton's observation is correct.

Occurrence.—Cannonball Formation, localities 112 and USGS 8475.

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EXPLANATION OF PLATE I
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<i>Nucula (Nucula) planimarginata</i> Meek and Hayden	293
FIGS. 1-3. Right exterior, posterior and left exterior of conjoined valves, hypotype, UND 9526, locality 106.	
FIG. 4. Right exterior of double-valved specimen, hypotype, UMMP 47362, locality 11.	
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PLATE I

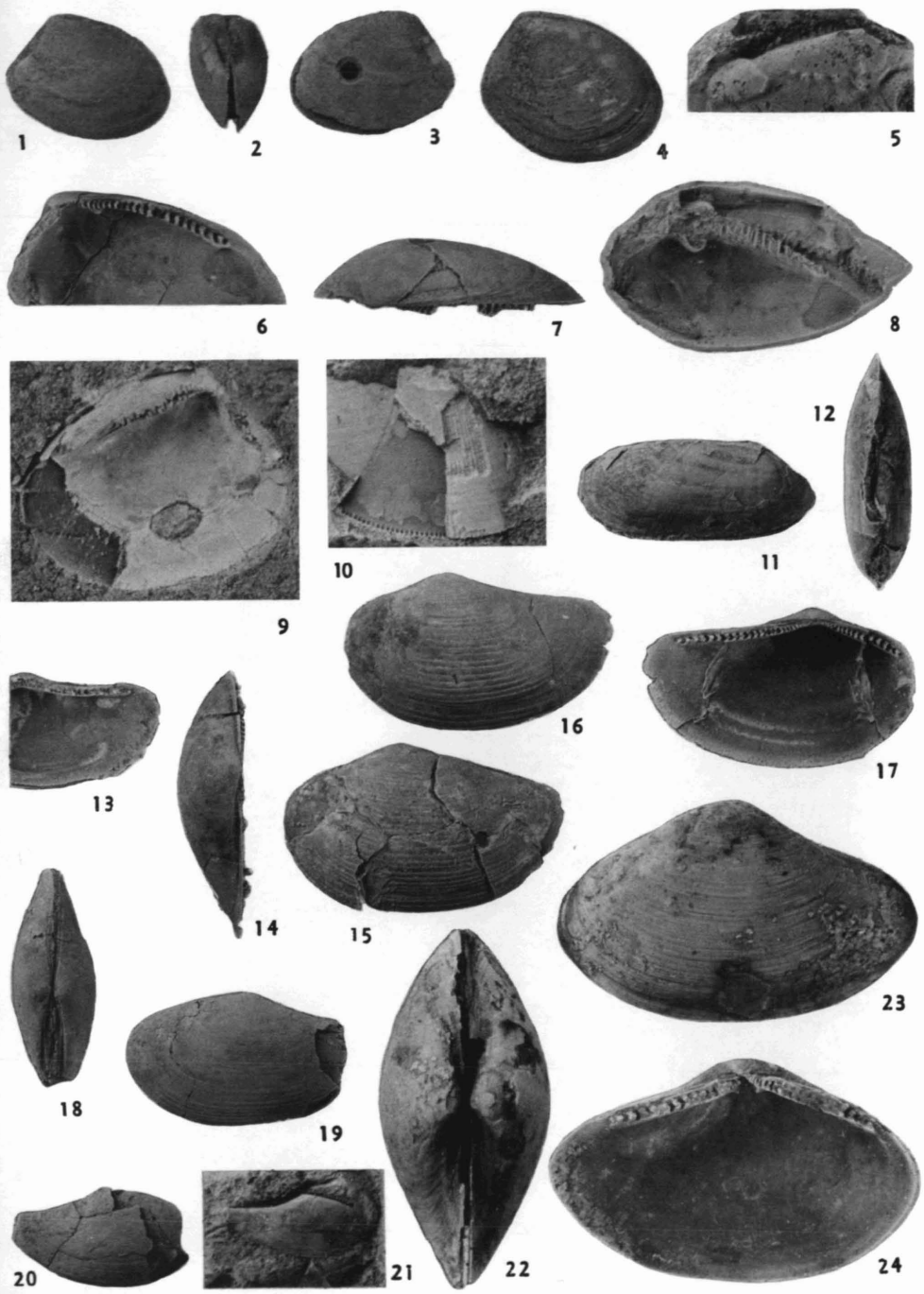


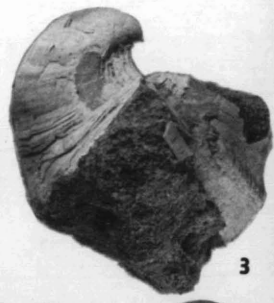
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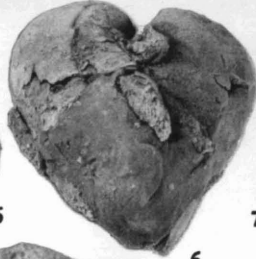
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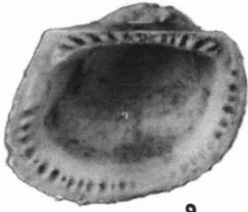
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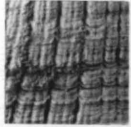
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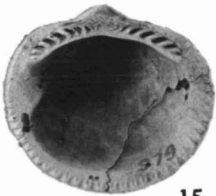
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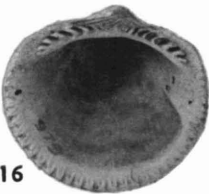
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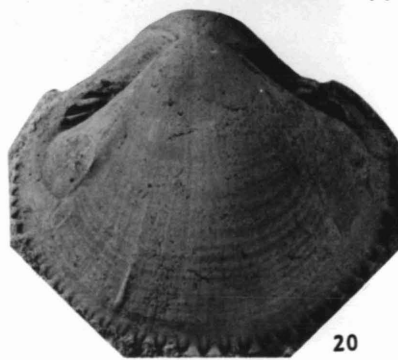
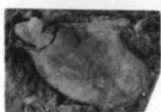
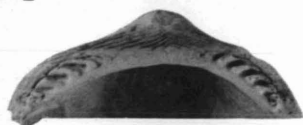
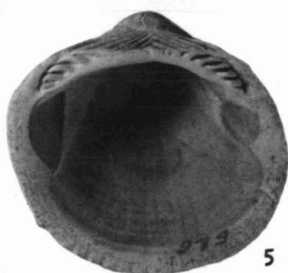
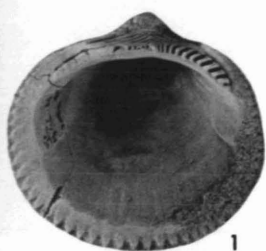
EXPLANATION OF PLATE II

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FIGS. 1, 4, 5. Dorsal, exterior and interior (sandstone adheres to ventral margin) of incomplete left valve, hypotype, UMMP 47351, locality 29, × 1.	
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FIGS. 16-18. Anterior, left lateral and dorsal views of specimen shown in Figure 15, $\times 4$.	

PLATE III



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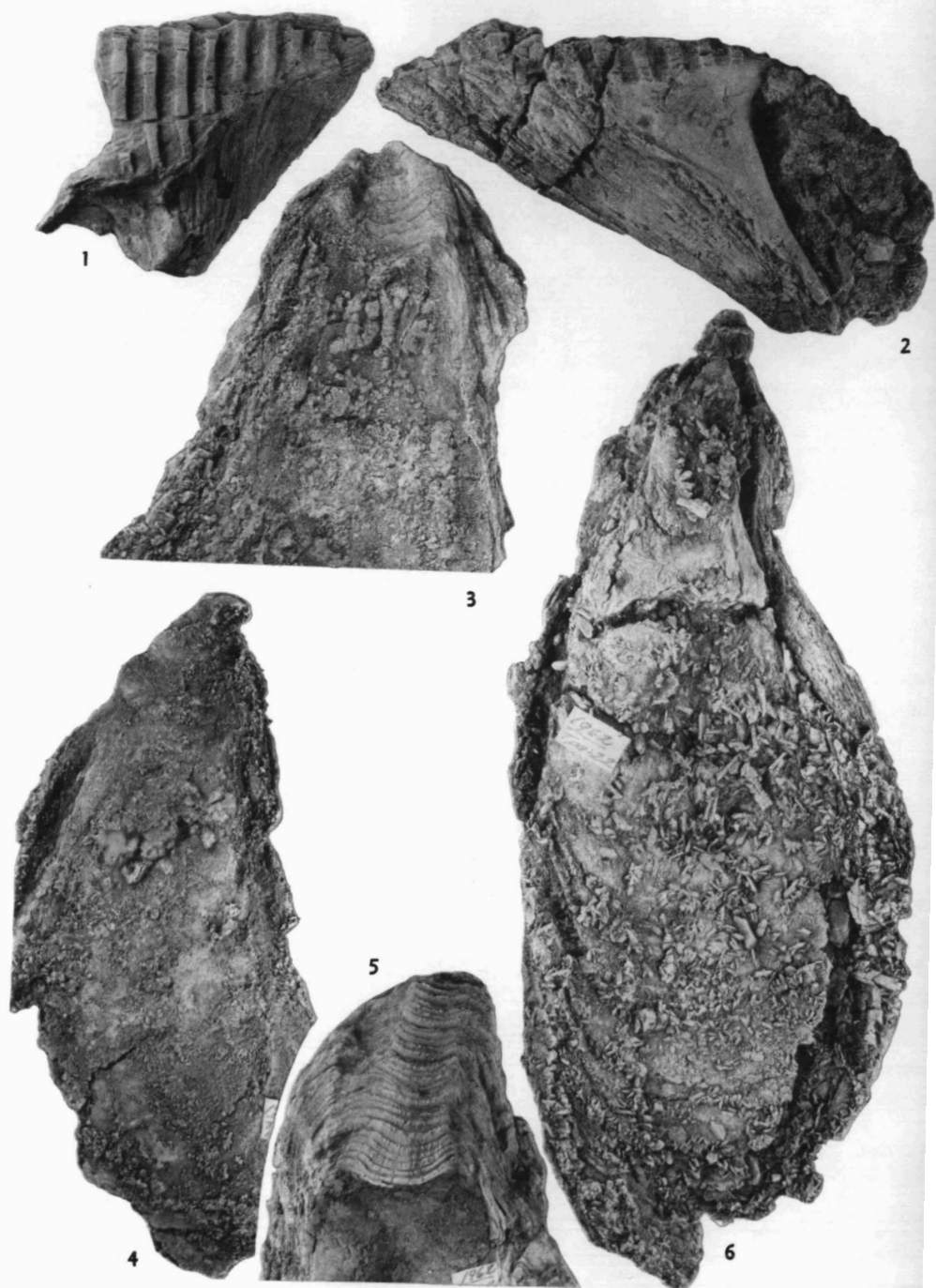
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PLATE IV



EXPLANATION OF PLATE IV

(All figures $\times 1$)

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<i>Isognomon lloydi</i> (Stanton)	317
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(All figures $\times 1$)

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PLATE V

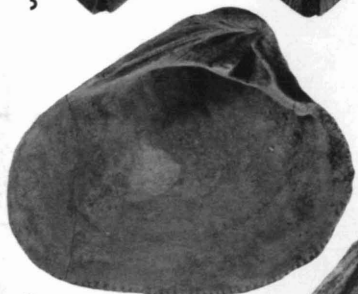
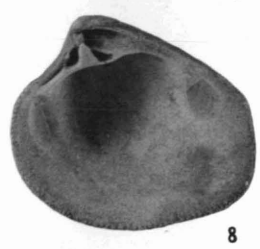
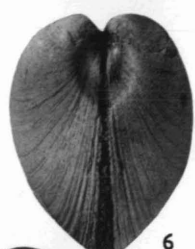
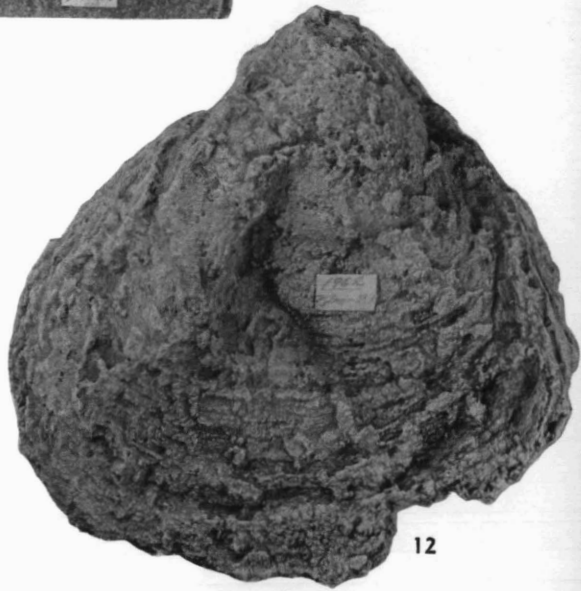
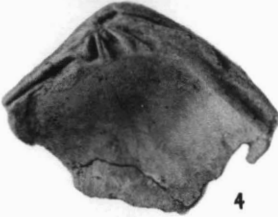


PLATE VI



EXPLANATION OF PLATE VI
(All figures $\times 1$)

	PAGE
<i>Corbicula cytheriformis</i> (Meek and Hayden)	329
FIGS. 1, 2. Exterior and interior of left valve, hypotype, USNM 32414, USGS 8384.	
<i>Corbicula berthoudi</i> White	326
FIGS. 3, 5, 6. Exterior, dorsal and interior of incomplete left valve, hypotype, USNM 32411, USGS 7963.	
FIG. 4. Hinge of incomplete right valve, hypotype, USNM 32412, USGS 8439.	
<i>Corbicula</i> cf. <i>C. berthoudi</i> White	328
FIG. 7. Hinge of incomplete right valve, hypotype, UMMP 47340, locality 115.	
FIG. 8. Hinge of incomplete right valve, hypotype, UMMP 47335, locality 115.	
FIG. 9. Hinge of incomplete left valve, hypotype, UMMP 47338, locality 115.	
FIGS. 10, 11. Exterior and interior of incomplete left valve, hypotype, UMMP 47345, locality 115.	
FIG. 12. Right exterior of distorted, double-valved specimen, hypotype, UMMP 47333, locality 115.	

EXPLANATION OF PLATE VII

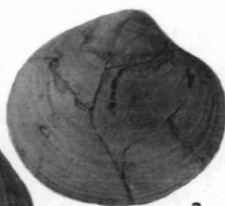
(All figures $\times 1$)

	PAGE
<i>Arctica ovata</i> (Meek and Hayden)	332
FIGS. 1, 4. Exterior and interior of right valve (tooth 3 <i>b</i> incomplete), hypotype, UMMP 47328, locality 12.	
FIG. 6. Dorsal exterior of double-valved specimen showing ligamental nymphs, hypotype, UMMP 47328, locality 12; right valve of this specimen shown in Figures 1 and 4.	
FIG. 7. Interior of large left valve, hypotype, UND 9531, locality 34.	
<i>Dosiniopsis deweyi</i> (Meek and Hayden)	338
FIG. 2. Exterior of right valve, hypotype, UND 9536, locality 34.	
FIG. 3. Interior of left valve, hypotype, UND 9534, locality 34.	
<i>Corbicula</i> cf. <i>C. berthoudi</i> White	328
FIG. 5. Oblique dorsal view of ventrally distorted double-valved specimen, hypotype, UMMP 47337, locality 115.	

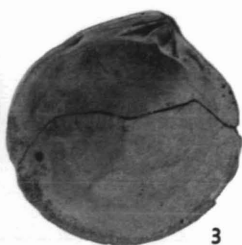
PLATE VII



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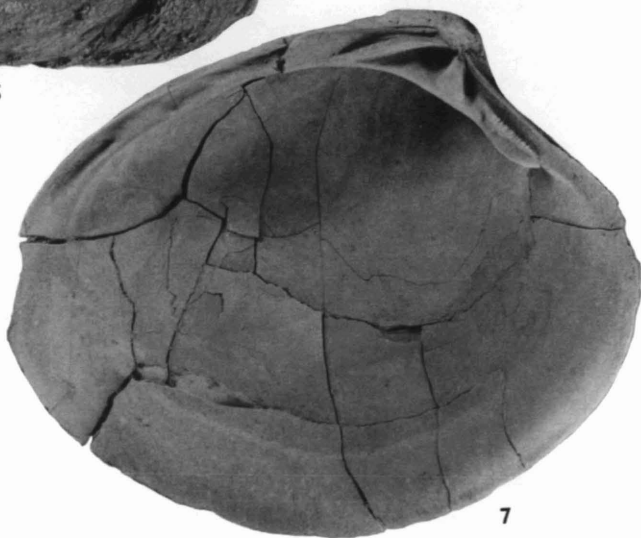
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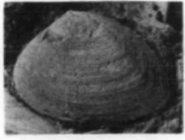


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PLATE VIII



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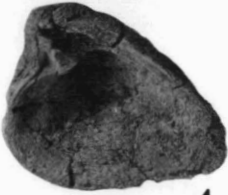
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EXPLANATION OF PLATE VIII

(Figures \times 1, except as noted)

	PAGE
<i>Bicorbula mactriformis</i> (Meek and Hayden)	345
FIG. 1. Exterior of left valve, hypotype, USNM 32419, USGS 8384, \times 2.	
FIGS. 2, 3. Dorsal and right interior of internal mold of both valves, hypotype, USNM 32419, USGS 8384, \times 2.	
<i>Bicorbula subtrigonalis</i> (Meek and Hayden)	344
FIGS. 4, 5. Interior and exterior of right valve, hypotype, USNM 132599, USGS 16000.	
FIG. 10. Anterior of incomplete double-valved specimen, hypotype, USNM 132600, USGS 16000.	
FIG. 11. Right hinge and left exterior of incomplete matched valves, hypotype, USNM 132601, USGS 16000.	
<i>Arctica ovata</i> (Meek and Hayden)	332
FIGS. 6, 7. Right and left hinges of matched valves, hypotype, UMMP 47341, locality 52.	
<i>Miltha (Plastomiltha) cedrensis</i> (Stanton)	334
FIGS. 8, 9, 12. Right interior, left interior and right exterior of matched valves, hypotype, UMMP 47357, locality 90.	
<i>Dosiniopsis deweyi</i> (Meek and Hayden)	338
FIGS. 13, 14. Interior and exterior of left valve, hypotype, UND 9533, locality 34.	
FIG. 16. Dorsal exterior of incomplete double-valved specimen showing faint lunule (anterior end uppermost), hypotype, UND 9535, locality 34.	
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FIG. 15. Exterior of left valve and part of corresponding right valve, hypotype, USNM 32420, USGS 9122.	

EXPLANATION OF PLATE IX

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<i>Caestocorbula sinistrirostellata</i> sp. nov.	347
FIGS. 1, 2. Right and left exteriors of immature, double-valved specimen showing posterior ridge and absence of rostral "snout," paratype, UMMP 47358, locality 37, $\times 4$.	
FIGS. 3, 4, 5. Left exterior, dorsal, and anterior of conjoined valves showing overlap of right valve, paratype, UMMP 47367, locality 37, $\times 4$.	
FIG. 6. Exterior of left valve, paratype, UMMP 47352, locality 37, $\times 4$.	
FIG. 7-9, 13. Left interior, left dorsal exterior, right dorsal exterior and right interior of matched valves, holotype, UMMP 47369, locality 37, $\times 4$.	
FIGS. 10, 11. Left and right exteriors of matched valves, paratype, UMMP 47355, locality 37, $\times 4$.	
<i>Nototeredo</i> (Meek and Hayden)	350
FIG. 12. Exterior of right valve of double-valved specimen, hypotype, UMMP 47370, locality 14, $\times 4$.	
FIG. 28. Incomplete shell and pallets in boring broken longitudinally; darker lines transverse to boring are growth lines of wood, hypotype, UMMP 47353, locality 27, $\times 4$.	
<i>Phenacomya haresi</i> (Stanton)	354
FIGS. 14-16. Left exterior (with overlap of right valve), anterior and dorsal exterior of double-valved specimen, hypotype, UMMP 47354, locality 104, $\times 4$.	
FIGS. 21, 25. Anterior and right exterior of rubber cast of external mold of specimen shown in figures 24 and 27; growth lines in Figure 21 indicate greater gape in earlier stages, $\times 1$.	
FIG. 22. Rubber cast of dorsal interior of specimen shown in Figures 24 and 27, showing chondrophores, $\times 1$.	
FIGS. 24, 27. Anterior and dorsal interior of internal mold of both valves, hypotype, UMMP 47331, locality 88, $\times 1$.	
<i>Periploma</i> sp.	355
FIGS. 17, 18. Dorsal and right exterior of double-valved specimen, with much of shell missing dorsally, hypotype, UMMP 47364, locality 92, $\times 1$; shell subsequently destroyed for determination of internal characters.	
FIG. 23. Posterior part of internal mold of specimen shown in Figures 17 and 18 showing broad pallial sinus, dorsal to which is groove representing riblike structure for support of chondrophore, $\times 2$.	
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<i>Laternula?</i> <i>subgracilis</i> (Whitfield)	357
FIGS. 19, 20. Left and dorsal views of internal mold, with little shell adhering postero-dorsally, hypotype, USNM 32401, USGS 8475, $\times 1$.	

PLATE IX

