Geology and Paleontology of Canal Zone and Adjoining Parts of Panama

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 306-E

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By **W. P. WOODRING**

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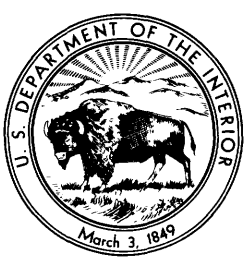
A contribution to the history of the Panamá land bridge



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DESCRIPTION OF TERTIARY MOLLUSKS (ADDITIONS TO GASTROPODS, SCAPHOPODS, PELECYPODS: NUCULIDAE TO MALLEIDAE)

By W. P. Woodring

ABSTRACT

Chapter E adds 112 described species and subspecies (a few briefly described) to the some 440 covered in preceding chapters: 27 additional gastropods, 18 scaphopods, and 67 pelecypods in 10 families. It is estimated that about 125 species are to be added in chapter F, the final chapter.

The Arcidae is by far the largest family in the pelecypods so far studied: 30 species in six genera. The genus *Anadara* is the largest in that family: 25 species, representing the subgenera *Hawaiarca?*, *Rasia*, *Tosarca*, *Grandiarca*, *Potiarca*, and *Cunearca*. *Potiarca*, based on a living western Pacific species, is adopted for many American species heretofore assigned to *Cunearca*.

Eighteen of the 27 additional gastropods were found at a new locality in the late Eocene part of the Gatuncillo formation. They are assigned to 16 genera, 14 of which are not represented at other Gatuncillo localities. The genera include *Faunus*, *Tympanotonos*, and *Bezanconia*, which are rare in America, and the rare endemic American genus *Harrisianella*.

The marine member of the Bohio(?) formation is now assigned to the late Eocene, instead of late Eocene or early Oligocene—the only change in age assignment. Eocene affinities are especially strengthened by the presence of *Samanoetia samanensis* and *Volvariella?*, if indeed the unnamed species represents that genus, as seems likely. Both the marine member of the Bohio(?) and the late Oligocene part of the Bohio contain early small species of *Anadara*, subgenus *Rasia*.

The fossils from the moderately deep-water facies of the late Oligocene Caimito formation include the earliest hexagonal *Dentalium* of the subgenus *Dentalium* s.s., from the American mainland, and a widespread and abundant species of the essentially deep-water subgenus *Fissidentalium*.

Anadara chiriquiensis chiriquiensis, a relatively small form of the subgenus *Grandiarca* that is widely distributed in the Miocene Caribbean province, occurs in the Culebra formation. For the most part it indicates brackish water.

Among the fossils from the La Boca formation proper, *Cyphoma* aff. *C. intermedia* is the earliest representative of an endemic American genus, and *Isognomon mimeticus*, a remarkable, narrowly mytiliform species is the type of the new subgenus *Mimonion*. Both the Culebra and La Boca, both of early Miocene age, contain predecessors of Gatun species.

As in other chapters, the largest number of species is from the middle Miocene Gatun formation: 50 species. *Bailya crossata* is the first Tertiary species of the genus from the Caribbean region, and the earliest now known. A bizarre, incomplete gastropod is described as xancid?, genus?. The Gatun contains 13 of the 24 species of *Anadara* and half of the 12 species of the subgenus *Rasia* of that genus. In consideration of two battered and worn specimens of a large form of the subgenus *Grandiarca*, identified as *Anadara grandis patricia?*, the similar Tertiary forms in the Caribbean region are reviewed and divided into a brackish-water group and a marine group. The Gatun fauna now totals some 330 species.

INTRODUCTION

Chapter E covers 112 species and subspecies, distributed as follows:

Species and subspecies of mollusks described in chapter E

Formation	Number of species and subspecies
Eocene series:	
Gatuncillo	22
Marine member of Bohio[1](?)	8
Oligocene series:	
Bohio[1]	5
Caimito	7
Miocene series:	
Culebra	7
La Boca proper	23
Alhajuela	5
Gatun[2]	50
Chagres proper	6

[1] In Spanish orthography Bohío.
[2] In Spanish orthography Gatún.

The original list of fossil localities was published on pages 112–130 of chapter A, but others were added in succeeding chapters, except the present one.

In the distribution tables the designation "sp." in locality columns indicates an incomplete or poorly preserved species that may or may not be the same as that in the species column, and the designation "?sp." indicates that the genus is questioned. Symbols for relative frequency are as follows:

Symbols used for relative frequency

Symbol	Number of specimens
R, rare	1–2
F, few	3–5
C, common	6–20
A, abundant	>20

ACKNOWLEDGMENTS

I am indebted to my colleague Druid Wilson for advice, especially concerning the family Arcidae and the genus *Exputens*, and to members of the staff of the Division of Mollusks, National Museum of Natural History. Dr. Katherine V. W. Palmer and Dr. Horace G. Richards provided facilities for the examination of collections at the Paleontological Research Institution and the Academy of Natural Sciences of Philadelphia, respectively.

CHANGE IN AGE ASSIGNMENT

As provisionally forecast in chapter D (p. 305), the age assignment for the marine member of the Bohio(?) formation is changed from late Eocene or early Oligocene to late Eocene.

It should be understood that the age assignments are Lyellian ages, not planktonic foraminiferal ages. For the Neogene of America, planktonic foraminiferal ages are almost invariably too young in terms of Lyellian ages.

NEW GENERIC AND SUBGENERIC NAMES

The following new generic and subgeneric names are proposed.

Charadreon, Pseudomelaniidae?

Type: *Charadreon leptus* Woodring, n. sp., Gatuncillo formation, Eocene, p. 469. Gender masculine.

Leptomurex, Muricidae, Ocenebrinae?

Type: *Leptomurex acares* Woodring, n. sp., Gatuncillo formation, Eocene, p. 476. Gender masculine.

Lissanucula, subgenus of *Ennucula*, Nuculidae.

Type: *Nucula* (*Nuculopsis*) *hilli* Woodring, Bowden formation, Jamaica, Miocene, p. 489. Gender feminine.

Mimonion, subgenus of *Isognomon*, Isognomonidae.

Type: *Isognomon* (*Mimonion*) *mimeticus* Woodring, n. sp., La Boca formation, Miocene, p. 526. Gender masculine.

FAUNAL SUMMARIES

EOCENE SERIES

GATUNCILLO FORMATION

The species from the Gatuncillo formation are listed in the following table. They include 19 collected by Mr. R. H. Stewart, geologist of the Panama Canal Company, and his assistants at a new locality on the upper course of Río Palenque, 3.4 km west of Nuevo San Juan. This locality was mentioned on pages 303 and 304 of chapter D, and was entered on page 301 as report locality 23b. According to a communication from Mr. Stewart, the Gatuncillo formation, consisting of conglomerate, siltstone, and silty mudstone, rests with marked unconformity on dark gray and green siliceous limestone of the basement complex. The fossils represent an unusual mixed shallow-water and moderately shallow-water biofacies—unusual for the Gatuncillo formation. Fifteen of the Gatuncillo genera so far covered were not found at other Gatuncillo localities. Though the matrix consists of silty mudstone, it contains no foraminifera or ostracodes. *Faunus* now lives at the mouth of rivers in the western Pacific area and *Tympanotonos* in the same habitat along the coast of tropical western Africa.

Additional gastropods and pelecypods (Nuculanidae to Malleidae) from Gatuncillo formation

	Localities						
	Madden basin			Río Palenque	Río Frijol area	Cerro Pelado	Río Casaya area
	9	11	12	23b	32	37a	38
Gastropods:							
Nerita listrota Woodring, n. sp.				R			
Nerita hadra Woodring, n. sp.				A			
Neritina ectypha Woodring, n. sp.				C			
Neritina sp.				R			
Teinostoma (*Idioraphe*) *elachistum* Woodring, n. sp.				A			
Bayania epelys Woodring, n. sp.				A			
Charadreon leptus Woodring, n. sp.				A			
Faunus xenicus Woodring, n. sp.				A			
Potamides? micraulax Woodring, n. sp.				F			
Hannatoma antyx Woodring, n. sp.[1]				A			R
Tympanotonos acanthodes Woodring, n. sp.				A			
Harrisianella camptica Woodring, n. sp.				A			
Bezanconia cosmeta Woodring, n. sp.				A			
Calyptraea lispa Woodring, n. sp.				C			
Globularia (*Globularia*) *megista* Woodring, n. sp.				A			
Leptomurex acares Woodring, n. sp.				R			
Cymia (*Tritonopsis*) n. sp.				R			
Leptadrillia? n. sp.				R			
Pelecypods:							
Saccella sp.						R	
Glycymeris (*Glycymeris*) cf. *G. caracoli* Anderson	F	R	R				
Brachidontes? sp.[2]				R			
Modiolus? sp.[2]					R		
Atrina sp.					R		
Exputens bostrychodes Woodring n. sp.			R		R		

[1] Recorded on p. 68 as *Hannatoma?* cf. *H. emendorferi* Olsson.
[2] Not described.

Several of the gastropods from locality 23b are noteworthy. So far as I am aware, the operculum of *Neritina ectypha*, which was in place in the aperture of a shell, is the first fossil *Neritina* operculum to be recorded from America. *Charadreon leptus*, the type of a new genus of uncertain affinities, is represented by an estimated thousands of specimens and *Hannatoma*

antyx by some 300. *Faunus*, *Tympanotonos*, and *Bezanconia* are rare in America, and *Harrisianella* is a rare Eocene endemic American genus. *Leptomurex acares* is the type of a new muricid genus. Its suture is not in the expectable location, but is a third of the way up the preceding whorl. An unnamed new species of *Cymia* is the earliest species of the subgenus *Tritonopsis* and of *Cymia* itself.

An unusual species of the Eocene genus *Exputens*, *E. bostrychodes*, was collected in Madden basin and in the Río Fríjol area.

Bayania, *Charadreon*, *Hannatoma*, *Harrisianella*, *Bezanconia*, *Globularia*, *Leptomurex*, *Tritonopsis*, and *Exputens* are extinct.

Though all except one of the unequivocally identified species and also the unnamed *Cymia* are endemic, several others are related to species that occur elsewhere, as shown in the following table.

Mollusks from Gatuncillo formation and occurrence elsewhere of same or related species

Species from Gatuncillo formation	Occurrence elsewhere of same or related species
Gastropods:	
Nerita listrota Woodring, n.sp.	*N. planospira* Anton, Holocene.
Teinostoma (*Idioraphe*) *elachistum* Woodring, n.sp.	*T. harrisi* Palmer, middle Eocene, Virginia.
Bayania epelys Woodring, n.sp.	*B. lactea* (Lamarck), early to late Eocene, western Europe.
Faunus xenicus Woodring, n.sp.	*F. ater* (Linné), Holocene.
Hannatoma antyx Woodring, n.sp.	*H. emendorferi* Olsson, late Eocene, Perú, Colombia, Venezuela.
Tympanotonos acanthodes Woodring, n.sp.	*T.* sp., middle Eocene, Jamaica.
Harrisianella camptica Woodring, n.sp.	Late Eocene, Tonosí area, Panamá.
Bezanconia cosmeta Woodring, n.sp.	*B. spirata* (Lamarck), middle Eocene, western Europe.
Globularia (*Globularia*) *megista* Woodring, n.sp.	*G. recurva dumblei* (Heilprin), middle Eocene, Texas.
Cymia (*Tritonopsis*) n.sp.	*C. subalveata* (Conrad), early Oligocene, Mississippi.
Pelecypod:	
Glycymeris (*Glycymeris*) cf. *G. caracoli* Anderson.	*G. caracoli* Anderson, late Eocene, Colombia.

MARINE MEMBER OF BOHIO(?) FORMATION

The table below lists the species from the marine member of the Bohio(?) formation. (For objections to that stratigraphic designation see page 304 of chapter D.) The identification of the unnamed *Volvariella?* is questioned solely because the columella is unknown. If it is a *Volvariella*, it is the youngest and largest species. *Cadulus dolichus* and the unnamed species are the earliest species of the subgenus *Gadilopsis*. Despite its age, *Saccella phlyctaena* is more similar in size and outline to *S. acuta*, which ranges from Miocene to the present time, than younger species of the genus in the faunas under consideration. *Anadara carmanensis* and the unnamed species are early small species of the subgenus *Rasia*. *Samanoetia samanensis*, the most characteristic species, was found in the three areas where this unit is recognized and was collected at Vamos Vamos by every collector who visited that now submerged locality, beginning with Alexander Agassiz in 1891 and ending with MacDonald and Vaughan in 1911.

Eocene affinities are strengthened by the presence of *Anadara carmenensis*, which occurs in late Eocene deposits in Colombia, *Samanoetia samanensis*, found in the late Eocene of Perú, and presumably by *Volvariella?*. *Samanoetia* and presumably *Volvariella?* are extinct.

An additional gastropod, scaphopods, and pelecypods (Nuculanidae to Noetiidae) from marine member of Bohio (?) formation

	Localities										
	Vamos Vamos					Palenquilla Point			Trinidad Island		
	40	40a	40b	40d	40e	41	41a	41b	42	42a	42c
Gastropod:											
Volvariella? sp.	----	----	----	----	----	R	----	F	----	----	----
Scaphopods:											
Dentalium sp.[1]	----	F	----	?R	----	----	----	----	----	----	----
Dentalium (*Laevidentalium?*) sp.	----	----	----	----	----	----	----	R	----	----	----
Cadulus (*Gadilopsis*) *dolichus* Woodring, n. sp.	----	----	----	----	----	----	----	F	----	----	----
Cadulus (*Gadilopsis*) sp.	----	----	----	----	----	----	----	----	F	----	----
Pelecypods:											
Saccella phlyctaena Woodring, n. sp.	F	----	----	A	R	F	----	F	C	----	R
Anadara (*Rasia*) *carmenensis* Clark	----	----	----	----	----	----	----	R	----	----	----
Anadara (*Rasia*) sp.	----	----	----	F	----	----	----	----	----	----	----
Samanoetia samanensis (Olsson)	R	F	R	F	----	F	F	C	R	C	----

[1] Not described.

OLIGOCENE SERIES

BOHIO FORMATION

The few species from the upper part of the Bohio formation on Barro Colorado Island are as follows:

Scaphopods and pelecypods (Nuculanidae to Arcidae) from upper part of Bohio formation on Barro Colorado Island

	Localities		
	42d	42g	42i
Scaphopods:			
Dentalium (*Laevidentalium?*) sp.	R	----	----
Cadulus sp.	R	----	----
Pelecypods:			
Adrana stena Woodring, n.sp.	C	R	----
Portlandia (*Portlandella?*) *euthynta* Woodring, n.sp.	----	----	R
Anadara (*Rasia*) *lita* Woodring, n.sp.	C	----	----

Adrana stena is related to *A. crenifera*, now living in the eastern Pacific Ocean, and *Anadara lita* to the Oligocene species *A. mississippiensis*.

CAIMITO FORMATION

Barbatia cf. *B. cancellaria* (loc. 55b) is the only species from the shallow-water facies of the Caimito formation. It occurs also in the La Boca formation and is related to *B. cancellaria*, living in the Caribbean region.

The fossils found in the moderately deep-water facies of the Caimito on Barro Colorado Island are listed below. *Dentalium armillatum proterum*, a forerunner of the Gatun nominate subspecies, is the earliest hexagonal species of the subgenus *Dentalium* s.s. to be recorded from the American mainland. *D. uscarianum*, assigned to the subgenus *Fissidentalium*, was found at six localities, as many as some 30 fairly complete specimens and about 100 fragments of varying size at a locality. The modern species of *Fissidentalium* for the most part live in deep water: 600 to 1,800 fathoms in the western Atlantic, but as shallow as 35 to 110 fathoms in the same region (Henderson, 1920, p. 61–65). Though *Acila isthmica isthmica* occurs in the Caimito, it ranges through the Miocene in the Canal Zone.

Scaphopods and pelecypods (Nuculidae to Nuculanidae) from moderately deep-water facies of Caimito formation on Barro Colorado Island

	Localities						
	54g	54h	54j	54k	54l	54m	54n
Scaphopods.							
Dentalium (Dentalium) armillatum proterum Woodring, n. subsp	-----	C	-----	C	-----	-----	-----
Dentalium (Fissidentalium) uscarianum Olsson	F	C	F	A	F	F	sp. R
Pelecypods:							
Nucula (Nucula) cf. *N. spheniopsis* Conrad	-----	F	-----	-----	-----	-----	R
Acila (Acila) isthmica isthmica (Brown and Pilsbry)	-----	-----	-----	F	F	R	R
Jupiteria aipeia Woodring, n. sp	-----	F	-----	C	-----	-----	-----
Saccella cf. *S. subcerata* (Woodring)	-----	-----	-----	R	-----	R	-----

The occurrence elsewhere and in other Canal Zone formations of Caimito fossils of moderately deep-water facies, and the affinities of others are as follows:

Mollusks from moderately deep-water facies of Caimito formation and occurrence elsewhere and in other Canal Zone formations of same or related species

Species from Caimito formation	Occurrence elsewhere and in other Canal Zone formations of same or related species
Scaphopods:	
Dentalium (Dentalium) armillatum proterum Woodring, n. subsp.	*D. armillatum armillatum* Toula, Gatun formation.
Dentalium (Fissidentalium) uscarianum Olsson.	Early Miocene, Costa Rica. Also La Boca formation.
Pelecypods:	
Nucula (Nucula) cf. *N. spheniopsis* Conrad.	*N. spheniopsis* Conrad, late Eocene to early Oligocene, Mississippi.
Acila (Acila) isthmica isthmica (Brown and Pilsbry).	Early Miocene, Colombia; middle Miocene, Costa Rica, Venezuela. Also La Boca and Gatun formations and Chagres sandstone.
Jupiteria aipeia Woodring, n.sp.	*J. brocchii* (Bellardi), Miocene, Italy.
Saccella cf. *S. subcerata* (Woodring).	*S. subcerata* (Woodring), middle Miocene, Jamaica.

MIOCENE SERIES

CULEBRA FORMATION

The present chapter covers 11 species from the early Miocene Culebra formation, which crops out only in the Gaillard Cut area along and near the Canal. One, however (the only gastropod), was already recorded and three others, identified only at the generic level, are not described. The species are listed in the accompanying table.

The unnamed, poorly preserved *Anadara* is doubtfully assigned to the central and western Pacific subgenus *Hawaiarca*, which is represented in the Caribbean region by very small species of early and middle Miocene age and occurs also in the late Miocene and Pliocene of Florida. *Anadara dariensis progonica* is a small predecessor of the Gatun nominate subspecies. *Anadara chiriquiensis chiriquiensis*, a greatly overnamed small form of the subgenus *Grandiarca*, occurs in the Culebra. It is widespread in the Miocene of the Caribbean region, as well as in Perú. For the most part it indicates brackish water. Despite its trivial name, the type locality is in the Río Changuinola district of the Bocas del Toro area, in the extreme northwestern part of Panamá. Though *Mytilus canoasensis vidali* is identified in the La Boca, Alhajuela, and Gatun formations, the best representation is in the Culebra.

Gastropod (corrected name) and pelecypods (Nuculidae to Mytilidae) from Culebra formation of Gaillard Cut area and occurrence in La Boca formation

	Localities															La Boca formation
	102	102a	103	104a	104b	106	107	108c	109	110	110a	111a	111b	112	112a	
Gastropod (corrected name):																
Xancus cf. *X. validus* (Sowerby) [1]	-----	----	----	R	R	----	----	----	------	----	-----	----	----	----	----	X
Pelecypods:																
Acila sp.[2]	R	----	----	----	----	----	----	----	------	----	-----	----	----	----	----	------
Saccella sp. (fine sculpture) [2]	-----	R	----	----	----	----	----	----	------	----	-----	----	----	----	----	------
Saccella aff. *S. balboae* (Brown and Pilsbry)	-----	----	----	----	----	----	----	R	------	----	-----	----	----	----	----	X
Adrana sp.[2]	R	----	----	----	----	----	----	----	------	----	-----	----	----	----	----	------
Anadara (*Hawaiarca?*) sp	R	----	----	----	----	----	----	----	------	----	-----	----	----	----	----	------
Anadara (*Rasia*) *dariensis progonica* Woodring, n. subsp	-----	----	----	----	----	R	----	----	Rsp	A	F	C	F	C	C	X
Anadara (*Rasia*) *athroa* Woodring, n. sp	-----	----	----	----	----	----	----	----	------	----	-----	R	----	----	----	------
Anadara (*Grandiarca*) *chiriquiensis chiriquiensis* (Gabb)	-----	----	R	----	----	----	----	----	------	A	-----	----	----	----	----	------
Anadara (*Grandiarca*) *balboai* (Sheldon)	?R	----	----	----	----	F	F	C	R	----	?R	----	----	----	----	X
Mytilus canoasensis vidali Ferreira and Cunha	-----	----	----	----	----	A	----	----	------	----	-----	----	----	----	----	X

[1] Recorded on p. 286 as *Xancus* cf. *X. rex* Pilsbry and Johnson.
[2] Not described.

The occurrence elsewhere and in other Canal Zone formations of the same or related species is shown in the following table:

Mollusks from Culebra formation and occurrence elsewhere and in other Canal Zone formations of same or related species

Species from Culebra formation	Occurrence elsewhere and in other Canal Zone formations of same or related species
Gastropod:	
Xancus cf. *X. validus* (Sowerby).[1]	*X. validus* (Sowerby), early Miocene, Dominican Republic, Haiti. Also La Boca formation proper and Emperador limestone member.
Pelecypods:	
Saccella aff. *S. balboae* (Brown and Pilsbry).	*S. balboae* (Brown and Pilsbry), Gatun formation, middle Miocene, Costa Rica. Also La Boca formation.
Anadara (*Rasia*) *dariensis progonica* Woodring, n. subsp.	*A. dariensis dariensis* (Brown and Pilsbry), Gatun formation, middle Miocene, Costa Rica, Darién area, Panamá, Colombia, Dominican Republic, Perú; late Miocene, Panamá. Also La Boca formation.
Anadara (*Rasia*) *athroa* Woodring, n.sp.?	*A. athroa* Woodring, n.sp., La Boca formation.
Anadara (*Grandiarca*) *chiriquiensis chiriquiensis* (Gabb).	Early Miocene, Haiti, Perú; middle Miocene, Panamá, Perú; middle(?) Miocene, Haiti, Venezuela; middle or late Miocene, Dominican Republic.
Anadara (*Grandiarca*) *balboai* (Sheldon).	*A. chiriquiensis chiriquiensis* (Gabb.) For distribution see above. Also La Boca formation.

[1] Recorded on p. 286 as *Xancus* cf *X. rex* Pilsbry and Johnson.

Mollusks from Culebra formation and occurrence elsewhere and in other Canal Zone formations of same or related species—Continued

Species from Culebra formation	Occurrence elsewhere and in other Canal Zone formations of same or related species
Pelecypods—Continued	
Mytilus canoasensis vidali Ferreira and Cunha.	Early Miocene, Brasil; middle(?) Miocene, Venezuela. Also La Boca, Alhajuela, and Gatun formations.

CUCARACHA FORMATION

Unidentifiable molds of *Anadara* were found in black, carbonaceous shale of the Cucaracha formation at locality 122.

LA BOCA FORMATION, INCLUDING EMPERADOR LIMESTONE MEMBER

Twenty-three described species in the present chapter added to the 48 in preceding chapters bring to 71 the total for the early Miocene La Boca formation proper. This total does not include 35, for the most part identified only at the generic level, that are recorded, but not described.

Five of the gastropods in the accompanying table were already recorded, as noted in the table footnotes. *Cyphoma* aff. C. *intermedia* is the earliest representative of the endemic American genus *Cyphoma*. The La Boca fossils include *Dentalium uscarianum*, a species of the subgenus *Fissidentalium* that occurs also in the moderately deep-water facies of the Caimito formation. *Isognomon mimeticus*, a remarkable narrowly mytiliform species, is the type of the subgenus *Mimonion*. Externally it mimics specimens of intermediate size of *Mytilus canoasensis vidali*. So far as known, *Mimonion* is extinct.

Additional gastropods, scaphopod, and pelecypods

	Localities							
	99a	99b	99c	99d	99f	99g	99h	100
Gastropods:								
Nerita (Nerita?) sp.								
Turritella collazica Maury [1]								
Turritella subgrundifera Dall [2]				R				
Architectonica (Architectonica) nobilis Röding, subsp.[3]								
Trochita sp.[4]								
Cyphoma aff. *C. intermedia* (Sowerby)								
Semicassis (Echinophoria) tostoma Woodring, n. sp.								
Xancus cf. *X. validus* (Sowerby [r])[5]								
Scaphopod:								
Dentalium (Fissidentalium) uscarianum Olsson		F						
Pelecypods:								
Acila (Acila) isthmica isthmica (Brown and Pilsbry)								
Saccella sp. (fine sculpture) [6]								
Saccella sp. (elongate) [6]								R
Saccella aff. *S. balboae* (Brown and Pilsbry)			R					
Adrana sp.[6]		R	F					
Barbatia (Barbatia) cf. *B. cancellaria* (Lamarck)	?sp.R					R		
Acar domingensis (Lamarck)?					F			
Anadara (Rasia) dariensis progonica Woodring, n. subsp.		C	C	F				
Anadara (Rasia) cf. *A. medioamericana* (Olsson)				R		F		
Anadara (Rasia) athroa Woodring, n. sp.								
Anadara (Tosarca) campta Woodring, n. sp.								
Anadara (Grandiarca) balboai (Sheldon)		A						
Anadara (Potiarca) aff. *A. chavezi* (Engerrand and Urbina)								
Glycymeris (Glycymeris) carbasina Brown and Pilsbry						R		
Glycymeris (Tucetona) sp.[6]					R			
Glycymeris (Tucetona) pectinata canalis Brown and Pilsbry?								
Glycymeris (Tucetona) secticostata schencki Nicol								
Mytilus canoasensis vidali Ferreira and Cunha					?sp.R			R
Brachidontes sp.					R	R		
Modiolus americanus (Leach)?					R			
Botula fusca (Gmelin)?								
Pteria inornata (Gabb)?							R	
Isognomon (Mimonion) mimeticus Woodring, n. sp.								

[1] Recorded on p. 98 as *Turritella* cf. *T. collazica* Maury.
[2] Recorded on p. 105 as *Turritella* cf. *T. subgrundifera* Dall.
[3] Recorded on p. 165 as *Architectonica (Architectonica)* cf. *A. nobilis* Röding
[4] Recorded in list on p. 37 as *Trochita?* cf. *T. trochiformis* (Born).

(Nuculidae to Isognomonidae) from La Boca formation proper

Localities—Continued																	
100a	100b	101	101a	101h	101i	114	115	115a	115b	116	116a	119	119c	125	127	127b	128
											C						
	R										R						
				C													
				A							F						
								?sp.R	?sp.R	F	A						
				R													
				A	F												
											R						
				F	A							R					
					F									C	R	R	C
														R			
																	F
	R				R												
					R				R					F			
						R		R			C						
											R						
				F					R								
										C	A						
				R													
?F		F	R						C		A						
										R							
											R		R				
							R				C						
											A	R					
											R						
						R		R									
											F						

[5] Recorded on p. 286 as *Xancus* cf. *X. rex* Pilsbry and Johnson.
[6] Not described.

The table below lists the occurrence elsewhere and in other Canal Zone formations of the same or related species.

Mollusks from La Boca formation proper and occurrence elsewhere and in other Canal Zone formations of same or related species

Species from La Boca formation proper	Occurrence elsewhere and in other Canal Zone formations of same or related species
Gastropods:	
Turritella collazica Maury [1]	Late Oligocene, Puerto Rico. Also Emperador limestone member.
Turritella subgrundifera Dall [2]	Early to middle Miocene, Florida; early Miocene, northeastern México.
Architectonica (Architectonica) nobilis Röding, subsp.[3]	*A. nobilis nobilis* Röding, early Miocene to Holocene.
Cyphoma aff. C. *intermedia* (Sowerby).	C. *intermedia* (Sowerby), Holocene.
Scaphopod:	
Dentalium (Fissidentalium) uscarianum Olsson.	Early Miocene, Costa Rica. Also Caimito formation.
Pelecypods:	
Acila (Acila) isthmica isthmica (Brown and Pilsbry).	For distribution see table for Caimito formation. Also Caimito and Gatun formations and Chagres sandstone.
Saccella aff. *S. balboae* (Brown and Pilsbry).	*Saccella balboae* (Brown and Pilsbry), Gatun formation, middle Miocene, Costa Rica. Also Culebra formation.
Barbatia (Barbatia) cf. *B. cancellaria* (Lamarck).	*B. cancellaria* (Lamarck), Holocene. Also Caimito formation.
Acar domingensis (Lamarck)?	*Acar domingensis* (Lamarck), Early Miocene to Holocene.
Andara (Rasia) dariensis progonica Woodring, n. subsp.	*A. dariensis dariensis* (Brown and Pilsbry), Gatun formation. For distribution see table for Culebra formation. Also Culebra formation.
Anadara (Rasia) cf. *A. medioamericana* (Olsson).	*A. medioamericana* (Olsson), middle Miocene, Costa Rica.
Anadara (Rasia) athroa Woodring, n. sp.	Questionably also Culebra formation.
Anadara (Tosarca) campta Woodring, n. sp.	*A. santarosana geraetera* (Gardner), early Miocene, Florida.
Anadara (Grandiarca) balboai (Sheldon).	*A. chiriquiensis chiriquiensis* (Gabb). For distribution see table for Culebra formation. Also Culebra formation.
Anadara (Potiarca) aff. *A. chavezi* (Engerrand and Urbina).	*A. chavezi* (Engerrand and Urbina). For distribution see table for Gatun formation.
Glycymeris (Glycymeris) carbasina Brown and Pilsbry.	For distribution see table for Gatun formation. Also Gatun formation.
Pelecypods—Continued	
Glycymeris (Tucetona) pectinata canalis Brown and Pilsbry?	*G. pectinata canalis* Brown and Pilsbry, Gatun formation. For distribution see table for Gatun formation.
Glycymeris (Tucetona) secticostata schencki Nicol.	*G. secticostata secticostata* Nicol, middle Miocene, Costa Rica; late Miocene, Panamá. Also Gatun formation and Chagres sandstone.
Mytilus canoasensis vidali Ferreira and Cunha.	Early Miocene, Brasil; middle(?) Miocene, Venezuela. Also Culebra, Alhajuela, and Gatun formations.
Brachidontes sp	*B. mississippiensis* (Conrad), Oligocene, Mississippi, Alabama.
Modiolus americanus (Leach)?	*M. americanus* (Leach), Holocene.
Botula fusca (Gmelin)?	*B. fusca* (Gmelin), Miocene to Holocene.
Pteria inornata (Gabb)?	*P. inornata* (Gabb). For distribution see table for Gatun formation.

[1] Recorded on p. 98 as *Turritella* cf. *T. collazica* Maury.
[2] Recorded on p. 105 as *Turritella* cf. *T. subgrundifera* Dall.
[3] Recorded on p. 165 as *Architectonica (Architectonica)* cf. *A. nobilis* Röding.

Before the flooding of Gatun Lake, MacDonald collected *Anadara dariensis progonica* and *Modiolus americanus?* from limestone on Río Chagres near the former site of Las Cruces (loc. 94). Both of these fossils are listed in the tables for the La Boca formation proper. The limestone may represent overlapping strata of the La Boca formation, although the La Boca has not been recognized in nearby areas.

Turritella collazica occurs in the Emperador limestone members of the La Boca in the Gaillard Cut area (loc. 123) and *Xancus* cf. *X. validus* in the Emperador of Madden basin (loc. 71). Both also are listed in the tables for the La Boca proper.

ALHAJUELA FORMATION

The few species from the early Miocene Alhajuela formation and the occurrence of the same or related species elsewhere and in other Canal Zone formations are listed in the following tables.

Pelecypods (Arcidae to Pinnidae) from Alhajuela formation

	Localities											
	Lower member						Upper member					
	76	77	79	82	82a	84a	85	85a	86	87	89	90a
Arca imbricata Bruguière	R											
Anadara (Rasia) dariensis dariensis (Brown and Pilsbry)?		sp.R				R						R
Anadara (Rasia) cf. *A. fissicosta* (Spieker)[1]							R			R		
Anadara (Tosarca) cf. *A. tectumcolumbae* (Maury)							C	R			R	R
Glycymeris (Tucetona) sp.[1]				R								
Glycymeris (Tucetona) pectinata canalis Brown and Pilsbry)?				sp.R	R							
Mytilus canoasensis vidali Ferreira and Cunha			R									
Atrina? sp.[1]							R		R			R

[1] Not described.

Pelecypods from Alhajuela formation and occurrence elsewhere and in other Canal Zone formations of same or related species

Species from Alhajuela formation	Occurrence elsewhere and in other Canal Zone formations of same or related species.
Arca imbricata Bruguière	Late Oligocene to Holocene. Also Gatun formation.
Anadara (Rasia) dariensis dariensis (Brown and Pilsbry)?	*A. dariensis dariensis* (Brown and Pilsbry), Gatun formation. For distribution see table for Culebra formation.
Anadara (Rasia) cf. *A. fissicosta* (Spieker).	*A. fissicosta* (Spieker), Gatun formation; early Miocene, Perú.
Anadara (Tosarca) cf. *A. tectumcolumbae* (Maury).	*A. tectumcolumbae* (Maury), late Miocene, Trinidad.
Glycymeris (Tucetona) pectinata canalis (Brown and Pilsbry)?	*G. pectinata canalis* Brown and Pilsbry, Gatun formation. For distribution see table for Gatun formation.
Mytilus canoasensis vidali Ferreira and Cunha.	Early Miocene, Brasil; middle(?) Miocene, Venezuela. Also Culebra, La Boca, and Gatun formations.

GATUN FORMATION

The distribution table for the middle Miocene Gatun formation on pages 462, 463 lists 55 species. Four of the gastropods, however, are already recorded in preceding chapters and one of the pelecypods is not described. (See footnotes at end of table.) This leaves a net addition of 50 described species to the 289 covered in earlier chapters.

Bailya crossata is the first Tertiary species of the genus from the Caribbean region and the earliest now known. An unfortunately incomplete, bizarre gastropod is described as xancid?, genus?. Any suggestions concerning its affinities would be welcomed.

The Gatun fossils include 13 of the 24 species of *Anadara* and half of the 12 species of the subgenus *Rasia* of that genus. *Anadara veatchi*, a species of the subgenus *Tosarca*, is the earliest member of a lineage that culminates in *Anadara hyphalopilema* now living in eastern Pacific waters. *Potiarca*, as a subgenus of *Anadara*, is adopted for many American species heretofore assigned to the subgenus *Cunearca*, including *Anadara chavezi* of the Gatun fauna. *Cunearca* itself, however, is represented by a Gatun species.

Gastropods, scaphopods, and pelecypods

	Localities																															
	Lower part													Middle part																		
														Eastern area																		
	134	136	136a	137	137a	138	138a	138b	138c	138d	138e	138f	138g	139	139b	139c	139d	139e	139f	139g	140	142	143	144	144a	144c	144d	145	146	147
Gastropods:																														
Trochita spirata Forbes? [1]		R	R						R																					
Crucibulum (*Crucibulum*) *spinosum* (Sowerby)																														
Typhis (*Pilsbrytyphis*) *woodringi* (Gertman) [2]																														
Engina turbinella (Kiener)												R																		
Bailya crossata Woodring, n. sp											R																			
Melongena cf. *M. propatula* Anderson												R																		
Xancus validus hysterus Woodring, n. subsp.[3]																														
Xancus dodonaius praelaevigatus (E. H. Vokes) [4]									F		R					R		R			R			R						
Xancid?, genus?																														
Scaphopods:																														
Dentalium (*Dentalium*) *armillatum armillatum* Toula									C		R				A	A	F	R	R	R										
Dentalium (*Dentalium*) *bothrum* Woodring, n. sp																														
Dentalium (*Tesseracme*) *dissimile* Guppy				R																										
Dentalium (*Graptacme*) sp																														
Dentalium (*Rhabdus?*) sp																														
Dentalium (*Laevidentalium*) *pyrum* Pilsbry and Sharp												sp. R																		
Dentalium (*Episiphon*) *innumerabile elassum* Woodring, n. subsp																													R	
Cadulus (*Gadilopsis*) *dentalinus* (Guppy)															R	R				R									A	
Cadulus (*Platyschides*) *epetrion* Woodring, n. sp			F	A		A	A	R	A	C	R	R			A	A	C	C	C	C										
Cadulus (*Platyschides*) *bushii* Dall															F														C	
Pelecypods:																														
Nucula (*Nucula*) cf. *N. cahuitensis* Olsson																R														
Nucula (*Nucula*) *tenuisculpta* Gabb																														
Acila (*Acila*) *isthmica isthmica* (Brown and Pilsbry)																														
Jupiteria subtumida (Woodring)?																														
Saccella acrita epacra Woodring, n. subsp			?R				F		A	C					A	A	R	R	R	C									R	
Saccella cf. *S. fabalis* (Olsson)																														
Saccella balboae (Brown and Pilsbry)		R		R		R	R		C	R	F																			
Adrana cf. *A. newcombi* (Angas)																														
Adrana sp.[5]									R						R															
Arca imbricata Bruguière											R																			
Calloarca (*Taeniarca*) *cachla* Olsson																													R	
Acar domingensis (Lamarck)																												R		
Anadara (*Rasia*) *dariensis dariensis* (Brown and Pilsbry)	?R	?C	R	?R	R	C	C	F	A	A		C	F	?R	C	A		A	F		R	R						F	R
Anadara (*Rasia*) *actinophora actinophora* (Dall)																														
Anadara (*Rasia*) *lienosa trochala* Woodring, n. subsp																														
Anadara (*Rasia*) cf. *A. emarginata* (Sowerby)																														
Anadara (*Rasia*) *sechurana* (Olsson)					R	A	C	R	A	A		C	C							F				R						
Anadara (*Rasia*) *fissicosta* (Spieker)		C	C	C	R		F	R	A	F		F	R		R	R														
Anadara (*Tosarca*) *veatchi veatchi* (Olsson)							R																			R				
Anadara (*Tosarca*) sp																														
Anadara (*Grandiarca*) *dolaticosta* (Pilsbry and Johnson)																														
Anadara (*Grandiarca*) *grandis patricia* (Sowerby)?																														
Anadara (*Potiarca*) *chavezi* (Engerrand and Urbina)				F	R	C	C	R	A	A	F	C	F	sp. C		R							sp. R	sp. F	sp. R					
Anadara (*Potiarca*) cf. *A. berjadinensis* (H. K. Hodson)										R	R																			
Anadara (*Cunearca*) *eumeces* Woodring, n. sp									R																					
Lunarca ovalis (Bruguière)?																														
Noetia (*Noetia*) *reversa macdonaldi* (Dall)					R		R		C			F																	R	
Glycymeris (*Glycymeris*) *carbasina* Brown and Pilsbry									R																					
Glycymeris (*Tucetona*) *epacra* Woodring, n. sp																											R			
Glycymeris (*Tucetona*) *pectinata canalis* Brown and Pilsbry																														
Glycymeris (*Tucetona*) *secticostata schencki* Nicol							R																							
Mytilus canoasensis vidali Ferreira and Cunha																				R										
Crenella divaricata (d'Orbigny)									C	R	R				F	F	R													
Crenella ecuadoriana santiaga Olsson																														
Atrina (*Servatrina*) aff. *A. serrata* (Sowerby)			R																	C										
Pteria inornata (Gabb)?						R			C	F					R	C		R		R										
Isognomon (*Melina?*) sp																														

[1] Recorded on p. 81 as *Trochita trochiformis* (Born).
[2] Recorded on p. 220 as *Typhis* (*Pilsbrytyphis*) *gabbi* Brown and Pilsbry.
[3] Recorded on p. 286 as *Xancus validus validus* (Sowerby)?.

(*Nuculidae to Isognomonidae*) *from Gatun formation*

Localities—Continued																																																									
Middle part—Continued																																					Upper part																				
Eastern area—Continued																						Western area															Eastern area															Western area					
147b	147c	147d	147e	147f	147g	147h	147i	150a	151	152	153	153a	155	155a	155b	155c	157	158	159	159b	159d	160	160c	160d	161	161a	161b	161c	161d	162	162a	166	168	169	170	170a	163	171	172	173	173a	174	175	176	176a	177	177b	177c	177d	177e	178	179	182	182a	183	184	185
					R																																						C	F	R		R										
													R							F																																			
													R				R									R																													
C	F				F	R	R	F										F							C	R					R			C					R						R	R	F										
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											R																																													F
																								R			A		F	F					?R				sp.R																	
																																																							R
A				C	A	A			R				F								R				R									R					R		C		F				R								R		
																A																															A				R						
A				A	A	A			F		R	R	R												C			F						C		C	F						R			A		C									
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A			F	R	C	C												C			R								R			F		A																							A
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A				R	C					R	R	R														R												R	R	R	R	R	R			C									R		R
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										R												C												F																							
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A	R	R	R	C	C	C		C	C		F	C	C	R	C	C	F	C	F		C			F	F	A	F							R				R					R		R			R			R		F	R	C		
															R																						F		R	R		R	C		R	F	C		?R	R	R						
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R					R								R				R																									R	F		F						R			R	C	R	R
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sp.R													R	R		R					C	sp.R		R	F			A	F	R	F			sp.R	sp.R															R							
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					R								R								R																																				
																																			R																						

[4] Recorded on p. 286 as *Xancus validus falconensis* H. K. Hodson.
[5] Not described.

Three battered and worn valves of *Anadara*, subgenus *Grandiarca*, were collected at locality 170. They were transported and buried some distance from their habitat, probably a brackish-water habitat, or were reworked from older strata. One represents a distinctive species: *Anadara dolaticosta*. The other two, identified as *Anadara grandis patricia?*, are allied to the large eastern Pacific type of *Grandiarca*, *Anadara grandis*. The Miocene and Pliocene allies of that species in the Caribbean region are reviewed and divided into a brackish-water group and a marine group. My acceptance many years ago of an alleged type (lectotype) of Sowerby's *Arca patricia* is repudiated, as was done, also many years ago, by Rutsch.

Six of the 36 unequivocally identified species and subspecies are endemic. The occurrence elsewhere of the other 30 is shown in the following table.

Occurrence elsewhere of mollusks from Gatun formation

	Gatun formation				Late Oligocene [1]	Early Miocene [2]	Middle Miocene						Late Miocene		Early Pliocene [8]	Late Pliocene [9]	Holocene
	Lower part	Middle part	Upper part, eastern area	Upper part, western area			Southeastern Costa Rica [3]	Northwestern Colombia [4]	Cercado formation, Dominican Republic	Gurabo formation, Dominican Republic	Bowden formation, Jamaica	Other [5]	Limón formation, Costa Rica [6]	Other [7]			
Gastropods:																	
Crucibulum (Crucibulum) spinosum (Sowerby)	×													×	×		×
Engina turbinella (Kiener)	×																×
Xancus dodonaius praelaevigatus (E. H. Vokes)	×	×							×	×		×					
Scaphopods:																	
Dentalium (Dentalium) armillatum armillatum Toula	×	×	×									×					
Dentalium (Tesseracme) dissimile Guppy	×					×	×		×	×	×	×					
Dentalium (Laevidentalium) pyrum Pilsbry and Sharp	×	×	×						×								
Cadulus (Gadilopsis) dentalinus (Guppy)		×	×	×						×	×						
Cadulus (Platyschides) bushii Dall		×	×														×
Pelecypods:																	
Nucula (Nucula) tenuisculpta Gabb			×				×		×								
Acila (Acila) isthmica isthmica (Brown and Pilsbry)			×	×		×	×					×					
Saccella acrita epacra Woodring, n. subsp	×	×		×								×					
Saccella balboae (Brown and Pilsbry)	×	×	×	×			×										
Arca imbricata Bruguiere	×				×	×	×					×	×		×	×	×
Calloarca (Taeniacra) cachla Olsson		×										×					
Acar domingensis (Lamarck)		×				×			×	×	×	×	×		×	×	×
Anadara (Rasia) dariensis dariensis (Brown and Pilsbry)	×	×	×	×				×		×		×	×				
Anadara (Rasia) actinophora actinophora (Dall)		×	×				×	×				×	×				
Anadara (Rasia) lienosa trochala Woodring, n. subsp			×									×					
Anadara (Rasia) sechurana (Olsson)	×	×										×					
Anadara (Rasia) fissicosta (Spieker)	×	×				×											
Anadara (Tosarca) veatchi veatchi (Olsson)	×	×	×	×				×					×				
Anadara (Grandiarca) dolaticosta (Pilsbry and Johnson)		×					×					×					
Anadara (Potiarca) chavezi (Engerrand and Urbina)	×	×	×						×		×	×					
Noetia (Noetia) reversa macdonaldi (Dall)	×	×					×	×				×		×			
Glycymeris (Glycymeris) carbasina Brown and Pilsbry	×	×	×	×		×	×	×									
Glycymeris (Tucetona) epacra Woodring, n. sp		×	×	×			×	×									
Glycymeris (Tucetona) pectinata canalis Brown and Pilsbry		×	×				×					×					
Mytilus canoasensis vidali Ferreira and Cunha		×				×						×					
Crenella divaricata (d'Orbigny)	×	×													×		×
Crenella ecuadoriana santiaga Olsson		×										×					

[1] San Sebastián formation, Puerto Rico.
[2] Las Perdices shale and deposits of early Miocene age in Río San Juan-Río Sinú area, Colombia; Thomonde formation, Haiti; Ayamón limestone and Ponce limestone, Puerto Rico; Pirabas formation, Brasil; Tampa limestone and Chipola formation, Florida; lower part of Zorritos formation, Perú.
[3] Lower part of Olsson's Gatun formation.
[4] Hibáchero, Piojó, and Tubará formations.
[5] Deposits of middle Miocene age in Bocas del Toro, Chiriquí, and Darién Provinces, Panamá; Cantaure formation, other deposits of middle Miocene age, and middle(?) Miocene part of Santa Ynés group, Venezuela; middle Miocene part of Brasso formation, Trinidad; Agueguexquite formation and other deposits of middle Miocene age in Tehuantepec area and Chiapas, México; Shoal River formation and Oak Grove sand member, Florida; Angostura and Daule formations, Ecuador; upper part of Zorritos formation, Cardalitos, and Montera formations, Perú.
[6] Upper part of Olsson's Gatun formation.
[7] Usiacurí formation, Colombia; Esmeraldas formation, Ecuador.
[8] Playa Grande and Mare formations, Venezuela; Matura formation and Courbaril member of Morne l'Enfer formation, Trinidad; Calocsahatchee formation, Florida.
[9] Moín formation, Costa Rica.

In marked contrast to the gastropods, no genus or subgenus in the scaphopod and pelecypod fauna of the Gatun formation so far covered is extinct. The following subgenera, however, are paciphiles; that is, they formerly lived in the Caribbean region, but now are extinct there and survive in the eastern Pacific Ocean.

Paciphile subgenera in fauna of Gatun formation

Tesseracme (subgenus of *Dentalium*)
Tosarca [1] (subgenus of *Anadara*).
Grandiarca [2] (subgenus of *Anadara*)
Noetia s.s.

[1] Occurs also in La Boca and Alhajuela formations.
[2] Occurs also in Culebra and La Boca formations.

A few paciphiles, listed below, are at the species level:

Paciphile species in fauna of Gatun formation

Crucibulum (Crucibulum) spinosum (Sowerby)
Dentalium (Episiphon) innumerabile elassum Woodring, n. subsp.
Saccella acrita epacra Woodring, n. subsp.
Anadara (Grandiarca) grandis patricia (Sowerby)?
Noetia (Noetia) reversa macdonaldi (Dall)
Crenella ecudoriana santiaga Olsson

Botula fusca, which is doubtfully recorded from the La Boca formation, survives on both sides of the Panamá land bridge.

One Bohio species and four Gatun species are more closely related to living eastern Pacific species than to

any known to be living in the western Atlantic Ocean. They are as follows:

Species from Bohio and Gatun formations more closely related to living eastern Pacific species than to any known to be living in the western Atlantic Ocean

Fossil species	Living eastern Pacific species
Species from Bohio formation:	
Adrana stena Woodring, n. sp.	*A. crenifera* (Sowerby)
Species from Gatun formation:	
Nucula (Nucula) cf. *N. cahuitensis* Olsson	*N. exigua* Sowerby
Saccella balboae (Brown and Pilsbry)	*S. fastigata* (Keen)
Anadara (Rasia) dariensis dariensis (Brown and Pilsbry)	*A. concinna* (Sowerby)
Anadara (Rasia) cf. *A. emarginata* (Sowerby)	*A. emarginata* (Sowerby)

CHAGRES SANDSTONE, INCLUDING TORO LIMESTONE MEMBER

Mollusks from the Chagres sandstone proper covered in the present chapter are listed in the following table.

Scaphopod and pelecypods (Nuculidae to Pinnidae) from the Chagres sandstone proper

	Localities						
	198	202	203	206	206a	206b	208
Scaphopod:							
Dentalium (Fissidentalium) granadanum esmeraldum Olsson	----	----	----	R	------	------	C
Pelecypods:							
Acila (Acila) isthmica isthmica (Brown and Pilsbry)	R	----	R	F	sp.R	------	F
Saccella cf. *S. ornata* (d'Orbigny)	----	----	----	F	------	F	----
Anadara (Rasia) honensis adiaphora Woodring, n. subsp	----	----	----	----	------	------	C
Glycymeris (Tucetona) secticostata schencki Nicol	----	R	----	----	------	------	----
Atrina (Servatrina) aff. *A. serrata* (Sowerby)	----	----	----	R	------	?sp.	----

The occurrence elsewhere and in other Canal Zone formations of the same or related form is as follows:

Mollusks from Chagres sandstone proper and occurrence elsewhere and in other Canal Zone formations of same or related form

Species from Chagres sandstone proper	Occurrence elsewhere and in other Canal Zone formations of same or related form
Scaphopod:	
Dentalium (Fissidentalium) granadanum esmeraldum Olsson	Esmeraldas formation, late Miocene, Eucador.
Pelecypods:	
Acila (Acila) isthmica isthmica (Brown and Pilsbry)	Also Caimito, La Boca, and Gatun formations.
Saccella cf. *S. ornata* (d'Orbigny)	*S. ornata* (d'Orbigny), late Miocene to Holocene.
Anadara (Rasia) honensis adiaphora Woodring, n. subsp.	*A. honensis honensis* (Olsson), middle Miocene, Costa Rica, Jamaica.
Glycymeris (Tucetona) secticostata schencki Nicol	Also La Boca and Gatun formations.
Atrina (Servatrina) aff. *A. serrata* (Sowerby)	*A. serrata* (Sowerby), Holocene. Also Gatun formation.

Unidentifiable molds of *Anadara*, subgenera *Rasia* and *Potiarca*, and of *Glycymeris*, subgenus *Tucetona*, were collected from the Toro limestone member.

DESCRIPTION OF TERTIARY MOLLUSKS—CONTINUED FROM CHAPTER D

GASTROPODS—CONTINUED FROM CHAPTER D

Additions and corrections to families covered in preceding chapters:—Twenty-six of the 35 gastropods described in the present chapter are in collections from the Gatuncillo, La Boca, and Gatun formations acquired since publication of chapter B. One is an overlooked species from the marine member of the Bohio(?) formation. The other eight were recorded in preceding chapters, but additional data, including corrections, are presented for them. The page citations in headings refer to preceding chapters.

Family NERITIDAE (p. 66)

Subfamily NERITINAE (p. 66)

The collection from the Gatuncillo formation at locality 23b, on Río Palenque, contains four species of neritids, an unusual number for an Eocene formation in the Caribbean region.

Genus Nerita Linné

Linné, Systema naturae, 10th ed., p. 776, 1758.

Type (logotype, Montfort, Conchyliologie systématique, v. 2, p. 347, 1810): *Nerita peloronta* Linné, living, Florida to Trinidad.

This ancient genus is not common in the Tertiary Caribbean province. Three Paleocene species, two

Eocene, a Miocene, a Pliocene, and two of doubtful Pliocene age are on record. Opercula are unknown.

Subgenus?

Nerita listrota Woodring, n. sp.

Plate 69, figures 11, 12, 17

Of medium size, moderately thick-shelled, practically flat-topped. Color, where not bleached, dark brown. Upper edge of early half of body whorl angulated, angulation progressively subdued on late half. Sculpture coarse, consisting of weakly, or obscurely, noded, closely spaced, spiral bands of varying width, that at angulation widest. Growth threads strong, or fairly strong. Outer lip thin, scalloped, short lirae within aperture. Columellar lip dentate: a wide, moderately strong, basal denticle, followed by five narrow, short denticles, and a strong, unequally bifid upper denticle. Callus sparsely papillate near columellar lip: two papillae distinct, two others obscure. Callus thick near lower border.

Height 15 mm, diameter 19 mm (type).

Type: USNM 646646.

Type locality: 23b (USGS 24553, Upper course of Río Palenque, 3.4 km in direct line west of Nuevo San Juan and 1.3 km northwest of settlement of Palenque, Colón Province, Panamá). Gatuncillo formation.

The outline and sculptural pattern of *Nerita listrota*, represented only by the type, suggest alliance with *N. granulosa* Deshayes (Cossmann and Pissarro, 1910–13, pl. 5, figs. 38–3), a late Eocene species from the Paris basin. The callus of the Panamá species is thicker and not rugose, and the spiral bands are more closely spaced. In outline and sculpture *N. listrota* resembles also *N. planospira* Anton (Martens, 1887–89, p. 23, pl. 4, figs. 4–7, 1887), living in the western Pacific Ocean. The nonascending outer lip of *N. listrota*, thicker callus, small central denticles on the columellar lip, and the absence of two channels at the upper edge of the callus show that the two species are not allied. No similar fossil or living American species is known.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Subgenus?

Nerita hadra Woodring, n. sp.

Plate 67, figures 1, 2, 6–8, 11, 12

Small, moderately thick-shelled, practically flat-topped. Overall color pattern generally spirally maculated. Sculpture fine, subdued, consisting of low, narrow, crowded, spiral threads, at intervals a thread wider than others. Threads generally colored with light brown, elongate rectangles or squares, longest rectangles on widest threads. On early three-quarters of body whorl of one specimen color absent on some spiral strips and solid on others. Outer lip thin, short lirae within aperture, except on largest shell (type). Columellar lip weakly dentate: a weak basal denticle, followed by little denticles, and a conspicuous, slender, upper denticle. Callus very thick for size of shell, especially lower part.

Height 8 mm, diameter (not quite complete) 10.5 mm (type).

Type: USNM 646647.

Type locality: Same as preceding species.

Twenty-one specimens of this small species were collected at locality 23b. The assignment to *Nerita* is based on the lirate outer lip and the thick callus. To be sure, the type, the largest specimen, shows no lirae. Though its outer lip is broken, the part where lirae appear on smaller specimens, two of which are shown on plate 67, figures 1, 2, 7, 8, is intact. On the aberrantly colored specimen (pl. 67, figs. 7, 8) the change in pattern takes place abruptly.

No comparable species are recognized.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Subgenus Nerita s.s.?

Nerita (Nerita?) species

Plate 73, figures 5, 6

Small, thick-shelled, practically flat-topped. Color pattern bleached, spiral bands light-colored and spaces between them dark-colored. Spiral bands relatively widely spaced, obscurely noded where not worn. Interior of outer lip denticulate. Columellar lip denticulate, size and arrangement of denticles obscured by calcareous crust. Surface of callus not well preserved.

Height 10.5 mm, diameter 11.2 mm (figured specimen).

Seven specimens of this unnamed species, all found in the La Boca formation at locality 116a, range in diameter from 4.5 to 11.2 mm. The illustrated shell, much of which is worn, is the only one on which the aperture can be exposed safely.

The spire is lower than that of the living American species and their fossil allies, and the spiral bands are not as closely spaced.

Occurrence: La Boca formation (early Miocene), locality 116a.

Genus Neritina Lamarck (p. 67)

Though 13 species of *Neritina* from the Tertiary Caribbean province have been described, the operculum of *N. ectypha* is the first to be found; in fact, the first in America.

Subgenus?

Neritina ectypha Woodring, n. sp.

Plate 67, figures 3–5, 9, 10, 14, 15

Very small, globose, spire very low. Prevailing color pattern consisting of brown, hair-like, closely spaced, wavy, axial lines on light-colored background. Irregular brown blotches generally superimposed on lines on parts of shell. At middle of shell light-colored band bearing widely spaced, looped, fine lines, convex toward outer lip, and similar, generally narrower, band on lower part of shell present or absent. Hair-like lines absent on an aberrant specimen, colored by three maculated spiral bands and widely spaced, coarse, axial lines between uppermost band and suture. Columellar lip weakly denticulate, uppermost denticle most distinct. Callus thick, bulging, outer edge sharply limited. Operculum light brown, peg moderately slender, rib slender and strongly arched.

Height 6.4 mm, diameter 7.1 mm (type).

Type: USNM 646650.

Type locality: 23b (USGS 24553, Upper course of Río Palenque, 3.4 km in direct line west of Nuevo San Juan and 1.3 km northwest of settlement of Palenque, Colón Province, Panamá) Gatuncillo formation.

This very small species is represented by 19 specimens. The thick, bulging callus and hair-like color pattern are noteworthy. The aberrantly colored shell is shown on plate 67, figures 5, 10. The operculum (pl. 67, fig. 9) was extracted from the shell illustrated on plate 67, figures 3, 4). During extraction it was slightly nicked and after the drawing was made, part of the peg was broken.

Occurrences: Gatuncillo formation (late Eocene), locality 23a.

Subgenus?

Neritina species

Plate 69, figures 21, 22

Small, globose, thick-shelled, spire very low. Color pattern consisting of spirally arranged, colorless crude rectangles, or more rounded eyes, on a brown background. Spiral arrangement interrupted by a few irregularly shaped colorless blotches. Columellar lip corroded. Callus moderately thick, slightly bulging, partly corroded.

Height 10.2 mm, diameter 10.9 mm (figured specimen).

Though this may be a new species, the apertural face of the single specimen is badly corroded.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Family VITRINELLIDAE (p. 69)

Genus Teinostoma H. and A. Adams (p. 69)

Subgenus Idioraphe Pilsbry (p. 69)

The earliest species of *Idioraphe*, *Teinostoma prenanum* Wade (Sohl, 1960, p. 62, pl. 6, figs. 9, 10) is of Late Cretaceous (late Campanian) age. The following is the first of pre-Miocene age from the Caribbean region.

Teinostoma (Idioraphe) elachistum Woodring, n. sp.

Plate 70, figures 3, 9, 10

Minute, moderately thick-shelled to thin-shelled, depressed dome-shaped. Periphery narrowly rounded. Body whorl partly enveloping spire, which is more or less covered with glaze of enamel. Faint spiral striae visible on some shells. Umbilical and parietal callus coalesced.

Height 0.6 mm, diameter 1.3 mm (type).

Type: USNM 646654.

Type locality: 23b (USGS 24553, Upper course of Río Palenque, 3.4 km in direct line west of Nuevo San Juan and 1.3 km northwest of settlement of Palenque, Colón Province, Panamá), Gatuncillo formation.

Teinostoma elachistum is most similar to *T. harrisi* (Palmer, 1937, p. 47, pl. 2, figs. 27, 28; middle Eocene, Virginia), but is smaller and more compressed. It is smaller also than *T. verrilli* Meyer (Palmer, in Harris and Palmer, 1946–47, p. 222, pl. 28, figs. 2, 4, 1947; late Eocene, Mississippi). That species, however, is more compressed.

Thirty-five specimens of this minute teinostome were collected at locality 23b. The glaze of a thin translucent shell is so thin that it does not conceal the spire.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Family TURRITELLIDAE (p. 97)

Genus Turritella Lamarck (p. 97)

Turritella collazica Maury

Plate 71, figure 18

Turritella collazica Maury, New York Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 1, p. 51, pl. 8, fig. 5, 1920 (Oligocene, Puerto Rico).

Turritella cf. *T. collazica* Maury, Woodring, this report, p. 98, pl. 16, fig. 13, 1957 (Miocene, Canal Zone).

Large, apical angle wide. Whorl profile concave, dominated by basal carina. Basal carina somewhat undulated on best preserved specimen, tripartate: wide lower and upper parts and narrow middle part on best preserved specimen; more equally tripartate on another. Weak coarse spiral sculpture apparent on remainder of whorl. Base missing. Growth lines obscure, sinus apparently shallow and growth-line angle narrow.

Height (3 whorls) 35 mm (estimated restored height 70 mm), diameter 23 mm (figured specimen). Height (4 whorls) 54 mm (estimated restored height 80 mm), diameter 29 mm (largest specimen).

Type: Am. Mus. Nat. Hist. 22556.

Type locality: Río Collazo near San Sebastián, San Sebastián quadrangle, Puerto Rico, San Sebastián formation.

When chapter A was prepared, the crushed mold from the Emperador limestone member of the La Boca formation, identified as *Turritella* cf. *T. collazica*, was the only specimen in the Canal Zone collections. Two others from the La Boca proper are now available. The shell of that illustrated is replaced by calcite. The other, the large specimen mentioned on p. 431, is in poor condition.

Maury's type, which is not well represented by her drawing, is available through the kindness of Dr. N. D. Newell. It is a crushed mold, but shows more features than the Emperador mold. The whorl profile is more concave than indicated in the drawing. The basal carina is weakly bipartate and the sculpture above the carina is weaker and coarser than in the drawing.

As noted by Maury, *T. collazica* has no allies in the Caribbean region. Unequivocal allies elsewhere are not recognized.

Occurrence: La Boca formation (early Miocene), localities 100b, 116a. Emperador limestone member of La Boca formation (early Miocene), locality 123. San Sebastián formation (late Oligocene), Puerto Rico.

Turritella subgrundifera Dall

Plate 74, figure 1

Turritella subgrundifera Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 2, p. 313, pl. 22, fig. 23, 1892 (Miocene, Florida). Pilsbry and Brown, Acad. Nat. Sci. Philadelphia Proc., v. 69, p. 35, 1917 (Miocene, Colombia). Merriam, California Univ. Dept. Geol. Sci. Bull., v. 26, no. 1, p. 48, pl. 29, figs. 8, 9, 1941 (Miocene, Florida). Gardner, U.S. Geol. Survey Prof. Paper 142, p. 590, pl. 57, fig. 1, 1944 (Miocene, Florida). Gardner, Geol. Soc. Am. Mem. 11, p. 153, 1945 (Miocene, México).

Turritella cf. *T. subgrundifera* Dall, Woodring, this report, p. 105, pl. 16, fig. 3, 1957 (Miocene, Canal Zone).

Height (incomplete) 32.2 mm, diameter 13.6 mm (figured specimen).

Type: USNM 113437.

Type locality: USGS 2214, Ten Mile Creek, 1 mile west of Baileys Ferry, Calhoun County, Florida, Chipola formation.

On the basis of seven additional specimens collected at locality 101h, the slender carinate *Turritella* in the La Boca formation is unequivocally identified as *T. subgrundifera*. Though the development of the sculpture and the growth line are still unknown, in size, apical angle, whorl profile, including the carina near the base, and strength and spacing of spiral threads, the best of the La Boca fossils closely resemble those from the Chipola formation of Florida.

Merriam (1941, p. 48) pointed out that *T. subgrundifera* is an early species of his *T. ocoyana* stock. It is a relatively small, slender, early ally of *T. abrupta* (p. 106, 430) and the Californian *T. ocoyana*.

Occurrence: La Boca formation (early Miocene) localities 99d, 101h. Miocene, Colombia (Brown and Pilsbry's record). Guajalote formation (early Miocene), northeastern México. Chipola formation (early Miocene) and Oak Grove sand member of Shoal River formation (middle Miocene), Florida.

Family PSEUDOMELANIIDAE

Genus Bayania Munier-Chalmas

Munier-Chalmas, in Fischer, Manuel de conchyliologie, p. 698, 1885.

Type (orthotype): *Melania lactea* Lamarck, Eocene, Paris basin.

Bayania epelys Woodring, n. sp.

Plate 68, figures 5, 6, 11, 12

?*Bayania* sp., Trechmann, Geol. Mag., v. 62, p. 496, pl. 24, fig. 2, 1925 (Eocene, Barbados).

Large for the genus, moderately inflated, thick-shelled or moderately thick-shelled, spire whorls almost flat-sided. Protoconch and earliest post-protoconch whorls almost flat-sided. Protoconch and earliest post-protoconch whorls not preserved. Whorls generally smooth; exceptionally upper part of mature body whorl or lower part of immature body whorl showing faint, coarse, spiral sculpture. Growth lines slightly arcuate on spire whorls and upper part of body whorl. Basal lip slightly patulous. Parietal callus fairly thick.

Height (incomplete) 26.7 mm (estimated restored height 31 mm), diameter 11.3 mm (type).

Type: USNM 646655; paratypes USNM 646656, 646657.

Type locality: 23b (USGS 24553, Upper course of Río Palenque, 3.4 km in direct line west of Nuevo San Juan and 1.3 km northwest of settlement of Palenque, Colón Province, Panamá), Gatuncillo formation.

Complete outer and basal lips are not preserved on any of the 36 specimens, repersenting growth stages from a height of 7 to 26.7 mm (estimated 8.5 to 31). The outline of the outer lip, however, is shown by the growth lines and the basal lip is preserved on two, one of which is illustrated (pl. 68, fig. 11). The type is the largest specimen, but a paratype (pl. 68, fig. 12) is in better condition.

The earliest preserved whorls are at a growth stage at which *Bayania lactea*, the early to late Eocene type of the genus, bears axial and spiral sculpture, which later disappears. The growth lines of *B. epelys*, and

therefore the outer lip, are slightly more arcuate than that of *B. lactea*. Despite these differences, the two species have basically similar features, including a slightly patulous basal lip. The middle Eocene American *B. secalis* (Lea) (Palmer, 1937, p. 184, pl. 21, figs. 18–20, 24) is much smaller (height 9 mm) and more slender. Like *B. epelys*, its early whorls lack axial and spiral sculpture. Trechmann's unnamed middle Eocene *Bayania* from Barbados may possibly be *B. epelys*.

Occurrence: Gatuncillo formation (late Eocene), locality 23b. Scotland group (middle Eocene), Barbados (identification doubtful).

Family PSEUDOMELANIIDAE?

Genus Charadreon Woodring, n. gen.

Type: *Charadreon leptus* Woodring, n. sp., Gatuncillo formation.

Small, slender to very slender. Spire whorls, except earliest few, practically flat-sided and slightly turreted. Early sculpture reticulate. Later sculpture consisting of axial ribs overriden by closely spaced spiral threads. Axial sculpture disappearing on intermediate whorls. Spiral sculpture continuing with undiminished strength or subdued on last few whorls. Outer lip, as shown by growth lines, sinuate, apex of wide, shallow sinus at upper third of whorl. Siphonal notch shallow. Siphonal fasciole slightly inflated or not inflated, set off by low thread.

The family relations of *Charadreon* are uncertain. Though it is but a step from the patulous basal lip of *Bayania* to the shallow siphonal notch of *Charadreon* and from the arcuate outer lip of *Bayania epelys* to the sinuate lip of *Charadreon*, perhaps the notch and sinus are incompatible with assignment to the family Pseudomelaniidae. Whether *Charadreon* is related to the modern fresh-water thiarids is doubtful.

Charadreon leptus Woodring, n. sp.

Plate 68, figures 1–4

Small, slender to very slender. Early post-protoconch whorls slightly bulging, other spire whorls practically flat-sided and slightly turreted. Body whorl slightly turreted. Protoconch blunt, 1¼ to 1½-whorled, end marked by gradual appearance of sculpture. Earliest sculpture reticulate, consisting of evenly spaced, fine, axial and spiral threads, absent on lower part of body whorl. At later stage axial threads transformed into more widely spaced ribs, and spiral threads into closely spaced, coarser threads overriding ribs. Axial ribs gradually disappearing at varying stage on intermediate whorls, generally last forming subdued nodes adjoining suture. Spiral threads persisting; on some shells fine, secondary threads between them, or subdued on last few whorls and so closely spaced that only a shallow stria appears between them. Growth lines strongly arcuate on spire whorls, apex of arc little above middle of whorl. On body whorl forming a wide, shallow sinus, apex at upper third of whorl. Siphonal notch shallow. Siphonal fasciole slightly inflated or not inflated, set off by low thread. Parietal callus moderately thick.

Height (not quite complete) 18 mm, diameter 6.5 mm (type).

Type: USNM 646658; paratype USNM 646659.

Type locality: same as preceding species.

Charadreon leptus is extraordinarily abundant at locality 23b, where an estimated several thousand were collected. Some 50, including glassy specimens, are minute shells consisting of the protoconch, or the protoconch and one or two post-protoconch whorls. Among them are the only ones that have an undamaged outer lip, but they represent a stage before the sinus was formed. Of mature shells only the paratype has an undamaged siphonal notch.

As shown by the illustrations, this is a variable species in outline and sculpture. The disappearance of axial sculpture is invariable, but the stage at which it disappears is variable, and the strength and spacing of the spiral threads on late whorls are also variable. Moderately slender specimens mimic the Oligocene western European *Bayania semidecussata* (Lamarck) (Cossmann, 1909, p. 98, pl. 1, figs. 12–14) and very slender specimens mimic the middle Eocene western European *B. bezanconi* (Vasseur) (Cossman, 1899, p. 13, pl. 2, figs. 11, 12).

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Family THIARIDAE

Subfamily MELANOPSINAE

Genus Faunus Montfort

Montfort, Conchyliologie systématique, v. 2, p. 426, 1810.

Type (orthotype): *Faunus melanopsis* Montfort (=*Strombus ater* Linné), living, western Pacific islands and Australia, at mouth of streams.

Faunus xenicus closely resembles *F. ater* not only in outline, practically smooth whorls, and apertural features, but even in closely spaced growth lines, which correspond to the lines marking darker color on shells of *F. ater*. It is more similar to *F. ater* than any of the Eocene European species that have been assigned to *Faunus*.

As pointed out by Olsson, *Pseudofaunus bravoensis* (Olsson, 1931, p. 86, pl. 15, figs. 9, 11), a larger, thick-shelled Oligocene Peruvian species that is the type of *Pseudofaunus*, is distinguished from *Faunus* chiefly by its strongly bulging siphonal fasciole. Its outer-lip sinus also is deeper, more symmetrical, and the apex is farther from the suture.

Faunus xenicus Woodring, n. sp.

Plate 69, figures 13, 14, 19

Moderately large, slender, spire whorls practically flat sided. Suture deeply incised. Mature body whorl set off by progressively widened sutural shelf, its outer edge swollen near outer lip. Earliest part of protoconch not preserved, remainder indistinguishable from early post-protoconch whorls. Sculpture limited to obscure spiral bands and threads, most distinct on lower part of body whorl, limited to that part on immature and some mature specimens; on others appearing on entire body whorl, or on that whorl and penult, or even antepenult. Growth lines closely spaced, asymmetrically arcuate on spire whorls, on body whorl forming wide, shallow, asymmetrical sinus, apex at upper fourth of whorl. Siphonal fasciole wide, flat, limited by low thread, bearing growth lines of wide, moderately deep, asymmetrical siphonal notch, apex near limiting low thread. Columellar lip thick.

Height (4 whorls) 37.5 mm (estimated restored height 55 mm), diameter (incomplete) 18 mm (type).

Type: USNM 646662; paratype 646663.

Type locality: Same as preceding species.

All of the 22 specimens are incomplete—in fact, half of them consist of only a few whorls—and none has undamaged apertural features. The closely spaced growth lines show that the outer-lip sinus is shallow. The growth lines on the siphonal fasciole, preserved on the type (pl. 69, fig. 14) and another specimen, reveal a moderately deep, asymmetrical siphonal notch. The fasciole itself is flat.

Faunus ater, the type of the genus, lacks a sutural shelf on mature body whorls, its suture is not as deeply incised, and the weak spiral sculpture on the base of the body whorl is more obscure.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Family CERITHIIDAE (p. 170)

Subfamily POTAMIDINAE (p. 176)

Genus Potamides Brongniart (p. 176)

Potamides? micraulax Woodring, n. sp.

Plate 69, figures 4, 15, 16

Of medium size, slender, spire whorls flat sided. Low, wide varix on intermediate whorls of one specimen. Earliest preserved whorls sculptured with axial ribs overridden by closely spaced spiral threads. Ribs gradually disappearing. Sculpture of intermediate and late whorls consisting of flat spiral bands separated by narrow, vertical-sided channels. Base sculptured with narrow, more widely spaced bands. Outer lip, as shown by growth lines, widely sinuate, apex at middle of whorl. Siphonal notch wide, very shallow. Siphonal fasciole flat, except a slight bulge near notch, limited by thread. Columellar lip thin.

Height (2+whorls) 20 mm (estimated restored height 38 mm), diameter (incomplete) 10.2 mm (type).

Type: USNM 646664; paratypes USNM 646665, 646666.

Type locality: Same as preceding species.

The early sculpture is potamidine-like, but intermediate and late sculpture is like that of a sharply incised *Telescopium*. Though the outer lip, as shown by the growth lines, and wide, shallow siphonal notch are *Potamides*-like, typical *Potamides* lacks a siphonal fasciole. The fasciole is preserved only on the type. Its slight budge near the notch probably is an abnormality. The smaller paratype is the only one of the five specimens showing varices. All five are incomplete.

The sculpture of *Morgania costata* (Woods, 1922, p. 83, pl. 9, figs. 7–10; Paleocene and Eocene, Perú) is similar, but the outline of the Peruvian species is pupoid.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Genus Hannatoma Olsson (p. 68)

Hannatoma is classified as a potamidine cerithid, instead of as a thiarid. It is a unique genus without known close allies. It occurs in Eocene deposits in Perú, Panamá, Colombia, and Venezuela, and in Oligocene in Perú. It is doubtful that it is a brackish-water genus.

Hannatoma antyx Woodring, n. sp.

Plate 68, figures 9, 15, 19, 20

Hannatoma? cf. *H. emendorferi* Olsson, Woodring, this report, p. 68, pl. 14, fig. 3, 1957 (Eocene, Canal Zone).

Moderately large, moderately slender, thick-shelled, flat-whorled outlined modified by flange-like spiral cords, especially sutural cord. Protoconch slender, two-whorled, whorls inflated, end marked by gradual appearance of sculpture. Earliest two or three post-protoconch whorls carinate below middle of whorl. Later early whorls evenly swollen. Earliest sculpture a carina-forming spiral thread, followed immediately by a thread above carina and later by other minor threads. Swollen, widely spaced axial ribs, overridden by spiral threads, appearing on third post-protoconch whorl and gradually disappearing on about tenth. As they disappear a sutural cord is strengthened and in few whorls dominates profile. Remaining whorls generally sculptured also with two generally flange-like cords, representing original carina-forming thread and later thread above it. On many specimens upper one reduced, exceptionally absent and lower cord almost as strong as sutural cord. Base of mature body whorl bearing three or four other widely spaced cords. Microscopic spiral sculpture on

unworn surfaces. Growth lines strong, outlining outer-lip wide, shallow sinus, apex between sutural cord and next lower cord. On fully mature specimens supplementary sinus on sutural cord of body whorl at resting stages marked by exaggerated growth lines. Siphonal notch wide, shallow, as shown by growth lines. Siphonal canal of moderate length, siphonal fasciole absent. Columellar lip thin.

Height (incomplete) 54.7 mm (estimated restored height 70 mm), diameter (almost complete) 20 mm (type).

Type: USNM 646667; paratype USNM 646668.

Type locality: Same as preceding species.

Hannatoma antyx, like *Charadreon leptus* but on a smaller scale, is extraordinarily abundant at locality 23b. Some 300 specimens, ranging in height from 4 to 54.7 mm (estimated 70 mm), are in the collection and perhaps an equal number, fragments of a whorl or two, were discarded. It is by far the largest collection of *Hannatoma* and the first collection to show the protoconch and the development of the sculpture. Of these hundreds, however, none has an undamaged aperture, not even any of the scores of very small specimens.

The type, which was damaged and repaired during growth, shows the prevailing sculptural pattern. The incomplete silicified specimen from the Río Casaya area, described in chapter A, has only two subequal cords on a whorl, like that shown on plate 68, figure 20. Disappearance of axial sculpture is shown on plate 68, figure 15.

The spiral cords are sharper and more flange-like than those of the other known species: *H. emendorferi* Olsson (1931, p. 82, pl. 15, figs. 3, 8; Eocene, Perú, Colombia, Venezuela), *H. gesteri* (Hanna and Israelsky) (Olsson, 1931, p. 81, pl. 16, figs. 2, 7; Oligocene, Perú), and *H. tumbezia* Olsson (1931, p. 82, pl. 15, figs. 1, 2; Oligocene, Perú).

Occurrence: Gatuncillo formation (middle and late Eocene), localities 23b, 38.

Genus Tympanotonos Schumacher

Schumacher, Essai d'un nouveau système des habitations des vers testacés, p. 211, 1817.

Type (monotype): *Tymponotonos fluviatills* [*fluviatilis*] Schumacher (=*Murex fuscatus* Linné), living, marshes at mouth of rivers, tropical west Africa.

The type species has been well illustrated by Pilsbry and Bequaert (1927, p. 246, pl. 20, figs. 1–9).

Tympanotonos acanthodes Woodring, n. sp.

Plate 68, figures 8, 10; plate 69, figures 23, 24

Large, slender, flat-whorled outline modified by spines near suture. Intermediate and some early whorls bearing a varix. Earliest preserved sculpture cerithoid, consisting of axial ribs, pinched off before reaching base of spire whorls, overridden by three spiral threads, later converted into flat cords, narrowed between ribs. Later slightly undulated, narrower cord added at base of spire whorls. On intermediate and late whorls ribs progressively reduced between cords. Cord near suture progressively more swollen where ribs formerly intersected it, swellings eventually forming conspicuous spines. Other cords narrower and noded, lower cord more closely noded than other two. Slightly noded secondary thread present or absent between those two. Microscopic spiral sculpture on unworn surfaces. Growth lines strong, exaggerated at intervals, outlining outer-lip wide, deep sinus, apex at about middle of spire whorls. Base bearing a strong cord near periphery, a lower cord below middle, and, at least on immature shells, microscopic spiral sculpture. Siphonal canal broken, siphonal notch shallow, according to growth lines. Siphonal fasciole slightly inflated, smooth, forming part of thick columellar lip. Columella of immature shells bearing a low median fold.

Height (3 whorls, siphonal canal broken) 36.5 mm (estimated restored height 75 mm), diameter (including spines) 27.5 mm (type).

Type: USNM 646671; paratypes USNM 646672, 646673.

Type locality: Same as preceding species.

This species is represented by 21 specimens, all fragments of 2 to 10 whorls. As with many other gastropods from locality 23b, the outer lip and the end of the siphonal canal are missing on all. The type and two paratypes, however, are practically the equivalent of an entire mature shell and some of the apertural features are preserved on the type and immature shells. A columellar fold is not apparent on the type species. Whether it is present on mature shells of the Panamá species is indeterminable.

Tympanotonos is rare in America. Trechmann recorded an unnamed early Eocene Jamaican species and one of middle Eocene age from Barbados (Trechmann, 1924, p. 14, pl. 2, fig. 6; 1925, p. 495, pl. 24, fig. 5, respectively). The spines of the Jamaican species, represented by three topotypes in USNM collections (USGS 18281, 21930), are blunter than those of *T. acanthodes*, and below the sutural cord spire whorls are sculptured with three coarsely noded cords and a fourth less noded cord at the base of whorls. According to the illustration, the Barbados species is not comparable to *T. acanthodes*.

T. lagunitensis Woods, 1922, p. 90, pl. 11, figs. 10–12; late Eocene, Perú) has been assigned to the endemic American genus *Diplocyma* (Pilsbry and Olsson, 1935, p. 11). Cossman (1906, p. 120) assigned *Cerithium hillsboroensis* Heilprin, an early Miocene Florida species, to *Tympanotonos*. It was placed under *Potamides* by Dall

(1890–1903, p. 286, pl. 15, fig. 12, 1892) and is best left there, despite the low, blunt spines on the sutural cord.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Genus Harrisianella Olsson

Olsson, Bull. Am. Paleontology, v. 15, no. 57, p. 20, 1979.
Type (orthotype): *Harrisianella peruviana* Olsson, middle and late Eocene, Peru.

This curious *Strioterebrum*-like cerithid genus is found in formations of middle and late Eocene age in Perú, in late Eocene deposits of eastern Colombia, and of the Tonosí area and Colón Province in Panamá, and in a late Eocene formation in Texas.

Harrisianella camptica Woodring, n. sp.

Plate 69, figures 3, 5–8

Of medium size, slender, whorls practically flat sided. Earliest whorls missing, earliest preserved whorls worn. Varix on early whorls of one specimen. Sculpture dominated by *Strioterebrum*-like, noded sutural cord. Nodes at first rectangular, later axially elongate and retractive. Remainder of spire whorls and of body whorl above base sculptured with closely spaced, generally coarse axial ribs, alined with nodes on sutural cord and connected with them by slight swellings in groove setting off cord. Ribs and retractive nodes forming arc, outlining wide, moderately deep, outer-lip sinus, apex near sutural cord. Ribs abruptly terminated by deep groove at base of spire whorls and at periphery of body whorl. On three specimens ribs and nodes exceptionally narrow. Base sculptured with two strong upper, spiral threads and two weak lower ones. Siphonal canal apparently short, end not preserved. Lowermost preserved part of smooth siphonal fasciole set off by low thread, upper part merging into wide, thick columellar lip.

Height (almost complete) 31.6 mm, diameter (almost complete) 10 mm (type).

Type: USNM 646674; paratype USNM 646675.

Type locality: Same as preceding species.

Harrisianella camptica is based on 25 incomplete specimens. The early whorls and some later parts of the type and others are worn or corroded. Three fragments, one of which is illustrated (pl. 69, figs. 7, 8), have exceptionally narrow ribs and nodes, but there is no gradation between them and the prevailing coarser ribs.

The sutural-cord nodes and ribs form a stronger arc than that of *H. peruviana* Olsson (1929, p. 21, pl. 8, fig. 7; middle and late Eocene, Perú), the type of the genus. In that respect *H. campicta* is similar to *H. plicifera* (Heilprin) (1880, p. 151, fig. 8; late Eocene, Texas), the only other described species of the genus. The ribs of that species, however, are wider, more closely spaced and disappear on the later part of the mature body whorl. So far as sculpture is concerned, Heilprin's drawing is better than Aldrich's (1897, p. 4, pl. 3, fig. 2), but Aldrich's figure 2a adequately shows the lower part of the shell. His illustrations were reproduced by Palmer (in Harris and Palmer), 1946–47, p. 302, pl. 39, figs. 11, 12, 1947). My colleague Druid Wilson called my attention to a collection of some 20 specimens of *H. plicifera* from a well in Texas (USGS 11137, W. A. Everett No. 1, Three Rivers, Live Oak County, depth unknown). They show a considerable range of variation in the width and spacing of ribs on immature whorls. None is as large as the largest of three in the type lot (USNM 8919).

H. camptica occurs also in the Búcaro formation of the Tonosí area in southwestern Panamá: the species mentioned by Palmer (in Harris and Palmer, 1946–47, p. 303, 1947).

Occurrence: Gatuncillo formation (late Eocene), locality 23b. Búcaro formation (late Eocene), Tonosí area, Panamá (USGS 8286, 8414).

Subfamily CERITHIINAE (p. 170)

Genus Bezanconia Bayle

Bayle, in Fischer, Manuel de conchyliologie, p. 680, 1884.
Type (monotype): *Cerithium spiratum* Lamarck, middle Eocene, Paris basin.

This distinctive Eocene genus is rare in America. It has been found only in Jamaica, Panamá, and Texas. At an early date Heilprin described the only *Bezanconia* from mainland North America as well as the only *Harrisianella*. His *Fusus marnochi* (Heilprin, 1880, p. 151, fig. 6; Aldrich, 1897, p. 5, pl. 3, figs. 4, 4a; late Eocene, Texas) is identified as an immature *Bezanconia* (type, USNM 8917).

Generic assignment of the Paleocene Peruvian cerithid described as *Bezanconia pupoidea* (Woods, 1922, p. 89, pl. 11, figs. 6–8) is doubtful.

Bezanconia cosmeta Woodring, n. sp.

Plate 68, figures 14, 16, 21

Of medium size, moderately slender to moderately inflated. Early whorls cerithoid, later whorls turreted, widely and deeply channeled adjoining suture. A varix, exceptionally two, on all whorls, except on a few earliest and mature body whorl; subdued on penult, or on penult and antepenult. Protoconch missing. Early sculpture like that of *Tympanotonos acanthodes:* axial ribs overridden by three spiral threads, later converted into cords and a narrow thread added at base of spire whorls. Ribs and later cords disappear at varying stage, exceptionally early on a few. Thread at base of spire whorls continuing, but subdued on some antepenult and later whorls. Immature base sculptured with spiral threads, uppermost two strongest, all generally subdued on mature shells. Microscopic spiral sculpture visi-

ble on unworn intermediate whorls. Growth lines forming shallow arc. Lirae or denticles on interior of some immature body whorls. Siphonal canal short. Siphonal notch apparently absent. Siphonal fasciole slightly inflated, smooth, on immature shells limited by overhanging shelf alined with columellar fold; on mature shells forming slightly inflated part of thick columellar lip. Mature columellar lip detached. Mature columellar fold weak, immature fold strong.

Height (incomplete) 41 mm (estimated restored height 51 mm), diameter (incomplete) 17 mm (type).

Type: USNM 646677; paratype USNM 646678.

Type locality: same as preceding species.

Twenty-eight specimens of this strongly sculptured *Bezanconia* were collected at locality 23b. Almost half of them, however, consist only of early whorls and another quarter are fragments of two or three whorls. As usual, the outer lip is broken on all. The type, a slender shell, has an undamaged mature columellar lip. Immature shells are distinguished from immature shells of *Tympanotonous acanthodes* by the consistent varices and stronger columellar fold of the *Bezanconia*, and by the internal lirae or denticles of at least some. No lirae or denticles are shown by an immature specimen of the type species, *B. spirata*, that has a height of 30 mm, the smallest available.

The strong early sculpture of *B. cosmeta* is unique. The earliest available whorls of *B. spirata* (diameter 3 to 9 mm) are sculptured with fine spiral threads. As noted by Trechmann, *B. woodsi* (Trechmann, 1924, p. 13, pl. 2, fig. 2; early Eocene, Jamaica), the only other known Caribbean species, is like a small version of *B. spirata*, but the channel adjoining the suture is narrower and shallower. The early whorls are missing on the type and a USNM topotype (USGS 18281).

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Family ARCHITECTONICIDAE (p. 163)

Genus Architectonica Röding (p. 163)

Subgenus Architectonica s.s.

Architectonica (*Architectonica*) cf. *A. nobilis* Röding, Woodring, this report, p. 165, 1959 (Miocene, Canal Zone).

Architectonica (Architectonica) nobilis Röding, subspecies

Plate 71, figures 4, 5, 10, 11

Moderately large, low-spired, umbilicus wide to moderately wide. Dorsal surface sculptured with four weakly noded cords, not including peripheral cord. Peripheral cord weakly noded. Ventral surface sculptured with narrow cord adjoining peripheral cord, coarsely noded umbilical cord, and wrinkles extending outward from umbilical cord.

Height 6.5 mm, diameter 13.5 mm (smaller figured specimen). Height (reduced by crushing) 8.5 mm, diameter 30.5 mm (larger figured specimen).

Despite replacement of shell material by calcite, among 25 specimens from the La Boca formation at locality 101h and five at locality 116a, about half are in good enough condition to show that they are not *Architectonica nobilis nobilis*, which ranges back to early Miocene time elsewhere in the Caribbean region (p. 167). The best preservation is shown by an immature specimen (pl. 71, figs. 4, 5, 11). The spire of the larger illustrated specimen is crushed and the dorsal sculpture is partly obliterated. The ventral sculpture is similar to that of the larger *A. nobilis karsteni* (this report, p. 167, pl. 30, figs. 1–3; Chagres sandstone), but the umbilicus of that form is narrower.

Though this may be a new subspecies, no mature specimen is well enough preserved to serve as a name-bearer.

The La Boca fossils (Culebra of chapter B, localities 99b, 99c, 100, 116) recorded on page 165 as *A.* cf. *A. nobilis* presumably are the same as those from localities 101h and 116a, but are unidentifiable as such.

Occurrence: La Boca formation (early Miocene), localities 101h, 116a.

Family CALYPTRAEIDAE (p. 79)

Genus Calyptraea Lamarck (p. 80)

Calyptraea lispa Woodring, n. sp.

Plate 69, figures 1, 2, 10

?Calyptraea cf. *C. aperta* (Solander), Woodring, this report, p. 80, 1957 (Eocene, Panamá).

Of medium size, high-spired, base subcircular to elliptical. Early and intermediate whorls forming wide-based cone, later part of mature body whorl shouldered. Suture distinct or indistinct. Protoconch consisting of 1½ to 1¾ capulid whorls, merging into first post-protoconch whorl. Growth lines strong. Diaphragm deeply sinuate at outer margin.

Height 9.5 mm, maximum diameter 19.2 mm (type). Height 2.3 mm, maximum diameter 5.5 mm (paratype).

Type: USNM 646680; paratype USNM 646681.

Type locality: 23b (USGS 24553, Upper course of Río Palenque, 3.4 km in direct line west of Nuevo San Juan and 1.3 km northwest of settlement of Palenque, Colón Province, Panamá), Gatuncillo formation.

This species combines the outline of the widespread, long-ranging (Paleocene to Miocene) *Calyptraea aperta* (Solander) (Cossmann and Pissarro, 1910–13, pl. 12, fig. 73–1), the lack of sculpture of *C. levis* Deshayes (1861–63, p. 276, 1861; *C. laevigata* Deshayes, 1824–37, p. 31, pl. 4, figs. 8–10, 1824, not *C. laevigata* Lamarck, 1822; Eocene, Paris basin) and other species,

and the deeply sinuate diaphragm of *C. labellata* Deshayes (1861–63, p. 277, pl. 9, figs. 5–7, 1861; Oligocene, Paris basin) and other species. In unsculptured surface and deeply sinuate diaphragm it is similar to *C. centralis* (Conrad), described on page 80, but the outline of that species is a smoothly tapering, low cone.

The type is the largest of 15 specimens, two-thirds of which are immature, including the paratype, the only specimen that has an intact diaphragm. Though the limestone molds, described as *C.* cf. *C. aperta*, have the outline of *C. lispa*, their diaphragm is unknown.

Occurrence: Gatuncillo formation (late Eocene), localities 9, 12 (identification doubtful both localities), 23b.

Genus Trochita Schumacher (p. 80)

Trochita spirata Forbes?

Trochita trochiformis (Born), erroneous designation for *T. radians* (Lamarck), Woodring, this report, p. 81, pl. 19, figs. 11–14, 1957 (Miocene, Panamá).

After publication of chapter A, in a personal communication the late L. G. Hertlein, of the California Academy of Sciences, called my attention to *Trochita spirata* Forbes (1850 (1852), p. 271, pl. 11, fig. 1; living, Gulf of California; Reeve, 1859, species 8, pl. 2, figs. 8, 8a), which was overlooked when the fossils from Panamà were identified. At a later date Olsson and Petit (1964, p. 565) expressed the opinion that the Gatun species is more suggestive of *T. spirata* than of *T. radians*.

I am indebted to Dr. Hertlein for the loan of five specimens of *T. spirata* from the coast of the state of Michoacán, México. The dark-colored interior—a feature not available in fossils—readily distinguishes that species from *T. radians*. In addition, however, the ribs are more widely spaced than those of *T. radians*. The ribs of the smaller Gatun specimen (pl. 19, figs. 11, 12) are widely spaced, whereas those of the larger (pl. 19, figs. 13, 14) are closely spaced. That is, the identification is equivocal.

The status of the middle Miocene Venezuelan fragment described as *T.* cf. *T. radians* (Jung, 1965, p. 497, pl. 66, figs. 1, 2) and of the early Pliocene Trinidad small specimens identified as *T. radians* (Jung, 1969, p. 473, pl. 47, figs. 12, 13) is uncertain, but they evidently are not *T. spirata*. In any event the Trinidad form is the last western Atlantic *Trochita*.

Occurrence: Lower part of Gatun formation (middle Miocene), localities 136, 136a.

Trochita species

Plate 72, figures 12, 16, 19

Trochita? cf. *T. trochiformis* (Born), Woodring, this report, p. 37 (list), 81 (mentioned without designation), 1957 (Miocene, Canal Zone).

Small, low-spired to moderately high-spired. Ribs of moderate width and height, closely spaced.

Height 12.5 mm, diameter 23.3 mm (figured specimen).

Some 40 specimens of *Trochita* from the La Boca formation at locality 116a are in better condition than the six formerly available. All are small, their diameter ranging from 12 to 30 mm. Their ribs consistently are closely spaced. Whether this *Trochita* is related to *T. radians*, as it appears to be, is questionable. On zoogeographic grounds it is doubtful that a Miocene Caribbean species is closely related to a species now living in waters bathed by the Humboldt Current: an aspect not considered in chapter A.

The ribs of the recently described late Miocene Florida species, *T. floridana* (Olsson and Petit, 1964, p. 563, pl. 81, figs, 2, 2a), the only species from eastern United States, not only are very closely spaced, they are also exceptionally high.

Occurrence: La Boca formation (early Miocene), localities 115a, 115b (*Trochita?* sp. for both localities, assigned to Culebra formation in chapter A), 116, 116a.

Genus Crucibulum Schumacher (p. 82)

Subgenus Crucibulum s.s.

Crucibulum (Crucibulum) spinosum (Sowerby)

Plate 73, figure 7

Calyptraea spinosa Sowerby, The genera of recent and fossil shells, fasc. 23 [p. 142], pl. 151, fig. 4, 1824 (age and locality not specified).

Crucibulum spinosum (Sowerby), Dall, U.S. Natl. Mus. Proc., v. 37, p. 173, 233, 1909 (living, California to Chile).

Crucibulum (Crucibulum) spinosum (Sowerby), Olsson, Neogene mollusks from northwestern Ecuador, Paleontological Research Inst., p. 196, pl. 34, fig. 5, 1964 (Miocene, Ecuador).

Crucibulum auriculatum Chemnitz, Sowerby, Monograph of the family Calyptraedae: in Thesaurus conchyliorum, p. 60, pl. 3, figs. 7–14, 1883 (living, Central America).

Crucibulum piliferum Guppy, Sci. Assoc. Trinidad Proc., pt. 3, p. 172, 1867 (Pliocene, Trinidad); reprint, Bull. Am. Paleontology, v. 8, no. 35, p. 51, 1921.

Crucibulum (Crucibulum) piliferum Guppy, Jung, Bull. Am. Paleontology, v. 55, no. 247, p. 475, pl. 47, figs. 14–16, 1969 (Pliocene, Trinidad).

Small, subcircular, low-spired, apex subcentral. Capulid protoconch and about first half of first postprotoconch whorl smooth. Remainder of shell sculptured with radial ribs of two ranks: (1) narrow, widely spaced ribs bearing low broken spines, generally appearing as stubby tubes or vaulted scales; (2) low, crowded, more or less irregular, minutely nodose ribs, generally trending at low angle to first order ribs. Cup broken, except basal part.

Height 9.7 mm, diameter 15.2 mm (figured specimen).

A small nicked *Crucibulum* in the large collection from the lower part of the Gatun formation at locality 138c is identified as *C. spinosum*, now living in eastern

Pacific waters. It presumably is immature, but may represent a small Miocene race, smaller than the Pliocene *C. piliferum*, which is considered to be a synonym of *C. spinosum*.

This is an example of a paciphile at the species level; that is, a species that formerly lived in the present Caribbean region, but now is extinct there and survives in eastern Pacific waters. Examples at the species level are rare.

Occurrence: Lower part of Gatun formation (middle Miocene), locality 138c. Esmeraldas formation (late Miocene), Ecuador. Melajo clay member of Springvale formation (late Miocene), Trinidad (immature, identification doubtful). Courbaril member of Morne l'Enfer formation (early Pliocene), Trinidad (immature, identification doubtful). Matura member of Talparo formation (early Pliocene), Trinidad. Living, eastern Pacific Ocean.

Family CYPRAEIDAE (p. 193)

Genus Siphocypraea Heilprin

Heilprin, Wagner Free Inst. Sci. Trans., v. 1, p. 86, 1887.

Type (monotype): *Cypraea (Siphocypraea) problematica* Heilprin, Pliocene, Florida.

Subgenus Muracypraea Woodring (p. 194)

Since *Muracypraea* was proposed as a subgenus of *Cypraea* its status has been discussed by several authors. The most satisfactory arrangement is that proposed by Olsson and Petit (1964, p. 577; 1968, p. 280), who classified it as a subgenus of *Siphocypraea*. Coomans (1963, p. 54) rejected *Muracypraea* as a synonym of *Akleistostoma* (Gardner, 1943(1944)–48, p. 213, 1948; type (orthotype): *Cypraea carolinensis* Conrad, late Miocene, North Carolina, Florida). Countless specimens of late Miocene age have turned up recently in Florida. They show gradation in a *carolinensis-problematica* lineage (Olsson and Petit, 1964, p. 556–560). That lineage is unknown in the Caribbean region, and *Muracypraea* is unknown in Florida.

Family OVULIDAE

Genus Cyphoma Röding

Röding, Museum Boltenianum, p. 21, 1798.

Type (logotype, Herrmannsen, Indicis generum malacozoorum, v. 1, p. 355, 1847): *Ovula gibbosa* (Linné); that is, *Cyphoma gibbosa* Röding=*Bulla gibbosa* Gmelin=*Bulla gibbosa* Linné, living, North Carolina to West Indies and northern South America.

As noted by Winckworth (1945, p. 139), though *Cyphoma* is a neuter noun, Röding chose to use it as though it were feminine.

Cyphoma aff. C. intermedia (Sowerby)

Plate 72, figures 13, 14

Large, thin-shelled, strongly inflated. Internal mold of later part slightly bulging at middle. Apertural features unknown.

Height (almost complete) 41 mm (estimated restored height 45 mm), diameter 20.3 mm (figured specimen).

An internal mold from the La Boca formation at locality 101h is of special interest as the earliest representative of the endemic American genus *Cyphoma*. A little of the thin shell adheres to the mold. The outline indicates alliance to *C. intermedia* (Sowerby, 1848, p. 479, pl. 100, figs. 61, 62), which ranges from North Carolina to Brazil. The fossil, however, is more inflated. The mold would not reproduce the low hump of *C. intermedia*, although it shows a slight bulge. A fine specimen of *C. intermedia* (USNM 646419) was found by Mrs. Shirley E. Hoerle in Olsson's unit A in peninsular Florida (Olsson, in Olsson and Petit, 1964, p. 521). It is as large as the La Boca fossil but is more slender. The anatomy of *C. intermedia* was described by Bayer (1943, p. 109, pl. 14, fig. 27).

C. puana (Anderson) (1929, p. 140, pl. 9, figs. 9, 10; Miocene, Columbia), a small species, evidently is related to *C. intermedia*.

C. mcgintyi Pilsbry (Pilsbry and McGinty, 1939, p. 2, pl. 1, figs. 3, 3a, 4, 11, 12) occurs in the late Miocene Limón formation of Costa Rica (USGS 20468) and *C. gibbosa* (Linné) in the late Pliocene Moín formation of that country: Dall's *Ultimus precursor* (in Guppy and Dall, 1896, p. 318, pl. 29, figs. 2, 3).

Occurrence: La Boca formation (early Miocene), locality 101h.

Family NATICIDAE (p. 84)

Subfamily GLOBULARIINAE (p. 94)

Genus Globularia Swainson (p. 94)

Subgenus Globularia s.s. (p. 94)

Globularia (Globularia) megista Woodring n. sp.

Plate 67, figures 13, 16–18

Large, subglobose, spire of moderate height, whorls narrowly channeled adjoining suture. Faint spiral lineation apparent on some shells. Aperture expanded. Umbilicus moderately wide. Sheath wide, bordered by sharp rim. Lobe wide, its outer edge generally well defined. (For terms sheath, rim, and lobe see Wrigley, 1946, p. 88 and p. 94 of present report).

Height 68 mm, diameter 57 mm (type). Estimated restored height 75 mm, diameter 60 mm (largest specimen).

Type: USNM 646682.

Type locality: 23b (USGS 24553, Upper course of Río Palenque, 3.4 km in direct line west of Nuevo

San Juan and 1.3 km northwest of settlement of Palenque, Colón Province, Panamá), Gatuncillo formation.

Fourteen half-mature to mature specimens (height about 40 to an estimated 75 mm) and 36 immature (height 1.5 to 17 mm) of this large species are available. Parts of the outer and basal lips are missing on all, except some of the immature shells, or cannot be reconstructed satisfactorily from small fragments.

In umbilical features (umbilicus, sheath, rim, and lobe) *G. megista* is similar to *G. recurva recurva* (Aldrich) (Palmer, 1937, p. 133, pl. 14, figs. 7, 8; middle Eocene, Alabama), but is larger and has a narrower sutural channel. In size, however, it is comparable to *G. recurva dumblei* (Heilprin) (Palmer, 1937, p. 134, pl. 14, fig. 10, 11; middle Eocene, Texas). Though in umbilical features *G. megista* closely resembles the middle and late Eocene *G. patula* (Lamarck) (Deshayes, 1824–37, p. 169, pl. 21, figs. 3, 4, 1832; Wrigley, 1946, p. 90, fig. 5), of the Anglo-Parisian basin, that species has a sutural narrow step instead of a channel and is smaller.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Family CASSIDIDAE (p. 197)

Genus Semicassis Mörch (p. 198)

Subgenus Echinophoria Sacco (p. 198)

Semicassis (Echinophoria) tostoma Woodring, n. sp.

Plate 71, figures 9, 12–14

Small, subglobose, distinctly shouldered. Terminal varix missing, preceding varix on body whorl generally absent. Sculpture consisting of weakly noded, low, narrow spiral threads, alternating with narrower, undulated threads. Nodes strongest on shoulder spiral thread, progressively more subdued downward on body whorl. Two similar, but narrower, undulated threads between shoulder and suture, one to three fine, secondary threads between them and flanking them. Outer lip and end of siphonal canal missing. Preserved upper part of siphonal fasciole inflated.

Height (incomplete) 28 mm, diameter (terminal varix missing) 23.5 mm (type). Height (almost complete) 20.7 mm, diameter (terminal varix missing) 16.8 mm (immature paratype).

Type: USNM 646713; paratype USNM 646714.

Type locality: 101h (USGS 23652, Panama Canal, west side of Las Cascadas Reach, Canal Stations 1608 to 1612 plus 23 meters, near top of canal cliff, Canal Zone), La Boca formation.

Semicassis tostoma is abundant in the La Boca formation at the type locality (30 specimens) and four immature specimens were collected at locality 101i. Much or all of the thin shell is missing on all of them.

The sculpture is more subdued than that of the two species from the Caimito formation described on pages 198–199, and that of *S. rondeleti* (Basterot) (Cossmann and Peyrot, 1922–24, p. 423, pl. 12, figs. 16, 17, 1924) from the Burdigalian of Aquitaine.

Occurrence: La Boca formation (early Miocene), localities 101h, 101i.

Family MURICIDAE (p. 214)

Subfamily OCENEBRINAE?

Genus Leptomurex Woodring, n. gen.

Type: *Leptomurex acares* Woodring, n. sp., Gatuncillo formation.

Small, moderately inflated, distinctly shouldered, lacking spines and varices. Uppermost part of all except earliest whorls abruptly turned upward, greatly attenuated in thickness, and overlapping lower third of preceding whorl. Axial sculpture consisting of wide, widely spaced ribs; spiral sculpture of low, wide bands, confined to body whorl. Siphonal canal of moderate length, deflected laterally from axial alinement and slightly bent backward. Siphonal notch shallow.

The position of the suture is the most diagnostic feature of this genus. It is not located at the abrupt angulation of the whorl, where it would be expected, but a third of the way up the preceding whorl. Though it is undesirable to base a genus on a species represented by one specimen, so far as I am aware the suture is unique for a muricid.

The subfamily status is uncertain, but the lack of spines and varices favors assignment to the Ocenebrinae.

Leptomurex acares Woodring, n. sp.

Plate 68, figures 22, 23

Protoconch blunt, 1½-whorled, lower edge, except that of tip, slightly angulated, end marked by disappearance of angulation and appearance of axial ribs. Ten ribs on first post-protoconch whorl, first few closely spaced and weak. Seven ribs on body whorl. Growth lines strong, sublamellar on ribs. Outer lip broken back, only uppermost part preserved. Weak lirae within aperture at lower end of broken lip. Four widely spaced lirae far within aperture opposite penult rib. Other features as described under genus.

Height 11.3 mm, diameter 6.8 mm (type).

Type: USNM 646684.

Type locality: 23b (USGS 24553, Upper course of Río Palenque, 3.4 km in direct line west of Nuevo San Juan and 1.3 km northwest of settlement of Palenque, Colón Province, Panamá), Gatuncillo formation.

Whether the single specimen is immature is indeterminable. Small size, however, is not unusual among Eocene muricids.

Occurence: Gatuncillo formation (late Eocene), locality 23b.

Subfamily TYPHINAE (p. 220)

Genus Typhis Montfort (p. 220)

Subgenus Pilsbrytyphis Woodring (p. 220)

Typhis (Pilsbrytyphis) woodringi (Gertman)

Siphonochelus (*Pilsbrytyphis*) *woodringi* Gertman, Tulane Studies Geology and Paleontology, v. 7, no. 4, p. 180, pl. 7, figs. 6a, 6b, 1969 (Miocene, Canal Zone).

Typhis (*Pilsbrytyphis*) *gabbi* Brown and Pilsbry, Woodring, this report, p. 220, pl. 32, figs. 2, 3, 5, 7, 1959 (Miocene, Canal Zone).

During the preparation of chapter B, I neglected to compare the *Typhis* identified as *T. gabbi* with the type of that species. The type is smaller, less slender, and, as pointed out by Gertman, its sculpture is basically spiral rather than axial, and a buttress extends from a varix to the preceding whorl. The specimen illustrated in chapter B on plate 32, figures 5 and 7, was selected as the type of *T. woodringi*. When it was unpacked in Washington it was found to be damaged.

Contrary to Gertman's statement (1969, p. 179), the type of *T. gabbi*, from the middle part of the Gatun formation, is the only specimen of that species. He alleged that all the specimens of *T. woodringi* are from the upper part of the Gatun formation, although it was recorded from the middle part (loc. 147g) on page 221. A total of 29 is now available from the upper part, but only one from the middle part. It seems strange that two species of this unusual subgenus are found in the Gatun formation.

Occurrence: Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, locality 147g. Upper part, eastern area, localities 175, 176, 176a, 177b, a lot collected by John R. Embich.

Subfamily THAIDINAE (p. 222, as family)

Genus Cymia Mörch (p. 223)

Subgenus Tritonopsis Conrad

Conrad, Am. Jour. Conchology, v. 1, p. 20, 1865.

Type (monotype): *Triton subalveatum* Conrad, Oligocene, Mississippi.

Cymia (Tritonopsis) n. sp.

Plate 70, figures 26, 27

Small, inflated, body whorl angulated at shoulder. Early whorls missing. Remaining whorls sculptured with three coarsely noded spiral bands between shoulder and suture, axial swellings between bands alined with nodes (nodes and swellings greatly reduced or suppressed on last third of body whorl), and two, later three, secondary threads between them. Four bands, decreasing in width downward, on preserved part of body whorl below shoulder, one to three secondary threads between them. Strong growth threads on entire shell, especially between spiral bands and threads. Strong lirae on interior of outer lip. Columellar fold strong. Basal part of siphonal canal and all of siphonal fasciole missing.

Height (incomplete) 13.5 mm (estimated restored height 17 mm), diameter 10.3 mm (figured specimen).

The Gatuncillo formation at locality 23a yielded the earliest known species of *Cymia*. It is left unnamed, as the one specimen is in poor condition. It has been repaired as far as possible. The position of the columellar fold, far down on the columella, probably is an artifact, due to faulty repairing.

This new species is similar in sculptural pattern to *C. subalveata*, the Oligocene type of *Tritonopsis*, but the secondary sculpture of the Panamá species is more delicate. It is angulated also at the shoulder, whereas the Oligocene species is rounded, as well as smaller, if the single specimen is mature.

Occurrence: Gatuncillo formation (late Eocene), locality 23a.

Family BUCCINIDAE (p. 256)

Genus Engina Gray

Gray, Zoology of Captain Beechey's voyage * * * in His Majesty's ship *Blossom*, p. 112, 1839.

Type (logotype, Gray, Zool. Soc. London Proc., p. 133, 1847): *Engina zonata* Gray (*Enzina* by error) (=*Purpura turbinella* Kiener), living, West Indies.

A photograph of the type species was published by Bartsch, who was misled by Gray's statement concerning the size. The error was corrected by Orr, who republished the photograph at original magnification, designated the specimen as the lectotype, and identified it as the common West Indian *Engina turbinella*. The two papers just mentioned are cited in the following synonymy.

Engina turbinella (Kiener)

Plate 74, figures 4, 5

Purpura turbinella Kiener, Species général et inconographie des coquilles vivantes, Genre Pourpre, p. 29, pl. 9, fig. 25, 1835–36 (living, locality unknown [West Indies]).

Engina turbinella (Kiener), Warmke and Abbott, Caribbean sea shells, p. 116, pl. 21, fig. d, 1961 (living, Florida Keys and West Indies).

Not *Engina turbinella* (Kiener), Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 1, 131, 1890 (Pliocene, Florida); =*Engina floridana* Olsson and Harbison.

Engina zonata Gray, Zoology of Captain Beechey's voyage * * * in his Majesty's ship *Blossom*, p. 113, 1839 (living, Atlantic Ocean). Bartsch, U. S. Nat. Mus. Proc., v. 79, art. 15, p. 7, pl. 1, fig. 6, 1931 (living, locality not specified). Orr, Nautilus, v. 75, p. 107, pl. 10, figs. A, B, 1962 (living, West Indies).

Small, inflated, biconic, concave between shoulder and suture. Sculpture consisting of wide, swollen axial ribs (nine on body whorl), a subdued primary spiral cord near suture, seven primary spiral cords on body whorl between shoulder and base, swollen on ribs, and closely spaced secondary spiral threads between primary cords. Interior of outer lip coarsely denticulate. Elongate, low denticles on columellar lip, a stronger denticle on upper part of parietal wall opposite a denticle on outer lip. Base of columella thickened. Long, narrow ridge on outer-lip side of insertion of siphonal canal. Siphonal canal short; siphonal notch shallow; siphonal fasciole slightly inflated.

Height (not quite complete) 10.9 mm, diameter 7 mm (figured specimen).

A small specimen of *Engina turbinella* was found in the lower part of the Gatun formation at locality 138f. The tip is worn and corroded, and the apertural face is worn. Many living shells are in the same condition, as the species lives in water a few feet deep on rocky bottoms. Though the primary spiral cords are more uniform than those of the usual run of *E. turbinella*, the fossil closely resembles a shell from suction-dredge tailings on Payardi Island, 3 km northeast of locality 138f. Closely related forms on the Pacific side of Panamá have been named *E. panamensis* and *E. tabogaensis* (Bartsch, 1931, p. 7, pl. 1, fig. 7; p. 8, pl. 1, fig. 8, respectively).

Occurrence: Lower part of Gatun formation (middle Miocene), locality 138f. Living, Florida Keys and Bahamas to northern Brazil.

Genus Bailya M[axwell] Smith

M[axwell] Smith, Panamic marine shells, p. 22, 1944.

Type (orthotype): *Triton anomalus* Hinds, living, eastern Pacific Ocean, Nicaragua to Panamá.

Triton parvus C. B. Adams (Clench and Turner, 1950, p. 322, pl. 40, fig. 12) or the closely related, if not synonymous, *Phos intricatus* (Dall, 1883 (1884), p. 325, pl. 10, fig. 9) would have been a better choice as the type species. *Triton anomalus* is a rare species, and its radula is unknown. Two shells from the Gulf of Dulce, Costa Rica, are in USNM collections (424961). Dr. H. A. Rehder informs me that the radula of *Triton parvus* is buccinid.

Bailya crossata Woodring, n. sp.

Plate 77, figures 14, 15

Moderately small, slender, somewhat turreted. Protoconch missing except last half whorl, which merges into first post-protoconch whorl. Sculpture consisting of narrow axial ribs, overridden by narrow primary spiral threads and closely spaced, low secondary spiral threads. Primary spiral threads swollen on ribs. Thirteen axial ribs on body whorl and eight primary spiral threads above base. Base sculptured with four frilled primary spiral threads on siphonal fasciole, terminal frill strong (uppermost two threads more widely spaced than others), and a stronger, more widely spaced, frilled primary thread still higher. Axial ribs attenuated or suppressed between these basal primary threads. Secondary threads between them, as on remainder of whorl. Entire shell delicately frosted by microscopic growth threads. Outer lip varicose, edge frilled, interior bearing short, low lirae. Columellar lip narrow. An elongate denticle on upper part of parietal wall opposite a lira on outer lip. Siphonal canal short; siphonal notch moderately deep; siphonal fasciole slightly inflated.

Height 16.9 mm, diameter 7.5 mm (type).

Type: USNM 646724.

Type locality: 138e (USGS 22391, Spoil from refinery-site suction-dredge operations on west side of Payardi Island, Colón Province, Panamá), lower part of Gatun formation.

The strongly frilled basal spiral threads alone distinguish *Bailya crossata* from other species. In addition it is slightly larger, and the spire is more distinctly turreted. It is the first Tertiary species from the Caribbean region to be recorded and the earliest species now known. The type is the only specimen.

Occurrence: Lower part of Gatun formation (middle Miocene), locality 138e.

Family MELONGENIDAE (p. 273)

Genus Melongena Schumacher (p. 273)

Melongena cf. M. propatula Anderson

Plate 73, figure 11

Of medium size, whorls uniformly overlapping earlier whorl. Spiral sculpture of wide, or fairly wide, bands on spire whorls and body whorl. On body whorl most distinct on and above shoulder, but extending in subdued form down to siphonal fasciole. A row of blunt spines on shoulder of body whorl (one spine on preserved half of penult). Another row of smaller spines near base. Siphonal fasciole narrow, strongly inflated.

Height (almost complete) 81.5 mm, diameter (not including spines), 49 mm (figured specimen).

The apertural face of the single specimen of this Gatun species is obliterated by corrosion. The wide, or fairly wide, spiral bands suggest alliance with *Melongena propatula* (Anderson, 1929, p. 133, pl. 11, figs. 1, 2), a middle Miocene Colombian species. If it is that species, however, it represents a stage preceding development of the greatly expanded mature body whorl. The type of *M. propatula* is in poor condition and so is a somewhat larger virtual topotype (USGS 10987).

The sculpture of the incomplete La Boca specimen, mentioned on page 273, is comparable.

Occurrence: Lower part of Gatun formation (middle Miocene), locality 138f.

Family XANCIDAE (p. 285)

Genus Xancus Röding (p. 285)

Xancus cf. X. validus (Sowerby)

Xancus cf. *X. rex* Pilsbry and Johnson, Woodring, this report, p. 286, 1964 (Miocene, Canal Zone).

Xancus sp., Woodring, this report, p. 286 (Oligocene [Miocene], Canal Zone).

E. H. Vokes (1964, p. 47, fig. 1), who illustrated the lectotype of *Xancus validus*, has shown that *X. rex* is a synonym of that species. The species recorded in chapter C as *X.* cf. *X. rex* occurs in the Culebra and La Boca formations.

X. validus is known to occur in the Baitoa formation of the Dominican Republic (USGS 8558, 8668), as well as in the Thomonde formation of Haiti (USGS 9779, 9782, 9948), both of late early Miocene age. It was not found in the Cercado or Gurabo formations by the Maury or USGS expeditions. The fine specimen illustrated by Maury (1917, p. 83, pl. 13, fig. 5) was collected by Gabb. Col. Heneken, whose fossils were described by Sowerby, collected along Río Yaque del Norte at and south of Santiago, and also farther west on Río Amina, Río Mao, and Río Gurabo, and at other scattered localities (Heneken, 1853, p. 122–125). The Baitoa formation crops out on Río Yaque del Norte south of Santiago. To be sure, however, 90 percent of the stratigraphically allocated species described by Sowerby occur in the Gurabo formation (and 20 percent exclusively in that formation), which also crops out on Río Yaque del Norte south of Santiago, as well as on the other rivers mentioned.

Occurrence: Culebra formation (early Miocene), localities 104a, 104b. La Boca formation (early Miocene), locality 116a (assigned to Culebra formation in chapter C). Emperador limestone member of La Boca formation (early Miocene), Madden basin, locality 71 (assigned to Caimito formation in chapter C).

Xancus validus hysterus Woodring, n. subsp.

Plate 73, figure 10; plate 74, figures 2, 3

Xancus validus validus (Sowerby)?, Woodring, this report, p. 286, pl. 47, fig. 13, 1964 (Miocene, Canal Zone).

Larger than *Xancus validus validus*, but whorl profile similar. Earliest preserved whorls weakly shouldered; shoulder later progressively stronger. Earliest knobs low, wide, strongly pinched in plane parallel to suture; at later stage knobs stronger, but wider and more pinched than those of nominate subspecies. Earliest preserved whorls worn, showing wide axial ribs and traces of spiral threads. A weak spiral cord appearing later well below shoulder. Mature body whorl sculptured with four widely spaced, subdued spiral cords between shoulder and pillar, and closely spaced, subdued cords on pillar. Microscopic spiral lineation visible on well-preserved shells. Growth threads occasionally exaggerated, but not strongly exaggerated at widely and regularly spaced intervals on slope between suture and shoulder.

Height (incomplete) 265 mm (estimated restored height 300 mm), diameter 110 mm (type).

Type: USNM 646726; paratype USNM 646727.

Type locality: 159b (USGS 6273, Lock site [at Gatun], Canal Zone, 10 to 50 feet (3 to 15 meters) below surface, middle part of Gatun formation.

The large size, late appearance of knobs, wider and more pinched knobs, and absence of strong, widely spaced, exaggerated growth threads on the slope between the suture and the shoulder distinguish this subspecies from the nominate subspecies. The exaggerated growth threads of the nominate subspecies are shown to good advantage in Maury's illustration (Maury, 1917, p. 83, pl. 13, fig. 5) and in Pilsbry's illustrations of *Xancus rex* (Pilsbry, 1922, p. 342, pl. 26, figs. 5, 8).

Only four specimens of *X. validus hysterus* are available. The specimen serving as the type was unaccountably overlooked when plate 47 was made up. The type and the immature paratype were collected at the same locality. Another large shell in the same lot—somewhat larger than the type, but less complete—is a little more inflated than the type (diameter 120 mm).

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, localities 155, 159b.

Xancus dodonaius praelaevigatus (E. H. Vokes)

Xancus praevoideus (error for *praeovoideus*, see errata following p. 251) Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 83, pl. 14, fig. 18, 1917 (Miocene, Dominican Republic). Not *Turbinella praeovoidea* Vrendenberg, 1916.

Xancus validus falconensis H. K. Hodson, Woodring, this report, p. 286, pl. 46, figs. 4–6, 1964 (Miocene, Canal Zone).

Turbinella praelaevigata E. H. Vokes, Tulane Studies in Geology, v. 2, no. 2, p. 52, 1964; new name for *Xancus praeovoideus* Maury.

Type: Cornell Univ. 36829.

Type locality: Bluff 3, Cercado de Mao, Dominican Republic, Cercado formation.

E. H. Vokes' (1964a, p. 96) objection to classifying *Xancus falconensis* as a subspecies of *X. validus* is justified.

Despite the identification in chapter C, which was made without benefit of specimens of *X. falconensis*, a series of 11 topotypes shows that *X. falconensis* is not a suitable name for the faintly knobbed or smooth *Xancus* from the Gatun. *X. falconensis* is slender and has

a strongly constricted pillar. Its shoulder, not far from the suture, is rounded or subrounded and on some specimens is marked by an obscurely undulated, low spiral thread. So far as known it is relatively small (maximum estimated restored height 170 mm).

Two species of *Xancus* are represented in the collection from the Oak Grove sand member of the Shoal River formation at USGS locality 2646, one smooth, the other knobbed. The only fairly complete specimen, which is smooth and immature, was selected as the type of *X. dodonaius* (Gardner, 1926–47, p. 440, pl. 49, fig. 2, 1944). A fragment of the body whorl of a larger shell also is smooth. Another specimen, consisting of the spire and upper part of half of the body whorl, is larger and more inflated than the type. The body whorl has a distinct shoulder, undulated by long, thinly pinched vestigial knobs, like those of *X. validus hysterus* at a comparable growth stage. The fragment of a large shell mentioned by Gardner, was collected at a nearby locality (USGS 7054). It is strongly shouldered and bears long, pinched knobs, like mature *X. validus hysterus*. No mature shells of *X. dodonaius* are in USNM collections. A mature specimen from the Chipola formation (height 210 mm) was illustrated by E. H. Vokes (1964, p. 50, pl. 1, fig. 2a).

X. praelaevigatus occurs in the Cercado and Gurabo formations of the Dominican Republic. Five specimens are in USNM collections from each formation (USGS 8525; 3516, 8519 respectively). Maury's photograph of the type of her *X. praeovoideus* is a better representation than the drawing in her Brazilian monograph (Maury, 1925a, p. 623, pl. 7, fig. 12). This *Xancus* is so similar to *X. dodonaius* that it is given subspecific rank under that species. The chief difference is that the sculpture of *X. praelaevigatus* disappears at a later growth stage.

The Gatun *Xancus*, which occurs also in the Darién area, is now identified as a large, variable, slender to moderately inflated, faintly knobbed to smooth form of *X. dodonaius praelaevigatus*. The maximum estimated height of USNM Dominican Republic specimens is 180 mm, but Pilsbry (1922, p. 343) estimated 200 mm for the largest in the Gabb collection. Estimated heights for the largest Gatun and Darién shells are 250 and 300 mm, respectively.

Despite its name, it is unlikely that *X. dodonaius praelaevigatus* is a predecessor of the small, ovate, living Brazilian *X. laevigatus*.

Occurrence: For occurrence in Gatun formation see p. 287. Middle Miocene deposits, Darién area, Panamá (USGS 8430, 8476, 8477, 8479). Cercado and Gurabo formations (middle Miocene), Dominican Republic.

Family XANCIDAE?

Genus?

Plate 73, figures 12, 13

Of medium size, spire of moderate height, whorls rapidly enlarging in diameter. Intermediate and late whorls strongly shouldered; widely spaced, spinose knobs on shoulder of late whorls. Earliest whorls missing, later early whorls worn, but showing gross features. Axial swellings on lower part of earliest preserved whorl transformed on next whorl into widely spaced knobs at base of whorl and evenutally into sinose knobs. Undulations on band adjoining suture transformed into closely spaced knobs, gradually flattened in plane parallel to suture, gradually becoming bipartate also in plane parallel to suture, and eventually transformed into strongly bifid knobs. Two widely spaced, low, undulated spiral cords near suture, followed by two closely spaced, low spiral threads near shoulder. Undulations transformed into pinched knobs on last bit of shell. Suture below shoulder knobs distinct on earliest preserved whorls, obscure or concealed on later whorls. Lower part of body whorl missing. Columella thick at broken end, upper part bearing 10 closely spaced, narrow wrinkles.

Height (incomplete) 36 mm, diameter (including knobs) 39.7 mm (figured specimen).

The affinities of this bizarre fossil are undetermined. The bifid knobs are especially bizarre. It is described and illustrated in the hope that a more complete specimen may be found eventually. It was more or less covered with a hydrozoon crust, especially the upper part of the spire, which was broken and worn before encrustration. The crust was removed, or almost entirely removed. Though the suture is distinct on the early preserved whorls, it is obscure or concealed on late whorls. Where the preservation is good on late whorls, fine growth lamellae extend across where the suture should be, indicating that an extension of the mantle covered it.

Were it not for the columella, it would not be unreasonable to interpret it as a bizarre *Vasum*. It is by no means certain, however, that it is a xancid; it may possibly be a cymatid.

Occurrence: Lower part of Gatun formation (middle Miocene), locality 138c.

Family CANCELLARIIDAE (p. 334)

Genus Cancellaria Lamarck (p. 334)

Subgenus Cancellaria s.s.

Cancellaria (Cancellaria) epistomifera sathra Woodring, n. name

Cancellaria (Cancellaria) epistomifera lipara Woodring, this report, p. 337, 1970, not *Cancellaria lipara* Woodring, U.S. Geol. Survey Prof. Paper 222, p. 76, 1950 (1951).

To propose a junior homonym is unfortunate, but for an author to propose a name invalidated by one of his own names is doubly unfortunate. I am indebted to Mr. R. E. Petit for pointing out the error.

Family TURRIDAE (p.360)

Subfamily CLAVINAE (p. 374)

Genus Leptadrillia Woodring?

Woodring, Carnegie Inst. Washington Pub. 385, p. 159, 1928.
Type (orthotype): *Turris (Surcula) parkeri* Gabb, Miocene, Dominican Republic and Jamaica.

Leptadrillia? n. sp.

Plate 69, figure 9

Of medium size, slender, whorls almost flat-sided. Early whorls missing. Sculpture consisting of narrow axial ribs, almost straight and axial on earliest preserved whorl, later arcuate and protractive; seven on last preserved whorl. Spiral sculpture limited to irregularly spaced lineation. According to ribs and growth lines, anal sinus wide and shallow. Aperture missing.

Height (incomplete) 22.5 mm, diameter (almost complete) 9.7 mm (figured specimen).

Though this Eocene species has distinctive features, it is left unnamed, as both protoconch and aperture are missing on the only specimen.

It is larger and more flat-sided than the Miocene to living genus *Leptadrillia*, and has a narrower apical angle. It is much larger than early Tertiary clavine turrids from southeastern United States characterized by absence of spiral sculpture, except on the pillar. *Pleurotoma tantula* (Conrad, 1848, p. 115, pl. 11, fig. 21, a poor illustration; Oligocene, Mississippi), which has a height of 11 mm, is the largest of these early Tertiary species. They are not as flatsided as the Panamá species.

Occurrence: Gatuncillo formation (late Eocene), locality 23b.

Family ACTEONIDAE (p. 415)

Subfamily ACTEONELLINAE?

Genus Volvariella Fischer

Fischer, Manuel de conchyliologie, p. 553, 1883.
Type (monotype): *Volvaria lamarcki* [*lamarckii*] Deshayes, Eocene, Paris basin.

Volvariella has been assigned to the Mitridae. Cernohorsky (1970, p. 64) recommended transferring it to the Acteonacea, close to *Cylindrites;* that is, in the family where Fischer originally allocated it.

Volvariella? species

Plate 70, figures 23–25

Large for the genus *Volvariella*, subcylindrical, slender. Spire high, somewhat loosely coiled. Sculpture subdued, consisting of low, narrow, flat, closely spaced spiral threads, minutely reticulated by microscopic axial threads. Growth lines exaggerated at irregular intervals and dark-colored axial bands on mature shells. Aperture narrow, base rounded. Columella not exposed.

Height (almost complete) 21.8 mm, diameter 7.5 mm (larger figured specimen). Height (almost complete) 6.9 mm, diameter 2.6 mm (smaller figured specimen). Height (almost complete) 27.5 mm, diameter 8 mm (largest specimen).

Four specimens of this species were collected from the Bohio(?) formation at locality 41b and one at locality 41. All are internal molds to which some shell material, replaced by calcite, adheres.

On reasonable grounds these fossils represent the genus *Volvariella*. They have the outline and sculpture of that genus. Nevertheless the generic assignment is questioned, as the columella is unknown. The lower part of the columella was found to be dissolved on the one specimen that was ground down. If the species is a *Volvariella*, it is the largest and youngest, even if the marine member of the Bohio(?) is of late Eocene age, rather than early Oligocene. It is four times as large as the only other American species, *V. aldrichi* Cossmann (Palmer, 1937, p. 413, pl. 65, figs. 3, 4; early to middle Eocene, Alabama), and its spire is more loosely coiled. The early Eocene type of the genus, *V. lamarckii* (Deshayes) (1861–63, p. 543, pl. 104, figs. 1, 2, 1862), has a height of 11 mm. According to Deshayes' illustration, the body whorl is somewhat loosely coiled, but Cossmann and Pissarro's illustration (1910–13, pl. 43, fig. 205 ter-2) shows tighter coiling.

Occurrence: Marine member of Bohio(?) formation (late Eocene), localities 41, 41b.

SCAPHOPODS

Family DENTALIIDAE

Genus Dentalium Linné

Linné, Systema naturae, 10th ed., p. 785, 1758.
Type (logotype, Montfort, Conchyliologie systématique, v. 2, p. 23, 1810): *Dentalium elephantinum* Linné, living, western Pacific Ocean.

The marine member of the Bohio(?) formation at localities 40a and 40d contains fragments of a small species listed as *Dentalium* sp.

Subgenus Dentalium s.s.

Dentalium (Dentalium) armillatum armillatum Toula

Plate 75, figures 15, 24, 25

Dentalium armillatum Toula, K. k. Geol. Reichsanstalt Jahrb., v. 61, p. 496, pl. 31, figs. 8a, 8b, 1911 (Miocene, Canal Zone).

Of medium size, slender, slightly curved. Apical part hexagonal, the six ribs narrow and sharply sculptured. A secondary rib appearing in each interspace short distance from apical end. At later stage more secondary ribs added and cross section becoming circular. Eventually as many as 12 secondary ribs in each original interspace, and primary ribs reduced to their strength. Entire sculpture reduced on anterior part of fragments that have greatest diameter. Apical orifice simple.

Length (incomplete at both ends) 40.4 mm, anterior diameter 3.9 mm, apical diameter 1.6 mm (figured specimen).

Type: Technische Hockschule, Vienna.

Type locality: Gatun Locks excavation, Canal Zone, middle part of Gatun formation.

Dentalium armillatum armillatum is the only abundant and widespread *Dentalium* in the Gatun formation. No specimen is entirely complete; that illustrated is the largest. Most of the collections consist of fragments, chiefly apical fragments. Indeed, five collections (locs. 138c, 139b, 147g, 147h, 147i) consist only of apical fragments at a stage before secondary ribs are introduced. Such fragments are indistinguishable from immature fragments of *D. cossmannianum* Pilsbry and Sharp (1898, p. 467, pl. 10, fig. 11, pl. 11, figs. 10, 11; Middle Miocene, Dominican Republic, Jamaica), which lacks secondary ribs at any growth stage. Fragments from locality 161 have only a few weak secondary ribs, and both primary and secondary ribs are subdued on anterior fragments, but are discernible. Five of 29 small fragments collected at locality 139b have faint to distinct, fine annular sculpture.

This *Dentalium* is larger than *D. equisetum* Olsson (1964, p. 203, pl. 38, figs. 8, 8a-c; Esmeraldas formation, Ecuador) and has stronger sculpture.

D. armillatum armillatum occurs in the *Globorotalia fohsi* zone of the Brasso formation of Trinidad (USGS 21230, 21234).

Occurrence: Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, localities 138c, 138e. Middle part, eastern area, localities 139b, 139c, 139d, 139e, 139f, 139g, 147b, 147c, 147g, 147h, 147i, 150a, 158; western area localities 161, 161a, 162a, 169. Upper part, eastern area, localities 172, 176a, 177, 177b. Middle Miocene part of Brasso formation, Trinidad.

Dentalium (Dentalium) armillatum proterum Woodring, n. subsp.

Plate 71, figures 8, 17

Secondary ribs fewer and weaker than those of nominate subspecies. Both primary and secondary ribs indistinct on anterior part of shell or disappearing there.

Length (incomplete at both ends) 40.2 mm, anterior diameter 3.5 mm, apical diameter 1.3 mm (type).

Type: USNM 646697.

Type locality: 54h (USGS 18841, Barro Colorado Island, western part of island, mouth of first stream north of Zetek House, Canal Zone), Caimito formation.

This subspecies occurs in the moderately deep-water facies of the Caimito formation on Barro Colorado Island, where five fairly complete shells and 19 fragments were collected. The weakly sculptured fragments from the middle part of the Gatun formation at locality 161, already mentioned, are intermediate between typical forms of the two subspecies.

D. armillatum proterum is the earliest hexagonal *Dentalium* s.s. from the American mainland. According to Guppy's locality data ("*Nucula* beds, Naparima"), he found an earlier species in the early Oligocene part of the Cipero formation of Trinidad. It was identified by Dall (in Guppy and Dall, 1896, p. 325) as his *D. gouldii*, but is not that living species.

Occurrence: Caimito formation (late Oligocene), localities 54h, 54k.

Dentalium (Dentalium) bothrum Woodring, n. sp.

Plate 75, figures 14, 23

Large, slightly curved, inflated, rapidly enlarging, strongly ribbed. Apex missing. Earliest preserved part sculptured with eight high ribs. Base of ribs pinched, crest rounded; interspaces strongly concave. Later a rapidly strengthened secondary rib appearing in each interspace. Still later a minor tertiary rib in some interspaces. Total of about 28 ribs on incomplete fragment, diameter 9 mm. Microscopic axial and annular threads on unworn parts of shell.

Length (incomplete at both ends) 39.5 mm (estimated restored length 65 mm), anterior diameter 8.2 mm, apical diameter 3.6 mm.

Type: USNM 646730.

Type locality: 179 (USGS 8413, Upper edge of Chilas [Chila] village, Río Indios [Indio], Colón Province, Panamá), upper part of Gatun formation.

The type, and a fragment of slightly greater diameter, of this rapidly enlarging, strongly ribbed species were found in the upper part of the Gatun formation in the western area, west of the Canal Zone. The micro-

scopic sculpture is not preserved on slightly worn parts of the shell.

The rapidly enlarging, strongly ribbed shell recalls the western Pacific *Dentalium elephantinum* Linné, the type of the genus. *D. laqueatum invalidum* Emerson (1954, p. 184; new name for *D. laqueatum regulare* Henderson, 1920, p. 26, pl. 1, fig. 8; living, West Indies; not *D. regulare* Ahlburg, 1906), which is more slender than *D. bothrum* and has more ribs, is the most similar American form.

Occurrence: Upper part of Gatun formation (middle Miocene), western area, locality 179.

Subgenus Tesseracme Pilsbry and Sharp

Pilsbry and Sharp, Manual of conchology, v. 17, p. 249, 1898.

Type (logotype, Woodring, Carnegie Inst. Washington Pub. 366, p. 199, 1925): *Dentalium quadrapicale* Sowerby, living, western Pacific Ocean.

Tesseracme is a paciphile subgenus that survived until Pliocene time in Florida. (For a definition of the term paciphile see p. 322).

Dentalium (Tesseracme) dissimile Guppy

Plate 75, figures 12, 13

Dentalium dissimile Guppy, Geol. Soc. London Quart. Jour., v. 22, p. 292, pl. 17, fig. 4, 1866 (Miocene, Jamaica). Gabb, Am. Philos. Soc. Trans., n. ser., v. 15, p. 244, 1873 (Miocene, Dominican Republic). Pilsbry and Sharp, Acad. Nat. Sci. Philadelphia Proc., v. 49 (1897), p. 469, pl. 11, figs. 3–5, 1898 (Miocene, Dominican Republic). Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 158, pl. 26, fig. 1, 1917 (Miocene, Dominican Republic). Pilsbry, Acad. Nat. Sci. Philadelphia, v. 73, p. 400, 1922 (Miocene, Dominican Republic).

Dentalium (Tesseracme) dissimile Guppy, Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 63, p. 166, 1911 (Miocene Jamaica).

Dentalium (Tesseracme) dissimile dissimile Guppy, Woodring, Carnegie Inst. Washington Pub. 366, p. 199, pl. 27, figs. 9–14, 1925 (Miocene, Jamaica).

Apical fragment quadrangular. Edges sharply raised. Faces smooth.

Length (incomplete at anterior end) 4 mm, anterior diameter 0.9 mm, apical diameter 0.6 mm (figured specimen).

Type: British Mus. (Nat. History) 64082.

Type locality: Bowden, Jamaica, Bowden formation.

A small apical fragment is the only specimen of this Miocene Caribbean species. It represents a stage before the appearance of secondary ribs and the assumption of a circular cross section. The length of a large Bowden shell is 51 mm and the smallest apical diameter of fragments 0.4 mm. An exceptionally large specimen from the Gurabo formation (USGS 8519) has a length of 73.5 mm, and the extreme apical part is missing.

Dentalium dissimile has been described and illustrated adequately by Pilsbry and Sharp, and Woodring. It first appeared in early Miocene time, was fairly widely distributed in middle Miocene, and probably continued until late Miocene.

The shell of *Dentalium ponderosum* Gabb (Pilsbry and Sharp, 1898, p. 470, pl. 10, figs. 1–3, p. 11, figs. 15, 16; Woodring, 1925, p. 200, pl. 27, figs. 15–17) is exceptionally thick, even thicker than the diameter of the orifice. It is associated with *D. dissimile* in the Bowden, Cercado, and Gurabo formations, and there are gradations between them. It is better treated as an infrasubspecific form of *D. dissimile* than as a variety or subspecies, as has been done.

Occurrence: Lower part of Gatun formation (middle Miocene), locality 137. Thomonde formation (early Miocene), Haiti (USGS 9907, 9945, 9946, 9782). Cercado and Gurabo formations (middle Miocene), Dominican Republic. Bowden formation (middle Miocene), Jamaica. Middle Miocene, southeastern Costa Rica (USGS 5882a, 5882b, 8343). Limón formation (late Miocene), Bocas del Toro area, Panamá (USGS 8496, identification doubtful).

Subgenus Fissidentalium Fischer

Fischer, Manuel de conchyliologie, p. 894, 1885.

Type (monotype): *Dentalium ergasticum* Fischer, living, eastern Atlantic Ocean.

The scaphopods of the subgenus *Fissidentalium* live mainly in deep water. They are found in the three formations under consideration that include moderately deep-water deposits: the Caimito and La Boca formations and the Chagres sandstone.

Dentalium (Fissidentalium) uscarianum Olsson

Plate 71, figures 6, 7, 16

Dentalium uscarianum Olsson, Bull. Am. Palentology, v. 9, no. 39, p. 166, pl. 15, fig. 1, 1922, assigned to subgenus *Fissidentalium* (Miocene, Costa Rica).

Large, moderately slender, slightly curved, strongly sculptured with high, rounded ribs. Apex hexagonal. Short distance from apex a rib appearing in each interspace. Other ribs added at later stages and cross section becoming circular. Total number of ribs on Caimito shells 20 to 26, usually 23, not including a few minor ribs. Apical orifice simple.

Length (incomplete at both ends) 52 mm, anterior diameter 7.3 mm, apical diameter 2.7 mm (larger figured specimen).

Type: Paleontological Research Inst. 21115.

Type locality: Río Cocles, Limón Province, Costa Rica, Uscari formation.

A *Fissidentalium*, identified as *Dentalium uscarianum*, is widespread in the moderately deep-water facies of the Caimito formation on Barro Colorado Island. It is abundant at locality 54k. The collection from that locality consists of some 30 fairly complete shells and

about 100 fragments of varying size. In addition, scores of the smallest fragments were discarded. The anterior fragment of greatest diameter (loc. 54l) is distorted by slight crushing and therefore has an oval outline. The diameter is 9.7 to 10.7 mm and the number of ribs is 23. If this shell were complete, its length would be about 100 mm. At a diameter of 0.7 to 0.9 mm the apical orifice is simple.

The type of *D. uscarianum* (anterior diameter 12 mm), is a fragment of a specimen larger than any Canal Zone specimen, and the sculpture is subdued on the anterior part. The apical sculpture of Uscari specimens is unknown.

Thirty fragments or poorly preserved specimens from the La Boca formation also are identified as *D. uscarianum*. The greatest diameter of those that clearly show ribs is about 6 mm. None has more than 15 widely spaced ribs. A fragment from the type region of *D. uscarianum* (USGS 8042) is sculptured with 15 ribs at the same diameter.

As noted by Olsson, the ribbing is similar to that of *D. floridense* Henderson (1920, p. 64, pl. 10, figs. 1, 2, 6, 7; living, southern Florida, Barbados, 35 to 110 fathoms). The ribs of that species are somewhat lower, and the apex bears a long, narrow slit on the convex side.

Occurrence: Caimito formation (late Oligocene) localities 54g, 54h, 54j, 54k, 54l, 54m. La Boca formation (early Miocene), localities 99b, 101h, 101i, 119. Early Miocene part of Uscari formation, Costa Rica.

Dentalium (Fissidentalium) granadanum esmeraldum Olsson

Plate 75, figures 32–34

Dentalium (*Fissidentalium*) *esmeraldum* Olsson, Bull. Am. Paleontology, v. 27, no. 106, p. 80, pl. 6, figs. 1, 2, 10, 1942 (Oligocene [Miocene], Ecuador, Olsson, Neogene mollusks from northwestern Ecuador, Paleontological Research Inst., p. 204, pl. 37, fig. 13, pl. 38, fig. 9, 1964 (Miocene, Ecuador).

Large, moderately slender, slightly curved, thick-shelled, sculptured with narrow, low, closely spaced ribs. Apex missing. Earliest preserved part sculptured with 20 main and several minor ribs. Thirty main and some minor ribs at diameter of 10 mm. Ribs gradually suppressed at diameter of about 10 to 12 mm. Microscopic axial and annular threads on unworn parts of shell.

Length (incomplete at both ends) 72 mm, anterior diameter 10.3 mm, apical diameter 3.2 mm (large figured specimen).

Type: Paleontological Research Inst. 4069.

Type locality; Punta Gorda, Esmeraldas Province, Ecuador, Esmeraldas formation.

The Chagres sandstone yielded two incomplete shells and six fragments of this Ecuadoran species. The apical part of the larger illustrated shell (pl. 75, fig. 33) is badly worn and the remainder somewhat worn, as is the type. The sculpture is shown to better advantage by the smaller illustrated shell (pl. 75, fig. 32).

As noted by Olsson (1942, p. 81), large shells of the nominate subspecies (Anderson, 1929, p. 144, pl. 13, fig. 3; Las Perdices shale, Colombia) retain their sculpture to the anterior end. The nominate subspecies is interpreted as a predecessor of the late Miocene form.

Occurrence: Chagres sandstone (late Miocene), localities 206, 208. Esmeraldas formation (late Miocene), Ecuador.

Subgenus Graptacme Pilsbry and Sharp

Pilsbry and Sharp, Manual of conchology, v. 17, p. 85, 1897.
Type (logotype, Woodring, Carnegie Inst. Washington Pub. 366, p. 201, 1925): *Dentalium eboreum* Conrad, living, North Carolina to West Indies.

Dentalium (Graptacme) species

A minute fragment (length 3 mm, anterior diameter 0.8 mm, apical diameter 0.5 mm), which was broken in half in handling, is the only specimen of *Graptacme*. The sculptured stage is exceptionally restricted; only the posterior half bears fine, faint axial threads. A relatively wide, shallow apical notch may be a real notch or a break.

Occurrence: Middle part of Gatun formation (middle Miocene), locality 170a.

Subgenus Rhabdus Pilsbry and Sharp?

Pilsbry and Sharp, Manual of conchology, v. 17, p. 112, 1897.
Type (orthotype): *Dentalium rectius* Carpenter, living, British Columbia to California.

Dentalium (Rhabdus?) species

Plate 75, figure 28

Apical fragments distinctly curved, enlarging in diameter at moderately rapid rate. Sculptured with annular rings, oblique to axis of shell, closely spaced or more widely spaced. Apical orifice simple.

Length (incomplete at anterior end, not quite complete at apical end) 3.2 mm, anterior diameter 0.8 mm, apical diameter 0.3 mm (figured specimen).

Six minute apical fragments of this annulated *Dentalium* were found in the Gatun formation. The relatively strong sculpture, which is unique in American fossil and living species, probably is apical only, as it is subdued near the anterior end of the largest fragments. The apical diameter of some of the fragments is smaller than that of the illustrated specimen.

Omniglypta (Kuroda and Habe, in Habe, 1953, p. 296; type (orthotype): *Dentalium cerinum* Pilsbry, living, Japan) has been proposed for an annulated western Pacific species. It is unlikely, however, that the presumably small Caribbean species is related to the moderately large, slender western Pacific species.

Occurrence: Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, locality 153a. Upper part, western area, locality 185.

Subgenus Laevidentalium Cossmann

Cossmann, Soc. Roy. Malacologique Belgique Annales, v. 23, p. 7, 1888 (pt. 3, p. 11 of separate publication, 1888).

Type (orthotype): *Dentalium incertum* Deshayes, lower and middle Eocene, Paris basin.

The marine member of the Bohio(?) formation (loc. 41b) and the Bohio formation itself (loc. 42d) contain smooth fragments indicating species having an estimated restored length of about 40 and 30 mm, respectively. The apical parts are missing. They are listed as *Dentalium* (*Laevidentalium*?) sp. It is improbable that they represent the same species, as the Bohio fragments are slightly compressed laterally.

Dentalium (Laevidentalium) pyrum Pilsbry and Sharp

Plate 75, figures 5, 16, 31

Dentalium pyrum Pilsbry and Sharp, Acad. Nat. Sci. Philadelphia Proc., v. 49 (1897), p. 472, pl. 11, figs. 6, 7, 1898 (Miocene, Dominican Republic).

Small, slender, slightly curved. Apical part circular, remainder slightly compressed laterally. Surface smooth, polished. Faint growth lines, slightly oblique to axis, showing through polished surface of some specimens. Apical orifice bearing a sheath; a narrow slit extending from sheath down into outer shell wall.

Length (incomplete at both ends) 13.6 mm, anterior diameter 2.1 by 2.4 mm, apical diameter 1.6 mm (larger figured specimen).

Type: Acad. Nat. Sci. Philadelphia 2714.

Type locality: Dominican Republic, Miocene.

Dentalium pyrum is known only by fragments wherever it has been found. It is characterized by its slightly flattened outline and apical sheath and slit. The largest of eight Gatun fragments, and also an apical fragment showing a perfectly preserved sheath and slit, are illustrated (pl. 75, figs. 5, 16, pl. 75, fig. 31, respectively). The slit is longer on another specimen that has a preserved apex (locality 161c). Apical features of the type shown by both are found in some species of the subgenera *Antalis*, *Fissidentalium*, and *Graptacme*, but those species are ribbed throughout, or ribbed in the apical part.

Very small, circular apical fragments from localities 138f and 173 are listed as *D.* (*Laevidentalium*) sp. They may represent *D. pyrum* or *D. haytense* Gabb (Pilsbry and Sharp, 1898, p. 471, pl. 11, figs. 8, 9; Woodring, 1925, p. 202, pl. 27, figs. 18–20; middle Miocene, Dominican Republic and Jamaica, respectively), which is circular, or practically circular, throughout and has a simple apical orifice.

The age range of *D. pyrum* is late early to middle Miocene.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, locality 138f (*D.* (*Laevidentalium*) sp.); middle part, western area, localities 161, 161c, 162, 162a, 170a (identification doubtful); upper part, eastern area, locality 173 (*D.* (*Laevidentalium*) sp.). Thomonde formation (early Miocene), Haiti (USGS 9945 (identification doubtful), 9946). Cercado formation (middle Miocene), Dominican Republic (USGS 8737).

Subgenus Episiphon Pilsbry and Sharp

Pilsbry and Sharp, Manual of conchology, v. 17, p. 117, 1897.

Type (logotype, Suter, Manual of the New Zealand Mollusca, p. 821, 1913): *Dentalium sowerbyi* Guilding, living, North Carolina to West Indies.

Dentalium (Episiphon) innumerabile elassum Woodring, n. subsp.

Plate 75, figure 26

Very small, very slender, barely increasing in diameter, barely curved, needle-like. Slightly compressed laterally, smooth. Base of broken pipe at apical orifice of type.

Length 5.5 mm, anterior diameter 0.6 mm, apical diameter outside pipe 0.4 mm (type).

Type: USNM 646738.

Type locality: 146 (USGS 5845, Quebrancha Hills overlooking Gatun Lake, 1.5 miles (2.4 km) northeast [east-southeast] of Gatun, Canal Zone), middle part of Gatun formation.

The type and a slightly larger specimen (length 6 mm) of this small, excessively slender, needle-like *Episiphon* are from the Gatun formation. In outline it closely resembles the nominate subspecies (Pilsbry and Sharp (1897–98, p. 119, pl. 18, figs. 6–8, 1897; living, Baja California to Panamá Bay), but is a third as large and more thick-shelled. As implied by the name, great numbers of the nominate subspecies were dredged by the *Albatross* not only in Panamá Bay, where the type lot was dredged, but also off La Paz, Baja California.

A larger and more curved, needle-like species from the middle Miocene strata on Río Banano, in southeastern Costa Rica (USGS 5882i), has fine, microscopic, closely spaced annular rings throughout its length. It is closely allied to *Dentalium sowerbyi* Guilding (Henderson, 1920, p. 77, pl. 13, figs. 2, 3, 10), the type of *Episiphon*.

Occurrence: Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, locality 146; upper part, western area, locality 185.

Family SIPHONODENTALIIDAE

Genus Cadulus Philippi

Philippi, Enumeratio molluscorum Siciliae, v. 2, p. 209, 1844.
Type (monotype): *Dentalium ovulum* Philippi, living, Mediterranean Sea and eastern Atlantic Ocean.

Subgenus?

Cadulus species

Small, moderately slender, slightly curved. Almost imperceptibly inflated at about a third of distance from broken anterior end. Apical end broken.

Length (broken at both ends) 5.1 mm, maximum diameter 0.8 mm, anterior diameter 0.7 mm, apical diameter 0.4 mm.

The affinities of this incomplete *Cadulus* from the Bohio formation of Barro Colorado Island are indeterminable.

Occurrence: Bohio formation (late Oligocene), locality 42d.

Subgenus Gadilopsis Woodring

Woodring, Carnegie Inst. Washington Pub. 366, p. 206, 1925.
Type (orthotype): *Ditrupa dentalina* Guppy, Miocene, Jamaica.

Proposal of *Gadilopsis* was inspired by Pilsbry's treatment in his classic publication on scaphopods, prepared in collaboration with Sharp. It is a formal name for the "group of *Cadulus dentalinus*" (Pilsbry and Sharp, 1897–98, p. 188, 1898). In simple apical orifice *Gadilopsis* resembles the subgenus *Gadila*, but the shell outline is different: needle-like, very slender, and the greatest inflation is close to the aperture. As noted by Pilsbry, his group includes species that are smooth, like *Gadila*, and species that are sculptured with fine annular rings [on the posterior part]. It may be added that the type species of *Gadilopsis* is sculptured or smooth. It would have been better to designate a living species as the type instead of a fossil species. Emerson (1962, p. 478; 1971, p. 79) rejected *Gadilopsis* as a synonym of *Gadila*.

Cadulus (Gadilopsis) dolichus Woodring, n. sp.

Plate 70, figure 7

Large for the subgenus, slender, slightly curved, very slowly enlarging in diameter. Greatest diameter close to aperture, which is oblique to axis of shell. Surface smooth and polished. Microscopic, closely and regularly spaced growth lines parallel to oblique aperture. Irregularly outlined, faintly colored, alternating light and dark bands parallel to aperture on one specimen. Apical orifice simple, at least at diameter of 0.6 mm.

Length 11.8 mm, maximum diameter 1.2 mm, apertural diameter 0.9 mm, apical diameter 0.6 mm (type).

Type: USNM 646689.

Type locality: 41b (USGS 18839, East side of Palenquilla Point, head of cove north of triangulation station and southwest of Corozo Island, Canal Zone), marine member of Bohio(?) formation.

Cadulus dolichus, from the marine member of the Bohio(?) formation at Palenquilla Point, is large, but not as large as the more slender and more strongly curved *C. elegantissimus* Pilsbry and Sharp (1898, p. 473, pl. 11, figs. 28–30; middle Miocene, Dominican Republic), which reaches a length of 14 mm. The type is complete, or practically complete. So is a slightly smaller specimen, broken in handling, that shows faint color bands. A still smaller specimen and two fragments also are available. Though all these shells were encased in hard calcareous sandstone and are replaced by calcite, their surface is exceptionally well preserved.

Occurrence: Marine member of Bohio(?) formation (late Eocene), locality 41b.

Cadulus (Gadilopsis) species

Very small, very slender, slightly curved. Greatest diameter at slight inflation near aperture. Faint traces of what may be annular rings on apical part of some specimens. Apical orifice simple.

Length 4.5 mm, greatest diameter 0.7 mm, apertural diameter 0.5 mm, apical diameter 0.2 mm.

Six specimens of a small *Cadulus* were found in the marine member of the Bohio(?) formation on Trinidad Island. Most of the replaced shell material is corroded. This species is left unnamed, as these fossils are poorly preserved. It is a likely predecessor of the late Tertiary and living species of *Gadilopsis*, which are equally slender, but are larger and more inflated near the aperture.

This species and *C. dolichus* are the earliest known species of *Gadilopsis*.

Occurrence: Marine member of Bohio(?) formation (late Eocene), locality 42.

Cadulus (Gadilopsis) dentalinus (Guppy)

Plate 75, figures 10, 11

Ditrupa dentalina Guppy, Sci. Assoc. Trinidad Proc., v. 2, no. 2, p. 87, 1867 (Miocene, Jamaica); reprint, Bull. American Paleontology, v. 8, no. 35, p. 71, 1921, Guppy, Geol. Magazine, decade 2, v. 1, p. 445, pl. 16, fig. 11 (an unrecognizable illustration), 1874. Guppy, Geol. Magazine, decade 2, v. 2, p. 42, 1875 (Miocene, Jamaica). Guppy, Geol. Soc. London Quart. Jour., v. 32, p. 532, 1876 (Miocene, Dominican Republic).

Cadulus dentalinus (Guppy), Pilsbry and Sharp, Manual of Conchology, v. 17, p. 190, pl. 36, figs. 21, 22, 1898, assigned to section *Gadila* (Oligocene [Miocene], Jamaica). Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 63, p. 168, 1911 (Oligocene [Miocene], Jamaica).

Cadulus (Gadilopsis) dentalinus (Guppy), Woodring, Carnegie Inst. Washington Pub. 366, p. 206, pl. 28, figs. 2, 3, 1925 (Miocene, Jamaica).

?Cadulus (Gadila) aff. *albicomatus* Dall, Toula, K. k. Geol. Reichsanstalt Jahrb., v. 61, p. 497, pl. 31, fig. 9, 1911 (Miocene, Canal Zone).

Cadulus (Gadila) spiniformis Gardner, U.S. Geol. Survey Prof. Paper 142, p. 630, pl. 62, fig. 19, 1947, assigned to section *Gadilopsis* (Miocene, Florida).

Small, very slender, needle-like, curvature moderate. Greatest inflation near slightly oblique aperture, generally strong, exceptionally moderate. Surface generally smooth. Irregularly spaced, exaggerated growth lines generally present on apical part; exceptionally replaced by weak, closely spaced annular rings. Faint, narrow, brownish bands, parallel to aperture, visible on some shells. Apical orifice simple.

Height 8.4 mm, maximum diameter 1.2 mm, apertural diameter 0.7 mm, apical diameter 0.3 mm (larger figured specimen).

Type material: Lectotype, herewith designated, USNM 115607 (the syntype illustrated by Woodring, see synonymy).

Type locality: Bowden, Jamaica, Bowden formation.

Cadulus dentalinus is widespread in the middle and upper parts of the Gatun formation and is locally abundant in the middle part, especially at locality 147b, where several hundred specimens were collected. A slight range of variation in the degree of slenderness and in the strength of the inflation near the aperture is apparent. Only a few shells, one of which is illustrated (pl. 75, fig. 10), show distinct apical sculpture, whereas on Jamaican shells such sculpture is almost invariably present and extends over a larger part of the shell. *C. spiniformis* closely resembles Gatun shells that lack apical sculpture.

An exceptionally large Jamaican specimen (length 10 mm) was named *C. hendersoni* (Woodring, 1925, p. 207, pl. 28, fig. 4). It should be treated as a form of *C. dentalinus*. Whether it is a subspecies or an infrasubspecific form is indeterminable. The Bowden molluscan fauna is a death assemblage swept up from many environments.

C. dentalinus is closely related to *C. acus* Dall (Henderson, 1920, p. 140, pl. 20, figs. 11, 13; living, southern Florida, western Gulf of Mexico, West Indies) and *C. perpusillus* (Sowerby) (Emerson, 1971), also known as *C. panamensis* Pilsbry and Sharp (1897–98, p. 191, pl. 36, figs. 23–25, 1898; living, Baja California and Gulf of California to Panamá). Both living species are apically sculptured. They run a little smaller than *C. dentalinus*, and *C. acus* is not as strongly inflated near the aperture as the other two.

Occurrence: Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, localities 139b, 139c, 139g, 146, 147b, 147f, 147g, 147h, 151, 155, 159d; western area, localities 161, 169. Upper part, eastern area, localities 172, 173a, 175, 177b; western area, locality 183. Bowden formation (middle Miocene), Jamaica. (Gurabo formation (middle Miocene), Dominican Republic (USGS 8714). Shoal River formation (middle Miocene), Florida.

Subgenus Platyschides Henderson

Henderson, U.S. Natl. Mus. Bull. 111, p. 104, 1920.

Type (orthotype): *Cadulus grandis* Verrill, living, Massachusetts to North Carolina.

Cadulus (Platyschides) epetrion Woodring, n. sp.

Plate 75, figures 1, 2

Small, slender, slightly curved. *Gadilopsis*-like in outline, greatest diameter at slight inflation near slightly oblique aperture. Surface smooth; faintly colored, alternating light and dark bands parallel to aperture on some specimens. Apex cut by four narrow, shallow notches.

Length 8 mm, maximum diameter 1.3 mm, apertural diameter 1 mm, apical diameter 0.4 mm (type).

Type: USNM 646741; paratype USNM 646732.

Type locality: 139c (USGS 22018, East side of road leading from Transisthmian Highway to refinery site on Payardi Island, Panamá; about 100 meters southwest of refinery gate), middle part of Gatun formation.

Cadulus epetrion is widespread and locally abundant in the lower part of the Gatun formation and in strata near the base of the middle part, but was found at higher horizons at only three localities.

Were it not for the apertural features, this species would be assigned to the subgenus *Gadilopsis*. The paratype (pl. 75, fig. 2) and six other shells, among hundreds, show the apical notches, or at least some of them, but many others have ragged apical edges. *C. annulatus* Pilsbry (1911, p. 168; Woodring, 1925, p. 207, pl. 28, figs. 5, 6; middle Miocene, Jamaica), incorrectly assigned to *Polyschides* in 1925, has a less pronounced inflation near the aperture and is sculptured with very fine annular rings.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, localities 136a, 137, 138, 138a, 138b, 138c, 138d, 138e, 138f. Middle part, eastern area, localities 139b, 139c, 139d, 139e, 139f, 139g, 155c. Upper part, eastern area, localities 177b, 178.

Cadulus (Platyschides) bushii Dall

Plate 75, figures 3, 4

Cadulus (carolinensis var.?) *bushii* Dall, Harvard Coll., Mus. Comp. Zoology Bull., v. 18, p. 430, 1889 (living, Barbados).

Cadulus carolinensis bushii Dall, Pilsbry and Sharp, Manual of conchology, v. 17, p. 153, pl. 33, fig. 59, 1898, assigned to subgenus *Polyschides* (living, Barbados).

Cadulus (Platyschides) bushii Dall, Henderson, U. S. Natl. Mus. Bull. 111, p. 125, pl. 19, fig. 10, 1920 (living, Barbados).

Small, moderately curved, moderately inflated, greatest inflation at about anterior third. Apex slightly com-

pressed dorsoventrally. Surface smooth, polished. Apex cut by four narrow, shallow notches.

Length 7 mm, maximum diameter 1.2 mm, apertural diameter 0.8 mm, apical diameter 0.4 mm (slender illustrated specimen).

Type: USNM 95376.

Type locality: Barbados, living.

Though it was not found in the lower part of the Gatun formation, *Cadulus bushii* is widespread in the middle part and in the upper part in the eastern area. It was abundant in the construction-period fresh cuts on the Panama Railroad southeast of Gatun. Like *C. dentalinus*, several hundred specimens are in the collection from locality 147b. Six specimens from various localities show some, or all, of the apical notches.

Slight variation, shown by the illustrations, affects the degree of inflation. The slender form (pl. 75, fig. 3) closely resembles the type and other USNM species from the type region, dredged at depths of 35 to 100 fathoms.

Occurrence: Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, localities 139b, 146, 147b, 147f, 147g, 147h, 151, 153, 153a, 155; western area, localities 161, 161c, 169, 170a. Upper part, eastern area, localities 163, 175, 177, 177c. Living, Barbados.

PELECYPODS

Family NUCULIDAE

Genus Nucula Lamarck

Lamarck, Soc. Histoire Nat. Paris Mém., p. 87, 1799.

Type (monotype): *Arca nucleus* Linné, living, eastern North Atlantic Ocean and Mediterranean Sea.

The representation of this ubiquitous genus is meager.

Subgenus Nucula s.s.

Nucula (Nucula) cf. N. spheniopsis Conrad

Plate 70, figures 11, 12

Small, trigonal, short, high, decidedly inequilateral. Sculpture consisting of narrow crowded concentric rugae, faintly undulated by indistinct radial threads. Hinge defective. Inner ventral margin crenulate.

Length 4.3 mm, height 4 mm, approximate diameter 2 mm (larger figured specimen).

The moderately deep-water facies of the Caimito formation on Barro Colorado Island yielded four specimens of this small, trigonal *Nucula*. The larger illustrated specimen shows the outline, but the outer shell layer is missing. The exterior is shown by the smaller illustrated shell, the smallest in the lot, although it is not entirely free of sandy matrix.

The outline and sculpture suggest alliance to a larger species (length 6.5 mm) that occurs in the early Oligocene Red Bluff clay of Mississippi. Red Bluff specimens in the Aldrich collection were identified by him as *N. spheniopsis* Conrad (Harris, in Harris and Palmer, 1946–47, p. 63, pl. 14, figs. 24–30, 1946). Though the outline of that late Eocene species is variable, the Caimito and Red Bluff fossils are less inequilateral.

Occurrence: Caimito formation (late Oligocene), localities 54h, 54n.

Nucula (Nucula) cf. N. cahuitensis Olsson

Plate 75, figure 9

Minute, elongate, moderately inequilateral. Sculpture of main part of shell consisting of narrow, crowded rugae, minutely reticulated by radial riblets, which are indistinct in spaces between rugae. Anterior dorsal part set off by abrupt change in sculpture: rugae wider and fewer than on main part of shell, perpendicular to dorsal margin. Similar, but more crowded, rugae on depressed posterior dorsal part. Thirteen anterior teeth and five posterior. Ventral margin not preserved.

Length 1.7 mm, height (incomplete) 1.2 mm, diameter 0.4 mm (figured specimen).

The illustrated minute right valve, nicked along the ventral margin, is the only *Nucula* from the middle part of the Gatun formation. It is more elongate than the middle Miocene Costa Rican *N. cahuitensis* (Olsson, 1922, p. 171, pl. 18, figs. 21–24), which has a subtrigonal outline. Like the species, the Gatun fossil has strongly discrepant dorsal sculpture. In that respect both species, as pointed out by Olsson for *N. cahuitensis*, are similar to the larger living eastern Pacific *N. exigua* Sowerby (Olsson, 1961, p. 56, pl. 1, figs. 2, 2a, 2b, 10, 10a). *N. vieta* Guppy (June, 1969, p. 316, pl. 13, figs. 4–7; Matura formation, Trinidad) and the probably synonymous *N. venezuelana* Weisbord (1964, p. 36, pl. 1, figs. 1–6; Mare and Playa Grande formations, Venezuela), both of early Pliocene age, are the last allies of *N. exigua* in the present Caribbean region.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, locality 139c.

Nucula (Nucula) tenuisculpta Gabb

Plate 75, figure 8

Nucula tenuisculpta Gabb, Am. Philos. Soc. Trans., n. ser., v. 15, p. 255, 1873 (Miocene, Dominican Republic). Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 161, pl. 26, fig. 8, 1917 (Miocene, Dominican Republic). Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 73, p. 401, pl. 38, fig. 6, 1922 (Miocene, Dominican Republic). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 172, pl. 18, fig. 25, 1922 (Miocene, Costa Rica).

Very small, height a little less than length, very inequilateral. Microscopic radial sculpture (really hidden sculpture) very faint, not affecting surface profile, absent on parts of shell. Concentric sculpture limited to a few exaggerated growth lines. Eleven teeth in an-

terior series and six in posterior. Inner ventral margin crenulate.

Length 3 mm, height 2.7 mm, diameter 0.8 mm (figured specimen).

Type: Acad. Nat. Sci. Philadelphia 2656.

Type locality: Dominican Republic, Miocene.

Three valves and a paired shell of a very small faintly sculptured *Nucula*, from the upper part of the Gatun formation in the eastern area, are identified as *N. tenuisculpta*. The illustrated right valve is the only one that is undamaged, aside from a slight posterior nick.

In the Dominican Republic *N. tenuisculpta* is abundant in the Cercado formation at USGS locality 8525. The sculpture is variable. Some shells are practically smooth, although at least some hidden microscopic radial sculpture is apparent. Concentric sculpture is irregular or absent. Both sets of sculpture are exaggerated in Pilsbry's drawing. No specimen in USNM collections is as large as the type (length 3.3 mm). The Gatun fossils are slightly more inequilateral than those from the Dominican Republic. A valve from the middle Miocene deposits in southeastern Costa Rica (USGS 5882g), like that from the same area illustrated by Olsson, has very faint hidden sculpture on part of the shell.

Occurrence: Upper part of Gatun formation (middle Miocene), eastern area, localities 177b, 177c. Cercado formation (middle Miocene), Dominican Republic. Middle Miocene deposits, southeastern Costa Rica.

Genus Ennucula Iredale

Iredale, Australian Mus. Records, v. 18, p. 202, 1931.

Type (orthotype, p. 231): *Nucula obliqua* Lamarck, living, Australia.

The type of the type species was illustrated by Schenck (1934, p. 37, pl. 3, figs. 4a, 4b).

Subgenus Lissanucula Woodring, n. name

Nuculopsis Woodring, Carnegie Inst. Washington Pub. 366, p. 14, 1925. Not *Nuculopsis* Girty, 1911, or Rollier, 1912.

Type (orthotype): *Nucula* (*Nuculopsis*) *hilli* Woodring, Miocene, Jamaica.

Of medium size, ovate, moderately inequilateral. Dorsal areas not depressed. Sculpture consisting of strong, closely spaced concentric rugae. Chondrophore moderately long, narrowly spoon-shaped, its axis slightly oblique to anterior tooth series. Inner ventral margin smooth.

Inasmuch as no records of any nuculids closely related to *Nucula hilli* have been found, it seems appropriate to propose a substitute name for *Nuculopsis*, a junior homonym on two counts, although no allies of that species are represented in the Panamá faunas. Since it was first photographed, the type of *N. hilli* was damaged and repaired at some unknown time. The repairing is satisfactory, except that the distal end of the chondrophore is missing.

As emphasized by Van de Poel (1955), the nuculids that have a smooth inner ventral margin differ in shell structure from those that have a crenulate margin. On that basis he classified the nuculids, aside from *Acila*, under two genera, *Nucula* and *Nuculoma*, and grouped other named taxa as subgenera. (*Nuculoma* Cossmann, 1907, is the oldest name for the smooth group. For citation, description, and illustrations of *Nuculoma* and other forms that have a smooth inner ventral margin, see Schenck, 1934, p. 26–41).

Lissanucula is most similar to *Ennucula*. The type of *Ennucula*, however, lacks concentric sculpture other than growth lines; the posterior dorsal part is depressed; and the chondrophore is longer, slightly increasing in diameter, and its axis is not as oblique to the anterior tooth series.

Hertlein and Strong (1940, p. 383–384) speculated as to whether *Nucolopsis* or *Nuculopsis* was intended in 1925, although the question could have been resolved unequivocally by an appeal to the author of the name. In the main heading the spelling is *Nucolopsis*, but in the species heading and discussions it is *Nuculopsis*. They settled for *Nucolopsis*, which in the original account was an unfortunate typographic error.

Nucula (*Nucolopsis*) *schencki* Hertlein and Strong (1940, p. 384, pl. 1, figs. 8–10; living, Port Guatulco, Oaxaca, México) is not related to *N. hilli*. It is a minute species, or immature specimen, of *Nucula* s.s.

Genus Acila H. and A. Adams

H. and A. Adams, The genera of Recent Mollusca, v. 2, p. 545, 1858.

Type (logotype, Stoliczka, India Geol. Survey Mem., Palaeontologia Indica, Cretaceous fauna of southern India, v. 3, p. XXI, 1870, p. 325, 1871): *Nucula divaricata* Hinds, living, western Pacific Ocean.

Two poorly preserved fossils from the Culebra formation are listed as *Acila* sp.

Subgenus Acila s.s.

Acila (Acila) isthmica isthmica (Brown and Pilsbry)

Plate 70, figure 4, plate 71, figure 15, plate 76, figures 1–3, 6, plate 82, figure 2

Nucula (*Acila*) *isthmica* Brown and Pilsbry, Acad. Nat. Sci. Philadelphia Proc. v. 63, p. 361, pl. 27, figs. 11, 12, 1911 (Miocene, Canal Zone).

Acila (*Acila*) *isthmica* (Brown and Pilsbry), Schenck, Eclogae Geol. Helvetiae, v. 28, p. 503, 1936 (Miocene, Colombia). Schenck, Geol. Soc. America Spec. Paper 4, p. 87, pl. 13, figs. 1, 3, 5, 6, 1936 (Miocene, Columbia).

Of medium size, asymmetrically trigonal, posterior dorsal area depressed. Posterior end weakly rostrate, sinus setting off rostrum very shallow and extending

only short distance from ventral margin. Primary divarication roughly median, secondary divarication rare. Ribs closely or moderately closely spaced, faintly to distinctly irregularly noded. Ribs on anterior dorsal area fewer and wider than on main part of shell, ending perpendicular to dorsal margin. Similar, but more closely spaced, ribs on depressed posterior dorsal area. Twenty-two to 24 feet in anterior series, 9 to 11 in posterior. Innermost posterior tooth on right or left valve longer than others. Chondrophore wide, short, Inner ventral margin crenulate.

Dimensions: See following table.

Type: Acad. Nat. Sci. Philadelphia 1742. Now lost or misplaced, missing as early as 1964.

Type locality: Gatun Locks excavation, Canal Zone, middle part of Gatun formation.

Occurrence of Acila (Acila) isthmica isthmica *and dimensions in mm of largest specimens*

Age	Formation		Number of specimens	Dimensions of largest specimen	
				Length	Height
Late Miocene	Charges sandstone		11	21.9	17.5
Middle Miocene	Gatun formation	Upper part, western area	39	22.8	18.5
		Upper part, eastern area	4	17.3	13
		Middle part, eastern area	2	18	13
Early Miocene	La Boca formation		22	24	17
Late Oligocene	Caimito formation		10	17	14

As shown by the preceding table, *Acila isthmica isthmica*, which is the only *Acila* s.s. in the present Caribbean region, has an age range of late Oligocene to late Miocene. It presumably has its roots in the Pacific Ocean. *A. isthmica burica* Olsson (1942, p. 25, pl. 1, figs. 2, 6, 8, 9; Charco Azul formation, southwestern Costa Rica) survived later than the nominate subspecies. It is considerably larger than the nominate subspecies (length up to 31.5 mm). In the area under study, however, no relation between size and age in *A. isthmica isthmica* is apparent.

All of the Caimito specimens were collected from the moderately deep-water facies on Barro Colorado Island. That illustrated (pl. 70, fig. 4) does not show the weak rostrum and the accompanying shallow, short sinus, as the extreme posterior end is missing. Much of the shell is missing on the illustrated large La Boca fossil (pl. 71, fig. 15). Though the species was based on two valves from the middle part of the Gatun formation, none is in some 60 collections from that part under study. The ribs on one of 30 shells from the upper part of the Gatun in the western area, shown on pl. 76, figs. 3, 6, are more widely spaced than on others. The discrepant dorsal sculpture duplicates that of *N. cahuitensis* and its allies.

Occurrence: Caimito formation (late Oligocene) localities 54k, 54l, 54m, 54n. La Boca formation (early Miocene), localities 101i, 125, 127, 127b, 128. Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, Gatun Locks excavation (Brown and Pilsbry's record). Upper part, eastern area, localities 171, 173, 177b; western area, localities 179, 183. Chagres sandstone (late Miocene), localities 198, 203, 206, 208. Las Perdices shale (early Miocene), Colombia. Middle Miocene deposits, Darién area, Panamá (USGS 8452, fragments, identification doubtful); southeastern Costa Rica (USGS 5883f); Venezuela (Schenck's record).

Family NUCULANIDAE

Genus Jupiteria Bellardi

Bellardi, Mongrafia delle Nuculidi trovate finora nei terreni terziari del Piemonte e della Liguria, p. 20, Torina, 1875. Type (logotype, Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 4, p. 579, 1898): *Leda concava* (Bronn) (*Nucula concava* Bronn), Miocene and Pliocene, Italy.

The importance of the shape of the chondrophore in classifying nuculanids was emphasized by Stewart (1930, p. 51–55). The chondrophore of *Jupiteria*, and also of *Saccella* (the following genus), is triangular and symmetrical. In addition, the species of *Jupiteria* are small, short, equilateral or moderately inequilateral, more or less corbuloid, bluntly rostrate, and concentrically sculptured, but the sculpture is weak or of moderate strength.

Jupiteria aipeia Woodring, n. sp.

Plate 72, figures 5, 9

Small, high and short to moderately elongate, bluntly rostrate. Dorsal areas very narrow, bearing only growth lines. Both areas set off by change in sculpture, posterior area more depressed than anterior. Concentric rugae moderately strong, closely spaced, uniform where not corroded. Chondrophore and hinge not exposed.

Length 8.6 mm, height 6.2 mm, diameter 3 mm (type).

Type: USNM 646703.

Type locality: 54h (USGS 18841, Barro Colorado Island, western part of island, mouth of first stream north of Zetek House, Canal Zone), Caimito formation.

Thirteen specimens of *Jupiteria aipeia* were found in the moderately deep-water facies of the Caimito formation on Barro Colorado Island. An immature left valve is more elongate than the others (length 7 mm,

height 4.2 mm, locality 54k). The outline is similar to that of the Miocene Italian *J. brocchii* (Bellardi) (Sacco, 1898, p. 57, pl. 12, figs. 6–10), but the sculpture of the Canal Zone species is stronger.

Occurrence: Caimito formation (late Oligocene), localities 54h, 54k.

Jupiteria subtumida (Woodring)?

Plate 75, figures 17, 22

Very small, moderately elongate, moderately inequilateral, bluntly rostrate. Dorsal areas not differentiated. Sculpture consisting of fine, crowded growth lines, slightly exaggerated here and there, and subdued on parts of shell. Chondrophore triangular. About 12 teeth in anterior and posterior series.

Length 3.4 mm, height 2.4 mm, diameter 1.1 mm (figured specimen).

The upper part of the Gatun formation in the Mount Hope area yielded three very small valves of *Jupiteria*, two of which probably were originally paired. They presumably are immature. They have the outline of the Miocene Jamaican *J. subtumida* (Woodring, 1925, p. 19, pl. 1, figs. 13, 14). The umbos of that species show faint traces of fine growth lines. At a later stage mature shells (length 6.5 mm) are coarsely and irregularly sculptured.

In American fossil species of *Jupiteria* have been recognized in Jamaica and the Canal Zone. *Leda solida* Dall (1881, p. 126; on dubious grounds renamed *Leda solidifacta* Dall, 1886, p. 252, pl. 7, figs. 7a, 7b), the sole surviving American species, is larger and more corbuloid than the fossils (length 9.7 mm). It was recognized by Dall as similar to *J. concava*. The type, dredged off Bahía Honda, Cuba, depth 287 fathoms, is the only specimen in USNM collections.

Occurrence: Upper part of Gatun formation (middle Miocene), eastern area, localities 177c, 177d.

Genus Saccella Woodring

Woodring, Carnegie Inst. Washington Pub. 366, p. 15, 1925. Substitute name for *Ledina* Sacco, December, 1898, not *Ledina* Dall, October, 1898.

Type (orthotype of *Ledina* Sacco): *Ledina fragilis* (Chemnitz) (*Arca fragilis* Chemnitz)=*Nucula commutata* Philippi=*Lembulus deltoideus* Risso, living, Mediterranean Sea.

Stewart (1930, p. 55) pointed out that it is unfortunate—in fact, he could have written inexcusable—that "a species having a distinct type specimen was not selected as the type species" for this widespread genus; that is, it is unfortunate that *Saccella* was not proposed as a new subgenus, rather than as a substitute name for *Ledina* Sacco, with a type species that has the above specification. Stewart went to great length in an attempt to fix the earliest available name for *Arca fragilis*, a name that appeared in a publication that is nomenclatorially unavailable. He came to the conclusion that *Lembulus deltoideus* is the earliest name.

The species of *Saccella* are similar to those of *Jupiteria*, but are strongly rostrate and generally are strongly sculptured. Whether *Saccella* is to be treated as a genus or as a subgenus of *Jupiteria* is debatable.

Group of Saccella acuta

The following five species (possibly except the first, which is imperfectly known) are more or less similar to *Saccella acuta* (Conrad) (1831–33, p. 32, unnumbered pl., fig. 3, 1832; Dall, 1886, p. 251, pl. 7, figs. 3a, 3b, 8). Many names have been proposed for nuculanids of the group of *S. acuta*, 20 in the Tertiary Caribbean province alone, ranging in age from Paleocene to Pliocene. All are strongly rostrate, and a sharp ridge limits the rostrum. Those features and the shape of the triangular, symmetrical chondrophore are not repeated in the descriptions.

Poorly preserved fossils from the Culebra and La Boca formations, perhaps not the same species, are listed as *Saccella* sp. (fine sculpture).

Saccella species

The collection from leached sandstone of the Gatuncillo formation capping Cerro Pelado (altitude 223 m), 1 km north-northwest of Gamboa, includes an internal mold of a small right valve of *Saccella*. It is moderately elongate, subequilateral, and rostrate. Impressions of the hinge teeth are preserved. The exterior mold was not recovered.

Length 7.5 mm, height 4 mm.

An incomplete external mold of a larger right valve (estimated restored length 13 mm) in the same collection may possibly represent the same species. It shows concentric rugae, but the posterior part is missing.

Occurrence: Gatuncillo formation (middle(?) Eocene), locality 37a.

Saccella phlyctaena Woodring, n. sp.

Plate 70, figures 8, 15, 16

Moderately small, moderately elongate, moderately inequilateral. Shallow anterior groove present or absent, or represented by faint ridge corresponding to anterior border of groove. Posterior dorsal area moderately wide, sculptured with threads slightly oblique to dorsal margin, fewer than rugae on rostral ridge. Anterior dorsal area very narrow, sharply limited, bearing low, short pustules oblique to dorsal margin, fewer than rugae beyond area. Concentric rugae strong, uniform, spacing of moderate width. Chondrophore and hinge not exposed.

Length 11 mm, height 6.5 mm, diameter 2.4 mm (type).

Type: USNM 646690.

Type locality: 40d (USGS 6028a, Vamos Vamos, lower bed, Canal Zone), marine member of Bohio(?) formation.

Saccella phlyctaena occurs in the three regions where the marine member of the Bohio(?) formation was found. Whether the anterior dorsal area is consistently pustular is not known, as many of the some 40 specimens do not show the area.

Among the species of the group of *S. acuta* in the faunas under study, this late Eocene species is most similar to *S. acuta*, which has been living in western Atlantic waters since Miocene time. The rugae of *S. acuta*, however, are slightly more closely spaced and its anterior dorsal area is not pustular. *S. phlyctaena* evidently is more closely related to the living eastern Pacific *S. acapulcensis* (Pilsbry and Lowe) (Olsson, 1961, p. 65, pl. 2, figs. 8, 8a), which has a pustular anterior dorsal area. The fossils may be distinguished by their slightly finer concentric rugae.

The poorly preserved type of *S. incognita* (Guppy) (1867, p. 501, fig. 1; Eocene, Trinidad)—the only specimen—is small and elongate (length 7.7 mm, height 4.4 mm). Guppy later (1882, p. 172, pl. 7, fig. 9) thought it was *S. packardi* (Forbes) (1848, p. 566, figs. 2, 3; 1848a, p. 348, figs. 2, 3; Eocene, Barbados), which, according to Forbes' illustrations, is short and high.

Occurrence: Marine member of Bohio(?) formation (late Eocene), localities 40, 40d, 40e, 41, 41b, 42, 42c.

Saccella cf. S. subcerata (Woodring)

Plate 71, figures 2, 3

Small, elongate, moderately inequilateral. Posterior dorsal area moderately wide, sculptured with threads slightly oblique to dorsal margin, fewer than rugae on rostral ridge. Anterior dorsal area very narrow, sculptured with closely spaced continuations of rugae beyond area. Concentric rugae moderately strong, not entirely uniform, closely spaced. Chondrophore and hinge not exposed.

Length 7 mm, height 4 mm, diameter 2 mm (figured specimen).

This species occurs in the moderately deep-water facies of the Caimito formation on Barro Colorado Island. It remotely resembles *Saccella subcerata* (Woodring, 1925, p. 17, pl. 1, figs. 6, 7; Miocene, Jamaica), but is more strongly rostrate. Though it may be a new species, a better sample than the three specimens now available is needed to justify a name.

The rugae are more or less corroded on two of these fossils and are corroded also on the central part of that illustrated. Despite the missing extreme posterior end, it can be seen that the illustrated right valve is faintly birostrate, a feature not shown by the other two.

Occurrence: Caimito formation (late Oligocene), localities 54k, 54m.

Saccella acrita epacra Woodring, n. subsp.

Plate 75, figures 18–21, 27, 29, 30

Very small, elongate, moderately inequilateral. Shallow anterior groove generally present, low ridge on anterior side of groove generally stronger than that on posterior side. Posterior dorsal area very wide, sculptured with crowded threads slightly oblique to dorsal margin, continuous with rugae on posterior ridge. Anterior dorsal area very narrow; low, short pustules, oblique to dorsal margin, present or absent. Concentric rugae generally strong, generally closely spaced, exceptionally moderately coarse, exceptionally subdued. Fourteen to 18 teeth in anterior series, 12 to 17 in posterior.

Length 5.6 mm, height 3.1 mm, diameter (both valves) 2.7 mm (type). Length 6.6 mm, height 3.9 mm, diameter 2.2 mm (largest figured specimen).

Type: USNM 646747.

Type locality: 147g (USGS 5899, Highest fossil-bearing beds, Quebrancha Hills, ¾ mi. (1.2 km) out from Gatun, Canal Zone), middle part of Gatun formation.

Saccella acrita epacra is the most abundant and most variable, as well as the smallest, *Saccella* in the Gatun formation. Some 500 specimens are in collections from the three parts of the formation, but none from the upper part in the eastern area. Minute, immature shells, down to a length of 0.8 mm, are fairly common.

The degree of elongation, the absence or presence and distinctness of the anterior groove, the absence or presence of pustules on the anterior dorsal area, and the strength, width, and spacing of the rugae are variable. The prevailing outline and sculpture in the middle part of the Gatun are represented by the type (pl. 75, figs. 19, 21). Rugae of intermediate spacing and a strong ridge on the anterior side of the shallow anterior groove are shown on plate 75, figure 27, and subdued rugae on plate 75, figure 20. Though a considerable range of variation in sculpture, including moderately coarse rugae, is shown by some 60 specimens in a middle Gatun collection (locality 169), moderately coarse sculpture is noteworthy among shells from the lower part of the formation and from strata near the base of the middle part (pl. 75, fig. 30).

The consistently wider posterior dorsal area distinguishes the fossils from *S. acrita acrita* (Dall, 1908, p. 374), which was dredged in great numbers by the *Albatross* in Panama Bay and off La Paz, Baja California, at depths of 10 to 29 fathoms. Though the type lot of several hundred specimens shows variation in subduing of

the fine sculpture and its absence on parts of the shell, the two faintly sculptured syntypes illustrated by Keen (1958, p. 20, fig. 16; 1971, p. 29, fig. 19) are not typical. Stronger sculpture, comparable to that of most of the Gatun fossils, is prevalent in the northern parts of the range, as shown by Olsson's illustration (1961, p. 60, pl. 2, fig. 7) of a shell dredged off Baja California. Pustules were not observed on the anterior dorsal area of living shells, but they are present or absent on the fossils.

An unrecorded small *Saccella* in the middle Miocene deposits of southeastern Costa Rica (USGS 5882g and other localities on Río Banano) has a somewhat narrower posterior dorsal area than the Gatun fossils and therefore is more similar to *S. acrita acrita*.

Small forms of *Saccella*, related to *S. acrita*, in the Alum Bluff group of Florida are overnamed. *S. canonica* (Dall, 1890–1903, p. 591, 1898; Gardner, 1926–47, p. 16, pl. 3, figs. 15–17, 1926; Chipola formation), which typically has exceptionally fine sculpture, is the oldest name. The type, a minute, immature valve (length 2.5 mm, fig. 16 of Gardner's illustrations) by itself, without the available growth series of topotypes, is unrecognizable.

Occurrence: Lower, middle, and upper part of Gatun formation (middle Miocene). Lower part, localities 136a (identification doubtful), 138a, 138c, 138d. Middle part, eastern area, localities 139b, 139c, 139d, 139e, 139f, 139g, 146, 147b, 147e, 147f, 147g, 147h, 158, 159d; western area localities 161d, 166, 169. Upper part, western area, locality 185. Middle Miocene deposits, Darién area, Panamá (USGS 8477).

Saccella cf. S. ornata (d'Orbigny)

Moderately small, moderately to distinctly elongate, moderately inequilateral. Posterior dorsal area moderately wide, sculptured with threads slightly oblique to dorsal margin. Anterior dorsal area very narrow, set off by subdued sculpture. Concentric rugae strong, narrow, closely spaced, uniform, but generally subdued on rostral ridge. Chondrophore and hinge not exposed.

Length 8.6 mm, height 5.2 mm, diameter 2.4 mm (most nearly complete specimen).

Eight valves from the Chagres sandstone are identified as *Saccella* cf. *S. ornata*. All of them are in poor condition. In outline and sculpture the most nearly complete specimen closely resembles that species as it occurs in the Esmeraldas formation of Ecuador (Olsson, 1964, p. 21, pl. 1, fig. 12), but is larger and lacks an anterior groove. Though other Chagres shells are more elongate than that mentioned, none shows an anterior groove.

S. ornata occurs also in the Pliocene of Ecuador and is living along the coast of Ecuador and Perú (Olsson, 1961, p. 60, pl. 2, figs. 3, 3a).

Occurrence: Chagres sandstone (late Miocene), localities 206, 206b.

Group of elongate species

An elongate species, represented in the La Boca formation by poorly preserved specimens, is listed as *Saccella* sp. (elongate).

Saccella cf. S. fabalis (Olsson)

Plate 77, figures 10, 16

Very small, very elongate, subequilateral, strongly rostrate. Posterior dorsal area narrow, sculptured with weak threads slightly oblique to dorsal margin. Anterior dorsal area very narrow, sculptured with subdued continuation of rugae, oblique to dorsal margin. Concentric rugae strong, widely spaced, dorsal face concave; narrower and slightly insinuated by slight depression on ventral side of rostral ridge. Hinge not completely exposed.

Length 5.2 mm, height 2.5 mm, diameter 1.2 mm (figured specimen).

This evidently is a new species, but it is represented by a single specimen, which may be immature. In a general way it may be compared with *Saccella fabalis* (Olsson, 1964, p. 22, pl. 1, fig. 11; middle Miocene, Ecuador), which is twice as large and has more closely spaced rugae that are not slightly insinuated on the ventral side of the rostral ridge.

Occurrence: Middle part of Gatun formation (middle Miocene), western area, locality 169.

Group of large species

Saccella aff. S. balboae (Brown and Pilsbry)

Poorly preserved fossils from the Culebra and La Boca formations have the outline and sculpture of *Saccella balboae*, the following species. They presumably represent that species or a closely allied predecessor. The estimated maximum length is about 16 mm.

Occurrence: Culebra formation (early Miocene), locality 108c. La Boca formation (early Miocene), localities 99c, 100b, 101i.

Saccella balboae (Brown and Pilsbry)

Plate 77, figures 9, 11, 19, 20, 23

Leda balboae Brown and Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 63, p. 362, pl. 27, fig. 8, 1911 (Miocene, Canal Zone). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 173, pl. 18, fig. 15, 1922 (Miocene, Costa Rica).

?Leda sp., Toula, K. k. Geol. Reichsanstalt Jahrb., v. 58, p. 719, pl. 27, fig. 2, 1909 (Miocene, Canal Zone).

Moderately large, high, subequilateral, strongly rostrate. Shallow anterior groove present or absent. Posterior dorsal area wide, sculptured with threads slightly oblique to dorsal margin, more or less continuous with rugae on rostral ridge. Anterior dorsal area very narrow, set off by low short pustules, practically

perpendicular to dorsal margin, or area not distinguishable. Concentric rugae strong, spacing of moderate width, dorsal face concave. Eighteen to 20 teeth in anterior series, 13 or 14 in posterior.

Length 19.6 mm, height 11.4 mm, diameter 8 mm (larger figured specimen).

Type: Acad. Nat. Sci. Philadelphia 1743 (larger of two specimens, as designated by Brown and Pilsbry).

Type locality: Gatun Locks excavation, Canal Zone middle part of Gatun formation.

Though *Saccella balboae* is widespread in the three parts of the Gatun formation, only three of some 70 specimens, one of which is illustrated (pl. 77, figs. 9, 23), are large. None of the three, however, is as large as the type (length 22.1 mm). In fact, immature shells, even to a minimum length of 1.1 mm, are common. Their coarser sculpture distinguishes them from immature shells of *S. acrita epacra*, with which they are associated at seven localities.

The sculpture is uniform, except that the rugae of a small right valve (length 8.2 mm), the only specimen from locality 185, are more closely spaced than on the others. Pustules on the anterior dorsal area, like those shown on plate 77, figure 11, were observed on shells from the lower part of the Gatun that show the area, but on none from the middle and upper parts. The presence or absence of pustules on shells of *S. acrita epacra* is devoid of stratigraphic significance.

S. balboae is related to *S. peruviana* (Dall) (1890–1903, p. 579, 1898; *Leda acuminata* Nelson, 1870, p. 205, pl. 7, fig. 8, not *Nucula* [*Leda*] *acuminata* von Buch, 1838; not *Leda peruviana* Dall, 1908, p. 377), a late Miocene species from Perú, and to *S. davidana* (Olsson) (1942, p. 28, pl. 1, fig. 3), an early Pliocene species from southwestern Panamá. Both are a little larger (length 25 and 27 mm, respectively), and the rugae of *S. peruviana* are slightly more closely spaced and those of *S. davidana* slightly coarser. The living eastern Pacific *S. fastigata* (Keen) (Olsson, 1961, p. 62, pl. 2, figs. 2, 2a, pl. 3, fig. 9) is still larger (length 34 mm) and more coarsely sculptured than *S. balboae*. No comparable species has been found in western Atlantic waters.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, localities 136, 137, 138, 138a, 138c, 138d, 138e. Middle part, eastern area, localities 147b, 147f, 147g, 152, 153, 153a; western area, locality 161a. Upper part, eastern area, localities 171, 172, 173, 173a 174, 175, 177; western area, localities 183, 185. Middle Miocene deposits, southeastern Costa Rica.

Genus Adrana H. and A. Adams

H. and A. Adams, the genera of Recent Mollusca, v. 2, p. 547, 1858.

Type (logotype, Stoliczka, India Geol. Survey Mem., Palaeontologia Indica, Cretaceous fauna of southern India, v. 3, p. XX, 1870, p. 320, 1871): *Nucula lanceolata* Lamarck, 1819, not *Nucula lanceolata* J. Sowerby, 1917, = *Leda taylori* Hanley, living, Pacific coast of Guatemala.

Adrana stena Woodring, n. sp.

Plate 70, figure 17

Large, slightly inequilateral, umbonal area slightly angulating dorsal margin. Anterior ventral margin broadly rounded, posterior ventral margin slightly insinuated. Posterior dorsal area narrow, set off by sharp carina. Anterior dorsal area very narrow, set off by suppression of sculpture and a weak carina. Entire shell, except dorsal areas, sculptured with narrow, closely spaced rugae, more closely spaced in umbonal area (absent on somewhat worn tips of umbos), somewhat coarser on and near posterior dorsal carina. Hinge not exposed.

Length (not quite complete) 48.5 mm, height 11.4 mm, diameter (both valves) 5.5 mm (type).

Type: USNM 646693.

Type locality: 42d (USGS 18837, Barro Colorado Island, northern part of island, stream heading west of Miller Trail near Miller 17, about 100 meters above mouth, Canal Zone), Bohio formation.

The type is the largest and most nearly complete of 10 specimens found in the Bohio formation of Barro Colorado Island. Shell material is missing on part of posterior end of the left valve of the type, and the posterior tip is also missing.

Adrana stena is most similar to *A. crenifera* (Sowerby) (Olsson, 1961, p. 70, pl. 3, figs. 4, 4a, 4b), now living in eastern Pacific waters. The Bohio fossils are a little larger and lack a strong carina setting off the anterior dorsal area.

Fragmentary remains from the Culebra and La Boca formations may represent *A. stena*, but are so poorly preserved that they are listed as *Adrana* sp. An incomplete external mold from the middle part of the Gatun formation (loc. 161d), comparable in size to *A. stena*, is also listed as *Adrana* sp.

Occurrence: Bohio formation (late Oligocene), localities 42d, 42g.

Adrana cf. A. newcombi (Angas)

Very small, very elongate, decidedly inequilateral, umbo at about anterior third of length. Umbonal area slightly angulating dorsal margin. Posterior dorsal area narrow, limited by a carina. Anterior dorsal area very narrow, weakly set off by subdued carina. Sculpture of narrow, closely spaced rugae limited to umbonal area and anterior dorsal part of shell, or to as much as anterior half. Faint scales present or absent on posterior dorsal carina. Hinge not exposed.

Length 14 mm, height 3.7 mm, diameter (both valves) 1.3 mm.

The description is based on three defective, small specimens from the middle part of the Gatun formation. In outline they are similar to immature valves of the living Caribbean *Adrana newcombi*. The sculpture of the living shells is finer and covers a larger part of the shell, all except about the posterior third or less, and the posterior dorsal carina is weaker and consistently lacks scales.

Treatment of three other defective, small, Gatun fossils is unresolvable without additional material. The anterior two-thirds of a right valve (loc. 139b) bears relatively coarse, widely spaced rugae. A posterior fragment of a left valve (loc. 138c) has relatively strong scales on the anterior part of the posterior dorsal carina and subdued scales on the remainder. It is associated with an anterior fragment of a different left valve that shows faint scales on the extreme anterior part of the posterior dorsal carina. All these fossils are listed as *Adrana* sp.

Altena (1968) recently pointed out that *Leda* (*Adrana*) *newcombi* Angas (1878, p. 314, pl. 18, figs. 16, 17), dredged in Navy Bay, Aspinwall—that is, Limón Bay, Colón, of present terminology—at a depth of eight fathoms, has many years precedence over *Yoldia perprotracta* Dall (1912, p. 1; 1925, p. 32, pl. 18, fig. 3). Dall's name was based on fossils collected from the informally named Atlantic muck at USGS locality 5850, near Mount Hope. The muck, formerly considered to be of Pleistocene age, is now known to have been deposited during the postglacial rise of sea level (p. 326 of chapter D). *A. newcombi* is living on the coast of Panamá in the Colón area and at Bocas del Toro Island, at an unspecified Cuban locality, and on the west and southwest coasts of Puerto Rico.

A late Miocene and early Pliocene species of *Adrana* from Trinidad has been doubtfully identified as *A. perprotracta* (Jung, 1969, p. 323, pl. 14, figs. 3, 4).

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, locality 158; western area, locality 161c.

Genus Portlandia Mörch

Mörch, Prodromus faunae molluscorum Grönlandiae, p. 21, Copenhagen, 1857.

Type (Opinion 769, Internat. Comm. Zoological Nomenclature, 1966): *Nucula arctica* Gray, living, Arctic and Boreal provinces.

Subgenus Portlandella Stewart?

Stewart, Acad. Nat. Sci. Philadelphia Special Pub. 3, p. 61, 1930.

Type (orthotype): *Leda rosa* M. A. Hanna, middle Eocene, California.

Portlandia (Portlandella?) euthynta Woodring, n. sp.

Plate 70, figure 14

Of medium size, moderately elongate, moderately inequilateral. Anterior dorsal margin slightly convex, posterior dorsal margin slightly concave at umbo, straight and slightly sloping from there to posterior end. Anterior and ventral margins rounded. Posterior margin curved and ascending steeply. Posterior dorsal area very narrow, lying between weak carinae, dorsal one wider and higher than ventral. Faint pustules, oblique to dorsal margin, visible in area and on ventral carina. Anterior dorsal area very narrow, faint pustules on ventral weak carina. Ventral middle part of shell sculptured with weak, closely spaced rugae. Chondrophore and hinge not exposed.

Length 13 mm, height 7.2 mm, diameter 2 mm (type).

Type: USNM 646694.

Type locality: 42i (USGS 18845, Barro Colorado Island, eastern part of island, stream east of Shannon Trail, about 365 meters southeast of Shannon 1, Canal Zone), Bohio formation.

An attempt to expose the chondrophore and hinge runs the risk of damaging the single specimen of this species from the Bohio formation of Barro Colorado Island. No species closely comparable to it has come to my attention, and subgeneric assignment is questionable. Alliance to *Portlandella* is suggested by the nonsinuate posterior ventral margin. The posterior dorsal margin of the type species of *Portlandella*, however, is more concave, the shell is more inflated, and sculpture other than growth lines is absent.

The posterior ventral margin of the living eastern Pacific *Yoldia martyria* Dall (1897, p. 9, pl. 2, fig. 15) is slightly insinuated, producing a subrostrate outline. The sinuation and rostration are not as pronounced as in *Portlandia* s.s., and the chondrophore is wider and shallower than that of *Portlandia* s.s. The type locality of Dall's species is off San Pedro Mártir Island, in the Gulf of California, but it has a remarkable northward range to Prince of Wales Island, Alaska, at depths of 30 to 135 fathoms (65 fathoms at the type locality). No lots are in USNM collections between northern Oregon and the type locality.

Occurrence: Bohio formation (late Oliogocene), locality 42i.

Family ARCIDAE

Subfamily ARCINAE

Genus Arca Linné

Linné, Systema naturae, 10th ed., p. 693, 1758.

Type (Internat. Comm. Zoological Nomenclature, Opinion 189, 1945): *Arca noae* Linné, living, Mediterranean Sea and eastern Atlantic Ocean.

Arca imbricata Bruguière

Plate 73, figure 2, Plate 77, figure 17

Arca imbricata Bruguière, Encyclopédie méthodique, v. 1, p. 98, 1789 (living, "mer des Indes, sur les côtes du cap de Bonne Espérance"). Gabb, Am. Philos. Soc., Trans., n. ser., v. 15, p. 254, 1873 (Miocene, Dominican Republic). Gabb, Philadelphia Acad. Nat. Sci. Jour., 2nd ser., v. 8, p. 378, 1881 (Pliocene, Costa Rica).

Arca (Arca) imbricata Bruguière, Weisbord, Bull. Am. Paleontology, v. 45, no. 204, p. 54, pl. 3, figs. 1–8, 1964 (Pleistocene, living, Venezuela; additional citations). Jung. Bull. Am. Paleontology, v. 55, no. 247, p. 326, pl. 14, figs. 7, 8, 1969 (Pliocene, Trinidad).

Arca umbonata Lamarck, Histoire naturelle des animaux sans vertèbres, v. 6, p. 37, 1819 (living, Jamaica). Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 163, pl. 30, fig. 11, 1917 (Miocene, Dominican Republic). Maury, New York Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 1, p. 6, 1920 (Oligocene, Miocene, Puerto Rico). Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 73, p. 403, 1922 (Miocene, Dominican Republic). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 182, pl. 22, fig. 2, 1922 (Miocene, Costa Rica). Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 35, pl. 3, fig. 6, pl. 8, fig. 4, 1925 (Pliocene, living, Trinidad). Ferreira, Mus. Paraense Emílio Goeldi Bol., n. ser., Geol., no. 9, p. 12, pl. 1, 1964 (Miocene, Brazil).

Arca (Arca) umbonata Lamarck, Jung, Bull. Am. Paleontology, v. 49, no. 223, p. 420, pl. 51, figs. 2, 4, 1965 (Miocene, Venezuela).

Arca (Arca) umbonata morantensis Woodring, Carnegie Inst. Washington Pub. 366, p. 30, pl. 2, figs. 10, 11, 1925 (Miocene, Jamaica).

Arca umbonata paezensis H. K. Hodson, Bull. Am. Paleontology, v. 13, no. 49, p. 3, pl. 1, fig. 7, 1927 ("Quaternary," Venezuela).

Small or of medium size, subrectangular except for posterior elongation, posterior angulation strong, byssal gape slight. Radial ribs relatively wide and widely spaced on posterior slope, narrow and closely spaced on remainder of shell. Ribs imbricated by irregularly spaced concentric grooves. Ligament area long and moderately wide, a pair of subumbonal ligament grooves on small shell from Gatun formation.

Length 27.7 mm, height 16.5 mm, diameter 10.8 mm (figured specimen from lower member of Alhajuela formation). Length 16.4 mm, height 9.9 mm, diameter 4.9 mm (figured specimen from Gatun formation).

Type: Unknown.

Type locality: Presumably Caribbean region, living.

The representation of this long-lived and far-ranging species is meager: a poorly preserved right valve of medium size from the lower member of the Alhajuela formation and a nicked small right valve from the lower part of the Gatun formation. The Alhajuela fossil, extracted from marly limestone at a now submerged locality on Río Chagres above the present Madden Dam, was identified by Dall as *Arca umbonata*, when it was received from MacDonald in 1911. Though the ventral margin is imperfect, a growth line shows a slight byssal insinuation. Living shells reach a length of 85 mm, but the largest of Miocene age so far recorded is half as large.

The posterior angulation of the Gatun specimen is stronger than that of the small shells from Bowden, Jamaica, which were named *A. umbonata morantensis*. That name is to be suppressed.

Occurrence: Lower member of Alhajuela formation (early Miocene), locality 76. Lower part of Gatun formation (middle Miocene), locality 138e. San Sebastián formation (late Oligocene), Puerto Rico. Tampa limestone (early Miocene), Florida. Aymamón limestone (early Miocene), Puerto Rico. Pirabas formation (early Miocene), Brazil. Chipola formation (early Miocene), Florida. Cercado formation (middle Miocene), Dominican Republic. Bowden formation (middle Miocene), Jamaica. Deposits of middle Miocene age, Costa Rica. Cantaure formation (middle Miocene), Venezuela. Oak Grove sand member of Shoal River formation (middle Miocene), Florida. Limón formation (late Miocene), Costa Rica. Matura formation and Courbaril member of Morne l'Enfer formation (early Pliocene), Trinidad. Moín formation (late Pliocene), Costa Rica. Living, North Carolina to Paraná, Brazil.

Genus Barbatia Gray

Gray, Synopsis of the contents of the British Museum, 44th ed., Mollusks, p. 81, 1842 (genus without species).

Type (monotype, Gray, Zool. Soc. London Proc., p. 197, 1847): *Arca barbata* Linné, living, Mediterranean Sea and eastern Atlantic Ocean.

Subgenus Barbatia s.s.

Barbatia (Barbatia) cf. B. cancellaria (Lamarck)

The genus *Barbatia* is represented by a poorly preserved specimen from the shallow-water facies of the Caimito formation and 11 specimens, also poorly preserved, from the La Boca formation. The moderate size (maximum length about 45 mm), relatively fine ribbing, especially on the posterior slope, and lack of distortion suggest alliance to *B. cancellaria*, now living in the Caribbean region, rather than to *B. candida*, also living there.

B. candida has a long Caribbean record, beginning in early Miocene time. The alleged five species of *Barbatia* from Bowden, Jamaica (Woodring, 1925, p. 34–36), including three based on very immature valves, are to be suppressed as *B. candida*. In other words, Dall was justified in identifying *B. candida* at Bowden (Dall, 1890–1903, p. 626, 1898).

Occurrence: Caimito formation (late Oligocene), locality 55b. La Boca formation (early Miocene), localities 99a (*Barbatia*? sp.), 99g, 114, 115a, 116a.

Genus Calloarca Gray

Gray, Annals and Mag. Nat. History, 2nd ser., v. 19, p. 369, 1857.
Type (monotype): *B[arbatia] alternata* (Sowerby) [*Byssoarca alternata*], living, tropical eastern Pacific Ocean.

Subgenus Taeniarca Olsson

Olsson, Neogene mollusks from northwestern Ecuador, Paleontological Research Inst., p. 25, 1964.
Type (orthotype): *Barbatia (Calloarca) taeniata* Dall [*Barbatia (Cucullaria) taeniata*], Pliocene, Florida.

Calloarca s.s. evidently is monotypic. *Taeniarca* lacks the carinate posterior ridge of *Calloarca* s.s. and the coarse ribs on the posterior slope of that subgenus. It embraces the three Miocene and Pliocene species from Florida assigned to *Calloarca* by Reinhart (1935, p. 23) and the following species, which occurs in the Gatun formation as well as in the middle Miocene of Ecuador.

Calloarca (Taeniarca) cachla Olsson

Plate 77, figure 7

Calloarca (Taeniarca) cachla Olsson, Neogene mollusks from northwestern Ecuador, Paleontological Research Inst., p. 25, pl. 3, fig. 9, 1964 (Miocene, Ecuador).

Small, inflated, elongate, decidedly inaequilateral, umbonal area wide. Middle ventral margin slightly insinuated and corresponding part of shell above insinuation slightly depressed. Ribs low and flat; those on main part of shell narrow, closely spaced, basically bipartate (exceptionally tripartate, or even quadripartate); those on posterior rounded ridge slightly wider and undivided; those between ridge and posterior dorsal margin narrow. Cardinal area narrow, hinge not preserved.

Length (incomplete) 21.5 mm (estimated restored length 25 mm), height 12.5 mm, diameter 10.5 mm (figured specimen).

Type: USNM 643853.

Type locality: Cueva de Angostura, Río Santiago, Ecuador, Angostura formation.

Twelve valves from the middle part of the Gatun formation are identified as *Calloarca cachla*. All, except three very small valves (loc. 169), are more or less corroded. The ribs on and near the posterior ridge of the single Ecuadorean valve are somewhat wider than those of the Gatun fossils.

The ribs of the Miocene species from Florida—*C. phalacra* (Dall, 1890–1903, p. 626, pl. 33, fig. 3, 1898, Chipola formation and Oak Grove sand member of Shoal River formation) and *C. leonensis* (Mansfield, 1932, p. 42, pl. 5, figs. 1, 3, 5, Mansfield's late Miocene *Cancellaria* zone)—are so closely spaced that the space between them is hardly wider than the groove dividing the ribs into two parts. *C. phalacra* has not yet been illustrated in exterior view. *C. taeniata* (Dall, 1890–1903, p. 631, pl. 25, figs. 1, 1a, 1898; Caloosahatchee formation), of Pliocene age, is the youngest known species and is far larger than any of Miocene age (length 52 to 55 mm). The large double-valve specimen illustrated by Dall in his figure 1 is herewith designated the lectotype. Dall evidently instructed McConnell to reconstruct from smaller isolated left valves the interior view of figure 1a.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, localities 146, 152; western area, localities 160, 169. Angostura formation (middle Miocene), Ecuador.

Genus Acar Gray

Gray, Annals and Mag. Nat. History, 2nd ser., v. 19, p. 369, 1857.
Type (logotype, Stoliczka, India Geol. Survey Mem., Palaeontologia Indica, Cretaceous fauna of southern India, v. 3, p. XXI, 1870): *B[arbatia] divaricata* Sowerby [*Byssoarca divaricata*], living, western Pacific Ocean.

Stoliczka's type designation far antedates the 1925 designation (Woodring, 1925, p. 37).

Acar domingensis (Lamarck)

Plate 77, figures 4, 8

Arca domingensis Lamarck, Histoire naturelle des animaux sans vertèbres, v. 6, p. 40, 1819 (living, San Domingue).
Barbatia (Acar) domingensis (Lamarck), Woodring, Carnegie Inst. Washington Pub. 366, p. 37, pl. 3, figs. 17, 18, 1925 (Miocene, Jamaica). Mansfield, Florida Dept. Conservation, Geol. Bull. 15, p. 199, pl. 10, fig. 13, 1937 (Miocene, Florida). Perrilliat Montoya, México Univ. Nac., Inst. Geología, Paleontología Mexicana, no. 14, p. 5, pl. 1, figs. 3, 4, 1963 (Miocene, México). Weisbord, Bull. Am. Paleontology, v. 45, no. 204, p. 61, pl. 4, figs. 1–9, 1964 (Pleistocene, living, Venezuela). Jung, Bull. Am. Paleontology, v. 55, no. 247, p. 328, pl. 15, figs. 1, 2, 1969 (Pliocene, Trinidad).
?Barbatia (Acar) sp. cf. *B. (Acar) domingensis* (Lamarck), Mansfield, Jour. Paleontology, v. 14, p. 175, pl. 25, fig. 11, 1940 (Oligocene, Alabama).
Barbatia (Acar) reticulata (Gmelin), Dall, Wagner Free Inst. Sci., v. 3, pt. 4, p. 629, 1898 (Eocene to living, southeastern United States). Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 166, pl. 30, fig. 16, 1917 (Miocene, Dominican Republic). Maury, New York Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 1, p. 7, 1920 (Miocene, Puerto Rico). Hubbard, New York Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 2, p. 106, 1920 (Miocene, Puerto Rico). Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 43, pl. 8, figs. 18, 21, 1925 (Pliocene, Trinidad; living Venezuela).

Of medium size, inflated, subquadrate, decidedly inequilateral. Posterior slope sharply set off by reduction in strength of concentric ridges. Middle of ventral margin slightly insinuated. Sculpture coarsely reticulate; concentric ridges very coarse, widely spaced; radial threads narrower, more closely spaced, swollen on concentric ridges. Cardinal area narrow, a few ligament grooves on posterior part. Adductor muscle scars raised.

Length 18 mm, height 10.2 mm, diameter 4.8 mm (figured specimen).

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Type: Unknown.

Type locality: Hispaniola, living.

Acar domingensis is represented by two valves (one in poor condition) from the middle part of the Gatun formation and probably by four poorly preserved, doubtfully identified valves from the La Boca formation. Though living shells have a length as great as 34 mm, the length of the largest fossils so far recorded, or observed in USNM collections, is less than 21 mm.

On the Bermudan platform Bretsky (1967) found that *A. domingensis* is "attached by its byssus to the undersurfaces of corals and, less commonly, of rocks."

The descendants of the Miocene *A. domingensis* in the eastern Pacific Ocean are known as *A. gradata* (Broderip and Sowerby) (Olsson, 1961, p. 82, pl. 6, figs.6, 6a, 6b). Conchologically they are indistinguishable from the westsern Atlantic descendants. The slight hinge difference mentioned by Reinhart (1939, p. 43) is by no means consistent. Heath (1941, p. 296), however, found that they are anatomically distinct.

Occurrence: La Boca formation (early Miocene; identification doubtful), localities 99f, 116a. Middle part of Gatun formation (middle Miocene), localities 145, 160d. Chickasawhay limestone (late Oligocene), Alabama (identification doubtful). Tampa limestone (early Miocene), Florida. Thomonde formation (early Miocene), Haiti. Aymamón limestone (early Miocene), Puerto Rico. Ponce limestone (early Miocene), Puerto Rico. Chipola formation (early Miocene), Florida. Cercado and Gurabo formations (middle Miocene), Dominican Republic (Gurabo formation, USGS 8544). Bowden formation (middle Miocene), Jamaica. Agueguexquite formation (middle Miocene), Tehuantepec area, México. Limón formation (late Miocene), Costa Rica. Caloosahatchee formation (early Pliocene), Florida. Matura formation (early Pliocene), Trinidad. Moín formation (late Pliocene), Costa Rica. Living, North Carolina to West Indies.

Subfamily ANADARINAE

As in other regions, anadarine arcids are abundant and highly diversified in the Tertiary Caribbean province. They range in length from 6 to 133 mm and in outline from narrowly elongate to subquadrate and to narrowly subtrigonal. Some 170 names have been proposed or used for Caribbean species of late Eocene to Pliocene age, all except 11 of which were based on Caribbean fossils. To be sure, some 30 are synonyms and perhaps others are. All except a few of the anadarines are the result of Miocene flowering.

A considerable percentage of Miocene Caribbean arcine species is still living: 50 percent of those in the present account. On the contrary, the percentage for anadarine species is very low: not more than about 3, and less than 1 of those in the present account.

Genus Anadara Gray

Gray, Zool. Soc. London Proc., p. 198, 1847.

Type (orthotype): *Arca antiquata* Linné, living, western Pacific and Indian Oceans.

The numerous fossil and living species of *Anadara* are difficult to classify satisfactorily. Nineteen names have been proposed for *Anadara*-like species and perhaps others escaped the count. According to the grade of taxa adopted in the present report, they rate as subgenera, insofar as they are usable.

Dall (1890–1903, p. 617–619, 633–657, 1898), who was influenced by the treatment adopted by Henry and Arthur Adams (1853–58, p. 537–538, 1857), assigned the American species to *Scapharca* (Gray, 1847, p. 198, *Scapharea* by error; type (orthotype): *Arca inaequivalvis* Bruguière, living, Indian Ocean), as a subgenus of *Arca*. As he adopted subdivisions (sections) under *Scapharca*, including *Anadara*, in headings the name *Scapharca* appears as a genus and his sections as subgenera. Following Dall's commanding lead, American paleontologists for many years used *Scapharca* for most of their anadarines.

Anadara and *Scapharca* appeared on the same page. It is irrelevant that *Anadara* immediately precedes *Scapharca*, but what is relevant is that the type species of *Scapharca* is an exceptional species. *Anadara* therefore is given precedence, as has been done tacitly by many paleontologists and zoologists. *Arca inaequivalvis* is subquadrate, relatively thin-shelled, decidedly inequivalve, the left valve overlapping the right, and its ribs undivided. The cardinal area is microscopically striate vertically. *Scapharca* is rejected for American species, as was done by Olsson (1961, p. 87). Though some American species are inequivalve, that does not make them species of *Scapharca*.

The cardinal area of *Arca antiquata*, described by Olsson (1961, p. 86) and H. E. Vokes (1969, p. 6), is vertically striate only, or combines the striae with shallow horizontal grooves, among which some short, generally slightly wavy, deeper grooves may be interspersed. *Anadara* s.s., like *Scapharca*, is rejected for American species, again as was done by Olsson (1961, p. 86).

Subgenus Hawaiarca Dall, Bartsch, and Rehder

Dall, Bartsch, and Rehder, Bernice P. Bishop Mus. Bull. 153, p. 27, 1938.

Type (orthotype): *Hawaiarca rectangula* Dall, Bartsch, and Rehder, living, Hawaii.

A noteworthy group of very small, elongate, early and middle Miocene Caribbean species, ranging in length from 7 to 11 mm, is doubtfully represented in the

faunas under consideration. This group includes *Anadara guajatica* (Sheldon and Maury) (Maury, 1920, p. 8, pl. 1, fig. 3; [Aymamón limestone], Puerto Rico), and the presumably synonymous *A.* cf. *A. donacia* (Dall) (Hubbard, 1920, p. 105, pl. 14, fig. 7, not fig. 6; Quebradillas [now Aymamón] limestone, Puerto Rico), a still unidentified species from the Thomonde formation of Haiti (USGS 9907, 9908), *A. donacia* (Dall) (Woodring, 1925, p. 48, pl. 5, figs. 8–11; Bowden formation, Jamaica), and *A. cibaoica* (Maury) (1917, p. 30, pl. 19, fig. 20; Cercado and Gurabo formations, Dominican Republic). The umbo of these fossils is narrowly sulcate. On many a shallow depression, extending from the umbo to the middle of the ventral margin, slightly insinuates the margin. The ribs in the depression, or in a corresponding position in the event that the depression is absent, are slightly to distinctly narrower than on either side, and the interior fluting of the margin is reduced. The narrow cardinal area is smooth, although faint markings, vertical or horizontal, are visible on some valves. The depression is least distinct, or absent, on the Thomonde fossils and most distinct, and most generally present, on *A. cibaoica*. How many species are to be recognized, however, is questionable. *A. cibaoica* is represented by an estimated 200 valves in USNM collections, and the Thomonde form and *A. donacia* by perhaps thousands. Five specimens of *A. donacia*, all immature, are articulated and show that the left valve is slightly larger than the right. They do not show a shallow depression or a gape, although the insinuation of the margin of many adult valves surely indicates a gape.

Through the generosity of my colleague Druid Wilson, it can be recorded that this group of species is represented, in late Miocene and Pliocene deposits in peninsular Florida, by a species larger (length up to 14.6 mm) and less elongate than the Caribbean forms. On one of the late Miocene valves (USGS 23727) four narrow ligament grooves extend obliquely upward across the narrow posterior part of the cardinal area. The ligament presumably did not cover the short, wider anterior part.

The concept of *Hawaiarca*, as a subgenus of *Anadara*, may be extended to include these American species, although the ribs of the type species are strongly noded. The type species is slightly inequivalve and has a median ventral, narrow gape. In Japan *Hawaiarca* has an age range of Pliocene to the present time. (Noda, 1966, p. 75). The American species left no known descendants in American waters.

The Oligocene Belgian species *Anadara sulcicosta* (Nyst) (Schenck and Reinhart, 1938, p. 22, pl. 1, fig. 3, pl. 2, fig. 1) reaches a length of 33 mm. It has a sulcate umbo and a slight median ventral gape. On account of the gape, Eames (1967) assigned the species to *Barbatia*, although it clearly is anadarine.

Many species of *Anadara*, both small and large, have a sulcate umbo, although the statement that it is found on every species examined, (Woodring, 1938, p. 30) means that the sampling was not extensive. The inference that the sulcate umbo indicates a median byssal gape at an early stage is confirmed by the life history of *A. subcrenata*, a Japanese species grown for food. On settling, the spat attaches itself to seaweed or some other object by a byssus; about a year after hatching, the attachment is abandoned and the animal buries in mud (Cahn, 1951, p. 37). On the contrary, *A. granosa*, also grown in Japan for food, has tightly closed valves even at an age of one month, when the length of the shell is about 2 mm (USNM 186586, hundreds of specimens).

Anadara (Hawaiarca?) species

Very small, elongate (height 56 percent of length), inequilateral (umbo at about anterior third of length). Umbo sulcate, shallow depression extending from sulcus toward ventral margin. Sculptured with about 29 faintly noded ribs.

Length 6.6 mm, height 3.7 mm.

A poorly preserved left valve from the Culebra formation is almost entirely a mold. The size, sulcate umbo, and depression suggest *Hawaiarca*. It may, however, be an immature specimen of a species of *Rasia*.

Occurrence: Culebra formation (early Miocene), locality 102.

Subgenus Rasia Gray

Gray, Annals and Mag. Nat. History, 2nd ser., v. 19, p. 371, 1857. Type (logotype, Stewart, Acad. Nat. Sci. Philadelphia, Special Pub. 3, p. 86, 1930): *Arca formosa* Sowerby, living, eastern Pacific Ocean.

Rasia is the earliest unequivocal name for the bulk of the American anadarines characterized by tent-shaped ligament grooves diverging at a wide angle. Gray's name was overlooked until attention was called to it by Stewart. The type species is elongate and its anterior ribs are divided. The status of *Cara*, introduced on the same page as *Rasia*, is uncertain. The type species, *Arca aviculoides* Reeve, 1844 (*avicularoides* by error in Gray; not *A. aviculoides* deKoninck, 1842, =*A. aviculaeformis* Nyst, 1848), designated by Stewart on the same page as the designation for *Rasia*, has been held to be an immature specimen of *A. formosa* (Olsson, 1961, p. 90) and to be a valid eastern Pacific species (Rost, 1955, p. 202, pl. 14, figs. 21a–21c, 23). Even if it is a valid species, as interpreted by Rost, it falls within the concept of *Rasia*. In any event, *Rasia* is given precedence.

Other names have been proposed for more or less similar anadarines, differing in outline and ribbing.

Diluvarca (Woodring, 1925, p. 40; type (orthotype): *Arca diluvii* Lamarck, Miocene to living, Mediterranean region), based on a misconception of *Arca antiquata* and improperly assigned subgeneric rank under *Barbatia*, was repudiated a few years after it was proposed (Woodring, 1928, p. 18, footnote), but was resuscitated recently (Olsson, 1961, p. 87). The type species is of medium size, equivalve, moderately elongate, and its ribs are undivided. The type of *Sectiarca* (Olsson, 1961, p. 97; type (orthotype): *Arca floridana* Conrad, living, Florida) is large, slightly inequivalve, elongate, and typically has divided ribs, except at the posterior end. The limits of these subgenera are vague.

For the present account the Caribbean anadarines assigned to *Rasia* are divided into four groups: (1) elongate (the group most similar in outline to the type species); (2) auriculate; (3) short; (4) subrounded. The group of elongate species is further divided into three subgroups based on size: small (length 6 to 30 mm); medium (length 31 to 44 mm); and large (length 45 to 117 mm).

In the following descriptions, if nothing is mentioned as to whether the shell is equivalve or inequivalve, it means that articulated shells, or valves that can be paired, are not available.

Group of elongate species

Subgroup of small species

Anadara (Rasia) carmenensis Clark

Plate 70, figure 5

Anadara (*Anadara*) *carmenensis* Clark, in Clark and Durham, Geol. Soc. America Mem. 16, p. 51, pl. 2, fig. 3, 1946 (Eocene, Colombia).

Small, elongate (height 54 percent of length), moderately inequilateral (umbo a little behind anterior third of length). Sculptured with about 25 ribs, apparently all divided below umbonal region, except at posterior end. Cardinal area narrow, corroded.

Length 6.5 mm, height 3.5 mm (figured specimen).

Type: California Acad. Sci. 7904.

Type locality: California Acad. Sci. 31694, 6 miles west of El Carmen, Bolívar, Colombia, deposits of late Eocene age.

Two small, presumably immature, valves from the marine member of the Bohio(?) formation are identified as *Anadara carmenensis*. Though they are poorly preserved, the illustrated right valve has the outline and divided ribs of that species. The other specimen, a fragment of a left valve replaced by calcite, has strongly divided, faintly noded ribs.

In the type region *A. carmenensis* reaches a length of 28 mm. The posterior end of the cardinal area of a right valve (length 13.6 mm) from the type region (USGS 11450) shows four closely spaced ligament grooves. The remainder of the area is corroded. No specimen from Colombia or the Canal Zone is well enough preserved to reveal whether the umbo is sulcate.

Occurrence: Marine member of Bohio(?) formation (late Eocene), locality 41b. Deposits of late Eocene age, Colombia.

Subgroup of species of medium size

Anadara (Rasia) dariensis progonica Woodring, n. subsp.

Plate 71, figure 1

Of medium size, elongate (height 60 to 65 percent of length), inequilateral (umbo at about anterior third of length), left valve slightly larger than right. Sculptured with 28 to 31 faintly noded ribs, about as wide as space between them. Ribs apparently not divided, or faintly to distinctly divided, generally only on anterior and posterior ends, exceptionally on practically entire shell, especially near ventral margin. Space between ribs bearing closely spaced concentric threads, exaggerated at irregularly spaced intervals. Cardinal area inaccessible or corroded.

Length 24.6 mm, height 14.9 mm, diameter (both valves) 11.8 mm (type). Length 31 mm, height 19.2 mm, diameter (both valves) 15 mm (largest specimen).

Type: USNM 646705.

Type locality: 112 (USGS 16910, West side of Gaillard cut, canal station 1759, about 30 meters southwest of edge of canal, basal part of bed 13 of section on p. 35, Canal Zone), Culebra formation.

Anadara dariensis progonica is a small predecessor of the nominate subspecies. In addition to being consistently smaller, some, including the type, have divided ribs on practically the entire shell: a feature observed on only eight of some 800 specimens of the nominate subspecies. Though the type is an articulated specimen, only the right valve is well preserved. Left valves of the nominate subspecies are more strongly noded than those of *A. dariensis progonica*.

This small subspecies is fairly common in the Culebra and La Boca formations (72 and 28 specimens, respectively), and is identified also in a collection from a submerged locality on Río Chagres at the former site of Las Cruces, upstream from Gamboa. The largest number was found in the transition zone between the Culebra and Cucaracha formations (localities 110, 111a, 112, 112a). Thirteen shells from the Culebra and two from the La Boca are articulated. None of these fossils is well enough preserved to show whether the umbo is sulcate.

Many are poorly preserved, but on some the effect of undivided ribs on any part of the shell apparently is not the result of preservation. If so, it is another feature distinguishing the two subspecies.

Fragmentary remains in carbonaceous shale near the base of the Cucaracha formation (loc. 122) are listed as *Anadara* sp.

Occurrence: Culebra formation (early Miocene), localities 106, 109 (*Anadara* sp.), 110, 110a, 111a, 111b, 112, 112a). La Boca formation (early Miocene), localities 99b, 99c, 99d, 101h, 115b. Deposits of early Miocene age at Las Cruces, locality 94.

Anadara (Rasia) dariensis dariensis (Brown and Pilsbry)

Plate 77, figure 3, 5, 13, 18, 21, 22, 24

Arca dariensis Brown and Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 63, p. 362, pl. 22, fig. 10, 1911 (Miocene, Canal Zone). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 184 (assigned to subgenus *Scapharca*), pl. 22, figs. 10–13, 1922 (Miocene, Canal Zone, Panamá). Li, Geol. Soc. China Bull., v. 9, p. 252, pl. 1, figs. 3, 3a, 1930 (Miocene, Canal Zone).

Scapharca (*Scapharca*) *dariensis* (Brown and Pilsbry), Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 55, pl. 6, fig. 5, 1925 (Miocene, Canal Zone).

Arca (*Scapharca*) *dariensis* Brown and Pilsbry, Anderson, California Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 147, 1929 (Miocene, Colombia).

Arca (*Diluvarca*) *dariensis* Brown and Pilsbry, Olsson, Bull. Am. Paleontology, v. 19, no. 68, p. 68, 1932 (Miocene, Perú).

Anadara (*Scapharca*) *dariensis* (Brown and Pilsbry), Oinomikado, Geol. Soc. Japan Jour., v. 46, p. 627, pl. 29, fig. 26, 1939 (Miocene, Colombia). Diaz de Gamero, Univ. Central Venezuela, Escuela Geol., Minas, Metalúrgica, Geos, no. 17, p. 34, 1968 (Miocene, Venezuela).

Not *Arca dariensis* Brown and Pilsbry, Hubbard, New York Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 2, p. 105, pl. 14, fig. 5, 1920 (Oligocene, Puerto Rico).

Arca gatunensis Toula, K. k. Geol. Reichsanstalt Jahrb., v. 61, p. 493, pl. 30, fig. 4, 1911 (Miocene, Canal Zone).

Scapharca losquemadica Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 173, pl. 30, fig. 1, 1917 (Miocene, Dominican Republic).

?Arca cf. *consobrina* Moore, Toula, K. k. Geol. Reichsanstalt Jahrb., v. 58, p. 717, pl. 27, fig. 1, 1909 (Miocene, Canal Zone).

?Arca (*Anadara*) *diluvii* Lamarck, Toula, K. k. Geol. Reichsanstalt Jahrb., v. 58, p. 718, 1909 (Miocene, Canal Zone).

Of medium size, elongate (height 60 to 67 percent of length, exceptionally 56 percent), inequilateral (umbo at about anterior third of length). Left valve decidedly larger than right. Umbo of smallest valves, and of well preserved larger valves, faintly to distinctly sulcate, especially on left valves. Sculptured with 27 to 33 ribs (generally 30 to 33). On both valves anterior and posterior ribs divided, except one or two adjoining anterior dorsal margin and as many as five adjoining posterior dorsal margin. Anterior ribs more widely spaced than posterior and divided by wide, shallow depression; posterior ribs by narrow groove. With eight exceptions among some 860 specimens, ribs on remainder of shell undivided; those on left valve strongly noded and wider than smooth or weakly noded ribs of right valve. Both branches of divided ribs noded, nodes stronger on anterior ribs than on posterior. Space between ribs bearing concentric threads of irregular strength and spacing, more conspicuous in wide spaces of right valve. Cardinal area narrow; one to four (generally two or three) paired ligament grooves and one or two (generally one) additional posterior limbs.

Length 36.3 mm, height 22 mm, diameter 9.1 mm (lectotype). Length 42.3 mm, height 24.6 mm, diameter 11.4 mm (largest specimen, figured).

Type material: Lectotype, herewith designated, right valve figured by Brown and Pilsbry, Acad. Nat. Sci. Phila. 1744.

Type locality: Gatun Locks excavation, Canal Zone, middle part of Gatun formation.

Anadara dariensis dariensis, which was well described by Brown and Pilsbry, is widespread and locally abundant throughout the Gatun formation, but less so in the upper part than in the other two. It is represented by some 860 specimens, ranging in length from 2 to 41.5 mm, 42 of which are articulated.

As shown by the illustrations, a considerable range of variation in the ratio of height to length is apparent. Variation affects also to some extent the degree of inflation. The most notable variation, however, is shown by eight valves that have divided median ribs: one from locality 138f, five from 139c, one from 146, and one from 183. Both right and left valves are affected, but on the five right valves and one left the ribs are divided only near the ventral margin. On two left valves the division extends some distance from the margin (pl. 77, figs. 3, 5). That shown on plate 77, figure 3 is remarkable, as it is the most elongate of the some 860 specimens.

As usual, locality 147b is notable for the large number of minute shells: 29 under 4 mm. The length of the largest specimens in the three parts of the Gatun is shown in the following table:

Length of largest specimens of Anadara dariensis dariensis

Gatun formation	Number of specimens	Length in mm of largest specimen
Upper part	24	41.5
Middle part	399	42.3
Lower part	444	36.5

This anadarine has no allies in present western Atlantic waters. It is closely allied, however, to the eastern Pacific *A. concinna* (Sowerby) (Olsson, 1961, p. 98, pl. 8, figs. 1, 1a), which first appeared in the fossil record during Pliocene time (Pilsbry and Olsson, 1941, p. 51). The living species is smaller and has a consistently low ratio of height to length and undivided posterior ribs. *A. inaequilateralis* (Guppy) (Woodring, 1925, p. 45, pl. 5, figs. 1–3; Bowden formation, Jamaica)

also is allied. It is smaller than *A. dariensis dariensis*, has a consistently low ratio of height to length, and left valves are not as strongly noded.

Occurrence: Lower member of Alhajuela formation (early Miocene), locality 84a (mold, identification doubtful). Upper member of Alhajuela formation (early Miocene), locality 90a (mold, identification doubtful. Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, localities 134 (immature, identification doubtful), 136 (immature, identification doubtful), 136a, 137 (immature, identification doubtful), 137a, 138, 138a, 138b, 138c, 138d, 138f, 138g. Middle part, eastern area, localities 139 (molds, identification doubtful), 139b, 139c, 139e, 139f, 140, 142, 146, 147, 147b, 147c, 147d, 147e, 147f, 147g, 147h, 150a, 151, 153, 153a, 155, 155a, 155b, 155c, 157, 158, 159, 159d; western area, localities 160d, 161, 161a, 161b, 169. Upper part, eastern area, localities 171, 175, 176a, 177c, 178; western area, localities 182, 182a, 183. Deposits of middle Miocene age, Darién area, Panamá (USGS 8429, 8430, 8433, 8477). Gurabo formation (middle Miocene), Dominican Republic. El Veral formation (middle or late Miocene), Venezuela. Tubará formation (middle Miocene), northeastern Colombia. Deposits of middle Miocene age, southwestern Colombia. Cardalitos formation (middle Miocene), Perú. Limón formation (late Miocene), Bocas del Toro area, Panamá.

Subgroup of large species

Anadara (Rasia) cf. A. medioamericana (Olsson)

Moderately large, elongate, inequilateral, umbonal area wide. Median ribs divided at early stage by groove somewhat narrower than branches; posterior ribs, except those near dorsal margin, divided by narrow groove; anterior ribs not preserved. Median ribs faintly noded.

Length (incomplete) 41.5 mm (estimated restored length 48 mm), height 28 mm, diameter 16 mm.

Five left valves and a right of a moderately large, elongate species from the La Boca formation are in poor condition. It can be seen, however, that the median ribs are divided, even at a height of 10 mm.

In general features this anadarine resembles the middle Miocene Costa Rican *A. medioamericana* (Olsson, 1922, p. 188, pl. 23, figs. 4–6). The median ribs of that species are divided at a later stage by a narrower groove.

Occurrence: La Boca formation (early Miocene), localities 99d, 99g.

Anadara (Rasia) honensis adiaphora Woodring, n. subsp.

Plate 82, figures 3, 6–8

Moderately large, elongate (height 67 to 69 percent of length), inequilateral (umbo at about anterior third of length), strongly inflated. Left valve slightly larger than right. Umbo of smallest specimen slightly sulcate. Sculptured with 29 to 33 ribs (generally 30 or 31), narrower than space between them, except at anterior and posterior ends. Ribs undivided, except a few anterior ribs of largest left valves divided near ventral margin. At early stage ribs of left valve moderately noded, at later stages less strongly noded; at early stage ribs of right valve weakly noded, later faintly noded or almost smooth. Concentric threads of irregular strength and spacing. Cardinal area of moderate width; three of four paired ligament grooves and one or two additional posterior limbs.

Length 52.5 mm, height 35.2 mm, diameter 20.7 mm (type). Length 46.7 mm, height 32.2 mm, diameter 17.6 mm (larger figured left valve).

Type: USNM 646779.

Type locality: 208 (USGS 8437, Caribbean coast at mouth of Río Indios [Indio], Panamá), Chagres sandstone.

Sixteen specimens, four of which are articulated, from the Chagres sandstone are classified as a subspecies of *Anadara honensis* (Olsson, 1922, p. 187, pl. 22, figs. 8, 9; middle Miocene, Costa Rica). *A. honensis adiaphora* is larger than the nominate subspecies, less elongate, and is sculptured with more ribs (29 to 33 as compared with 26 or 27). In the type region—southern Limón Province—the maximum length of the nominate subspecies is 39 mm. A larger somewhat worn valve (length 45.5 mm) was collected farther north in Limón Province, probably on Río Blanco (USGS 8343). A valve from Bowden, Jamaica, which was overlooked or unavailable when the Bowden pelecypods were described (Woodring, 1925) has a length of 49.9 mm.

A. margaretae (Maury, 1917, p. 169, pl. 28, fig. 1; middle Miocene, Dominican Republic) is much larger than the subspecies of *A. honensis* (length 80 mm). The anterior and median ribs of the left valve are strongly noded and the space between posterior ribs bears strong concentric lamella.

Occurrence: Chagres sandstone (late Miocene), locality 208.

Anadara (Rasia) actinophora actinophora (Dall)

Plate 76, figures 4, 7, 9, 11

Scapharca (Scapharca) actinophora Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 4, p. 647, pl. 33, fig. 26, 1898 (Miocene, Canal Zone).

Arca actinophora (Dall), Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 185 (assigned to subgenus *Scapharca*), pl. 23, figs. 7, 8, pl. 25, fig. 3, 1922 (Miocene, Canal Zone, Panamá, Costa Rica).

Arca (Scapharca) actinophora (Dall), Hodson, Hodson, and Harris, Bull. Am. Paleontology, v. 13, no. 49, p. 12, 1927 (Miocene, Venezuela). Anderson, California Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 147, 1929 (Miocene, Colombia).

?Anadara (Anadara) istmica Perrilliat Montoya, México Univ. Nac., Inst. Geología, Paleontología Mexicana, no. 8, p. 12, pl. 1, figs. 3–5, 1960 (Miocene, México).

Moderately large, elongate (height 53 to 71 percent of length, 62 to 71 for mature shells), inequilateral (umbo at about anterior third of length), strongly inflated, ventral margin strongly arcuate, except on some immature shells. Left valve slightly larger than right. Umbo distinctly sulcate. Sculptured with 33 to 41 ribs (generally 40 or 41). On right valve ribs narrower than space between them except at anterior and posterior ends; on left valve almost as wide, or fully so. Ribs undivided, except a few anterior ribs on largest specimen (loc. 175), and practically all ribs on a right valve (loc. 177e). Ribs of left valve strongly and closely noded except a few near posterior dorsal margin; those of right valve less strongly, or weakly, noded. Concentric threads, for most part regularly spaced, conspicuous in space between ribs, alined with nodes. Cardinal area of moderate width; two or three paired ligament grooves and one to three additional posterior limbs.

Length 46 mm, height 29 mm, diameter 13.8 mm (type). Length 48.8 mm, height 32.3 mm, diameter (both valves) 27 mm (larger figured specimen). Length (incomplete) 54.2 mm (estimated restored length 60 mm), height 42.7 mm, diameter (both valves) 34 mm (largest specimen).

Type: USNM 135597.

Type locality (see explanation of Dall's plate): Panama Railroad at Monkey Hill [Mount Hope], Canal Zone, upper part of Gatun formation.

Anadara actinophora actinophora is rare in the middle part of the Gatun formation (1 valve) and common in the upper part in the eastern area (34 specimens, 13 of which are articulated). The proportion of articulated shells is noteworthy: 38 percent of those from the upper part and half of the 14 from locality 175. The size range in the upper part is 2.5 to an estimated 60 mm. Two immature valves from locality 175 (length 32 mm) are more elongate and have a less arcuate ventral margin than others of the same size collected at other localities. A right valve, the only specimen from locality 177e, is unique in having practically all the ribs divided. The sample shows a marked range of variation in the ratio of height to length, less so for mature specimens.

This anadarine is a large representative of a group characterized by a strongly arcuate ventral margin, and its left valve is strongly noded. The left valve of *A. istmica* (length 41) is unknown. The right valve, however, is indistinguishable from Canal Zone valves of the same size. The anterior and posterior ribs, and median ribs near the ventral margin, are divided on the type, but not on a USNM valve (USGS 10346). *A. marksi* (Olsson, 1964, p. 27, pl. 2, fig. 8, pl. 3, figs. 2, 2a, length 46 mm; middle Miocene, Ecuador) has weakly noded ribs on the left valve. It is considered to be a subspecies of *A. actinophora*. Gardner realized that her *A. strebla* (Gardner, 1926–47, p. 33, pl. 8, figs. 1, 2, 1926, length 45.5 mm; Shoal River formation, Florida) is related to *A. actinophora*. Its posterior end is more pointed and the ribs of the left valve are weakly noded.

Occurrence: Middle and upper parts of the Gatun formation (middle Miocene). Middle part, eastern area, locality 155b. Upper part, eastern area, localities 163, 172, 173, 174, 175, 176a, 177, 177b, 177d, 177e, 178. Deposits of middle Miocene age, Costa Rica, Venezuela. Tubará formation (middle Miocene), Colombia. Limón formation (late Miocene) Bocas del Toro area, Panamá.

Anadara (Rasia) lienosa trochala Woodring, n. subsp.

Plate 76, figures 5, 8, 10

Large, elongate (height 57 or 58 percent of length), inequilateral (umbo at about anterior third of length), strongly inflated, posterior margin rounded. Left valve slightly larger than right. Umbo distinctly sulcate. Sculptured with 40 or 41 ribs. Lower half of anterior ribs of left valve divided, others and all of right valve undivided. Ribs of right valve slightly narrower than those of left, except at posterior end. Ribs of left valve moderately noded, except at posterior end; those of right valve weakly noded. Concentric threads, of regular or irregular spacing, conspicuous in spaces between ribs. Cardinal area wide; six paired ligament grooves, and an additional anterior limb in middle of series and two additional posterior limbs at upper end of series.

Length 67.6 mm, height 38.6 mm, diameter 21.6 (type, right valve). Length 68.2 mm, height 39.6 mm, diameter 21.3 mm (paratype, left valve).

Type: USNM 646763; paratype, USNM 646764.

Type locality: 175 (USGS 8410, Cuts on north [west] side of French Canal [East Diversion], Mount Hope, Canal Zone), upper part of Gatun formation.

The upper part of the Gatun formation at locality 175 yielded a right valve and a left valve, which can be paired, of the largest and most elongate of the species of the subgenus *Rasia* in the faunas under consideration.

The general plan is that of *Anadara lienosa lienosa* (Say) and its living descendant *A. lienosa secticostata* (Reeve), also known as *A. floridana* (Conrad). The upper part of the posterior margin of both subspecies is truncated, whereas the entire posterior margin of *A. lienosa trochala* is rounded. To be sure, the Gatun sample is meager. Two left valves and a right (maximum length 70 mm) of *A. lienosa trochala* are in a collection from strata of middle Miocene age in the Tehuantepec area of México (USGS 7251). Unlike the

Gatun shells, the ribs, except the posterior ones, are divided on the lower third to lower half of the valves, depending on the size. The nominate subspecies itself occurs in the Agueguexquite formation of the Tehuantepec area (Perrilliat Montoya, 1960, p. 14, pl. 1, figs. 1, 2; length 95 mm). If the Agueguexquite formation is of middle Miocene age, the nominate subspecies is a Caribbean migrant in southeastern United States, where it is unknown earlier than late Miocene.

A. floridana, that is, *A. lienosa secticostata*, is the type of the subgenus *Sectiarca* (Olsson, 1961, p. 97).

Occurrence: Upper part of Gatun formation (middle Miocene), eastern area, locality 175. Middle Miocene deposits, Tehuantepec area, México.

Group of auriculate species

Anadara (Rasia) cf. A. emarginata (Sowerby)

Plate 77, figures, 1, 2

Small, elongate (height 64 percent of length), very inequilateral (umbo almost at anterior fourth of length), strongly inflated, auriculate. Ventral margin sloping downward toward posterior end, slightly insinuated. Umbo sulcate. Sculptured with 30 ribs. Median ribs narrower than space between them. Anterior ribs and lower part of anterior median ribs weakly divided. Concentric threads between ribs greatly subdued. Anterior ribs weakly noded, median ribs almost smooth, posterior ribs, as usual, smooth. Cardinal area very narrow; posterior limb of a ligament groove only.

Length 20.9 mm, height 13.4 mm, diameter 6.3 mm (figured specimen).

A small, presumably immature (and therefore not named), left valve, from the upper part of the Gatun formation in the western area, is the only auriculate anadarine. It has no fossil or living allies in the Caribbean region, but is allied to the living eastern Pacific *Anadara emarginata* (Sowerby) (Maury, 1922, p. 23, pl. 2, figs. 5, 10; Olsson, 1961, p. 91, pl. 8, figs. 6, 6a). Although the number of ribs is the same or about the same, the posterior ribs of the living species are wider than those of the Gatun fossil and the anterior and median ribs are noded. A. *emarginata* reaches a length of almost 50 mm.

The slight insinuation of the ventral margin of the Gatun fossil indicates a gape. An exceptional paired right and left valve of *A. emarginata* (USNM 716408; Santa Elena, Ecuador; length 32.5 mm) has a distinct gape and extraordinarily narrow median ribs in line with the gape. Its six ligament grooves are bent, rather than angulated, a little behind the umbo.

The byssus of immature and mature *A. auriculata*—that is, *A. notabilis*, a western Atlantic auriculate species—was described by Perry (1940, p. 29, pl. 1, figs. 6a, 6b), and her figure 6a shows the mature byssus. She was mistaken, however, in mentioning a byssal notch.

Occurrence: Upper part of Gatun formation (middle Miocene), western area, locality 184.

Group of short species

Many species show gradations between the arbitrarily divided groups of elongate and short species. The early Tertiary species of both groups in the faunas under consideration are small.

Anadara (Rasia) species

Small, short (height about 78 percent of length), very inequilateral (umbo a little behind anterior fourth of length). Sculptured with about 24 undivided ribs, about twice as wide as space between them, except at anterior and posterior ends. Cardinal area inaccessible.

Length (practically complete 14.1 mm, height (incomplete) 9 mm (estimated restored height 11 mm), diameter 6 mm.

This unnamed species is represented in the marine member of the Bohio(?) formation by two poorly preserved right valves, the larger incomplete and the other very small (length 5 mm). The ribs of the larger valve are wide for the size of the shell.

Occurrence: Marine member of Bohio(?) formation (late Eocene), locality 40d.

Anadara (Rasia) lita Woodring, n. sp.

Plate 70, figures 1, 2, 6, 13

Small, short (height 77 to 79 percent of length), inequilateral (umbo near anterior third of length), strongly inflated. Umbo slightly sulcate. Sculptured with 22 to 24 ribs. At early stage ribs about as wide as space between them, later a little narrower than space. Ribs of right valve weakly or faintly noded; a few near anterior end weakly divided near ventral margin on type. Ribs of left valve strongly noded, except those on posterior area. Cardinal area wide for size of shell; a pair of ligament grooves and an additional posterior limb on type.

Length (not quite complete) 18 mm, height 14.2 mm, diameter 7.5 mm (type).

Type: USNM 646695; paratype 646854.

Type locality: 42d (USGS 18837, Barro Colorado Island, northern part of island, stream heading west of Miller Trail near Miller 17, about 100 meters above mouth, Canal Zone), Bohio formation.

The upper part of the Bohio formation on Barro Colorado Island yielded two right and four left valves of *Anadara lita*. A more elongate right valve (length 10.1 mm, height 6.6 mm) from the same locality is doubtfully referred to it.

A. mississippiensis (Conrad) (Sheldon, 1916, p. 32, pl. 7, figs. 12–16, as *Arca lesueuri* (Dall); Byram marl, Mississippi) is more elongate; the ribs of the left valve

are strongly noded and divided, whereas those of the right valve are weakly or faintly noded and undivided, or only the anterior ribs are divided. [*Arca mississippiensis* Conrad, 1847, is not a secondary homonym of *Byssoarca mississippiensis* Conrad, 1840. Therefore Dall's substitute name, *Scapharca lesueuri* (Dall, 1890–1903, p. 643, 1898), is not justified].

Anadara meroensis (Olsson) (1931, p. 39, pl. 2, figs. 2, 3, 5, 6; Heath formation, Perú) also is more elongate and its ribs are divided, as well as narrower and more numerous than those of *A. lita*.

Occurrence: Bohio formation (late Oligocene), locality 42d.

Anadara (Rasia) athroa Woodring, n. sp.

Plate 72, figures 4, 6, 8

Of medium size, moderately to distinctly short (height 67 to 76 percent of length), very inequilateral (umbo a little behind anterior fourth of length). Sculptured with 34 to 39 (generally 37 to 39) closely spaced, weakly to strongly noded, undivided ribs. Cardinal area moderately narrow, not completely exposed.

Length 37.9 mm, height 26.5 mm, diameter 12 mm (type). Length 45.5 mm, height 31.8 mm, diameter 16 mm (largest specimen).

Type: USNM 640716.

Type locality 116a (USGS 20956, East bank of Panama Canal at Canal station 1870, near Paraiso, Canal Zone), La Boca formation.

The collections from the La Boca formation contain 29 valves of this species, characterized by the large number of closely spaced, weakly to strongly noded ribs. Most of them, embedded in crumbly, pebbly sandstone, are fragile. The largest specimen is poorly preserved. Two small, incomplete valves from the transition zone between the Culebra and La Boca formations are doubtfully identified as *Anadara athroa*.

No close ally is recognized.

Occurrence: Culebra formation (early Miocene), locality 111a (identification doubtful). La Boca formation (early Miocene), localities 116, 116a.

Anadara (Rasia) sechurana (Olsson)

Plate 79, figures 1–6, 8

Arca (*Diluvarca*) *sechurana* Olsson, Bull. Am. Paleontology, v. 19, no. 68, p. 67, pl. 4, fig. 1, 1932 (Miocene, Perú).

Of medium size, *Lunarca*-like in outline. Moderately short to very short (height 70 to 87 percent of length), inequilateral (umbo at about anterior third of length), moderately to strongly inflated. Left valve slightly larger than right. Umbo of smallest valves distinctly sulcate. Posterior margin rounded to obliquely truncated. Anterior part of ventral margin of smallest valves (length 1.5 to 7 mm) sloping more steeply than at later stage. Sculptured with 31 to 35 ribs of varying width and spacing, generally wider than space between them. Ventral part of few anterior ribs on three right and three left valves divided by shallow groove; faint trace of groove on a few others; otherwise ribs undivided. Ribs of left valve generally moderately or weakly noded; those of right valve smooth or faintly noded. Cardinal area very narrow to very wide; ligament grooves variable: an unpaired anterior and posterior limb; or as many as three posterior limbs and no anterior ones; or one to four (generally one or two) paired grooves, bent rather than angulated, and one or two additional posterior limbs.

Length 35.8 mm, height 27.6 mm, diameter 10.2 mm (figured left valve). Length 38.4 mm, height 30.4 mm, diameter 10.8 mm (largest specimen).

Type: Paleontological Research Inst. 2175.

Type locality: Punta Picos, Tumbes Dept., Perú, upper part of Zorritos formation.

Three hundred and fifty specimens of *Anadara sechurana* from the Gatun formation, including eight that are articulated, are available. All except five were found in the lower part of the formation, 175 at locality 138c. The exceptions occur in the middle part, three of them near the base of that part.

This species is widely variable in almost every diagnostic feature: outline, inflation, width and spacing of ribs, and width of cardinal area and arrangement of ligament grooves. Relatively elongate (pl. 79, fig. 5) and sharply truncated (pl. 79, fig. 8) valves, however, are rare, and so are those that have a very wide cardinal area (pl. 79, fig. 4).

No closely comparable fossil or living species is recognized. *A transversa* (Say) (Sheldon, 1916, p. 47, pl. 11, figs. 4–6), which ranges from Massachusetts to Florida and the Gulf of Mexico, is less *Lunarca*-like.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, localities 137a, 138, 138a, 138b, 138c, 138d, 138f, 138g. Middle part, eastern area, localities 139g, 144, 144a. Upper part of Zorritos formation and Montera formation (both middle Miocene), Perú.

Anadara (Rasia) fissicosta (Spieker)

Plate 78, figures 1–6

Arca (*Scapharca*) *fissicosta* Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 102, pl. 5, fig. 11, 1922 (Miocene, Perú).

Of medium size, almost invariably *Lunarca*-like in outline. Moderately short to very short (height 70 to 91 percent of length, generally 78 to 84), very inequilateral (umbo at about anterior fourth of length), moderately inflated. Left valve larger than right. Umbo sulcate. Posterior margin rounded to obliquely subtrun-

cated. Sculptured with 32 to 45 (generally 38 to 45) narrow, closely spaced ribs, generally wider than space between them. Faint trace of median groove on few anterior ribs of two right valves, otherwise ribs undivided. Ribs of left valve almost invariably strongly and closely noded, exceptionally moderately noded on some small valves; those of right valve smooth or faintly noded. Cardinal area narrow to moderately narrow; one to three (generally one) paired ligament grooves, generally bent, exceptionally angulated, and an additional posterior limb; or no paired grooves and only a posterior limb.

Length: 29.5 mm, height 23.8 mm, diameter (both valves) 21.4 mm (figured articulated specimen). Length 36.6 mm, height (not quite complete) 29 mm (estimated restored height 32 mm), diameter 15.5 mm (largest specimen, figured).

Type: USNM 562365.

Type locality: Quebrada Zapotal, Zorritos area, Tumbes Dept., Perú, lower part of Zorritos formation.

Anadara fissicosta, like *A. sechurana*, is abundant in the lower part of the Gatun formation and rare in the middle part. Two of the 92 specimens, 10 of which are articulated, were collected from strata near the base of the middle part: a minute right valve and the illustrated relatively elongate left (pl. 78, fig. 2). These fossils range in length from 2 to 36.6 mm. The largest has also the widest cardinal area (pl. 78, figs. 1, 3). Two poorly preserved specimens from the upper member of the Alhajuela formation are listed as *Anadara* cf. *A. fissicosta*.

It is noteworthy that both short anadarines in the Gatun formation are Peruvian species. Those two species are allied. *A. fissicosta* is distinguished by its generally higher rib count and especially by the almost invariable strong noding of left-valve ribs; it also runs smaller and shorter. To be sure, the rib count overlaps in the two species. Nevertheless some 80 percent of the shells of *A. fissicosta* have a count of 38 to 45. A total of 15 left valves, all of moderate or small size, have a count of 32 to 37 (seven from locality 138c, four locality 138d, three locality 138f, and one locality 139c). That from locality 139c (pl. 78, fig. 2) has the lowest ratio of length (70 percent). It resembles in a general way *A. perplura* (Woodring, 1925, p. 44, pl. 4, fig. 7; Bowden formation, Jamaica), which is more inflated and has wider ribs.

In Panamá *A. fissicosta* reaches a slightly larger size than in Perú. A few anterior ribs on the type, a right valve, are divided near the ventral margin. Two right valves from Panamá (locs. 138c and 138g) show a faint trace of a median groove on a few anterior ribs, but the difference in that feature is of no taxonomic significance. No Peruvian left valve is available.

Perhaps too many other names have been proposed for short anadarines in the Zorritos formation of Perú: *A. zapatolensis*, *A. singewaldi*, and *A. singewaldi doma* (Spieker, 1922, p. 101, pl. 5, fig. 10; p. 103, pl. 5, figs. 12, 13; p. 106, respectively), and *A. spiekeri* (Olsson, 1932, p. 65, pl. 2, figs. 2, 3, 6). The anadarines that bear those names are smaller than *A. fissicosta* and like that species show a considerable range in outline. Their rib count is 31 to 36 as compared with 39 for the single Peruvian *A. fissicosta*. (The 50 count cited for *A. singewaldi doma* evidently is a typographic error for 30, actually 31.)

Comparable short anadarines occur in early and middle Miocene formations in Venezuela: *A. zuliana* and the synonymous *A. zuliana maracaibensis* (H. K. Hodson, in Hodson, Hodson, and Harris, 1927, p. 4–5, pl. 4, figs. 7–11, and *A.* cf. *A. spiekeri* (Jung, 1965 p. 432, pl. 53, figs. 6, 7).

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, localities 136, 136a, 137, 137a, 138a, 138b, 138c, 138d, 138f, 138g. Middle part, eastern area, localities 139b, 139c. Lower part of Zorritos formation (early Miocene), Perú.

Group of subrounded species

The group of subrounded species is not represented in the faunas under consideration. It is typified by *Anadara pennelli* (Gabb) (Pilsbry, 1922, p. 403, pl. 39, figs. 3, 4), which is abundant in the Cercado formation of the Dominican Republic. That species has seven synonyms, including *A. tolepia* (Dall, 1890–1903, p. 649, pl. 33, figs. 7, 8, 1898; Miocene, Dominican Republic), *A. arthurpennelli* (Maury, 1917, p. 178, pl. 29, figs. 9, 10; Miocene, Dominican Republic), and *A. microtera* (Woodring, 1925, p. 49, pl. 5, figs. 12, 13: Miocene, Jamaica).

Subgenus Tosarca Noda

Noda, Palaeontological Soc. Japan, Trans. and Proc., no. 59, p. 104, 1965.

Type (orthotype): *Anadara* (*Tosarca*) *tosaensis* Noda, Pliocene, Japan.

Tosarca is used for subquadrate anadarines, which are further characterized by a wide umbonal area.

Anadara (Tosarca) campta Woodring, n. sp.

Plate 73, figure 8

Of medium size, very short (height 81 percent of length), very inequilateral (umbo at about anterior fourth of length), umbonal area wide and inflated. Outline subquadrate, anterior margin rounded, posterior margin obliquely truncated. Posterior umbonal slope subangulated, posterior area slightly concave. Left valve sculptured with about 33 moderately noded ribs, slightly wider than space between them. Ribs divided, except on posterior area. Right valve unknown. Cardinal area

moderately wide; traces of three posterior limbs of ligament grooves visible.

Length (practically complete) 34.6 mm, height 28 mm, diameter about 17 mm (type).

Type: USNM 646719.

Type locality: 101h (USGS 23652, Panama Canal, west side of Las Cascades Reach, Canal stations 1608 to 1612 plus 23 meters, near top of Canal cliff, Canal Zone), La Boca formation.

Though little shell material is left on two left valves of *Anadara campta* from the La Boca formation, the outline and ribbing, except the ribbing on part of the posterior area, are well shown on the larger (the type) and the cardinal area is exposed on the smaller.

The ribs of this species are narrower and less strongly noded than those of the left valve of *A. santarosana geraetera* (Gardner, 1926–47, p. 31, pl. 7, figs. 1, 2, 1926; Chipola formation, Florida) and the median ribs are divided.

Occurrence: La Boca formation (early Miocene), locality 101h.

Anadara (Tosarca) cf. A. tectumcolumbae (Maury)

Plate 73, figure 3

Of medium size, very short (height 80 to 81 percent of length), inequilateral (umbo at anterior third of length). Outline subquadrate, anterior margin rounded, posterior margin obliquely truncated. Posterior umbonal slope subangulated, posterior area slightly concave. Sculptured with 30 or 31 ribs, slightly wider than space between them. Anterior ribs faintly divided, weakly noded at least on left valve. Cardinal area narrow, corroded.

Length 36.5 mm, height (not quite complete) 25.5 mm (estimated restored height 30 mm), diameter about 13 mm (figured specimen).

This species occurs in the upper member of the Alhajuela formation. It is most similar to *Anadara tectumcolumbae* (Maury, 1925, p. 52, pl. 7, fig. 4; G. D. Harris in Waring, 1926, p. 109, pl. 20, figs. 1, 2, as a variety; Savaneta glauconitic sandstone member of Springvale formation, Trinidad), which is larger (length 40 to 60 mm), shorter (height 85 to 88 percent of length), and has more ribs (35 to 39).

The 11 specimens are molds, or almost entirely molds. That illustrated is a latex cast.

Occurrence: Upper member of Alhajuela formation (early Miocene), localities 85, 85a, 89, 90a.

Anadara (Tosarca) veatchi veatchi (Olsson)

Plate 78, figures 7–11

Arca Veatchi Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 139 (assigned to subgenus *Scapharca*), pl. 23, figs. 1–3, 1922 (Miocene, Panamá).

Arca (*Scapharca?*) *veatchi* Olsson, Anderson, California Acad. Sci. Proc. 4th ser., v. 18, no. 4, p. 150, 1929 (Miocene, Colombia).

Arca (Scapharca) *veatchi* Olsson, Barrios, Colombia Servicio Geol. Nac., Bol. Geol., v. 6 nos. 1–3 (Informe 1082), p. 230, pl. 1, figs. 4, 5, 1960 (Miocene, Colombia).

Large, *Cardium*-like, very short (height almost equal to length), inequilateral (umbo at about anterior third of length), umbonal area wide and inflated. Outline subquadrate, anterior margin broadly rounded, posterior margin slightly rounded. Anterior part of ventral margin of smallest shells (length 10 to 12.7 mm) sloping more steeply than at later stage. Left valve slightly larger than right. Umbo sulcate. Sculptured with 40 to 48 (generally 42 to 45) narrow, closely spaced ribs; as usual, anterior and posterior ribs wider and more widely spaced than elsewhere. Ribs of right valve faintly noded or smooth, except for stronger noding on anterior ribs; anterior and posterior ribs divided by one to three grooves (generally one). Ribs of left valve strongly and closely noded, except for weaker noding on anterior and posterior ribs; anterior and posterior ribs, and ventral part of median ribs, divided by one to three grooves. Concentric threads between ribs, alined with nodes, generally conspicuous. Cardinal area narrow; one to two pairs of ligament grooves and an additional posterior limb.

Length 54.5 mm, height 49.2 mm, diameter 20.5 mm (largest figured specimen). Length (incomplete) 55.2 mm (estimated restored length 63 mm), height 56.3 mm, diameter (both valves, reduced by crushing) 34 mm (largest specimen).

Type: Paleontological Research Inst. 21201.

Type locality: Water Cay, Bocas del Toro area, Panamá Limón formation.

This handsome species was the first of its lineage to be named. Though it occurs in the middle Miocene of Panamá, Colombia, and Venezuela, and in the late Miocene of Panamá, it left no descendants in the western Atlantic Ocean. The lineage was continued in the Pliocene of Ecuador by *Anadara hopkinsi* (Pilsbry and Olsson, 1941, p. 51, pl. 11, figs. 1, 2), which is larger than *A. veatchi* (length 93 mm), less distinctly noded, and its ribs are divided by more numerous grooves, and servives in the eastern Pacific Ocean: *A. hyphalopilema* (Campbell, 1962; off Guaymas, México). The living species is larger than *A. veatchi* (length and height 60 mm) and, like *A. hopkinsi*, its ribs are divided by more numerous grooves and it is less distinctly noded. It has a remarkable feltlike periostracum.

A. veatchi veatchi occurs throughout the Gatun formation but is nowhere abundant. Eight of the 23 specimens are immature and two are represented only by fragments.

The ribs of the only available left valve from Colombia are moderately noded. A Venezuelan subspecies—*A. veatchi matarucana* (H. K. Hodson, in Hodson, Hodson, and Harris, 1927, p. 10, pl. 3, figs. 4, 5; Jung, 1965, p. 429, pl. 52, figs. 5, 6, 9; Caujarao and Cantaure formations)—has an ill-defined, rounded posterior umbonal slope.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, locality 138a. Middle parts, eastern area, localities 147b, 147g, 155, 157. Upper part, eastern area, localities 174, 175, 176a, 178; western area, localities 182a, 183, 184, 185. Tubará formation (middle Miocene), Colombia. Limón formation (late Miocene), Bocas del Toro area, Panamá.

Anadara (Tosarca) species

Two immature left valves from the middle part of the Gatun formation have a length of 3 and 9 mm. The umbo of the smaller is faintly sulcate and of the larger not sulcate. The anterior part of the ventral margin slopes less steeply than that of the smallest valves of *Anadara veatchi veatchi*. They are sculptured with 32 or 36 closely spaced, narrow ribs, which are not quite as strongly noded as those of left valves of *A. veatchi veatchi*.

Perhaps this anadarine is an unnamed species that occurs in middle Miocene deposits in southeastern Costa Rica (USGS 5882c) and northeastern Colombia (USGS 11323, 11334, and other localities). It reaches a length of 45 mm and has 30 to 32 ribs. At a mature stage the ribs are more widely spaced than those of *A. veatchi veatchi*.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, localities 144c, 155c.

Subgenus Grandiarca Olsson

Olsson, Mollusks of the tropical eastern Pacific; Panamic-Pacific Pelecypoda, p. 93, Paleontological Research Inst., 1961.

Type (orthotype): *Arca grandis* Broderip and Sowerby, living, eastern Pacific Ocean.

The sole surviving species, the type species, and also the Tertiary species now assigned to *Grandiarca* have been referred to the genus *Senilia* (Gray, 1842, p. 81, genus without species; type (orthotype and tautotype, Gray, 1847, p. 198): *Arca senilis* Linné, living, west coast of Africa) by several authors (Mörch, 1861, p. 205; Lamy, 1907, p. 262; Woodring, 1928, p. 58, 71, 79–80; Olsson, 1932, p. 71–76). Reinhart's (1935, p. 41) objection to that arrangement was justified, but his assignment of them to his *Larkinia* (Reinhart, 1935, p. 41; type (orthotype and tautotype): *Anadara larkinii* (Nelson) [*Arca larkinii* Nelson]; Miocene, Perú) was hardly an improvement. *Anadara larkinii* (Olsson, 1932, p. 75, pl. 2, figs. 1, 4, 5) is a remarkable species; it combines a narrow umbo, subtrigonal outline, angular posterior umbonal slope, flattened, barely concave posterior area, coarsely noded ribs, and very wide cardinal area; in addition it is equivalve. The only resemblance to *Grandiarca* lies in the coarsely noded undivided ribs, very wide cardinal area, and equal size of the valves. *A. larkinii* has no known predecessors. It survived until early Pliocene time in Ecuador (Pilsbry and Olsson, 1941, p. 53). A closely related new species occurs in the early Pliocene El Salto formation of Nicaragua (USGS 3094).

Anadara grandis lives in mud or muddy sand bordering mangrove swamps, as does *Senilia senilis* (Yonge, 1955, p. 202). Great piles of the big thick shells of *A. grandis* may be seen along the brackish-water lower course of Río Tumbes in northern Perú, where, as elsewhere, it is used for food. Río Tumbes is the southern limit of *A. grandis* and of mangrove swamps on the Pacific coast of South America (Olsson, 1961, p. 94).

The species of *Grandiarca* in the Tertiary Caribbean province are found in brackish-water, mixed brackish-water and marine, and marine assemblages; that is, they evidently tolerated a considerable range of salinity. Though they occur in the western Atlantic part of the province in Jamaica, Haiti, the Dominican Republic, Anguilla, Tobago, Trinidad, Venezuela, Colombia, Panamá, and Costa Rica, none survives in the western Atlantic Ocean, and only the type species survives in the eastern Pacific Ocean. The age range in the Caribbean part of the province is early Miocene to early Pliocene; in the Pacific part early Miocene to the present time.

Two groups of *Grandiarca* are represented in the Tertiary Caribbean province: a group of small or relatively small species, typified by *Anadara chiriquiensis*, and a group of large species typified by *A. grandis*.

Group of small species

Anadara (Grandiarca) chiriquiensis chiriquiensis (Gabb)

Plate 72, figures 17, 18

Arca chiriquiensis Gabb, Acad. Nat. Sci. Philadelphia Proc., 1860, p. 567, 1861 (Miocene, Panamá). Pilsbry. Acad. Nat. Sci. Philadelphia Proc., v. 73, p. 405, pl. 40, figs. 2–6, pl. 41, figs. 1–3, 1922 (Miocene, Panamá, Dominican Republic).

Scapharca (Scapharca) chiriquiensis (Gabb), Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 4, 642, 1898 (Miocene, Panamá, Dominican Republic). Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 59, pl. 2, fig. 2, 1925 (Miocene, Dominican Republic).

Scapharca chiriquiensis (Gabb), Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 174, pl. 28, fig. 2, 1917 (Miocene, Dominican Republic). Woodring, in Woodring, Brown, and Burbank, Geology of the Republic of Haiti, Republic Haiti Geol. Survey, p. 191, pl. 16, figs. 6–8, 1924 (Miocene, Haiti).

Not *Arca (Scapharca) chiriquiensis* Gabb, Tucker and Wilson, Bull. Am. Paleontology, v. 18, no. 65, p. 4, pl. 1, figs. 1, 5, 1932 (Miocene, Florida), = *Arca (Anadara) sellardsi* Mansfield.

Arca websteri Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 62, p. 488, 1910 (Miocene, Haiti). Not *Arca websteri* Forbes, Tertiary fluvio-marine formation of the Isle of Wight: Geol. Survey Great Britain and Mus. Practical Geol. Mem., p. 62, 68, explanation of plate, pl. 3, figs. 8, 8a, 1856.

Arca chiriquiensis websteri Pilsbry, Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 73, p. 406, pl. 41, fig. 4, 1922 (Miocene, Haiti).

Scapharca chiriquiensis websteri (Pilsbry), Woodring, in Woodring, Brown, and Burbank, Geology of the Republic of Haiti, Republic Haiti Geol. Survey, p. 201, pl. 16, figs. 9–11, 1924 (Miocene, Haiti).

Scapharca chiriquiensis bolivari Weisbord, Bull. Am. Paleontology, v. 14, no. 54, p. 8, pl. 1, figs. 4–9, 1928 (Miocene, Colombia).

Arca (Senilia) chiriquiensis bolivari (Weisbord), Barrios, Colombia Servicio Geol. Nac. Bol. Geol., v. 6, nos. 1–3 (Informe 1082), p. 229, pl. 1, fig. 2, 1960 (Miocene, Colombia).

Anadara sp. aff. *A. chiriquiensis bolivari* (Weisbord), Hedberg, Geol. Soc. Am. Bull., v. 48, p. 2,011, pl. 8, figs. 1, 1a, 2, 1937 (Miocene, Venezuela).

?Arca septifera Grzybowski, Neues Jahrb., Beilage-Band, v. 12, p. 633, pl. 18, figs. 2, 2a, 1899 (Miocene, Perú).

?Arca (Anadara) septifera Grzybowski, Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 117, pl. 6, figs. 5, 6, 1922 (Miocene, Perú).

?Arca (Senilia) chiriquiensis septifera Grzybowski, Olsson, Bull. Am. Paleontology, v. 19, no. 68, p. 73, pl. 1, fig. 5, 1932 (Miocene, Perú).

Arca obesiformis Grzybowski, Neues Jahrb., Beilage-Band, v. 12, p. 633, pl. 18, figs. 3, 3a, 1899 (Miocene, Perú).

Arca (Scapharca) obesiformis Grzybowski, Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 115, pl. 6, figs. 1, 2, 1922 (Miocene, Perú).

Arca (Senilia) chiriquiensis obesiformis Grzybowski, Olsson, Bull. Am. Paleontology, v. 19, no. 68, p. 74, 1932 (Miocene, Perú).

Arca (Scapharca) imporcata Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 113, pl. 5, figs. 19, 20, 1922 (Miocene, Perú).

Arca (Scapharca) crescens Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 116, pl. 6, fig. 34, 1922 (Miocene, Perú).

Arca (Anadara) nelsoni Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 119, pl. 6, figs. 7, 8, 1922 (Miocene, Perú).

Arca (Anadara) toroensis Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 121, pl. 6, figs. 9, 10, pl. 7, fig. 1, 1922 (Miocene, Perú).

Arca (Senilia) chiriquiensis toroensis Spieker, Olsson, Bull. Am. Paleontology, v. 19, no. 68, p. 11, pl. 1, figs. 3, 4, 1932 (Miocene, Perú).

Arca (Anadara) toroensis crassa Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 124, pl. 7, fig. 2, 1922 (Miocene, Perú).

Arca (Anadara) toroensis prolata Spieker, Johns Hopkins Univ., Studies in Geology, no. 3, p. 125, pl. 7, fig. 3, 1922 (Miocene, Perú).

Of medium size, very short (height 86 to 96 percent of length), inequilateral (umbo at anterior third of length), strongly inflated. Posterior margin obliquely subtruncated, extended at ventral end. Sculptured with 31 or 32 ribs, wider than space between them. Anterior and median ribs of left valve strongly to moderately noded. Ribs of available right valves corroded. Cardinal area very wide for size of shell; at least three paired ligament grooves.

Length 42.2 mm, height 37.6 mm, diameter 23 mm (figured corroded specimen).

Type: The specimen illustrated by Pilsbry (1922, pl. 40, fig. 2; see explanation of his plate), Acad. Nat. Sci. Philadelphia 2724.

Type locality: Río Changuinola district, Bocas del Toro area, Panamá, deposits of middle Miocene age.

Anadara chiriquiensis chiriquiensis is identified in collections from two localities in the Culebra formation: a left valve from locality 103 (pl. 72, fig. 18), where it is associated with *Crassostrea*, and 25 corroded valves from locality 110, one of which is illustrated (pl. 72. fig. 17). Locality 110 is in the transition zone between the Culebra and Cucaracha formations. The fossils in that zone represent a mixed brackish-water and marine association.

This greatly overnamed anadarine is variable in outline. Eight names have been proposed for specimens from the Zorritos formation of Perú. All occur in the upper part of the formation and one in both upper and lower parts. Should population studies be undertaken, some of the names may be found useful.

The type and paratype lots, now consisting of eight specimens, were collected by John Evans (1861, p. 48) during his exploration for coal (lignite) in extreme northwestern Panamá. He found fossils ("cardium, cerithium, arca, obeliscus, pinna, solen, natica, &c.") in strata ovelying coal-bearing rocks on two tributaries of Río Changuinola. Gabb gave to Dall three articulated specimens from the original lot (USNM 13229). The paratype illustrated by Pilsbry (1922, plate 40, figure 3) (length 73 mm) is the largest so far recorded. Orcutt collected a fine large left valve in the Central Plain of Haiti (USNM 496471, length 60 mm). The recorded rib count ranges from 27 to 32.

Arca websteri was based on a relatively elongate Haitian form. The name is a junior homonym.

Arca anguillana (Cooke, 1919, p. 127, pl. 5, figs. 10a, 10b; Anguilla formation, Anguilla) is tentatively classified as a small subspecies of *Anadara chiriquiensis* (length 31.3 mm). The type, a right valve, is the only specimen. It has the outline of the typical form of the nominate subspecies, but the ribs are more closely spaced and more finely noded than those of the typical form. A larger sample is desirable.

Anadara garitensis (Olsson, 1932, p. 75, pl. 1, fig. 1), which occurs in the late Miocene Tumbes formation of Perú, is the largest and highest of the group of small species of *Grandiarca* (length 78 mm, height 80 mm). It is sculptured with about 24 ribs.

Occurrence: Culebra formation (early Miocene) localities 103, 110. Deposits of middle Miocene age, Bocas del Toro area, Panamá. Lower and upper parts of Zorritos formation (early and middle Miocene, respectively), Perú. Thomonde, Maïssade, and Las Cahobas formations (early and middle(?) Miocene), Haiti. Middle(?) Miocene part of Santa Inés group, Venezuela. Deposits of middle or late Miocene age, Dominican Republic. Deposits of middle Miocene age, Columbia.

Anadara (Grandiarca) balboai (Sheldon)

Plate 72, figures 10, 11, 15

Arca dalli Brown and Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 64, p. 510, pl. 24, fig. 4, 1913 (Miocene, Canal Zone). Not *Arca* (*Macrodon*) *dalli* E. A. Smith, 1885.

Arca balboai Sheldon, Palaeontographica Americana, v. 1, no. 1, p. 69, 1916. Substitute name for *Arca dalli* Brown and Pilsbry.

Scapharca (*Scapharca*) *balboae* (Sheldon), Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 65, 1925 (Miocene, Canal Zone).

Arca invalida Hanna, California Acad. Sci. Proc., 4th ser., v. 13, no. 10, p. 157, 1924. Substitute name for *Arca dalli* Brown and Pilsbry.

Of medium size, moderately short to very short (height 73 to 94 percent of length, generally 83 to 89), inequilateral (umbo at anterior third to almost fourth of length), strongly inflated, equivalve. Posterior margin slightly rounded to obliquely subtruncated, extended or broadly rounded at ventral end. Sculptured with 27 to 37 (generally 31 to 33) ribs, slightly to decisively wider than space between them. Anterior ribs of right valve moderately to strongly noded, others weakly noded to smooth. Ribs of left valve moderately to strongly noded. Cardinal area moderately narrow to moderately wide; two paired ligament grooves and an additional posterior limb.

Length 38 mm, height 29.5, diameter 19 mm (larger figured specimen). Length 38.2 mm, height 28 mm, diameter about 15 mm (largest specimen).

Type: Acad. Nat. Sci. Philadelphia 3831, now lost or misplaced.

Type locality: Bottom of Culebra Cut, near Tower N, Canal Zone, lignitic clay below "*Pecten* bed;" that is, Las Cascadas Reach, Gaillard Cut, near Canal station 1600, La Boca formation.

Anadara balboai occurs in the Culebra and La Boca formations (16 and 70 specimens, respectively, three articulated). It is a variable species—variable in outline and spacing of ribs. The greatest variability is shown by well-preserved immature shells from the La Boca at locality 116a. The size range at that locality is 7.7 to 33.3 mm. The specimens from locality 99b are virtual topotypes so far as locality is concerned, but are from a higher level in the La Boca than the type. They are not well preserved. The largest specimens were found in the Culebra formation.

In general features *A. balboai* is similar to *A. chiriquiensis*. It is not only smaller than that species, it also has more slender rib nodes, and its cardinal area is narrower. In fact, for a species of *Grandiarca* the cardinal area is unexpectedly narrow. Perhaps *A. balboai* represents a branch of the *A. chiriquiensis* lineage adapted to an open sea habitat, although at six of the nine localities where it is unequivocally identified, it was collected in association with *Potamides* and *Crassostrea*, both of which prefer brackish water. At those localities, however, also normal marine genera were collected.

This species has not been found elsewhere.

Occurrence: Culebra formation (early Miocene), localities 102 (identification doubtful), 106, 107, 108c, 109, 110a (identification doubtful). La Boca formation (early Miocene), localities 99b, 100a (identification doubtful), 101, 101a, 115b, 116a.

Anadara (Grandiarca) dolaticosta (Pilsbry and Johnson)

Plate 80, figures 6–9, 12

Arca dolaticosta Pilsbry and Johnson, Acad. Nat. Sci. Philadelphia Proc., v. 69, p. 188, 1917 (Miocene, Panamá). Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 73, p. 406, pl. 41, figs. 5, 6, 1922 (Miocene, Panamá).

Moderately large (but not as large as largest *Anadara chiriquiensis*), *Cardium*-like, length and height almost equal, almost equilateral, umbonal area very wide and very inflated. Margins defective. Sculptured with 26 wide ribs, wider than space between them. Ribs of right valve, except a few near dorsal margins, coarsely and strongly noded. Cardinal area wide; three paired ligament grooves and an additional posterior limb.

Length (incomplete) 48 mm (estimated restored length 55 mm), height (incomplete) 49.2 mm (estimated restored height 57 mm), diameter 30 mm (figured specimen from locality 170).

Type: Acad. Nat. Sci. Philadelphia 2738.

Type locality: Same as preceding species.

This remarkable species is represented by a battered, corroded right valve, which clearly was transported and buried some distance from its habitat, or was reworked from older strata. It was found in the middle part of the Gatun formation in the western area.

The type of *Anadara dolaticosta* and another specimen were collected by Evans at the type locality of *A. chiriquiensis*. In 1917 I collected, from middle Miocene strata, 13 specimens, six articulated, at three localities (USGS 8009, 8010, 8011) on Quebrada Schawb (prob-

ably an erroneous transliteration of an Indian name), the first upstream southeastward-flowing tributary of Río Yorkin; that is, on the Costa Rican side of the Costa Rica-Panamá boundary, about 40 km northwest of the type region. The length of the Costa Rican fossils ranges from 12.4 to 57 mm. One of medium size is illustrated (pl. 80, figures 7, 8, 12) to show the outline and the uncorroded ribs. The ribs are narrower than those of the Gatun fossil, but that feature is variable in the Costa Rican sample.

A closely related species, or a subspecies of *A. dolaticosta*, is found in middle Miocene strata on the Pacific side of Panamá in both Darién and Chiriquí Provinces (USGS 8432, and 6513, 6514, 7958, respectively). The ribs of the Pacific form are lower and not as coarsely noded. *A. zorritosensis* (Woods, 1922, p. 112, pl. 18, figs. 5a–5c; Olsson, 1932, p. 74; Zorritos formation, Perú) also is closely related. According to the illustration, the wide ribs are separated by very narrow spaces. It was not represented in the Zorritos collections studied by Spieker (1922) and Olsson (1932).

A. dolaticosta—as noted by Pilsbry and Johnson, a very distinct species—left no descendants.

Occurrence: Middle part of Gatun formation (middle Miocene), western area, locality 170. Middle Miocene deposits, southeastern Costa Rica, northwestern Panamá.

Group of large species

The group of large species of *Grandiarca* embraces the living *Anadara grandis grandis* and its fossil allies, many of which are some 100 mm long. *A grandis grandis* itself is the largest. A massive valve (USNM 3622) has a length of 145 mm and weighs 1.2 kg.

The fossil allies are widespread in the Miocene of the present Caribbean region and there range into the Pliocene. They are subdivided as brackish-water and marine species, or subspecies. Evidence is available that *A. grandis patricia* lived in a brackish-water habitat in the northern part of the Dominican Republic (Maury, 1917a, p. 25; 1922, p. 32), in Trinidad (Rutsch, 1942, p. 221), and in southeastern Costa Rica, where it occurs in strata interbedded with lignite. Though the habitat of the specimens from the Gatun formation is unknown, they did not live with the marine fossils collected at the same locality and are arbitrarily classified as brackish-water. On the contrary, *A. grandis colombiensis* is associated with marine fossils in Colombia, as noted by Anderson (1929, p. 149), Venezuela, and the southwestern part of the Dominican Republic. *A. waringi* also is associated with marine fossils.

A survey of 270 fossil and living USNM specimens is tabulated on page 512. A short, high form of *A. grandis patricia* is recorded from Tobago (Trechmann, 1934, p. 488, pl. 25, figs. 12, 13), but none is available. All of those tabulated, except the articulated specimen from the southwestern part of the Dominican Republic listed as *Anadara* n. sp., are more or less similar in outline, and all are similar in number of ribs and noding of anterior ribs. *A. grandis colombiensis*, as identified, is the most variable of the fossil forms, even at a single locality in Colombia. *A. waringi*, an endemic Trinidad species, is the least variable. It is the smallest, and its median ribs generally are noded. Only one specimen is in collections from the San José calcareous silt member of the Manzanilla formation; the others are from the overlying Montserrat glauconitic sandstone member. (For citations for the species and subspecies see footnotes at end of table).

Anderson (1929, p. 148) commented on the hinge of his *Arca usiacurii* (that is, *Anadara grandis colombiensis*) as compared with that of *Anadara grandis grandis*. Though he emphasized the branching of the teeth near the ends of the hinge of his fossils, that feature is trivial or nonexistent. His illustrations (*Arca usiacurii*, pl. 19, fig. 6, pl. 21, fig. 4; *Arca grandis*, pl. 18, fig. 1) show that the hinge of the fossils is higher. The difference, however, is not consistent. As listed in the table, the hinge of 67 percent of the Colombian fossils that show the hinge, including all of medium size, is higher than that of *Anadara grandis grandis*, but 14 percent, all large valves, resemble the living form in that feature. There is also no consistency in marine forms as compared with brackish-water forms. Nevertheless in the brackish-water group a hinge as high as that of many valves of *A. grandis colombiensis* was observed only on some valves of *A. grandis patricia* from Trinidad. The tendency toward a high hinge and the marine habitat are considered to be justification for the recognition of *A. grandis colombiensis*.

As shown in the table, the age range of the Caribbean fossils is early(?) Miocene to early Pliocene. At three of the four localities in the southwestern part of the Dominican Republic (USGS 8572, 8590, 8760) *A. grandis colombiensis* and *Anadara* n. sp. are associated with *Orthaulax aguadillensis*. Elsewhere that species occurs in formations dated as early Miocene, although, of course, it may have survived later in the Dominican Republic. Marine fossils recently found in the Caparo clay member of the Talparo formation in central Trinidad are of Pliocene age (June, 1969a, p. 85), early Pliocene.

Tertiary and living large species of Anadara, *subgenus* Grandiarca

	Species and subspecies	Age	Number of specimens	Maximum length, in mm	Height in percentage of length	Outline	Number of ribs	Noding of ribs, other than anterior ribs	Height of hinge	Occurrence
Brackish-water species	*Anadara grandis grandis* (Broderip and Sowerby) [1,2]	Pliocene to Holocene	48 (Holocene)	145 (USNM 3622)	76–87	Inequilateral, ventral part of posterior margin slightly to distinctly extended.	23–27	Ventral part of median ribs of some shells irregularly noded.	Low to intermediate	Holocene, Baja California to northern Perú.[2] Pleistocene, Ecuador,[3] Perú.[2] Pliocene, Carmen Island, Gulf of California.[4]
	Anadara grandis patricia (Sowerby) [7]	Early Pliocene	81	94 (103, Maury) [4]	87–96	Inequilateral, ventral part of posterior margin somewhat extended.	24–27	Ventral part of median ribs generally irregularly noded.	Low to high	Caparo clay member of Talparo formation, Trinidad.[5 6]
		Late(?) Miocene	2	133 (British Mus. Nat. History 98047)	90–92	Inequilateral, ventral part of posterior margin somewhat to strongly extended.	25–27	Ventral part of median ribs of some shells noded.	Intermediate	Strata of late(?) Miocene age in valley of Río Yaque del Norte, Dominican Republic.[7 8 9]
		Middle Miocene	1	110±	90±	Inequilateral, ventral part of posterior margin extended	27	Ventral part of median ribs irregularly noded.	Inaccessible	"Carbon Creek," north side of Talamanca Valley, southeastern Costa Rica (USGS 7841).
			1 and a fragment of left valve	88.5, estimated restored 95	90±	do	25	do	Worn and corroded	Middle part of Gatun formation. See following description. Identification doubtful.
Marine species		Late Miocene	2	95±	90±–93±	do	26	do	High	August Town formation, Jamaica (USGS 11203).
			3	80	95–97	do	26–28	Middle and ventral parts of median ribs noded.	do	Cerros de Sal formation, Barahona Province, Dominican Republic (USGS 8742)
	Anadara grandis colombiensis (Weisbord) [10 11]	Middle to late Miocene	56	119	85–100	Very variable. Inequilateral to subequilateral. Posterior part short to long. Ventral part of posterior margin extended to rounded.	23–29	Ventral part of median ribs of some shells noded.	Low (14%), intermediate (19%), high (67%)	Hibáchero, Piojó and Tubará formations (middle Miocene) and Usiacurí formation (late Miocene), Atlántico Dept., Colombia.[10 11] Middle Miocene deposits, Río Sinú-Río San Juan area, Río Atrato area, Colombia (USGS 11555, 11562, 11587, 11654).
			8	94	91–96	Inequilateral to subequilateral, ventral part of posterior margin slightly to moderately extended.	25–27	Median ribs generally noded.	Intermediate	Chiguaje formation (middle Miocene, USGS 24700) and La Vela formation (middle or late Miocene),[12] Falcón, Venezuela.
	Anadara waringi (Maury) [13 14]	Middle Miocene	59	69 (72, Maury) [13]	87–98	Inequilateral, ventral part of posterior margin moderately to strongly extended.	25–27	do	Low	San José calcareous silt member and Montserrat glauconitic sandstone member of Manzanilla formation, Trinidad.[13 14]
	Anadara grandis colombiensis Weisbord)	Early(?) Miocene	8	95±	90±–95	Inequilateral, ventral part of posterior margin somewhat extended.	27–28	Ventral part of median ribs of some shells noded.	Low to high	Azua Province, Dominican Republic (USGS 8570, 8572, 8760)
	Anadara n.sp.		1	111	81	Very inequilateral, posterior margin strongly rounded.	25	Ventral part of median ribs irregularly noded.	Inaccessible	Azua Province, Dominican Republic (USGS 8590).

[1] Maury, 1922, p. 32, pl. 3, fig. 13, as *Scapharca (Scapharca) grandis.*
[2] Olsson, 1961, p. 93, pl. 7, figs. 1, 1a-1c.
[3] Reinhart, 1943, p. 65, as *Anadara (Larkinia) grandis.*
[4] Hanna and Hertlein, 1927, p. 140, as *Arca grandis.*
[5] Maury, 1925, p. 57, pl. 2, fig. 5, as *Scapharca (Scapharca) patricia.*
[6] Rutsch, 1942, p. 214, pl. 8, figs. 1a, 1b, as *Anadara (Larkinia) patricia.*
[7] Sowerby, 1850, p. 52, as *Arca patricia.*
[8] Maury, 1917, p. 173, pl. 27, as *Scapharca patricia.*
[9] Pilsbry, 1922, p. 404, pl. 40, fig. 1, as *Arca grandis.*
[10] Weisbord, January, 1929, p. 5, pl. 1, fig. 1, as *Scapharca grandis colombiensis;* p. 8, pl. 1, figs. 2, 3, as *Scapharca grandis cedralensis.*
[11] Anderson, March, 1929, p. 148, pl. 19, fig. 6, pl. 20, fig. 6, pl. 21, fig. 4, as *Arca (Anadara) usiacurii.*
[12] Hodson, Hodson, and Harris, 1927, p. 7, pl. 7, figs. 1, 4, as *Arca grandis waringi.*
[13] Maury, 1925, p. 58, pl. 3, figs. 2, 5, as *Scapharca patricia waringi.*
[14] Rutsch, 1942, p. 219, pl. 8, figs. 2a, 2b, as *Anadara (Larkinia) waringi.*

Anadara (Grandiarca) grandis patricia (Sowerby)?

Plate 79, figures 12, 13

Large, thick-shelled, height about 90 percent of length, inequilateral (umbo at about anterior third of length). Posterior margin defective, but ventral part apparently extended. Sculptured with 25 ribs, of about same width as space between them. Despite corrosion, irregularly arranged, coarse nodes apparent on ventral part of anterior and median ribs. Cardinal area very wide, corroded. Hinge completely worn away.

Length (incomplete) 88.5 mm (estimated restored length 95 mm), height (incomplete), 67.5 mm (estimated restored height 85 mm), diameter about 40 mm (figured specimen).

The illustrated left valve and a fragment of the posterior ventral part of a smaller left valve were collected at the same locality as *Anadara dolaticosta*. In addition, the collection includes two fragments of *Grandiarca* too incomplete for identification. All these specimens of *Grandiarca* are battered and corroded. Their condition stands in marked contrast to the 14 well-preserved marine species with which they are associated.

Noding of median ribs and distinct extension of the ventral part of the posterior margin is more common in *A. grandis patricia* than in *A. grandis grandis*, although better preservation is needed for satisfactory identification. Perhaps the assumed habitat influenced the identification.

Arca patricia, described, but not illustrated, by Sowerby, was the first of the *grandis*-like fossils to be named. In 1925 the late L. R. Cox, of the British Museum (Natural History), forwarded a cast of the alleged type, actually lectotype, of that species (12828 of the Register of Geological Society of London Collection). It is a right valve of a much-named small *Anadara* of the subgenus *Rasia*, named *Arca pennelli* by Gabb. (See p. 506 of present account.) Though it was naive to suppose that this is Sowerby's species, I accepted it (Woodring, 1925a). Sowerby was an experienced conchologist. He compared his species with *Arca grandis* and he named it *Arca patricia*. There is nothing patrician about *Arca pennelli*. For these reasons Weisbord (1929, p. 7) was skeptical about the alleged lectotype, and Rutsch (1942, p. 215) rejected it. On the contrary, Anderson (1929, p. 149) proposed a new name, *Arca patriarcha*, for the traditional *Arca patricia*.

Charles Davies Sherborn, the meticulous compiler of the Index Animalium, registered the Heneken collection, which originally included *Arca patricia*, after it was transferred from the Geological Society of London to the British Museum (Natural History). On page 385 of the original of the Register of the Geological Society of London Collection, Foreign Series, he wrote the following warning, published in German translation by Pflug (1961, p. 8):

> Sowerby certainly drew from these specimens; none of the types were marked; the loose papers have been shifted about; identification has in many cases been difficult, so the searcher must in every case verify my conclusions and accept or reject as he thinks proper.

It seems strange that Sherborn identified the small species as *Arca patricia*, although, as a matter of fact, he added two question marks in the Register.

Two left valves of *Arca patricia* are in the collections of Caribbean fossils in the British Museum (Natural History) (98047 in Register 19 of Additions to Department of Paleontology, entered in 1879). A strip of paper glued to the better of the two reads "Miocene, St. Domingo." The Register entry reads "8 bivalves, Miocene, St. Domingo, Col. Heniker [Heneken] Collection." Unless grounds are apparent for doubting the authenticity of the Register data, this lot qualifies as the type lot, or perhaps what is left of the type lot. The better of the two valves has a length of 124 mm, the other, which is much worn, is a little larger, 133 mm.

According to Col. Heneken's account (1853, p. 128), he found "large Conchifera of the family of Arcacea in great abundance; they cover the surface in patches of compact seams" on "the sandstone plain of Savaneta [Sabaneta]," on the south side of Río Yaque del Norte between Río Cana and Río Guayubín. The Maury expedition collected the large arcid on Río Cana (Maury, 1917a, p. 25) from strata that are younger than the early middle Miocene Cercado formation farther upstream. Their relations to the late middle Miocene Gurabo formation are unknown, but they presumably were deposited during the regressive stage of the transgression that started with the early Miocene Baitoa formation and continued during the middle Miocene, and probably are of late Miocene age.

The only USNM Dominican Republic specimens are in two lots collected in the foothills of the Cordillera Septentrional, on the north side of Río Yaque del Norte.

Occurrence: Middle part of Gatun formation (middle Miocene), western area, locality 170.

Subgenus Potiarca Iredale

Iredale, Great Barrier Reef expedition, 1928–29, Scientific Reports, v. 5, no. 6, Mollusca, pt. 1, p. 284, British Museum (Natural History), 1939.

Type (orthotype): *Potiarca (pilula) saccula* Iredale; that is, a subspecies of *Arca pilula* Reeve, living, western Pacific Ocean.

Ever since Dall's treatment in 1898 (Dall, 1890–1903, p. 633–636, 1898) the American fossil and living species of *Potiarca* have been assigned to his subgenus *Cunearca*, the next subgenus under consideration. I am indebted to my colleague Druid Wilson for pointing out that *Potiarca* is available for American species as well as western Pacific species. To be sure, *Potiarca* and *Cunearca* are more or less similar in several features. Both are inequivalve, the sculpture of the two valves of both is discrepant, and the ribs of both, with the exception of two Miocene species of *Potiarca*, are undivided. The outline of both also is similar, although most species of *Potiarca* are less elongate. The cardinal area of both is wide and triangular. The progressively greater overlap of the left valve—progressively greater from the anterior end to the posterior end of the ventral margin—is the most characteristic shell feature of *Cunearca*, whereas the overlap of *Potiarca* is less pro-

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nounced and of uniform extent. The ribs of the left valve of *Cunearca* are wider than those of *Potiarca* and are separated by a narrow space. The cardinal area of *Cunearca* is horizontally striated. Some species of *Potiarca* have a similar cardinal area, but other species have ligament grooves of various shapes, ranging from one or two angulated chevrons to as many as four bent or wavy continuous, or discontinuous, grooves. Still other species include specimens that are only horizontally striate and specimens that have ligament grooves. Stanley (1970, p. 126, pl. 6, fig. 3) found that *Anadara chemnitzii*—a species of *Potiarca*—secretes an unusual byssus, consisting of a single thread with a sheet-like terminal pad.

Potiarca is widespread and locally exceptionally abundant in the Miocene of the Tertiary Caribbean province. The earliest are of early Miocene age. In southeastern United States, however, the subgenus is unknown before late Miocene time. It survives on both sides of Panamá: *Anadara chemnitzii* (Philippi) in the western Atlantic Ocean and the closely related *A. nux* (Sowerby) in the eastern Pacific.

The fossil species in the present Caribbean region are overnamed, especially those of Miocene age. Twenty-five names have been proposed, including six for those in the early Miocene Pirabas formation of Brasil and the same number for those in the Miocene of the Dominican Republic.

Anadara cumanensis (Dall, 1890–1903, p. 633) is identified as a small *A. chemnitzii*. Though the catalog specifies only one specimen, a right and a left valve are under the catalog number 115678. The left valve practically agrees with Dall's measurements and is designated the lectotype, and Cumaná, Venezuela, is designated the type locality. The left valve from an island in Lago de Enriquillo, Dominican Republic, loaned to Maury and illustrated by her (1925, p. 70, pl. 5, fig. 4) is missing or misplaced. *Anadara* aff. *A. filicata*, from the Pliocene of Trinidad (Jung, 1969, p. 333, part, not pl. 15, fig. 7), also is identified as a small *A. chemnitzii*. The type material of *Arca limonica* (Dall, 1912, p. 2: post-glacial "Atlantic muck," Canal Zone) consists of three minute, subcircular right valves (length 2.4 to 3.5 mm). They doubtless are immature *A. chemnitzii*. To designate a lectotype would serve no useful purpose.

Molds from the Toro limestone member of the Chagres sandstone are listed as *Anadara* sp.

Anadara (Potiarca) aff. A. chavezi (Engerrand and Urbina)

Plate 72, figure 2

Of medium size, height a little less than length, inequilateral. Posterior margin barely rounded, ventral part not extended. Right valve sculptured with about 27 ribs, slightly narrower than space between them, except at anterior and posterior ends, where they are of about same width as space, or a little wider. Anterior ribs noded, others smooth. Cardinal area missing.

Length 18 mm, height about 17 mm, diameter about 7.5 mm (figured specimen).

An almost complete, but defective, right valve is the only *Potiarca* found in the La Boca formation. So far as it goes, it is comparable to *Anadara chavezi*, the next species. If it is not that species, it is its immediate predecessor.

Occurrence: La Boca formation (early Miocene), locality 116.

Anadara (Potiarca) chavezi (Engerrand and Urbina)

Plate 81, figures 1–3, 6, plate 82, figure 5

Arca (Scapharca) chavezi Engerrand and Urbina, Soc. Geol. Mexicana Bol., v. 6, p. 131, pl. 60, figs. 56–60, 62–65, 1910 (Miocene, México).

Anadara cf. *A. Chavezi* (Engerrand and Urbina). Alencaster Y, in Ríos Macbeth, Asoc. Mexicana Geólogos Petroleros Bol., v. 4, p. 347, pl. 17, figs. 6, 7, 1952 (Miocene, México).

Scapharca cor-cupidonis Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 175, pl. 30, figs. 5–7, 1917 (Miocene, Dominican Republic).

Scapharca riocanensis Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 176, pl. 30, figs. 3, 4, 1917 (Miocene, Dominican Republic).

Arca perfaceta Pilsbry and Johnson, Acad. Nat. Sci. Philadelphia Proc., v. 69, p. 190, 1917 (Miocene, Dominican Republic). Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 73, p. 407, pl. 39, figs. 17–20, 1922 (Miocene, Dominican Republic).

Arca pomponiana Pilsbry and Johnson, Acad. Nat. Sci. Philadelphia Proc., v. 69, p. 190, 1917 (Miocene, Dominican Republic). Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 73, p. 407, pl. 42, figs. 4–6, 1922 (Miocene, Dominican Republic).

Barbatia (Diluvarca) opthanta Woodring, Carnegie Inst. Washington Pub. 366, p. 50, pl. 5, figs. 14, 15, 1925 (Miocene, Jamaica; immature).

?Anadara (Cunearca) sp., Alancaster-Ibarra, in Masson and Alencaster-Ibarra, Asoc. Mexicana Geólogos Petroleros Bol., v. 3, p. 204, fig. 4, 1951 (Miocene, México).

Of medium size to moderately large. Left valve larger than right. Umbo of smallest shells faintly sulcate. Outline variable, height somewhat less than length to somewhat more, moderately unequilateral. Posterior margin of mature shells slightly rounded to obliquely subtruncated, ventral part slightly to distinctly extended. Small shells (length 5 to 8 mm) generally subcircular; smallest (length <5 mm) invariably subcircular, though still slightly inequilateral. Sculptured with 24 to 31 ribs (generally 26 to 28, with peak at 26). Median ribs of right valve slightly narrower than space between them, or of about same width; anterior ribs strongly noded, posterior ribs less strongly noded, median ribs generally smooth, exceptionally more or less

noded on ventral part. Ribs of left valve wider than space between them; all ribs noded, but nodes subdued or absent on outermost part of posterior ribs. Cardinal area wide; horizontally striate, ligament grooves present or absent; if present, consisting of one or two angulated or bent chevrons, or bent or wavy, continuous or discontinuous, irregular grooves.

Length 23.2 mm, height 20 mm, diameter 10.1 mm (figured right valve of medium size). Length 30.5 mm, height 26.4 mm, diameter 14.6 mm (figured large left valve).

Type: Location unknown.

Type locality: Zuluzum, a folk name for a locality on Río Chacamás, near Palenque, northeastern Chiapas, México, deposits of middle Miocene age.

Anadara chavezi is represented in the Gatun formation by 265 specimens, two of which are articulated. The distribution in the three parts of the formation is very uneven, as shown by the following table.

Distribution of Anadara (Potiarca) chavezi

Gatun formation	Number of specimens
Upper part, eastern area	1
Middle part, eastern area	12
Middle part, western area	38
Lower part	214

The distribution suggests that *A. chavezi*, like *A. chemnitzii*, preferred shallow water. The Gatun formation represents deposition in progressively deeper water in the eastern area, from the lower part upward.

All the specimens from the lower part are small or of medium size, ranging in length from 1.7 to 26 mm (pl. 81, figs. 2, 6, pl. 82, fig. 5). The collections from the middle part include shells that are small, of medium size, and four decidedly larger, two of which are illustrated (pl. 81, figs. 1, 3). The 27 valves from locality 161c are the only ones showing a graded size series from large to very small. The single valve from the upper part is small and short (length 14.4 mm, height 15.3 mm).

The numerous specimens from the lower part are fairly uniform in outline, whereas those from the middle part show a range from elongate (pl. 81, fig. 1) to short (pl. 81, fig. 3). The ventral part of the median ribs of 12 percent of right valves of suitable size (length > 10 mm) are more or less noded, but not as strongly noded as the median ribs of left valves. A noded right valve is shown on plate 81, figure 6.

A collection from a middle Miocene locality 3 km northeast of Santa Rosa, in the Isthmus of Tehuantepec (USGS 9995, 23737), contains perhaps tens of thousands of *A. chavezi*. The locality is about 350 km west of the type locality. A casual inspection indicates that, like those from the lower part of the Gatun formation, they are fairly uniform in outline and size. The maximum length is about 25 mm. Small shells are subcircular. The ribs of a small sample number 24 to 29, with peaks at 24 and 26. No right valve examined has distinct nodes on median ribs. The cardinal area is horizontally striate only or bears as many as four bent ligament grooves. The collection, made by Bruce Wade in 1920, was divided between the U.S. National Museum and The Johns Hopkins University. Both parts are now in the National Museum. The molluscan fauna of an estimated 450 species is being monographed by Sra. Dra. Carmen Perrilliat de Pérez, of the Instituto de Geología of the Universidad Nacional Autónoma de México.

Several hundred topotypes of *A. corcupidonis*, from the Cercado formation of the Dominican Republic (USGS 8525), are available. They also are fairly uniform in outline and size, and small valves are subcircular. The maximum length is 26 mm and the rib count is 24 or 25. As in the Santa Rosa collection, the median ribs of the right valves examined are not distinctly noded. All the large valves examined bear ligament grooves: one or two angulated chevrons, or as many as three bent, wavy, or even zigzag grooves.

It might be expected that a Gatun species of *Potiarca* would be *A. pittieri* (Dall), based on middle Miocene fossils from southeastern Costa Rica (Dall, 1912, p. 9; 1925, p. 5, pl. 17, fig. 7; Olsson, 1922, p. 192, pl. 24, figs. 2–6). Dall selected, from several hundred specimens collected at USGS locality 5882h on Río Banano, five valves as types. The left valve he later illustrated is herewith designated the lectotype. The median ribs of right valves are almost invariably noded, but on a few the nodes are greatly suppressed. *A. hindsi* (Olsson, 1922, p. 193, pl. 24, figs. 7–9) was based on even greater suppression. The chief difference, however, between *A. pittieri* and *A. chavezi* lies in the elongate outline of small shells of *A. pittieri*.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, localities 137, 137a, 138, 138a, 138b, 138c, 138d, 138e, 138f, 138g. Middle part, eastern area, localities 139 (*Anadara* sp., molds), 139c, 143 (*Anadara* sp.), 144 (*Anadara* sp., molds), 144a (*Anadara* sp., molds), 147b (*Anadara* sp., minute), 155, 155a, 155c, 159d; western area, localities 160 (*Anadara* sp., mold), 160d, 161, 161c, 161d, 162, 162a, 169 (*Anadara* sp.), 170 (*Anadara* sp., minute). Upper part, eastern area, locality 177e. Cercado formation (middle Miocene), Dominican Republic. Bowden formation (middle Miocene), Jamaica. Deposits of middle Miocene age, Chiapas, México.

the Springvale formation, where it reached a larger size than in the Pliocene deposits. The subsurface species from southeastern United States—*N. gardnerae* (MacNeil, 1938, p. 37, pl. 6, figs. 16, 17)—was based on two small valves recovered from a well in Texas. Druid Wilson called my attention to two larger valves (length 18.1 and 19.8 mm) from a well in the lower part of Plaquemines Parish, Louisiana (USGS 9279). As realized by MacNeil, *N. gardnerae* is closely related to *N. sheldoniana;* it may eventually be found to be that species.

Arca (*Scapharca*) *charanensis* (Spieker, 1922, p. 109, pl. 5, fig. 15, an inadequate illustration), from the lower part of the Zorritos formation of Perú, suggests a species of the subgenus *Eontia*, an earlier occurrence than any in southeastern United States.

Noetia (Noetia) reversa macdonaldi (Dall)

Plate 81, figures 12, 13, plate 82, figures 1, 4

Arca (*Noetia*) *macdonaldi* Dall, Smithsonian Misc. Colln., v. 59, no. 2, p. 9, 1912 (Miocene, Costa Rica). Dall, U.S. Natl. Mus. Proc., v. 66, art. 17, p. 5, pl. 17, fig. 9, 1925 (Miocene, Costa Rica). Hodson, Hodson, and Harris, Bull. Am. Paleontology, v. 13, no. 49, p. 3, 1927 (Miocene, Venezuela). Anderson, California Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 147, 1929 (Miocene, Colombia). Barrios, Colombia Servicio Geol. Nac., Bol. Geol., v. 6, nos. 1–3 (Informe 1082), p. 228, pl. 1, fig. 3, 1960 (Miocene, Colombia).

Arca macdonaldi Dall, Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 194 (assigned to subgenus *Noetia*), pl. 25, figs. 4, 5, 1922 (Miocene, Costa Rica).

Noetia macdonaldi MacNeil, U.S. Geol. Survey Prof. Paper 189–A, p. 35, pl. 6, figs. 10–13, 1938 (Miocene, Costa Rica, Colombia).

Arca macdonaldi subreversa Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 194 (in discussion), pl. 25, figs. 6, 7, 1922 (Miocene, Costa Rica).

Noetia macdonaldi alta MacNeil, U.S. Geol. Survey Prof. Paper 189–A, p. 36, pl. 6, figs. 1, 2, 8, 9, 1938 (Miocene, Costa Rica.)

Noetia macdonaldi truncata MacNeil, U.S. Geol. Survey Prof. Paper 189–A, p. 36, pl. 6, figs. 3, 4, 1938 (Miocene, Colombia).

Noetia colombiana MacNeil, U.S. Geological Survey Prof. Paper 189–A, p. 34, pl. 5, figs. 10, 11, 1938 (Miocene, Colombia).

Noetia mauryae MacNeil, U.S. Geol. Survey Prof. Paper 189–A, p. 34, pl. 5, figs. 18, 19, 1938 (Miocene, Colombia).

Noetia ecuadoria MacNeil, U.S. Geol. Survey Prof. Paper 189–A, p. 33, pl. 5, figs. 12, 13, 20, 1938 (Miocene, Ecuador).

Noetia (*Noetia*) *ecuadoria* MacNeil, Olsson, Neogene mollusks from northwestern Ecuador, Paleontological Research Inst., p. 32, pl. 2, fig. 10, 1964 (Miocene, Ecuador).

Noetia dauleana Marks, Bull. Am. Paleontology, v. 33, no. 139, p. 52, pl. 1, figs. 7–9, 1951 (Miocene, Ecuador).

Noetia dauleana paraguanensis Jung, Bull. Am. Paleontology, v. 49, no. 223, p. 434, pl. 53, figs. 10, 11, 1965 (Miocene, Venezuela).

Moderately large, ratio of height to length variable (75 to 91 percent). Posterior margin obliquely truncated or subtruncated, ventral part strongly to slightly extended, moderately inequilateral. Umbo moderately high to high, umbonal area relatively narrow to wide. Degree of angularity of posterior umbonal slope variable, posterior area flat to slightly concave. Sculptured with 30 to 38 low, flat ribs (generally 32 to 35). Ribs on main part of shell narrower than space between them, those at anterior and posterior ends wider than space. An interstitial thread (exceptionally two) generally present between ribs on posterior area near angulated posterior unbonal slope, or between few ribs on both sides of slope, exceptionally only between few ribs in front of slope. Exaggerated growth lamellae of variable distinctness convex upward on ribs and concave upward in space between ribs. Vertically striated ligamental part of cardinal area in front of umbo, short posterior part set off from main part of shell by groove or shelf.

Length 46.5 mm, height 37.7 mm, diameter 19.5 mm (figured larger left valve, largest specimen).

Type material: Lectotype, herewith designated, USNM 214344.

Type locality: USGS 5882m, Río Banano, Limón Province, Costa Rica, middle Miocene.

This *Noetia* occurs in the lower and middle parts of the Gatun formation, but is nowhere abundant. Even the small sample of 19 complete specimens shows the variability of features on which species and subspecies have been based: height of umbo, width of umbonal area, extension of ventral part of posterior margin, degree of angularity of posterior umbonal slope, and presence or absence of interstitial threads near the posterior umbonal slope. The illustrated larger left valve (pl. 81, figs. 12, 13) is the largest of the Gatun fossils. The illustrated smaller left valve (pl. 82, fig. 4) has the features of *N. macdonaldi alta;* that is, a high ratio of height to length, high umbo, and narrow umbonal area. The illustrated right valve (pl. 82, fig. 1) is elongate, and its umbo is low. It is similar to the type of *N. colombiana*, but not all the valves in the type lot of that form are so elongate.

After extracting some minute valves, Dall selected as types of *N. macdonaldi* the entire lot of 12 valves collected by MacDonald at locality 5882m on Río Banano. The right valve (length 55.6 mm) he later illustrated, reduced almost one-half, was accepted as the holotype by MacNeil, but is now designated the lectotype. It is almost twice as large as the largest of the remaining syntypes and also the largest of any specimens in eight other collections from Río Banano available to Dall. A comparable specimen from Colombia has been illustrated (MacNeil, 1938, pl. 6, fig. 11). Those two are the only large ones in USNM collections. The Costa Rican fossils are variable in outline. One of the re-

maining syntypes (length 25.5 mm, height 23.8 mm) has the outline of *N. macdonaldi alta.*

N. macdonaldi and the cited synonyms are so similar to the living *N. reversa* (Maury, 1922, p. 9, pl. 1, figs. 7, 11; Olsson, 1961, p. 101, pl. 10, figs. 1, 1a, 1b) that it may be a strained interpretation to distinguish them, even at the subspecific level. Of 50 specimens of the nominate subspecies in USNM collections three have a decidedly extended outline; about five percent show interstitial threads; and a posterior nonligamental part of the cardinal area is indistinguishable, or very narrow. The posterior umbonal slope of immature valves of the nominate subspecies (length 25 mm) is more sharply angulated than that of Gatun valves of the same size, but remaining syntypes of *N. macdonaldi* of the same size are as sharply angulated as living shells. It is evident that the fossils present a greater range of variation than the nominate subspecies, and that is the chief basis for classifying *A. macdonaldi* and its synonyms as a subspecies of *N. reversa.* Olsson's comments (1961, p. 102; 1964, p. 32) are appropriate.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, localities 137a, 138a, 138c, 138f. Middle part, eastern area, localities 146, 155, 155a; western area, localities 160, 170. Early to late Miocene deposits Colombia. Cantaure formation and other middle Miocene deposits, Falcón, Venezuela. Middle Miocene deposits, Limón Province, Costa Rica. Daule and Angostura formations (middle Miocene), Ecuador.

Family GLYCYMERIDIDAE

Genus Glycymeris da Costa

da Costa, The British Conchology, p. 168, 1778.

Type (tautotype): *Glycymeris orbicularis* da Costa (=*Arca glycymeris* Linné), living, northern eastern Atlantic Ocean and Mediterranean Sea.

Subgenus Glycymeris s.s.

Glycymeris (Glycymeris) cf. G. caracoli Anderson

Plate 69, figure 18

Of medium size, subcircular, umbo median. Dorsal margins sloping. Traces of weak ribbing on ventral part of internal molds.

Length 25 mm, height 25.3 mm, diameter 7.5 mm (figured specimen).

The outline and what is shown of the ribbing of seven internal molds, from limestone of the Gatuncillo formation in Madden basin, suggest *Glycymeris caracoli* (Anderson, 1928, p. 21, pl. 1, fig. 9; Clark, in Clark and Durham, 1946, p. 54, pl. 2, figs. 9–11, 13), a late Eocene Colombian species.

Occurrence: Gatuncillo formation (late Eocene), localities 9, 11, 12.

Glycymeris (Glycymeris) carbasina Brown and Pilsbry

Plate 79, figures 9, 10, plate 81, figures 9, 10

Glycymeris carbasina Brown and Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 63, p. 363, pl. 28, fig. 9, 1911 (Miocene, Canal Zone). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 179, pl. 19, figs. 1, 2, 5, 1922 (Miocene, Costa Rica).

Glycymeris carbasina Brown and Pilsbry?, Anderson, California Acad. Sci. Proc., v. 18, no. 4, p. 152, 1929 (Miocene, Colombia).

Pectunculus (*Axinaea*) *gatunensis* n. f., aff. *Axinaea albolineata* Lischke, Toula, K. K. Geol. Reichsanstalt Jahrb., v. 61, p. 493, pl. 31, fig. 2, 1911 (Miocene, Canal Zone).

Moderately large, subcircular, equilateral, umbo median, tip of umbo slightly opisthogyrate. Dorsal margin short, horizontal, rounding into anterior and posterior margins. Umbo of unworn shells and small immature shells sculptured with many low, narrow ribs, generally a little wider than space between them. At later stage, fine closely spaced radial striae superimposed on ribs, which gradually become still lower, and on space between them. Fine, closely spaced concentric striae appearing at very early stage, the two sets of striae forming almost microscopic decussated surface. Main ribs absent near dorsal margins, except on umbo. Cardinal area narrow, amphidetic, symmetric or slightly asymmetric on mature shells, asymmetric on most immature shells, anterior part longer than posterior.

Length 42.7 mm, height 40.5 mm, diameter 13.2 mm (larger figured specimen, largest specimen).

Type material: Lectotype, herewith designated, the specimen illustrated by Brown and Pilsbry, the largest of four in the type lot, Acad. Nat. Sci. Philadelphia 1745.

Type locality: Gatun Locks excavation, Canal Zone, middle part of Gatun formation.

The description is based on 28 specimens from the Gatun formation. Though the species ranges through the formation, the only valve from the lower part is minute (length 3.5 mm). Five imperfect valves, four of which are large, from the La Boca formation also are identified as *Glycymeris carbasina.*

The lectotype is immature (length 18 mm), representing a stage before the ribs become very low and when radial striae appear only near the ventral margin. Olsson recorded a length of 55 mm for large Costa Rican shells. The largest Colombian shell in USNM collections has a length of 50 mm, but an incomplete valve suggests almost 65. The ventral part of the posterior margin of the larger illustrated valve is nicked, not subtruncated. The asymmetric cardinal area of a well-preserved immature valve is shown on plate 79, figure 9.

This species is identified along the southwest border of the Caribbean Sea: in southeastern Costa Rica, Panamá and Colombia. It is especially abundant in the Piojó formation of Colombia. Its age range is early to

middle Miocene. The sculpture is the same as that of *G. jamaicensis* (Dall, 1890–1903, p. 608, 1898; Woodring, 1925, p. 24, pl. 2, figs. 1–3; Miocene, Jamaica), but the ventral part of the posterior margin of that species is obliquely subtruncated (specified as anterior margin in the 1925 account). It would be better to treat *G. jamaicensis* as a Miocene subspecies of *G. undata* (Linné), now living in the Caribbean region. The Miocene subspecies is distinguished by its smaller size and more strongly ribbed umbo.

Occurrence: La Boca formation (early Miocene), localities 99g, 116a, 119c. Gatun formation (middle Miocene). Lower part, locality 138c. Middle part, eastern area, localities 155, 155a, 155b, 159; western area, locality 169. Upper part, eastern area, localities 171, 172, 177b; western area, locality 182. Early Miocene deposits, Río San Juan-Río Sinú area, Bolívar Dept., Colombia, Middle Miocene deposits, Limón Province, Costa Rica. Hibáchero, Piojó, and Tubará formations (middle Miocene), Atlántico Dept., Colombia.

Subgenus Tucetona Iredale

Iredale, Australian Mus. Records, v. 18, p. 202, 1931.
Type (orthotype): *Glycymeris flabellatus* Tenison-Woods [*Pectunculus flabellatus*], living, South Australia.

It seems strange that no species of *Tucetona* is in collections from the lower part of the Gatun formation. The Gatun specimen, or specimens, recorded by Brown and Pilsbry (1911, p. 364) as *Glycymeris acuticostata* (Sowerby) were not found.

Group of Glycymeris subovata

The group of *Glycymeris subovata*, characterized by wide, almost flat ribs, separated by a linear, or slightly wider, groove, is widespread in the Miocene of southeastern United States from Virginia to Florida, and is found also in the Caribbean region. It became extinct at the end of Miocene time.

Glycymeris (Tucetona) epacra Woodring, n. sp.

Plate 81, figures 7, 11

Glycymeris lloydsmithi Pilsbry and Brown, Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 181, pl. 25, figs. 8–10, 1922 (Miocene, Costa Rica), Weisbord, Bull. Am. Paleontology, v. 14, no. 54, p. 10, pl. 1, figs. 12, 13, 1929 (Miocene, Colombia). Anderson, California Acad. Sci. Proc., v. 18, no. 4, p. 152, 1929 (Miocene, Colombia).

Of medium size, trigonal-ovate, umbonal area narrow, its margins steeply sloping. Height slightly greater than length, posterior margin slightly to distinctly extended. Umbo worn. Sculptured with about 28 to about 31 very low, almost flat ribs, separated by linear groove, except near upper margins, where space between them is slightly wider than elsewhere. Ribs fading out adjoining upper margins, less distinct near ventral margin of mature shell. Cardinal area short, narrow, amphidetic.

Length 33.7 mm, height 36.2 mm, diameter 11 mm (type, largest specimen).

Type: USNM 646880.

Type locality: 182a (USGS 8488, Caribbean coast east of San Miguel [Río Miguel], station 25 plus 400 feet (120 meters), Panamá), Upper part of Gatun formation.

Glycymeris epacra is repersented by five immature valves from the middle part of the Gatun formation, two immature from the upper part in the eastern area, and six, including mature valves, from the upper part in the western area. Most of those from the western area, including the type, are more or less worn. The illustrations show the range of variation in outline.

The typical form of *G. subovata* (Say) (Gardner, 1926–47, p. 35, pl. 8, figs. 3–8, 1926) and *G. drymanos* Gardner (1926–47, p. 36, pl. 9, figs. 1, 2, 1926), which is extraordinarily abundant in the Oak Grove sand member of the Shoal River formation of Florida, are more subcircular than *G. epacra*.

There is a possibility that *G. epacra* is *G. lloydsmithi* (Pilsbry and Brown, 1917, p. 39, pl. 6, fig. 6; Miocene, Colombia), as Olsson, Weisbord, and Anderson thought. The type, and only specimen, however, is badly worn and the type locality so indefinite that topotypes cannot be recovered.

Occurrence: Middle and upper parts of Gatun formation (middle Miocene). Middle part, western area, localities 168, 169. Upper part, eastern area, locality 173; western area, localities 182, 182a. Middle Miocene deposits, Limón Province, Costa Rica; Atlántico Dept., Colombia.

Group of Glycymeris pectinata

Molds from the lower member of the Alhajuela formation and the Toro limestone member of the Chagres sandstone are listed as *Glycymeris* sp.

Glycymeris (Tucetona) pectinata canalis Brown and Pilsbry

Plate 81, figures 4, 5, 8

Glycymeris canalis Brown and Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 63, p. 364, pl. 28, fig. 10, 1911 (Miocene, Canal Zone). Nicol, Jour. Paleontology, v. 19, p. 622, pl. 85, figs. 1, 2, type [lectotype], (Miocene, Canal Zone).

?Glycymeris canalis Brown and Pilsbry, Hodson, Hodson, and Harris, Bull. Am. Paleontology, v. 13, no. 49, p. 15, 1927 (Miocene, Venezuela). Barrios, Colombia Serv. Geol. Nac., Bol. Geol., v. 6, nos. 1–3 (Informe 1082), p. 235, pl. 3, figs. 6, 7, 1960 (Miocene, Colombia).

?Pectunculus spec. ind. (n. sp?) Toula, K. k. Geol. Reichsanstalt Jahrb., v. 58, p. 718, pl. 28, fig. 13, 1909 (Miocene, Canal Zone).

Not *Glycymeris canalis* Brown and Pilsbry, Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 177, pl. 18, figs 2–7, 1922 (Miocene, Costa Rica); = *G. secticostata* Nicol.

Not *Glycymeris canalis* Brown and Pilsbry, Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 31, pl. 18, figs. 3, 4, 1925 (Miocene, Trinidad).

Of medium size, trigonal-ovate, umbonal area narrow, its margins sloping. Height equal to length, or slightly greater than length, posterior margin slightly extended. Sculptured with 22 to 31 (generally 30) low, arched primary ribs of moderate width, wider than space between them; space between ribs exceptionally very narrow. Ribs generally fading out near upper margins. Minor secondary sculpture appearing at height of 10 to 20 mm: an interstitial narrow rib or thread in some spaces between ribs, especially anterior ribs, generally at edge of space immediately adjoining primary rib, exceptionally in middle of space. On unworn surfaces fine, closely spaced concentric threads on ribs and in space between them. "Resting stages" conspicuous on many shells, especially those of large size. Cardinal area short, narrow, amphidetic.

Length 34.6 mm, height 36 mm, diameter 11 mm (figured right valve).

Type material: Lectotype, herewith designated, the specimen illustrated by Brown and Pilsbry, the largest of four in the type lot, Acad. Nat. Sci. Philadelphia 1747.

Type locality: Gatun Locks excavation, Canal Zone, middle part of Gatun formation.

Though the upper part of the Gatun formation yielded two immature valves of *Glycymeris pectinata canalis*, the remaining 31 specimens identified without qualification are from the middle part. Collections from the Gatun Third Locks excavation are the most satisfactory and include the only fully mature valves. Eighteen specimens in one of those collections (155b) represent a growth series from a length of 9.8 to 35 mm. Eight valves from the La Boca formation, ranging in length from 9 to 21.8 mm, and an external mold from the lower member of the Alhajuela formation (length 12.6 mm) are doubtfully identified as *G. pectinata canalis*. The ribs of another small La Boca valve, listed as *Glycymeris* sp., are somewhat angular.

The lectotype is immature (length 14.6 mm), at a growth stage preceding the appearance of minor secondary sculpture. Plate 81, figure 5, shows an immature left valve that has a very narrow space between primary ribs and a faint trace of an interstitial thread between some anterior ribs.

The middle Miocene *Glycymeris* in southeastern Costa Rica that has arched, instead of angular, ribs is accepted as *G. pectinata canalis*. Only a few immature valves are in Río Banano USNM collections (USGS 5882g, 5882h). Typical mature shells are found in middle Miocene deposits on the Pacific side of Panamá in Chiriquí Province (USGS 7955). Despite unillustrated records, it is doubtful whether the typical form occurs in Colombia and Venezuela. On the ventral part of the shell of *G. canalis colombiensis* (Weisbord, 1929, p. 11, pl. 2, figs. 3, 4) the ribs are separated by linear grooves.

As recognized by Brown and Pilsbry, *G. pectinata canalis* is closely related to *G. pectinata pectinata* (Gmelin), living in the Caribbean region. Many large specimens of the nominate subspecies show minor secondary sculpture like that of the fossils. The nominate subspecies, however, is somewhat smaller (maximum length 32 mm in USNM collections); in fact, most lots are decidedly smaller. A very narrow space between ribs is the prevailing sculpture among living shells.

Occurrence: La Boca formation (early Miocene; identication doubtful), localities 115, 116a. Lower member of Alhajuela formation (early Miocene; identification doubtful), locality 82 (sp.), 82a. Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, localities, 144d, 147b, 155, 155a, 155b; western area, localities 160, 160c. Upper part, eastern area, locality 173. Middle Miocene deposits, Limón Province, Costa Rica. Middle Miocene deposits, Chiriquí Province, Panamá.

Group of Glycymeris arctata

A group of species typified by *Glycymeris arctata* (Conrad) (1848, p. 125, pl. 13, fig. 24; Oligocene, Mississippi) is unknown in southeastern United States later than early Miocene time. It is represented in the Tampa limestone, of that age, by *G. lamyi* (Dall, 1915, p. 122, pl. 20, figs. 11, 13; *G. lamyi tampae* Mansfield, 1937, p. 190, pl. 10, figs. 4, 6, 7, is a synonym.) On the contrary, the group survived in the Caribbean region until late Miocene time, but left no descendants in western Atlantic or eastern Pacific waters.

Glycymeris (Tucetona) secticostata schencki Nicol

Plate 72, figure 1, plate 75, figures 6, 7

Glycymeris schencki Nicol, Jour. Paleontology, v. 21, p. 349, pl. 50, figs. 1–6, 1947 (Miocene, Canal Zone).

Moderately small, trigonal-ovate, umbonal area narrow, its margins sloping. Height slightly less to slightly greater than length, posterior margin slightly extended. Umbo sculptured with 19 to 26 arched primary ribs of uniform width and spacing, or partly irregular in width and spacing. Ribs of about same widths as space between them, or narrower than space, exceptionally wider than space. At height of 4 to 12 mm, primary ribs split into two parts, eventually on large shells into three or four parts. At about same stage as splitting of ribs, interstitial rib or thread appearing in space between primary ribs, eventually two or three. Interstitial rib exceptionally as wide as branches of primary ribs on main part of shell. One to five primary ribs adjoining upper margins

not split. Fine closely spaced concentric threads in space between ribs and on unworn ribs. Cardinal area short, narrow, amphidetic.

Length 24.5 mm, height 23.3 mm, diameter 7.2 mm (largest figured specimen, a topotype).

Type: Stanford Univ. 7880.

Type locality: 173 (Stanford Univ. 2654, Panama Railroad realinement [Third Locks realinement], cut about ¾ mile (1 km) north of north end of Gatun Third Locks excavation, Canal Zone), upper part of Gatun formation.

All of the 11 Gatun specimens of this highly sculptured *Glycymeris* in USNM collections were found in the upper part of the Gatun formation in the eastern area. Nicol, however, recorded one from the lower part, and another from the middle part. It occurs also in the La Boca formation and the Chagres sandstone. In the La Boca 21 were collected at locality 116a (length 10 to 20.8 mm), many of which are more or less worn, and a large, poorly preserved one (estimated restored length 29.5 mm) at locality 119. One of the better preserved valves from locality 116a is illustrated (pl. 72, fig. 1). It is exceptional in having, on the main part of the shell, interstitial ribs of the same width as branches of the primary ribs. A Gatun shell, on which the secondary sculpture appears at a later stage than on others is shown on plate 75, figure 6. The Chagres fossils consist of two external molds.

At an early stage the type of *G. secticostata secticostata* (Nicol, 1945, p. 623, pl. 85, fig. 3; the specimen illustrated as *G. canalis*, variety, by Olsson, 1922, p. 178, pl. 18, fig. 4) is sculptured with 25 ribs, which are split at a height of 15 mm. Four other available specimens, all illustrated by Olsson and designated as paratypes by Nicol, have about the same number. In this small sample the stage at which the ribs are split and interstitial ribs appear varies from a height of 15 to 22 mm. The only significant differences between the nominate subspecies and *G. secticostata schencki* lie in the angular or subangular primary ribs of the nominate subspecies, as compared with the arched ribs of the Canal Zone subspecies, and in the later appearance of rib-splitting in the nominate subspecies.

The nominate subspecies occurs also in the late Miocene Limón formation of the Bocas del Toro area. Panamá (USGS 8345, 8495, 8500).

So far as size is concerned, the group of *G. arctata* culminated in *G. usiacurii* (Anderson, 1929, p. 153, pl. 22, figs. 3, 4), which occurs in middle Miocene deposits in Venezuela and in the late Miocene Usiacuri formation of Colombia. It is the largest species of the group, reaching a length of 47 mm in Colombia. *G. lamyi* Dall (Anderson, 1929, p. 152, pl. 22, figs. 7, 8), *G. lloydsmithi striatidenta* (Nicol, 1945, p. 624; substitute name for *G. lloydsmithi multicostata* Weisbord, 1929, p. 10, pl. 2, figs. 1, 2, not *Pectunculus* [*Glycymeris*] *multicostatus* Sowerby, 1833), *G. canalis democraciana* F. and H. Hodson (in Hodson, Hodson, and Harris, 1927, p. 17, pl. 2, figs. 2, 5, pl. 3, fig. 2), and *G.* aff. *G. democraciana* (Jung, 1965, p. 437, pl. 54, figs. 2, 5, 6) are synonyms of *G. usiacurii*. The affinities of *G. lloydsmithi* are mentioned under *G. epacra*.

Occurrence: La Boca formation (early Miocene), localities 116a, 119. Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, locality 138a (Nicol's record). Middle part, eastern area, locality 155 (Nicol's record). Upper part, eastern area, localities 171, 173, 176a, 177b. Chagres sandstone (late Miocene), locality 202.

Family MYTILIDAE

Aside from a species of *Mytilus* and the genus *Crenella*, mytilids are meagerly represented in the faunas under consideration.

Genus Mytilus Linné

Linné, Systema naturae, 10th ed., p. 704, 1758.

Type (logotype, Anton, Verzeichniss der Conchylien, p. 17, 1839): *Mytilus edulis* Linné, living, eastern and western North Atlantic Ocean.

Mytilus canoasensis vidali Ferreira and Cunha

Plate 73, figures 1, 4

Mytilus sp., Hedberg, Geol. Soc. America Bull., v. 48, p. 2024, pl. 8, fig. 6, 1937 (Miocene, Venezuela).

Mytilus vidali Ferreira and Cunha, Mus. Paraense Emilio Goeldi Bol., n. ser., Geol., no. 8, p. 22, pl. 2, figs. 1a, 1b, 1959 (Miocene, Brasil).

Moderately large, height 45 to 53 percent of length. Umbo at extreme anterior end. Umbonal swelling close to ventral margin. Ventral margin slightly concave, apex of concavity at middle of shell; dorsal margin broadly and strongly arcuate; posterior margin narrowly arcuate. Exterior apparently marked only by growth lines, some of which are impressed on some internal molds. Impressions of resilial-ridge pits on two molds. Other internal features unknown.

Length 77 mm, height 34.7 mm, diameter (reduced by crushing) 9 mm (larger figured specimen).

Type: 4773, Mus. Nacional, Univ. Fed. Rio de Janeiro.

Type locality: Colonia Pedro Teixeira, 2.5 km north of Capanema, Pará, Brasil, Pirabas formation.

The Culebra formation at locality 106 yielded some 30 internal molds of a mytilid ranging in length from 9.5 to 77 mm. The larger illustrated specimen (pl. 73, fig. 4) is the only large one. Most of the others are small, but three are of intermediate size, one of which is illustrated (pl. 73, fig. 1). It shows the impression of pits on part of the resilial ridge, although they do not show

on the photograph. On one of the others of intermediate size the pits extend along a considerable length of the resilial ridge. A small mold from the La Boca formation, two small molds from the lower member of the Alhajuela formation, and a small mold from the middle part of the Gatun formation are identified as the Culebra form. The Gatun specimen shows the impression of pits on the anterior part of the resilial ridge.

Though the internal features, other than the pitted resilial ridge, are unknown, this mytilid is assigned to *Mytilus. M. canoasensis vidali*, as represented in the Culebra formation, is three times as large as the nominate subspecies (Olsson, 1931, p. 41, pl. 1, fig. 12; length 24.5 mm; Oligocene, Peru), although in Brasil it is of intermediate size (length 50 mm) and in Venezuela is comparable in size to the nominate subspecies. Larger samples, especially from Peru, may indicate that size is not a reliable guide for distinguishing the Oligocene and Miocene forms.

Occurrence: Culebra formation (early Miocene), locality 106. La Boca formation (early Miocene), localities 99f (*Mytilus?* sp.), 100. Lower member of Alhajuela formation (early Miocene), locality 79. Middle part of Gatun formation (middle Miocene), eastern area, locality 139g. Pirabas formation (early Miocene), Brasil. Middle(?) Miocene part of Santa Inés group, eastern Venezuela.

Genus Brachidontes Swainson

Swainson, A treatise on malacology, p. 384, 1840.

Type (monotype): [*Modiola*] *sulcata* [Lamarck, 1819] = *Mytilus citrinus* Röding = *Arca modiolus* Linné, living, western Atlantic Ocean.

A small (length 10 mm), thin-shelled, incomplete valve from the Gatuncillo formation at locality 23b is listed as *Brachidontes?* sp.

Brachidontes species

Plate 72, figure 7

Of medium size, height about 55 percent of length. Extreme anterior end missing. Umbonal swelling about median on anterior third of shell, closer to ventral margin than to dorsal margin on middle third, flattened on posterior third. Ventral margin slightly convex; posterior margin arcuate; dorsal margin defective. Sculptured with very narrow, very low, very closely spaced riblets, which are subdued near ventral margin near anterior end of shell. Internal features unknown.

Length (not quite complete) 27.5 mm (estimated restored length 29 mm), height 16 mm, diameter 8.5 mm (figured specimen).

This unnamed, evidently new, species is remarkable for its minute ribbing. It is represented by three valves: that illustrated, another of about the same size but less complete, and a poorly preserved, immature valve, all from the La Boca formation. Not only is the extreme anterior end of the illustrated specimen missing, the anterior part of the umbonal ridge is pinched by compression.

The riblets are narrower and lower than those of *Brachidontes mississippiensis* (Conrad, 1848, p. 126, pl. 12, fig. 19; Mansfield, 1940, p. 176, pl. 25, fig. 40; Oligocene, Mississippi, Alabama), and the La Boca species is less elongate.

Occurrence: La Boca formation (early Miocene), localities 99f, 99g.

Genus Modiolus Lamarck

Lamarck, Soc. Hist. Nat. Paris Mem., p. 87, 1799.

Type (monotype and tautotype): *Mytilus modiolus* Linné, living, northern eastern and western Atlantic, and northern eastern Pacific Oceans.

Though *Volsella* Scopoli, 1777, has priority, *Modiolus* was validated by the International Commission on Zoological Nomenclature in Opinion 325, published in 1955.

The Gatuncillo formation at locality 32 yielded an incomplete valve listed as *Modiolus?* sp.

Modiolus americanus (Leach)?

Plate 72, figure 3

Small to moderately small, height about 60 percent of length. Umbo little short of anterior end of shell. Umbonal swelling wide and strong, decreasing in strength on posterior third of shell. Ventral margin almost straight, anterior dorsal margin straight, sloping toward anterior end of shell; posterior dorsal margin convex; posterior margin arcuate. Growth lines closely spaced on best preserved part of shell. Internal features unknown.

Length 25.6 mm, height 15 mm, diameter 10.7 mm (figured specimen).

Three valves—one from the La Boca formation and two from a submerged locality on Río Chagres at the former site of Las Cruces—are doubtfully identified as *Modiolus americanus* (Reeve, 1858, pl. 4, fig. 15, and accompanying text, as *Modiola tulipa* Lamarck), the common species living off southeastern United States, the West Indies, and southward to northern Brasil. The small illustrated valve, the only complete one, and the larger La Boca specimen (estimated restored length 33 mm) retain shell material. Specimens of *Modiolus* that are small or of moderate size are notoriously difficult to identify. Though the fossils have the outline of *M. americanus*, the most characteristic feature of that species, however, is the reddish or reddish purple coloration, or brownish rays, on the umbonal swelling and dorsal part of the shell. Perhaps *M. waringi* (Maury, 1925, p. 93, pl. 17, fig. 1; Savaneta glauconitic sandstone

member of Springvale formation, Trinidad) is an exceptionally large form of *M. americanus* (length 127 mm).

An eastern Pacific species, tentatively identified as *M. americanus* (Soot-Ryen, 1955, p. 67, pl. 6, figs. 27, 28, text fig. 56), has been described as a new species, *M. pseudotulipus* (Olsson, 1961, p. 127, pl. 14, figs. 2, 2a). If two species are represented, they doubtless had a common ancestry.

Occurrence: La Boca formation (early Miocene), locality 99f. Deposits of early Miocene age at Las Cruces, locality 94.

Genus Crenella Brown

Brown, Illustrations of the conchology of Great Britain and Ireland, pl. 31, figs. 12–14, 1827.

Type (monotype): *Crenella elliptica* Brown = *Mytilus decussatus* Montagu, living, northern eastern and western Atlantic, and northern eastern Pacific Oceans.

Crenella divaricata (d'Orbigny)

Plate 80, figures 10, 11

Nuculocardia divaricata d'Orbigny, Mollusques, in de la Sagra, Histoire physique, politique, et naturelle de l'île de Cuba, v. 2, p. 311, pl. 27, figs. 56–59, 1847(?) (living, Cuba).

Crenella divaricata (d'Orbigny), Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 4, p. 803, 1898 (Pliocene, Florida; living, North Carolina to West Indies). Weisbord, Bull. Am. Paleontology, v. 45, no. 204, p. 102, pl. 9, figs. 9–12, 1964 (Pliocene, Venezuela).

?*Crenella divaricata* (d'Orbigny), Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 95, pl. 18, fig. 13, 1925 (Miocene, Trinidad).

Not *Crenella divaricata* (d'Orbigny), Gabb, Am. Philos. Soc. Trans., n. ser., v. 15, p. 252, 1873 (Miocene, Dominican Republic); = *C. diuturna* Pilsbry and Johnson. Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 194, pl. 26, fig. 18 (unrecognizable), 1917 (Miocene, Dominican Republic); = *C. diuturna* Pilsbry and Johnson.

Small, broadly ovate, asymmetric, posterior part more extended than anterior. White prodissoconch distinctly set off by darker coloration of remainder of shell or by "resting stage." Sculpture subdued, riblets divaricating along submedian line. Faint trace of microscopic decussation. Four to six coarse teeth in anterior series (generally four or five); nine to 12 fine teeth in posterior series. Other margins of shell generally strongly crenulated.

Length 1.6 mm, height 2.1 mm, diameter 0.8 mm (figured specimen).

Type: Probably in British Museum (Natural History).

Type locality: Living, off Cuba.

This living species occurs in the lower part of the Gatun formation and in the middle part in the eastern area, but is nowhere abundant. A total of 34 specimens, one of which is articulated, are in the collections. The decussation is fainter than on most living shells examined.

These Gatun fossils are smaller and more narrow than *Crenella diuturna* (Pilsbry and Johnson, 1917, p. 195; Pilsbry, 1922, p. 414, pl. 38, fig. 7, text fig. 37); their decussation is less distinct, and their teeth more delicate. *C. diuturna* is abundant in the Cercado formation of the Dominican Republic. The late Miocene Trinidad *Crenella*, recorded as *C. divaricata*, reaches a height of 5 mm and its decussation is relatively coarse.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, localities 138c, 138d, 138e. Middle part, eastern area, localities 139b, 139c, 139d, 147b, 152, 159d. Caloosahatchie formation (Pliocene), Florida. Playa Grande and Mare formations (Pliocene), Venezuela. Living, North Carolina to northern Brazil.

Crenella ecuadoriana santiaga Olsson

Plate 80, figures 2, 3

Crenella ecuadoriana santiaga Olsson, Neogene mollusks from northwestern Ecuador, p. 33, pl. 1, fig. 13, Paleontological Research Inst., 1964 (Miocene, Ecuador).

Very small, narrowly ovate, almost symmetric. Prodissoconch forming a conspicuous cap or less distinctly set off. Sculpture generally strong, riblets divaricating along median line. Near ventral margin of mature shells one or two median riblets split into two parts. On same part of mature shells a thread appearing in one or two spaces between riblets. Three to six coarse teeth in anterior series (generally three); seven to nine fine teeth in posterior series. Other margins of shell moderately crenulated.

Length 2.3 mm, height 3 mm, diameter 0.6 mm (figured specimen).

Type: USNM 644250.

Type locality: Cueva de Angostura, Río Santiago, Ecuador, Angostura formation.

This *Crenella* is a small Miocene predecessor of the Pliocene nominate subspecies (Pilsbry and Olsson, 1941, p. 55, pl. 18, figs. 2, 3; height up to 3.6 mm), which is still living in eastern Pacific waters (Olsson, 1961, p. 130, pl. 17, figs. 7, 7a). The Gatun fossils are slightly more narrow than the type of *C. ecuadoriana santiaga* and their sculpture generally is stronger. So far as sculpture is concerned they closely resemble the nominate subspecies.

Contrary to the meager representation of *C. divaricata*, 175 specimens of *C. ecuadoriana santiaga* were collected, 11 of which are articulated. All, however, were found in the middle part of the Gatun formation in the western area.

Occurrence: Middle part of Gatun formation (middle Miocene), western area, localities 161c, 166, 169, 170a. Angostura formation (middle Miocene), Ecuador.

Genus Botula Mörch

Mörch, Catalogus conchyliorum * * * Comes de Yoldi, pt. 2, p. 55, 1853.

Type (logotype, Dall, Bartsch and Rehder, Bernice P. Bishop Mus. Bull. 153, p. 59, 1938) : *Mytilus fuscus* Gmelin, living. western Atlantic and eastern Pacific Oceans.

The type designation was discussed by Iredale (1939, p. 415), who designated the species designated by Dall, Bartsch, and Rehder a year earlier.

Botula fusca (Gmelin)?

Small, elongate, subcylindrical, umbo terminal. Anterior margin subtruncated; dorsal margin slightly convex; posterior margin arcuate; ventral margin almost straight. Posterior part of shell marked by finely engraved, closely spaced growth lines. Internal features unknown.

Length 13 mm, height 5.5 mm, diameter (both valves) 6.3 mm.

An articulated specimen from the La Boca formation is doubtfully identified as *Botula fusca* (Soot-Ryen, 1955, p. 86, pl. 9, fig. 52, text figs. 70–72; Warmke and Abbott, 1961, p. 163, pl. 31, fig. 9). The fossil is badly cracked and will not stand much handling; in fact, several patches of shell peeled off during examination.

Most shells of *B. fusca*, formerly designated *B. cinnamomea* (Lamarck), have a low swelling extending from the umbo to the ventral margin, an insinuation of the margin behind the swelling, and irregularly spaced and strongly marked "resting stages." The species has an age range of early Miocene to the present time and is living in both western Atlantic and eastern Pacific waters. *B. hispaniolae* (Maury, 1917, p. 193, pl. 35, fig. 11; Miocene, Dominican Republic) is a typical representative.

Occurrence: La Boca formation (early Miocene), locality 116a.

Family PINNIDAE

Genus Atrina Gray

Gray, Synopsis of the contents of the British Museum, 44th ed., Mollusks, p. 83, 1842 (genus without species).

Type (monotype, Gray, Zool. Soc. London Proc., p. 199, 1847) : *P[inna] nigra* [Chemnitz] [Dillwyn]=*Pinna vexillum* Born, living, western Pacific Ocean.

Internal molds from the upper member of the Alhajuela formation are listed as *Atrina?* sp.

Subgenus?

Atrina species

Plate, 69, figure 20

Small, broadly wedge-shaped, moderately inflated. Dorsal margin straight; ventral margin slightly convex. Dorsal and median parts sculptured with six wide ribs, wider than space between them, except near dorsal margin. Ventral part sculptured with wide concentric swellings, wider than space between them. Internal features unknown.

Length (incomplete) 33 mm (estimated length by projecting missing anterior part 45 mm), height 26 mm, diameter 9 mm (figured specimen).

This coarsely sculptured species, found in the Río Fríjol area of the Gatuncillo formation, is represented by a gaping articulated internal mold, the right part of which is in better condition than the left. An unknown length of the posterior part presumably is missing. This species evidently is new.

Occurrence: Gatuncillo formation (late Eocene), locality 32.

Subgenus Servatrina Iredale

Iredale, Great Barrier Reef expedition, 1928–29, Scientific Reports, v. 5, no. 6, Mollusca, pt. 1, p. 317, British Museum (Natural History) 1939.

Type (orthotype) : *Pinna assimilis* Reeve, living, western Pacific Ocean.

Atrina (Servatrina) aff. A. serrata (Sowerby)

Plate 82, figures 9–11

?Atrina sp., Woodring, Carnegie Inst. Washington Pub. 366, p. 57, pl. 6, fig. 9, 1925 (Miocene, Jamaica).

?Atrina sp., Jung, Bull. Am. Paleontology, v. 49, no. 223, p. 439, 1965 (Miocene, Venezuela).

?Atrina sp., Jung, Bull. Am. Paleontology, v. 55, no. 247, p. 342, 1969 (Miocene, Trinidad).

Moderately large (estimated length at least 125 mm), wedge-shaped so far as known, moderately inflated, thin-shelled. Dorsal margin straight; ventral margin slightly concave near anterior end, convex farther from anterior end. Dorsal and median parts sculptured with narrow, closely spaced ribs. Ventral part sculptured with concentric swellings. Swellings smooth or inner nacreous layer bearing small, narrow, rectangular pustules, alined parallel to ribs, corresponding calcite layer generally missing. Nacreous layer extending to broken posterior end of specimen having highest posterior end (height something more than 40 mm).

Length (incomplete) 64.5 mm, height 25 mm, diameter about 5 mm (larger figured specimen).

This pinnid occurs in the lower and middle parts of the Gatun formation and in the Chagres sandstone. All of the 19 specimens are incomplete, especially at the posterior end, as usual with fossil pinnids; a few are almost complete at the anterior end. Much, or all, of the thin calcite layer is missing, revealing the equally thin nacreous layer. The most satisfactory specimens were found at locality 139g, in the middle part of the Gatun, where 14 were collected, five of which are small fragments. By projecting the missing anterior part of the

highest specimen, mentioned in the description, a length of about 100 mm is indicated. Inasmuch as the nacreous layer extends about two-thirds to three-fourths of the length of the shell (Turner and Rosewater, 1958, p. 310), a total length of at least about 125 mm is estimated, even if the nacreous layer extends no farther than the broken posterior end. Only a few specimens, two of which are illustrated (pl. 82, figs, 10, 11), show pustules on the ventral part of the shell.

These fossils are interpreted to represent a pinnid allied to the living western Atlantic *Atrina serrata* (Sowerby) (Turner and Rosewater, 1958, p. 320, pls. 170, 171). The typical form of that species is sculptured with many narrow ribs bearing closely spaced vaulted scales. The sculpture, however, is not uniform. The early part of a pair of valves from Port-au-Prince, Haiti (USNM 347210), for example, is sculptured much like the Panamá fossils, and low scales do not appear until a late stage. The sculpture of other Miocene forms resembles that of the Panamá species: *A. harrisi* (Dall, 1890–1903, p. 663, pl. 29, fig. 11, 1898; Choptank formation, Maryland; the type is in poor condition, but better specimens are now available, for example, a topotype, USNM 646825); specimens from the Oak Grove sand member of the Shoal River formation of Florida, identified by Dall as *A. chipolana* (Dall, 1890–1903, p. 662, 1898), though the type material, from the Chipola formation, is unidentifiable; and specimens of late Miocene of Pliocene age from Florida (USNM 646824) that show pustules like those on the two Gatun fragments. Though the diagnostic feature of *Servatrina*—the location of the posterior adductor scar, well within the posterior border of the nacreous layer—is not observable on any of these fossils, they are assigned to that subgenus, as it is unlikely that the external features belie the affinities.

The doubtfully identified fossils from Jamaica, Venezuela, and Trinidad are small fragments.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, locality 136a. Middle part, eastern area, locality 139g; western area, localities 166, 169. Chagres sandstone (late Miocene), localities 206 206b (*Atrina?* sp.). Identification doubtful: Bowden formation (middle Miocene), Jamaica; Cantaure formation (middle Miocene), Venezuela; Melajo clay member of Springvale formation (late Miocene), Trinidad.

Family PTERIIDAE

Genus Pteria Scopoli

Scopoli, Introductio ad historiam naturalem, p. 397, 1777.

Type (monotype): *Mytilus hirundo* Linné, living, eastern Atlantic Ocean and Mediterranean Sea.

Pteria inornata (Gabb)?

Plate 73, figure 9, plate 80, figures 4, 5

Small, moderately inflated. Anterior auricle subtriangular, swollen, set off by groove. Length of posterior auricle unknown.

Length (incomplete) 28 mm, height 24 mm, diameter about 6 mm (largest figured specimen).

Unsatisfactory material from the La Boca and Gatun formations is doubtfully identified as *Pteria inornata* (Pilsbry, 1922, p. 408, pl. 43, figs. 6, 7; Miocene, Dominican Republic). Almost all of these fossils are parts of left valves or molds of incomplete left valves. Five were recovered from the La Boca and some 30 from the Gatun, but most of the Gatun fossils are small shell fragments.

The type of *P. inornata*, shown in Pilsbry's figure 6, is in poor condition. As remarked by Pilsbry, the small mold illustrated in his figure 7 shows the outline. Fragments of small valves, smaller than the type, are abundant in the Cercado formation on Río Mao at USGS locality 8525 (Maury's bluff 3). The species has been recognized in the Bowden formation of Jamaica (Woodring, 1925, p. 58, pl. 6, fig. 11), the middle Miocene deposits of southeastern Costa Rica (Olsson, 1922, p. 195, pl. 28, fig. 9), and possibly in the late Oligocene San Sebastián formation of Puerto Rico (Maury, 1920, p. 13).

The perfect preservation of the moderately large Oligocene species, *P. argentea* (Conrad) (1848, p. 126, pl. 12, fig. 10), as represented in the Mint Spring marl member of the Marianna limestone, stands in marked contrast to the wretched condition of many of the American Tertiary species.

Occurrence: La Boca formation (early Miocene), localities 99h, 114, 115a. Lower and middle parts of Gatun formation (middle Miocene). Lower part, localities 138, 138c, 138d. Middle part, eastern area, localities 139b, 139c, 139e, 139g, 147g, 155, 159d.

Family ISOGNOMONIDAE

Genus Isognomon [Lightfoot]

Lightfoot, anonymous in Catalogue of the Portland Museum, p. 9, 1786.

Type (tautotype): *Ostrea isognomon* [*isognomum*] Linné, living, western Pacific Ocean. "176, *Ostrea isognomon* L., called *Isognoma lignea* by S[olander]". For the usage of *Isognoma* and *Isognomon* in the Portland Catalogue see Rehder (1967, p. 6), but for item 3041 in that account substitute 1242. The gender of *Isognomon* is masculine.

Subgenus Mimonion Woodring, n. subgen.

Type: *Isognomon* (*Mimonion*) *mimeticus* Woodring, n. sp., Miocene, Canal Zone.

Of medium size, narrowly mytiliform, barely and broadly inflated, moderately thick-shelled. Anterior

margin slightly concave, apex of shallow concavity near dorsal third of height; dorsal and posterior margins forming broad arc; ventral margin narrowly arcuate. Ventral and posterior surface bearing very low, irregularly spaced undulations. Eight wide ligament grooves about as wide as space between them. Shell margin bent inward at site of byssus. Muscle scar close to posterior margin of shell, elongate, upper end hook-shaped, but not bent.

The type is a remarkable, narrowly mytiliform species. The outline is strikingly different from that of the hammer-shaped type of *Isognomon* s.s. It differs also from the subovate outline of *Melina*, cited under the next subgeneric heading. *Mimonion* is much more narrowly mytiliform than the Jurassic subgenus *Mytiloperna* (von Ihering, 1903, p. 123; type (monotype): *Mytiloperna americana* (Forbes) (*Perna americana* Forbes), Jurassic, Chile), the type of which is an enormous species (height 295 mm). Small European species also are more broadly mytiliform.

Isognomon (Mimonion) mimeticus Woodring, n. sp.

Plate 71, figures 19, 20

Features of the subgenus, which is monotypic.

Height 49 mm, width 25 mm, diameter 6.5 mm (type).

Type: USNM 646893.

Type locality: 116a (USGS 20956, East bank of Panama Canal at Canal station 1870, near Paraiso, Canal Zone), La Boca formation.

Isognomon mimeticus is represented by the type (a complete, but badly cracked, right valve) and three fragments. As the type will not stand much pressure, thorough cleaning, including dislodging the pebble on the interior, was not attempted.

The exterior mimics specimens of intermediate size of *Mytilus canoasensis vidali*, such as that shown on plate 73, figure 1. It can be seen, however, that *I. mimeticus* lacks a swollen umbonal ridge, the apex of the concavity of the anterior margin (designated ventral for *Mytilus*) is farther toward the umbo, and part of the surface is weakly undulated.

Occurrence: La Boca formation (early Miocene), locality 116a.

Subgenus Melina Retzius?

Retzius,, Dissertatio historico-naturalis nova testaceorum genera, p. 22, 1788.

Type (logotype, Herrmannsen, Indicis generum malacozoorum, v. 2, p. 37, 1847): *Ostrea ephippium* Linné, living, western Pacific Ocean.

Isognomon (Melina?) species

Plate 80, figure 1

?Isognomon sp., Woodring, Carnegie Inst. Washington Pub. 366, p. 58, pl. 6, fig. 10, 1925 (Miocene, Jamaica).

Presumably moderately large, at least dorsal part thick-shelled, outline unknown. Thirteen ligament grooves (three modified by deformity caused by boring organism) slightly wider than space between them. Byssal groove moderately wide, moderately deep.

Height (incomplete) 29 mm, width (incomplete) 37.5 mm, thickness of shell in dorsal area 6.8 mm.

The middle part of the Gatun formation at locality 170 yielded two fragments of *Isognomon*: the illustrated thick-shelled dorsal fragment of a right valve and a thin-shelled fragment of another right valve, the ligament area of which is missing.

The illustrated specimen is more thick-shelled than any species of the genus living in American waters. Perhaps it is the unnamed species represented at Bowden, Jamaica, by a thick-shelled dorsal fragment of a left valve that retains only the anteriormost three ligament grooves. The byssal groove of that fragment, however, is wide and deep. Though the outline of the immature left valve from Bowden (height 7 mm) was described as subquadrate, the posterior margin defective and therefore the outline is questionable. Three of the four ligament grooves are remarkably wide.

Occurrence: Middle part of Gatun formation (middle Miocene), western area, locality 170. Bowden formation (middle Miocene), Jamaica (identification doubtful).

Family MALLEIDAE

Genus Exputens Clark

Clark, Jour. Paleontology, v. 8, p. 270, 1934.

Type (logotype, H. E. Vokes, New York Acad. Sci. Annals, v. 38, p. 51, 1939): *Exputens llajasensis* Clark, Eocene, California.

Though Clark doubtless intended *Exputens llajasensis* to be the type, he did not so designate it. The other species described by Clark, *E. alexi*, evidently is a small form of *E. llajasensis*.

This Eocene genus is recorded from the middle Eocene of California and the middle Eocene of the Ukraine (Zelinska, 1963, p. 104, pl. 1, figs. 9, 9a, as *Vulsella longicauda* (Archiac); *Ostrea longicauda* Archiac, 1850, p. 439, pl. 13, fig. 3, however, is not a species of *Exputens*), and the late Eocene of Florida: *Vulsella ocalensis* MacNeil, 1934, p. 431, figs. 5–11; assigned to *Exputens* by Palmer, in Palmer and Brann, (1965, p. 143). My colleague Druid Wilson has recognized the genus in the late Eocene of Georgia (USGS 7126, 7127, 7121), and in the middle Eocene (USGS 7832) and middle or late Eocene (USGS 22369) of North Carolina. Mr. Wilson also offered advice concerning the age of the occurrences in the southeastern states and called my attention to the Russian publication.

Exputens bostrychodes Woodring, n. sp.

Plate 68, figures 7, 13, 17, 18

Of medium size, short, height almost equal to length, equilateral or apparently almost equilateral. Anterior and posterior margins arcuate. Wide swollen ridge extending obliquely downward from umbo. Posterior part compressed. Tip of umbo coiled. Conspicuous concave auricle extending outward and upward from posterior side of umbo. Ligament groove deep, triangular, curving posteriorly from tip of umbo, sharply limited on anterior side. Surface marked by irregularly spaced and irregularly exaggerated growth lines, most conspicuous on umbonal ridge and anterior part of shell.

Length 23.7 mm, height 20.4 mm, diameter (both valves) 13 mm (type). Length (incomplete) 30 mm (estimated restored length 35 mm), height 26.2 mm, diameter (both valves) 14.6 mm (paratype).

Type: USNM 646890; paratype USNM 646891.

Type locality: 12 (USGS 17162, Madden basin, Panamá, lumber road south of Río Puente, 4 km east of Casada Larga), Gatuncillo formation.

In many respects *Exputens bostrychodes* is a remarkable species. Other species are auriculate, but their auricle is not so large in proportion to the size of the shell; the ligament groove of other species is shallower and not curved; no other species is so short, high, and equilateral.

The type and paratype are articulated, but the valves of both are slightly rotated. The posterior part of the ligament groove of the right valve of the paratype is shallow. It evidently is malformed; perhaps the missing auricle of that valve was broken off during life. Unlike the other mollusks from the marly limestone at the type locality, the shell material of these two specimens is preserved, although the outer calcite layer is missing in small patches. A poorly preserved right valve was collected from sandstone at locality 32.

Occurrence: Gatuncillo formation (late Eocene), localities 12, 32.

REFERENCES CITED

Adams, Henry, and Adams, Arthur, 1853–58, The genera of Recent Mollusca, v. 2, 660 p., London.

Aldrich, T. H., 1897, Notes on Eocene Mollusca, with descriptions of some new species: Bull. Am. Paleontology, v. 2, no. 8, 26 p., 5 pls.

Altena, C. O. van Regteren, 1968, *Yoldia perprotracta* Dall, a synonym of *Leda newcombi* Angas: Basteria, v. 32, p. 3.

Anderson, F. M., 1928, Notes on lower Tertiary deposits of Colombia and their molluscan and foraminiferal fauna: California Acad. Sci. Proc., 4th ser., v. 17, no. 1, p. 1–28, pl. 1.

——— 1929, Marine Miocene and related deposits of north Columbia: California Acad. Sci. Proc., 4th Ser., v. 18, no. 4, p. 73–213, pls. 8–23.

Angas, G. F., 1878, Descriptions of nine new species of land and marine shells from various localities: Zool. Soc. London Proc., 1878, p. 311–314, pl. 18.

Archiac, A., 1850, Description des fossiles du groupe nummulitique recuellis par M. S.-P. Pratti et M. J. Delbos aux environs de Bayonne et de Dax: Soc. Geol. France Mem., 2nd ser., v. 3, pt. 2, p. 397–502, pls. 8–18.

Bartsch, Paul, 1931, Descriptions of new marine mollusks from Panama, with a figure of the genotype of *Engina*: U.S. Natl. Mus. Proc., v. 79, art. 15, 10 p., 1 pl.

Bayer, F. M., 1943, Observations on marine Mollusca, with descriptions of new species: Nautilus, v. 56, p. 109–124, pls. 12–15.

Bretsky, S. S., 1967, Environmental factors influencing the distribution of *Barbatia domingensis* (Mollusca, Bivalvia) on the Bermuda platform: Yale Univ., Peabody Mus., Postilla, no. 108, 14 p., 2 figs.

Brown, A. P., and Pilsbry, H. A., 1911, Fauna of the Gatun formation, Isthmus of Panama: Acad. Nat. Sci. Philadelphia Proc., v. 63, p. 336–373, pls. 22–29.

Cahn, A. R., 1951, Clam culture in Japan: U.S. Dept. Interior, Fish and Wildlife Service, Leaflet FL–399, 103 p. 38 figs.

Campbell, Bruce, 1962, A new deep-water *Anadara* from the Gulf of California: Veliger, v. 4, p. 152–154, pl. 37, 1 fig.

Cernohorsky, W. O., 1970, Systematics of the families Mitridae and Volutomitridae: Auckland Inst. and Mus. Bull. 8, 190 p., 18 pls., 222 figs.

Clark, B. L., and Durham, J. W., 1946, Eocene faunas from the Department of Bolivar, Colombia: Geol. Soc. America Mem. 16, 126 p., 28 pls.

Clench, W. J., and Turner, R. D., 1950, The western Atlantic marine mollusks described by C. B. Adams: Harvard Univ. Mus. Comp. Zoology, Occasional Papers on Mollusks, v. 1, no. 15, p. 233–404, pls. 29–49.

Conrad, T. A., 1831–33, American marine conchology, 73 p., 17 pls., Philadelphia.

——— 1848, Observations on the Eocene formation and descriptions of one hundred and five new fossils of that period from the vicinity of Vicksburg, Mississippi: Acad. Nat. Sci. Philadelphia Jour., 2d ser., v. 1, p. 111–134, pls. 11–14.

Cooke, C. W., 1919, Tertiary mollusks from the Leeward Islands and Cuba: Carnegie Inst. Washington Pub. 291, p. 103–156, 16 pls.

Coomans, H. E., 1963, Systematics and distribution of *Siphocypraea mus* and *Propustularia surinamensis* (Gastropoda, Cypraeidae): Studies on the fauna of Curaçao and other Caribbean islands, v. 15, no. 68, p. 51–71, 2 pls.

Cossmann, M., 1899, Mollusques éocéniques de la Loire-Inférieure, v. 2, pt. 1, 54 p., 5 pls., Nantes.

——— 1906, Essais de paléoconchologie comparée, pt. 7, 261 p., 14 pls., Paris.

——— 1909, Idem, pt. 8, 248 p., 4 pls., Paris.

Cossman, M., and Peyrot, A., 1922–24, Conchologie néogénique de l'Aquitaine, v. 4, 621 p., 18 pls., Bordeaux.

Cossmann, M., and Peyrot, A., 1922–24, Conchologic néogénique des coquilles fossiles des environs de Paris, v. 2, 22 p., 65 pls., Paris.

Dall, W. H., 1881, Preliminary report on the Mollusca (Blake Expedition): Harvard Coll. Mus. Comp. Zoology Bull., v. 9, p. 33–144.

——— 1883 (1884), On a collection of shells sent from Florida by Mr. Henry Hemphill: U.S. Natl. Mus. Proc., v. 6, p. 318–342, pl. 10.

——— 1886, Report on the Mollusca (Blake Expedition); pt. 1, Brachiopoda and Pelecypoda: Harvard Coll. Mus. Comp. Zoology Bull., v. 12, no. 6, p. 171–318, 9 pls.

——— 1890–1903, Contributions to the Tertiary fauna of Florida: Wagner Free Inst. Sci. Trans., v. 3, 6 pts., 1,654 p., 60 pls.

——— 1897, Notice of some new or interesting species of shells from British Columbia and the adjacent region: British Columbia Nat. History Soc. Bull. 2, art. 1, p. 1–18, pls. 1, 2.

——— 1908, The Mollusca and the Brachiopoda (Albatross Expedition): Harvard Coll. Mus. Comp. Zoology Bull., v. 43, p. 205–487, 22 pls.

——— 1912, New species of fossil shells from Panama and Costa Rica: Smithsonian Misc. Colln., v. 59, no. 2, 10 p.

——— 1915, A monograph of the molluscan fauna of the *Orthaulax pugnax* zone of the Oligocene of Tampa, Florida: U.S. Natl. Mus. Bull. 90, 173 p., 27 pls.

——— 1925, Illustrations of unfigured types of shells in the collection of the United States National Museum: U.S. Natl. Mus. Proc., v. 66, p. 1–41, pls. 1–36.

Deshayes, G.-P., 1824–37, Description des coquilles fossiles des environs de Paris, v. 2, 814 p., 106 pls., Paris.

——— 1861–63, Description des animaux sans vertèbres découverts dans le bassin de Paris, v. 2, 968 p., 107 pls., Paris.

Eames, F. E., 1967, The arcid species *sulcicosta* Nyst: Malac. Soc. London Proc., v. 37, p. 296.

Emerson, W. K., 1954, Notes on the scaphopod mollusks; rectifications of nomenclature: Biol. Soc. Washington Proc., v. 67, p. 183–187.

——— 1962, A classification of the scaphopod mollusks: Jour. Paleontology, v. 36, p. 461–482, pls. 76–80, 2 figs.

——— 1971, *Cadulus* (*Gadila*) *perpusillus* (Sowerby, 1832) an earlier name for *C.* (*G.*) *panamensis* Sharp and Pilsbry, 1898: Nautilus, v. 84, p. 77–81, 4 figs.

Evans, John, 1861, Geological report, in [Report of] Chiriqui Commission: U.S. 36th Congress, 2nd Session, House Executive Document 41, p. 45–55.

[Forbes, Edward], 1848, Description of some new fossil shells from Bissexhill and Springfield in Barbados, in Schomburgk, R. H., A history of Barbados * * *, p. 565–566, 5 figs., London.

——— 1848a, in Schomburgk, Description of some new fossil shells from Bissex Hill and Springfield in Barbados: Annals and Mag. Nat. History, 2nd ser., v. 1, p. 347–349, 5 figs.

——— 1850 (1852), On the marine Mollusca discovered during the voyages of the Herald and Pandora, by Capt. Kellett, R. N., and Lieut. Wood, R. N.: Zool. Soc. London Proc., 1850, p. 270–274, pls. 9, 11.

Gardner, Julia, 1926–47, The molluscan fauna of the Alum Bluff group of Florida: U.S. Geol. Survey Prof. Paper 142, 656, p., 62 pls.

——— 1943 (1944)–48, Mollusca from the Miocene and lower Pliocene of Virginia and North Carolina: U.S. Geol. Survey Prof. Paper 199, 310 p., 38 pls., 4 figs.

Gray, J. E., 1842, Synopsis of the contents of the British Museum, 44th ed., Mollusks, p. 48–92.

——— 1847, A list of the genera of Recent Mollusca, their synonyms and types: Zool. Soc. London Proc., p. 129–219.

Guppy, R. J. L., 1867, Notes on West Indian geology, with remarks on the existence of an Atlantis in the early Tertiary period, and descriptions of some fossils from the Caribbean Miocene: Geol. Mag., decade 1, v. 4, p. 496–501, 6 figs.

——— 1881 (1882), On the Recent and Tertiary species of *Leda* and *Nucula* found in the Westindies, with notices of Westindian shells: Sci. Assoc. Trinidad Proc., v. 2, no. 4, pt. 12, p. 168–180, pl. 7; reprint Bull. Am. Paleontology, v. 8, no. 35, p. 89–101, pl. 5, 1921.

Guppy, R. J. L., and Dall, W. H., 1896, Descriptions of Tertiary fossils from the Antillean region: U.S. Natl. Mus. Proc., v. 19, p. 303–331, pls. 27–30.

Habe, Tadashige, 1953, Genera of Japanese shells; Pelecypoda and Scaphopoda, no. 4, p. 281–326, illus.

Hanna, G. D., and Hertlein, L. G., 1927, Expedition of the California Academy of Sciences to the Gulf of California in 1921; Geology and paleontology: California Acad. Sci. Proc., 4th ser., v. 16, no. 6, p. 137–156, pl. 5.

Harris, G. D., and Palmer, K. V. W., 1946–47, The Mollusca of the Jackson Eocene of the Mississippi embayment (Sabine River to the Alabama River): Bull. Am. Paleontology, v. 30, no. 117; pt. 1, p. 1–206, pls. 1–25, 1946; pt. 2, p. 207–563, pls. 26–64, 1947.

Heath, Harold, 1941, The anatomy of the pelecypod family Arcidae: Am. Philos. Soc. Trans., n. ser., v. 31, p. 287–319, 22 pls.

Heilprin, Angelo, 1880, On some new species of Eocene Mollusca from the southern United States: U.S. Natl. Mus. Proc., v. 3, p. 149–152, 9 figs.

Henderson, J. B., 1920, A monograph of the east American scaphopod mollusks: U.S. Natl. Mus. Bull. 111, 117 p., 20 pls.

Heneken, T. S., 1853, On some Tertiary deposits in San Domingo, with notes on the fossil shells, by J. C. Moore, and on the fossil corals, by W. Lonsdale; Geol. Soc. London Quart. Jour., v. 9, p. 115–134, 7 figs.

Hertlein, L. G., and Strong, A. M., 1940, Mollusks from the west coast of Mexico and Central America: New York Zoological Soc., Zoologica, v. 25, p. 369–430, 2 pls.

Hodson, Floyd, Hodson, H. K., and Harris, G. D., 1927, Some Venezuelan and Caribbean mollusks: Bull. Am. Paleontology, v. 13, no. 49, 160 p., 40 pls.

Hubbard, Bela. 1920, Tertiary Mollusca from the Lares district, Porto Rico: New York Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 2, p. 79–164, pls. 10–25.

Iredale, Tom, 1939, Great Barrier Reef expedition, 1928–29, Scientific Reports, v. 5, no. 6, Mollusca, pt. 1, 425 p., 7 pls., British Mus. (Nat. History).

Jung, Peter, 1965, Miocene Mollusca from the Paraguaná Peninsula, Venezuela: Bull. Am. Paleontology, v. 49, no. 223, p. 385–652, pls. 50–79, 2 figs.

——— 1969, Miocene and Pliocene mollusks from Trinidad: Bull. Am. Paleontology, v. 55, no. 247, p. 289–657, pls. 13–60, 4 figs.

——— 1969a, Pliocene molluscan fauna from Trinidad: Tulane Univ., Studies in Geol. and Paleontology, v. 7, no. 2, p. 85–89, 1 pl.

Keen, A. M., 1958 Sea shells of tropical west America, 624, p., illus., Stanford Univ. Press.

——— 1971, Sea shells of tropical west America, 2nd ed., 1064 p., illus., Stanford Univ. Press.

Lamy, Edouard, 1907, Révision des *Arca* vivants du Muséum d'Histoire Naturelle de Paris: Jour. Conchyliologie, v. 55, p. 1–111, 199–307, pls. 1, 3.

MacNeil, F. S., 1934, The pelecypod genus *Vulsella* in the Ocala limestone of Florida and its bearing on correlation: Washington Acad. Sci. Jour., v. 24, no. 10, p. 428–431, 11 figs.

——— 1938, Species and genera of Tertiary Noetinae: U.S. Geol. Survey Prof. Paper 189–A, 49 p., 6 pls., 2 figs.

475-796 O - 73 - 6

——— 1940, Supplementary notes on the occurrence of Tertiary Noetinae: Jour. Paleontology, v. 14, p. 507–509.

Mansfield, W. C., 1932, Miocene pelecypods of the Choctawhatchee formation of Florida: Florida Geol. Survey Bull. 8, 240 p., 34 pls.

——— 1937, Mollusks of the Tampa and Suwannee limestones of Florida: Florida Geol. Survey, Geol. Bull. 15, 334 p., 21 pls.

——— 1940, Mollusks of the Chickasawhay marl: Jour. Paleontology, v. 14, p. 171–226, pls. 25–27.

Martens, Eduard von, 1887–89, Die Gattungen *Nerita* und *Neritopsis*, in Martini and Chemnitz, Systematisches Conchylien-Cabinet, n. ser., v. 2, pt. 11, 147, p., 15 pls.

Maury, C. J., 1917, Santo Domingo type sections and fossils; pt. 1: Bull. Am. Paleontology, v. 5, no. 29, 251 p., 39 pls.

——— 1917a, Santo Domingo type sections and fossils; pt. 2: Bull. Am. Paleontology, v. 5, no. 30, 62 p., 3 pls.

——— 1920, Tertiary Mollusca from Porto Rico: New York Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 1, p. 1–77, pls. 1–9.

——— 1922, The Recent Arcas of the Panamic province: Palaeontographica Americana, v. 1, no. 4, 46 p., 3 pls.

———1925, A further contribution to the paleontology of Trinidad (Miocene horizons): Bull. Am. Paleontology, v. 10, no. 42, 250 p., 43 pls.

——— 1925a, Fosseis terciarios do Brasil: Brasil Servico Geol. y Mineral. Mon. 4, 711 p., 24 pls., map.

Merriam, C. W., 1941, Fossil Turritellas from the Pacific Coast region of North America: California Univ. Dept. Geol. Sci. Bull., v. 26, no. 1, p. 1–214, pls. 1–41, 19 figs.

Mörch, O. A. L., 1861, Beiträge zur Molluskenfauna Central-Amerikas: Malakozoologische Blätter, v. 7, p. 170–213.

Nelson, E. T., 1870, On the molluscan fauna of the later Tertiary of Peru: Connecticut Acad. Arts and Sci. Trans., v. 2, p. 186–206, pls. 6–7.

Nicol, David, 1945, Restudy of some Miocene species of *Glycymeris* from Central America and Colombia: Jour. Paleontology, v. 19, p. 622–624, pl. 85.

Noda, Hiroshi, 1966, The Cenozoic Arcidae of Japan: Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 38, p. 1–161, pls. 1–14, 16 figs.

Olsson, A. A., 1922, The Miocene of northern Costa Rica: Bull. Am. Paleontology, v. 9, no. 39, 309 p., 32 pls.

——— 1929, Contributions to the Tertiary paleontology of northern Peru; pt. 2, Upper Eocene Mollusca and Brachiopoda: Bull. Am. Paleontology, v. 15, no. 57, 50 p., 8 pls.

——— 1931, Contributions to the Tertiary paleontology of northern Peru; pt. 4, the Peruvian Oligocene: Bull. Am. Paleontology, v. 17, no. 63, 164 p., 21 pls.

——— 1932, Contributions to the Tertiary paleontology of northern Peru; pt. 5, the Peruvian Miocene: Bull. Am. Paleontology, v. 19, no. 68, 264 p., 24 pls.

——— 1942, Tertiary and Quarternary fossils from the Burica Peninsula of Panama and Costa Rica: Bull. Am. Paleontology, v. 27, no. 106, 106 p., 12 pls.

——— 1961, Mollusks of the tropical eastern Pacific; Panamic-Pacific Pelecypoda, 574, p., 86 pls., Paleontological Research Inst., Ithaca, N.Y.

——— 1964, Neogene mollusks from northwestern Ecuador, Paleontological Research Inst., 256 p., 38 pls., Ithaca, N.Y.

Olsson, A. A., and Petit, R. E., 1964, Some neogene Mollusca from Florida and the Carolinas: Bull. Am. Paleontology, v. 47, no. 217, p. 505–574, pls. 77–83.

——— 1968, Notes on *Siphocypraea*: Bull. Am. Paleontology, v. 54, no. 242, p. 277–289, pl. 18.

Palmer, K. V. W., 1937, The Claibornian Scaphopoda, Gastropoda, and dibranchite Cephalopoda of the southern United States: Bull. Am. Paleontology, v. 7, no. 32, 730 p., 90 pls.

Palmer, K. V. W., and Brann, D.C., 1965, Catalogue of the Paleocene and Eocene Mollusca of the southern and eastern United States; pt. 1: Bull. Am. Paleontology, v. 48, no. 218, 443 p., 3 pls.

Perrilliat Montoya, María del Carmen, 1960, Moluscos del Mioceno de la Cuenca Salina del Istmo de Tehuantepec, México; Paleontología Mexicana, no. 8, 38 p., 4 pls., 2 figs.

——— 1963, Moluscos de la formación Agueguexquite (Mioceno medio) del Istmo de Tehuantepec, México: Paleontología Mexicana, no. 14, 45 p., 6 pls., 2 figs.

Perry, L. M., 1940, Marine shells of the southwest coast of Florida: Bull. Am. Paleontology, v. 26. no. 95, 260 p., 39 pls.

Pflug, H. D., 1961, Mollusken aus dem Tertiär von St. Domingo: Acta Humboldtiana, Geol. et Palaeontologica ser., no. 1, 107 p., 26 pls., 1 fig.

Pilsbry, H. A., 1911, Scaphopods of the Jamaican Oligocene and Costa Rican Pliocene: Acad. Nat. Sci. Philadelphia, Proc., v. 63, p. 165–169, 5 figs.

——— 1922, Revision of W. M. Gabb's Tertiary Mollusca of Santo Domingo: Acad. Nat. Sci. Philadelphia Proc., v. 73, p. 305–435, pls. 16–47, 48 figs.

Pilsbry, H. A., and Bequaert, J., 1927, The aquatic mollusks of the Belgian Congo, with a geographical and ecological account of Congo malacology: Am. Mus. Nat. History Bull., v. 53, art. 2, 602 p., 77 pls., 93 figs., 15 maps.

Pilsbry, H. A. and Brown, A. P., 1917, Oligocene fossils from the neighborhood of Cartagena, Colombia, with notes on some Haitian species: Acad. Nat. Sci. Philadelphia Proc., v 69, p. 32–41, pls. 5, 6.

Pilsbry, H. A. and Johnson, C. W., 1917, New Mollusca of the Santo Domingan Oligocene: Acad. Nat. Sci. Phila. Proc., v. 69, p 150–202.

Pilsbry, H. A. and McGinty, T. L., 1939, The genus *Cyphoma* in Florida: Nautilus, v. 53, p. 1–4, pl. 1.

Pilsbry, H. A., and Olsson, A. A., 1935, Tertiary fresh-water mollusks of the Magdalena embayment, Colombia: Acad. Nat. Sci. Philadelphia Proc., v. 87, p. 7–39, pls. 2–5, 1 fig.

——— 1941, A Pliocene fauna from western Ecuador: Acad. Nat. Sci. Philadelphia Proc., v. 93, p. 1–79, pls. 1–19.

Pilsbry, H. A. and Sharp, B[enjamin], 1897–98, Scaphopoda: Manual of conchology, v. 17, p. v–xxxii, 1–280, pls. 1–39.

——— 1898, Scaphopoda of the San Domingo Tertiary: Acad. Nat. Sci. Philadelphia Proc., v. 49 (1897), p. 465–476, pls. 10, 11.

Reeve, L. A., 1858, Monograph of the genus *Modiola:* in Conchologia iconica, v. 10, 11 pls., and accompanying text, London.

——— 1859, Monograph of the genus *Trochita:* in Conchologia iconica, v. 11, 3 pls., and accompanying text, London.

Rehder, H. A., 1967, Valid zoological names of the Portland Catalogue: U.S. Natl. Mus. Proc., v. 121, no. 3579, 51 p.

Reinhart, P. W., 1935, Classification of the pelecypod family Arcidae: Mus. Royal Historie Nat. Belgique Bull., v. 11, no. 13, 68 p., 4 pls.

——— 1939, The holotype of *Barbatia* (*Acar*) *gradata* (Broderip & Sowerby): San Diego Soc. Nat. History Trans., v. 9, no. 10, p. 39–46, 3 pls.

——— 1943, Mesozoic and Cenozoic Arcidae from the Pacific slope of North America: Geol. Soc. America Spec. Paper 47, 117 p., 15 pls., 3 figs.

Rost, Helen, 1955, A report on the family Arcidae (Pelecypoda): Allan Hancock Pacific Exped., v. 20, no. 2, p. 173–249, pls. 11–16, figs. 79–95.

Rutsch, Rolf, 1942, Larkinien (Arcidae) aus dem Jungtertiär von Trinidad (B. W. I.): Eclogae Geol. Helvetiae: v. 35, p. 213–223, pl. 8.

Sacco, Federico, 1898, I molluschi dei terreni terziarii del Piemonte e della Liguria, pt. 26, 92 p., 12 pls.

Schenck, H. G., 1934, Classification of nuculid pelecypods: Mus. Royal Histoire Nat. Belgique Bull., v. 10, no. 20, 78 p., 5 pls.

Schenck, H. G., and Reinhart, P. W., 1938, Oligocene arcid pelecypods of the genus *Anadara:* Mus. Royal Hist. Nat. Belgique Mem., 2nd ser., pt. 14, 73 p., 6 pls., 12 figs.

Sheldon, P. G., 1916, The Atlantic slope Arcas: Palaeontographica Americana, v. 1, no. 1, 101 p., 16 pls.

Sohl, N. F., 1960, Archeogastropoda, Mesogastropoda, and stratigraphy of the Ripley, Owl Creek, and Prairie Bluff formations: U.S. Geol. Survey Prof. Paper 331–A, p. 1–151, pls. 1–18, figs. 1–11.

Soot-Ryen, Tron, 1955, A report on the family Mytilidae (Pelecypoda): Allan Hancock Pacific Expeditions, v. 20, no. 1, 174 p., 10 pls., 78 figs.

Sowerby, G. B., 1848, Monograph of the genus *Ovulum*, in Thesaurus conchyliorum, pt. 9, p. 467–484, pls. 99–101, London.

——— 1850, *in* Moore, J. C., Descriptions of new species of fossil shells found by J. S. Heniker [Heneken], Esq.: Geol. Soc. London Quart. Jour., v. 6, p. 44–53, pls 9, 10.

Spieker, E. M., 1922, The paleontology of the Zorritos formation of the north Peruvian oil fields: Johns Hopkins Univ., Studies in Geology, no. 3, 177 p., 10 pls.

Stanley, S. M., 1970, Relation of shell form to life habits of the Bivalvia (Mollusca): Geol. Soc. America Mem. 125, 296 p., 40 pls., 48 figs.

Stewart, R. B., 1930, Gabb's California type lamellibranchs: Acad. Nat. Sci. Philadelphia, Special Pub. 3, 314 p., 17 pls., 5 figs.

Trechmann, C. T., 1924, The Carbonaceous Shale or Richmond formation of Jamaica: Geol. Mag., v. 61, p. 2–19, pls. 1, 2.

——— 1925, The Scotland beds of Barbados: Geol. Mag., v. 62, p. 481–504, pls. 21–24, 1 fig.

——— 1934, Tertiary and Quarternary beds of Tobago: Geol. Mag., v. 71, p. 481–493, pls. 24, 25, 1 fig.

Turner, R. D., and Rosewater, Joseph, 1958, The family Pinnidae in the western Atlantic: Johnsonia, v. 3, no. 38, p. 285–326, pls. 149–171.

Van de Poel, Luc, 1955, Structure du test et classification des nucules: Inst. Royal Sciences Nat. Belgique Bull., v. 31, no. 3, 11 p.

Vokes, E. H., 1964, The genus *Turbinella* (Mollusca, Gastropoda) in the New World: Tulane Studies in Geology, v. 2, no. 2, p. 39–68, 3 pls., 1 fig.

——— 1964a, Additions to the New World Turbinellas: Tulane Studies in Geology, v. 3, no. 1, p. 95–96.

Vokes, H. E., 1969, The anadarid genus *Caloosarca* in the western Atlantic region: Tulane Studies in Geology, v. 7, no. 1, p. 1–40, 6 pls., 3 figs.

von Ihering, H., 1903, Notes sur quelques mollusques fossils du Chile: Revista Chilena Historia Nat., v. 7, p. 120–127, pls. 8, 9.

Warmke, G. L., and Abbott, R. T, 1961, Caribbean seashells, 348 p. 44 pls., 34 figs. Livingston Publishing Co., Narberth, Pa.

Waring, G. A., 1926, The geology of the Island of Trinidad, British West Indies: Johns Hopkins Univ., Studies in Geology, no. 7, 180 p., 20 pls., 1 fig.

Weisbord, N. E., 1929, Miocene Mollusca of northern Colombia: Bull. Am. Paleontology, v. 14, no. 54, 74 p., 9 pls.

——— 1964, Late Cenozoic pelecypods from northern Venezuela: Bull. Am. Paleontology, v. 45, no. 204, 564, p., 59 pls., 8 figs.

Winckworth, R., 1945, The types of the Boltenian genera: Malacolog. Soc. London Proc., v. 26, p. 136–148.

Woodring, W. P., 1925, Miocene mollusks from Bowden, Jamaica; pelecypods and scaphopods: Carnegie Inst. Washington Pub. 366, 222 p., 28 pls.

——— 1925a, *Arca patricia* Sowerby, a Miocene fossil from the Dominican Republic: Science, v. 62, p. 518–519

——— 1928, Miocene mollusks from Bowden, Jamaica; pt. 2, Gastropods and discussion of results: Carnegie Inst. Washington Pub. 385, 564 p., 40 pls., 3 figs.

——— 1938, Lower Pliocene mollusks and echinoids from the Los Angeles basin, California, and their inferred environment: U.S. Geol. Survey Prof. Paper 190, 67 p., 9 pls., 2 figs.

Woods, Henry, 1922, Mollusca from the Eocene and Miocene deposits of Peru, in Bosworth, T. O., Geology of the Tertiary and Quaternary periods in the north-west part of Peru, p. 51–113, pls. 1–20, London.

Wrigley, Arthur, 1946, English Eocene and Oligocene Ampullinids: Malacolog. Soc. London Proc., v. 27, p. 88–104, 31 figs.

Yonge, C. M., 1955, A note on *Arca* (*Senilia*) *senilis* Lamarck [Linné]: Malacolog. Soc. London Proc., v. 31, p. 202–208, 3 figs.

Zelinska, V. O., 1963, Mollusks of middle Eocene strata in Pobuzhzhe district: Geologichnye Zhur., v. 23, no. 4, p. 99–105, 1 pl. (in Russian).

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[Italic page numbers indicate major references and descriptions]

PLATES 67–82

[Contact photographs of the plates in this report are available, at cost, from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225]

PLATE 67

[All specimens from loc. 23b]

FIGURES 1, 2, 6–8, 11, 12. *Nerita hadra* Woodring, n. sp. (p. 466).

1, 2. Height 5.5 mm, diameter 7 mm. USNM 646648.

6, 11, 12. Type. Height 8 mm, diameter (not quite complete) 10.5 mm. USNM 646647.

7, 8. Height 5.8 mm, diameter 7.5 mm. USNM 646649.

3–5, 9, 10, 14, 15. *Neritina ectypha* Woodring, n. sp. (p. 467).

3,4. Height 5.3 mm, diameter (incomplete) 4.8 mm. USNM 646651.

5, 10. Height 6.3 mm, diameter (incomplete) 7 mm. USNM 646652.

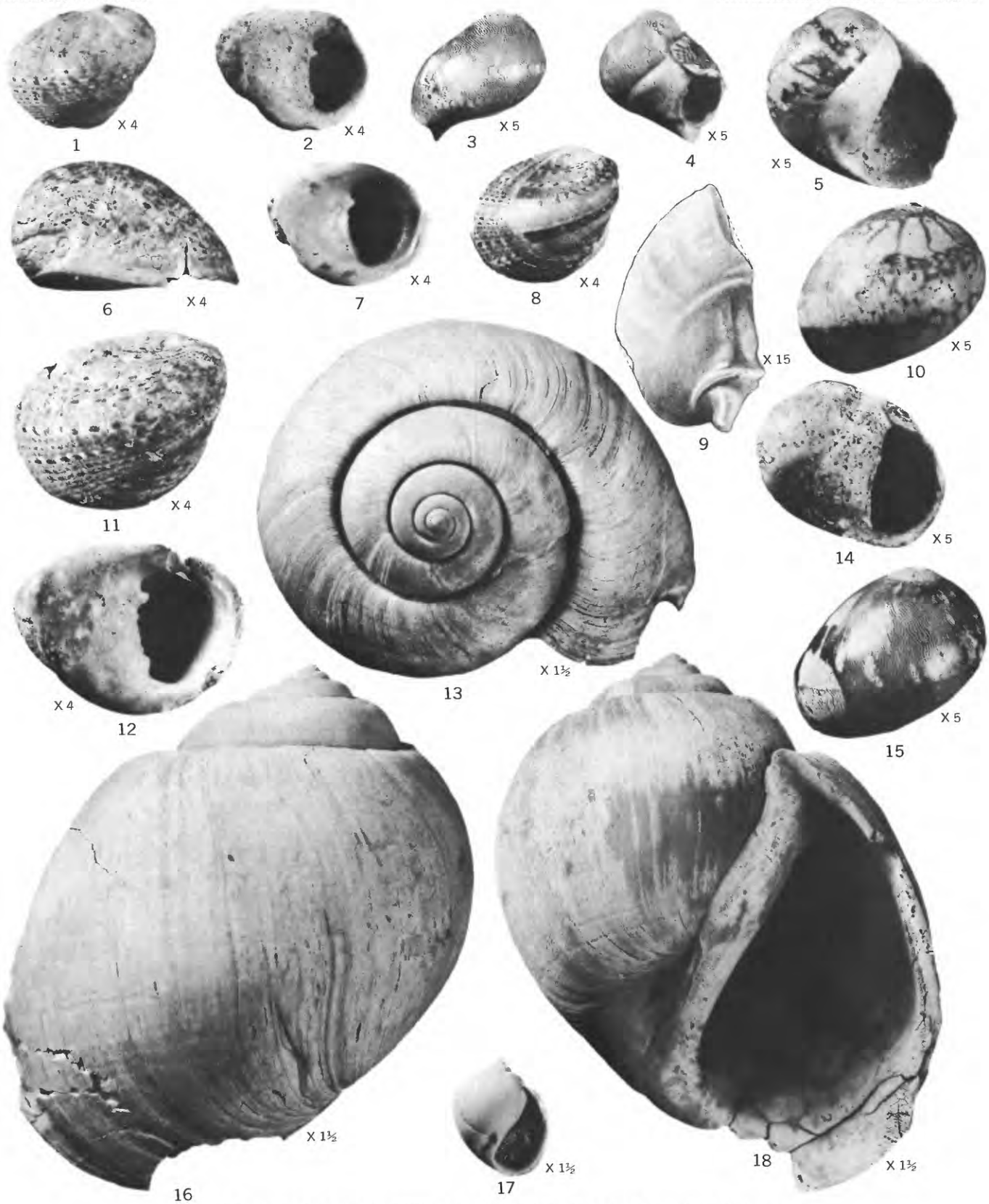
9. Operculum originally in place in aperture of shell shown in figs. 3,4. Length 2.9 mm, width 1.7 mm. USNM 646651.

14, 15. Type. Height 6.4 mm, diameter 7.1 mm. USNM 646650.

13, 16–18. *Globularia* (*Globularia*) *megista* Woodring, n. sp. (p. 475).

13, 16, 18. Type. Height (incomplete) 68 mm, diameter (incomplete) 57 mm. USNM 646682.

17. Immature. Height 14.8 mm, diameter 12.5 mm. USNM 646683.



LATE EOCENE MOLLUSKS FROM GATUNCILLO FORMATION

PLATE 68

[Specimens from loc. 23b, unless otherwise specified]

FIGURES 1–4. *Charadreon leptus* Woodring, n. sp. (p. 469).

1. Paratype. Height (incomplete) 8.9 mm, diameter 3.5 mm. USNM 646659.
2. Height (not quite complete) 12.9 mm, diameter 4 mm. USNM 646660.
3. Height (incomplete) 13.7 mm, diameter 3.7 mm. USNM 646661.
4. Type. Height (not quite complete) 18 mm, diameter 6.5 mm. USNM 646658.

5, 6, 11, 12. *Bayania epelys* Woodring, n. sp. (p. 468).

5, 6. Type. Height (incomplete) 26.7 mm, diameter 11.3 mm. USNM 646655.

11. Paratype. Height (not quite complete) 22.2 mm, diameter 9.8 mm. USNM 646657.

12. Paratype. Height (not quite complete) 23.4 mm, diameter 9.7 mm. USNM 646656.

7, 13, 17, 18. *Exputens bostrychodes* Woodring, n. sp. (p. 528).

Locality 12.

7, 13, 17. Type, articulated specimen. Length 23.7 mm, height 20.4 mm. USNM 646890.

18. Paratype, articulated specimen. Length (incomplete) 30 mm. USNM 646891.

8, 10. *Tympanotonos acanthodes* Woodring, n. sp. (p. 471).

8. Paratype. Height (incomplete) 34 mm, diameter (incomplete) 17mm. USNM 646672.

10. Paratype. Height (incomplete) 9.6 mm, diameter (incomplete) 4.5 mm. USNM 646673.

9, 15, 19, 20. *Hannctoma antyx* Woodring, n. sp. (p. 470).

9. Protoconch and early post-protoconch whorls. Height 0.8 mm, diameter 0.4 mm. USNM 646670.

15. Paratype. Height (not quite complete) 41.8 mm, diameter (almost complete) 15 mm. USNM 646668.

19. Type. Height (incomplete) 54.7 mm, diameter (almost complete) 20 mm. USNM 646667.

20. Height (incomplete) 44.8 mm, diameter (almost complete) 16.8 mm. USNM 646669.

14, 16, 21. *Bezanconia cosmeta* Woodring, n. sp. (p. 472).

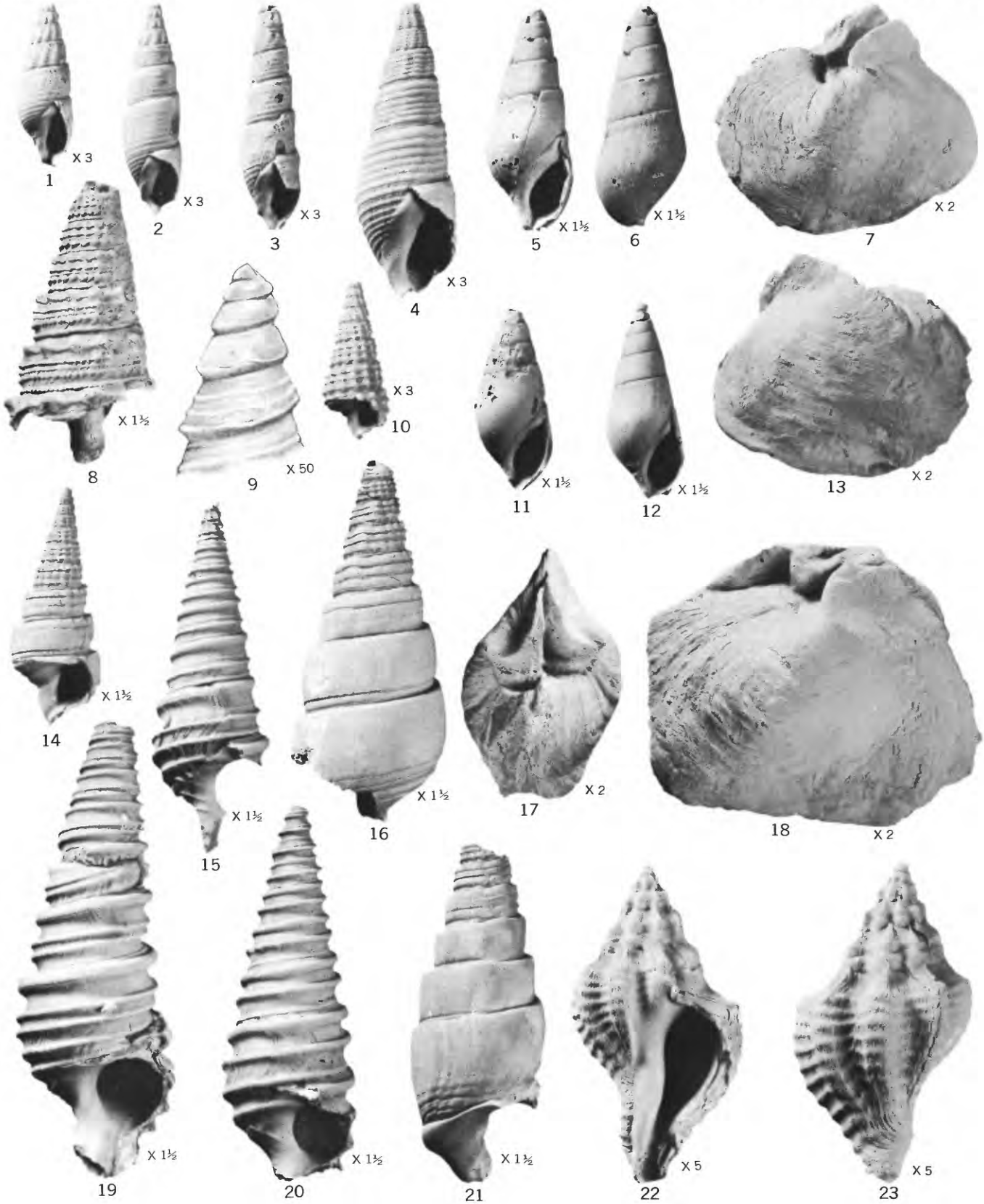
14. Paratype. Height (almost complete) 28.5 mm, diameter (incomplete) 11mm. USNM 646678.

16. Height (incomplete) 43.2 mm, diameter (incomplete) 20 mm. USNM 646679.

21. Type. Height (incomplete) 41 mm, diameter (incomplete) 17mm. USNM 646677.

22, 23. *Leptomurex acares* Woodring, n. sp. (p. 476).

Type. Height 11.3 mm, diameter 6.8 mm. USNM 646684.



LATE EOCENE MOLLUSKS FROM GATUNCILLO FORMATION

475-796 O - 73 - 7

PLATE 69

[Specimens from loc. 23b, unless otherwise specified]

FIGURES 1, 2, 10. *Calyptraea lispa* Woodring, n. sp. (p. 473).
1. Paratype. Height 2.3 mm, maximum diameter 5.5 mm. USNM 646681.
2, 10. Type. Height 10.5 mm, maximum diameter 19.2 mm. USNM 646680.

3, 5–8. *Harrisianella camptica* Woodring, n. sp. (p. 472).
3. Paratype. Height (incomplete) 14.5 mm, diameter (almost complete) 6.5 mm. USNM 646675.
5, 6. Type. Height (almost complete) 31.6 mm, diameter (almost complete) 10 mm. USNM 646674.
7, 8. Height (incomplete) 15 mm, diameter (almost complete) 9 mm. USNM 646676.

4, 15, 16. *Potamides? micraulax* Woodring, n. sp. (p. 470).
4. Paratype. Height (not quite complete) 18.9 mm, diameter (incomplete) 7.2 mm. USNM 646666.
15. Type. Height (incomplete) 20 mm, diameter (incomplete) 10.2 mm. USNM 646664.
16. Paratype. Height (not quite complete) 27 mm, diameter (incomplete) 9.8 mm. USNM 646665.

9. *Leptadrillia?* n. sp. (p. 481).
Height (incomplete) 22.5 mm, diameter (almost complete) 9.7 mm. USNM 646686.

11, 12, 17. *Nerita listrota* Woodring, n. sp. (p. 466).
Type. Height 15 mm, diameter 19 mm. USNM646646.

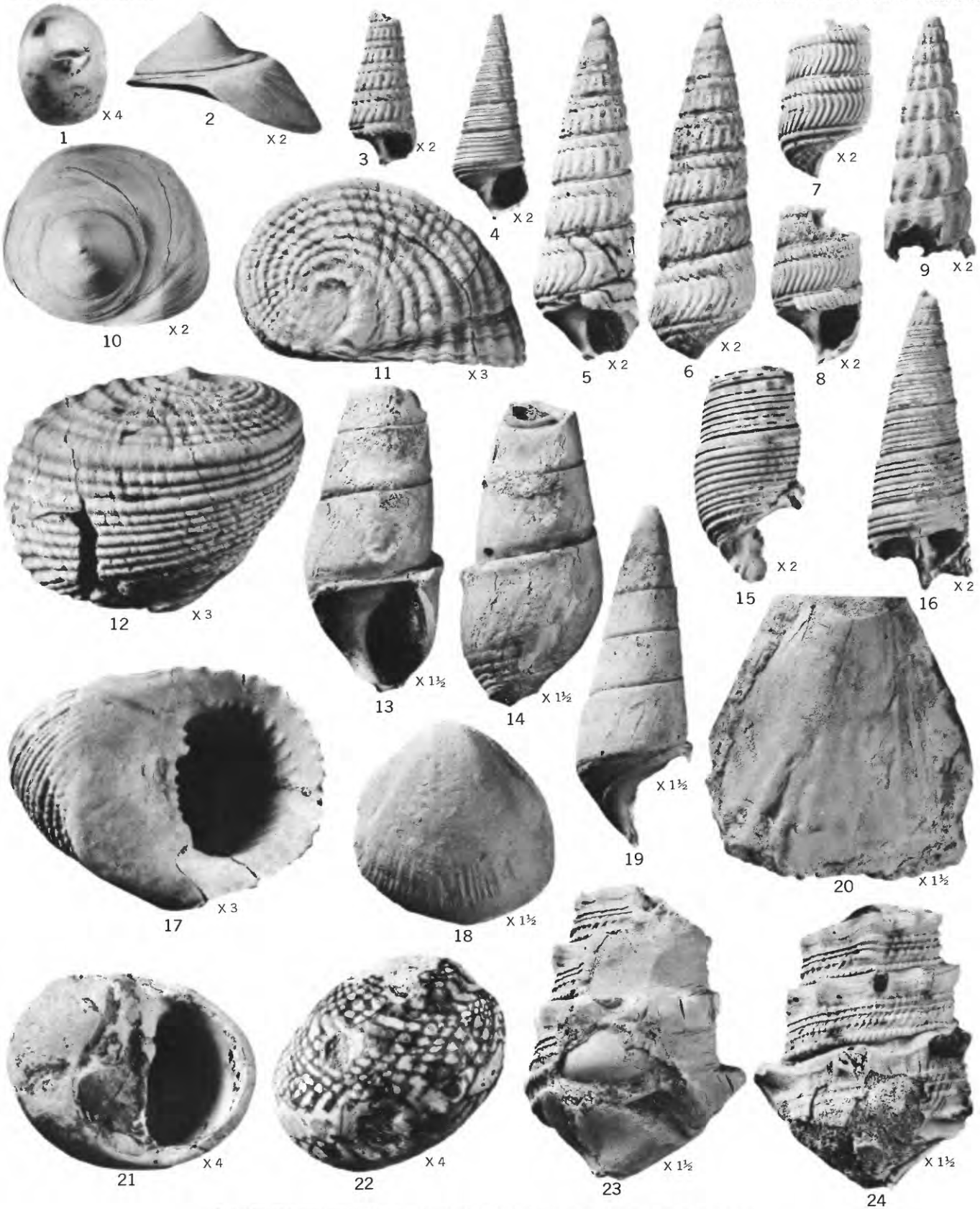
13, 14, 19. *Faunus xenicus* Woodring n. sp. (p. 470).
13, 14. Type. Height (incomplete), 37.5 mm, diameter (incomplete) 18 mm. USNM 646662.
19. Paratype. Height (not quite complete) 41.5 mm, diameter (incomplete) 14.5 mm. USNM 646663.

18. *Glycymeris* (*Glycymeris*) cf. *G. caracoli* Anderson (p. 519).
Length 25 mm, height 25.3 Locality 12. USNM 646851.

20. *Atrina* sp. (p. 525).
Length (incomplete) 33 mm, height 26 mm. Locality 32. USNM 646889.

21, 22. *Neritina* sp. (p. 467).
Height 10.2 mm, diameter 10.9 mm. USNM 646653.

23, 24. *Tympanotonos acanthodes* Woodring, n. sp. (p. 471)
Type. Height (incomplete) 36.5 mm, diameter (including spines) 27.5 mm. USNM 646671.



LATE EOCENE MOLLUSKS FROM GATUNCILLO FORMATION

PLATE 70

FIGURES 1, 2, 6, 13. *Anadara* (*Rasia*) *lita* Woodring, n. sp. (p. 504).
Locality 42d. Bohio formation.
1, 6. Type. Length (not quite complete) 18 mm, height 14.2 mm. USNM 646695.
2. Length 9 mm, height 7mm. USNM 646696.
13. Paratype. Length 13.7 mm, height 10.5 mm. USNM 646854.

3, 9, 10. *Teinostoma* (*Idioraphe*) *elachistum* Woodring, n. sp. (p. 467).
Type. Height 0.6 mm, diameter 1.3 mm. Locality 23b. Gatuncillo formation. USNM 646654.

4. *Acila* (*Acila*) *isthmica isthmica* (Brown and Pilsbry) (p. 489).
Length 15.5 mm, height 12.3 mm. Locality 54l. Caimito formation. USNM 646702.

5. *Anadara* (*Rasia*) *carmenensis* Clark (p. 500).
Length 6.5 mm, height 3.5 mm. Locality 41b. Marine member of Bohio(?) formation. USNM 646692.

7. *Cadulus* (*Gadilopsis*) *dolichus* Woodring, n. sp. (p. 486).
Type. Length 11.8 mm, maximum diameter 1.2 mm, apical diameter 0.9 mm. Locality 41b. Marine member of Bohio(?) formation. USNM 646689.

8, 15, 16. *Saccella phlyctaena* Woodring, n. sp. (p. 491).
Marine member of Bohio(?) formation.
8, 16. Type. Length 11 mm, height 6.5 mm. Locality 40d. USNM 646690.
15. Length 9.7 mm, height 5.5 mm. Locality 41b. USNM 646691.

11, 12. *Nucula* (*Nucula*) cf. *N. spheniopsis* Conrad (p. 488).
Caimito formation.
11. Length 3 mm, height 3 mm. Locality 54n. USNM 646701.
12. Length 4.3 mm, height 4 mm. Locality 54h. USNM 646700.

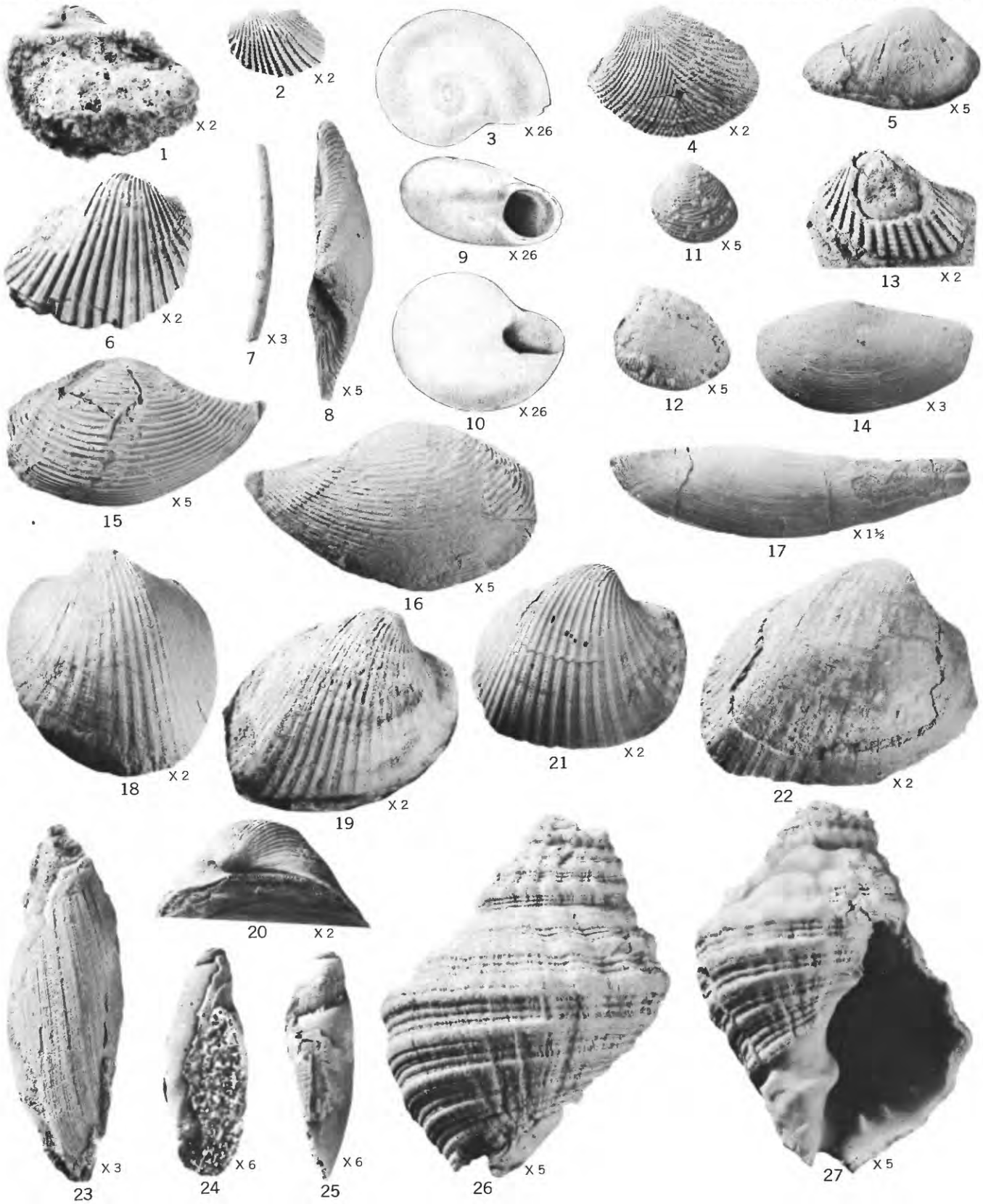
14. *Portlandia* (*Portlandella?*) *euthynta* Woodring, n. sp. (p. 495).
Type. Length 13 mm, height 7.2 mm. Locality 42i. Bohio formation. USNM 646694.

17. *Adrana stena* Woodring, n. sp. (p. 493).
Type. Length (not quite complete) 48.5 mm, height 11.4 mm. Locality 42d. Bohio formation. USNM 646693.

18–22. *Samanoetia samanensis* (Olsson) (p. 517).
Marine member of Bohio(?) formation.
18. Length 20.2 mm, height 19.5 mm. Locality 42a. USNM 646853.
19, 20. Length 22 mm, height 18.5 mm. Locality 42a. USNM 646887.
21. Length 19 mm. height 17.2 mm. Locality 41b. USNM 646852.
22. Length (not quite complete) 25.8 mm, height 21 mm. Locality 40b. USNM 135225.

23–25. *Volvariella?* sp. (p. 481).
Marine member of Bohio (?) formation.
23. Height (almost complete) 21.8 mm, diameter 7.5 mm. Locality 41. USNM 646687.
24, 25. Height (almost complete) 6.9 mm, diameter 2.6 mm. Locality 41b. USNM 646688.

26, 27. *Cymia* (*Tritonopsis*) n. sp. (p. 477).
Height (incomplete) 13.5 mm, diameter 10.3 mm. Locality 23b. Gatuncillo formation. USNM 646685.



LATE EOCENE MOLLUSKS FROM GATUNCILLO FORMATION AND MARINE MEMBER OF BOHIO(?) FORMATION, AND LATE OLIGOCENE MOLLUSKS FROM BOHIO AND CAIMITO FORMATIONS

PLATE 71

FIGURE 1. *Anadara* (*Rasia*) *dariensis progonica* Woodring, n. subsp. (p. 500).
Type. Length 24.6 mm, height 14.9 mm. Locality 112. Culebra formation. USNM 646705.

2, 3. *Saccella* cf. *S. subcerata* (Woodring) (p. 492).
Length 7 mm, height 4 mm. Locality 54k. Caimito formation. USNM 646704.

4, 5, 10, 11. *Architectonica* (*Architectonica*) *nobilis* Röding, subsp. (p. 473).
Locality 101h. La Boca formation.
4, 5, 11. Height 6.5 mm, diameter 13.5 mm. USNM 646709.
10. Height (reduced by crushing) 8.5 mm, diameter 30.5 mm. USNM 646710.

6, 7, 16. *Dentalium* (*Fissidentalium*) *uscarianum* Olsson (p. 483).
Locality 54k. Caimito formation.
6. Apical end of specimen shown in fig. 7.
7. Length (incomplete at anterior end) 13.6 mm, anterior diameter 2.7 mm, apical diameter 0.9 mm. USNM 646699.
16. Length (incomplete at both ends) 52 mm, anterior diameter 7.3 mm, apical diameter 2.7 mm. USNM 646698.

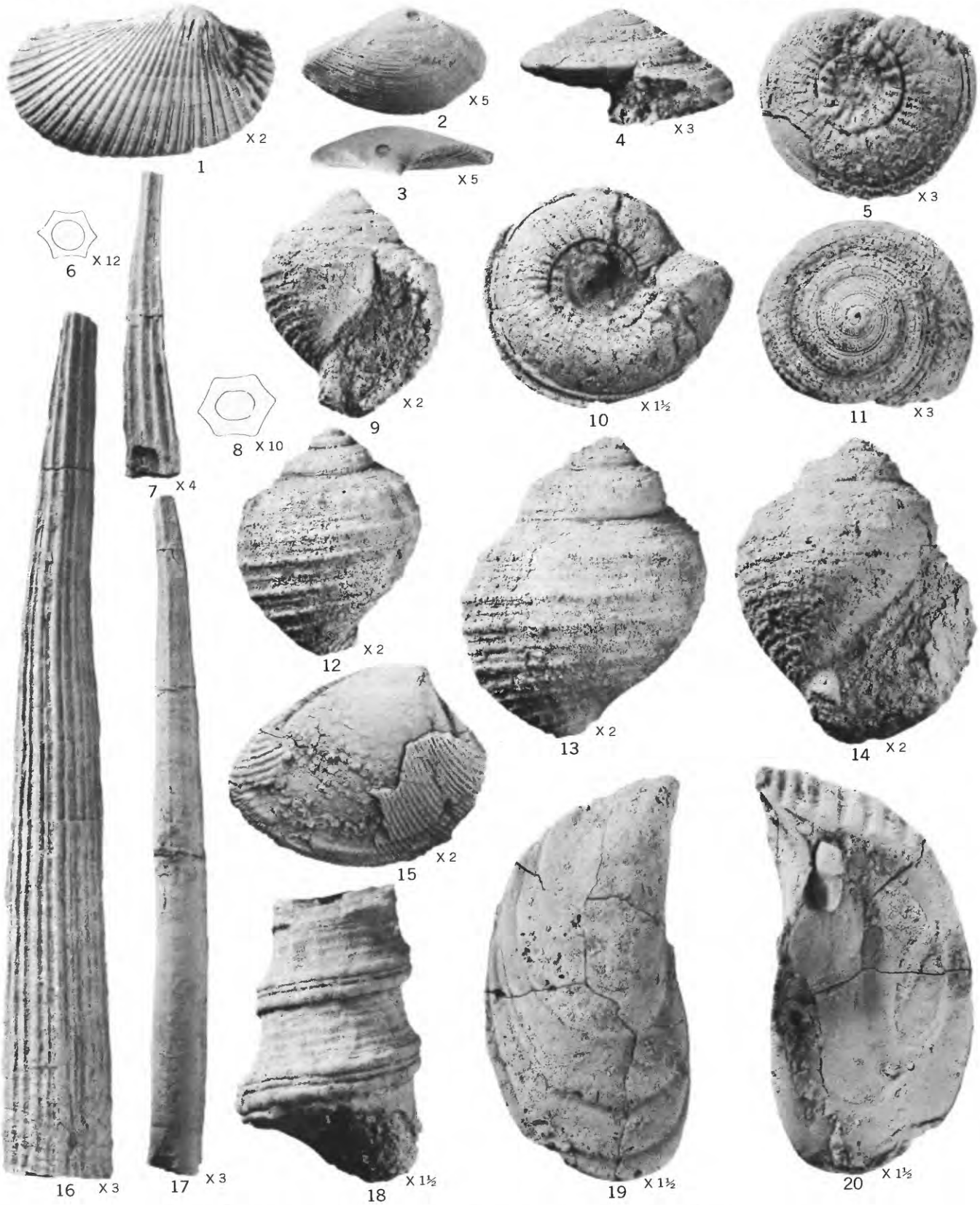
8, 17. *Dentalium* (*Dentalium*) *armillatum proterum* Woodring, n. subsp. (p. 482).
8. Apical end of specimen shown in fig. 17.
17. Type. Length (incomplete at both ends) 40.2 mm, anterior diameter 3.5 mm, apical diameter 1.3 mm. Locality 54h. Caimito formation. USNM 646697.

9, 12–14. *Semicassis* (*Echinophoria*) *tostoma* Woodring, n. sp. (p. 476).
Locality 101h. La Boca formation.
9, 12, Paratype. Height (almost complete) 20.7 mm, diameter (terminal varix missing) 16.8 mm. USNM 646714.
13, 14. Type. Height (incomplete) 28 mm, diameter (terminal varix missing) 23.5 mm. USNM 646713.

15. *Acila* (*Acila*) *isthmica isthmica* (Brown and Pilsbry) (p. 489).
Length 24 mm, height 17 mm. Locality 101i. La Boca formation. USNM 646715.

18. *Turritella collazica* Maury (p. 467).
Height (incomplete) 35 mm, diameter 23 mm. Locality 116a. La Boca formation. USNM 646707.

19, 20. *Isognomon* (*Mimonion*) *mimeticus* Woodring, n. sp. (p. 527).
Type. Height 49 mm, width 25 mm. Locality 116a. La Boca formation. USNM 646893.



LATE OLIGOCENE MOLLUSKS FROM CAIMITO FORMATION, AND EARLY MIOCENE MOLLUSKS FROM CULEBRA AND LA BOCA FORMATIONS

PLATE 72

FIGURE 1. *Glycymeris* (*Tucetona*) *secticostata schencki* Nicol (p. 521).
Length 20.3 mm, height 19.9 mm. Locality 116a. La Boca formation. USNM 646862.

2. *Anadara* (*Potiarca*) aff. *A. chavezi* (Engerrand and Urbina) (p. 514).
Length 18 mm, height about 17 mm. Locality 116. La Boca formation. USNM 646861.

3. *Modiolus americanus* (Leach)? (p. 523).
Length 25.6 mm, height 15 mm. Locality 94. La Boca formation USNM 646888.

4, 6, 8. *Anadara* (*Rasia*) *athroa* Woodring, n. sp. (p. 505).
4. Length 29.3 mm, height 20 mm. Locality 116. La Boca formation. USNM 646717.
6. Length 16 mm, height 8.4 mm. Locality 116a. La Boca formation. USNM 646718.
8. Type. Length 37.9 mm, height 26.5 mm. Locality 116a. La Boca formation. USNM 646716.

5, 9. *Jupiteria aipeia* Woodring, n. sp. (p. 490).
Type. Length 8.6 mm, height 6.2 mm. Locality 54h. Caimito formation. USNM 646703.

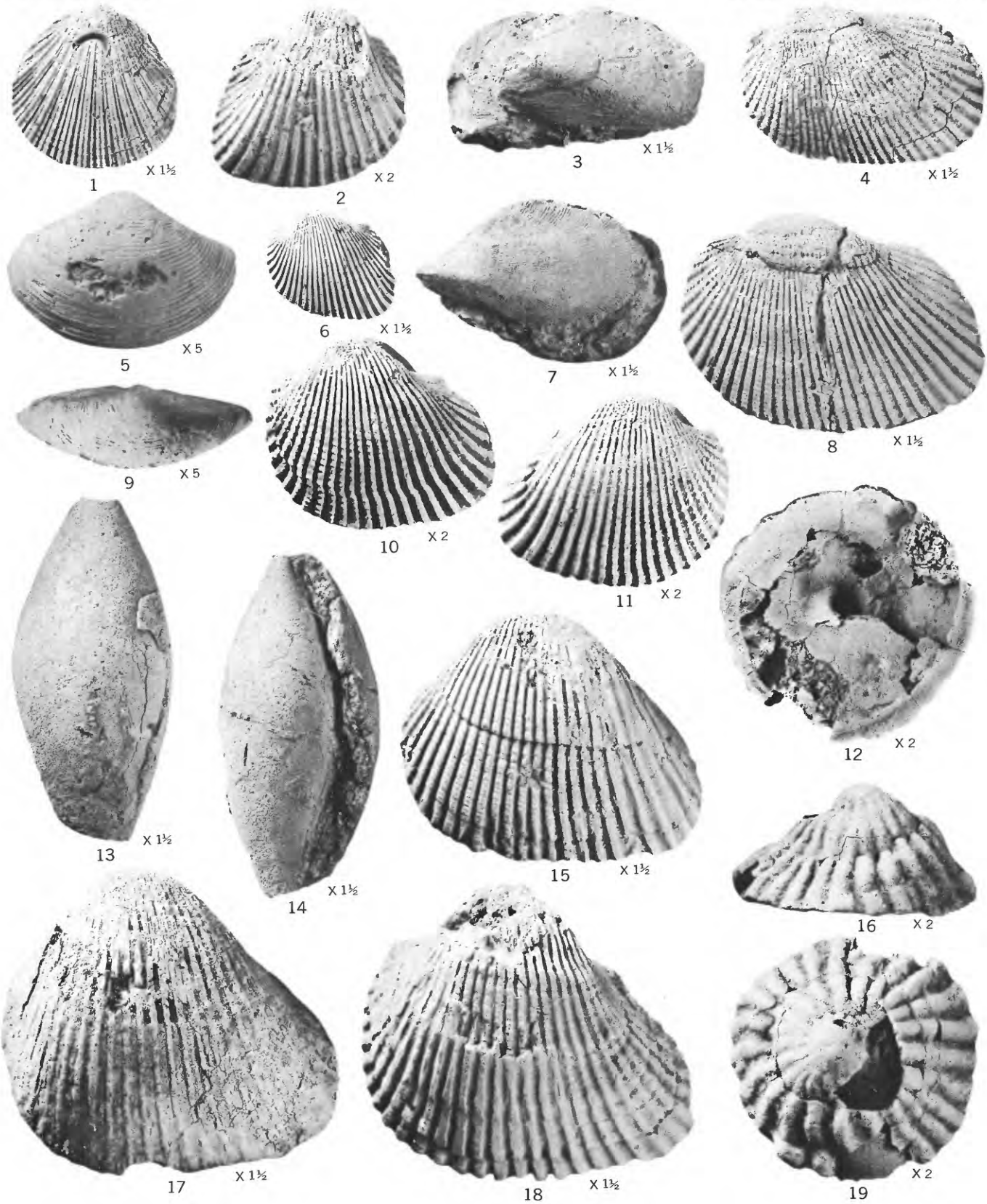
7. *Brachidontes* sp. (p. 523).
Length (not quite complete) 27.5 mm, height 16 mm. Locality 99f. La Boca formation. USNM 646863.

10, 11, 15. *Anadara* (*Grandiarca*) *balboai* (Sheldon) (p. 510).
10, 11. Articulated specimen. Length 21.9 mm, height 18 mm. Locality 116a. La Boca formation. USNM 646860.
15. Length 38 mm, height 29.5 mm. Locality 108c. Culebra formation. USNM 646857.

12, 16, 19. *Trochita* sp. (p. 474).
Height 12.5 mm, diameter 23.3 mm. Locality 116a. La Boca formation. USNM 646711.

13, 14. *Cyphoma* aff. *C. intermedia* (Sowerby) (p. 475).
Height (almost complete) 41 mm, diameter 20.3 mm. Locality 101h. La Boca formation. USNM 646712.

17, 18. *Anadara* (*Grandiarca*) *chiriquiensis chiriquiensis* (Gabb) (p. 508).
17. Length 42.2 mm, height 37.6 mm. Locality 110. Culebra formation. USNM 646856.
18. Length 42.3 mm, height 36.5 mm. Locality 103. Culebra formation. USNM 646855.



LATE OLIGOCENE MOLLUSKS FROM CAIMITO FORMATION, AND EARLY MIOCENE MOLLUSKS FROM CULEBRA AND LA BOCA FORMATIONS

PLATE 73

FIGURES 1, 4. *Mytilus canoasensis vidali* Ferreira and Cunha (p. 522).
1. Length 49.2 mm, height 23.7 mm. Locality 106. Culebra formation. USNM 646859.
4. Length 77 mm, height 34.7 mm. Locality 106. Culebra formation. USNM 646858.

2. *Arca imbricata* Bruguière (p. 496).
Length 27.7 mm, height 16.5 mm. Locality 76. Alhájuela formation. USNM 646720.

3. *Anadara* (*Tosarca*) cf. *A. tectumcolumbae* (Maury) (p. 507).
Latex cast. Length 36.5 mm, height (not quite complete) 25.5 mm. Locality 85a. Alhajuela formation. USNM 646721.

5, 6. *Nerita* (*Nerita*?) sp. (p. 466).
Height 10.5 mm, diameter 11.2 mm. Locality 116a. La Boca formation. USNM 646706.

7. *Crucibulum* (*Crucibulum*) *spinosum* (Sowerby) (p. 474).
Height 9.7 mm, diameter 15.2 mm. Locality 138c. Lower part of Gatun formation. USNM 646722.

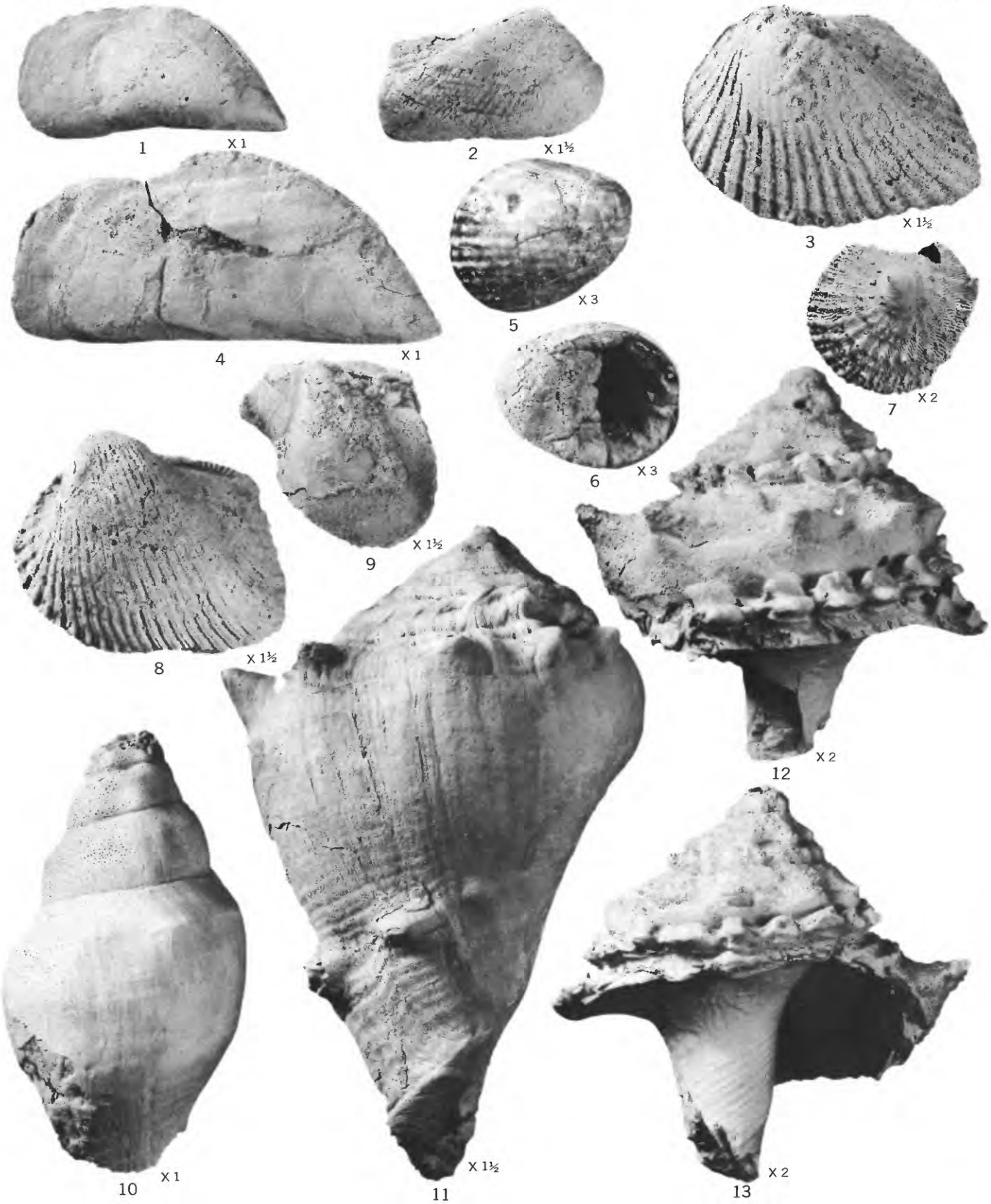
8. *Anadara* (*Tosarca*) *campta* Woodring, n. sp. (p. 506).
Type. Length (practically complete) 34.6 mm, height 28 mm. Locality 101h. La Boca formation. USNM 646719.

9. *Pteria inornata* (Gabb)? (p. 526).
Length (incomplete) 24.5 mm, height (incomplete) 23.5 mm. Locality 114. La Boca formation. USNM 646892.

10. *Xancus validus hysterus* Woodring, n. subsp. (p. 479).
Immature paratype. Height (incomplete) 77 mm, diameter 45 mm. Locality 159b. Middle part of Gatun formation. USNM 646727.

11. *Melongena* cf. *M. propatula* Anderson (p. 478).
Height (almost complete) 81.5 mm, diameter (not including spines) 49 mm. Locality 138f. Lower part of Gatun formation. USNM 646725.

12, 13. Xancid?, genus? (p. 480).
Height (incomplete) 36 mm, diameter (including knobs) 39.7 mm. Locality 138c. Lower part of Gatun formation. USNM 646728.



EARLY MIOCENE MOLLUSKS FROM CULEBRA, LA BOCA, AND ALHAJUELA FORMATIONS, AND MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 74

FIGURE 1. *Turritella subgrundifera* Dall (p. 468).
Height 32.2 mm, diameter 13.6 mm. Locality 101h. La Boca formation. USNM 646708.

2, 3. *Xancus validus hysterus* Woodring, n. subsp. (p. 479).
Slightly reduced. Type. Height (incomplete) 265 mm, diameter 110 mm. Locality 159b. Middle part of Gatun formation. USNM 646726.

4, 5. *Engina turbinella* (Kiener) (p. 477).
Height (not quite complete) 10.9 mm, diameter 7 mm. Locality 138f. Lower part of Gatun formation. USNM 646723.

EARLY MIOCENE MOLLUSK FROM LA BOCA FORMATION AND MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 75

FIGURES 1, 2. *Cadulus* (*Platyschides*) *epetrion* Woodring, n. sp. (p. 487).
Locality 139c. Middle part of Gatun formation.
1. Type. Length 8 mm, miximum diameter 1.3 mm, apertural diameter 1 mm, apical diameter 0.4 mm. USNM 646741.
2. Paratype. Length 7 mm, maximum diameter 1.2 mm, apertural diameter 0.9 mm, apical diameter 0.3 mm. USNM 646732.

3, 4. *Cadulus* (*Platyschides*) *bushii* Dall (p. 487).
Locality 147b. Middlepart of Gatun formation.
3. Length 7 mm, maximum diameter 1.2 mm, apertural diameter 0.8 mm, apicald iameter 0.4 mm. USNM 646733.
4. Length 6.5 mm, maximum diameter 1.4 mm, apertural diameter 1 mm, apical diameter 0.5 mm. USNM 646734.

5, 16, 31. *Dentalium* (*Laevidentalium*) *pyrum* Pilsbry and Sharp (p. 485).
Middle part of Gatun formation.
5, 16. Length (incomplete at both ends) 13.6 mm, anterior diameter 2.1 mm, apical diameter 1.6 mm. Fig. 16 anterior end. Locality 162a. USNM 646736.
31. Apical end. Diameter at lower end of sheath 0.7 mm. Locality 162. USNM 646737.

6, 7. *Glycymeris* (*Tucetona*) *secticostata schencki* Nicol (p. 521).
Upper part of Gatun formation, eastern area.
6. Length 19 mm, height 20 mm. Locality 171 USNM 646886.
7. Topotype. Length 24.5 mm, height 23.3 mm. Locality 173. USNM 646885.

8. *Nucula* (*Nucula*) *tenuisculpta* Gabb (p. 488)
Length 3 mm, height 2.7 mm. Locality 177b. Upper part of Gatun formation, eastern area. USNM 646743.

9. *Nucula* (*Nucula*) cf. *N. cahuitensis* Olsson (p. 488).
Length 1.7 mm, height (incomplete) 1.2 mm. Locality 139c. Middle part of Gatun formation. USNM 646742.

10, 11. *Cadulus* (*Gadilopsis*) *dentalinus* (Guppy) (p. 486).
Locality 147b. Middle part of Gatun formation.
10. Height 8.4 mm, maximum diameter 1.2 mm, apertural diameter 0.7 mm; apical diameter 0.3 mm. USNM 646740.
11. Height 5.4 mm, maximum diameter 0.9 mm, apertural diameter 0.6 mm, apical diameter 0.3 mm. USNM 646739.

12, 13. *Dentalium* (*Tesseracme*) *dissimile* Guppy (p. 483).
Length (incomplete at anterior end) 4 mm, anterior diameter 0.9 mm, apical diameter 0.6 mm. Fig. 12 anterior end. Locality 137. Lower part of Gatun formation, USNM 646731.

14, 23. *Dentalium* (*Dentalium*) *bothrum* Woodring, n. sp. (p. 482).
Type. Length (incomplete at both ends) 39.5 mm, anterior diameter 8.2 mm, apical diameter 3.6 mm. Fig. 14 apical end. Locality 179. Upper part of Gatun formation, western area. USNM 646730.

15, 24, 25. *Dentalium* (*Dentalium*) *armillatum armillatum* Toula (p. 482).
Length (incomplete at both ends) 40.4 mm, anterior diameter 3.9 mm, apical diameter 1.6 mm. Fig. 15 apical end: fig. 25, anterior end. Locality 177b. Upper part of Gatun formation, eastern area. USNM 646729.

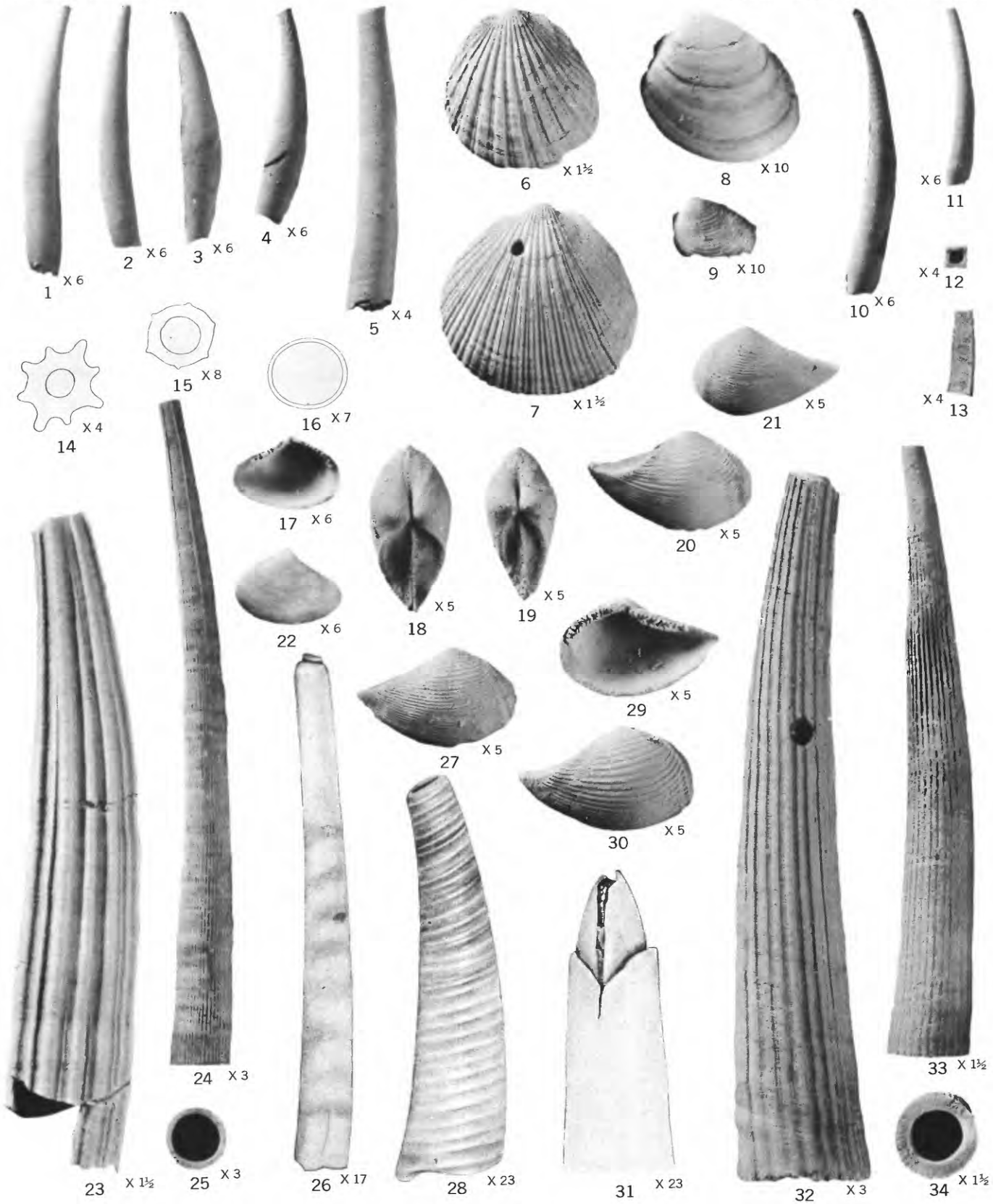
17, 22. *Jupiteria subtumida* (Woodring)? (p. 491).
Length 3.4 mm, height 2.4 mm. Locality 177c. Upper part of Gatun formation, eastern area. USNM 646746.

18–21, 27, 29, 30. *Saccella acrita epacra* Woodring, n. subsp. (p. 492).
18, 20. Articulated specimen. Length 6 mm, height 3.6. Locality 139c. Middle part of Gatun formation. USNM 646748.
19, 21. Type, articulated specimen. Length 5.6 mm, height 3.1 mm. Locality 147g. Middle part of Gatun formation. USNM 646747.
27, 29. Length 6.1 mm, height 3.7 mm. Locality 185. Upper part of Gatun formation, western area. USNM 646749.
30. Length 6.6 mm, height 3.9 mm. Locality 138c. Lower part of Gatun formation, USNM 646750.

26. *Dentalium* (*Episiphon*) *innumerable elassum* Woodring, n. subsp. (p. 485).
Type. Length 5.5 mm, anterior diameter 0.6 mm, apical diameter outside pipe 0.4 mm. Locality 146. Middle part of Gatun formation. USNM 646738

28. *Dentalium* (*Rhabdus?*) sp. (p. 484).
Length (incomplete at anterior end, not quite complete at apical end) 3.2 mm, anterior diameter 0.8 mm, apical diameter 0.3 mm. Locality 185. Upper part of Gatun formation, western area. USNM 646735.

32–34. *Dentalium* (*Fissidentalium*) *granadanum esmeraldum* Olsson (p. 484).
Locality 208. Chagres sandstone.
32. Length (incomplete at both ends) 42.8 mm, anterior diameter 8.4 mm, apical diameter 3.6 mm. USNM 646777.
33, 34. Length (incomplete at both ends) 72 mm, anterior diameter 10.3 mm, apical diameter 3.2 mm. Fig. 34 anterior end. USNM 646776.



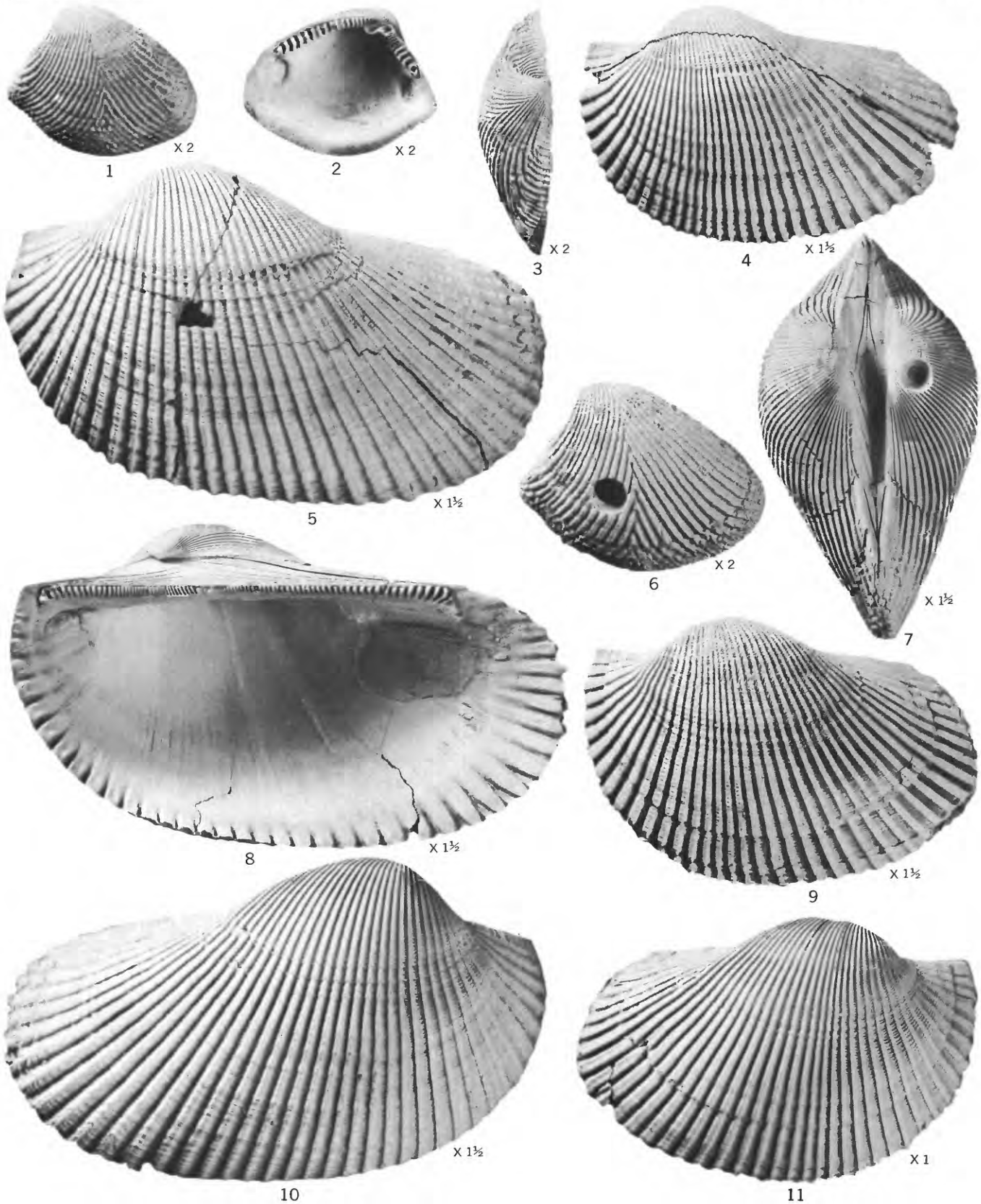
MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION AND
LATE MIOCENE MOLLUSKS FROM CHAGRES SANDSTONE

PLATE 76

FIGURES 1–3, 6. *Acila* (*Acila*) *isthmica isthmica* (Brown and Pilsbry) (p. 489).
Upper part of Gatun formation, western area.
1, 2. Length 21.9 mm, height 17.5 mm. Locality 183. USNM 646745.
3, 6. Length 22.8 mm, height 18.5 mm. Locality 179. USNM 646744.

4, 7, 9, 11. *Anadara* (*Rasia*) *actinophora actinophora* (Dall) (p. 502).
Upper part of Gatun formation, eastern area.
4. Type. Length 47 mm, height 29 mm. Locality 177. USNM 135597.
7, 9, 11. Articulated specimen. Length 48.8 mm, height 32.3 mm. Locality 175. USNM 646762.

5, 8, 10. *Anadara* (*Rasia*) *lienosa trochala* Woodring, n. subsp. (p. 503).
Locality 175. Upper part of Gatun formation, eastern area.
5. Paratype. Length 68.2 mm, height 39.6 mm. USNM 646764.
8, 10. Type. Length 67.6 mm, height 38.6 mm. USNM 646763.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

475-796 O - 73 - 8

PLATE 77

FIGURES 1, 2. *Anadara* (*Rasia*) cf. *A. emarginata* (Sowerby) (p. 504).
Length 20.9 mm, height 13.4 mm. Locality 184. Upper part of Gatun formation, western area. USNM 646765.

3, 5, 13, 18, 21, 22, 24. *Anadara* (*Rasia*) *dariensis dariensis* (Brown and Pilsbry) (p. 501).
3. Length 24 mm, height 13.5 mm. Locality 138f. Lower part of Gatun formation. USNM 646761.
5. Length 29 mm, height 17.5 mm. Locality 139c. Middle part of Gatun formation. USNM 646760.
13, 22, 24. Articulated specimen. Length 35.3 mm, height 22.7 mm. Locality 147h. Middle part of Gatun formation. USNM 646759.
18. Length 41.5 mm, height 24 mm. Locality 183. Upper part of Gatun formation, western area. USNM 646758.
21. Length 42.3 mm, height 24.6 mm. Locality 155b. Middle part of Gatun formation USNM 646757.

4, 8. *Acar domingensis* (Lamarck) (p. 497).
Length 18 mm, height 10.2 mm. Locality 160d. Middle part of Gatun formation. USNM 646756.

6. *Anadara* (*Potiarca*) cf. *A. berjadinensis* (H. K. Hodson) (p. 516).
Length 33.9 mm, height 27.8 mm. Locality 138e. Lower part of Gatun formation. USNM 646872.

7. *Calloarca* (*Taeniarca*) *cachla* (Olsson) (p. 497).
Length (incomplete) 21.5 mm, height 12.5 mm. Locality 160. Middle part of Gatun formation. USNM 646755.

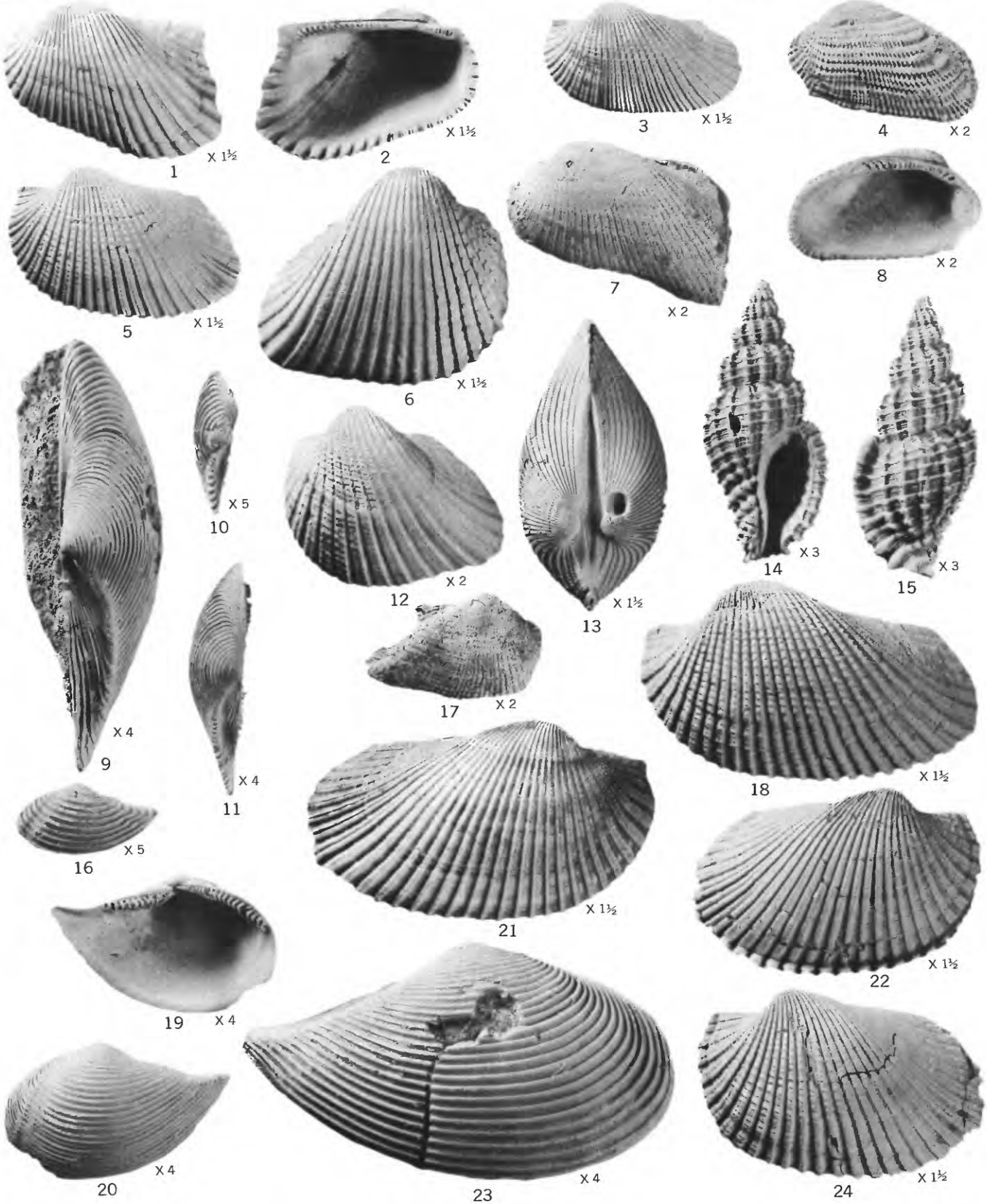
9, 11, 19, 20, 23. *Saccella balboae* (Brown and Pilsbry) (p. 493).
9, 23. Length 19.6 mm, height 11.4 mm. Locality 171. Upper part of Gatun formation, eastern area. USNM 646752.
11, 19, 20. Length 10.7 mm, height 6.1 mm. Locality 136. Lower part of Gatun formation. USNM 646753.

10, 16. *Saccella* cf. *S. fabalis* (Olsson) (p. 493).
Length 5.2 mm, height 2.5 mm. Locality 169. Middle part of Gatun formation. USNM 646751.

12. *Anadara* (*Cunearca*) *eumeces* Woodring, n. sp. (p. 516).
Type. Length 20.5 mm, height 17 mm. Locality 138c. Lower part of Gatun formation. USNM 646873.

14, 15. *Bailya crossata* Woodring, n. sp. (p. 478).
Type. Height 16.9 mm, diameter 7.5 mm. Locality 138e. Lower part of Gatun formation. USNM 646724.

17. *Arca imbricata* Bruguière (p. 496).
Length 16.4 mm, height 9.9 mm. Locality 138e. Lower part of Gatun formation. USNM 646754



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 78

FIGURES 1–6. *Anadara* (*Rasia*) *fissicosta* (Spieker) (p. 505).

1, 3. Length 36.6 mm, height (not quite complete) 29 mm. Locality 138c. Lower part of Gatun formation. USNM 646772.

4–6. Articulated specimen. Length 29.5 mm, height 23.8 mm. Locality 136. Lower part of Gatun formation. USNM 646771.

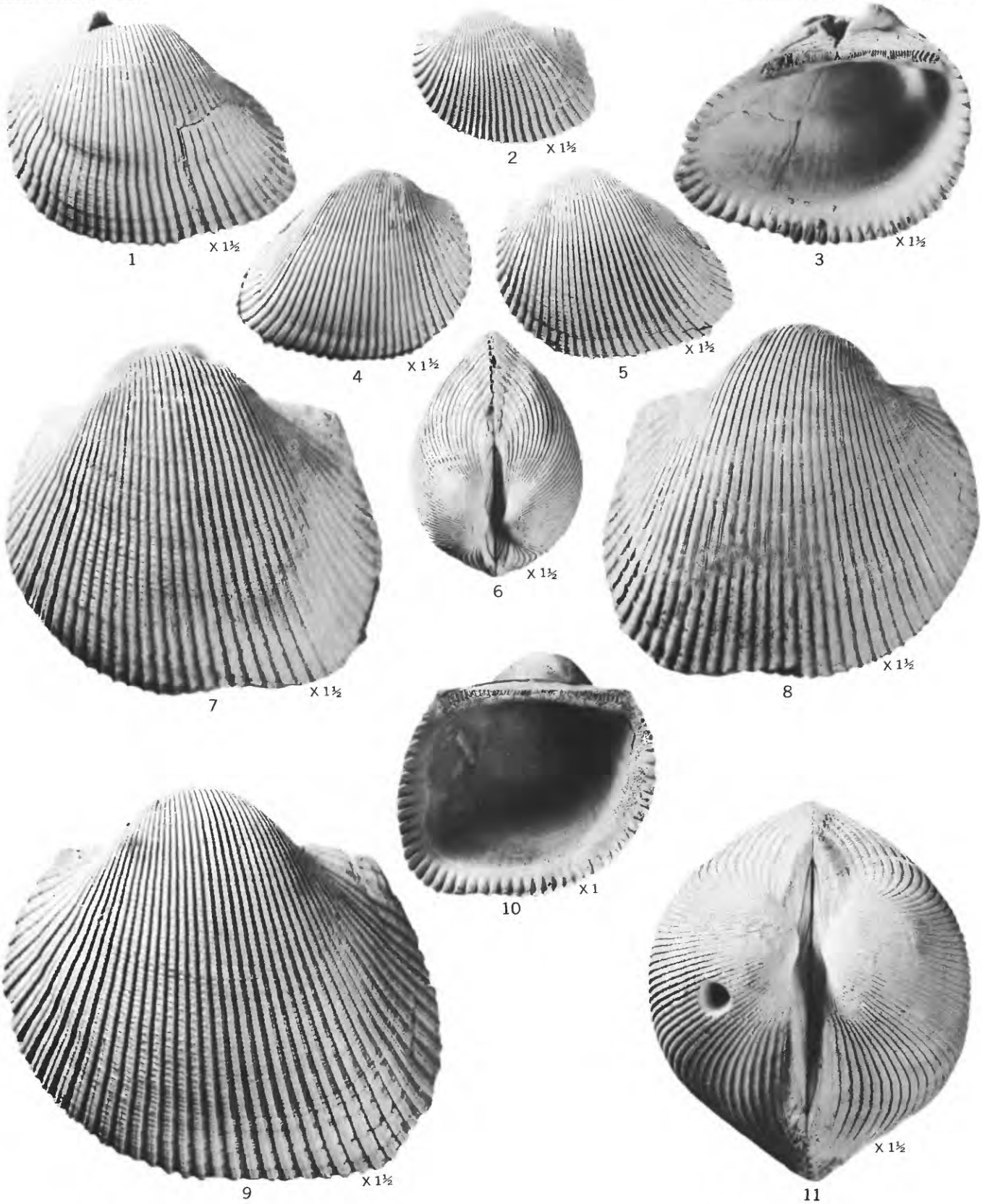
2. Length 22.6 mm, height 16.5 mm. Locality 139c. Middle part of Gatun formation. USNM 646773.

7–11. *Anadara* (*Tosarca*) *veatchi veatchi* (Olsson) (p. 507).

7, 8, 11. Articulated specimen. Length 46.6 mm, height 44.7 mm. Locality 183. Upper part of Gatun formation, western area. USNM 646775.

9. Length 54.5 mm, height 49.2 mm. Locality 155. Middle part of Gatun formation. USNM 646774.

10. Length 47.8 mm, height 44.9 mm. Locality 182a. Upper part of Gatun formation, western area. USNM 646905.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

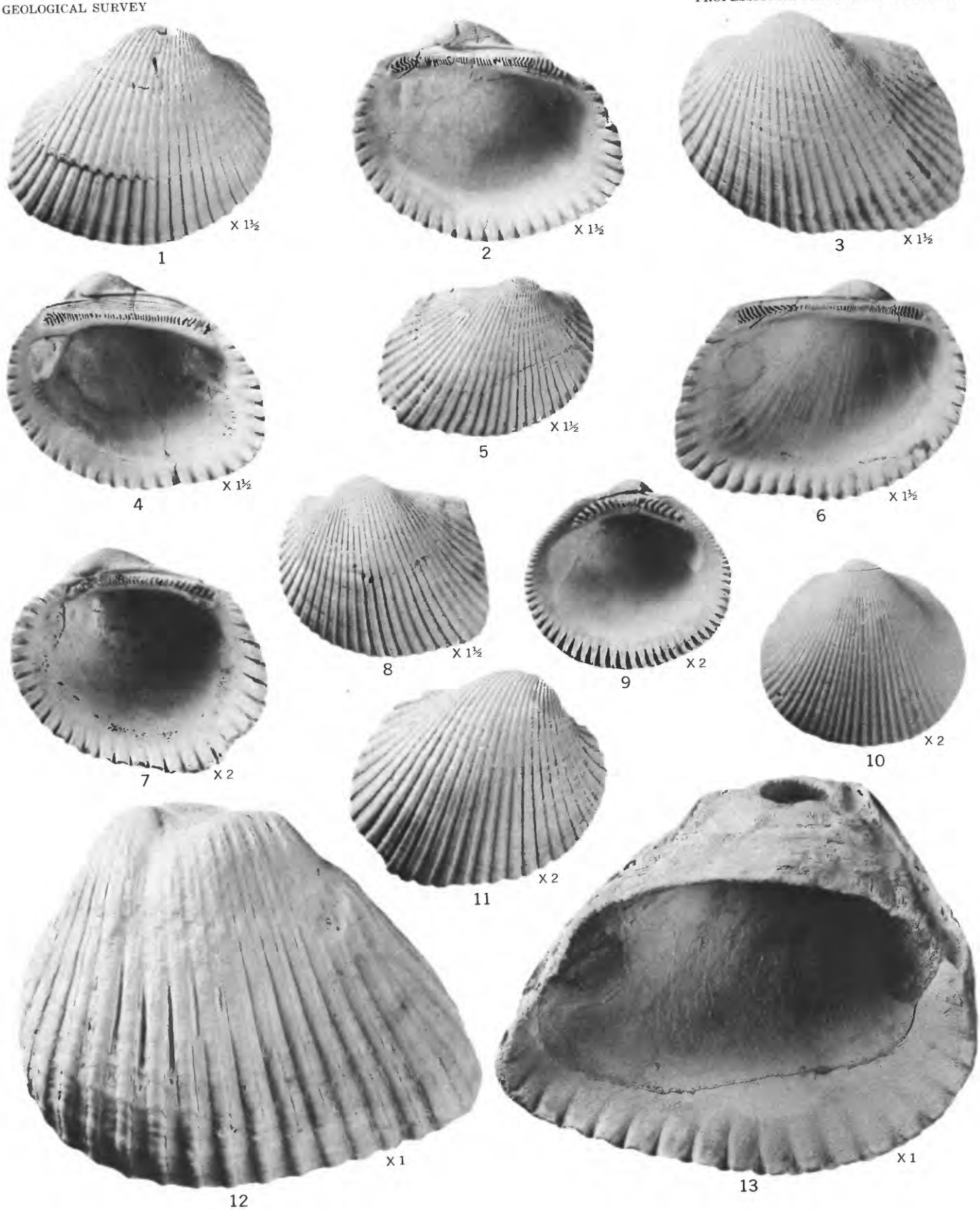
PLATE 79

FIGURES 1–6, 8. *Anadara* (*Rasia*) *sechurana* (Olsson) (p. 505).
Locality 138c. Lower part of Gatun formation.
1, 2. Length 33 mm, height 27.2 mm. USNM 646766.
3, 6. Length 35.8 mm, height 27.6 mm. USNM 646767.
4. Length 31.2 mm, height 25.7 mm. USNM 646770.
5. Length 27.2 mm, height 19.4 mm. USNM 646768.
8. Length 26.6 mm, height 23.2 mm. USNM 646769.

7, 11. *Lunarca ovalis* (Bruguière)? (p. 516).
Length 23.7 mm, height 20.9 mm. Locality 160d. Middle part of Gatun formation. USNM 646874.

9, 10. *Glycymeris* (*Glycymeris*) *carbasina* Brown and Pilsbry (p. 519).
Immature. Length 19.2 mm, height 17.2 mm. Locality 172. Upper part of Gatun formation, eastern area. USNM 646879.

12, 13. *Anadara* (*Grandiarca*) *grandis patricia* (Sowerby)? (p. 512).
Length (incomplete) 88.5 mm, height (incomplete) 67.5 mm. Locality 170. Middle part of Gatun formation. USNM 646866.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 80

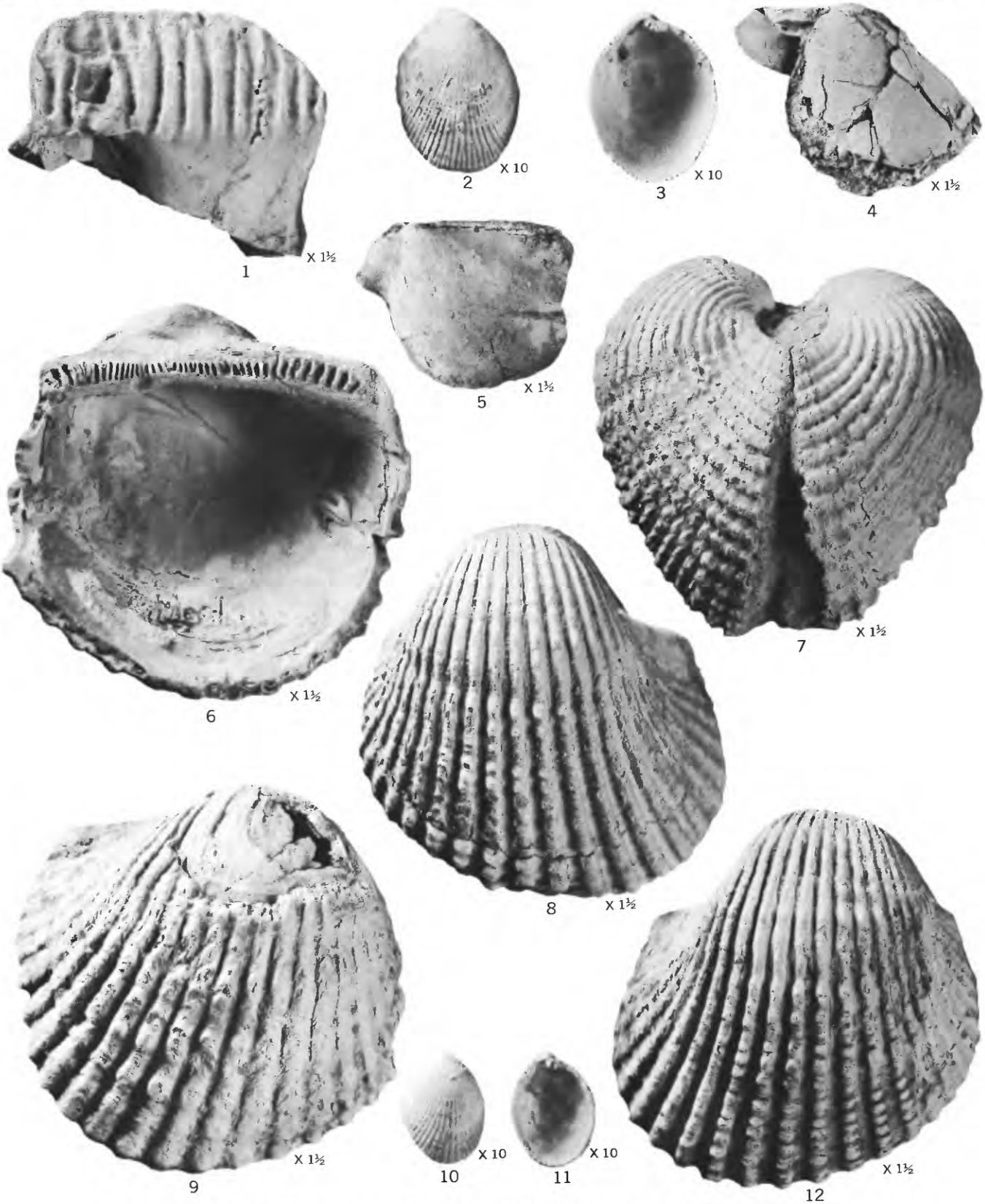
FIGURE 1. *Isognomon* (*Melina?*) sp. (p. 527).
Height (incomplete) 29 mm, width (incomplete) 37.5 mm. Locality 170. Middle part of Gatun formation. USNM 646901.

2, 3. *Crenella ecuadoriana santiaga* Olsson (p. 524).
Length 2.3 mm, height 3 mm. Locality 170a. Middle part of Gatun formation. USNM 646895.

4, 5. *Pteria inornata* Gabb? (p. 526).
4. Length (incomplete) 28 mm, height 24 mm. Locality 147g. Middle part of Gatun formation. USNM 646899.
5. Length (incomplete) 26 mm, height (incomplete) 20 mm. Locality 139g. Middle part of Gatun formation. USNM 646900.

6–9, 12. *Anadara* (*Grandiarca*) *dolaticosta* (Pilsbry and Johnson) (p. 510).
6, 9. Length (incomplete) 48 mm, height (incomplete) 49.2 mm. Locality 170. Middle part of Gatun formation. USNM 646864.
7, 8, 12. Length 45 mm, height 45.8 mm. USGS 8010, Quebrada Schawb, Costa Rica. Deposits of middle Miocene age. USNM 646865.

10, 11. *Crenella divaricata* (d'Orbigny) (p. 524).
Length 1.6 mm, height 2.1 mm. Locality 159d. Middle part of Gatun formation. USNM 646894.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION AND COSTA RICA

PLATE 81

FIGURES 1–3, 6. *Anadara* (*Potiarca*) *chavezi* (Engerrand and Urbina) (p. 514).

1. Length 30.5 mm, height 26.4 mm. Locality 159d. Middle part of Gatun formatiou. USNM 646870.
2. Length 18.8 mm, height 17.4 mm. Locality 138c. Lower part of Gatun formation. USNM 646868.
3. Length 24.5 mm, height 27 mm. Locality 159d. Middle part of Gatun formation. USNM 646871.
6. Length 14.5 mm, height 13.7 mm. Locality 138c. Lower part of Gatun formation. USNM 646869.

4, 5, 8. *Glycymeris* (*Tucetona*) *pectinata canalis* Brown and Pilsbry (p. 520). Middle part of Gatun formation, eastern area.

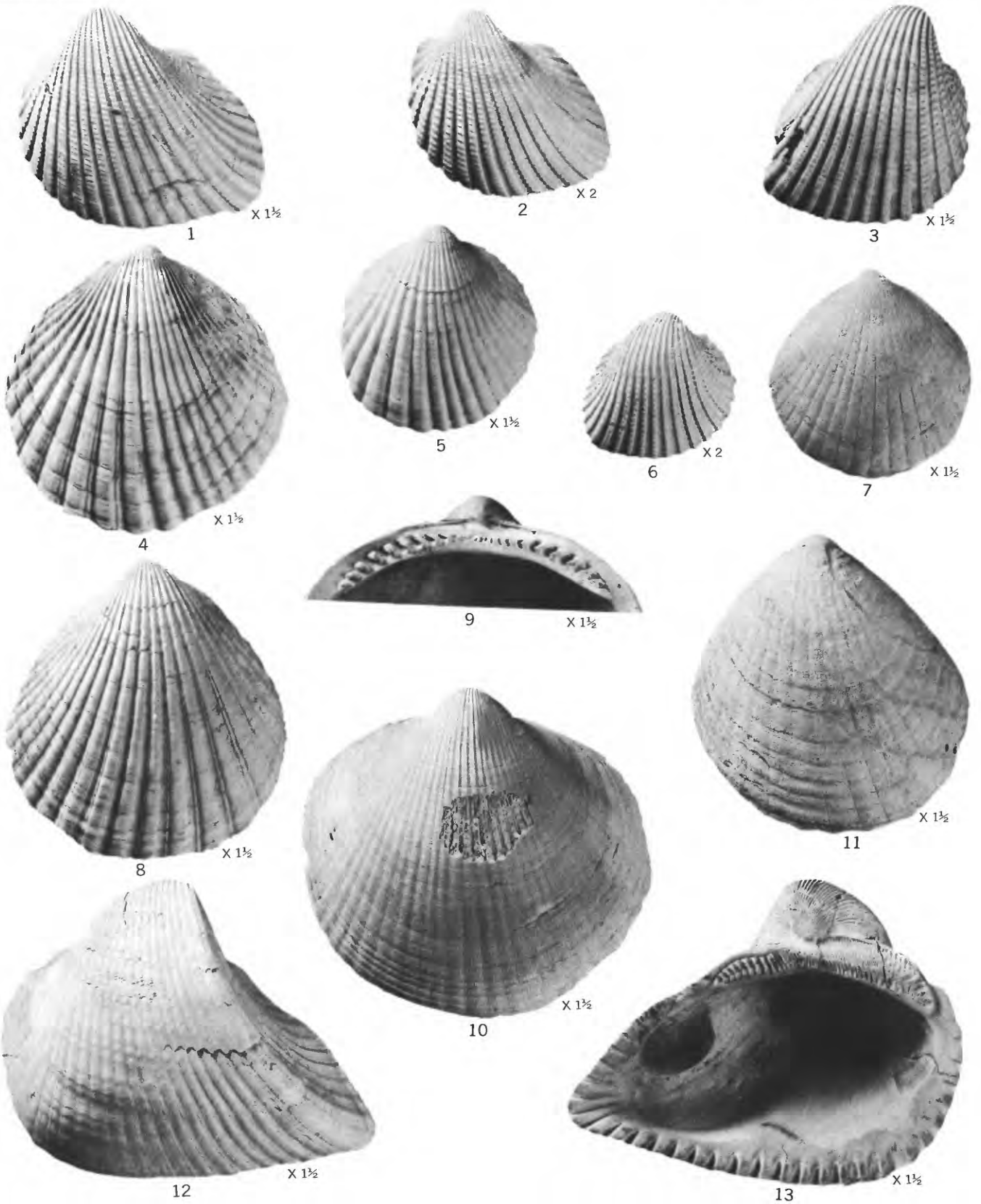
4. Length 34.6 mm, height 36 mm. Locality 155a. USNM 646882.
5. Length 24.4 mm, height 25.4 mm. Locality 155a. USNM 646884.
8. Length 35 mm, height 35 mm. Locality 155b. USNM 646883.

7, 11. *Glycymeris* (*Tucetona*) *epacra* Woodring, n. sp. (p. 520). Upper part of Gatun formation, western area.

7. Length 24.8 mm, height 25 mm. Locality 182. USNM 646881.
11. Type. Length 33.7 mm, height 36.2 mm. Locality 182a. USNM 646880.

9, 10. *Glycymeris* (*Glycymeris*) *carbasina* Brown and Pilsbry (p. 519). Length 42.7 mm, height 40.5 mm. Locality 155. Middle part of Gatun formation. USNM 646878.

12, 13. *Noetia* (*Noetia*) *reversa macdonaldi* (Dall) (p. 518). Length 46.5 mm, height 37.7 mm. Locality 138a. Lower part of Gatun formation. USNM 646875.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 82

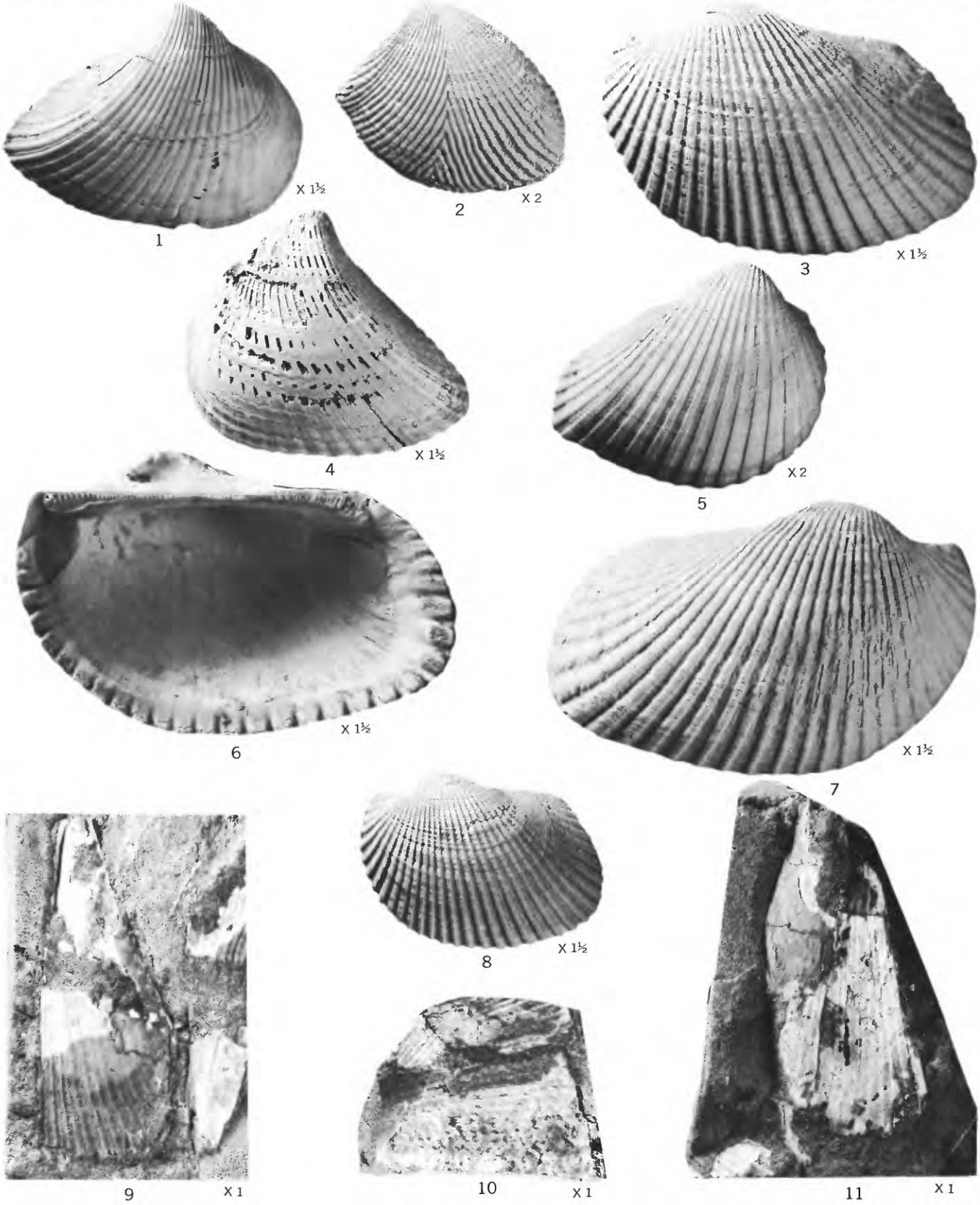
FIGURES 1, 4. *Noetia* (*Noetia*) *reversa macdonaldi* (Dall) (p. 518).
Middle part of Gatun formation, eastern area.
1. Length 36.4 mm, height 27.3 mm. Locality 155a. USNM 646877.
4. Length 35.7 mm, height 30 mm. Locality 155. USNM 646876.

2. *Acila* (*Acila*) *isthmica isthmica* (Brown and Pilsbry) (p. 489).
Length 21.9 mm, height 17 mm. Locality 208. Chagres sandstone. USNM 646778.

3, 6–8. *Anadara* (*Rasia*) *honensis adiaphora* Woodring, n. subsp. (p. 502).
Locality 208. Chagres sandstone.
3. Length 46.7 mm, height 32.2 mm. USNM 646780.
6, 7. Type. Length 52.5 mm, height 35.2 mm. USNM 646779.
8. Length 30.2 mm, height 21.5 mm. USNM 646906.

5. *Anadara* (*Potiarca*) *chavezi* (Engerrand and Urbina) (p. 514).
Length 23.2 mm, height 20 mm. Locality 137. Lower part of Gatun formation. USNM 646867.

9–11. *Atrina* (*Servatrina*) aff. *A. serrata* (Sowerby) (p. 525).
Locality 139g. Middle part of Gatun formation.
9. Length (incomplete) 64.5 mm, height 25 mm. USNM 646896.
10. Ventral fragment. Length (incomplete) 40 mm, height (incomplete) 20 mm. USNM 646898.
11. Length (incomplete) 60 mm, height 23 mm. USNM 646897.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION AND
LATE MIOCENE MOLLUSKS FROM CHAGRES SANDSTONE

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