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STRATIGRAPHIC DISTRIBUTION OF NUCULOID BIVALVES IN THE PENNSYLVANIAN OF OHIO.

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ABSTRACT — Nuculoids are the most abundant form of bivalves found in the Pennsylvanian System in Ohio. Ten species and subspecies have been found representing the genera *Clinopistha*, *Nuculopsis*, *Paleyoldia*, *Palaeoneilo* and *Phestia*. Several thousand specimens collected from 15 different stratigraphic units at 112 localities indicate most forms are long ranging. The most prominent stratigraphic differentiation is between the Pottsville and Allegheny Groups where *Phestia bellistriata prolongata* (MORNINGSTAR) is restricted to the Pottsville and *Clinopistha laevis* MEEK & WORTHEN, *Phestia arata* (HALL) and *Phestia attenuata* (MEEK) are found only above this boundary in the Allegheny and Conemaugh Groups.

Epibionts are uncommon on nuculoid bivalves. The nuculoids were probably rapid, free burrowers and deposit feeders. They are most commonly found preserved in dark gray to black shales which may be calcareous and/or with a high silt content.

Introduction

The present study is concerned with the stratigraphic distribution of the nuculoid bivalves in the marine units of the Pennsylvanian System in Ohio. These units are exposed in the eastern portion of the state (fig. 1) which is in the western margin of exposure of the Pennsylvanian and form part of the Appalachian Plateau of the central Appalachian Mountains.

A secondary purpose involves the interpretation of paleoecologic relationships of this group. A study of the relationships between shell form and life habits, lithology and to some extent occurrence with other life forms is used as a basis for this interpretation.

A number of authors have previously described isolated or partial stratigraphic occurrences of nuculoids in the Ohio Pennsylvanian (STEVENS, 1858; MEEK, 1875; HERRICK, 1887; MARK, 1911, 1912; MORNINGSTAR, 1922; DRISCOLL, 1966; MURPHY, 1966, 1967). Their reported occurrences, in as far as they can be verified, have been incorporated into the stratigraphic distribution in this report. Many reports on areas outside of Ohio contain references to the occurrence of this group and MCALESTER's (1968) discussion of the type species of Paleozoic nuculoids have been most helpful.

STURGEON began systematic collection and study of Pennsylvanian invertebrates in Ohio 40 years ago and part of these collections form the primary basis for the present study. Many students and co-workers have aided in the collection of material and to them we extend our gratitude. Our appreciation is also extended to A.G. UNKLESBAY, University of Missouri, S.M. BERGSTROM, Ohio State University, A.J. ROWELL, University of Kansas, A.L. MCALESTER, Yale University, G.A. COOPER, U.S. National Museum and D.W. STONE, Marietta College for making numerous specimens available for comparative study. The Bowling Green State University NSF Institutional Grant Committee and the Ohio University Fund provided

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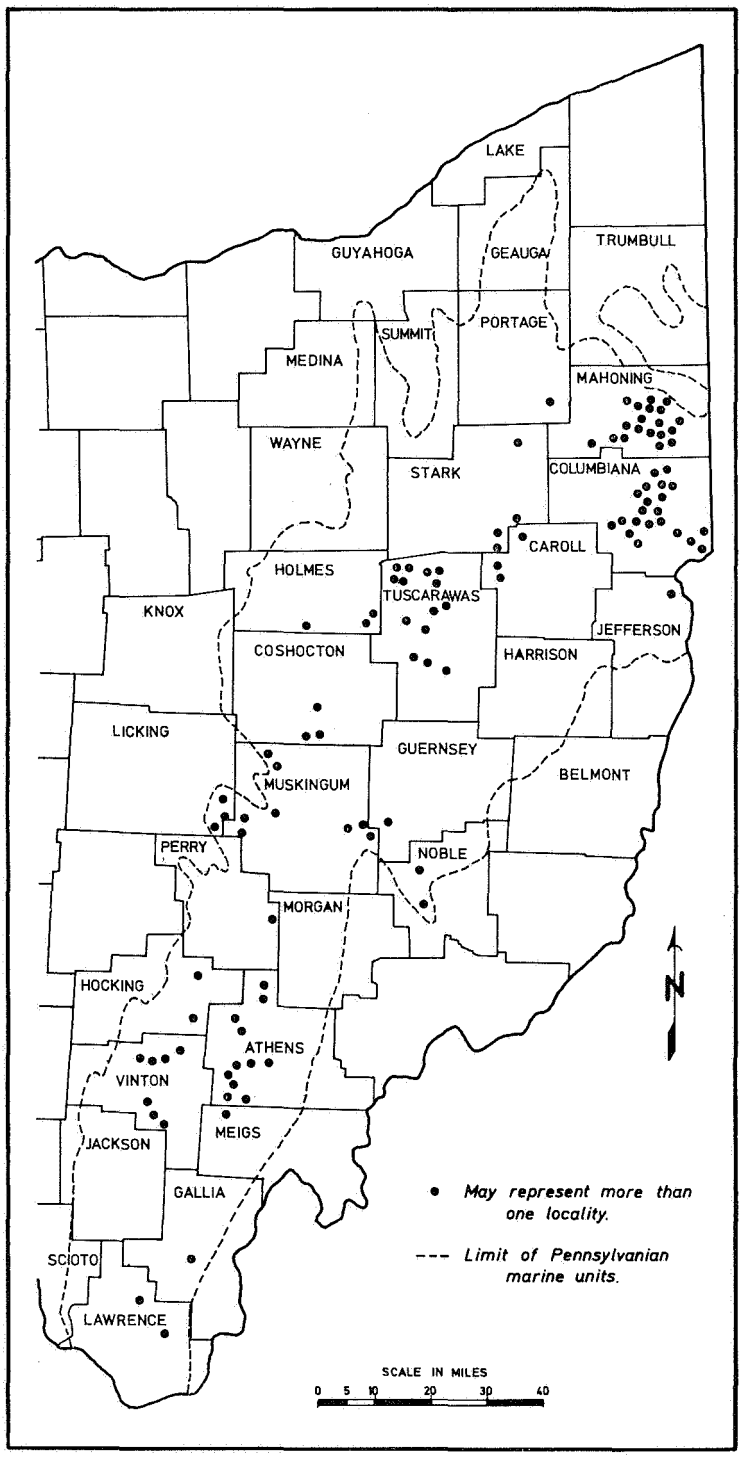


Fg. 1. Distribution of nuculoid collecting localities in the Pennsylvanian System of Ohio.

partial support in the form of supplies and travel expenses for this project.

Stratigraphy

Brackish-water and marine fossils are known in approximately 27 members of the lowest three stratigraphic groups (Pottsville, Allegheny, and Conemaugh) of the Pennsylvanian System in Ohio (table 1). None are definitely known in the upper part of the Conemaugh Group or in the overlying Monongahela Group. CROSS and SCHEMEL (1956, p. 38) have, however, reported brackish-water fossils in Monongahela strata of West Virginia.

The members bearing brackish-water and marine fossils are cyclothemic and quite diversified in lithology. They range from

TABLE 1

Marine units in the Pennsylvanian System in Ohio and the number of localities from which bivalves and nuculoids have been collected.

GROUP	Marine units	No. loc. w/ bivalves	No. loc. w/ nuculoids
CONEMAUGH	Skelley ls. & sh.	3	0
	Gaysport ls. & sh.	1	0
	Ames ls. & sh.	14	2
	Portersville sh. & ls.	10	6
	Cambridge ls. & sh.	9	4
	U. Brush Creek ls. & sh.	3	1
	L. Brush Creek ls. & sh.	4	2
	(Undiff. Brush Creek)	18	11
	Mason	1	1
ALLEGHENY	(Unnamed shale)	1	0
	Dorr Run sh.	9	1
	Washingtonville sh.	24	16
	Tuscarawas sh.	1	0
	Columbiana sh. & ls.	37	22
	Vanport ls., flint & sh.	23	11
	Zaleski flint, ls. & sh.	6	0
	Putnam Hill ls. & sh.	40	22
POTTSVILLE	U. Mercer flint, ls. & sh.	4	1
	Sand Block ironstone	0	0
	L. Mercer ironstone	0	0
	L. Mercer ls. & sh.	43	9
	Boggs ls., flint & ironstone	4	1
	Lowellville or Poverty Run ls. & sh.	3	1
	Bear Run sh.	0	0
	Quakertown sh.	0	0
	Anthony sh.	0	0
	Sharon ironstone	0	0
	Harrison ironstone	1	0

calcareous limestones to shaly, flinty, and/or ferruginous, limestones or from flints to calcareous, shaly, and/or ferruginous flints; from black carbonaceous shales to gray, calcareous, and clayey and/or silty shales; and include even clay ironstones.

These fossiliferous beds are normally only a few inches to several feet thick, but several limestones are 15 to 20 or even more feet thick and in places fossiliferous shales are 30 or more feet in thickness. The fossiliferous beds are distributed at more or less regular intervals through more than 700 feet of strata. Figures derived mostly from the generalized geologic section of Ohio's rocks (STOUT, 1930, 1943, 1947) indicate that brackish-water and marine fossiliferous members have a total thickness of 63 feet and an average individual thickness of 30 inches and that the coals over which those members normally lie average roughly 20 feet apart. These data also reveal that brackish-water and marine beds comprise approximately 9 percent of the total thickness and published reports disclose that the greater amount of this thickness is marine. It should be remembered that the above figures are only averages and that in the field actual thicknesses may vary considerably for different portions of the section and at different geographic localities for the same parts of the section. Another item to note is that thickness figures for most brackish-water and marine members are undoubtedly too small. At many localities a considerable thickness of fossiliferous shale overlies the limestone unit, and these fossiliferous shales have been overlooked in many places. Hence many recorded stratigraphic sections do not show the complete thickness of the shales. It is likely that most fossil collections have been made from the limestones and from the more conspicuously fossiliferous shales adjacent to the limestones.

Table 1 gives the order of the brackish-water and marine units but does not indicate the non-marine portions of the sequence nor the relative thickness of any of the units. The Lowellville and Poverty Run units are thought to be stratigraphic equivalents in different areas of the state.

Stratigraphic distribution of nuculoids

Marine bivalves were obtained from 259 localities and 21 different stratigraphic units in this study. Two or more units are exposed at the same locality in several instances. Several thousand nuculoids were collected at 112 of these localities and from 15 of the units and from one to several hundred specimens were obtained from each locality. The stratigraphic distribution of numbers of localities containing bivalves and those containing nuculoids is shown in table 1. In many cases more than one collection has been made from a particular locality. In the following discussion the relative abundance (rare, 1-4 specimens; common, 5-14 specimens; and, abundant, 15+ specimens) of each taxon in each stratigraphic unit is given. The number in parenthesis following the name of the unit indicates the number of localities at which it has been found in that unit.

Clinopistha laevis MEEK and WORTHEN is rare to common in the Columbiana (6) and Putnam Hill (4) units and rare in the Cambridge (1), Washingtonville (1) and Vanport (1) units. The occurrence in the Cambridge unit is based upon a single partial specimen and is somewhat questionable. Other than this the species appears restricted to the Allegheny Group.

The most abundant and widespread species is *Nuculopsis girtyi* SCHENCK. It is rare to abundant in the Lower Brush Creek (2), undifferentiated Brush Creek (8), Washingtonville (11), Columbiana (13), and Putnam Hill (18) units; rare to common in the Portersville (6), Cambridge (3), Vanport (5) and Lower Mercer (3), units; and, rare in the Ames (2) and Upper Mercer (1) units. Also reported from the Sharon and Harrison units by MORNINGSTAR (1922) but these could not be checked.

Nuculopsis anodontoides (MEEK) is commonly found associated with *N. girtyi*. It is rare to abundant in the undifferentiated Brush Creek (4) and Columbiana (11) units; rare to common in the Portersville (3), Cambridge (1), Lower Brush Creek (1),

Washingtonville (5) and Putnam Hill (11) units; and, rare in the Vanport (1), Upper Mercer (1), Lower Mercer (1) and Poverty Run (1) units. Also reported from the Ames unit by MARK (1912) but this could not be checked.

Nuculopsis croneisi SCHENCK is the least common species of this genus in these units. It is rare to common in the Washingtonville (2), Columbiana (9) and Putnam Hill (4) units and rare in the undifferentiated Brush Creek (3), Vanport (3) and Upper Mercer (1) units.

Palaeoneilo oweni (MCCHESNEY) is abundant in the Lower Brush Creek (1) unit; rare to abundant in the Washingtonville (11) and Columbiana (11) units; rare to common in the Putnam Hill (4) and Boggs (2); and, rare in the Portersville (1), Cambridge (1) and Vanport (1) units.

Paleyoldia stevensoni (MEEK) is one of the less common nuculoids. It is rare to abundant in the undifferentiated Brush Creek (4) unit; common in the Lower Brush Creek (1) unit; rare to common in the Columbiana (3) unit; and, rare in the Washingtonville (1) and Lower Mercer (1) unit.

With the exception of *Nuculopsis*, representatives of the genus *Phestia* are the most abundant nuculoids in our collections. *P. bellistriata* (STEVENS) is longer ranging than other taxa in this genus and is rare to abundant in the undifferentiated Brush Creek (3) unit; rare to common in the Washingtonville (2), Columbiana (8), Putnam Hill (5) and Lower Mercer (7) units; and rare in the Portersville (4), Lower Brush Creek (2) and Vanport (3) units; and, questionably present as rare in the Upper Brush Creek (1) and Mason (1) units. Also reported by MORNINGSTAR (1922) from the Boggs and Lowellville units and by MARK (1912) from the Ames unit but these occurrences could not be verified.

The most restricted form is *Phestia bellistriata prolongata* (MORNINGSTAR). It is rare in the Lower Mercer (1) unit. MORNINGSTAR (1922) also reports it in the Boggs unit but this can not be verified. This species is restricted to the Pottsville Group.

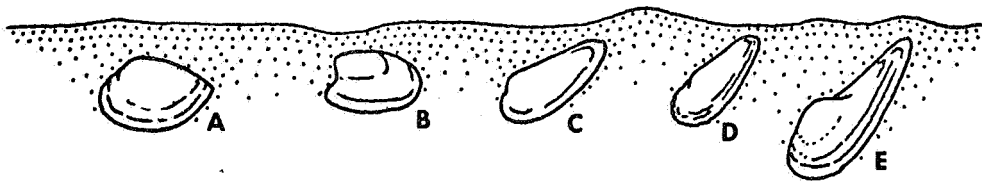
Phestia arata (HALL) is rare to abundant in the undifferentiated Brush Creek (6) unit; rare to common in the Lower Brush Creek (2) and Putnam Hill (3) units; and rare in the Portersville (1), Cambridge (2), Dorr Run (1); Washingtonville (1), Columbiana (2) and Vanport (3) units. This species is restricted to the Allegheny and Conemaugh Groups.

Phestia attenuata (MEEK) is rare to common in the Columbiana (3) unit and rare in the Portersville (1), Lower Brush Creek (2) and Putnam Hill (2) units. It is restricted to the Allegheny and Conemaugh Groups.

As can be seen in the foregoing discussion the usefulness of the nuculoids as stratigraphic indicators in the Pennsylvanian System in Ohio is limited. The greatest difference appears to be across the Pottsville-Allegheny boundary with *Phestia bellistriata prolongata* restricted below the boundary and *Clinopistha laevis*, *Phestia arata* and *Phestia attenuata* restricted above it. Although preservation in most of the Pottsville units is poor, the large number of collections made from the Lower Mercer unit, where preservation is good, tends to indicate that the restrictions described are valid.

Paleoecology

The occurrence of marine bivalves in the Pennsylvanian of Ohio is controlled by a number of environmental parameters such as salinity, substrate, food, space, temperature, and the presence or lack of physical barriers which controlled their migration into acceptable habitats. The competition for space and food with the brachiopods, at this time, was possibly among the more important controls of their distribution. BRETSKY (1969) has shown that the more stenotopic articulate brachiopods dominated offshore habitats leaving nearshore areas to the bivalves which are more tolerant of physical and chemical changes in their environments. Rarely have we found any great mixing of brachiopod and bivalve assemblages except where evidence of a thanatocoenose or death assemblage is present and the shells are broken, worn and disarticulated. It is not uncommon to find a few of one group



Fg. 2. Inferred life positions of A, B, *Nuculopsis;* C, *Palaeoneilo;* D, *Paleyoldia;* and, E, *Phestia,* burrowing deposit-feeders, a few cm below the surface of the substrate, x 0.9.

mixed in with the other but the fauna is clearly dominated by one or the other group.

At many of the localities, from which numerous specimens of bivalves were collected, brachiopods may also be abundant (STURGEON and HOARE, 1968). They are not normally found associated on the same depositional plane at any one locality but are separated and indicate different positions relative to the shoreline at a given time. Inarticulate brachiopods, such as *Lingula* which is a nearshore form, may commonly be found in association with numerous bivalves.

There has been no attempt made here to run detailed sediment analyses in association with bivalve occurrences. The general lithology in which a particular taxon of the forms under discussion occurs is given in the following discussion.

Epibionts were not found associated with the nuculoids in these collections except for very rare occurrences of *Serpulopsis* tubes on a few specimens of *Nuculopsis girtyi.* Poor shell preservation in many bivalves may obscure epibiont relationships but this does not appear to be the case in the nuculoids which commonly have well preserved shells. It is more likely due to the relatively small size of individuals in this group and their infaunal mode of life.

Nuculoids are the most abundant group of bivalves present in the collections and commonly have the valves articulated. They were often found associated with brachiopod faunas, much more so than other bivalve forms. This is probably due to the fact that they were rapid, free burrowers and deposit feeders like modern forms (STANLEY, 1970) and the Pennsylvanian forms were not in as much competition with the associated brachiopod faunas (fig. 2).

The nuculoids were most commonly found in dark shales which may be calcareous or with a high silt content. Specimens collected from 107 localities where the lithology is known are distributed in the following manner: 73 occurrences in dark gray to black shale, which may be calcareous and/or with a high silt content; 14 occurrences in fine-grained, black limestone; 11 occurrences in light gray shale; six occurrences in fine-grained, light gray limestone, which may be noduliferous; and, three occurrences in a brown calcarenite. This distribution of sedimentological occurrences agrees well with those reported by DICKENS (1963) and STANLEY (1970, 1972).

SYSTEMATIC PALEONTOLOGY

Subclass *PALAEOTAXODONTA*
KOROBKOV, 1954
Order *NUCULOIDA* DALL, 1889
Superfamily *CTENODONTACEA*
WÖHRMANN, 1893
Genus *Clinopistha* MEEK & WORTHEN, 1870
Clinopistha laevis MEEK & WORTHEN
Pl. 1, fig. 1-3

1870 *Clinopistha radiata* var. *laevis* MEEK & WORTHEN, p. 44.
1873 *Clinopistha radiata* var. *laevis* MEEK & WORTHEN, p. 584, pl. 27, fig. 7a-f.
1961 *Clinopistha radiata* MEEK & WORTHEN — HOARE, p. 93, pl. 13, fig. 4, 5.
1968 *Clinopistha radiata* var. *laevis* MEEK & WORTHEN — MCALESTER, p. 20, pl. 4, fig. 1-16.

Medium-sized, strongly inequilateral, equivalved and inflated nuculids. Beaks small, tightly incurved and opisthogyrate; anterior margin broadly rounded; escutcheon absent; ovate external ligament marked by a callus posterior to umbones; surface marked by fine to moderately coarse growth lines; and, internal mold shows very faint, low, radiating ridges of unequal intensity which are not reflected on shell surface.

Dentition not observed, presumably taxodont and lacking a resilifer; muscle scars faintly impressed with a large, subquadrate, anterior adductor scar located anterodorsally; smaller, subovate, posterior adductor scars located just ventral to posterior callus; and, pallial line absent (fig. 3). Other interior features not observed. Worthwhile measurements not possible.

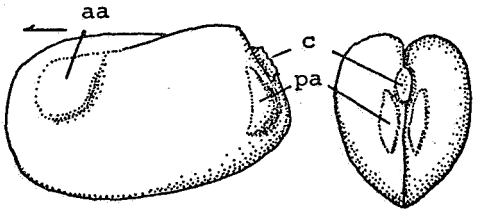


Fig. 3. Left lateral and posterior views of internal mold of *Clinopistha laevis* MEEK & WORTHEN, x 2; aa-anterior adductor scar, pa-posterior adductor scar, c-callus.

Discussion — *Clinopistha laevis* is the only known species of this genus present in the Pennsylvanian of Ohio and is a rare form. Comparing the Ohio specimens with specimens from the Tebo Formation (Desmoinesian) of Missouri, identified by HOARE (1961) as *C. radiata* Hall, no difference can be seen in shape or ornamentation. The radiating ridges on the internal mold do not affect the shell surface in specimens from either area but can be seen through the shell material where it is exfoliated.

Occurrence — Rare to common in the Columbiana and Putnam Hill units and rare in the Vanport, Washingtonville, and Cambridge units.

Repository — Hypotypes, OSU-27143, BGSU-305.

Superfamily *NUCULACEA* GRAY, 1824
Family *NUCULIDAE* GRAY, 1824
Genus *Nuculopsis* GIRTY, 1911
Nuculopsis girtyi SCHENCK
Pl. 1; fig. 4-8

1858 *Nucula ventricosa* HALL, p. 716, pl. 29, fig. 4, 5a, b.
1915 *Nuculopsis ventricosa* (HALL) — GIRTY (a), p. 117, pl. 15, fig. 1-8.
(see for synonymy up to this date).
1921 *Nuculopsis ventricosa* (HALL) — PLUMMER & MOORE, p. 120, pl. 13, fig. 41, 42; pl. 21, fig. 24-27.
1922 *Nuculopsis ventricosa* (HALL) — MORNINGSTAR, p. 204, pl. 10, fig. 20.
1930 *Nuculopsis ventricosa* (HALL) — SAYRE, p. 106, pl. 8, fig. 2-2c.
1931 *Nuculopsis ventricosa* (HALL) — MORSE, p. 300.
1934 *Nuculopsis girtyi* SCHENCK, p. 29, pl. 2, fig. 19; pl. 3, fig. 2a, b.
1939 *Nuculopsis (Nuculopsis) girtyi* SCHENCK, p. 40.
1958 *Nuculopsis girtyi* SCHENCK — LINTZ, p. 100.
1961 *Nucula (Nuculopsis) girtyi* SCHENCK — HOARE — p. 101, pl. 13, fig. 7, 8.
1968 *Nuculopsis girtyi* SCHENCK — MCALESTER, p. 39, pl. 12, fig. 10-18.
1969 *Nuculopsis girtyi* SCHENCK — KEEN, p. 231, fig. 7a-c.

Medium-sized, inequilateral, equivalved, subtrigonal and inflated nuculids. Beaks small, incurved and opisthogyrate; posteroventral margin produced; lunule and escutcheon absent; and, surface marked by fine to coarse growth lines.

Hinge structure of taxodont dentition with up to 15 chevron-shaped denticles anterior to small resilifer and up to six denticles posterior to it; resilifer marked on top by denticles; muscle scars and pallial line strongly impressed; large, ovate, anterior adductor scars located anterodorsally; ovate, posterior adductor scars located posteroventrally; small, ovate, anterior protractor scars present above and behind the anterior adductor scars; and, three or four small, ovate scars located posterolaterally from the protractor scars

may represent the anterior retractor scars (fig. 4). Measurements are given in table 2.

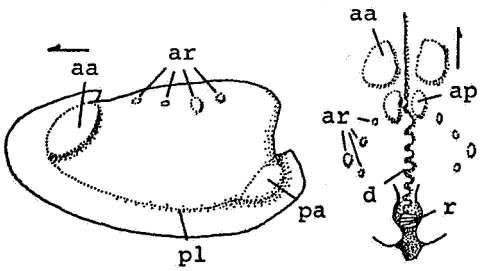


Fig. 4. Left lateral and dorsal views of internal mold of *Nuculopsis girtyi* SCHENCK, x 3; aa-anterior adductor scar, pa-posterior adductor scar, ap-anterior protractor scar, ar-anterior retractor scar, r-resilifer, pl-pallial line, d-dentition.

Discussion — This is the most common type of nuculid present in the Pennsylvanian of Ohio. If differs from *N. anodontoides* (MEEK), with which it is found associated, by being less trigonal in shape with beaks being more depressed, a relatively more inflated shell, a flatter or more depressed anterodorsal margin, less strongly developed anterior retractor scars, lacking posterior pedal retractor scars and having opisthogyrate rather than orthogyrate beaks. Other forms which are present in the collections are differentiated under those species.

Occurrence — Rare to abundant in the Brush Creek, Washingtonville, Columbiana, and Putnam Hill units; rare to common in the Portersville, Cambridge, Vanport and Lower Mercer units; and, rare in the Ames and Upper Mercer units. Also reported from the Harrison and Sharon units by MORNINGSTAR (1922).

Repository — Hypotypes, OSU-27166-27169.

Nuculopsis anodontoides (MEEK)
Pl. 1; fig. 9-14

1871 *Nucula anodontoides* MEEK, p. 71.
1897 *Nucula ventricosa* HALL — HIND (non FLEMING, 1828), p. 180, pl. 14, fig. 16, 16a.
1912 *Nucula anodontoides* MEEK — MARK, p. 306, pl. 14, fig. 14.
1915 *Nucula anodontoides*? MEEK — GIRTY (a), p. 111, pl. 13, fig. 1-5.
1930 *Nucula anodontoides* MEEK — SAYRE, p. 104, pl. 8, fig. 8, 8a.
1931 *Nucula anodontoides* MEEK — MORSE, p. 300.
1958 *Nuculopsis anodontoides* (MEEK) — LINTZ, p. 100.

Medium-sized, inequilateral, equivalved, subtrigonal and moderately inflated nuculids. Beaks elevated, small, incurved and orthogyrate; anterior margin narrowly curved; lunule and escutcheon absent; and, surface marked by fine, evenly spaced growth lines and faint radial lirae.

Hinge structure taxodont with up to nine large, chevron-shaped denticles anterior to the resilifer and seven smaller, chevron-shaped denticles posterior to it; resilifer large and marked on top by denticles; muscle scars and pallial line strongly impressed; pallial sinus lacking; large, ovate, anterior and posterior adductor scars located anterodorsally and at the posterior extremity respectfully; small, kidney-shaped, anterior protractor scars located just posterior to the anterior adductors; narrowly ovate, posterior protractors are located just anterior to the posterior adductors; and, three subcircular to ovate scars anterior to the beaks may represent anterior retractor scars (fig. 5). Measurements are given in table 2.

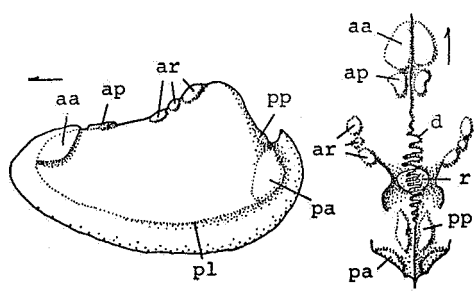


Fig. 5. Left lateral and dorsal views of internal mold of *Nuculopsis anodontoides* (MEEK), x 3; aa-anterior adductor scar, pa-posterior adductor scar, ap-anterior protractor scar, ar-anterior retractor scar, r-resilifer, pl-pallial line, d-dentition.

TABLE 2

Measurements of species of *Nuculopsis* in mm.

Species	Unit	Spec.	Length	Height	Width
N. girtyi	Brush Cr.	1	10.6	6.7	6.4
		2	10.8	7.0	5.8
		3	11.1	6.8	6.1
		4	10.8	7.1	5.0
		5	10.8	7.9	5.4
		6	12.0	7.8	6.6
		7	8.0	5.1	4.1
		8	11.0	6.9	6.5
	Putnam Hill	1	10.8	7.2	6.8
		2	10.8	7.3	7.3
		3	9.0	5.8	5.2
		4	7.2	6.9	6.9
N. anodontoides	Brush Cr.	1	15.1	11.3	8.5
		2	15.5	10.4	8.9
		3	14.2	10.2	7.6
		4	13.2	10.2	6.9
		5	14.5	10.4	7.6
		6	11.7	8.5	6.2
	Columbiana	1	11.1	8.2	6.0
		2	12.4	8.9	7.0
		3	9.2	6.4	4.0
N. croneisi	Brush Cr.	1	8.4	6.7	3.6

Discussion — *Nuculopsis anodontoides* is differentiated from *N. girtyi* SCHENCK under the latter species. The presence of orthogyrate beaks is noted in extending the variability of this feature in the Family Nuculidae (KEEN, 1969, p. 230).

Occurrence — Rare to abundant in the Brush Creek and Columbiana units; rare to common in the Portersville, Cambridge, Wasnigtonville and Putnam Hill units; and, rare in the Vanport, Upper Mercer, Lower Mercer and Poverty Run units. Also reported from the Ames unit by MARK (1912).

Repository — Hypotypes, OSU-27170-27173.

Nuculopsis croneisi SCHENCK

Pl. 1; fig. 15-17

1859 *Nucula parva* MCCHESNEY, p. 54.

1865 *Nucula parva* MCCHESNEY, p. 39, pl. 2, fig. 8a-c.

1867 *Nucula parva* MCCHESNEY, p. 39, pl. 2, fig. 8a-c.

1873 *Nucula parva* MCCHESNEY — MEEK and WORTHEN, p. 589, pl. 26, fig. 8a, b.

1888 *Nucula parva* MCCHESNEY — KEYES, p. 233.

1889 *Nucula parva* MCCHESNEY — MILLER, p. 495.

1891 *Nucula parva* MCCHESNEY — KEYES, p. 29.

1894 *Nucula parva* MCCHESNEY — KEYES, p. 121.

1911 *Nucula parva* MCCHESNEY — GIRTY, p. 119.

1912 *Nucula parva* MCCHESNEY — MARK, p. 297.

1913 *Nucula parva* McCHESNEY — KREBS and TEETS, p. 133.
1914 *Nucula parva* McCHESNEY — PRICE, p. 154.
1915 *Nucula parva* McCHESNEY — MATHER, p. 210, pl. 15, fig. 21.
1918 *Nucula parva* McCHESNEY — PRICE, p. 787.
1922 *Nucula parva* McCHESNEY — MORNINGSTAR, p. 202.
1939 *Nuculopsis (Palaeonucula) croneisi* SCHENCK, p. 24, pl. 7, fig. 1-4.
1958 *Palaeonucula croneisi* SCHENCK — LINTZ, p. 100.

Small, inequilateral, equivalved, and subtriangular nuculids. Beaks small, incurved and orthogyrate; anterior margin narrowly rounded; and, surface marked by fine, evenly spaced lirae numbering up to 11 in a span of 1 mm at a distance of 3 mm ventral to the beak.

Hinge structure and interior features not observed. Measurements given in table 2.

Discussion — *Nuculopsis croneisi* differs from *N. girtyi* SCHENCK by being subtriangular in shape, having orthogyrate beaks and regular and closely spaced concentric lirae. *N. anodontoides* (MEEK) is a more strongly inflated species and lacks the concentric lirae of *N. croneisi*. It is possible that immature specimens of other species of concentrically marked *Nuculopsis* have been included here. Their small size prevents a comparison of distinguishing characteristics.

Occurrence — Rare to common in the Washingtonville, Columbiana, and Putnam Hill units and rare in the Brush Creek, Vanport and Upper Mercer units.

Repository — Hypotypes, OSU-27174, 27251, 28989.

Superfamily *NUCULANACEA*
H. ADAMS & A. ADAMS, 1858
Family *MALLETIIDAE*
ADAMS & ADAMS, 1858
Genus *Palaeoneilo* HALL & WHITFIELD, 1869
Palaeoneilo oweni (McCHESNEY)
Pl. 1; fig. 22-23; Pl. 2; fig. 1-5

1859 *Leda oweni* McCHESNEY, p. 52.
1865 *Leda polita* McCHESNEY, p. 53.
1867 *Leda knoxensis* McCHESNEY, p. 39, pl. 2, fig. 9a-c.
1867 *Yoldia? oweni* McCHESNEY, p. 38, pl. 2, fig. 10a-c.
1871 *Yoldia (Palaeoneilo) carbonaria* MEEK, p. 72.
1875 *Yoldia (Palaeoneilo) carbonaria* MEEK, p. 336, pl. 19, fig. 5.
1889 *Yoldia carbonaria* MEEK — MILLER, p. 516.
1910 *Yoldia carbonaria* MEEK — RAYMOND, p. 155.
1911 *Anthraconeilo taffiana* GIRTY, p. 132.
1912 *Yoldia carbonaria* MEEK — MARK, p. 297.
1914 *Anthraconeilo taffiana* GIRTY — PRICE, p. 515, pl. 43, fig. 18.
1915 *Anthraconeilo taffiana* GIRTY — GIRTY (a), p. 114, pl. 15, fig. 9.
1922 *Anthraconeilo bownockeri* MORNINGSTAR, p. 208, pl. 10, fig. 21.
1958 *Anthraconeilo taffiana* GIRTY — LINTZ, p. 100.
1961 *Anthraconeilo taffiana* GIRTY — HOARE, p. 104, pl. 13, fig. 6.
1966 *Palaeoneilo oweni* (McCHESNEY) — MURPHY, p. 868, pl. 101, fig. 1-8, 10-12, 14-20.
1968 *Anthraconeilo taffiana* GIRTY — McALESTER, p. 16, pl. 18, fig. 1-6; pl. 19, fig. 1-11.

Large, inequilateral, equivalved, elongate, and inflated nuculaniform shells. Beaks small, incurved, anterior of mid-length and prosogyrate; posterior margin somewhat attenuate to truncate; lunule absent and escutcheon narrowly elongate; surface marked by fine to moderately coarse growth lines; and, posterior radial groove broad and shallow.

Hinge structure taxodont with six larger denticles anterior to beak and 26 smaller teeth posterior to beak; resilifer absent; muscle scars lightly impressed with a large anterior adductor scar visible; other scars not discernable; and, faint pallial line paralleling margin anteriorly, not visible posteriorly

(fig. 6). Other interior features not observed. Measurements given in table 3.

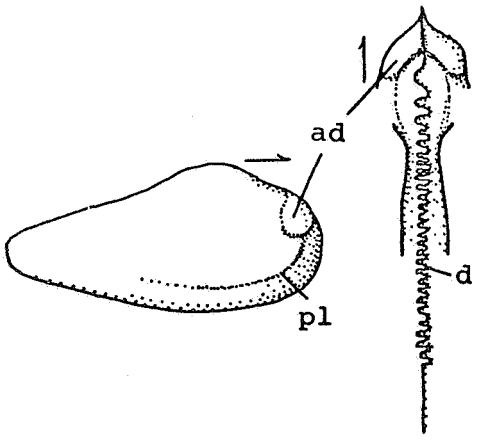


Fig. 6. Right lateral, x3, and dorsal, x4 views of internal mold of *Palaeoneilo oweni* (McChesney). ad-anterior adductor scar, pl-pallial line, d-dentition.

Discussion — This is the only species of *Palaeoneilo* which can be identified with certainty in our collection. Morningstar's (1922) description of *Anthraconeilo bownockeri* from the Sharon unit is based upon poorly preserved internal molds which show little variation from those described here with the exception that the holotype is less produced posteriorly and may be a slightly truncate specimen similar to some of the Allegheny and Conemaugh specimens of *P. oweni.* Murphy (1966) made an extensive comparison of described species of *Palaeoneilo* and concluded that most were synonymous with *P. oweni.*

Occurrence — Rare to abundant in the Washingtonville and Columbiana units; common to abundant in the Brush Creek unit; rare to common in the Putnam Hill and Boggs units; and, rare in the Portersville, Cambridge and Vanport units.

Repository — Hypotypes, OSU-27175-27179.

Family *NUCULANIDAE*
Adams & Adams, 1858
Genus *Paleyoldia* Lintz, 1958
Paleyoldia stevensoni (Meek)
Pl. 1; fig. 18-21

1871 *Yoldia stevensoni* Meek, p. 72.
1875 *Yoldia stevensoni* Meek, p. 335, pl. 19, fig. 4a, b.
1922 *Yoldia stevensoni* Meek — Morningstar, p. 108.

Medium-sized, equilateral, nuculaniform, and compressed or non-inflated shells. Beaks small, near mid-length and opisthogyrate; anterior margin more strongly curved dorso-anteriorly; posterior margin attenuate to narrowly truncate; lunule and escutcheon absent; narrow ligament gape on both sides of umbones; surface marked by fine concentric straie, 15-16 in a space of 2 mm measured at a distance of 3 mm from the beak; and, straie do not parallel the posteroventral margin but approach it at an oblique angle.

Hinge structure with taxodont dentition having 10 large denticles anterior to the beak which decrease in size anteriorly and seven denticles posterior to the beak; five intermediate denticles are present above the resilifer; muscle scars and pallial line lightly impressed; large, anterior adductor scars present; small, subtriangular, posterior adductor scars visible; strongly developed, posterior pedal retractor scars present; and, pallial line shows a broad sinus below the posterior adductor scars and then becomes obscure anteriorly (fig. 7). Measurements given in table 3.

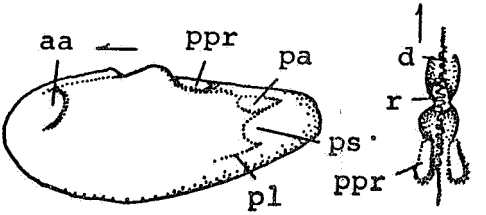


Fig. 7. Left lateral and dorsal views of internal mold of *Paleyoldia stevensoni* (Meek), x3; aa-anterior adductor scar, pa-posterier adductor scar, ppr-posterior pedal retractor scar, r-resilifer, pl-pallial line, ps-pallial sinus, d-dentition.

Discussion — *Paleyoldia stevensoni* has approximately the same form as *P. glabra* (Beede & Rogers). The two species apparently

differ on the basis of external ornamentation. LINTZ (1958) describes the latter species as having approximately 4 straie per mm whereas *P. stevensoni* has 7-8 per mm. The range of variation of ornamentation is unknown for these species and other than the above difference *P. stevensoni* would be included in synonymy with *P. glabra.*

MORNINGSTAR (1922) reports *Yoldia glabra* from the Putnam Hill unit but does not illustrate the specimens. From her description it appears that she was describing specimens of the genus *Phestia.*

Occurrence — Rare to abundant in the Brush Creek unit; rare to common in the Columbiana unit; and, rare in the Washingtonville and Lower Mercer units.

Repository — Hypotypes, OSU-27180-27182.

TABLE 3

Measurements of *Palaeoneilo oweni* and *Paleyoldia stevensoni* in mm.

Species	Unit	Spec.	Length	Height	Width
P. oweni	Columbiana	1	17.3	10.6	7.3
		2	18.2	10.6	7.2
		3	15.7	9.7	6.2
		4	15.2	10.0	6.5
		5	16.1	9.3	6.1
		6	21.0	11.5	8.2
		7	16.3	10.0	7.9
	Washingtonville	1	12.4	6.7	5.2
		2	18.4	9.6	7.0
		3	19.4	10.5	9.2
		4	15.0	7.9	6.0
		5	16.0	8.2	6.0
		6	18.7	10.1	7.6
		7	14.0	7.9	6.3
		8	19.4	10.2	8.7
P. stevensoni	Brush Cr.	1	17.5	8.5	3.6
	Brush Cr.	1	17.7	8.7	3.5
		2	13.9	7.2	3.0

Genus *Phestia* CHERNYSHEV, 1951

Phestia bellistriata (STEVENS)

Pl. 2; fig. 6, 7

1858 *Leda bellistriata* STEVENS, p. 261.

1858 *Leda bellistriata* STEVENS — HALL, p. 717, pl. 29, fig. 6a-d.

1858 *Nucula (Leda) Kazanensis* SWALLOW, p. 190.

1887 *Nuculana bellistriata* (STEVENS) — HERRICK, p. 40, pl. 4, fig. 26.

1900 *Nuculana bellistriata* (STEVENS) — BEEDE, p. 148, pl. 20, fig. 14-14b.

1903 *Leda bellistriata* STEVENS — GIRTY, p. 442.

1910 *Nuculana bellistriata* (STEVENS) — RAYMOND, p. 155.

1911 *Leda bellistriata* STEVENS — MARK, p. 310, pl. 9, fig. 5.

1912 *Leda bellistriata* STEVENS — MARK, p. 297.

1915 *Leda bellistriata* STEVENS — GIRTY (a), p. 122, pl. 14, fig. 1-9a.
1915 *Leda bellistriata* STEVENS — MATHER, p. 212, pl. 15, fig. 19.
1921 *Leda bellistriata* STEVENS — PLUMMER & MOORE, pl. 7, fig. 1, 5-6a; pl. 14, fig. 13, 14.
1922 *Leda bellistriata* STEVENS — MORNINGSTAR, p. 204, pl. 10, fig. 27.
1924 *Leda bellistriata* STEVENS — MORGAN, pl. 48, fig. 7, 7a, 8.
1930 *Leda bellistriata* STEVENS — SAYRE, p. 106, pl. 8, fig. 7-7c.
1931 *Leda bellistriata* STEVENS — MORSE, p. 315, pl. 50, fig. 8-15.
1951 *Leda bellistriata* STEVENS — CHOW, p. 25, pl. 3, fig. 3.
1953 *Nuculana bellistriata* (STEVENS) — TASCH p. 358.
1958 (non) *Culunana bellistriata* (STEVENS) — LINTZ, p. 106, pl. 16, fig. 16, 17.
1961 *Nuculana bellistriata* (STEVENS) — HOARE, p. 103, pl. 13, fig. 10.
1965 *Polidevcia bellistriata* (STEVENS) — DRISCOLL, p. 80.
1966 *Polidevcia bellistriata* (STEVENS) — DRISCOLL, p. 2, pl. 1, fig. 1-15; pl. 2, fig. 1-12.
1967 *Polidevcia bellistriata* (STEVENS) — MURPHY, p. 1498, pl. 195, fig. 3.
1968 *Culunana bellistriata* (STEVENS) — MCALESTER, p. 25, pl. 34, fig. 7-13.

Medium-sized, inequilateral, equivalved, inflated, and nuculiform shells. Beaks small, tightly incurved and opisthogyrate; anterior margin uniformly convex, posterior margin produced and narrowly convex, and ventral margin evenly convex; lunule and escutcheon narrowly triangular; ridge radiating from unbonal area to posterior extremity causing posterodorsal valve area to be concave along hinge line posterior to beaks; and, surface marked by numerous, closely spaced, fine ridges and narrow interspaces with 10-15 ridges occupying the space of 3 mm at a distance of 2 mm ventral of the beak area and becoming obscure as they approach the radiating ridge and only fine growth lines continuing onto the concave valve area to the dorsal margin.

The hinge structure shows taxodont dentition with at least eight chevron-shaped denticles anterior to the chondrophore and at least seven denticles posterior to it; chondrophore with reduced denticles above it; and, muscle scars and pallial line not observed. Measurements given in table 4.

Discussion — The differentiation of *Phestia bellistriata* and *P. arata* (HALL), with which it is most likely to be confused, is discussed under the latter species. Specimens which have been assigned to *P. attenuata* (MEEK) are consistantly smaller, with finer surface ornamentation and have more attenuate posterior shell areas. They do not appear to be juvenile specimens of *P. bellistriata.* The surface ornamentation of *P. bellistriata* and *P. arata* approach one another in some collections in terms of the size and number of ridges. Differentiation can usually be made on shell form.

Occurrence — Rare to abundant in the Brush Creek unit; rare to common in the Washingtonville, Columbiana, Putnam Hill and Lower Mercer units; and, rare in the Portersville, Mason, and Vanport units. Also reported from the Lowellville and Boggs units by MORNINGSTAR (1922) and by MARK (1912) from the Ames unit.

Repository — Hypotype, OSU-27183.

Phestia bellistriata prolongata
(MORNINGSTAR) Pl. 2; fig. 8.

1922 *Leda bellistriata prolongata* MORNINGSTAR, p. 206, pl. 10, fig. 28, 29.

Large, equivalved, inequilateral, elongate, and nuculiform shells. Anterior margin broadly rounded, posterior margin greatly produced, dorsal margin posterior to beaks concave, and ventral margin broadly convex; lunule and escutcheon not seen; and surface marked by fine, closely spaced, concentric ridges.

Hinge structure and other interior features not observed. Worthwhile measurements not possible.

Discussion — The holotype specimen, designated by MORNINGSTAR (1922, pl. 10, fig. 28) is still available in the repository at

Ohio State University. No other specimens could be found in the collections there nor were others found in our collections. The much larger size and more produced posterior portion are distinctive of this form which we feel is a subspecies of *P. bellistriata* (STEVENS). The specimen is an internal mold and does not show features clearly but does have faint impressions of the concentric ridges.

Occurrence — Rare in the Lower Mercer unit. Also reported by MORNINGSTAR (1922) from the Boggs unit.

Repository — Holotype, OSU-15254.

Phestia arata (HALL)
Pl. 2; fig. 9-14

1852 *Leda (Nucula) arata* HALL, p. 413, pl. 2, fig. 5a, b.
1884 *Nuculana bellistriata* (STEVENS) — WHITE p. 146, pl. 31, fig. 8, 9.
1888 *Nuculana bellistriata* (STEVENS) — KEYES p. 232.
1894 *Nuculana bellistriata* (STEVENS) — KEYES p. 122, pl. 45, fig. 4a, b.
1896 *Nuculana bellistriata* (STEVENS) — SMITH, p. 245.
1915 *Leda arata* HALL — GIRTY (b), p. 351, pl. 31, fig. 1-8.
1958 *Culunana bellistriata* (STEVENS) — LINTZ, p. 107, pl. 16, fig. 16, 17.
1966 *Polidevcia arata* (HALL) — DRISCOLL, p. 7, pl. 3, fig. 1-14.
1967 *Polidevcia arata* (HALL) — MURPHY, pl. 195, fig. 1, 2.

Medium to large-sized, inequilateral, equivalved, inflated, and nuculaniform shells. Beaks small, tightly incurved, and opisthogyrate; anterior margin uniformly curved and slightly produced, posterior margin produced and narrowly curved, and ventral margin evenly convex anteriorly but straight to slightly concave posteriorly; lunule narrowly ovate and escutcheon narrowly triangular; ridge radiating from umbonal region to posterior extremity with valve surface concave posterior to beaks along hinge line; and, surface marked by numerous angular ridges, steeper on the dorsal side, separated by flat to concave interspaces marked by fine growth lines, with 7-8 ridges occupying the space of 3 mm at a distance of 2 mm ventral from the beak area. The ridges become obscure as they approach the posteriorly radiating ridge and the fine growth lines continue over the surface to the dorsal margin.

Hinge structure with taxodont dentition having up to 12 chevron-shaped denticles anterior to the chondrophore and up to 17 denticles posterior to it; chondrophore well developed and has up to six reduced denticles above it; muscle scars well developed consisting of prominent anterior and posterior adductors, small triangularly shaped anterior and posterior pedal retractors along the hinge line, small anterior protractor scars at the posterior edge of the anterior adductors, small subtriangular accessory scars of unknown function posterior to the posterior adductor scars, and two small scars of unknown function located just ventral to the umbonal area; a strong internal ridge runs from the umbonal cavity curving posteriorly; inner margin of valves finely crenulate; and, pallial line not visible (fig. 8). Measurements given in table 4.

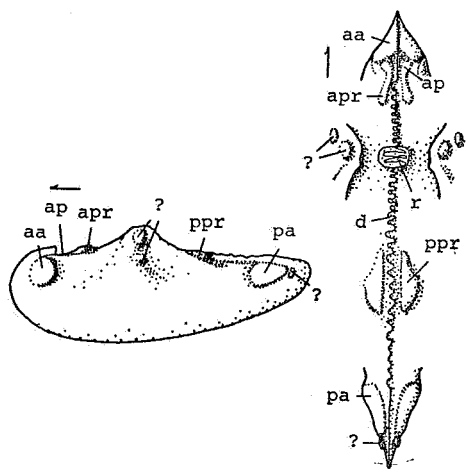


Fig. 8. Left lateral, x1.5, and dorsal, x2, views of internal mold of *Phestia arata* (HALL). aa-anterior adductor scar, pa-posterior adductor scar, ap-anterior protractor scar, ppr-posterior pedal retractor scar, apr-anterior pedal retractor scar, ?-scars of unknown function, r-resilifer, d-dentition.

Discussion — *Phestia arata* differs from *P. bellistriata* by having more widely spaced and coarser concentric ridges, a posterior portion that is higher and less attenuate, and an anterior margin which is more produced causing the beaks to be relatively nearer mid-length of the shell.

Occurrence — Rare to abundant in the Brush Creek unit; rare to common in the Putnam Hill unit; and, rare in the Portersville, Cambridge, Dorr Run, Washingtonville, Columbiana and Vanport units.

Repository — Hypotypes, OSU-27185-27189.

Phestia attenuata (MEEK)
Pl. 2; fig. 15-16

1866 *Nucula kazanensis* GEINITZ, p. 20, pl. 1, fig. 33, 34. (non) VERNEUIL, 1845)

1872 *Nuculana bellistriata* var. *attenuata* MEEK, p. 206, pl. 10, fig. 11a, b.

1900 *Nuculana bellistriata* var. *attenuata* MEEK — BEEDE, p. 149.

1912 *Leda meekana* MARK, p. 307, pl. 15, fig. 1.

1915 *Nuculana bellistriata* var. *attenuata* MEEK — GIRTY (a), p. 125, pl. 14, fig. 10-11b.

1922 *Leda meekana* MARK — MORNINGSTAR, p. 206, pl. 10, fig. 25-26.

Small, inequilateral, equivalved, slightly inflated, and nuculiform shells. Beaks small, tightly incurved, and opisthogyrate; anterior margin uniformly convex and not produced, posterior margin attenuate, and very narrowly curved and ventral margin convex anteriorly and shallowly concave posteriorly; lunule and escutcheon narrow and not deeply impressed; and, surface marked by very fine, concentric ridges and narrow interspaces with up to 17 ridges in the space of 3 mm just ventral to the beak area.

Hinge structure and other interior features not observed. Measurements given in table 4.

Discussion — *Phestia attenuata* was originally designated by MEEK (1872) as a variety of *P. bellistriata.* It differs from this species by the narrow and more attenuate posterior portion of the shell, by consistantly finer ornamentation and by smaller shell size.

Occurrence — Rare to common in the Columbiana unit and rare in the Portersville, Brush Creek, and Putnam Hill units. Also reported from the Lower Mercer unit by MORNINGSTAR (1922).

Repository — Hypotypes, OSU-27190, 27191.

TABLE 4

Measurements of species of *Phestia* in mm.

Species	Unit	Spec.	Length	Height	Width
P. bellistriata	Washingtonville	1	17.8	9.3	6.3
P. arata	Brush Cr.	1	21.6	10.7	8.3
		2	25.7	11.7	9.9
		3	17.2	8.8	5.7
		4	21.6	10.7	8.6
		5	23.9	11.2	8.0
		6	24.0	12.4	8.3
		7	16.4	8.2	5.6
		8	27.4	12.8	10.6
		9	23.2	11.4	9.5
		10	22.8	11.4	9.2
		11	22.6	11.3	7.2
		12	24.3	11.6	8.4
		13	21.2	10.5	7.2
		14	14.3	7.5	5.0
		15	18.4	9.3	6.9
		16	25.5	11.8	8.9
		17	26.7	12.7	9.6
		18	21.6	10.8	7.8
P. attenuata	Brush Cr.	1	8.3	3.6	2.0
		2	6.0	2.8	1.2
		3	8.0	3.6	—

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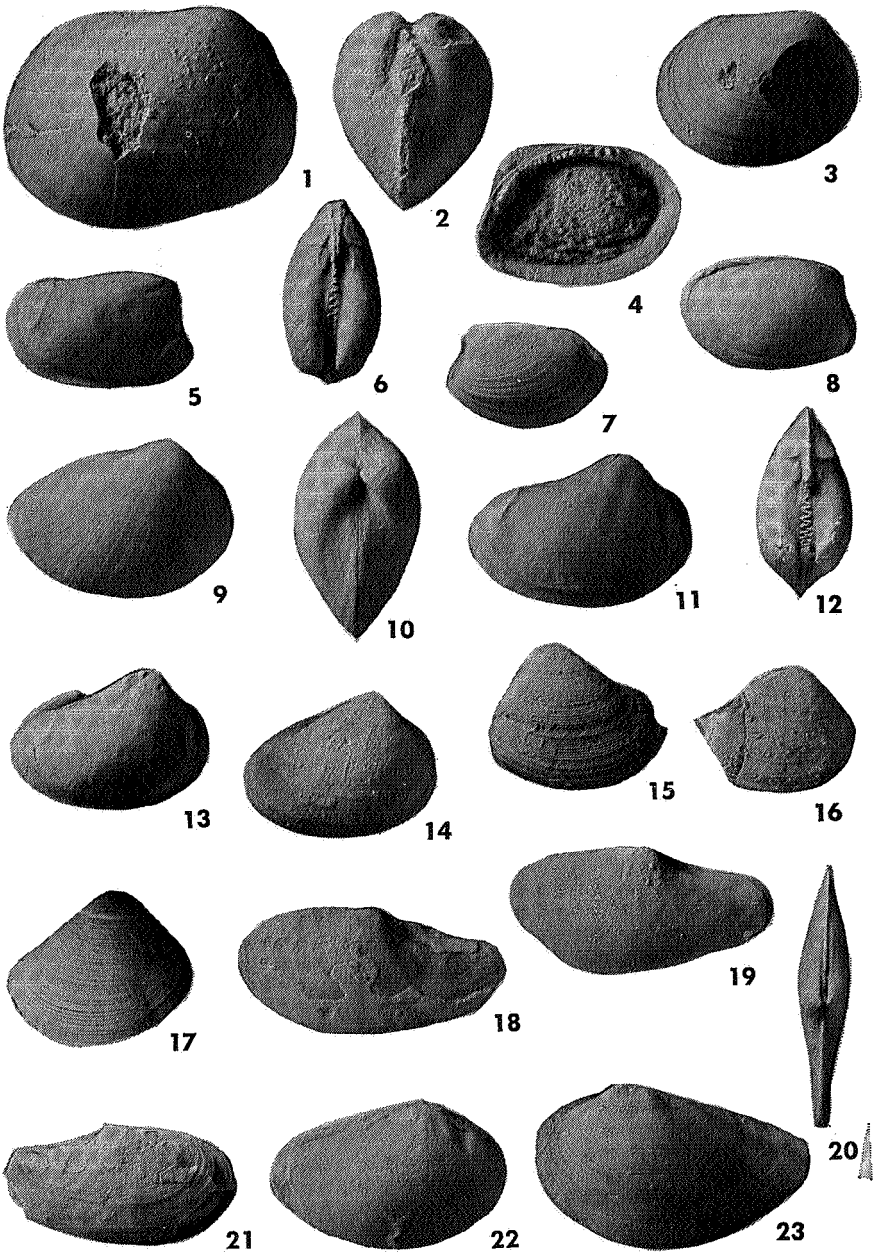
Plate 1



EXPLANATION OF PLATE 1

(All figures x2 except where noted)

Fig. 1-3. *Clinopistha laevis* MEEK & WORTHEN.
1,2. Left valve and posterior views; Tebo Formation, near Lewis, Henry Co., Missouri; OSU-28993.
3. Left valve; Columbiana limestone, OSU-27143.

Fig. 4-8. *Nuculopsis girtyi* SCHENCK.
4. Dentition of left valve; Brush Creek shale, OSU-27168.
5,6. Left valve and dorsal views of internal mold; Brush Creek shale, OSU-27169.
7,8. Right and left valves; Brush Creek shale, OSU-27167, 27166.

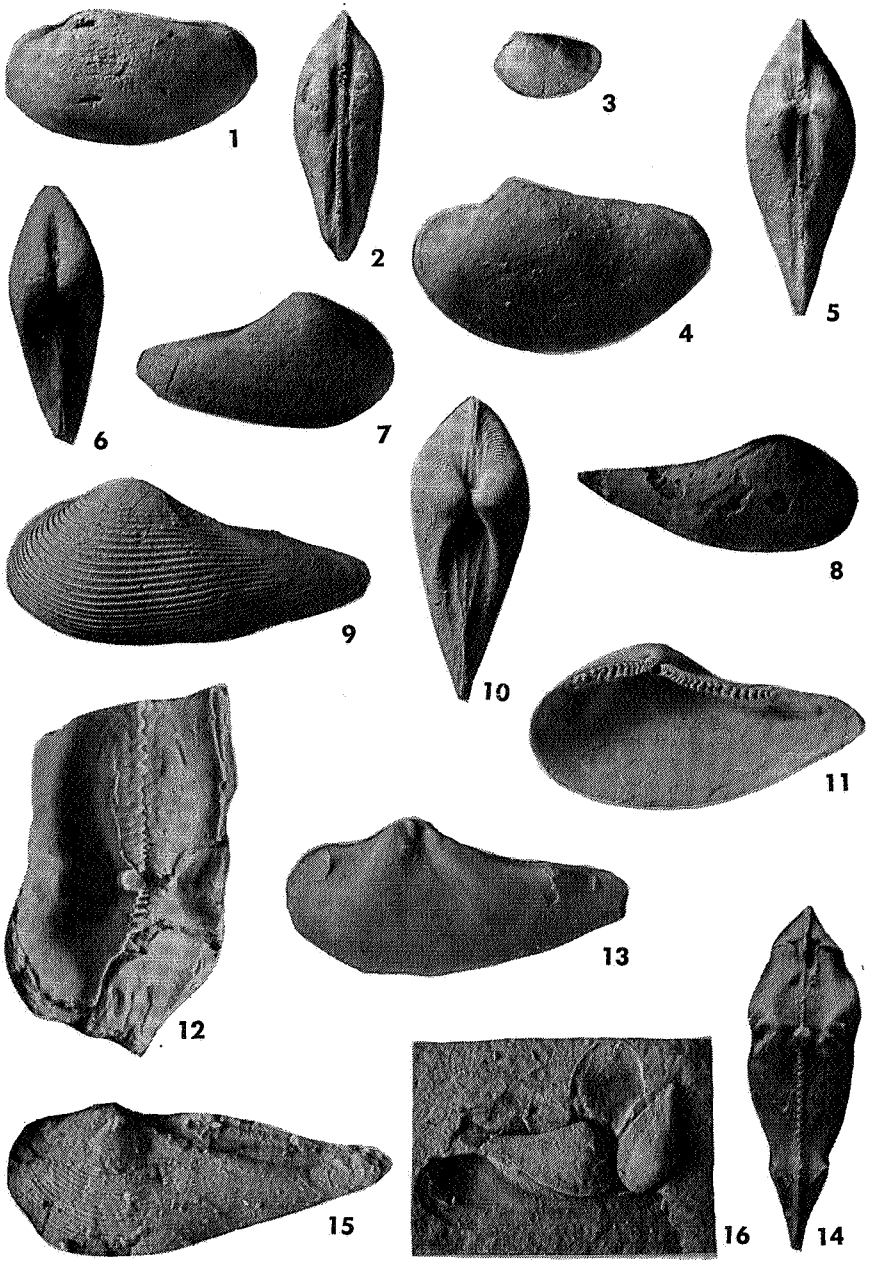
Fig. 9-14. *Nuculopsis anodontoides* (MEEK).
9-11. Left valve and dorsal views and left valve view of internal mold; Brush Creek shale, OSU-27170, 27171.
12,13. Dorsal and left valve views of internal mold; Washingtonville shale, OSU-27172.
14. Left valve; Columbiana shale, OSU-27173.

Fig. 15-17. *Nuculopsis croneisi* SCHENCK.
15. Right valve, x3; Brush Creek shale, OSU-28989.
16. Left valve; Columbiana shale, OSU-27174.
17. Left valve, x3; Washingtonville shale, OSU-27251.

Fig. 18-21. *Paleyoldia stevensoni* (MEEK).
18. Left valve with shell partly missing; Brush Creek shale, OSU-27180.
19,20. Left valve and dorsal views of internal mold; Brush Creek shale, OSU-27182.
21. Right valve with shell partly missing; Washingtonville shale, OSU-27181.

Fig. 22-23. *Palaeoneilo oweni* (MCCHESNEY).
22. Right valve; Washingtonville shale, OSU-27176 (same as MURPHY's pl. 101, fig. 18, 1966).
23. Left valve; Washingtonville shale, OSU-27178 (same as MURPHY's pl. 101, fig. 20, 1966).

Plate 2



EXPLANATION OF PLATE 2

(All figures x2 except where noted)

Fig. 1-5. *Palaeoneilo oweni* (McCHESNEY).
1,2. Left valve and dorsal views of internal mold; Columbiana shale, OSU-27177 (same as MURPHY's pl. 101, fig. 19, 1966).
3. Left valve of immature individual; Brush Creek shale, OSU-27179 (same as MURPHY's pl. 101, fig. 15, 1966).
4,5. Left valve and dorsal views; Columbiana shale, OSU-27175.

Fig. 6-7. *Phestia bellistriata* (STEVENS). Dorsal and right valve views; Washingtonville shale, OSU-27183.

Fig. 8. *Phestia bellistriata prolongata* (MORNINGSTAR). Right valve view of badly weathered specimen xl; Lower Mercer Limestone, holotype, OSU-15254 (MORNINGSTAR's pl. 10, fig. 28, 1922).

Fig. 9-14. *Phestia arata* HALL. Left valve, dorsal, right valve interior, hinge line interior and left valve and dorsal views of internal mold; Brush Creek shale, OSU-27186, 27185, 27187, 27189, 27188.

Fig. 15-16. *Phestia attenuata* (MEEK).
15. Left valve, crushed, x4; Portersville shale, OSU-27190.
16. Two specimens and external molds, x3; Lower Brush Creek shale, OSU-27191.

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