Neogene Paleontology of the Northern Dominican Republic. 24. Propeamussiidae and Pectinidae (Mollusca: Bivalvia: Pectinoidea) of the Cibao Valley

Thomas R. Waller

Bulletins of American Paleontology

Number 381, July 2011

BULLETINS OF AMERICAN PALEONTOLOGY

Established 1895

Paula M. Mikkelsen
Editor-in-Chief

Warren D. Allmon
Director

Editorial Board

Jason S. Anderson, University of Calgary
Kenneth Angielczyk, Field Museum of Natural History
Carlton Brett, University of Cincinnati
Ann F. Budd, University of Iowa
Peter Dodson, University of Pennsylvania
Daniel Fisher, University of Michigan
Dana H. Geary, University of Wisconsin-Madison
Peter J. Harries, University of South Florida
John Pojeta, United States Geological Survey
Carrie E. Schweitzer, Kent State University
Geerat J. Vermeij, University of California at Davis
Emily H. Vokes, Tulane University (Emerita)
William Zinsmeister, Purdue University

Bulletins of American Paleontology is published semiannually by Paleontological Research Institution. For a list of titles and to order back issues online, go to http://museumoftheearth.org. Numbers 1-94 (1895-1941) of Bulletins of American Paleontology are available from Periodicals Service Company, Germantown, New York, http://www.periodicals.com. Subscriptions to Bulletins of American Paleontology are available in hard-copy and electronic formats to individuals or institutions; non-US addressees pay an additional fee for postage and handling. For current rates, additional information or to place an order, see http://museumoftheearth.org or contact:

Publications Office
Paleontological Research Institution
1259 Trumansburg Road
Ithaca, New York 14850-1313
Tel. (607) 273-6623, ext. 20
Fax (607) 273-6620
publications@museumoftheearth.org

This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

Neogene Paleontology of the Northern Dominican Republic. 24. Propeamussiidae and Pectinidae (Mollusca: Bivalvia: Pectinoidea) of the Cibao Valley

Thomas R. Waller

Bulletins of American Paleontology

Number 381, July 2011

ISSN 0007-5779
ISBN 978-0-87710-494-0
Library of Congress Catalog Card Number 2011931850
© 2011, Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, New York 14850, U. S. A.

NEOGENE PALEONTOLOGY OF THE NORTHERN DOMINICAN REPUBLIC. 24. PROPEAMUSSIIDAE AND PECTINIDAE (MOLLUSCA: BIVALVIA: PECTINOIDEA) OF THE CIBAO VALLEY

Thomas R. Waller
Department of Paleobiology, National Museum of Natural History, Smithsonian Institution,
Washington, DC 20013-7012 USA, email wallert@si.edu

ABSTRACT

Based on approximately 25,000 specimens from the Miocene and Pliocene of the Cibao Valley, northern Dominican Republic, the bivalve family Propeamussiidae is represented by two genera and four species, including two new species, *Cyclopecten acuminatus* and *C. zalaya;* the family Pectinidae is represented by three subfamilies, six tribes, 18 genera, and 35 species. New taxa in the Pectinidae include six new genera (*Interchlamys*, *Chagrepecten*, *Gurabopecten*, *Paraleptopecten*, *Zamorapecten*, and *Antillipecten*), 15 new species (*Caribachlamys guayubinensis*, *C. jungi*, *Mimachlamys blowi*, *M. vokesorum*, *Palliolum*? *cibaoense*, *Argopecten parathetidis*, *Chagrepecten paracactaceus*, *Gurabopecten uniplicatus*, *Lindapecten baitoaensis*, *L. paramuscosus*, *Euvola gurabensis*, *Zamorapecten maoensis*, *Antillipecten janicoensis*, *A. microlineatus*, and *A. quemadosensis)*, one species in open nomenclature (*Paraleptopecten* sp. *a*), and one new subspecies (*Argopecten eccentricus lacabrensis*). In addition, a new name, *Euvola jamaicensis*, replaces the name *E. barretti* (Woodring, 1925). Lectotypes are designated for *Cyclopecten guppyi* (Dall, 1898) and *Cryptopecten phrygium* (Dall, 1886). Four of the genera (20%) and all but four of the species (90%) in the two families are extinct. Among the Pectinidae, 60% of the species but only 5% of the genera are endemic to the northern Dominican Republic. The high species endemism is possibly an artifact due to the absence in many other regions of precisely correlative strata as well as to differences in facies and sampling methods. Assemblages of the two families change composition going upward in stratigraphic sections measured along each major river, reflecting increasing depth of deposition, changing bottom conditions, and association with coral reefs or marine grasses and algae. Evolutionary changes within particular lineages help to resolve several previous biostratigraphic uncertainties and controversies, including the age of limestones on the Río Yaque del Norte and in the Guayubín area. Detailed study of these changes has also shed new light on the causes of dramatic faunal differences between stratigraphic sections on the Río Gurabo and Río Mao, separated by only 10 km.

RESUMEN

El estudio de aproximadamente 25,000 ejemplares del Mioceno y Plioceno marino del Valle del Cibao, en el norte de la República Dominicana, nos permite indicar que la familia de bivalvos Propeamussiidae está representada por dos géneros y cuatro especies, dos de ellas especies nuevas, *Cyclopecten acuminatus* y *C. zalaya*, y que la familia Pectinidae está representada por tres subfamilias, seis tribus, 18 géneros y 35 especies. Los taxones nuevos de Pectinidae incluyen seis géneros nuevos (*Interchlamys*, *Chagrepecten*, *Gurabopecten*, *Paraleptopecten*, *Zamorapecten* y *Antillipecten*), 15 especies nuevas (*Caribachlamys guayubinensis*, *C. jungi*, *Mimachlamys blowi, M. vokesorum*, *Palliolum*? *cibaoense*, *Argopecten parathetidis*, *Chagrepecten paracactaceus*, *Gurabopecten uniplicatus, Lindapecten baitoaensis*, *L. paramuscosus*, *Euvola gurabensis*, *Zamorapecten maoensis*, *Antillipecten janicoensis, A. microlineatus* y *A. quemadosensis)*, una especie en nomenclatura abierta (*Paraleptopecten* specides *a*) y una subespecie nueva (*Argopecten eccenttricus lacabrensis*). Además, un nombre nuevo, *Euvola jamaicensis*, reemplaza el nombre *E. barretti* (Woodring, 1925). Lectotipos de *Cyclopecten guppyi* (Dall, 1998) y *Cryptopecten phrygium* (Dall, 1886) son designados. Cuatro de los géneros (20%) y todas de las especies excepto cuatro (90%) en las dos familias, están extintas. Entre los Pectinidae, 60% de las especies pero solamente 5% de los géneros son endémicos para el norte de la República Dominicana. El alto endemismo de las especies posiblemente es un artefacto parcialmente causado por la ausencia de estratos exactamente correlacionados en muchas otras regiones asi como por diferencias en las facies y en los métodos de muestreo. Los asociasiones de las especies cambian en su composición a lo largo de cada río principa a medida que ascendemos estratigraficamente, lo que refleja aumentos en la profundidad de deposición, cambios en las condiciones del fondo y el grado de asociación con los arrecifes de coral o los céspedes marinos y las algas. Los cambios evolutivos en algonos llinajes nos permiten solucionar algunas incertidumbres estratigráficas y controversias, incluyendo la edad de las calizas en el Río Yaque del Norte y en la region de Guayubín. El estudio detallado de estos cambios nos ha permitido iluminar las causas de las differencias faunisticas grandes entre las secciones estratigráficas del Río Gurabo y el Río Mao, los que están separados por solamente 10 km.

INTRODUCTION

The Dominican Republic Project was launched in 1977 by Peter Jung and John B. Saunders of the Naturhistorisches Museum Basel (NMB), Switzerland, for the purpose of documenting in detail the systematic paleontology, biostratigraphy, and paleoecology of the thick Miocene and Pliocene stratigraphic sections well exposed in the Cibao Valley. From 1978-1980, Jung, Saunders, and others (listed by Saunders *et al.*, 1986: 9), working with a team of French surveyors led by Bernard Biju-Duval, made collections of macro- and microfossils that were precisely stratigraphically documented. The collections (*ca.* 5 tons) were processed and meticulously sorted in Basel, and parts of the sorted material were sent on loan to taxonomic specialists for detailed study.

The resulting studies have led to a long and continuing series of publications, mainly in the *Bulletins of American Paleontology*, dealing thus far with planktic foraminiferans, calcareous nannoplankton, corals, bryozoans, brachiopods, mollusks, echinoids, and fish otoliths. The first contribution in this series is the familiar "red book" by Saunders *et al.* (1986) that has been on the desk of every participant. It is a detailed account of the geologic setting, field surveys, columnar sections, lithologies, paleoenvironments, and age determinations for each of the major sections, and it provides the locality numbering systems and locality data used by all participants in the project. These localities include those for collections made independently by Emily H. Vokes and the late Harold E. Vokes, molluscan paleontologists then of Tulane University (TU), who graciously allowed their collections to be included in the project. [See E. Vokes (1989) for a detailed account of their field work, with some interesting differences in stratigraphic interpretations compared to Saunders *et al.* (1986).]

McNeill *et al.* (2008) provided a useful summary of the tectonic, geologic, and stratigraphic setting of the east-west trending Cibao Valley and depositional basin, the formation of which is intimately connected with the complex strike-slip and transpressional tectonics associated with Hispaniola's location along the northern boundary of the Caribbean Plate. The valley is bounded on the south by the Hispaniola Fault zone and the Cordillera Central, and on the north by the Septentrional Fault zone and the Cordillera Septentrional (McNeill *et al.*, 2008: fig. 2.1). Freiheit & Geary (2009) provided a succinct summary of the Neogene depositional history of the relatively undeformed strata on the southern side of the Cibao Valley.

The present study is concerned with fossil scallops that comprise the families Propeamussiidae Abbott, 1954, and Pectinidae Rafinesque, 1815. Because scallop shells are composed mainly of calcite rather than aragonite, they are more resistant to dissolution during diagenesis than are wholly aragonitic shells (most other mollusks) and consequently are commonly well preserved in the fossil record. Coupled with the rapid rates of evolution of many genera in the family Pectinidae as well as clear changes in the composition of pectinid faunas with depth, this group is of particular biostratigraphic and paleoecological interest. For these reasons, the family Pectinidae has served as a basis for biostratigraphic zonation in many parts of the world, particularly in the Cenozoic (*e.g.*, MacNeil, 1967: 2; Ward & Blackwelder, 1975; Addicott, 1978; Smith, 1991b; Beu, 1995: 10; Mandic, 2004) .

Background

Saunders *et al.* (1986: 10-11) and E. Vokes (1989) reviewed previous paleontological and stratigraphic studies in the Dominican Republic. The first extensive collecting expedition to yield fossils with detailed locality and stratigraphic data is that of Maury (1917a, b), who described 14 species of pectinids including four new species. However, only nine of these taxa are valid, the others being junior synonyms or misidentifications. Pilsbry & Johnson (1917), in a study that overlapped the work of Maury (1917a), introduced three more new pectinid species, two of which are junior synonyms. Aside from one new pectinid subspecies described by Pilsbry (1922) and another by Smith (1991b), there have been no further additions to the list of Propeamussiidae and Pectinidae in the Neogene of the Dominican Republic until the present study.

Materials and Methods

This study is based on specimens collected in the Cibao Valley of the northern Dominican Republic (Text-figs 1-2) from the Baitoa, Cercado, Gurabo, and Mao formations as well as from strata that cannot be placed reliably in a named formation on the basis of lithology. These formations range in age from late Early Miocene to Middle Pliocene (Saunders *et al.*, 1986: table 4). The material collected by Saunders *et al.* (1986) and loaned by the NMB to the author for detailed study consists of *ca.* 15,800 specimens from 173 localities. The material collected by the Vokeses consists of *ca.* 6,600 specimens from 77 localities, many of which coincide with NMB localities. The Propeamussidae and Pectinidae collected by the Vokeses bear TU locality numbers and are now reposited in the Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington, DC. Also included in this study are Smithsonian collections made much earlier (1917, 1919) by T. W. Vaughan, C. W. Cooke, and others of the United States Geological Survey (USGS). These comprise *ca.* 1,800 specimens from 35 localities. Saunders *et al.* (1986) plotted most of these localities on maps and gave detailed locality data. Data for localities mentioned in the present study not given by Saunders *et al.* (1986) are provided in Appendix 1.

The positions of localities in the measured stratigraphic

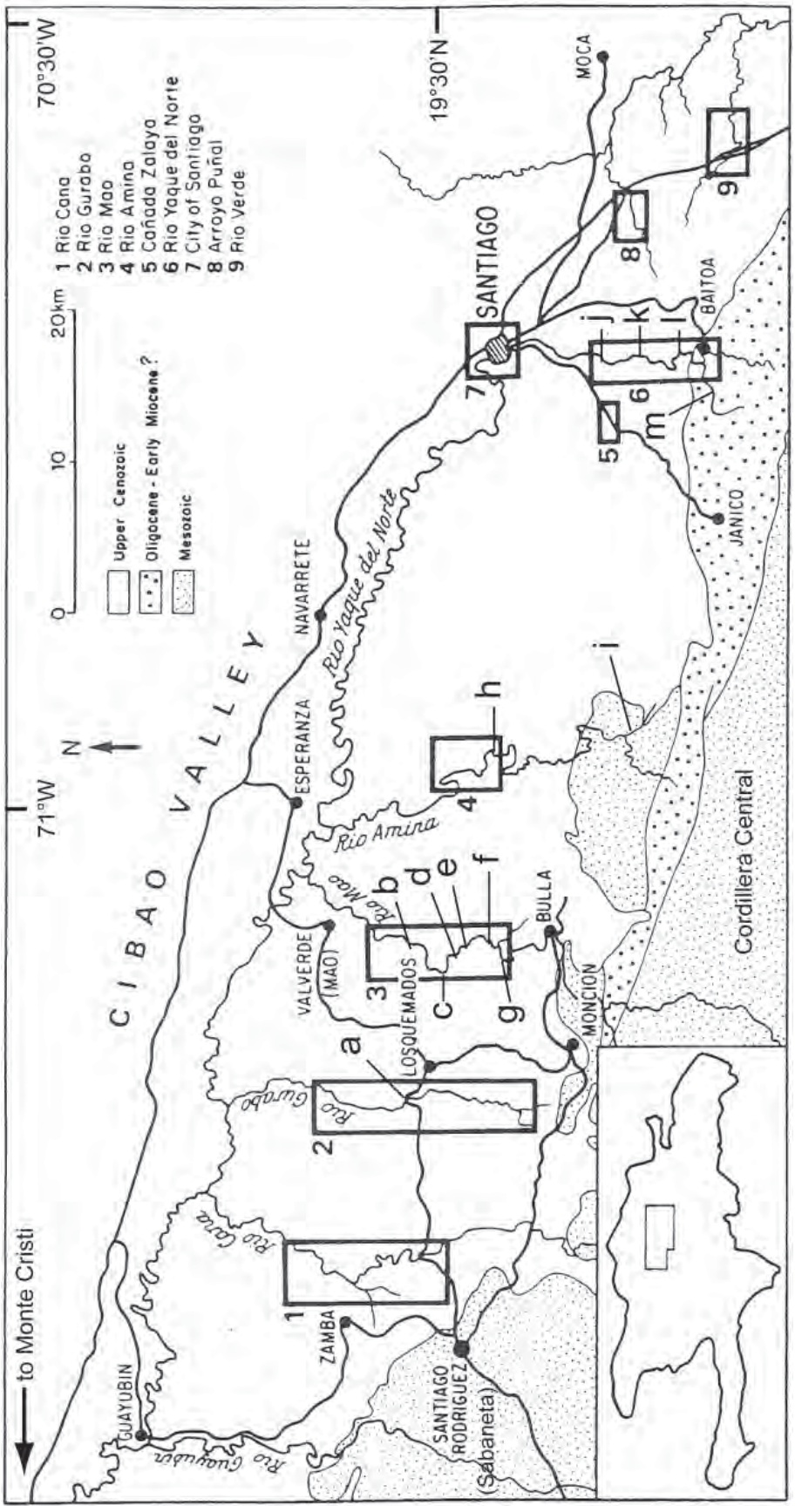
Text-fig. 1. Map of the Caribbean area showing some of the Neogene localities mentioned in the text.

sections in Saunders *et al.* (1986: fold-out text-figures) are expressed in meters above the base of the section. These distances were determined by overlaying a millimeter scale on the text-figures and should be regarded as approximations, the main purpose of which is to establish the relative positions of stratigraphic samples. A database was created in which these values were entered for each locality in a stratigraphic section that yielded specimens for study. This proved to be a valuable tool for arranging samples in particular sections in stratigraphic order for each species and for retrieving data for each locality.

Morphological terms used in taxonomic descriptions are defined in the *Treatise on Invertebrate Paleontology* (Cox, 1969: N102) or in the author's previous studies of the Pectinidae (Waller, 1969, 1972a, 1984, 1986, 1991). Given the diverse literature sources, some of these terms (in **boldface**) are reviewed here:

Antimarginal refers to sculptural features that are continuously oriented approximately perpendicular to the shell margin during ontogeny, in contrast to **commarginal**, referring to sculptural features that are parallel to the shell margin and **radial** referring to features that radiate from the origin of growth at the beak of the shell. Antimarginal structures are coincident with radial structures in the central sector of the shell, but intersect radial structures at increasing angles approaching the anterodorsal and posterodorsal margins of the disk. Antimarginal striae form a sweeping, curved pattern on the disks of many pectinoideans, exemplified especially by species of the Mesozoic genus *Camptonectes* Agassiz in Meek, 1864 (hence the term "*Camptonectes* striae" in older literature), and by those of the extant genera *Delectopecten* Stewart, 1930, and *Palliolum* Monterosato, 1884.

The term **byssal notch** refers to the opening for the byssus at the base of the right anterior auricle. The growth track left by the byssal notch as it advances during ontogeny and is filled in by shell material is referred to as the byssal fasciole. The byssal notch is described as **deep** if it extends inward from the anterior margin for approximately half the length of



Text-fig. 2. Sketch map of the southern flank of the Cibao Valley, northern Dominican Republic, showing locations of the major stratigraphic sections (modified from Saunders *et al.*, 1986: text-fig. 3). Sections 1-8 yielded Pectinidae; sections 1-3, 5, 6, and 9 yielded Propeamussiidae. TU and USGS collections are from these sections as well as from intervening areas. See Saunders *et al.* (1986: appendix 4) for locality data. Letters indicate some of the localities mentioned in the text: a, Caimito; b, Mao Adentro; c, Arroyo La Sabirma; d, Cercado de Mao; e, Maury's Bluff 1; f, Maury's Bluff 2; g, Maury's Bluff 3; h, Potrero Dam; I, Río Albano; j, La Barranca; k, Angostura Gorge; l, López ; m, Río Bao.

the auricle or greater, exemplified by many species of *Chlamys* Röding, 1798, as **moderate** if it is only approximately a third the length of the auricle, exemplified by many species of *Aequipecten* Fischer, 1886, and **shallow** if it barely indents the anterior auricle margin, as in species of *Pecten* Müller, 1776, or *Amusium* Röding, 1798. **Byssal sinus** refers to the corresponding marginal indentation at the base of the left anterior auricle, this indentation always being shallower than the byssal notch. This is because in living position with the right valve against the substratum, the byssal notch is protected by the more advanced margin of the byssal sinus.

Interlocking megascopic structures on the hinge plates of pectinoideans are referred to as **hinge teeth** rather than **cardinal crura**, because the term **crura** (singular **crus**)has been used for structures that might or might not occur on the hinge plate and do not interlock (*e.g.,* auricular crura occurring on inner shell surface at base of auricles). Following Waller (1986: 39; 1991: fig. 6), pectinoidean hinge teeth are named with reference to the right valve. The tooth immediately below and parallel to the outer ligament on each side of the hinge is termed the **dorsal tooth**; the teeth next to resilium, initially parallel to the margins of the resilium, but commonly turned laterally in later ontogeny, are referred to as **resilial teeth**. **Intermediate teeth**, commonly multiple, lie between the dorsal and resilial teeth (Pl. 18, Fig. 8). Hinge teeth of the left valve are named with respect to their right-valve counterparts, *e.g.*, **infradorsal**, referring to teeth on the left valve that fit into sockets on the ventral side of the dorsal teeth of the right valve. The hinge plates of many pectinoideans also possess **crenulations** or **micro ridges**, microscopic interlocking dorsoventrally trending structures that occur on the hinge plate, commonly on teeth and sockets (visible in Pl. 1, Figs 2 and 5, Pl. 11, Fig. 6, and Pl. 15, Fig. 3). These crenulations mark the **apposition zone** of the hinge plate, meaning those areas that are pressed tightly together, with only thin sheets of mantle tissue intervening. The micro ridges form after metamorphosis on the dissoconch. They are independent of the hinge teeth (**provinculum**) of the prodissoconch.

Linear macroscopic ridges on the inner shell surface that do not interlock are referred to as **buttresses**. **Auricular buttresses** occur on the inner shell surface at the base of the auricles of many pectinoideans, commonly with raised termini called **denticles**. The denticles at the distal ends of corresponding buttresses on opposite valves commonly contact one another when valves are closed, probably providing protection for fragile valve margins. The internal ribs of Propeamussiidae are actually buttresses, although I continue to refer to them in the present study as **internal ribs**. **Internal carinae** refers to the thickened edges of plicae on the inner surface of the shell near its margin. In shells that were originally plicate, but have become secondarily smooth, as in the genus *Amusium*, the paired internal carinae are all that remain of former plicae (Waller, 1991: fig. 5).

A system for encoding rib patterns on the left valves of species of *Lyropecten* Conrad, 1862, and *Nodipecten* Dall, 1898, originally devised by Smith (1991b: 47), was slightly modified by Waller (2007: 931). In the present study, this system is also applied to species of *Paraleptopecten* n. gen. Key ribs are those that are higher or wider than adjacent ribs. They are encoded by capital letters, N for a key rib with nodes and R for a key rib without nodes. The central key rib (that which most nearly describes a right angle with the hinge line and extends the farthest at the ventral margin) is indicated as either Nc or Rc. The lower-case letters "n" and "r" refer, respectively, to ribs of normal height with or without nodes. The central sector is the radial sector that contains the central key rib and the first key rib anterior and posterior to it. The same system of annotation can be extended to the anterior and posterior sectors, defined as lying between a lateral key rib and the adjacent disk flank. Smaller or incipient ribs adjacent to the disk flanks and weakly set off from the disk flank are indicated in parentheses. In the following example of *Nodipecten magnificus* (G. B. Sowerby I, 1835) as figured by Waller (2007: fig. 2.2), the annotation begins at the left anterior disk flank, indicated by a forward slash, and ends at the posterior disk flank, indicated by a backward slash. The central sector is in boldface: /r N n **N 2n Nc 2n N** r N r\.

All pectinoidean shells are bimineralic. In the Propeamussiidae, the right valve has an outermost layer of simple prismatic calcite persisting throughout ontogeny and forming a marginal fringe, underlain by a thin layer of foliated-calcite, which in turn is underlain by an innermost layer of crossed-lamellar aragonite (Waller, 1972b, 2006b; Carter, 1990: 256). The left valve lacks an outer prismatic layer, consisting only of an outer layer of foliated-calcite and an inner layer of crossed-lamellar aragonite. In Cenozoic and Recent Pectinidae, the outer prismatic calcite layer of the right valve is limited to early ontogeny (with a few deep-water exceptions) or is absent altogether, and the shell is dominated by foliated-calcite. On the inner shell surface, the area inside the pallial line can be entirely composed of crossed-lamellar aragonite, or this inner layer can be covered during ontogeny by an innermost layer of foliated-calcite. The extent of this innermost layer varies among species and to some extent among geographic populations. In the following descriptions, I refer to this as the **foliated-calcite re-entry**, because during ontogeny the layer originates dorsally in the umbonal cavity and progresses ventrally, in some taxa reaching the pallial line and thus covering the crossed-lamellar aragonite. The extent of the re-entry is described with reference to the adductor scar, whether reaching the top or bottom of this scar or extending entirely to the pallial line. In fossils shells, the calcitic layers commonly are

gray in color, in contrast to the inner aragonitic layer, which commonly turns chalky white or is dissolved completely during diagenesis (Pl. 5, Fig. 22; Pl. 7, Fig. 14; Pl. 8, Fig. 4).

Most of the nearly 25,000 specimens in the present study were examined with a Wild M5 binocular microscope to ascertain the ontogeny of microsculpture on both valves. Photographs of specimens larger than *ca.* 4 mm are digital TIFF images taken with a Nikon CoolPix 4500 digital camera and processed with Adobe Photoshop. Some of these images are composite images that combine three focal planes using Helicon Focus software. To enhance contrast for photography, most specimens were coated lightly with ammonium chloride using the technique described by Kier *et al.* (1965), the exceptions being those specimens that displayed color patterns or were too fragile to risk removal of the water-soluble coating. Images of very small specimens were captured on an Olympus SZX-12MDU motorized stereo-zoom microscope with composite images generated using Image Pro Plus v6.1.0.346 EDF (extended depth of field) plugin software.

The species concept employed herein is based on the principal that species represent interbreeding populations that in many cases display substantial variation in shell morphology. If this variation was found to be continuous within samples by visual and microscopic assessment, the variation was regarded as infraspecific. Species were distinguished on the basis of morphological differences that did not intergrade within samples. Chronological subspecies were recognized only if morphological variation appeared to occur in comparable stratigraphic sequence among stratigraphic sections without reversal. In situations in which the sequence of change was not consistent or showed indications of reversal, it was concluded that these morphological differences resulted from environmental factors such as differences in substratum or water depth and turbulence. These assessments are discussed separately for each species represented by more than a few specimens.

The ages in millions of years (Ma) expressed in this paper are based on the geochronology in Gradstein *et al.* (2004), in which the Pliocene Epoch is regarded as consisting of three stages (Zanclean, Piacenzian, and Gelasian) with its upper limit at the top of the Gelasian Stage at 1.81 Ma. Recently the International Union of Geological Sciences ratified a decision by the International Commission on Stratigraphy to move this boundary to the base of the Gelasian stage at *ca.* 2.56 Ma, thereby restricting the Pliocene to two stages and to a span of time of only *ca.* 2.8 million years (Gibbard *et al.*, 2010). Because this decision was published after the present study was nearly completed, it has not been followed here. Future studies that refer to the Pliocene and Pleistocene will have to consider this change and define terms accordingly.

ABBREVIATIONS

ahl — anterior hinge length.

ANSP — Academy of Natural Sciences, Philadelphia, Pennsylvania, U.S.A.

BMNH — The Natural History Museum, London, U.K.

CAS — California Academy of Sciences, San Francisco, California, U.S.A.

CM — Carnegie Museum, Pittsburgh, Pennsylvania, U.S.A.

cvx — convexity of valve, measured from plane of commissure to highest point above this plane.

DV — double valve (referring to a pair of matching valves, either articulated or separate).

EL-I — evolutionary stage I of *Argopecten eccentricus lacabrensis* n. ssp.

EL-II — evolutionary stage II of *Argopecten eccentricus lacabrensis* n. ssp.

hl — hinge length.

Ht — height of valve measured from origin of growth (apex of resilifer) to ventral margin along a line perpendicular to hinge line.

ICZN — International Code of Zoological Nomenclature.

L — length of shell, measured along a line parallel to hinge line.

LV — left valve(s).

NMB — locality numbering system of the Naturhistorisches Museum, Basel, Switzerland.

NMB G — catalog number of the Naturhistorisches Museum, Basel, Switzerland.

MNHNP — Museum National d'Histoire Naturelle, Paris, France.

phl — posterior hinge length.

PRI — Paleontological Research Institution, Ithaca, New York, U.S.A.

RV — right valve(s).

TU — Tulane University, New Orleans, Louisiana, U.S.A. (specimens now reposited at PRI and USNM).

UCMP — Museum of Paleontology, University of California, Berkeley, California, U.S.A.

USGS — United States Geological Survey, Washington, DC, locality register of Cenozoic mollusks.

USNM — National Museum of Natural History, Smithsonian Institution, Washington, DC, U.S.A. Numbers preceded by USNM are catalog numbers in the Department of Paleobiology; those preceded by USNM(IZ) are catalog numbers in the Department of Invertebrate Zoology.

RESULTS

PROPEAMUSSIID AND PECTINID BIODIVERSITY

Maury (1917a) described two genera, four subgenera, and 14 species (including four new species) of Propeamussiidae

and Pectinidae from the Cibao Valley. In contrast, the present study recognizes 20 genera (six new), 39 species (17 new plus one new name and one in open nomenclature), and three subspecies (one new). Four of the genera (20%) and all but four (90%) of the species are extinct. Two of the extant genera survive today only in the western Indo-Pacific region (*Amusium*) or in the eastern Pacific (*Leopecten* Masuda, 1971a). The four extant species [*Parvamussium marmoratum* (Dall, 1881), *Cryptopecten phrygium* (Dall, 1886), *Antillipecten antillarum* (Récluz, 1853), and *Nodipecten nodosus* (Linnaeus, 1758)] all live today in the western Atlantic region. In the most complete stratigraphic section (that on the Río Gurabo), nine pectinoidean species occur in the Cercado Formation, 16 species in the Gurabo Formation, and seven species in the Mao Formation.

PALEOECOLOGY

Assemblages of Propeamussiidae and Pectinidae change going up section in each major river canyon, reflecting increasing depth, changing bottom conditions, or association with coral reefs or marine grasses and algae. Five such assemblages have been recognized in the Cercado, Gurabo, and Mao formations, each assemblage named after its most common or notable species. (a) The *Argopecten eccentricus* assemblage is interpreted as having lived in shallow water, from just below tide level to *ca.* 50 m, on sandy bottoms having patches of eel grass and marine algae. This interpretation is indicated by commonly associated large soritid foraminiferans, known to attach to blades of eelgrass (Saunders *et al.*, 1986: 15), and the neritid gastropod *Smaragdia viridis* (Linnaeus, 1758), known to be a seagrass specialist (Costa *et al.*, 2001: 61). At the lowest stratigraphic levels (most shallow depths of deposition), this pectinid assemblage is also associated with species of the gastropod *Neritina* Lamarck, 1816, that are commonly restricted to freshwater or brackish-water environments (Costa *et al.*, 2001: 47). The *A. eccentricus* assemblage typically occurs in the Cercado Formation as well as in the shallow-water parts of the Gurabo Formation. E. Vokes (1989: 21) determined that the depths of deposition in these deposits range from 0-20 m based on the depth ranges of muricid gastropod species that are still extant.

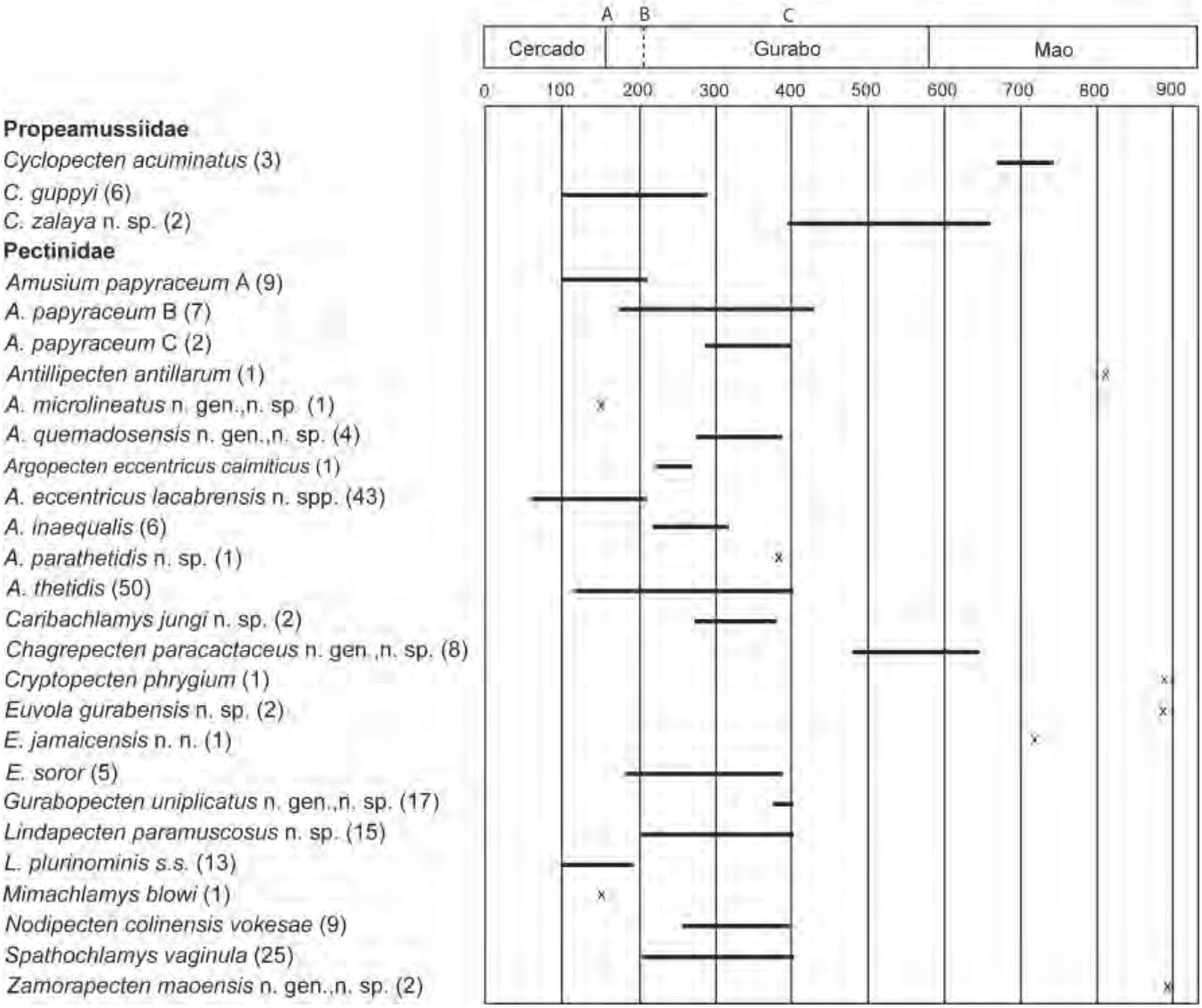
Two subassemblages are recognized. In the *Argopecten eccentricus* subassemblage, *A. eccentricus* (Gabb, 1873) is commonly the only pectinid species present or greatly outnumbers other species. *Lindapecten plurinominis* (Pilsbry & Johnson, 1917) is commonly a distant second in abundance, and the small propeamussid *Cyclopecten guppyi* (Dall, 1898) and the pectinid *Leptopecten thompsoni* (Maury, 1917a) are rare or absent. In the *L. thompsoni* subassemblage, *A. eccentricus* is still the most abundant species, but *L. thompsoni* is common and frequently abundant also, and *C. guppyi* is a common associate. The fragility of the shells of both *L. thompsoni* and *C. guppyi* suggest a more sheltered environment for the latter subassemblage and perhaps more abundant seagrass or algae for settlement. Cheetham & Jackson (1996: fig. 8.10) documented the presence of seagrasses based on the impression of seagrass cells on the attachment bases of cheilostome bryozoans at locality NMB 16918, where the *L. thompsoni* subassemblage is present.

(b) The *Argopecten thetidis* assemblage is interpreted as having lived on the middle to outer shelf in the depth range of 50-200 m on open sandy or silty bottoms subject to sediment transport and beyond the depth of abundant marine grasses. Associated species include *A. inaequalis* (G. B. Sowerby I, 1850), *Spathochlamys vaginula* (Dall, 1898), and *Amusium papyraceum* (Gabb, 1873), as well as a species of the genus *Dimya* Rouault, 1850, a small, cemented ostreiform bivalve that in present-day seas is seldom found at depths shallower than 100 m. *Gurabopecten uniplicatus* n. gen., n. sp. is not present in this assemblage.

(c) The *Gurabopecten uniplicatus* assemblage is interpreted as having lived on the outer edge of the shelf, at *ca.* 200 m. The presence of *G. uniplicatus* n. sp. distinguishes this assemblage from the *Argopecten thetidis* assemblage. Associated species, including *Dimya* sp., are the same as in the *A. thetidis* assemblage.

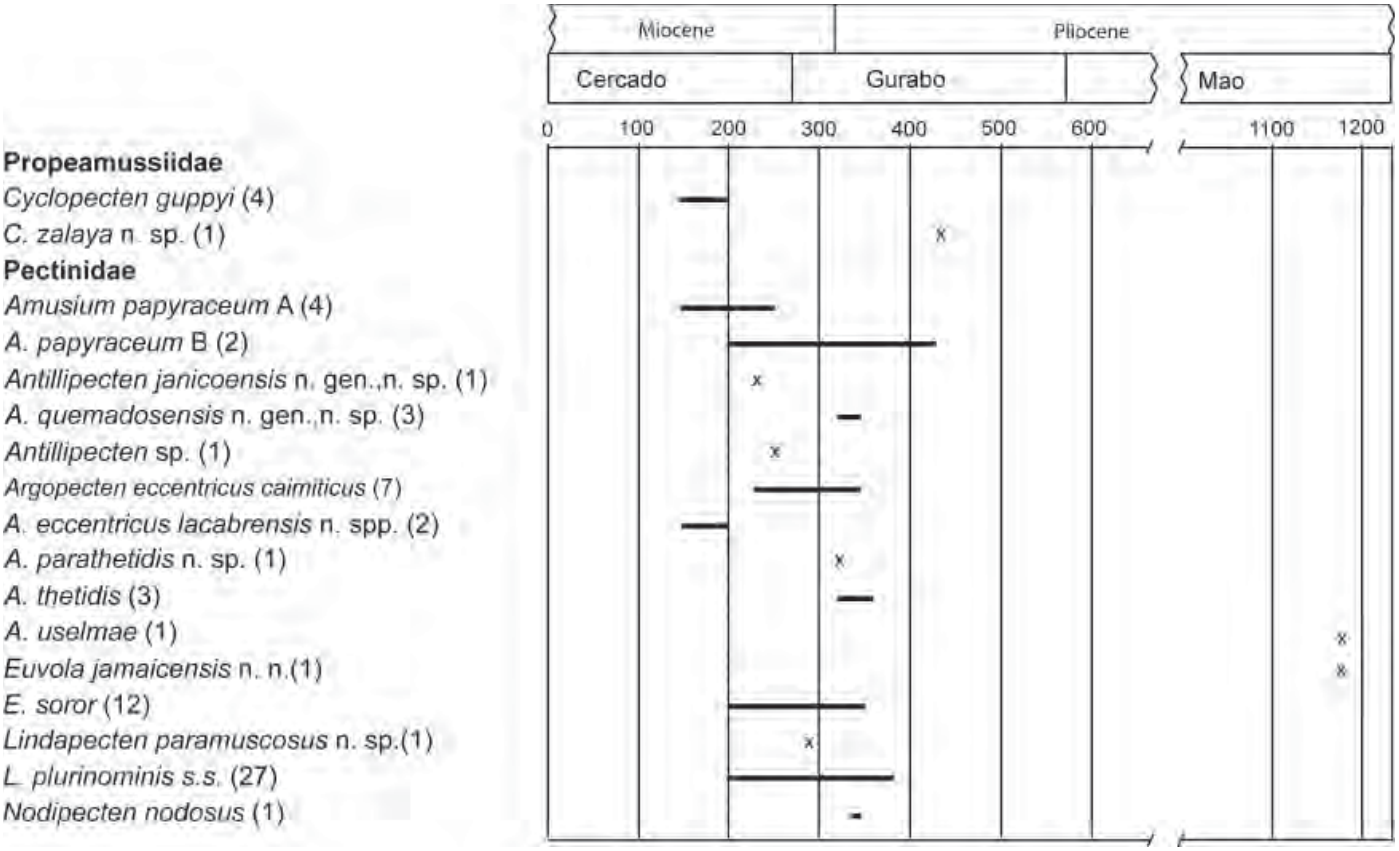
(d) The *Chagrepecten paracactaceus* assemblage lived on silty to mud bottoms probably at depths > 200 m. In addition to species of *Chagrepecten* n. gen., species in this assemblage include the pectinids *Cryptopecten phrygium* and *Zamorapecten maoensis* n. gen., n. sp. and the propeamussiids *Cyclopecten acuminatus* n. sp., *C. zalaya* n. sp., and *Parvamussium marmoratum*. Abundance of all of these species is very low. In present day seas, *C. phrygium* is most common at depths of 90-200 m, with a total depth range for both living and dead specimens being 73-290 m. Extant *P. marmoratum* most commonly live at depths from 70-200 m, with a total known depth range of 44-548 m based on USNM(IZ) collections. E. Vokes (1989: 21) estimated water depths for localities such as TU 1227 to be 150-350 m.

(e) The *Interchlamys interlineata* assemblage is associated with coral reefs and carbonate sediments, with the common presence of closed articulated shells of *I. interlineata* (Gabb, 1873) in fine carbonate sediments suggesting catastrophic burial in a back-reef environment. The stratigraphically higher occurrences of this assemblage contain species of *Caribachlamys* Waller, 1993, in association with *I. interlineata*, but at lower levels of the assemblage, only species of *Caribachlamys* are present. Such coralline facies probably represent fairly shallow water. E. Vokes (1989: 21) estimated a water depth of 20-50 m for these facies based on the depth ranges of muricid species with extant counterparts.



Text-fig. 3. Stratigraphic ranges of Propeamussiidae and Pectinidae on Río Gurabo plotted in meters above base of section, with number of collecting localities for each species in parentheses. Solid (A) and dashed lines (B) separating the Cercado and Gurabo Formations indicate, respectively, the boundaries chosen by Saunders *et al.* (1986) and E. Vokes (1989). Single occurrences are marked "x." The Miocene-Pliocene boundary (C) is probably in the interval from 395-400 m according to Saunders *et al.* (1986: text-fig. 14).

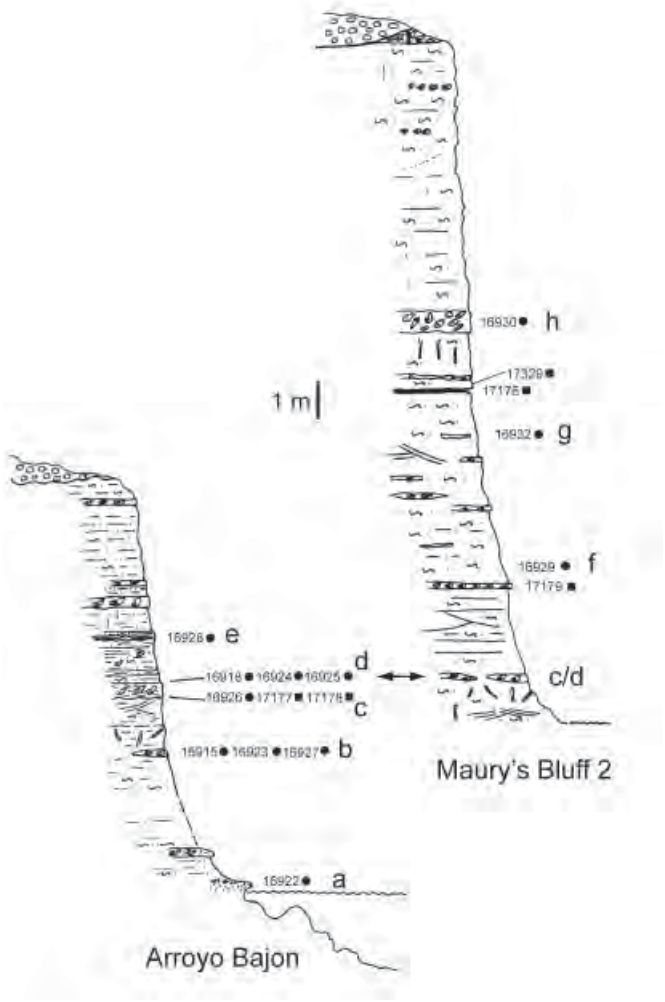
In the thicker river sections, assemblages (a) through (d) succeed one another in accord with the deepening-upward nature of these sections. In the Río Gurabo section (Text-fig. 3), the *Argopecten eccentricus* subassemblage, dominated by *A. eccentricus lacabrensis* n. ssp., is present from 59 m above the base of the section (NMB 15918) up to just above the Cercado-Gurabo boundary of E. Vokes (1989) at 208 m (NMB 15873 and 15874). As indicated by Nehm (2001:14), this interval contains seagrass-associated gastropods. Above 208 m extending up to *ca.* 380 m (TU 1231), the *A. eccentricus* subassemblage is replaced by the *A. thetidis* assemblage. Within this latter interval, there are only two occurrences of *A. eccentricus,* and these are of the subspecies *A. e. caimiticus* (Maury, 1917a) (NMB 16808 at 222-226 m and NMB 16833 at 287 m). These probably represent either fluctuations in depth of deposition or transport from shallower sites of deposition by downslope movement. The *Gurabopecten uniplicatus* assemblage begins with the lowest stratigraphic oc-



Text-fig. 4. Stratigraphic ranges of Propeamussiidae and Pectinidae on Río Cana plotted in meters above base of section, with number of collecting localities for each species in parentheses. Single occurrences are marked "x." The Miocene-Pliocene boundary is at least as low as *ca.* 315 m (Saunders *et al.*, 1986: 23).

currence of this species at *ca.* 385 m above the base of the section (TU 1211) and continues to near the top of the exposed Gurabo Formation at 403 m (NMB 15814). This interval includes evidence for rapid deepening based on increased numbers of planktic foraminiferans (Saunders *et al.*, 1986: 16), with ostracodes suggesting depths of 180-200 m (Bold, 1988). Between 403 m above the base of the section and the start of a covered interval at *ca.* 430 m, only *Dimya* sp. and a few fragments of *Amusium papyraceum* were collected. The stratigraphically lowest pectinids collected above the covered interval are at 570-580 m above the base of the section in the Mao Formation and indicate the *Chagrepecten paracactaceus* assemblage. This assemblage continues in the Mao Formation up to *ca.* 760 m above the base of the section (NMB 15829). Above this, there is evidence of a mixture of deep-water and shallower species as already noted by Saunders *et al.* (1986: 16), possibly indicating downslope transport. Pectinids present include the shallow-water species *Euvola jamaicensis* n. n. and *Antillipecten antillarum* at 807-810 m (NMB 15830 and 15834) and the deep-water species *Zamorapecten maoensis*, *Euvola gurabensis* n. sp., *Cryptopecten phrygium*, and *Dimya* sp. at 893-895 m (NMB 16122 and 15831 to TU 1352 and NMB 15833).

Pectinid assemblages in the Río Cana section (Text-fig. 4) support the current understanding that this section on the whole represents shallower water than the Río Gurabo section (Bold, 1988: 15). The *Argopecten eccentricus* subassemblage is present from the stratigraphically lowest pectinid-bearing sample at 147 m above the base of the section (NMB 17005) in the Cercado Formation up to *ca.* 430 m above the base of the section (NMB 16866) in the Gurabo Formation. There is evidence for the presence of seagrasses from the base of this interval to at least as high as *ca.* 340 m above the base of the section (Nehm, 2001: 14). Two of the three chronological subspecies of *A. eccentricus* are present, *A. e. lacabrensis* n. ssp. in the four stratigraphically lowest samples from 147-200 m above the base of the section, and *A. e. caimiticus* in all of the higher samples from 228 m (NMB 16842) to *ca.* 430 m (NMB 16866). On the whole, *Lindapecten plurinominis* is more common in the *A. eccentricus* assemblage in this section than on the Río Gurabo. Only a few specimens of *A. thetidis* (G. B. Sowerby I, 1850) are present in the entire Río Cana



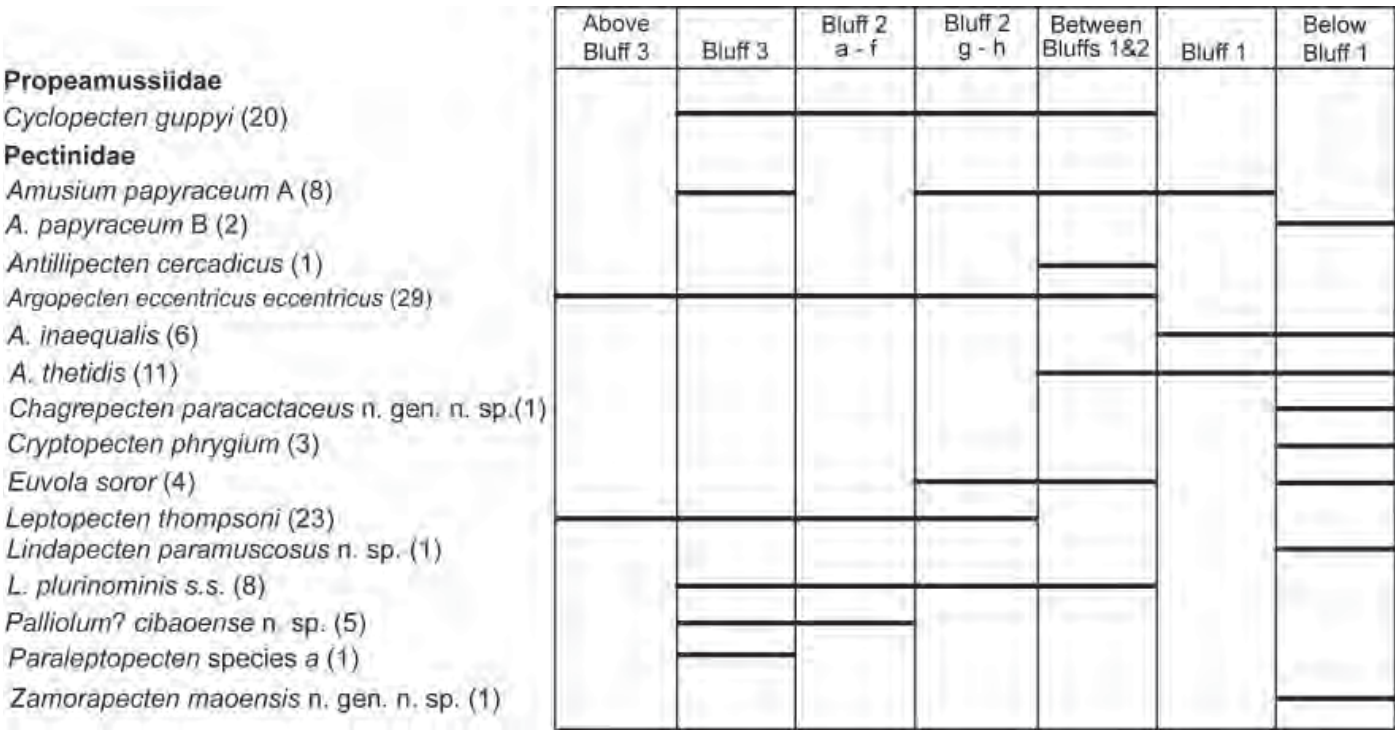
Text-fig. 5. Correlation of Río Mao Bluff 2 and adjacent Arroyo Bajón sections (Text-fig. 2: area 3) modified from Saunders *et al.* (1986: text-figs 31-32) to show stratigraphic levels (lower-case letters) referred to in text. Black squares represent NMB microfossil samples. Black circles are pectinid-bearing NMB macrofossil samples.

section. These occur at 321 m and 361 m but are associated with the *A. eccentricus* assemblage. At 434 m above the base of the section (NMB 17009), there is a switch to the deeper-water *Chagrepecten paracactaceus* assemblage as indicated by the presence of juvenile *Cryptopecten phrygium* (not included in Text-fig. 4) and *Cyclopecten zalaya* n. sp. still within the Gurabo Formation. This is the stratigraphically highest pectinid-bearing sample from the Río Cana.

On the Río Mao, the pectinid assemblage present in the Cercado Formation at Maury's Bluffs 2 and 3 and Arroyo Bajón (Text-figs 5-6) is the *Leptopecten thompsoni* subassemblage of the *Argopecten eccentricus* assemblage. The most abundant pectinid is *A. eccentricus eccentricus* (Gabb, 1873), a chronological subspecies that is intermediate between the stratigraphically lower *A. eccentricus lacabrensis* n. ssp. and the higher *A. eccentricus caimiticus* and which is absent in the Río Gurabo and Río Cana sections. *Leptopecten thompsoni* is second in abundance. *Cyclopecten guppyi* is third in abundance and clearly more common here than in the *Argopecten eccentricus* assemblage elsewhere. There is a gradual but fluctuating change to the *Argopecten thetidis* assemblage in samples from between Bluff 2 and Bluff 1 signaled by an increase in numbers of *A. thetidis*. Only the *A. thetidis* assemblage is present at Bluff 1 in the Gurabo Formation. The *Chagrepecten paracactaceus* assemblage begins downstream from Bluff 1 in what E. Vokes (1989: 18) referred to as the deepest Gurabo (TU 1292) and continues downstream to approximately halfway between Bluff 1 and the type section of the Mao Clay Member of the Mao Formation at Mao Adentro. No propeamussiids or pectinids were collected from the Mao Formation on the Río Mao.

The distribution of Pectinidae collected on the Río Amina is shown in Text-figs 7-8. The *Argopecten eccentricus eccentricus* subassemblage is present in levels a and b and in the lower part of level c. The chronological subspecies present is *A. eccentricus eccentricus*, commonly associated with *Lindapecten plurinominis* and *Amusium papyraceum*. The *Argopecten thetidis* assemblage is present from upper level c to level e. There is no evidence for any deeper-water assemblages in the samples on hand.

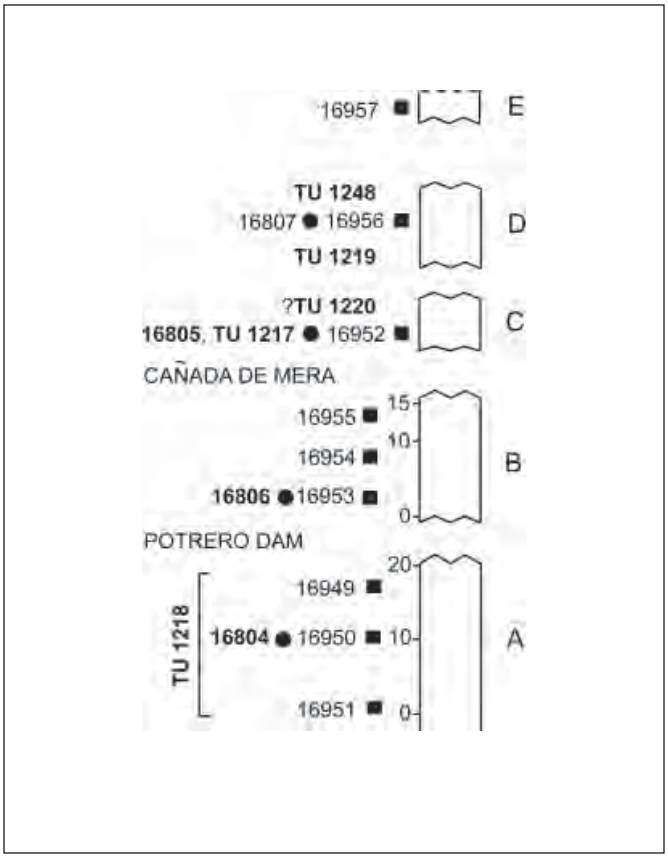
Only two pectinid-bearing samples (TU 1227 and 1227A) are on hand from the Arroyo Zalaya, plotted on a map of the Cañada Zalaya area by Saunders *et al.* (1986: text-fig. 36). E. Vokes (1989: 16) referred to TU 1227 as "a narrow canyon cut into a deeper-water facies of the Gurabo beds" with TU 1227A being a "gravity-flow lens" in the midst of the deep-water beds. Saunders *et al.* (1986: 34), with reference to microfossil sample NHB 17312 (within the sampling range of TU 1227), reported an age of upper *Globorotalia margaritae* Zone (Early Pliocene, Zanclian), according to the Gradstein *et al.* (2004) scale, and showed this locality in their table 3 as correlating with the lower Mao Formation on the Río Gurabo. Both TU 1227 and 1227A contain deep-water propeamussiids and pectinids. At TU 1227, the presence of the *Chagrepecten paracactaceus* assemblage is indicated by the presence of 10 specimens of *Parvamussium marmoratum*, but shallower water species are also present, including *Argopecten thetidis* and *Lindapecten plurinominis*. This is the same locality from which H. Vokes (1989: 124) reported *Nemocardium* (*Microcardium*) *islahispaniolae* (Maury, 1917a), a species known only from the deeper-water facies of the Gurabo and Mao formations. TU 1227A contains *Argopecten thetidis* (104 valves), *A. inaequalis* (31 valves), *Gurabopecten uniplicatus* n. gen., n. sp. (3 valves), *Lindapecten paramuscosus* n. sp. (2



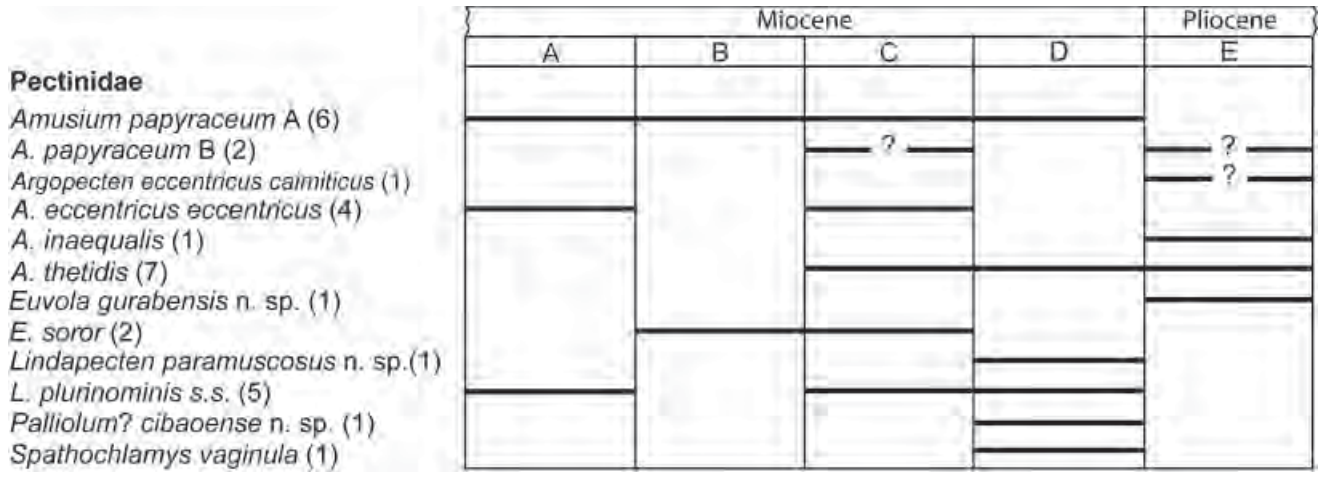
Text-fig. 6. Stratigraphic ranges of Pectinidae on Río Mao including Arroyo Bajón. The letters beneath the Bluff 2 headings refer to stratigraphic levels shown in Text-fig. 5. Numbers of localities for each species are in parentheses.

valves), *Spathochlamys vaginula* (1 valve), *Cyclopecten zalaya* n. sp. (146 valves), and *Parvamussium marmoratum* (1 fragment). This is clearly a mixed assemblage, with a clear preponderance of deep-water species.

In the schematic column of the Río Yaque del Norte given by Saunders *et al.* (1986: text-fig. 24), the only recognizable pectinid assemblage is at La Barranca (NMB 17268), where the *Argopecten eccentricus* subassemblage is present. The collection includes only a single worn valve of what is probably *A. eccentricus caimiticus*, a single valve of a *Lindapecten* species too worn for identification, and fragments of *Amusium papyraceum*. The *Argopecten thetidis* assemblage is present in collections from on or near the westward-flowing part of the Río Yaque del Norte west of Santiago (TU 1205-1207). In the southward flowing part of the Río Yaque del Norte north of Baitoa, the only pectinids collected in the Baitoa



Text-fig. 7 (*at right*). Schematic column for the central portion of Río Amina to show localities yielding pectinids (after Saunders *at al.*, 1986: text-fig. 35). Letters denote parts of the column mentioned in the text. Black squares represent NMB microfossil samples. Black circles are NMB macrofossil samples. Pectinid-bearing localities are in bold-face type. The Miocene-Pliocene boundary probably lies between (D) and (E) according to Saunders *et al.* (1986: table 3).



Text-fig. 8. Stratigraphic ranges of Pectinidae on Río Amina, with numbers of collecting localities for each species in parentheses. The five lettered stratigraphic levels indicate parts of the discontinuous section shown by Saunders *et al.* (1986: text-fig. 35) and Text-fig. 7 herein, with level A being the oldest. In addition to the macrofossil localities plotted by Saunders *et al.* (1986: text-fig. 35), three additional localities are included in this plot and assigned to levels depending on their geographic and extrapolated stratigraphic level relative to the other localities: level C: USGS 8518 (see Appendix 1 for locality data); level E: TU 1371 and TU 1412 (locality data given by Saunders *et al.*, 1986: 66-67). Question marks indicate uncertain identifications of morphotypes or subspecies.

Formation are *Lindapecten baitoaensis* n. sp., known only from that formation, and *Euvola soror* (Gabb, 1873), a long-ranging species that occurs in the upper Baitoa, Cercado, and Gurabo formations. Other evidence suggests that the Baitoa Formation was deposited under very shallow-water conditions (Bold, 1988; E. Vokes, 1979), and an abundance of species of the seagrass epibiont gastropod *Smaragdia* Issel, 1869, suggests the presence of eelgrass (Nehm, 2001: 15). Species of *Argopecten* Monterosato, 1889, have not been found in the Baitoa Formation, possibly because the age of the formation precedes the first appearance of this genus in this area.

In the Río Verde area, the only pectinid sample on hand is from TU 1250, where numerous gravity flows of shallow-water material into deeper-water sediments occur (E. Vokes, 1989: 12). As would be expected, both shallow- and deep-water pectinid assemblages are present. The deep-water elements include members of the *Gurabopecten uniplicatus* and *Chagrepecten paracactaceus* assemblages, the latter including *Cyclopecten zalaya* n. sp. and *Parvamussium marmoratum*. The shallow-water *Argopecten eccentricus* subassemblage is also present, represented by *A. eccentricus caimiticus* and *Cyclopecten guppyi. Lindapecten paramuscosus* n. sp., *Amusium papyraceum,* and *Euvola soror* are also present.

BIOSTRATIGRAPHY

Twenty-three of the 39 species of Propeamussiidae and Pectinidae described in the present study occur in only one or two stratigraphic sections and are of little use for establishing biostratigraphy for the Cibao Valley. Among the remainder, however, are taxa that are both abundant and widespread among the sampled sections. Their stratigraphic distributions, as well as their associated ecological assemblages, shed light on some of the biostratigraphic uncertainties and controversies discussed by previous workers.

Cercado-Gurabo Boundary on the Río Gurabo

As pointed out by Bold (1968: 39), the Cercado and Gurabo formations were originally conceived by Maury (1917b) as biostratigraphic zones. Indeed, they were originally named after marine gastropods that served as index fossils (the *Aphera islacolonis* and *Sconsia laevigata* Zones, respectively) and only later were given formational names (Maury, 1919). Saunders *et al.* (1986: 39, text-figs 4, 6) attempted to clarify the definitions of the formational names by selecting lectostratotypes and defining lower and upper boundaries on a lithologic basis. The boundary between the Cercado and overlying Gurabo formations in their lectostratotypes on the Río Gurabo was placed at the base of a "major conglomerate" at 145 m above the base of the section. E. Vokes (1989: 18), however, disagreed with this choice of a boundary, pointing out that the conglomerate is merely intraformational and "not that different from the many other gravel lenses in the Cercado Formation." She found that the conglomerate indeed is overlain by the continuation of a typical Cercado fauna and that the real change to a Gurabo-type fauna occurs higher, between localities TU 1297 and 1296. This change is at a vertical distance of 207 m above

the base of the measured section of Saunders *et al.* (1986: text-fig. 4) along a lithologically gradational contact.

The pectinid faunule in the Río Gurabo section (Text-fig. 3) undergoes more significant change in species composition at the Cercado-Gurabo boundary selected by E. Vokes (1989) than at that selected by Saunders *et al.* (1986). At Vokes' boundary, *Amusium papyraceum* Morphotype A, *Argopecten eccentricus lacabrensis* n. ssp., and *Lindapecten plurinominis* in the Cercado Formation are replaced by *A. papyraceum* Morphotype B, *A. e. camiticus*, and *L. paramuscosus* n. sp. in the Gurabo. As shown in Table 7, the chronological subspecies *A. e. eccentricus*, which occurs stratigraphically between *A. e. lacabrensis* n. ssp. and *A. e. caimiticus*, is missing in the Río Gurabo section, suggesting an hiatus at the Cercado-Gurabo boundary of Vokes. This boundary also marks the first appearance of *Spathochlamys vaginula* in the Río Gurabo section, signaling change to deeper-water conditions.

Position of the "Arca beds" on the Río Cana

Maury (1917b) was uncertain about the stratigraphic position of the so-called *Arca* beds in the Río Cana section relative to formational boundaries. These beds are characterized by the abundant presence of a large arcoid bivalve, *Anadara* (*Larkinia*) *patricia* (G. B. Sowerby I, 1850), in several beds associated with lignites and thin beds with more normal-marine fossils. Saunders *et al.* (1986: 21 and references therein) interpreted the paleoenvironment as being muddy, intertidal, brackish water possibly associated with mangroves. The beds collectively occupy *ca.* 15 m in the Río Cana section, between *ca.* 218 and 231 m above the base of the measured section (Saunders *et al.*, 1986: text-figs 15-16). Maury (1917b: fold-out stratigraphic chart) placed these beds with a query in the center of her *Sconsia laevigata* Zone (Gurabo Formation), correlating the *Arca* beds with her Zone D on the Río Gurabo. Bold (1968: 36, 38) also placed the *Arca* beds in the Gurabo Formation, but rather at the very base of the formation, and he suggested that an unconformity might be present between the Cercado and Gurabo formations at the base of these beds. Saunders *et al.* (1986), in contrast, placed the *Arca* beds within the upper Cercado Formation and placed the Cercado-Gurabo boundary much higher, at the base of a conglomerate 275 m above the base of the section and *ca.* 45 m above the top of the *Arca* beds. In a later study of marine ostracodes from the Cibao Valley, Bold (1988: 15) concluded that the most logical position for the Cercado-Gurabo boundary in the Río Cana section is at the base of a conglomerate at *ca.* 180 m above the base of the section, well below the lowest *Arca* bed.

The only pectinid that is restricted to beds stratigraphically below the *Arca* beds on the Río Cana (Text-fig. 4) is *Argopecten eccentricus lacabrensis* n. ssp., the first of three chronological subspecies that are proposed herein as biozones in the shallow-water facies of the Cercado and Gurabo formations (see Systematic Paleontology section). The second subspecies, *A. e. eccentricus*, does not occur, or at least has not yet been collected, in the Río Cana section. Within the interval of the *Arca* beds and immediately above in the Río Cana section (Text-fig. 4), the only subspecies present is *A. e. caimiticus*, which in the Río Gurabo section (Text-fig. 3) occurs only in the Gurabo Formation beginning at the Cercado-Gurabo boundary chosen by E. Vokes (1989). The absence of the *A. e. eccentricus* biozone, which elsewhere is present in shallow-water deposits, suggests an unconformity below the *Arca* beds, as already suggested by Bold (1968: 38) on the basis of ostracodes. The presence of the *A. e. caimiticus* biozone within and above the *Arca* beds suggest that they correlate with the Gurabo Formation in the Río Gurabo section.

Unconformity in the Río Gurabo Section

The unconformity in the Río Cana section suggested by the missing *Argopecten eccentricus eccentricus* biozone below the base of the *Arca* beds is possibly also present in the Río Gurabo section (Text-fig. 3). In the latter section, *A. e. lacabrensis* n. ssp. is abundantly present in the Cercado Formation to a level that is 208 m above the base of the section (NMB 15874). Above this level, deeper-water species, particularly *A. thetidis*, are present. In an interval 222-226 m above the base of the section (NMB 16808), *A. eccentricus* reappears, but in the form of *A. e. caimiticus* that is remarkably similar in morphology to specimens from within the *Arca* beds on the Río Cana 228 m above the base of the section (NMB 16842). The absence of *A. e. eccentricus* suggests that the biozone that it represents might have been cut out by erosion during a minor marine transgression.

Correlation of the Río Mao Sections

There is general agreement that Maury's (1917b) Bluff 3 on the Río Mao, the furthest upriver of her three numbered bluffs (Text-fig. 2), has a Cercado fauna, and that the same applies to Bluff 2. Bluff 1, the furthest downriver, has a Gurabo fauna, and the Cercado-Gurabo boundary lies somewhere between Bluffs 2 and 1 (H. Vokes, 1989: caption of text-fig. 2). However, some authors have commented on some remarkable differences in the species composition of the Cercado faunas of the Río Mao compared to those of the Río Gurabo, even though they are only *ca.* 10 km apart. For example, Jung (1986: 9) found that two species of the gastropod *Strombina* Mörch, 1852, each represented by more than 1,000 specimens and both occurring in the Cercado Formation, have mutually exclusive distributions on the Río Gurabo and the Río Mao. H. Vokes (1989: 101) found that one species of a cardiid bivalve represented by more than 3,000 specimens occurs in the lower Cercado Formation on the Río Mao, and a second spe-

cies of a cardiid is represented by 180 valves "in the same relative horizon" on the Río Gurabo, but not a single specimen of either species has been found on the Río Mao.

A similar phenomenon occurs with pectinid species in the two river sections. *Leptopecten thompsoni* is represented by more than 3,000 specimens, 96% of which are from the Cercado Formation at Bluffs 2 and 3 on the Río Mao, and only two specimens occur in the Cercado Formation of the Río Gurabo section (Table 14; see also the Systematic Paleontology section.) Virtually all of the Río Mao samples of *L. thompsoni,* however, are associated with the *Argopecten eccentricus eccentricus* biozone, which is absent on the Río Gurabo. The conclusion is that the paucity of *L. thompsoni* is the result of a pinching out of this biozone between the two rivers, resulting in the possible presence of an unconformity in both the Río Gurabo and Río Cana sections, as discussed above.

Correlation of "Mao Adentro" Limestones

Saunders *et al.* (1986: 30) referred to an unresolved question regarding the age of limestones that form Angostura Gorge on the Río Yaque del Norte. These limestones have not yielded planktic foraminiferans or calcareous nannoplankton for dating. However, based on planktic foraminferans obtained from silts just above the top of the limestone sequence, Saunders *et al.* (1986) placed this level near the base of the *Globorotalia margaritae* Zone, with associated nannofossils indicating the upper part of NN11 Zone, approximating the Miocene-Pliocene boundary. In contrast, locality NMB 17277, adjacent to the base of the limestone sequence, yielded species of a coral genus, *Coscinaraea* Milne-Edwards & Haime, 1848, not known to occur later than the early part of the Middle Miocene in the Caribbean region, an age that would suggest correlation with the Baitoa Formation upstream from the gorge. The same coral genus occurs upstream at López (NMB 16943) and at Arroyo López (NMB 17274). The controversy arises because the date based on the coral conflicts with an age of late Miocene based on ostracodes at Arroyo López (NMB 17316 and 17317).

Pectinids were collected at two of these localities, and their species identities strongly suggest a late Miocene age for strata in the Arroyo López area (NMB 17274) and a latest Miocene or early Pliocene age at the base of the limestone sequence (NMB 17277). The species present at NMB 17274 are *Nodipecten colinensis colinensis* (F. & H. Hodson in Hodson *et al.*, 1927) and *Leopecten gatunensis* (Toula, 1909). The former species is Late Miocene in age based on correlations with formations in Venezuela and Panama; the latter is Late Miocene in age based on correlations outside the Dominican Republic (detailed in the Systematic Paleontology section). The only pectinid collected at NMB 17277 is *Interchlamys jacobiana* (Cooke, 1919), which has an age range of late Miocene to early Pliocene based on occurrences in Cuba and Puerto Rico (see Systematic Paleontology section). These pectinids clearly contraindicate a Middle Miocene age for the base of the limestone section.

Pectinids also indicate that the limestones that cap the Samba Hills in the Guayubín area (TU 1245, 1281, and 1438) could be younger in age than the base of the limestone sequence at Angostura Gorge and more in accord with the upper part of the sequence. This is indicated by the presence in the Guayubín limestones (TU 1245 and 1438) of *Interchlamys interlineata*, the probable descendant of *I. jacobiana*, as well as the presence of the endemic species *Caribachlamys guayubinensis* n. sp., the closest relatives of which are in the Late Pliocene to Recent (see Systematic Paleontology section). *Interchlamys interlineata* is also present in the limestones in the Gurabo Hills northeast of Santiago (USGS 8724), which Cooke (in Vaughan *et al.*, 1921: 73) regarded as probably correlative with the Mao Adentro Limestone. Cooke also thought that a correlative limestone occurs on the northern side of the Río Yaque del Norte west of Santiago (USGS 8663). However, these limestones, overturned and with a strike paralleling the front of the Cordillera Septentrional, contain two pectinid species that indicate a younger, mid-Pliocene age. One is *Euvola jamaicensis* n. n., originally described from the Bowden shell beds of Jamaica as *Pecten* (*Pecten*) *barretti* Woodring, 1925. The other is a fragment of a left valve of what I tentatively identify as *Lindapecten exasperatus* (G. B. Sowerby II, 1842), based on its scale development and extrapolated rib count. (This specimen was found in the Smithsonian collections too late for illustration, but it has been cataloged as USNM 5411021 to serve as a voucher.) This is a Recent species that first appears in the middle Pliocene (see the Systematic Paleontology section).

Correlation of the Potrero Dam section, Río Amina

Saunders *et al.* (1986: 33) reported that only the highest sample at Potrero Dam on the Río Amina (NMB 16949) yielded age data based on a "poor flora" of calcareous nannoplankton indicating a possible NN12 Zone age, thus approximating the Miocene-Pliocene boundary. In their table 3, they correlated the Potrero Dam section with Maury's (1917b) Bluff 1 on the Río Mao, thus indicating correlation with the Gurabo Formation. Maury (1917b: 452) had earlier indicated that beds along the Río Amina correlated with the Gurabo Formation (her Zones A-F) but did not state exactly from where her samples came along the river.

Pectinids from the lowest part of the composite section for the Río Amina, given by Saunders *et al.* (1986: text-fig. 35), from locality TU 1218 at the Potrero dam, comprise an interesting assemblage. It contains *Argopecten eccentricus eccentri-*

cus, indicating the presence of a biozone that correlates with Bluffs 2 and 3, Cercado Formation, on the Río Mao. Gurabo correlatives appear at a higher stratigraphic level, particularly *A. e. caimiticus*, which appears near the top of the Río Amina composite section (Text-figs 7-8).

Correlation Outside the Dominican Republic

Because the Propeamussiidae and Pectinidae of the Dominican Republic are so highly endemic, relatively few species contribute to stratigraphic correlation with other regions. Among those species that do have outside distributions, the potentially most useful ones are those that are parts of clades for which successive segments can be recognized and tested for use as chronostratigraphic markers. Stratigraphic correlations within the tropical eastern American region that appear to be corroborated by pectinid distributions are the following:

(1) Correlation of the uppermost beds of the Mao Formation with the Bowden shell beds of Jamaica is indicated by the co-occurrence in the two formations of species that might have lived on the outer shelf and were susceptible to downslope transport into deeper-water environments. These species are *Argopecten uselmae* (Pilsbry & Johnson, 1917) and *Euvola jamaicensis* n. n. In addition, some extant species with broader depth ranges that extend into shallow water make their first appearance in both the Mao Formation and Bowden shell beds. These are *Antillipecten antillarum* and *Argopecten ameleus* (Woodring, 1925). The Bowden shell beds have now been dated as late Middle Pliocene (late Piacenzian; Kohl & Robinson, 1998). Saunders *et al* (1986: 23, 33) dated the uppermost Mao Formation at localities containing *A. uselmae* as Middle Pliocene "not above the middle of the *Globorotalia exilis* Subzone of the *Globorotalia miocenica* Zone" (Río Cana, NMB 16885) and "upper part of the *Globorotalia margaritae* Zone of the lower part of the *Globorotalia miocenica* Zone" (Río Amina area, NMB 16958, equivalent to TU 1216) on the basis of planktic foraminiferans. That part of the Mao Formation on the Río Gurabo containing *E. jamaicensis* n. n. has been dated as *Globorotalia miocenica* Zone, middle Pliocene (Saunders *et al.*, 1986: 19). The presence of *E. jamaicensis* n. n. in the Camuy Formation of Puerto Rico and in an unnamed formation in Guadeloupe (Mongin, 1968, as *Pecten ventonensis* Cooke, 1919) indicates that these formations could also be correlated with the uppermost beds of the Mao Formation and with the Bowden shell beds.

(2) Correlation of the limestones of the Mao Formation with the La Cruz Formation in the Santiago area of southeastern Cuba as well as with part of the Ponce Formation of southern Puerto Rico and an unnamed formation of probable Pliocene age in Guadeloupe is indicated by the presence of the *Interchlamys jacobiana — I. interlineata* lineage in these areas.

(3) Correlation of the upper Cercado and lower Gurabo formations of the Dominican Republic with the lower part of the Ponce Formation of southern Puerto Rico and the lower part of the La Cruz Formation of southeastern Cuba is suggested by the co-occurrence of *Antillipecten cercadicus* (Maury, 1917a).

(4) E. Vokes (1979) dated the Baitoa Formation as late Early Miocene (Burdigalian) on the basis of the concurrent stratigraphic ranges of marine gastropods and correlated the formation with the Chipola Formation of Florida. Akers (1972: 10) had earlier arrived at a Burdigalian age for the Chipola on the basis of planktic foraminferans, which indicated placement in the *Globigerinatella insueta* Zone (N7 and N8). There is an indication, however, that the Baitoa Formation could be slightly younger than the Chipola. Bold (1988: 11) dated the Baitoa Formation in the López section of the Río Yaque del Norte on the basis of ostracodes, indicating a late Early Miocene (N7, late Burdigalian) to early Middle Miocene (N10, late Langhian) age and possibly more likely near the latter part of this range.

The Baitoa Formation in the López section dated by Bold (1988) is also the source of *Lindapecten baitoaensis* n. sp., known only from this formation. As explained in detail in the Systematic Paleontology section under the genus *Lindapecten* Petuch, 1995, a possible evolutionary trend in the time of appearance during ontogeny of secondary radial costae possibly indicates that *L. baitoaensis* n. sp. could be geologically somewhat younger than *L. chipolanus* (Dall, 1898) of the Chipola Formation.

(5) Bold (1988: 12) determined that the age of strata exposed in the Arroyo López section of the Río Yaque del Norte are late Miocene in age on the basis of ostracodes, correlating with the upper Cercado Formation of the Río Gurabo section. He further noted that one of the ostracodes also occurs in the Gatun Formation of Panama.

The two species of pectinids from this part of the section corroborate Bold's (1988) findings. One, *Nodipecten colinensis vokesae* (Smith, 1991b), occurs elsewhere in the Cibao Valley in the upper Cercado and lower Gurabo formations. The second species, *Leopecten gatunensis*, was originally described from the Gatun Formation of Panama.

PALEOBIOGEOGRAPHY

Numerous studies, recently reviewed by Landau *et al.* (2008), have divided the marine tropical and paratropical regions of the Americas into provinces and subprovinces. The most ambitious recent work is that of Petuch (2004), who recognized 12 provinces and 30 subprovinces based mainly on percentages of endemic marine gastropods over a period of geological time ranging from the early Oligocene to the present day (but see critical comments by Allmon, 2005, and Landau *et al.*, 2008).

In the present study of the Propeamussiidae and Pectinidae of the Cibao Valley of the Dominican Republic, 24 of 38 positively identified species (63%) and one of 21 genera (4.7%) are endemic, but it is unclear what this means given the lack of detailed knowledge of these taxonomic groups in Neogene faunas from the tropical American region outside of the Dominican Republic. Clearly species can appear to be endemic for many reasons, including absence of precisely the same facies (environment of deposition) elsewhere, the low probability of species that are rare in the large collections from the Cibao Valley occurring in much smaller collections from other regions, the absence of precisely chronostratigraphically correlated deposits in other regions (particularly important for comparing the distributions of rapidly evolving species), and true endemism involving either paleoendemics or neoendemics as defined by Cronk (1992, 1997; see also Waller, 2007).

At the species level, the Cibao Valley Propeamussiidae and Pectinidae support the concept of a Neogene "West Indian subprovince" that is distinct from a "Colombian-Venezuelan-Trinidad subprovince" as originally developed by Woodring (1974). These pectinoid families also underscore the distinctness of the West Indian subprovince from a Caloosahatchian Province (Carolinas, Florida Peninsula, and northern Gulf of Mexico) as developed by Petuch (2004). Among the 19 species reported herein that occur outside of the Dominican Republic, 10 have distributions that are entirely Antillean. Only one species occurs in the Jackson Bluff Formation of Florida as well as in the Bowden Formation of Jamaica. It is *Spathochlamys vaginula*, a close relative of *S. benedicti* (Verrill & Bush in Verrill, 1897), an extant species that has a very broad geographic and depth range (Waller, 1993: 232). The only Dominican Republic species that also occur in Venezuela are *Nodipecten colinensis colinensis*, *N. nodosus*, and *Leopecten gatunensis*. *Leopecten* is the only paciphile pectinid genus present in the Dominican Republic. Woodring (1966: 426) introduced the term "paciphile" for taxa that lived on both sides of the Isthmus of Panma in the Miocene but now survive only on the Pacific side. The only certain caribphile genus (Woodring's term referring to taxa that lived on both sides of the Isthmus in the Miocene but survive today only on the Caribbean side) is *Lindapecten*. The genus *Amusium*, which was broadly distributed in the Miocene and Pliocene in the tropical American region, survives today only in the western Indo-Pacific.

Evolution

The thick sequence of sediments comprising the Cercado and Gurabo formations spans a relatively short time period of approximately three million years, from Late Miocene (late Zone NN11, Messinian) to Early Pliocene (Zone NN13, early Zanclean), but displays a very great change in depth of deposition, from intertidal to depths estimated at more than 200 m (chronology based on Saunders *et al.*, 1986: table 3, and the timescale of Gradstein *et al.*, 2004: fig. 21.1, with additions from McNeill *et al.*, 2008). If species are rapidly evolving, one would expect to see successive morphological changes within these sequences. The challenge, however, is to distinguish morphological change due to evolution from ecophenotypic change due to successively deeper and offshore environments going up section.

In the Systematic Paleontology section, the evolution of each species found in the Neogene of the Cibao Valley is assessed, and there is evidence for both phyletic and ecophenotypic change within the stratigraphic sequences, particularly for those species represented by abundant specimens over long stratigraphic intervals. The three chronosubspecies of *Argopecten eccentricus* recognized herein appear to represent a single lineage that changes anagenetically within the Cercado-Gurabo sequence. These changes occur within the shallow-water "Cercado" facies, so that the issue of environmental change related to water depth is alleviated. The estimated depths of deposition for the collecting sites for this species range from just below tidal level to *ca.* 50 m. That the succession of subspecies is evolutionary rather than ecophenotypic is indicated by the fact that the succession of subspecies is always the same within the "Cercado" facies in each sampled section. In contrast, certain species that occur in the deeper-water "Gurabo" facies, for which the depth range is much greater (50- >200 m), show morphological change that is interpreted as ecophenotypic. These changes are not strictly successional within or among stratigraphic sections. Examples are the three morphotypes recognized within the species *Amusium papyraceum* as well as the morphological variations described for *Argopecten thetidis*.

Other species in the Cibao Valley do not show evidence of evolution within local stratigraphic sequences, but their phylogenetic position within a clade can be inferred by morphological comparisons to species elsewhere in the tropical American region that may differ in geological age. The genera *Interchlamys* n. gen., *Lindapecten*, *Nodipecten*, and *Euvola* Dall, 1898, described in the Systematic Paleontology section, provide examples.

Lastly, there is the case of *Gurabopecten uniplicatus* n. gen., n. sp., which occurs only in a narrow stratigraphic range within the Gurabo Formation precisely where depth of deposition has been determined to increase rapidly. The phylogenetic position of this species near *Argopecten thetidis* is indicated by a comparison of the early ontogenetic stages of the two species, but there is no evidence for any *A. thetidis-G. uniplicatus* transition within the Cibao Valley sequences. Rather, the relationship is corroborated by a single specimen of *A. thetidis* that demonstrates instability in rib strength and spacing, indicat-

ing that variation in *A. thetidis* might have been the source for the peculiar morphology that became fixed in *G. uniplicatus*.

SYSTEMATIC PALEONTOLOGY

Phylum **MOLLUSCA** Cuvier, 1797
Class **BIVALVIA** Linnaeus, 1758
Subclass **PTERIOMORPHIA** Beurlen, 1944
Superorder **EUPTERIOMORPHIA** Boss, 1982
Order **OSTREOIDA** Férussac, 1822
[emend., Waller, 1978]
Suborder **PECTINOIDINA** H. & A. Adams, 1858
Superfamily **PECTINOIDEA** Rafinesque, 1815
[emend. Waller, 1978]

Family **PROPEAMUSSIIDAE** Abbott, 1954

Genus ***CYCLOPECTEN*** Verrill, 1897

Cyclopecten Verrill, 1897: 70.

Type species.—*Pecten pustulosus* Verrill, 1873, by subsequent designation (Sykes *et al.*, 1898).

Diagnosis.—Small Propeamussiidae with persistent byssal notch, internal disk ribs absent or limited to anterior and posterior sides of disk, disk gapes absent; prismatic fringe of RV very narrow, with prismatic layer commonly having alternating commarginal rows of large, radially elongate prisms and small polygonal prisms, less commonly lacking alternation, with all prisms small; sculpture of LV highly variable, from smooth to coarsely clathrate or with coarse pustules formed by commarginal lamellae; sculpture of RV with fine commarginal lirae related to commarginal prism bands, rarely with fine radial costellae formed by alignment of noded prisms; well-developed hinge teeth absent; apposition zones of hinge plates with well-developed transverse micro ridges or crenulations or roughened and without micro ridges.

Remarks.—Verrill's (1897) original concept of the genus *Cyclopecten* encompasses a broad array of propeamussiid species that lack regular internal ribs. Due to the sculpture-dampening effect of an ontogenetically persistent simple columnar prismatic calcite layer on the right valve (Waller, 1972b), sculptural elaboration occurs mainly or entirely on the left valve. Sculptural patterns on the left disk are highly diverse, from glossy smooth, to weak sculpture confined to the umbo, to deeply reticulate with pointed or cuspate scales at the intersections of commarginal lamellae and radial costellae. The genus is also diverse in the patterns of prisms on the right valve. In some taxa, these prisms are rectangular, arranged in commarginal rows, and of rather uniform shape, increasing only very gradually in size through ontogeny. In other taxa, commarginal bands of larger prisms, commonly radially elongate and rectangular in shape, alternate with commarginal bands of much smaller polygonal prisms that have no alignment within their band.

Internal features are also diverse. The apposition zones of the hinge plate can be crenulated with prominent vertical or slanted ridges and grooves or can be a simple roughened surface with no sign of vertical crenulation. In general, hinge teeth are not present except for a weak resilial tooth on each side of the resilifer of the right valve in some taxa. Even the absence of internal disk ribs, regarded as diagnostic for *Cyclopecten* by Verrill (1897), is variable. The type species, *C. pustulosus* (Verrill, 1873), with its characteristic rows of pustulose scales on the left valve, is not far removed from *C. hoskynsi* (Forbes, 1844), which has similar sculpture on its left valve. But the latter species is variable in the presence of internal ribs, which can be developed only laterally but in some cases can be present in an unstable pattern across the entire inner surface of the disk in late ontogeny. Internal ribs are also variably developed in *C. fenestratus* (Forbes, 1844), which some authors would place in *Parvamussium* (*e.g.*, Dijkstra & Gofas, 2004: 39).

The scope of *Cyclopecten* is further complicated in low-latitude seas by the very small shell size of many of the species that occur there, many of which are undescribed. In some cases, they are neotenic and difficult or impossible to distinguish from the juvenile stages of known species that have not yet developed characteristic prism patterns on the right valve or radial and commarginal sculpture on the left valve.

Similipecten Winckworth, 1932 (junior synonym *Arctinula* Thiele, 1934) is another propeamussiid genus that lacks internal ribs. Its type species, *S. similis* (Laskey, 1811) of the eastern Atlantic, as well as *S. groenlandicus* (G. B. Sowerby II, 1842) of Arctic seas and *S. minor* (Locard, 1898) of the northeastern Atlantic, differ from *Cyclopecten* in having a prismatic layer that consists entirely of tiny polygonal prisms lacking radial or commarginal alignment and narrow hinge plates that lack pustules or transverse ridges. The extant western Atlantic species *C. nanus* (Verrill & Bush in Verrill, 1897), assigned to *Similipecten* by Mikkelsen & Bieler (2007), is regarded tentatively as a *Cyclopecten* rather than *Similipecten* based on its commarginal rows of radially elongate prisms and its strongly cross-ridged hinge plates.

Geographic range.—Cosmopolitan, at present rare in water shallower than *ca.* 40 m, more commonly in deep water from 100-2,000 m.

Stratigraphic range.—Paleocene?, Oligocene to Recent.

Cyclopecten acuminatus n. sp.
Pl. 1, Figs 1-3

Diagnosis.—Small *Cyclopecten* with tiny prisms in very narrow commarginal rows, apposition zones of hinge with transverse ridges, smooth left exterior with anterior disk flank forming sharp angle at intersection with disk; right anterior auricle narrowly tapering with prominent thin dorsal scroll, left anterior auricle bearing coarse commarginal ridges along its base; posterior auricles pointed, with posterior auricular margins forming acute angles with dorsal margins.

Description.—*Cyclopecten* of small size, not known to exceed 5 mm Ht; disk unevenly rounded with posterior margin slightly flattened, equivalved, acline, convexity moderate; auricles relatively large, anterior auricle narrowly tapering with deep byssal notch, posterior auricles pointed, with posterior auricular margins forming acute angles with dorsal margins. Exterior of left disk smooth and glossy, exterior of right disk with very fine commarginal ridges separating prism bands; right anterior auricular surface crossed by raised commarginal lamellae outlining its narrowly tapering form, byssal fasciole set off by single weak radial costella; left anterior auricle with prominent raised commarginal lirae on its ventral part; posterior auricles lacking radials, bearing only fine commarginal growth lines; disk flanks of RV low and rounded, but anterior disk flank of LV steep, forming sharp angle with disk surface. Hinge lacking discrete teeth, but with ventrally convex apposition zone on each side of hinge plate crossed by regular vertical ridges that incline dorsally toward beak; internal ribs absent except for weak rib developed from internal aragonitic layer on posterior side. Shell microstructure consisting of thin prismatic outer layer on RV with tiny irregularly rectangular prisms arranged in narrow commarginal bands reaching maximum width of only *ca.* 20 μm; thin outer non-prismatic calcitic layer on LV; inner layer of crossed-lamellar aragonite present on disk and auricles of both valves, appearing opaque white as seen through gray, translucent outer calcitic layers. Adductor scars not fully exposed, but left adductor scar apparently not deeply impressed. Pigment patterns rare, observed as evenly distributed white spots on one LV.

Etymology.—Referring to the acutely pointed auricles and angular intersection of the left anterior disk flank with the disk surface.

Holotype and measurements.—NMB G17491 (Pl. 1, Figs 1-2), partial LV missing periphery of disk, height from dorsal margin to midventral fracture 2.7 mm, length from anterior margin to posterior fracture 3.1 mm, hl 2.6 mm.

Type locality.—NMB 15829, Río Gurabo, Mao Formation, 758-761 m above base of section (Saunders *et al.*, 1986: text-fig. 4), northern Dominican Republic.

Other material.—Thirteen paratypes: NMB 15823 (1 partial LV); NMB 15828 (1 RV, 8 LV, poorly preserved on blocks of matrix); NMB 15829 (1 LV, 2 RV), all from the Mao Formation on the Río Gurabo, spanning a stratigraphic interval from 670-761 m above the base of the section as plotted by Saunders *et al.* (1986, text-fig. 4).

Remarks.—The concept of *Cyclopecten acuminatus* n. sp. is based mainly on the holotype (Pl. 1, Figs 1-2) and the single right valve from locality NMB 15828 (Pl. 1, Fig. 3). The other specimens are too poorly preserved to be of much use in assessing variation or in expanding the description. Because specimens that are free of matrix are incomplete and those that are embedded in matrix have only their exteriors accessible, the presence and extent of lateral internal ribs are uncertain. There is little doubt, however, that these are not the juveniles of much larger *Parvamussium*. Left valves are readily identifiable by directing light at a low angle from the posteroventral side. This brings out the sharpness of the intersection between the disk and the anterior disk flank as well as showing the coarseness of the commarginal ridges along the base of the left anterior auricle.

The species clearly lived in deep water, as evidenced by its association with *Dimya* sp. and *Chagrepecten paracactaceus* n. gen., n. sp. Saunders *et al.* (1986: 16) commented on the common occurrence of turbidity-flow deposits between 600 and 700 m above the base of the section on the Río Gurabo and inferred, on sedimentological grounds, that depths of deposition higher in the section, from *ca.* 700-770 m, were still probably >100 m.

Comparisons.—*Cyclopecten acuminatus* n. sp. is morphologically closest to *C. zalaya* n. sp. but differs in having much more acute auricles, particularly the right anterior one, and in having a left anterior disk flank that forms a sharp angle with the disk surface. See the section on *C. zalaya* n. sp. for other comparisons.

Evolution.—*Cyclopecten zalaya* n. sp., which stratigraphically precedes but broadly overlaps *C. acuminatus* n. sp., is possibly the ancestral species. If this is the case, then evolutionary trends involved the loss of more centrally located internal ribs and an increase in the acuteness of auricles and disk flanks.

Occurrence.—In the northern Dominican Republic, *Cyclopecten acuminatus* n. sp. is known only from the lower part of the Mao Formation at the three localities listed above.

Distribution.—*Cyclopecten acuminatus* n. sp. has not been recognized outside of the Dominican Republic.

Cyclopecten guppyi (Dall, 1898)
Pl. 1, Figs 4-8; Tables 1, 3

Pecten (Pseudamusium) guppyi Dall, 1898: 718 (in part), pl. 34, fig. 13, not fig. 12 (= *Cyclopecten zalaya* n. sp.).
Chlamys (*Palliolum*?) *guppyi* Dall. Woodring, 1925: 72 (in part), pl. 8, figs 13-14, not figs 15-16 (= *Cyclopecten zalaya* n. sp.).
Pseudamussium guppyi Dall. Gardner, 1926: 49.

Original description.—"Shell small, suborbicular, moderately convex, smooth, with the surface covered with microscopic *Camptonectes* striation; ears small, the anterior slightly larger, all with very minute radiation and concentric lines; notch narrow, small, with no ctenolium; interior smooth, without lirae or developed crura; traces of the auricular crura alone perceptible; cardinal margin bearing a sharply cross-striated, very distinct provinculum; basal margins flattened, posterior margin slightly compressed. Alt 6, lat. 6 mm" (Dall, 1898: 718).

Description.—*Cyclopecten* of small size, with maximum known Ht barely more than 5 mm; disk unevenly circular, with anterior margin more sharply rounded than posterior margin, imparting wedge-like appearance; curvature of posterior margin very slightly straightened in some specimens; RV slightly convex, LV nearly twice as convex as right. Auricles large relative to size of disk, with posterior auricles slightly shorter than anterior; right anterior auricle with deep byssal notch with sharp apex, anterior margin rising from byssal notch with slight curvature, then curving steeply to intersect dorsal margin, dorsal margin with narrow scroll near distal end; anterior margin of left anterior auricle shallowly sigmoidal with only very slight byssal sinus; overall trend of margin forming slightly obtuse angle with dorsal margin; posterior margins of posterior auricles slightly outwardly convex with overall trend forming slightly obtuse angle with dorsal margin. Exterior sculpture very weak to absent; exterior of right disk nearly smooth except for very fine commarginal lines representing bands of rectangular prisms that are slightly longer in antimarginal direction than in commarginal direction; exterior of left disk smooth except for faint radial costellae near margins of some specimens; right anterior auricle with raised commarginal lirae and fine, slightly scabrous radial costellae on ventral third, ventralmost costa strongest, setting off narrow byssal fasciole; sculpture on other auricles more subdued or absent, when present consisting of fine radial costellae in ventral third of auricles crossed by raised commarginal lamellae in trough where auricles meet disk; disk flanks of RV rounded, poorly demarcated, lacking costellae, having only fine commarginal growth lines; anterior disk flank of LV steep, meeting disk along sharp line; left posterior disk flank not clearly demarcated in early ontogeny, both left disk flanks lacking radial costellae. Hinge lacking discrete teeth but with broad, ventrally convex apposition zone on each side of hinge plate crossed by regular vertical ridges that incline dorsally toward beak; apposition zones dark gray in contrast to adjacent white inner shell layer and in some specimens separated from this layer by sharp ledge. Interior of disk lacking internal ribs; small node or thin buttress present on interior of base of posterior auricle of each valve, not extending beyond mid-length of auricle; interior of base of left anterior auricle swollen distally, probably filling byssal notch of opposite valve; inner surface adjacent to disk margin beveled, especially on LV. Shell microstructure of RV consisting of very thin outer layer of simple columnar prismatic calcite extending to margin of disk, with tiny prisms rectangular in shape and arranged in narrow (20-25 μm) commarginal rows. Thin foliated calcitic layer present inside outer prismatic layer of RV and forming outer surface of LV. Innermost shell layer of both valves commarginal crossed-lamellar aragonite, extending nearly to margins of disk but withdrawn slightly from distal margins of auricles. Adductor scars indistinct except for impressed dorsal margin of right adductor scar high in umbonal region. Pigment pattern on LV consisting of randomly arranged translucent gray spots on more opaque white background; no pattern observed on RV.

Type material and measurements.—Cotypes, USNM 135779, 1 RV, Ht 4.3 mm, and 1 LV, HT 4.7 mm, figured by Woodring (1925: pl. 8, figs 13-16). The left valve is herein selected as the lectotype, because its morphology corresponds more closely to Dall's description than does that of the right valve. The right valve is determined to be of a different species, described below as *Cyclopecten zalaya* n. sp.

Type locality.—USGS 2580, "Bowden Formation at Bowden, on the east side of Port Morant, in the parish of St. Thomas, lying on the south coast of Jamaica near its eastern end. The beds crop out on the slope of the hills facing the bay." (Woodring, 1925: 7).

Other material.—Jamaica: USNM 353223, locality USGS 2580, 3 RV, 1 LV, in Dall's (1898) type series. Dominican Republic: 125 RV, 136 LV, from 29 localities in the northern Dominican Republic (Table 1).

Remarks.—Neither Dall (1898) nor Woodring (1925) rec-

Table 1. Occurrence of *Cyclopecten guppyi* in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Aee, *A. eccentricus s. s.*; Ael, *A. eccentricus lacabrensis* n. ssp.; Amp, *Amusium papyraceum*; At, *Argopecten thetidis*; B1, Bluff 1; B2, Bluff 2; B1/B2, between B1 and B2; Cz, *Cyclopecten zalaya* n. sp.; Dm, *Dimya* sp.; DV, matching valves; Es, *Euvola soror*; Gu, *Gurabopecten uniplicatus* n. gen., n. sp., Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis s. s.*; Lt, *Leptopecten thompsoni*; LV, left valve; Pa, *Paraleptopecten* sp. *a*; Pc, *Palliolum? cibaoense* n. sp.; Pvm, *Parvamussium marmoratum*; RV, right valve; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana								
NMB 16817	347	Gurabo	2	1	0	4.5	Aee, Es, Lpl	
----------								Miocene/Pliocene boundary at least as low as 315 m (Saunders *et al.*, 1986: 23)
TU 1230	200	Cercado	0	3	0	3.2	Ael, Amp, Es	
NMB 16857	148	Cercado	2	0	0	4.2	Ael, Amp	
NMB 17005	147	Cercado	0	1	0	3.3	Ael	
Río Gurabo								
----------								Miocene/Pliocene boundary (Saunders *et al.*,1986, text-fig. 14)
NMB 15941	392	Gurabo	0	1	0	3.6	Dm, Gu, Sv	
NMB 15849	274.5	Gurabo	1	0	0	1.7	At, Sv	
NMB 15860	255	Gurabo	1	2	0	4.9	At, Sv	
NMB 15906	131	Cercado	1	0	0	2.6	Ael	
TU 1375	124-126	Cercado	0	1	0	2.7	Ael, At	
TU 1358	102-104	Cercado	2	0	0	3.9	Ael, Amp, Lpl	
Rio Mao								
TU 1410	B2/B1	Cercado	0	1	0	3.9	Aee, Amp, At, Es	
NMB 16932	B2, g	Cercado	1	0	0	4.0	Aee	
NMB 16929	B2, f	Cercado	6	11	0	4.8	Aee, Lpl, Lt	
NMB 16928	B2, e	Cercado	0	2	0	4.1	Aee, Lpl, Lt	
NMB 16924	B2, d	Cercado	1	0	0	3.1	Aee, Lt	
NMB 16918	B2, d	Cercado	1	1	0	5.3	Aee, Lt, Pc	
NMB 16926	B2, c	Cercado	0	1	0	3.7	Aee, Lt	
NMB 16916	B2, b-f	Cercado	0	1	0	3.5	Aee, Lt	
TU 1379	B2, b-e	Cercado	38	34	0	4.6	Aee, Lt	
NMB 16915	B2, b	Cercado	1	0	0	4.3	Aee, Lt	
NMB 16927	B2, b	Cercado	4	2	0	4.0	Aee, Lt	
NMB 16923	B2, b	Cercado	0	1	0	4.1	Aee, Lt	
NMB 16917	B2, b	Cercado	0	1	0	4.5	Aee, Lt	
NMB 16922	B2, a	Cercado	2	0	0	3.4	Aee, Lt	
NMB 16912	B3	Cercado	1	0	0	3.9	Aee, Lt, Pc	
USGS 8525	B3	Cercado	19	34	0	4.7	Aee, Lt, Pc	
TU 1294	B3	Cercado	37	30	0	4.8	Aee, Lpl, Lt, Pa, Pc	

Table 1 (continued).

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Verde								
TU 1250	--	Gurabo	1	1	0	2.4	Aec, Amp, At, Cz, Es, Gu, Lpa, Pvm	
Santiago area								
TU 1227A	--	Gurabo	4	7	0	4.6	Ai, Amp, At, Cz, Gu, Lpa, Pvm, Sp	

ognized that the cotypes of *Cyclopecten guppyi* represent two distinct species, one with internal ribs and the other without. In the abundant material from the Dominican Republic (Table 1), all of the specimens of *Cyclopecten* from the Cercado and lower Gurabo formations lack internal ribs and are assigned to *C. guppyi*. Specimens higher in the section, in the upper Gurabo and Mao formations, have a lateral internal rib on each side of the disk on each valve and are assigned to *C. zalaya* n. sp. The two species co-occur only in situations involving gravity-flow deposits in which shallower water specimens have been carried into deeper water. The distributions of the two species establish that *C. guppyi* is the shallower species and *C. zalaya* the deeper. This conclusion is corroborated by the association of *C. guppyi* with shallow-water species as well as by the common presence in *C. guppyi* of severe marginal fracturing repaired during life (Pl. 1, Fig. 8). The presence of these injuries around the entire margin of the disk but not on the auricles suggests damage by shell-nipping predators, not by tumbling in sediment above wave base during severe storms.

Contrary to Dall's description of *C. guppyi, "Camptonectes* striae," *i.e.*, antimarginal striae, are not present. In the specimens from Bowden, epitaxial crystallization of calcite on the surface of the shells has occurred. On the left valve, this crystallization accentuates the antimarginal grain of groups of crystals in the outer foliated-calcite layer. It is therefore a diagenetic effect and not indicative of actual microsculpture. It is not present in the better preserved material from the Dominican Republic. Also contrary to Dall's description, the cross-ridged apposition zones of the hinge are not a provinculum, a term usually now reserved for the hinge of the prodissoconch. The apposition zones and the first coarse cross-ridges originate on the dissoconch after the end of the prodissoconch stage.

Morphological variation in *Cyclopecten guppyi* mainly involves the degree of expression of radial costellae on auricles. Among specimens from the Dominican Republic, most specimens have barely discernible auricular costellae on the ventral or distal parts of the auricles of the left valve. In the relatively few specimens available from the Bowden Formation, the radial costellae are more developed. The same applies to the presence of weak, widely spaced commarginal lirae on the umbo of the left valve, these being more consistently developed in the Bowden material. There is also variation in umbonal angle within the Dominican Republic material, with many specimens having a somewhat broader angle than that of the Bowden specimens. Pigment patterns of left valves consistently have randomly distributed gray spots on a more opaque, whitish background, with one exception, where opaque white pigment with broad V-shaped indentations in its ventral boundary is present on the umbo of the left valve.

Extant *Cyclopecten* species of small size in tropical waters occur over a broad depth range but are seldom found living at depths shallower than *ca.* 30 m. *Cyclopecten guppyi*, however, is commonly associated in the Cercado and lower Gurabo formations with *Smaragdia*, a neritid gastropod genus that is regarded as a seagrass specialist associated with seagrasses that are commonly restricted to depths < 30 m in low-energy conditions (Costa *et al.*, 2001: 61).

Comparisons.—Cyclopecten guppyi is readily distinguished from *C. zalaya* n. sp. of the Dominican Republic Neogene in lacking internal lateral disk ribs. *Cyclopecten guppyi* also has more numerous costellae on the right anterior auricle, a pigment pattern that does not have radial arrays, and a more angular apex of the byssal notch. Further differences are mentioned in the section on *C. zalaya* n. sp.

Cyclopecten nanus, an extant species broadly distributed in the western Atlantic region, differs from *C. guppyi* in having very fine, closely spaced radial costellae over the entire surface of the disk and auricles of the left valve, more abundant costellae over most of the surface of its right anterior auricle, and posterior auricular margins that are more deeply sigmoidal.

Cyclopecten aotus (Olsson, 1922) from the Pliocene of Puerto Limon, Costa Rica, based on the larger of two syn-

Table 2. Occurrence of *Cyclopecten zalaya* n. sp. in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; At, *Argopecten thetidis*; Cg, *Cyclopecten guppyi*; Cp, *Chagrepecten paracactaceus* n. gen., n. sp.; Crp, *Cryptopecten phrygium*; Dm, *Dimya* sp.; DV, matching valves; Es, *Euvola soror*; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; LV, left valve; Pvm, *Parvamussium marmoratum*; RV, right valve; Sv, *Spathochlamys vaginula*; --, not recorded. An asterisk (*) marks the type locality.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana								
NMB 17009	434	Gurabo	1	0	0	5.2	Crp	
Río Gurabo								
NMB 15827	658-660	Mao	3	3	0	6.3	Cp, Dm	
NMB 15935	399	Gurabo	1	1	0	4.4	none	
----------								Miocene/Pliocene boundary (Saunders *et al.*,1986, text-fig. 14)
Río Verde								
TU 1250	--	Gurabo	12	11	0	5.2	Aec, Amp, At, Cg, Es	
Santiago area								
TU 1227A*	--	Gurabo	67	79	0	5.0	Ai, Amp, At, Cg, Gu, Lpa, Pvm, Sp	Saunders *et al.* (1986: 34) suggested early Pliocene age

types (PRI 21161), is probably a junior synonym of *C. nanus* because of similar fine costae on its left disk and auricles as well as similarities in shape. The "*Camponectes* striations" said by Olsson (1922: 204) to be present in *C. aotus* are diagenetic features due to epitaxial crystallization of calcite, precisely as described above in Bowden *C. guppyi*.

Cyclopecten oligolepis (Brown & Pilsbry, 1913) from the Miocene La Boca and Gatun formations of Panama (Woodring, 1982: 576, pl. 104, figs 9, 12-13), is smaller than *C. guppyi*, seldom reaching 3 mm Ht, and has relatively larger posterior auricles, the posterior extremities of which are nearly as far extended as the posterior extremity of the disk. Many specimens of *C. oligolepis* have cancellate sculpture on the left disk caused by the intersection or radial costellae and widely spaced commarginal lirae. In other specimens, this cancellation is only weakly present and restricted to the umbonal region, and in some specimens the cancellation is also present on the proximal parts of the left auricles. Some specimens of *C. oligolepis* also have faint, very fine radial costellae on the right valve consisting of radially aligned tiny nodes on the commarginal bands of rectangular prisms. The pigment pattern preserved in a few specimens of *C. oligolepis* is like that described for *C. guppyi*.

Cyclopecten defuniak (Gardner, 1926), from the Middle Miocene Shoal River Formation of Florida, closely resembles *C. guppyi* in shape, but the latter species has a more inflated left valve and less prominent costellae on left auricles. The anterior margin of the right anterior auricle of *C. defuniak* is evenly rounded, whereas that of *C. guppyi* slants upward from

Table 3. Morphological comparison of *Cyclopecten guppyi* and *C. zalaya* n. sp.

	C. guppyi	***C. zalaya* n. sp.**
Shape of disk	opisthocline	acline
Left anterior disk flank	sharp, steep	sloping
Apex of byssal notch	acute	rounded
Costellae on R anterior auricle	multiple	one
Costellae on other auricles	weakly present	absent
Lateral ribs on inner disk surface	absent	present
Pigment pattern	none, or spots only	rays on RV, spots in rays on LV

the byssal notch before curving to meet the dorsal margin.

Cyclopecten diktuotus (Gardner, 1926), from the Lower to Middle Miocene Oak Grove Sand of Florida, resembles *C. nanus* rather than *C. guppyi* in having fine, closely spaced radial costellae on its left valve. The right valve of *C. diktuotus* has radially aligned nodes on adjacent commarginal rows of prisms, as in *C. oligolepis*.

All of the species mentioned above have tiny calcitic prisms in the outer layer of the right valve that are of fairly uniform size and arranged in commarginal rows that are commonly no more than 10 µm in width. All of these species also have a prodissoconch that is relatively large compared to the size of the adult shell and that appears to consist almost entirely of the PI stage, as evidenced by lack of commarginal growth lines except near the margin. This is generally regarded as an indication of lecithotrophic larval development (Ockelmann, 1965; Waller, 1981), a common if not universal phenomenon within the Propeamussiidae.

Evolution.—The sparse distribution, small sample sizes, and apparent great variation of *Cyclopecten guppyi* do not permit the recognition of any evolutionary trends in the Dominican Republic statigraphic sections.

Occurrence.—In the Dominican Republic, *Cyclopecten guppyi* is known only from the Cercado and lower Gurabo formations.

Distribution.—Outside of the Dominican Republic, *Cyclopecten guppy* is known from the Bowden Formation of Jamaica, late Middle Pliocene.

Cyclopecten zalaya n. sp.
Pl. 1, Figs 9-12; Tables 2-3

Diagnosis.—Small *Cyclopecten* with tiny prisms of more or less uniform size in commarginal rows, broad apposition zones of hinge with prominent transverse ridges, single internal rib on each side of disk formed from inner aragonitic layer, smooth left exterior, and shallowly sigmoidal posterior auricular margins.

Description.—Cyclopecten of small size, not known to exceed 5 mm Ht; disk unevenly circular, with anterior margin more sharply rounded than posterior; equivalved, convexity moderate; acline, with anterior slightly more extended than posterior; auricles of moderate size relative to size of disk, approximately equal in length or posterior auricle slightly shorter than anterior; right anterior auricle with shallow byssal notch with rounded or blunt apex, anterior margin rounded, dorsal margin with narrow, very tightly folded, fragile scroll near distal end; anterior margin of left anterior auricle shallowly sigmoidal, its dorsal part intersecting dorsal margin at obtuse angle and ventral part nearly vertical, lacking byssal sinus, dorsal margin straight; posterior margins of posterior auricles straighter than margin of left anterior auricle and meeting dorsal margin at slightly acute angle; dorsal margin of right posterior auricle with shallow, fragile scroll near distal end. Exterior sculpture of right disk consisting of fine commarginal lines demarcating commarginal bands of rectangular calcitic prisms; right anterior auricle with commarginal lirae and single, slightly scabrous radial costa setting off narrow byssal fasciole that otherwise would not be distinguishable from surface of auricle; other auricles lacking radial costellae, crossed only by weak commarginal lirae; left disk nearly smooth except for fine commarginal lirae and even finer growth lines, surface glossy in well-preserved specimens; disk flanks of RV valve low, anterior one slightly concave, sloping toward auricle, posterior flank lower and steeper; disk flanks of LV low and moderately steep. Hinge lacking discrete teeth but having ventrally convex apposition zone on each side of hinge plate crossed by regular vertical ridges that incline dorsally toward beak; apposition zones dark gray in contrast to adjacent white inner shell layer. Interior of disk with single internal rib on each side near disk flank, posterior rib stronger and beginning earlier in ontogeny than anterior rib, rarely 1 or 2 additional incipient internal ribs present on medial side of posterior rib, rib termini attenuated or slightly raised; very thin rib or knob present on interior of base of each auricle, more developed on posterior side than anterior. Shell microstructure of RV consisting of very thin outer layer of simple columnar prismatic calcite extending to margin of disk, with tiny, radially elongate, rectangular prisms arranged in commarginal rows, maximum dimensions of prisms *ca.* 40 µm. Thin foliated calcitic layer inside outer prismatic layer of RV and forming outer surface of LV. Inner shell layer of both valves commarginal crossed-lamellar aragonite, extending nearly to margins of disk but withdrawn slightly from distal margins of auricles; internal ribs forming within crossed-lamellar layer, lacking calcitic cores. Dorsal margins of adductor scars impressed, that of RV much higher in umbonal region than that of LV. Pigment patterns commonly well developed from beak to margin; RV with 12-17 broad, opaque white rays of somewhat uneven trend, with bifurcation and intercalation toward margin; LV with white spots commonly clustered in 4-7 indistinct, distally widening, radial bands.

Etymology.—Named for Arroyo Zalaya, northern Dominican Republic.

Holotype and measurements.—USNM 540939, 1 LV, 4.4 mm Ht, 4.3 mm L, 0.4 mm cvx (Pl. 1, Fig. 10).

Type locality.—TU 1227A, Arroyo Zalaya, "Turbidity flow lens (*ca.* 30" long, 6" thick) *ca.* two feet above base of outcrop at point approximately 75 feet downstream from highway bridge," northern Dominican Republic (Saunders *et al.*, 1986: 65).

Other material.—Northern Dominican Republic: 178 specimens (84 RV, 94 LV) from five localities (Table 2); Jamaica, Bowden shell beds: 1 RV in Dall's type material of *Cyclopecten guppyi*, USNM 135779.

Remarks.—*Cyclopecten zalaya* n. sp. is remarkably constant in shape and external sculpture. The pigment patterns, other than the general plan of opaque radial rays on the right valve and less distinct clustering of white spots into radial rays on the left valve, are much more variable. Among the abundant specimens from TU 1227A, a few have no pigment pattern, whereas on others, the patterns are limited to the umbonal region. The great majority of specimens have only a single internal rib on the interior of the disk on each side, but a few have one or two additional incipient ribs on the medial side of the posterior rib. This was observed on four right valves from TU 1227A and on another right valve from TU 1250.

In the Dominican Republic, *Cyclopecten zalaya* n. sp. co-occurs with *C. guppyi* only at two localities where gravity-flow deposits are present (E. Vokes, 1989: 12; E. Vokes & D'Attilio, 1980: 52). In such mixed deposits, *C. guppyi* would likely be the shallower-water species that was swept into the deeper-water habitat of *C. zalaya* n. sp. The evidence for this is afforded by the records of these species in the Dominican Republic. *Cyclopecten guppyi* occurs in the shallow-water facies of the Cercado Formation, whereas *C. zalaya* n. sp. is restricted to the deeper-water facies of the upper Gurabo Formation (Tables 1-2).

Comparisons.—*Cyclopecten zalaya* n. sp. resembles *C. acuminatus* n. sp. very closely. The right valves are not distinguishable on the basis of shape, auricular sculpture, or the configuration of prisms in the outer prismatic shell layer. Left valves, however, are distinguishable on the basis of the sculpture and shape of the left anterior auricle. In *C. zalaya* n. sp., the byssal sinus is very shallow and the shape of the anterior margin is shallowly sigmoidal, intersecting the dorsal margin at an obtuse angle. In *C. acuminatus* n. sp., the left anterior auricle is pointed, with a prominent byssal sinus that begins in early ontogeny as evidenced by the trends of coarse commarginal ridges. In addition, *C. zalaya* n. sp. has more prominent lateral internal ribs.

In the Dominican Republic Neogene, *Cyclopecten zalaya* n. sp. is readily distinguished from *C. guppyi* by the characters listed in Table 3.

Cyclopecten almirantensis (Olsson, 1922), known only from a right valve from the Bocas del Toro basin of Panama (probably from the Pliocene Caya Agua Formation; Collins, 1993: 708) is small in size and has a single internal lateral disk rib on each side, but differs from *C. zalaya* n. sp. in many other characters: costate auricles; radially aligned nodes on the prismatic calcite layer of the right valve; commarginal prism bands that alternate between tiny polygonal prisms and larger, radially elongate prisms; lateral internal aragonitic ribs that have calcitic cores (because their termini are within the foliated-calcite marginal secretion band on the shell interior); and less well-developed vertically ridged apposition zones on its hinge plates.

Cyclopecten thalassinus (Dall, 1886), an extant species with a broad geographic range in the tropical and temperate western Atlantic and a depth range from 40- >500 m (Abbott, 1974: 449; Theroux & Wigley, 1983), is a close living counterpart of *C. almirantensis* and differs from *C. zalaya* n. sp. in the same manner. In addition, *C. thalassinus* commonly has sculpture of high relief on its left valve.

In the eastern Pacific region, the extant species *Cyclopecten cocosensis* (Dall, 1908), from Cocos Island, Costa Rica, and the Gulf of Panama at depths from 95-113 m, has single internal lateral disk ribs as well as a pigment pattern on its right valve consisting of whitish rays (Grau, 1959: 30). But it also has radial costellae and early reticulation on its left disk as well as commarginal prism bands alternating in prism size, more like the outer prismatic layer of *C. thalassinus* than like that of *C. zalaya* n. sp.

Evolution.—In the Dominican Republic, the stratigraphic distributions of *Cyclopecten zalaya* n. sp. and *C. guppyi* are clearly facies controlled. Although the latter occurs stratigraphically lower, in the Cercado Formation, there is no reason to think that its acutal stratigraphic range precedes that of *C. zalaya* n. sp. This is because no comparable deep-water facies in which *C. zalaya* n. sp. would be expected to occur are present in the Cercado Formation. Elsewhere the relationships of *Cyclopecten*s of very small shell size are still too poorly known to understand their evolutionary relationships.

Occurrence.—In the northern Dominican Republic *Cyclopecten zalaya* n. sp. is known only from the Pliocene part of the Gurabo Formation and the lower Mao Formation at 5 localities (Table 2).

Distribution.—Outside the Dominican Republic, the new species is known only from the Bowden shell bed, Bowden Formation, Jamaica, now regarded as late Middle Pliocene in age (Kohl & Robinson, 1998; Donovan, 1998: 6).

Genus ***PARVAMUSSIUM*** Sacco, 1897

Amussium (*Parvamussium*) Sacco, 1897: 48.

Type species.—*Pecten* (*Pleuronectes*) *duodecimlamellatus* Bronn, 1832, by original designation (Sacco, 1897: 48), Pliocene, Italy (Schultz, 2001: 161).

Diagnosis.—Propeamussiidae with outer prismatic layer of RV extending as a broad, flexible flange beyond inner shell layers; internal ribs on disk well developed and regularly spaced, commonly embedded in an inner aragonitic layer; shorter internal ribs commonly intercalated between earlier ribs in late ontogeny; byssal notch persisting throughout ontogeny; disk gapes very narrow or absent.

Remarks.—Extensive synonymy lists for *Parvamussium* were provided by Hertlein (1969: N350). Some authors regard *Parvamussium* as a subgenus of *Propeamussium* de Gregorio, 1884, whereas others find it convenient to separate these taxa on the basis of the byssal notch, which disappears early in ontogeny in *Propeamussium* but persists in *Parvamussium*, and on the presence of broad disk gapes, present in *Propeamussium* but not in *Parvamussium*. This separation is followed here, with the caveat that this is not a clear separation for many extant propeamussiid species.

Geographic range.—Cosmopolitan, commonly in deep water, 100-800 m.

Stratigraphic range.—Middle Jurassic to Recent (Waller, 2006b: 324).

Parvamussium marmoratum (Dall, 1881)
Pl. 1, Figs 13-16; Table 4

Amussium lucidum marmoratum Dall, 1881: 117.
Amusium (*Propeamusium*) *pourtalesianum marmoratum* Dall. Dall, 1886: 212, pl. 4, fig. 3.
Amusium (*Propeamusium*) *pourtalesianum striatulum* Dall, 1886: 212; 1889: 34.
Propeamussium pourtalesianum (Dall, 1886). Abbott, 1974: 449, fig. 5207.

Description.—*Parvamussium* of small size, commonly <15 mm Ht, prosocline, margin of disks unevenly circular, with posterior somewhat extended, anterior auricles longer than posterior, LV more convex than RV, disk flanks of both valves low but steep, disk gapes absent; exterior of right disk formed by columnar prismatic calcite with alternating bands of large, radially elongate prisms and much smaller polygonal prisms, with regularly spaced commarginal lirae formed on larger-prism bands; right anterior auricle with rounded anterior margin and moderately deep, ontogenetically persistent byssal notch without ctenolium, surface of auricle with single radial costella demarcating flat byssal fasciole, rarely with finer radial costae crossed by commarginal lamellae present on auricular surface; posterior margin of posterior auricle sigmoidal to nearly straight, forming acute angle with dorsal margin, dorsal margins of both right auricles commonly dentate, caused by projections of commarginal lamellae; ventral border of RV commonly flexed when valves are tightly closed, made possible by projection of flexible prismatic outer layer beyond distal tips of internal ribs and beyond distal margins of inner shell layers; surface of left disk underlain by foliated-calcite, initially smooth and glossy from beak to 2-3 mm Ht, then with matte surface that is either smooth or with very fine radial costellae varying in number and spacing and increasing distally by intercalation; left disk flanks low and steep, commonly roughened by dense lamellae and minutely scabrous radial costellae; anterior margin of left anterior auricle nearly straight, forming acute angle with dorsal margin, either lacking radial costae or with weakly developed costellae and projecting commarginal lamellae in ventral sector; posterior margin of posterior auricle as on RV. Interiors of disks of both valves commonly with 10, rarely 9 or 11, regularly spaced inner ribs consisting of fibrous calcite embedded in crossed-lamellar aragonite inner shell layer; additional riblet or knob at border of disk and auricle on each side but commonly somewhat stronger on posterior side, and commonly an additional riblet or knob on posterior auricular surface dorsal to basal auricular riblet; intercalated inner ribs common on disk in late ontogeny of large individuals, when present most commonly in posterior sector; hinge plate simple, apposition zones roughened but without cross-ridging even in early ontogeny, hinge teeth absent.

Type material.—Dall (1881: 117) did not specify a holotype for his *Amussium lucidum* variety *marmoratum,* and his type series from the dredging expeditions of the U.S. Coastal Steamer "Blake" is now divided among the collections of the USNM(IZ) and the Museum of Comparative Zoology in Cambridge, Massachusetts. Because I have not studied all of the potential syntypes, I am not designating a lectotype.

Type locality.—Dall (1881: 117) did not specify a particular locality for his variety *marmoratum*, and later (Dall, 1886: 212) stated that this variety occurs at all depths and throughout the range of the nominal species. This is a broad area that includes the Gulf of Mexico and Caribbean and a very broad depth range, said by Dall (1886: 211) to be 13-805 fathoms (24-1,472 m).

Table 4. Occurrence of *Parvamussium marmoratum* in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; At, *Argopecten thetidis*; Cg, *Cyclopecten guppyi*; Cz, *C. zalaya* n. sp.; DV, matching valves; Es, *Euvola soror*; frag, fragment; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis s. s.*; LV, left valve; RV, right valve; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Verde								
TU 1250	--	Gurabo	0	1	0	5.0	Aec, Amp, At, Cg, Cz, Es, Gu, Lpa	
Santiago area								
TU 1227	--	Gurabo	3	7	0	12.0	Amp, At, Lpl	
TU 1227A	--	Gurabo	frag	0	0	7.6	Ai, Amp, At, Cg, Cz, Gu, Lpa, Sv	
TU 1357	--	Gurabo	4	0	0	6.1	none	

Other material.—Recent: 85 lots of Recent *Parvamussium marmoratum s. l.,* in the USNM(IZ), from the western Atlantic region; Dominican Republic Neogene: 7 RV, 8 LV, from 4 localities (Table 4).

Remarks.—The species *Parvamussium pourtalesianum* (Dall, 1886) was subdivided by Dall (1886) into three varieties (subspecies in the sense of the ICZN): *P. pourtalesianum s.s.*, *P. p. marmoratum* (Dall, 1881), and *P. p. striatulum* (Dall, 1886). However, because Dall's 1881 name has priority, the correct nominal species name is *P. marmoratum*, and the subspecies in Dall's sense are thus *P. m. marmoratum*, *P. m. pourtalesianum*, and *P. m. striatulum*. Further collecting and study since Dall's time have resulted in the synonymy of the first two subspecies (Abbott, 1974: 449), and indeed this synonymy was anticipated by Dall (1886: 212), who noted, "The variety *marmoratum*, with its brilliant mottling of orange, scarlet, brown, bright yellow, and opaque white dots or flecks, appeared indifferently at most of the stations in company with the pale translucent typical form."

On the other hand, there is no general agreement on the status of *Parvamussium marmoratum striatulum*. This putative subspecies differs from the other two subspecies in having weak radial costellae on its left valve that originate at the boundary between the proximal glossy zone and distal matte zone on the exterior surface, these costellae commonly fading out before reaching the ventral margin. Additionally, the pigment patterns on the left valves of the costellate form are commonly weaker, lacking the bold white spots present on many *P. marmoratum s.s.* The right valves of the two subspecies are indistinguishable, because they do not develop radial costellae. Although some samples from some localities have left valves that are all of the costellate form, a few samples contain both non-costellate and costellate forms. There is no demonstrable geographic boundary that separates costellae-bearing populations from non-costellate ones, the former occurring in the Gulf of Mexico as well as in the Antilles and in the tropical western Atlantic as far south as Brazil (USNM 752646, specimens collected alive), although costellate specimens are absent from samples from the Atlantic side of the southeastern United States. This distribution suggests that the costellate form is the result of discontinuous genetic variation within populations and that *P. m. striatulum* cannot be viewed as a geographic subspecies. For these reasons, this taxon is regarded as a junior synonym of *P. marmoratum*.

In the USNM(IZ) collections of extant *Parvamussium marmoratum*, the total depth range is 44-548 m. The vast majority (81%) of samples, however, are from depths of 70-200 m. The occurrence of this species in the Neogene of the Dominican Republic (Table 4) is consistent with a deep-water origin for the sediments in which it occurs. At localities TU 1227, 1227A, and 1250 there is evidence of deep-water turbidity-flow deposits (E. Vokes & D'Attilio, 1980: 52; E. Vokes, 1989: 12). An exuberant entry in the original Tulane University Locality Register (now in Department of Paleobiology, Smithsonian Institution) reads, "Deep water Gurabo (600 m!)."

Comparisons.—All of the left valves of the fossil specimens from the Dominican Republic identified with *Parvamussium marmoratum* have radial costellae. They differ from extant members of the species in having a slightly more extensive

proximal glossy zone before the start of radial costellae (*ca.* 4 mm in the fossil specimens as compared to 2-3 mm in extant specimens). The fossils also appear to have a somewhat thicker inner crossed-lamellar aragonitic layer that dampens the relief of the proximal ends of the internal ribs. Specimens from TU 1357 are all small (5-6 mm Ht), and because they are all right valves, they cannot be positively identified. Two of three valves that have accessible interiors have 11 internal disk ribs, the third having 10.

Amusium (*Parvamussium*) *spendulum* Woodring, 1925, from the Bowden beds of Jamaica, was said by Woodring to be remarkably similar to *P. pourtalesianum* (= *P. marmoratum* herein). Although the holotype, a right valve, is poorly preserved, it differs from *P. pourtalesianum* in lacking a distinct byssal notch and fasciole, in being higher than long in spite of its small size (7.6 mm Ht), and in having a different prism arrangement in its outer shell layer, with a less clear alternation of bands of prisms of different sizes. If I have interpreted the configuration of its anterior auricle correctly, it is more likely a young specimen of *Propeamussium*.

Evolution.—So far as known, this is the first report of *Parvamussium marmoratum* in the fossil record, and there is insufficient material for assessing evolutionary trends.

Occurrence.—In the Dominican Republic, *Parvamussium marmoratum* is known only from the upper Gurabo Formation, early Pliocene.

Distribution.—Fossil representatives of *Parvamussium marmoratum* are thus far unknown outside of the Dominican Republic.

Family **PECTINIDAE** Rafinesque, 1815 [emend. Waller, 1978]

Although the family Pectinidae is regarded as monophyletic on both morphological and molecular genetic grounds (Waller, 1978, 2006a; Puslednik & Serb, 2008), classification within the family is still in a state of flux. The arrangement of taxa in the present study is eclectic, reflecting the broadly accepted phylogenetic separation of three major subfamilies, Chlamydinae, Palliolinae, and Pectininae, as well as the unsettled relationships of tribes within these subfamilies (Puslednik & Serb, 2008, and references therein). Tribes, genera within tribes, and species within genera are presented here in alphabetical order.

Subfamily **CHLAMYDINAE** von Teppner, 1922
Tribe **CRASSADOMINI** Waller, 1993

Genus ***CARIBACHLAMYS*** Waller, 1993

Caribachlamys Waller, 1993: 217.

Type species.—*Pecten sentis* Reeve, 1853, by original designation.

Diagnosis.—"Byssate, non-cemented Crassadomini with lecithotrophic-type prodissoconch (large PI stage, short or absent PII stage); strong antimarginal striae present between commarginal lirae in rib interspaces in early ontogeny." (Waller, 1993: 217).

Geographic range.—Caribbean Sea and adjacent waters of the warm-temperate to tropical western Atlantic from North Carolina to Brazil and Bermuda, near shore, subtidal to *ca.* 30 m, commonly byssate on coral rubble or rocks, with dead shells transported to deeper water from steep seaward forereefs (Waller, 1993).

Stratigraphic range.—Upper Pliocene to Recent (Waller, 1993: 217).

Caribachlamys guayubinensis n. sp.
Pl. 2, Figs 6-9

Diagnosis.—*Caribachlamys* with 30 or fewer ribs at 30 mm Ht, without clear clustering of ribs on RV or ordering on LV; scales on ribs open and concave on their ventral sides, not closed and knobby.

Description.—Shell reaching *ca.* 45 mm Ht, height exceeding length, umbonal angle narrow, ranging from *ca.* 83° in submature specimens to somewhat over 90° in largest specimens, acline to slightly prosocline, convexity moderate with RV slightly more convex than LV, disk gapes absent. Disks with radial ribs originating < 1 mm from beak on LV, increasing in number throughout ontogeny by branching on sides of ribs on RV and by intercalation near edges of rib interspaces on LV, 16-19 ribs at 5 mm Ht, 23-30 mm by 30 mm Ht, with higher numbers at greater shell heights; primary ribs equal to or narrower than interspaces, with rounded crests and steep sides; all ribs bearing wide, strongly projecting, distally inclined, distally concave scales. Antimarginal or diagonal microstructure in interspaces in early ontogeny; commarginal lamellae weakly developed in early ontogeny, absent later. Disk flanks moderately high and rounded on LV, much steeper or even slightly inturned on RV, commonly lacking radial costellae. Auricles very unequal, anterior slightly more than twice length of posterior; right anterior auricle with 4 or 5 strong scabrous radial costae, broad byssal fasciole, deep byssal

notch, and active ctenolium; left anterior auricle with anterior margin concave ventrally, slightly convex dorsally, with overall trend forming acute angle of 60° with dorsal margin, with 3 or 4 moderately strong, scabrous radial costae in dorsal half, fainter costae in ventral half; posterior auricles with posterior margin nearly straight in ventral part, becoming slightly concave in dorsal part before intersecting dorsal margin, overall trend of margin forming obtuse angle of *ca.* 134° with dorsal margin, surface with 4 or 5 costae of uneven strength, strongest along dorsal margin; total hl slightly greater than ½ L. Hinge dentition as in *Chlamys*, with moderately strong dorsal and infradorsal teeth and weak resilial teeth. Ribs on interior of shell lacking carinate edges near shell margin. Muscle scars and extent of foliated-calcite re-entry on shell interior not accessible or not preserved.

Etymology.—Named after the town of Guayubín, Province of Monte Christi, northern Dominican Republic.

Type material.—Holotype, USNM 540944, 1 LV, 38 mm Ht (restored), 34.0 mm L (Pl. 2, Fig. 7).

Type locality.—TU 1438, Mao Adentro Limestone Member?, Mao Formation, road cut 0.5 km south of bridge at Guayubín, on road to Sabaneta, northern Dominican Republic.

Other material.—Paratypes: 3 RV, 2 LV, from the type locality, TU 1438; TU 1281, one partial LV; TU 1245, one partial LV, all from the "Mao Adentro Limestone" in the Guayubín area.

Remarks.—All of the specimens of *Caribachlamys guayubinensis* n. sp. are associated with a somewhat chalky, white, bioclastic limestone showing evidence of dissolution of aragonitic components, including branching corals. It is unclear whether the limestones exposed at the northwestern end of the Samba (or Zamba) Hills in the vicinity of Guayubín (localities TU 1245, 1281, 1438) should be assigned to the Mao Adentro Limestone, the type locality for which is on the Río Mao (Vaughan in Vaughan *et al.,* 1921: 73). H. Vokes (1989: 123), referring to these limestones at locality TU 1281 near Guayubín, remarked that they represent a "back-reef and/or lagoonal facies" and that although their assignment to the Mao Adentro Limestone is debatable, they are "the source of the material in the Mal Adentro gravity flows," that is the true Mao Adentro Limestone on the Río Mao. Saunders *et al.* (1986: 38) emphasized that they had no direct evidence for the age of the true Mao Adentro Limestone.

The presence in the Guayubín area of three species, *Caribachlamys guayubinensis* n. sp., *Mimachlamys vokesorum* n. sp., and *Argopecten ameleus*, that are unknown in other shallow-water facies of the Cibao Valley suggests that the Guayubín limestones are younger than these other facies. This is supported by the occurrence of *A. ameleus*, a species described from the Bowden Formation (Bowden shell bed) of Jamaica, which is now regarded as late Middle Pliocene in age (Kohl & Robinson, 1998), and by the presence of *C. guayubinensis* n. sp., the closest relatives of which are Late Pliocene to Recent species.

One of the main diagnostic features of the genus *Caribachlamys* reported by Waller (1993: 217) is the presence of a lecithotrophic-type prodissoconch in which the PI stage is large and the PII stage short or absent. None of the seven specimens of *C. guayubinensis* n. sp. has the prodissoconch preserved, but these specimens are placed in *Caribachlamys* based on their rib pattern, scale development, and microsculpture.

Comparisons.—Among the known species of *Caribachlamys* (Waller, 1993), *C. guayubinensis* n. sp. is closest to *C. mildredae* (Bayer, 1941), an extant species known from southeastern Florida (Waller, 1993: 225, figs 9c-e). Unlike that species, *C. guayubinensis* n. sp. lacks the clear clustering of ribs on the right valve and multiple ordering of ribs on the left valve and has fewer ribs at a comparable size (25-30 at 30 mm Ht, compared to 35-40 in *C. mildredae*).

Evolution.—The occurrence of *Caribachlamys guayubinensis* n. sp. within a limited geographic area in limestones that could all be of approximately the same age does not allow recognition of any stratigraphic trends within the Dominican Republic. However, *C. guayubinensis* n. sp. might be an early member of a clade that contains the extant species *C. mildredae* and *C. imbricata* (Gmelin, 1791). These extant species share three characters not found or scarcely developed in *C. guayubinensis* n. sp.; rib clustering (on right valve), rib ordering (on left valve), and a tendency to develop knobby closed scales, the last feature being well developed in *C. imbricata*.

Occurrence and distribution.—Known only from the "Mao Adentro Limestone" of the Guayubín area, northern Dominican Republic.

Caribachlamys jungi n. sp.
Pl. 2, Figs 1-5

Diagnosis.—*Caribachlamys* with *ca.* 60 closely spaced, rounded, minutely scaled radial costae on disks.

Description.—Shell small, not known to exceed 15 mm Ht, height exceeding length in ratio of 1.12:1, umbonal angle

moderately narrow, *ca.* 95°, prosocline, of moderate convexity with LV slightly more convex than RV, lacking disk gapes. Disks with numerous closely spaced radial costae varying in width and not clustered; costae beginning at 0.9 mm from beak, initially 11 or 12 in number, then increasing rapidly to 35-40 at 5 mm Ht and *ca.* 60 by 10 mm Ht; mode of increase initially by intercalation on both valves, later by intercalation throughout ontogeny of LV and initially by intercalation and later by branching on RV; costae rounded, bearing small distally concave scales that are more strongly developed at sides of disk than in central part; interspaces bearing strong antimarginal microsculpture, most strongly developed at sides of disk and on disk flanks; regular commarginal lamellae absent; disk flanks costate, with costae merging with those of auricles on left anterior and both posterior sides. Auricles very unequal, anterior outer ligament groove twice the length of posterior outer ligament groove; right anterior auricle with 7 radial costae crossed by imbricated commarginal lamellae, bordered ventrally by broad, commarginally rugose byssal fasciole; byssal notch deep with rounded apex, floored by active ctenolium having 3 or 4 strong teeth, anterior margin broadly rounded; left anterior auricle with sigmoidal margin and shallow byssal sinus, overall trend of margin forming acute angle with dorsal margin, bearing 15-17 closely spaced, scabrous radial costae that transition to costae of anterior disk flank; posterior auricles with 5 or 7 somewhat weaker scabrous costellae, posterior margins of posterior auricles slightly outwardly convex to nearly straight, forming obtuse angle with dorsal margin. Hinge dentition as in *Chlamys*, with strong dorsal and resilial teeth on RV and corresponding sockets on LV. Ribs on interior of shell lacking carinate edges near shell margin. Adductor scars not well preserved and shapes not determined. Foliated-calcite re-entry lacking, umbonal areas of disk interiors entirely aragonitic. Prodissoconchs not preserved.

Etymology.—Named in honor of Dr. Peter Jung of Basel, Switzerland, one of the founders of the Dominican Republic Project, who patiently sorted tens of thousands of macrofossils and entrusted the study of selected groups to taxonomic specialists.

Type material.—Holotype, NMB G17495, 1 LV, 14.5 mm Ht, 13.0 mm L (Pl. 2, Figs 1-2).

Type locality.—NMB 16934 (= NMB 15855), left bank of Río Gurabo *ca.* 1.5 km upstream from crossing of the old road running from Sabaneta to Los Quemados, lower Gurabo Formation, *ca.* 274-277 m above base of section (Saunders *et al.*, 1986: 62, text-fig. 4), Upper Miocene.

Other material.—Paratype (Pl. 2, Figs 3-5), 1 RV, USNM 540948, from locality TU 1215 (= USGS 8539-8543), "Río Gurabo, bluffs on both sides, from the ford on the Los Quemados-Sabaneta road upstream to approximately 1 km above the ford (= USGS 8539-8543; Maury's Zone D)" (Saunders *et al.*, 1986: 64). Text-fig. 4 of Saunders *et al.* (1986) indicates that this site ranges from *ca.* 275-384 m above the base of the section, in the Upper Miocene part of the Gurabo Formation.

Remarks.—The two specimens of *Caribachlamys jungi* n. sp. are almost the same size and have anterior and posterior hinge lines of identical length, suggesting that they could be matching valves, even though one was collected by the NMB team and the other by the Vokeses. This, however, is not the case in that growth disturbances on the right valve are not reflected on the left valve. As with *C. guayubinensis* n. sp., the prodissoconchs of *C. jungi* n. sp. are not preserved, and placement in the genus *Caribachlamys* is based on rib pattern, scale development, and microsculpture.

At the type locality (NMB 16934 = NMB 15855), the only pectinid found in association with *Caribachlamys jungi* n. sp. is *Nodipecten colinensis vokesae*. At the other locality (TU 1215), there is a much richer assemblage of associated pectinids (*Argopecten thetidis*, *Lindapecten paramuscosus*, *Antillipecten quemadosensis* n. sp., and *Amusium papyraceum* Morphotype C), possibly reflecting the greater spatial and stratigraphic span of this locality. Saunders *et al.* (1986: 54) commented that at NMB 15855, the fossils are "scattered in silts and coral rubble around huge, partly inverted coral heads." For locality TU 1215, E. Vokes (1989: 16) referred to the outcrop as consisting of "alternating layers of branching coral masses and green shale" rich in muricid gastropods. She interpreted this as a coralline facies of the Gurabo Formation representing depths of 20-50 m. The associated pectinids suggest the deeper end of this range or deeper, with the corals having been tumbled downslope into fine sediments.

Comparisons.—Among the known species of *Caribachlamys* (Waller, 1993), *C. jungi* n. sp. is closest to the Recent species *C. sentis* (Reeve, 1853) of the tropical and subtropical western Atlantic, Gulf of Mexico, and Caribbean (Waller, 1993: 217). *Caribachlamys sentis* of comparable size to the new species differs in having a narrower umbonal angle that is < 90°, fewer and stronger radial costae with larger scales that extend across the rib crests, and a relatively larger left anterior auricle with a straighter anterior margin that forms a sharper angle with the dorsal margin. *Caribachlamys paucirama* Waller, 1993, from the Middle and Upper Pliocene and Lower Pleistocene of Florida, resembles *C. jungi* n. sp. in the shape of its left anterior auricle, but differs in having an umbonal angle of < 90°, fewer costae that are separated near the margin by inter-

spaces as wide or wider than the costae, and relatively broader scales that extend across the rib crests. *Caribachlamys jungi* n. sp. superficially resembles species in the genus *Spathochlamys* Waller, 1993, but unlike that genus, its scales are concave in the direction of shell growth, rib interspaces lack commarginal lirae, there are no regular medial costellae, and the edges of ribs on the inner surface near the margin lack carinate edges.

Evolution.—Waller (1993) reviewed the fossil record of *Caribachlamys*, which at that writing extended only as far back as the Pliocene. *Caribachlamys jungi* n. sp., from the Upper Miocene part of the Gurabo Formation, is therefore the oldest known species in the genus. It might have given rise to *C. sentis*, the stem species of the genus as depicted in the phylogeny of Waller (1993: fig. 8).

Occurrence and distribution.—Known only from the lower part of the Gurabo Formation, of Late Miocene age, on the Río Gurabo, northern Dominican Republic.

Tribe **MIMACHLAMYDINI** Waller, 1993

Genus ***INTERCHLAMYS*** n. gen.

Type species.—Pecten interlineatus Gabb, 1873, Pliocene, Dominican Republic.

Diagnosis.—Mimachlamydini of *Aequipecten*-like shape, height and length approximately equal, length of anterior auricle approximately equal to or greater than length of posterior auricle. Primary radial ribs of disks strong and persistent in central sector of disk but decreasing in amplitude and width adjacent to disk flanks; primary ribs originating after early smooth zone on which microsculpture is reduced or absent; commarginal lamellae tending to be prominent and thickened, forming distally concave loops over rib crests and distally convex loops in interspaces, reflecting dentate valve margin. Hinge dentition of RV dominated by single dorsal tooth on each side of resilifer; intermediate teeth absent; resilial teeth poorly developed.

Etymology.—The prefix *inter* refers to the medial costa that nearly fills rib interspaces of the type species; the suffix *chlamys* refers to the pectinid genus *Chlamys* Röding, 1798.

Remarks.—Interchlamys n. gen. includes two groups of species that differ greatly in maximum size. The group with species of smaller size (< 50 mm Ht) is represented by *Pecten interlineatus* Gabb, 1873, from limestones of probable mid-Pliocene age in the Mao Formation of the Dominican Republic and *Pecten* (*Aequipecten*) *jacobianus* Cooke, 1919, from the Pliocene La Cruz Formation of the Santiago area, southeastern Cuba. The group containing species of larger size (commonly exceeding 70 mm Ht) is represented by four nominal taxa: (a) *Pecten interlineatus aidei* Harris in Hodson *et al.*, 1927, from the Pliocene of Venezuela; (b) *Pecten (Lyropecten*) *tamiamiensis* Mansfield, 1932, from the Pliocene of southern Florida; (c) *Pecten mediacostatus mediacostatus* Hanna, 1926, from the Miocene? and Pliocene of southern California and Baja California, Mexico (Moore, 1984: B29); and (d) *Chlamys mediacostata grewingki* Hertlein, 1966, from the Pliocene of Baja California. All of these species share a similar early ontogeny of external sculpture, namely an umbonal smooth zone that in the unweathered state is glossy and nearly devoid of microsculpture, with radial ribs beginning to form as very low undulations within this zone. All of the species in the second group have in common the presence of a single medial riblet in rib interspaces that appears early in ontogeny, only slightly later than the radial ribs. A medial riblet is also present in all of the species that comprise the genus *Spathochlamys*, but these species lack the early umbonal smooth zone. Instead the early ontogeny of *Spathochlamys* is like that in *Mimachlamys* Iredale, 1929, with a clearly pitted microsculpture on the left beak and an earlier appearance of primary radial ribs.

In the Dominican Republic, only the two species of the first group of *Interchlamys* n. gen. are present, *I. jacobiana* and *I. interlineata*, both associated with coral-bearing limestones. *Interchlamys jacobiana* is the stratigraphically lower species, occurring at NMB 17277 on the Río Yaque del Norte near the base of the limestones that form Angostura Gorge. These basal limestones have not been precisely dated, but they are apparently no older than Late Miocene (based on ostracodes lower in the section that indicate a Late Miocene age), and they are no younger than the Miocene-Pliocene boundary, which occurs near the top of the limestone section (Saunders *et al.*, 1986: 30, table 3). *Interchlamys interlineata* occurs in the stratigraphically higher limestones of probable mid-Pliocene age in the Guayubín area (Saunders *et al.*, 1986: table 3).

The same pair of species of *Interchlamys* n. gen. occurs in southeastern Cuba in the Santiago de Cuba area, described by Cooke (1919) as *Pecten* (*Aequipecten*) *jacobianus* and *Pecten* (*Plagioctenium*) *crucianus*, the latter regarded herein as a junior synonym of *I. interlineata*. The relative stratigraphic positions of the Cuban specimens, however, cannot be determined from the original locality data given by Cooke (1919). Both of Cooke's species share the same type locality (USGS 3440), the description for which is "northeast portion of Santiago; fossils in marl on hillside; Oligocene." All occurrences of both species in Cuba are within the broad area of exposure of the La Cruz Formation. Bold (1975: 131) regarded this formation to be Pliocene or younger based on the presence of the ostracode, *Radimella confragosa* (Edwards, 1944). Later stud-

ies, however, extended the first appearance of this taxon into the Upper Miocene (Bold, 1988: 7; Saunders *et al.*, 1986: 23). The species of the second group on the eastern side of the Americas are concentrated in Middle and Upper Pliocene formations, *Interchlamys aidei* mainly on the Paraguaná and Araya Peninsulas of Venezuela, and *I. tamiamiensis* in the Tamiami and Pinecrest formations of Florida.

Interchlamys n. gen. probably evolved from *Mimachlamys* by becoming more aequipectinoid in shape, *i.e.*, becoming more equilateral, with a broader umbonal angle and auricles of more equal length, and developing stronger carinae on the edges of plicae on the inner shell surface. Clues to an origin within the Mimachlamydini are provided by traces of antimarginal striae at the margins of the umbonal smooth zone as well as in early rib interspaces in *I. jacobiana* and *I. interlineata*. Based on exceptionally well-preserved specimens, no trace of this microsculpture remains on the early smooth zones of *I. tamiamiensis*. It also seems to be absent on *I. aidei*, although the specimens of this species that are available are not exceptionally well preserved, and abrasion might have removed the striae. Additionally, the low, trigonal to rounded ribs and narrow interspaces of species of *Interchlamys* n. gen. are approached by some species of *Mimachlamys*, an example being *M. vokesorum* n. sp., which co-occurs with *I. interlineata* in the Pliocene "Mao Adentro Limestone" in the Guayubín area of the Dominican Republic.

Although more material is needed to assess evolutionary change in *Interchlamys* n. gen. within the Dominican Republic, there is a suggestion of such change in the material on hand. The succession begins with *I. jacobiana* of the late Miocene of the Dominican Republic, which lacks medial costae in rib interspaces (Pl. 2, Fig. 16). In *I. jacobiana* from the somewhat younger Pliocene La Cruz Formation of Cuba, the overall morphology is similar but medial costae are variably developed (Pl. 2, Figs 14-16). *Interchlamys interlineata* is the most derived in the sense that it develops scales and has consistent medial costae in interspaces as well as a more complex pattern of secondary radial costae in late ontogeny (Pl. 2, Figs 10, 13). Evolution in the second group of *Interchlamys* n. gen. probably occurred independently of the first group after branching off from a common ancestor, because there seems to be broad temporal overlap between the two groups.

Geographic range.—Tropical and subtropical western Atlantic and eastern Pacific, southern Florida, Cuba, Dominican Republic, Venezuela, southern California, and Baja California, Mexico.

Stratigraphic range.—Upper Miocene?, Pliocene.

Interchlamys interlineata (Gabb, 1873)
Pl. 2, Figs 10-13

Pecten interlineatus Gabb, 1873: 256; Pilsbry, 1922: 411, pl. 45, fig. 3.

Pecten (*Chlamys*) *interlineatus* Gabb. Dall, 1898: 716; not Tucker & Wilson, 1932: 5, pl. 4, fig. 7 (= *Pecten interlineatus aidei* Harris in Hodson *et al.*, 1927).

Pecten (*Plagioctenium*) *gabbi* Dall, 1898: 717, pl. 29, fig. 3; Maury, 1917a: 187; not Cooke, 1919: 140, pl. 12, fig. 8 (= undetermined genus and species).

Pecten (*Plagioctenium*) *crucianus* Cooke, 1919: 139, pl. 10, figs 8, 9a-b.

Chlamys (*Lyropecten*) *interlineatus* (Gabb). Tucker-Rowland, 1938: 26, in part (pl. 5, fig. 18), not pl. 5, fig. 5 (= *Pecten interlineatus aidei* Harris in Hodson *et al.*, 1927).

Chlamys cruciana (Cooke). Mongin, 1968: 483, pl. 41, fig. 3; de Huelbes, 1988: 31, figs 8-10.

Original description.—"Shell slightly convex, nearly equilateral, base and sides evenly rounded; ears large, radiately ribbed; surface marked by *ca.* eighteen round or sub-angulated ribs, with a single small line in each interspace. Length 1 inch" (Gabb, 1873: 256).

Description.—Shell reaching 47 mm Ht, length and height approximately equal throughout ontogeny, slightly prosocline with posterior slightly more extended from midline than anterior, equiconvex with convexity of closed, articulated shell *ca.* 20-30% of Ht, disk gapes absent. Disks with 17-21 radial plicae, most commonly 18 or 19, on LV originating at *ca.* 4 mm Ht after early pre-radial stage bearing coarse antimarginal striae; ribs broader than interspaces and rounded in profile in early ontogeny but becoming trigonal, with narrow crest and sloping flanks; single scabrous costa present on narrow rib crests beginning in mid-ontogeny with additional secondary costae forming on rib flanks and on either side of medial costae near margin; single scabrous medial costa forming in rib interspaces early in ontogeny. Commarginal lamellae looping ventrally across crests of secondary costae, forming distally pointing blunt scales, with scales more prominent on lateral ribs and interspaces. Disk flanks low but steep, all but the right anterior flank bearing fine scabrous costellae. Auricles small relative to size of disk, total hl *ca.* 50-60% L, ahl slightly longer than phl. Right anterior auricle with 4 or 5 strong, scabrous costae and deep byssal notch with active ctenolium; other auricles with more numerous, finer costae; anterior margin of left anterior auricle sigmoidal, with shallow byssal sinus, overall trend forming acute angle with dorsal margin; posterior margins of posterior auricles nearly straight, forming obtuse angle of *ca.* 112-116° with dorsal margin. Hinge denti-

tion of RV dominated by strong dorsal tooth on each side of resilifer, bordered dorsally by deep groove for outer ligament. Internal plicae with carinate edges near shell margin. Muscle scars and extent of internal shell layers not accessible.

Type material.—Holotype, ANSP 2846, an articulated shell illustrated by Pilsbry (1922: pl. 45, fig. 3), 24.7 mm Ht, 23 mm L.

Type locality.—Dominican Republic. Although Gabb (1873) did not furnish locality data other than "Santo Domingo," the type specimen possibly came from the vicinity of locality TU 1245, a road cut in the Mao Adentro Limestone, just south of the bridge at Guayubín, on the road to Sabaneta, northern Dominican Republic, where the species is abundant and well preserved. H. & E. Vokes (1992: 12) remarked that locality TU 1245 is almost certainly an area visited by Gabb, because the geology conforms closely to Gabb's description.

Other material.—Northern Dominican Republic, Mao Adentro Limestone: TU 1245 (the designated type locality), 17 articulated DV, 1 RV; TU 1438, road cut 0.5 km south of bridge at Guayubín, on road to Sabaneta, 3 RV, 2 LV; USGS 8724, Gurabo hills, province of Santiago, *ca.* 2 mi northeast from Santiago near rock-crushing site for road metal, 1 RV. Southeastern Cuba, La Cruz Formation, Pliocene: USGS 3439, Jurauga railroad road cut, La Cruz, 1 LV; USGS 3440, northeastern portion of Santiago, marl on hillside, 1 LV [holotype of *Pecten* (*Plagioctenium*) *crucianus* Cooke, 1919]; USGS 3441, east of La Cruz, near railroad crossing of road to Morro Castle, 1articulated DV(paratype of *P. crucianus*).

Remarks.—The presence of almost all articulated shells filled with fine lime mud at TU 1245 suggests that these specimens were buried alive, perhaps as a result of a storm that moved them off of a shallow, coral-rich carbonate bank or patch reef into much finer sediment, such as might be expected in a backreef lagoon. The presence of numerous small, solitary serpulid worm tubes and occasional immature scleractinian corals and oysters attached to either valve suggests that burial was not rapid, and that the dead articulated shells served as a substratum within the photic zone, probably in very shallow water. The articulated shell of *Pecten crucianus* from Cuba, regarded as a junior synonym of *Interchlamys interlineata*, has a similar association of matrix and epifauna. De Huelbes (1988: 31), in his study of *Chlamys cruciana* (= *I. interlineata*), reported that 42 of the 103 specimens from the La Cruz Formation were articulated.

Comparisons.—*Interchlamys interlineata* differs from *I. jacobiana* in having higher ribs and a medial costa in interspaces. *Interchlamys aidei*, although having a medial costa filling rib interspaces, has rounded rather than trigonal ribs and lacks pointed scales atop secondary costae. (See also the preceding section on the genus *Interchlamys* n. gen.) *Dimarzipecten crocus* (Cooke, 1919), of the late Early to early Middle Miocene Anguilla Formation of Anguilla, has a medial costa in interspaces that begins much later than in *I. interlineata.* Furthermore, *D. crocus* is chlamydiform, with a narrow umbonal angle and asymmetric auricles, and has a coarse oblique antimarginal microsculpture that is prominent in rib interspaces and on disk flanks in early ontogeny. Although *I. interlineata* superficially resembles large specimens of *Spathochlamys vaginula*, the former species is more equilateral than the latter. The radial ribs of all *Spathochlamys* species begin abruptly much closer to the beak than in *Interchlamys* n. gen.

Evolution.—See remarks for the genus *Interchlamys* n. gen.

Occurrence.—In the Dominican Republic, *Interchlamys interlineata* is known only from the Mao Adentro Limestone Member of the Mao Formation, Pliocene.

Distribution.—Outside of the Dominican Republic, *Interchlamys interlineata* has been reported from the La Cruz Formation in the vicinity of Santiago de Cuba (Cooke, 1919; de Huelbes, 1988) and an unnamed formation of probable Pliocene age in Guadeloupe (Mongin, 1968).

Interchlamys jacobiana (Cooke, 1919)
Pl. 2, Figs 14-17

Pecten (*Aequipecten*) *jacobianus* Cooke, 1919: 139, pl. 11, figs 7a-b, 8.

Original description.—"Shell equivalve, slightly oblique, moderately convex, with *ca.* 16 low, broad, radiating medial ribs and several additional obsolete distal [lateral] ribs; additional radial sculpture of raised threads, usually one on summit and one or more on each side of every rib and one or two in the interspaces, increasing in number by interpolation toward the periphery; concentric sculpture of low, wavy lamellae, crossing ribs, threads, and interspaces; *Camptonectes* striation present; posterior ears oblique, with faint radiating threads crossed by fine lamellae; anterior ears the larger, with coarser threads; byssal notch *ca.* one-half the length of the ear; ctenolium present; inner margin grooved in accordance with the external ribbing, but grooves do not extend over the medial portion of the disk" (Cooke, 1919: 139).

Description.—Shell not known to exceed 38 mm Ht, height

exceeding length through most of ontogeny, becoming equal to length in largest specimens, equilateral and equiconvex with convexity of closed, articulated shell *ca.* 25-30% of Ht; disk gapes absent; disks with 18-19 radial ribs originating gradually in early ontogeny after smooth zone marked by widely spaced antimarginal striae; ribs in central sector low and trigonal, with central keel, bordered by rib flanks that slope at low angle to very narrow interspace; edges of rib flanks becoming slightly raised adjacent to interspace or giving rise to secondary radial costae so that two costae occupy interspace separated by narrow central intercostal space; rarely with single medial costa in some but not all rib interspaces; additional secondary costae on rib crests near margin of large individuals; lateral ribs very low to obsolete, these areas then dominated by secondary costae. Commarginal lamellae prominent, looping proximally over rib crests and distally over interspaces, absent over central keels of rib crests, not forming distinct spines. Disk flanks low and rounded, all but right anterior flank having scabrous radial costellae. Auricles small relative to size of disk, total hl *ca.* 60% of L, ahl longer than phl; right anterior auricle with 4 or 5 strong, scabrous costae and deep byssal notch with active ctenolium; other auricles with more numerous very fine costae, tending to become obsolete on posterior auricles; anterior margin of left anterior auricle sigmoidal, with shallow byssal sinus and overall trend of anterior margin forming acute angle with dorsal margin; posterior margins of posterior auricles outwardly slightly convex, forming obtuse angle with dorsal margin of *ca.* 110°. Right hinge dentition dominated by dorsal teeth, resilial teeth poorly developed; internal plicae with carinated edges near shell margin; muscle scars and extent of internal shell layers not accessible.

Holotype and measurements.—Holotype, USNM 167115, 1 articulated DV, 28.5 mm Ht, 26.7 mm L (Cooke, 1919: pl. 11, figs 7a-b; Pl. 2, Figs 14-16).

Type locality.—USGS 3440, northeastern portion of Santiago, Cuba; fossils on hillside (Cooke, 1919: 109), La Cruz Formation, Pliocene.

Other material.—Dominican Republic: Gurabo Formation, late Miocene, locality NMB 17277, Río Yaque del Norte, southern end of Angostura Gorge, in "dense coral carpet of thinly branched poritids near top. Massive coral heads below (*Siderastrea*, *Porites* and large *Coscinaraea* up to 60 cm diameter) with large branching *Montastrea*. Most corals in living position." (Saunders *et al.*, 1986: text-fig. 27): 2 DV, 3 RV, 2 LV.

Cuba: La Cruz Formation, Pliocene: USNM 167116 (USGS 3436), southern side of Santiago, Cuba, along trocha [trail] in small escarpment separating Terrace I from Terrace 2 of coastal shelf, 20-ft level, 2 RV, 3 LV; USNM 167110 (USGS 3446), first deep cutting on railroad east of La Cruz, near Santiago, Oriente Province, 2 RV, 3 LV; USGS 3440 (type locality), 5 DV; USGS 3443, northeastern portion of Santiago, marls at foot of hill, 1 LV; USGS 3447, Trocha de Santiago de Cuba, Oriente Province, second exposure on northern side of trocha [trail] east from waterfront, stratum 3 (Cooke, 1919: 109), 1 DV, 1 LV.

Puerto Rico: USGS 21911, Urbano Magueyes, Peñueles quadrangle, Puerto Rico meter grid coordinates 20900N, 131000E, Ponce Limestone, 1 RV, 2 LV, associated with *Leopecten gatunensis* and therefore assumed to be of Late Miocene age.

Remarks.—The age of the occurrence of *Interchlamys jacobiana* in the Dominican Republic along the Río Yaque del Norte (NMB 17277) has not been precisely determined, although it is clearly stratigraphically lower than the occurrence of *I. interlineata* at the opposite (downstream) end of Angostura Gorge. The nearest age determination stratigraphically below NMB 17277 is at NMB 17316, said to be late Miocene on the basis of ostracodes determined by Bold (in Saunders *et al.*, 1986: 30), but there is no dating information between this locality and the upper end of the gorge, which is thought to be near the Miocene-Pliocene boundary (Saunders *et al.*, 1986: 30). It would appear, then, that NMB 17277 is late Miocene (Messinian) in age.

In Cuba, *Interchlamys jacobiana* has the same type locality (USGS 3440) as *I. cruciana*, the latter regarded herein as a junior synonym of *I. interlineata*. The vague data for this locality (see above), however, leaves room for the possibility that in Cuba, as in the Dominican Republic, *I. jacobiana* could stratigraphically underlie *I. interlineata*.

The occurrence in the Ponce Limestone of southern Puerto Rico is reported for the first time. Although many paleontologists have regarded the age of the Ponce to be Miocene, they have disagreed as to which part of the Miocene (Monroe, 1980: 82). Bold (1969) concluded that the formation is latest Miocene in age on the basis of ostracodes.

Comparison.—Compared to *Interchlamys interlineata, I. jacobiana* has radial sculpture of lower relief, especially on the lateral sides of the disks adjacent to the disk flanks, and its rib interspaces commonly have a secondary costa on each side of a very narrow, central trough. Single medial costae are not consistently present, even on the same valve, and are commonly offset to one side. Distally pointing scales are well developed in *I. interlineata* but not in *I. jacobiana*.

Evolution.—See remarks for the genus *Interchlamys* n. gen.

Occurrence.—In the Dominican Republic, *Interchlamys jacobiana* is known only from near the basal part of the Mao Adentro Limestone Member of the Mao Formation, of probable latest Miocene age.

Distribution.—Outside of the Dominican Republic, *Interchlamys jacobiana* is known from southeastern Cuba in the vicinity of Santiago and La Cruz, Oriente Province, La Cruz Formation, of probable Pliocene age (Bold, 1975: 131; see also Remarks above). The species has also been identified from the lower member of the Ponce Formation in southern Puerto Rico.

Genus ***MIMACHLAMYS*** Iredale, 1929

Mimachlamys Iredale, 1929: 163.

Type species.—Pecten asperrimus Lamarck, 1819, by original designation.

Original diagnosis.—"In *Mimachlamys* the valves are both convex, but the left valve is more convex than the right, the auricles are unequal, the posterior being much smaller than the anterior. The byssal gape is deep and very strong, pectinidial teeth are present, a deeply furrowed fasciole occurring. The sculpture consists of closely scaled numerous radials flanked with subsidiary more delicate riblets, a deep gutter intervening between each group, which becomes filled up with such riblets as maturity is reached. The prodissoconch is smooth, with concentric growth lines, the succeeding sculpture being plain riblets with scratched intervals, the scales developing later. The sculpture on the two valves does not differ appreciably in design." (Iredale, 1929: 163).

Emended diagnosis.—Mimachlamydini with rib interspaces lacking commarginal lamellae, having instead divaricating, diagonal, or herringbone antimarginal microsculpture; rib crests smooth between scales. Primary ribs continuous from early dissoconch, with only minor intercalation or branching in early ontogeny; scaly secondary costae commonly present on ribs and interspaces.

Remarks.—The greatest species diversity of *Mimachlamys* in present-day oceans is in the western Pacific and Indian Oceans, there being only one species, *M. varia* (Linnaeus, 1758), occurring in the warm-temperate to cool-temperate regions of the eastern Atlantic (Waller, 1991: 30; 1993: 228). The two new species described below from the late Miocene and early Pliocene of the Dominican Republic and *M. landi* (Cooke, 1921) from the Pliocene La Cruz Formation of Cuba are the only known representatives of *Mimachlamys* thus far recognized in the tropical western Atlantic region. The genus apparently became extinct in this region in the Pliocene.

Geographic range.—In present-day seas, limited to tropical to cool-temperate eastern Atlantic and western Indo-Pacific, living offshore to mid-continental shelf depths.

Stratigraphic range.—Eocene to Recent in eastern Atlantic and Indo-Pacific regions; upper Miocene and Pliocene in the tropical western Atlantic.

Mimachlamys blowi n. sp.
Pl. 3, Figs 1-5

Diagnosis.—Mimachlamys with 23-26 simple rounded ribs bearing widely spaced, distally concave scales; secondary costae absent; posterior auricles much smaller than anterior, with posterior auricular margins forming obtuse angle of *ca.* 130º with dorsal margin.

Description.—Shell reaching *ca.* 50 mm Ht, height exceeding length, prosocline, convexity moderate with LV more convex than RV, disk gapes absent; disks with 23-26 simple radial ribs, all originating by *ca.* 2.5 mm Ht from beak; secondary costae absent; ribs nearly semicircular in profile in early ontogeny, becoming rounded-trigonal in late ontogeny, broader than interspaces on both valves; scales on ribs widely and irregularly spaced, distally concave. Divaricating to diagonal antimarginal microsculpture present in rib interspaces, ending abruptly at bases of rib flanks; ribs lacking microsculpture except for very fine growth lines that pass straight across ribs but form ventrally convex arcs across rib interspaces; raised commarginal lamellae absent. Disk flanks low and steep on RV, anterior flank smooth, posterior flank with few scabrous costellae; disk flanks of LV higher, both bearing scabrous costellae. Posterior auricles only approximately half length of anterior; posterior auricular margins nearly straight, intersecting posterior dorsal margin of auricle at obtuse angle of *ca.* 130º; total hl approximately half L. Right anterior auricle with 5 strong radial costae bearing blunt scales, broad byssal fasciole, and deep byssal notch floored by strong active ctenolium; left anterior auricle with nearly straight anterior margin forming acute angle with dorsal margin and 10 radial costae of moderate strength bearing delicate, distally concave scales; posterior auricles with 4 or 5 weaker costae and more delicate scales. Hinge dentition and muscle scars not accessible; ribs on shell interior near margin rounded, without internal carinae.

Etymology.—Named in honor of the late Warren C. Blow, a dedicated paleontologist who was my assistant for 32 years.

Type material.—Holotype, NMB G17497, 1 RV, 41.0 mm Ht, 38.0 mm L (Pl. 3, Fig. 5).

Type locality.—Locality NMB 15893, Cercado Formation, *ca.* 150 m above base of section on Río Gurabo, northern Dominican Republic, as plotted by Saunders *et al.* (1986: text-fig. 4), associated with poritid corals in a fine gray silt disconformably overlain by a massive conglomerate regarded by Saunders *et al.* as the base of the Gurabo Formation.

Other material.—NMB G17498, a pair of offset valves, the RV incomplete, from the type locality, NMB 15893 (Pl. 3, Figs 1-4).

Remarks.—The specimens of *Mimachlamys blowi* n. sp. are associated with a fine gray silt containing fragments of finely branched poritid corals in a chaotic arrangement. The *Mimachlamys* specimens appear to be originally paired valves that have become offset and distorted, perhaps due to syndepositional movement as would be expected in soft sediment in a submarine slump. This is precisely the depositional setting of the basal part of the much younger Mao Formation that yielded *M. vokesorum*, n. sp. (see below).

Comparisons.—Mimachlamys blowi n. sp. closely resembles only *M. vokesorum* n. sp., a new species described below from the Mao Adentro Limestone Member of the Mao Formation. Compared to the Mao species, *M. blowi* n. sp. has narrower, higher ribs that are less trigonal in profile, a narrower umbonal angle, and less obtuse angles between posterior auricular margins and dorsal margin. Also, unlike *M. vokesorum* n. sp., *M. blowi* n. sp. lacks secondary costae along the bases of rib flanks. *Mimachlamys landi* from the La Cruz Formation, Pliocene, of Cuba has similar scaly ribs and interspace microsculpture but differs in that its ribs are more numerous (>30), finer, and more rounded in profile without any hint of trigonality.

Evolution.—Because there are no similar *Mimachlamys* species known from older deposits in the tropical American region, it is not possible to infer when and where *M. blowi* n. sp. originated. Based on close morphological resemblance and stratigraphic position, *M. blowi* n. sp. is probably ancestral to *M. vokesorum* n. sp. If so, then the more obtuse posterior auricles, broader ribs, and more flaring shape of the latter species represent evolutionary changes, perhaps related to the evolution of greater mobility for predator avoidance or for avoiding local transient environmental changes. The very similar depositional settings of the two species suggest similar habitats,

Occurrence and distribution.—Known only from the type locality in the northern Dominican Republic.

Mimachlamys vokesorum n. sp.
Pl. 3, Figs 6-9

Diagnosis.—Mimachlamys with 22 or 23 simple, broad trigonal ribs much broader than interspaces and bearing small distally concave scales; secondary costae appearing in late ontogeny along bases of lateral ribs facing center of shell; posterior auricles much smaller than anterior and with posterior auricular margins forming obtuse angle of *ca.* 140º with dorsal margin.

Description.—Shell 52 mm Ht, height slightly exceeding length, strongly prosocline, biconvexity moderate with LV slightly more convex than RV, disk gapes absent. Disks with 22 or 23 primary ribs originating by 4 mm Ht from beak, rib profiles rounded-trigonal in early ontogeny, becoming more distinctly trigonal and much broader than interspaces in late ontogeny, becoming narrower and lower near disk flanks; secondary costae originating in late ontogeny along bases of rib flanks on sides of lateral ribs that face center of shell; medial costae in rib interspaces absent; narrow crests of ribs bearing very small, distally concave, irregularly spaced scales; divaricating to diagonal antimarginal microsculpture in rib interspaces ending abruptly at bases of rib flanks; ribs lacking microsculpture except for very fine growth lines; raised commarginal lamellae absent. Disk flanks lower on anterior side than on posterior, all except right anterior flank bearing fine scabrous radial costellae. Posterior auricles much smaller than anterior, with length of posterior auricle *ca.* 60% of length of anterior; posterior auricular margins nearly straight, forming angle of *ca.* 140º with dorsal margin; total hl 47% of L. Right anterior auricle with 6 strong, scabrous radial costae, broad byssal fasciole, and deep byssal notch with strong active ctenolium; left anterior auricle with nearly straight anterior margin forming acute angle with dorsal margin, bearing radial costae but number not determined because of adhering matrix; left posterior auricle bearing 4 fine, slightly scabrous, radial costellae; right posterior auricular surface obscured by matrix. Interior characters not accessible.

Etymology.—Named in honor of Emily H. Vokes and the late Harold E. Vokes, who collected the holotype of this species and who contributed enormously to our knowledge of tropical American mollusks.

Type material.—Holotype, USNM 540950, 1 articulated DV, 52.1 mm Ht, 50.0 mm L (Pl. 3, Figs 6-9).

Type locality.—TU 1245, "Mao Adentro Limestone?," road

cut 5 km south of bridge at Guayubín, on road to Sabaneta, northern Dominican Republic.

Other material.—None.

Remarks.—As stated above in Remarks under *Caribachlamys guayubinensis* n. sp., the stratigraphic position and formational assignment of the limestones in the Guayubín area are not yet resolved, but there is some indication based on the species present that these limestones might be younger than the true Mao Adentro Limestone Member of the Mao Formation along the Río Mao.

Comparisons.—The only species of *Mimachlamys* close to *M. vokesorum* n. sp. is *M. blowi* n. sp., described above. *Mimachlamys vokesorum* n. sp. differs from the latter in having trigonal ribs that are broader relative to interspaces, a more flaring, prosocline shape, posterior auricular margins forming a more obtuse angle with the dorsal margin, and secondary costae in late ontogeny adjacent to lateral ribs.

Evolution.—See under *Mimachlamys blowi* n. sp.

Occurrence and distribution.—Known only from the type locality, TU 1245, in the northern Dominican Republic.

Genus ***SPATHOCHLAMYS*** Waller, 1993

Spathochlamys Waller, 1993: 229.

Type species.—Pecten benedicti Verrill & Bush in Verrill, 1897, Recent, tropical and warm temperate western Atlantic, Caribbean, Gulf of Mexico, by original designation.

Original diagnosis.—Mimachlamydini with rounded or broadly trigonal ribs separated by interspaces each containing a single very narrow riblet; crests of major ribs bearing narrow erect pointed scales that are concave on their upper (dorsal) sides; edges of ribs on inner surfaces of valves strongly carinate; microsculpture in early rib interspaces obscure or dominated by commarginal lirae which cross interspaces without strong curvature (Waller, 1993: 229).

Geographic range.—"Western Atlantic from at least Massachusetts to Brazil and throughout the Gulf of Mexico and Caribbean; eastern Pacific and Gulf of California from southern California to Ecuador and westward to the Galápagos Islands" (Waller, 1993: 229), living offshore to depths as great as 800 m.

Stratigraphic range.—Upper Miocene to Recent.

Spathochlamys vaginula (Dall, 1898)
Pl. 3, Figs 10-14; Table 5

Pecten (*Chlamys*) *ornatus* Lamarck? var. *vaginulus* Dall, 1898: 715-716, "Oligocene," Bowden, Jamaica.

Pecten vaginulus Dall. Maury, 1917a: 186, pl. 34, fig. 7. Tertiary, Samba Hills, Dominican Republic.

Chlamys (*Chlamys*) *vaginulus* (Dall). Woodring, 1925: 65-66, pl. 8, figs 1-2. "Miocene," Bowden, Jamaica.

Spathochlamys vaginula (Dall). Waller, 1993: 238-241, figs 11c-p. Uppermost Miocene (Zone N17) through lower Pliocene (Zone N19/N20), North Carolina, Florida, Jamaica, and Dominican Republic.

Description.—Spathochlamys of small size, rarely exceeding 20 mm Ht, *Chlamys*-like in shape, acline to slightly prosocline with Ht exceeding L; convexity moderate, with LV slightly more convex than RV; disk gapes absent. Disks with 22-26 radial ribs originating within 1.5 mm from beak on both valves, approximately equal to interspaces in width, initially rounded in profile, becoming somewhat trigonal later, with rounded to bluntly pointed scales on rib crests beginning in mid-ontogeny in central sector, earlier in lateral sectors; thin medial riblet in rib interspaces variably developed, originating *ca.* 5 mm from beak; weak single costa present at base of rib flanks of some specimens in late ontogeny; commarginal lirae present in rib interspaces in early ontogeny, commonly absent later. Disk flanks high, not especially steep, with microscopic antimarginal striae in early ontogeny and fine radial costellae in late ontogeny. Anterior auricles approximately twice length of posterior auricles, all with scabrous radial costellae; byssal notch deep with prominent fasciole; active ctenolium prominent, with 6 or 7 teeth; total hl *ca.* 50-60% L; left anterior auricle triangular, its anterior margin forming acute angle with dorsal margin; posterior margins of posterior auricles outwardly concave, ventral part of margin forming obtuse angle with dorsal margin, dorsal part of margin curving to meet dorsal margin at right angle. Right hinge dentition dominated by single dorsal tooth and weak resilial tooth on each side of resilifer; intermediate teeth absent. Interior of both valves entirely aragonitic inside pallial line; foliated-calcite re-entry absent; LV with large pedal retractor scar merging with posterodorsal part of adductor scar.

Type material.—Lectotype designated by Waller (1993: 238), USNM 135786, RV figured by Woodring (1925: pl. 8, figs 1-2) and refigured by Waller (1993: figs 11c-d).

Type locality.—Bowden shell beds, Bowden Formation, Jamaica.

Other material.—95 single valves from 35 localities in the northern Dominican Republic, all from the Gurabo Formation except TU 1410, upper Cercado Formation (Table 5).

Remarks.—Spathochlamys benedicti, the extant counterpart and probable descendant of *S. vaginula* in the western Atlantic region, lives in tropical to temperate waters at mid-shelf depths commonly from 40-90 m, less commonly as shallow as 2 m and as deep as 800 m (Waller, 1973, 1993). Waller (1993: 232) noted, "The deep byssal notch, prominent active ctenolium, adhering byssal threads on mature dried shells, and data taken at the time of collection all indicate that *S. benedicti* is probably byssally attached throughout life. Individuals attach to a great variety of substrates, including coral debris, sponges, and algal mats (Waller, 1973 and unpub. data)." The occurrences of *S. vaginula* in the northern Dominican Republic indicate a similar preference for deep water, evidenced by apparent restriction of the species to the Gurabo Formation where it is commonly associated with other deep-water species, particularly the pectinids *Argopecten thetidis* and *Gurabopecten uniplicatus* n. gen., n. sp. as well as the cementing bivalve, *Dimya* sp. (Table 5).

Comparisons.—Spathochlamys vaginula is the only member of its genus thus far found in the Neogene of the Dominican Republic. As stated by Waller (1993: 238), the species "differs from both of the extant species, *S. benedicti* [western Atlantic region] and *S. vestalis* (Reeve, 1853) [eastern Pacific], primarily in having less scaly rib crests on the central part of the disk at least in early ontogeny and in having less trigonal ribs at an early growth stage." Compared to *Interchlamys* (n. gen.) *interlineata*, *S. vaginula* has radial ribs that begin earlier in ontogeny after a pitted rather than smooth zone on the left umbonal area, finer medial costae, and more pointed, concave-up scales.

Evolution.—Waller (1993) discussed the evolution of *Spathochlamys* and provided a phylogeny showing the origins of extant species relative to the closure of seaway connections between the Atlantic and Pacific. It was hypothesized that the genus originated in the Miocene from the earlier Miocene genus *Dimarzipecten* Ward, 1992, on the eastern side of the Americas, spreading to the eastern Pacific in the Late Miocene. In an analysis of shallow-water Pectinidae in the Galápagos Islands, Waller (2007: 244) provided further data relevant to the evolution of *Spathochlamys*, particularly in the eastern Pacific region. In the present study, no evolutionary trends were observed within *S. vaginula* in the Dominican Republic material.

Occurrence.—In the northern Dominican Republic, *Spathochlamys vaginula* is known only from the upper Cercado Formation and the Gurabo Formation, uppermost Miocene and Lower Pliocene.

Distribution.—Outside of the Dominican Republic, *S. vaginula* has been reported from the Middle Pliocene Bowden Formation of Jamaica (type locality) and the Middle and Upper Pliocene Jackson Bluff and Tamiami formations of Florida (Waller, 1993: 241).

Subfamily **PALLIOLINAE** Korobkov in Eberzin, 1960
Tribe **PALLIOLINI** Korobkov in Eberzin, 1960
[emend. Waller, 2006a]

Genus ***PALLIOLUM*** Monterosato, 1884
Subgenus ***PALLIOLUM*** Monterosato, 1884

Pecten (Palliolum) Monterosato, 1884: 5

Type species.—Pecten incomparabilis Risso, 1826, by subsequent designation (Crosse, 1885).

Diagnosis.—Pectinidae of small size, commonly pellucid, with RV slightly less convex than LV, chlamydiform in shape with anterior auricles much longer than posterior, posterior auricles well demarcated from disk, posterior margins of posterior auricles forming obtuse angle with dorsal margin; disk gapes narrow or absent; sculpture dominated by antimarginal striae, radial sculpture when present commonly appearing late in ontogeny, consisting of broad radial folds or narrow, minutely scabrous costae; byssal notch deep, floored by persistent ctenolium with small teeth; foliated-calcite on inner shell surface with laths in irregular, specular patches.

Remarks.—The concept of *Palliolum* used here encompasses three common extant species of the eastern Atlantic region*: P. incomparabile* (the type species), *P. tigerinum* (Müller, 1776), and *P. striatum* (Müller, 1776). The last has a small distribution in the northwestern Atlantic, apparently resulting from trans-Atlantic dispersal via a northern route. The generic name has been overused for a group of unrelated taxa. Abbott (1974: 446), for example, listed under this genus *P. subimbrifer* (Verrill & Bush in Verrill, 1897), *P. leptaleum* (Verrill, 1884), *P. reticulum* (Dall, 1886), *P. imbrifer* (Lovén, 1846), *P. undatum* (Verrill & Smith in Verrill, 1885), and *P. ringnesia* (Dall, 1924). All of these except *P. undatum* belong in the family Propeamussiidae based on their primary absence of a ctenolium and the presence of an ontogenetically persistent outer layer of columnar prismatic calcite on the right valve. *Palliolum undatum* belongs in *Hyalopecten* Verrill, 1897, a pectinid with a well-developed ctenolium and ontogeneti-

Table 5. Occurrence of *Spathochlamys vaginula* in the Cibao Valley. Abbreviations: Aa, *Argopecten ameleus*; Ae, *A. eccentricus s. l.*; Aec, *A. eccentricus caimiticus*; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; Anq, *Antillipecten quemadosensis* n. sp.; Apa, *Argopecten parathetidis* n. sp.; At, *Argopecten thetidis*; B1, Bluff 1; B2/B1, between B2 and B1; Cg, *Cyclopecten guppyi*; Dm, *Dimya* sp.; DV, matching valves; EE, *Argopecten eccentricus eccentricus* evolutionary stage; Eg, *Euvola gurabensis* n. sp.; Es, *E. soror*; frag, fragment; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis s.s.*; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Pvm, *Parvamussium marmoratum*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo								
NMB 15815	402	Gurabo	1	0	0	11.5	At, Gu, Dm	
NMB 15962	400	Gurabo	0	1	0	10.0	At, Gu, Lpl, Dm	
NMB 15804	399	Gurabo	0	1	0	8.6	At, Gu	
----------								Miocene/Pliocene boundary (Saunders *et al.*, 1986: text-fig. 14)
NMB 15937	395	Gurabo	0	2	0	5.1	At, Dm	
NMB 15939	394-397	Gurabo	0	2	0	7.0	Amp, At, Dm	
TU 1210	394-396	Gurabo	0	frag	0	--	Amp, At, Gu, Lpa, Ncv	
NMB 15805	393-395	Gurabo	3	4	0	6.0	Gu, Dm	
NMB 15940	393	Gurabo	1	1	0	6.6	At, Dm	
NMB 15941	392	Gurabo	2	1	0	5.9	Cg, Gu, Dm	
NMB 15835	391	Gurabo	2	2	0	12.2	Dm	
USGS 8548	388-396	Gurabo	1	0	0	16.5	At	
TU 1369	388?	Gurabo	0	1	0	15.9	Amp, At, Gu, Lpa	
TU 1279	387-389	Gurabo	1	0	0	9.0	At, Es, Gu, Lpa	
TU 1211	381-385	Gurabo	1	2	0	15.9	Apa, At, Gu, Lpa	
NMB 15843	323-328	Gurabo	2	0	0	17.5	At	
NMB 15842	314-317.5	Gurabo	1	0	0	4.5	Ai, At	
NMB 15846	285-287	Gurabo	1	0	0	8.2	At, Dm	
NMB 15849	274.5	Gurabo	1	1	0	5.1	At, Cg	
NMB 15860	255	Gurabo	0	1	0	6.1	At, Cg	
NMB 15869	224	Gurabo	3	2	0	5.5	Ae, At, Lpa	
NMB 16810	221-223	Gurabo	1	0	0	19.8	At	
NMB 15865	221-223.5	Gurabo	1	2	0	11.0	Amp, At	
NMB 15871	220-223	Gurabo	0	1	0	5.1	At	
NMB 16809	220-223	Gurabo	1	0	0	3.3	none	
----------								Possible unconformity accounting for missing Biozone EE
TU 1296	204-223	Gurabo	1	0	0	11.0	At, Lpa	Maury's Zone F, basal Gurabo Fm according to E. Vokes (1989: 18)

Table 5 (continued).

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Mao								
NMB 16910	B1	Gurabo	1	0	0	18.2	Aee, Amp, At	
TU 1410	B2/B1	Cercado	0	1	0	14.8	Aee, Amp, At, Cg, Es	
Río Amina								
TU 1219	level d	Gurabo	3	1	0	17.4	Amp, At, Lpa, Lpl	
Río Yaque del Norte								
TU 1206	--	Gurabo?	2	1	0	15.7	Amp, Apa, At, Es	
Santiago area								
TU 1205	--	Gurabo	1	0	0	11.4	Aec, Amp, Apa, At, Es	
TU 1227A	--	Gurabo	13	17	0	14.6	Ai, Amp, At, Cg, Cz, Gu, Lpa, Pvm	Arroyo Zalaya; turbidity-flow lens (Vokes & D'Attilio, 1980: 52)
USGS 8726	--	Gurabo	0	1	0	13.0	Aec, Anq, At, Es	Called Gurabo Fm by Vaughan *et al.* (1921: 142)
TU 1380	--	Gurabo?	1	0	0	13.1	Amp, Ai, At	
Road cuts								
TU 1209	--	Gurabo	0	2	0	15.0	At, Eg, Gu, Lpa, Ncv	
TU 1409	--	Gurabo?	1	1	0	18.2	Ai, Amp, At	
TU 1435	--	Gurabo?	1	0	0	16.3	Aa, Amp, At, Es, Lpl	

cally abbreviated prismatic calcitic layer but differing from *Palliolum* in shape, sculpture, and the microfabric of its foliated-calcite shell layers.

Geographic range.—In present-day seas, limited to the eastern Atlantic, from Norway to Morocco including the Mediterranean, commonly offshore to depths of *ca.* 2,000 m.

Stratigraphic range.—Upper Oligocene to Recent.

Palliolum*? *cibaoense n. sp.
Pl. 4, Figs 1-4; Table 6

Diagnosis.—Small, thin-shelled Palliolini lacking antimarginal microsculpture; disks smooth except for microscopic commarginal growth lines; anterior auricles with radial costae; posterior auricles with weak radial costae or smooth, posterior margins of posterior auricles forming very obtuse angle with dorsal margins.

Description.—Shell small, not known to exceed 9 mm Ht, slightly prosocline; margin of disk nearly circular, Ht and L approximately equal; LV distinctly more convex than RV; disk gapes apparently absent; hl short, less than half length of shell, ahl longer than phl (ahl/phl *ca.* 1.4); right anterior auricle with shallowly rounded anterior margin and deep byssal notch floored by active ctenolium of 4 or 5 small teeth; left anterior auricle with sigmoidal margin leading to shallow byssal sinus; posterior margins of posterior auricles slightly outwardly convex and forming obtuse angle of *ca.* 130° with dorsal margin. Exterior of disks and disk flanks smooth except for faint, irregularly spaced commarginal lines and very fine, short antimarginal striae on anterior and posterior extremi-

ties of disk; right anterior auricle with broad, sunken byssal fasciole and 3 or 4 weak to moderately strong radial costae crossed by imbricated commarginal lamellae; left anterior auricle with 6 or 7 radial costae of variable strength, in some cases fading distally; posterior auricles separated from disk by low, rounded disk flanks and possessing only very weak, barely discernible costae. Shell translucent, lacking pigment patterns. Prodissoconch possibly of lecithotrophic type consisting mainly of PI stage with little or no PII, length 177 µm. Hinge dentition consisting mainly of dorsal and infradorsal teeth crossed by transverse microscopic ridges; resilial teeth weak or absent. Adductor scars poorly exposed but striate and nonstriate scars of RV well separated on anterior sides of scars. Foliated-calcite re-entry restricted to umbonal region on both valves. Outer columnar prismatic layer of RV not definitely detected and possibly absent.

Etymology.—Named after the Cibao Valley of the northern Dominican Republic.

Holotype and measurements.—USNM 540952 (Pl. 4, Fig. 1), 1 LV, 9.0 mm Ht, 9.0 mm L, 1.6 mm cvx. During the process of being handled, a large but very thin piece of the outer shell layer in the center of the disk was broken off and could not be reattached in precisely its original position.

Type locality.—USGS 8516, bluff on right bank of Río Amina at ford near Potrero, Province of Santiago, Dominican Republic, Gurabo Formation, collected by T. W. Vaughan and C. W. Cooke, 02 May 1919. Saunders *et al.* (1986: text-fig. 34) indicated that USGS 8516 is from the same locality as TU 1219, and their text-fig. 35 shows the position of TU 1219 relative to NMB localities. Their discussion of these localities (1986: 33) indicates that TU 1219 is just below the Miocene/Pliocene boundary.

Other material.—Five single valves from four localities, all from the Cercado Formation on the Río Mao at Bluffs 2 and 3 (Table 6).

Remarks.—Based on its association with *Argopecten eccentricus eccentricus*, *Leptopecten thompsoni*, and *Cyclopecten guppyi* at Bluffs 2 and 3 on the Río Mao, *Palliolum*? *cibaoense* n. sp. was probably a shallow-water species that lived in association with marine grasses in clear, normal marine waters. The association of the type specimen with *A. thetidis* and *Amusium papyraceum* on the Río Amina suggests deposition in deeper water than at the Río Mao localities. The rarity of this species is possibly due to the difficulty of finding and recognizing it because of its small size and very fragile shell.

Comparisons.—The reason for the generic query is that all extant species and known fossil species of *Palliolum* from the eastern Atlantic have prominent antimarginal striae, at least on their disk flanks in early ontogeny. Although these prominent striae are absent on the Dominican Republic specimens, their shell shape greatly resembles that of the type species of *Palliolum*. *Eburneopecten* Conrad, 1865, a Paleogene palliolinine genus of the Atlantic Coastal Plain of the United States, tends to be smooth but has a shallower byssal notch and sharply crested right dorsal auricular margins. *Palliolum*? *cibaoense* n. sp. is readily distinguished from comparably sized propeamussiids in the genus *Cyclopecten* in possessing a ctenolium and lacking a persistent prismatic outer shell layer on the right valve. *Palliolum*? *cibaoense* n. sp. also has more prominent dentition on both valves as well as an aragonitic inner shell layer that is delimited by the pallial line rather than extending nearly to the shell margins as in *Cyclopecten*.

Evolution.—If the new species is indeed a member of the genus *Palliolum*, it is possible that it might have an eastern Atlantic origin. The smoothness of its exterior would be expected to be a derived feature, because the fossil record of true *Palliolum* indicates more strongly sculptured ancestors.

Occurrence.—In the Dominican Republic, *Palliolum*? *cibaoense* n. sp. is known only from the Cercado Formation at Bluffs 2 and 3 on the Río Mao and from the Gurabo Formation on the Río Amina, of late Miocene age.

Distribution.—Palliolum? *cibaoense* n. sp. is known only from the Late Miocene of the northern Dominican Republic.

Subfamily **PECTININAE** Rafinesque, 1815
Tribe **AEQUIPECTININI** Nordsieck, 1969

Genus ***ARGOPECTEN*** Monterosato, 1889

Argopecten Monterosato, 1889: 20.
Plagioctenium Dall, 1898: 696.

Type species.—Pecten solidulus Reeve, 1853, by subsequent designation (Monterosato, 1899: 193), = *Pecten ventricosus* G. B. Sowerby II, 1842, not *Pecten circularis* G. B. Sowerby I, 1835 (Waller, 1995); Recent, eastern Pacific from southern California and Gulf of California to Peru (Coan *et al.*, 2000: 235).

Diagnosis.—"Shell biconvex, ranging from right-convex through equiconvex to left-convex. Outline of disk in plane of commissure generally symmetrical, frequently prosocline in

Table 6. Occurrence of *Palliolum? cibaoense* n. sp. in the Cibao Valley. Abbreviations: Aee, *Argopecten eccentricus eccentricus*; Amp, *Amusium papyraceum*; At, *Argopecten thetidis*; B2, Bluff 2; B3, Bluff 3; Cg, *Cyclopecten guppyi*; DV, matching valves; Lpl, *Lindapecten plurinominis s.s.*; Lt, *Leptopecten thompsoni*; LV, left valve; Pa, *Paraleptopecten* sp. *a*.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Mao								
NMB 16918	B2, d	Cercado	1	0	0	2.9	Aee, Cg, Lt	
NMB 16912	B3	Cercado	1	0	0	4.5	Aee, Cg, Lt	
USGS 8525	B3	Cercado	0	1	0	3.3	Aee, Cg, Lt	
TU 1294	B3	Cercado	0	1	0	6.6	Aee, Cg, Lpl, Lt, Pa	
Río Amina								
USGS 8516	level d	Gurabo	0	1	0	9.0	Amp, At	Type locality of *Palliolum? cibaoense* n. sp.

adult stage, more rarely opisthocline. Auricles approximately equal in length; anterior auricles with distinct byssal notch and sinus, with ctenolium generally present but commonly absent in adults of some species. Ornament consisting mainly of radial plicae and concentric [commarginal] lamellae, the latter commonly well developed in interspaces and rarely projecting strongly over crests of plicae; radial costae never abundant on disk and limited to one or a few arising distally in interspaces or at sides of plicae, more rarely arising on crests of plicae." (Waller, 1969: 32).

Geographic range.—Tropical to cool-temperate western Atlantic from Massachusetts to Florida, Gulf of Mexico, Caribbean, to Brazil; eastern Pacific from southern California to Peru, inshore subtidal and offshore to depths of *ca.* 25-200 m, living on sandy bottoms, commonly associated with eelgrass.

Stratigraphic range.—Middle Miocene to Recent.

Argopecten ameleus (Woodring, 1925)
Pl. 4, Figs 5-10

Chlamys (*Plagioctenium*) *ameleus* Woodring, 1925: 70, pl. 8, fig. 9.

Original description.—"Shell small, subequivalve, suborbicular, the two valves equally inflated; both valves sculptured with 21 to 23 strong, subrounded ribs, separated by narrower interspaces; concentric sculpture of fine lamellae usually appears in interspaces and occasionally on ribs, absent on submargins; auricles unequal, both bearing inconspicuous radials; on the posterior auricle the radials are more prominent ventrally, but on the anterior auricle they are broader and stronger dorsally, overridden by fine concentric lamellae, coarser and more irregular on the anterior auricle" (Woodring, 1925: 70-71).

Description.—Shell not known to exceed 18 mm Ht, slightly longer than high, with convexity of both valves moderate, that of LV only slightly greater than that of RV. Disks with 20-23 simple ribs with smooth, slightly rounded crests somewhat broader than interspaces on RV and narrower than interspaces on LV; rib profiles rounded to trapezoidal. Commarginal lamellae commonly limited to rib interspaces and rib flanks throughout ontogeny, rarely extending onto edges of rib crests especially on LV, leaving a smooth area in center of crest. Commarginals prominent in interspaces, passing either straight across interspaces or curved ventrally, recurving to form shallow distally open arcs on rib flanks; projecting scales and secondary radial costae absent. Disk flanks shallow, smooth except for fine commarginals, moderately sloped on RV but steeper on LV. Auricles small, total hl slightly greater than half L, anterior longer than posterior; right anterior auricle with 3 or 4 scabrous radial costae, slightly scrolled dorsal margin, rounded anterior margin, and deep byssal notch; dorsal border of byssal notch nearly parallel to hinge line; ctenolium with 4 or 5 teeth in specimens of 18-19 mm Ht. Left anterior auricle with 5 or 6 radial costae, anterior margin forming acute angle with dorsal margin, byssal sinus moderately deep. Posterior auricle of both valves with 4-6 radial costae fading distally on dorsal half of auricle; posterior auricular margin moderately sigmoidal with overall trend forming right angle or slightly obtuse angle with dorsal margin. Right hinge with single strong resilial tooth on each side of resilifer, each bordered dorsally by deep socket to accommodate dorsal tooth of LV; irregular cross-ridges promi-

nent on all hinge teeth. Foliated-calcite re-entry on interior of RV extending ventrally to just below level of ventral margin of striate part of adductor scar and therefore underlying anterior part of this scar, on LV foliated-calcite re-entry extending to mid-adductor level.

Holotype and measurements.—USNM 352785, 1 RV, 14.0 mm Ht, 14.4 mm L, 3.8 mm cvx, refigured herein (Pl. 4, Figs 5-7).

Type locality.—Bowden, Jamaica, "on the east side of Port Morant, in the parish of St. Thomas, lying on the south coast of Jamaica near its eastern end" (Woodring, 1925: 7), from the Bowden shell beds, late Middle Pliocene in age (Kohl & Robinson, 1998: 39, fig. 5).

Other material.—Dominican Republic: TU 1281, road metal quarry on highway, south side of Río Yaque, 1 km east of Guayubín on road to Mao, Mao Adentro Limestone Member of the Mao Formation (H. & E. Vokes, 1992: 13), 5 RV, 3 LV; TU 1435, road cut 1.5 km north of junction at El Limpio, on road from Piedra Gorda (which is 25 km west of Santiago and 24 km east of Mao, on south side of Río Yaque) to Cuesta Arriba, 1 RV.

Remarks.—The single right valve of *Argopecten ameleus* from TU 1435 (USNM 540954, Pl. 4, Fig. 8) is associated with abundant *A. thetidis* of the more derived type (disk flanks bearing scabrous costae) without any indication of intergradation between the two species. This would suggest that this road cut is in the upper Gurabo Formation, but there is also the possibility that this single specimen could have been introduced into this lot accidentally or that more than one formation is present.

Comparisons.—Argopecten ameleus resembles the early ontogenetic stages of *A. eccentricus eccentricus* in having smooth, gently rounded rib crests on the right valve. Compared to that subspecies, however, *A. ameleus* lacks any sign of crestal troughs even on the largest specimen. It also has more prominent commarginal lamellae in rib interspaces and a deeper byssal notch with a more prominent active ctenolium. The posterior margin of the right posterior auricle of *A. ameleus* is more deeply sigmoidal and more strongly costate, and the free margins of the right auricles commonly form a less obtuse angle where they meet the dorsal margins. *Argopecten ameleus* differs from the stratigraphically lower forms of *A. thetidis* in having more rounded ribs and a much less extensive foliated-calcite re-entry and in lacking any sign of troughs on rib crests. Compared to the holotype of *A. ameleus* from the Bowden Formation of Jamaica, the Dominican Republic specimens have at least one less rib. Compared to *A. uselmae* of the Bowden Formation, *A. ameleus* lacks rib crests that overhang the rib flanks and has a considerably broader umbonal angle and more numerous ribs (20-22 compared to 17-18). Compared to extant *A. nucleus* (Born, 1778), *A. ameleus* lacks strong radial costae on its disk flanks, is less gibbous, and has posterior auricular margins that form a less obtuse angle with the dorsal margins.

Evolution.—Because *Argopecten ameleus* is thus far known only from 9 valves from the Dominican Republic and 3 valves from Jamaica, evolutionary trends cannot be discerned with any confidence. The only difference between specimens from the Mao Formation of the Dominican Republic and the slightly younger Bowden shell bed (compare Saunders *et al.*, 1986: text-fig. 39 and Kohl & Robinson, 1998: 39) is a slight increase in the number of ribs in the latter. The origin of the species is unknown.

Occurrence.—In the Dominican Republic, *Argopecten ameleus* occurs in the Mao Formation (Mao Adentro Limestone Member?) near Guayabin and possibly in the upper Gurabo Formation north of El Limpio, of Pliocene age.

Distribution.—Outside of the northeastern Dominican Republic, *Argopecten ameleus is* known only from the Bowden Formation of southeastern Jamaica.

Argopecten eccentricus eccentricus (Gabb, 1873)
Pl. 4, Figs 11-14; Pl. 5, Figs 1-5; Tables 7-8

Pecten eccentricus Gabb, 1873: 256; Pilsbry, 1922: 412, pl. 45, fig. 12.
Pecten (*Plagioctenium*) *excentricus* Gabb. Dall, 1898: 717.
Pecten excentricus Gabb. Maury, 1917a: 187, pl. 34, fig. 8; Richards, 1968: 50.

Original description.—"Shell slightly inequivalve, sub-circular, oblique, ears small, surface covered with twenty-two flat ribs, sometimes slightly grooved, and with concave interspaces. Diameter 1 to 1.5 inch. Nearest to *P. irradians*, Lam., but more oblique, and with broader, flatter ribs" (Gabb, 1873: 256).

Description.—Shell not known to exceed 35 mm Ht, with length slightly greater than height in mid- to late-ontogeny. Convexity of valves nearly equal, ranging from slightly left-convex to equiconvex in early ontogeny to slightly right-convex in late ontogeny. Disks commonly with 21-23 interlocking radial ribs, broader on RV than on LV, with rib profiles ranging from sharply rounded in early ontogeny to broadly trapezoidal in late ontogeny; rib crests of RV commonly with

single shallow medial groove beginning at 12-17 mm Ht; rib crests of LV either similarly grooved or with narrow, flattened crest beginning in late ontogeny; commarginal lamellae in interspaces of both valves commonly absent or obscure through most of ontogeny, uncommonly appearing in late ontogeny and crossing rib crests. Auricles small and slightly unequal, with anterior auricles slightly longer than posterior; right anterior auricle with 3 or 4 radial costae, slightly scrolled dorsal margin, and nearly circular anterior margin forming obtuse angle with dorsal margin at point of intersection; byssal notch moderately deep, with short, active ctenolium with 1-3 active teeth continuing into late ontogeny, rarely obsolescent. Right posterior auricle with 4-6 radial costae in early ontogeny; dorsal costae commonly fading out beyond 2 or 3 mm from beak, leaving 2-4 relatively strong ventral costae that continue to posterior margin of auricle, less commonly dorsal costae persisting to posterior margin. Left auricles with variable number of radial costae, commonly 5-8, more numerous on posterior auricle; left anterior auricle with sigmoidal anterior margin forming shallow byssal sinus; posterior margins of posterior auricles sigmoidal with posterior sinus shallow to absent and overall trend of margin forming obtuse angle with dorsal margin. Anterior disk flanks of RV commonly without radial costae; other disk flanks with very low, indistinct costae. Right hinge dentition with single strong resilial tooth on each side of resilifer, weaker single dorsal tooth bordering outer-ligamental groove on each side of hinge, and infra-dorsal socket between teeth on each side; left dentition with single infradorsal tooth on each side of resilifer fitting into infradorsal sockets of RV. Extent of foliated-calcite re-entry on interior of RV variable, commonly filling anterior separation of striate and nonstriate adductor scars and extending ventrally along anterior margin of nonstriate scar; on LV, extending ventrally at least half-way down anterior margin of adductor scar and commonly to anteroventral margin of scar.

Type material and measurements.—Lectotype (see Remarks), ANSP 2854, 1 LV, 30 mm Ht, 32 mm L (Pilsbry, 1922: 413).

Type locality.—Dominican Republic. No further details of the locality can be discerned from Gabb's (1873) original description.

Other material.—Approximately 7,200 specimens from 35 localities in the northern Dominican Republic (Table 7). All but four of these specimens are single valves.

Remarks.—Gabb (1873: 256) did not figure *Pecten eccentricus*, nor did he specify a holotype. The first illustration of the species was by Maury (1917a: pl. 34, fig. 8, a right valve, PRI 28965), but this specimen is from Maury's collection, not Gabb's. Pilsbry (1922: 413; pl. 45, fig. 12) redescribed the species and figured "Type no. 2854 A.N.S.P.," a left valve that is from Gabb's type series. Although not specified as a lectotype by Pilsbry, this designation effectively established a lectotype in the meaning of the 4th edition of the International Code of Zoological Nomenclature (ICZN, 1999: Article 74.5). Unfortunately, this specimen is incomplete and abraded. The uneven wearing of the anteroventral region (determined by tracing commarginal growth lines and observing their truncation in this region) likely contributed to Gabb's description of this fossil as "oblique" and to his choice of the name "eccentricus." Dall's (1898: 717) correction of the spelling of the name to "excentricus" is an unjustified emendation.

Argopecten eccentricus eccentricus varies among samples in the frequency of occurrence of medial grooves on rib crests of right valves of 15 mm Ht or greater and in the ventral extent of the foliated-calcite re-entry on valve interiors. Samples from eight stratigraphic levels on the Río Mao at Bluff 2 and the adjacent section at the mouth of Arroyo Bajón (Text-fig. 5) indicate that a change occurs between levels a-f and levels g-h (Text-fig. 6, Table 8). Samples from levels a-e have high percentages of specimens bearing grooved rib crests, ranging from 63-100%, with the highest percentages occurring in samples from levels a-b. (Level f did not have large enough specimens to yield a percentage, but it appears that most specimens show the beginnings of these grooves.) In samples from level g, however, only 10% of the specimens display grooved rib crests on right valves, and in the sample from level h, no grooves were observed at all. Right valves of *A. e. eccentricus* from Bluff 3, upstream from Bluff 2, corroborate this difference. Because of the low dip of strata to the north (*ca.* 3°), the stratigraphic section at Bluff 3 probably overlaps at least the lower part of the sections at Bluff 2 and Arroyo Bajón (Saunders *et al.*, 1986: 31). Samples from two levels at Bluff 3 both contain high percentages of right valves having grooved rib crests (see Pl. 5, Fig. 1), suggesting that both of these levels are coeval with the lower beds (levels a-f) in the Bluff 2/Arroyo Bajón section.

Specimens from levels g-h also have less extensive foliated-calcite re-entry on valve interiors than in specimens from samples a-f, the largest specimens from the upper levels showing relatively less extensive re-entries than do smaller specimens. The mechanism by which this reduction occurs during ontogeny is indicated in specimens from NMB 16931. These show that secretion of the foliated-calcite re-entry near the adductor scar of the right valve ceases at 22-30 mm Ht, after which aragonite takes over. In both the loss of grooved rib crests and the reduction of the FC re-entry, the specimens from levels g-h are transitional between *Argopecten eccentricus eccentricus* and *A. e. caimiticus*, the latter being the stratigraphically highest chronological subspecies.

Table 7. Occurrence of *Argopecten eccentricus* in the Cibao Valley. Abbreviations: Ael, *Argopecten eccentricus lacabrensis* n. ssp.; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; Anc, *Antillipecten cercadicus*; Anj, *A. janicoensis* n. sp.; Anq, *Antillipecten quemadosensis* n. sp.; Ans, *Antillipecten* sp.; Apa, *Argopecten parathetidis* n. sp.; At, *A. thetidis*; B1, Bluff 1; B2, Bluff 2; B2/B1, between B2 and B1; Cg, *Cyclopecten guppyi*; Cz, *C. zalaya* n. sp.; Dm, *Dimya* sp.; DV, matching valves; EC, *Argopecten eccentricus caimiticus* evolutionary stage; EE, *A. eccentricus eccentricus* evolutionary stage; Eg, *Euvola gurabensis* n. sp.; EL-I, Ael evolutionary stage I; EL-I/II, between Ael evolutionary stages I and II; EL-II, Ael evolutionary stage II; Es, *E. soror*; FC, foliated calcite; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis s. s.*; Lt, *Leptopecten thompsoni*; LV, left valve; Nn, *Nodipecten nodosus*; Pa, *Paraleptopecten* sp. *a*; Pc, *Palliolum? cibaoense* n. sp.; Pvm, *Parvamussium marmoratum*; RV, right valve; Sv, *Spathochlamys vaginula*; --, not recorded. Evolutionary stages and lettered stratigraphic levels are explained in the text.

Localities TU 1230 and USGS 8534 were not plotted on the stratigraphic section by Saunders *et al.* (1986). Their position at *ca.* 200 m in the Río Cana section is based on their geographic position between the plotted localities NMB 16999 (207 m) and NMB 17002 (178 m) assuming a uniform dip. The specimens are anomalous in that they have low foliated-calcite re-entry on valve interiors. Vaughan & Woodring in Vaughan (1921: 108) noted the presence of other anomalous taxa at USGS 8534. Possibly there is a structural complication.

Six samples taken at *ca.* 228 m above the base of the Río Cana section are within the interval that contains the "*Scapharca patricia* beds" of Maury (1917b), which she regarded as in her "*Sconsia laevigata* Formation," later named the Gurabo Formation (Maury, 1919). Saunders *et al.* (1986: 20, text-fig. 16) placed these beds in the Cercado Formation, but Bold (1988: 15, text-fig. 5) gave biostratigraphic support for Maury's original molluscan zonation and placed the interval containing the *Scapharca* beds in the Gurabo Formation.

Locality	Level (m)	Formation	Evolutionary Stage	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana									
NMB 16866	427	Gurabo	EC	0	0	1	11.5	none	
TU 1356	355-362	Gurabo	EC	1	0	0	18.0	none	
NMB 16858	354	Gurabo	EC	1	0	0	14.1	none	
NMB 16817	347	Gurabo	EC	18	18	0	20.2	Anc, Cg, Es, Lpl	
NMB 16818	347	Gurabo	EC	17	19	0	20.2	Anq, Es, Lpl	Coralline facies
NMB 16878	339	Gurabo	?	0	2	0	--	Lpl	Very abraded
TU 1354	336-346	Gurabo	EC	46	16	0	22.7	Anq, Es, Lpl, Nn	
NMB 16819	335-346	Gurabo	EC	1	2	0	15.8	none	
NMB 16961	327	Gurabo	?	1	1	0	6.1	Lpl	Juvenile
NMB 16824	319	Gurabo	?	1	0	0	4.6	Lpl	Juvenile
NMB 16972	317.5	Gurabo	EC	3	3	0	14.5	none	
NMB 16828	309	Gurabo	EC	7	5	0	19.8	Es, Lpl	
NMB 16821	306	Gurabo	EC	7	7	0	21.0	Lpl	Near Miocene/Pliocene boundary
NMB 16976	306	Gurabo	EC	2	0	0	6.8	none	Juveniles
NMB 16831	287	Gurabo	EC	0	1	0	13.5	Es, Lpl	
NMB 16833	287	Gurabo	EC	9	6	0	19.1	Lpa, Lpl	Extensive FC re-entry
NMB 16832	287	Gurabo	EC	4	3	0	17.3	Dm, Lpl	Extensive FC re-entry
NMB 16835	252	Gurabo	EC	67	44	0	21.0	Amp, Ans, Es, Lpl	Extensive FC re-entry
NMB 16983	250	Gurabo	EC	2	5	0	11.0	Lpl	
NMB 16836	243	Gurabo	EC	9	6	0	14.8	Es, Lpl	
NMB 16984	241	Gurabo	EC	3	1	0	8.0	none	
NMB 16837	236.5	Gurabo	EC	50	48	0	19.0	Lpl	
NMB 16838	233	Gurabo	EC	47	25	0	18.5	Amp, Es, Lpl	

Table 7 (continued).

Locality	Level (m)	Formation	Evolutionary Stage	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana (continued)									
NMB 16986	232	Gurabo	EC	3	3	0	15.5	none	
NMB 16839	231	Gurabo	EC	13	17	0	19.6	Lpl	
NMB 16844	228	Gurabo	EC	7	5	0	17.9	Anj, Lpl	
NMB 16993	228	Gurabo	EC	0	1	0	11.5	Lpl	
NMB 16989	228	Gurabo	EC?	4	0	0	6.8	Lpl	Abraded juveniles
NMB 16852	228	Gurabo	EC	1	0	0	17.7	Lpl	
NMB 16843	228	Gurabo	EC	0	1	0	14.0	none	
NMB 16842	228	Gurabo	EC	7	4	0	19.0	Es	
----------									Possible unconformity accounting for missing Biozone EE
USGS 8534	200	Cercado	EL-II	5	0	0	7.3	Lpl	
TU 1230	200	Cercado	EL-II	179	144	0	10.2	Amp, Cg, Es	Abundant tiny juveniles
NMB 16857	148	Cercado	EL-II(H)	67	34	0	10.0	Amp, Cg	Lamellate forms common
NMB 17005	147	Cercado	EL-II	27	19	0	11.8	Cg	
Río Gurabo									
NMB 16808	222-226	Gurabo	EC	0	1	0	10.5	At, Lpa	
----------									Possible unconformity accounting for missing Biozone EE
NMB 15874	208	Gurabo	EL-II(H)	29	7	0	10.0	none	Lamellate juveniles
NMB 15873	208	Gurabo	EL-II(H)	81	54	0	17.0	none	Lamellate form
----------									Cercado/Gurabo Fm of E. Vokes (1989:18)
NMB 15876	206	Cercado	EL-II(H)	15	9	0	10.0	none	Lamellate juveniles
NMB 15878	193	Cercado	EL-II(H)	107	96	0	15.7	Amp, Es, Lpl	Lamellate form
NMB 15881	185	Cercado	EL-II(H)	5	1	0	12.5	none	Abraded lamellate juveniles
NMB 15882	184.8	Cercado	EL-II(H)	24	23	0	12.0	none	Mostly lamellate juveniles
TU 1297	183-211	Cercado	EL-II(H)	17	10	0	17.0	Amp, At, Es, Lpl	Cercado Fm of E. Vokes (1989: 18); lamellate form
NMB 15886	175	Cercado	EL-II(H)	1	0	0	14.0	Amp, Lpl	Lamellate form
NMB 15890	175	Cercado	EL-II(H)	40	23	0	16.4	Amp, Lpl	Lamellate form
USGS 8737	159-173	Cercado	EL-II(H)	13	10	0	14.8	none	Cercado Fm according to Vaughan *et al.* (1921); lamellate form
TU 1418	155	Cercado	EL-II(H)	1	1	0	15.3	none	Cercado/Gurabo contact according to Saunders *et al.* (1986); lamellate form
USGS 8738	152	Cercado	EL-II	6	4	0	15.5	none	Just below Cercado/Gurabo boundary of Saunders *et al.* (1986)
NMB 15894	149	Cercado	EL-II	1	0	0	13.3	none	

Table 7 (continued).

Locality	Level (m)	Formation	Evolutionary Stage	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo (continued)									
NMB 15895	145	Cercado	EL-II	79	57	0	20.0	none	Near first occurrence of the ostracode *Radimella* (Bold, 1988).
NMB 15896	135	Cercado	EL-II	53	48	0	19.8	none	
NMB 15897	134.5	Cercado	EL-II	49	34	0	12.8	none	Mostly lamellate juveniles
NMB 15898	131-133	Cercado	EL-II	7	5	0	18.0	Amp, At	
NMB 15906	131	Cercado	EL-II	1,379	1,268	3	22.1	Cg	
NMB 15905	130	Cercado	EL-II	2	0	0	13.0	Amp	
NMB 15907	126	Cercado	EL-II	838	657	1	22.0	none	
NMB 15904	126	Cercado	EL-II	565	533	0	22.9	none	Many lamellate forms
NMB 15902	125	Cercado	EL-I/II	3	1	0	14.5	Amp	EL-I/EL-II transition
NMB 15899	124-126	Cercado	EL-I/II	6	3	0	17.0	Amp	EL-I/EL-II transition
TU 1375	124-126	Cercado	EL-II	1	0	0	16.7	At, Cg	
USGS 8739	122-126	Cercado	EL-I/II	14	7	0	21.0	Amp, At	EL-I/EL-II transition
NMB 15901	122	Cercado	EL-I/II	25	17	0	21.0	none	EL-I/EL-II transition
NMB 15900	121	Cercado	EL-II	141	99	0	20.5	none	
NMB 15903	120	Cercado	EL-I/II	1,006	872	0	23.8	none	EL-I/EL-II transition
NMB 15910	118	Cercado	EL-I/II	215	206	0	19.5	none	EL-I/EL-II transition
NMB 15908	117-119	Cercado	EL-I	31	26	0	20.0	Lpl	
TU 1373	117-126	Cercado	EL-I	76	40	0	18.2	none	Might contain both EL-I and EL-II
TU 1359	111-118	Cercado	EL-I	88	61	0	21.8	Lpl	
NMB 15909	111-113	Cercado	EL-I	46	26	0	21.0	Lpl	Type locality of Ael
NMB 15911	110	Cercado	EL-I	37	65	0	14.5	Lpl	
NMB 15912	104	Cercado	EL-I	31	94	0	15.8	none	
NMB 15913	103	Cercado	EL-I	9	16	0	15.5	none	
TU 1358	102-104	Cercado	EL-I	69	135	0	15.9	Amp, Cg, Lpl	Mostly tiny juveniles
TU 1419	up to 100	Cercado	EL-I	7	6	0	19.0	none	
NMB 15914	100	Cercado	EL-I	30	93	0	11.0	Lpl	Mostly juveniles
TU 1376	99-102.5	Cercado	EL-I	18	50	0	14.7	Amp, Lpl	
TU 1377	up to 99	Cercado	EL-I	42	89	0	17.8	Lpl	Abundant juveniles
NMB 15915	99	Cercado	EL-I	6	4	0	15.8	Lpl	Abundant juveniles
TU 1378	84-85	Cercado	EL-I	5	13	0	10.0	none	
NMB 15916	75	Cercado	EL-I	6	9	0	6.7	none	Juveniles
NMB 15918	59-61	Cercado	EL-I?	0	1	0	3.3	none	Juvenile
Río Mao									
NMB 16803	B2/B1	Cercado	EE	6	8	0	19.5	Anc, At, Es, Lpl	

Table 7 (continued).

Locality	Level (m)	Formation	Evolutionary Stage	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Mao (continued)									
USGS 8522	B2/B1	Cercado	EE	23	18	0	19.6	At, Lpl	Abraded
NMB 16802	B2/B1	Cercado	EE	47	51	0	17.9	none	
USGS 8521	B2/B1	Cercado	EE	122	94	0	18.1	Amp, At, Es, Lpl	
TU 1410	B2/B1	Cercado	EE	41	32	0	18.8	Amp, At, Cg, Es	Between Bluffs B2 and B1
NMB 16930	B2, h	Cercado	EE	33	27	0	28.2	Cg, Lt	
USGS 8526	B2, g-h	Cercado	EE	37	16	0	34.7	Amp, Es, Lpl, Lt	
NMB 16931	B2, g-h	Cercado	EE	29	20	0	32.0	Lt	
NMB 16914	B2, g/h	Cercado	EE	47	49	0	24.0	Amp, Lt	Between levels g and h
NMB 16932	B2, g	Cercado	EE	54	41	0	24.2	Cg	
NMB 16929	B2, f	Cercado	EE	64	55	0	15.2	Cg, Lpl, Lt	
NMB 16928	B2, e	Cercado	EE	78	42	0	22.2	Cg, Lpl, Lt	
NMB 16924	B2, d	Cercado	EE	188	90	0	24.2	Cg, Lt	
NMB 16918	B2, d	Cercado	EE	123	118	0	24.0	Cg, Lt, Pc	
NMB 16926	B2, c	Cercado	EE	209	211	0	22.0	Cg, Lt	
NMB 16916	B2, b-f	Cercado	EE	47	37	0	21.7	Cg, Lt	
TU 1379	B2, b-e	Cercado	EE	254	190	0	24.6	Cg, Lt	
NMB 16915	B2, b	Cercado	EE	301	266	0	24.9	Cg, Lt	
NMB 16927	B2, b	Cercado	EE	560	483	0	27.4	Cg, Lt	
NMB 16923	B2, b	Cercado	EE	125	91	0	18.0	Cg, Lt	
NMB 16917	B2, b	Cercado	EE	69	64	0	19.0	Cg, Lt	
NMB 16922	B2, a	Cercado	EE	53	45	0	19.2	Cg, Lt	
NMB 16912	B3	Cercado	EE	153	126	0	27.1	Cg, Lt, Pc	Overlies NMB 16913
NMB 16913	B3	Cercado	EE	347	298	0	21.0	Lt	Underlies NMB 16912
USGS 8525	B3	Cercado	EE	240	232	1	19.0	Cg, Lt, Pc	
TU 1294	B3	Cercado	EE	335	289	0	26.4	Cg, Lpl, Lt, Pa, Pc	
USGS 8529	upstream from B3	Cercado	EE	3	2	0	19.5	Lt	
TU 1295	upstream from B3	Cercado	EE	3	3	0	18.7	Lt	
Río Amina									
TU 1220	level c	Gurabo?	EE	0	1	0	21.1	Amp, At, Lpl	
USGS 8518	level c	Gurabo?	EE	25	13	0	21.5	Amp, Es, Lpl	
TU 1218	level a	Gurabo?	EE	22	17	1	32.4	Lpl	
NMB 16804	level a	Gurabo?	EE	22	22	0	17.4	Amp, Lpl	

Table 7 (continued).

Locality	Level (m)	Formation	Evolutionary Stage	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Amina area									
TU 1371	--	Gurabo?	EC?	0	1	0	8.7	Amp, Ai, Ar, Eg	
Río Albano									
USGS 8729	--	Cercado	EE	37	32	0	33.3	Lt	
Río Yaque del Norte									
NMB 17268	--	?	EC?	1	1	0	11.5	Amp, Apa, Lpl	Very abraded
Río Verde									
TU 1250	--	Gurabo	EC	7	0	0	16.7	Amp, At, Cg, Cz, Es, Gu, Lpa, Pvm	Gravity flows
Santiago area									
TU 1205	--	Gurabo	EC	25	14	0	17.9	Amp, Apa, At, Es, Sv	
USGS 8726	--	Gurabo	EC	2	1	0	14.8	Anq, At, Es, Sv	
TU 1405	--	Gurabo	EC	11	8	0	19.0	At, Es	Gravity flows
TU 1339	--	Gurabo?	EC	6	5	0	18.0	At, Es, Lpl	
TU 1406	--	?	EC	11	10	0	18.1	Amp, Anj, Anq, At, Es, Lpa, Lpl, Lt, Nn	
TU 1439	--	?	EE	32	21	2	25.1	At, Es	
TU 1407	--	?	EL-II	5	10	0	16.0	Amp, Es	
Road cuts									
TU 1222	--	?	EC	10	12	0	21.0	Amp, Anq, Apa, At, Es, Lpl	
TU 1340	--	Cercado	EE	169	169	0	22.9	At, Lpl, Lt	
TU 1382	--	Cercado	EE	3	0	0	18.8	Es?	
TU 1437	--	?	EC	1	0	0	20.0	Amp, At, Lpl	

Specimens from between Bluffs 1 and 2 of the Río Mao are also *Argopecten eccentricus eccentricus* but resemble specimens from Bluff 2 levels g-h more than they resemble specimens from levels a-f based on the relatively low frequency of right valves with troughs on rib crests. However, the specimens from between Bluffs 1 and 2 differ from all of the Bluff 2 specimens in having more prominent commarginal lamellae in the rib interspaces and minute scales on the edges of the rib crests of the right valve. These specimens are associated with *A. thetidis* and *Spathochlamys vaginula*, both of which indicate deeper water, suggesting that these delicate sculptural features might be ecophenotypic.

Specimens of *Argopecten eccentricus eccentricus* from locality TU 1439 (road cut 16 km south of traffic circle at Santiago de los Caballeros, on road to Baitoa) have unusually pinched interspaces which can project from the shell margin as distally

Table 8. Percentages of RVs of *Argopecten eccentricus eccentricus* with grooved ribs on Rio Mao at Bluffs 2 and 3. Only RVs > 15 mm Ht were counted. Levels are shown in Text-fig. 6.

NMB Locality	Bluff, Level	% with grooved ribs	Specimens
16930	2, h	0	7
16914	2, g/h	31	13
16932	2, g	10	10
16928	2, e	86	14
16924	2, d	67	12
16918	2, d	80	5
16926	2, c	63	16
16917	2, b	93	14
16922	2, a	100	5
16912	3, upper	88	17
16913	3, lower	75	32

projecting spines (Pl. 5, Figs 4-5). This morphology might be phenotypic in that it consistently starts after a growth stop along which there are repaired injuries to the margin. Such repaired injuries continue to be frequent on both valves in the subsequent pinched-interspace area. In earlier parts of the valves, the morphology is typical of *A. eccentricus eccentricus*.

Comparisons.—Argopecten eccentricus eccentricus differs from *A. e. lacabrensis* n. ssp. in having nearly equiconvex rather than distinctly left-convex valves in early ontogeny, auricles of more equal length rather than with the right anterior auricle noticeably longer than the posterior auricles, less deeply sinuate posterior auricular margins that meet the dorsal margins at more obtuse angles, and earlier fade-out of dorsal costae on the right posterior auricle. Compared to *A. e. caimiticus*, *A. e. eccentricus* is less gibbous, with narrower ribs on the right valve that are trapezoidal rather than rectangular and frequently have grooved crests, and with ribs of the left valve frequently with flattened rib crests rather than sharply rounded and somewhat rugose crests.

Brown & Pilsbry (1911: 365) thought that *Pecten operculariformis* Toula, 1909, based on a single right valve from the Gatun Formation of Panama, is closely related to *Argopecten eccentricus s. l.* from the Dominican Republic. This relationship is not at all indicated by Toula's figure (1909: pl. 26, fig. 3), which shows that his species is in the genus *Euvola*.

Argopecten eccentricus eccentricus closely resembles the extant Caribbean *A. nucleus* in shape, ribbing, and size of auricles in relationship to disk, but the latter differs in being more gibbous and in having prominent radial costae on its disk flanks forming a transition in amplitude between disk ribs and auricular costae.

Evolution.—Argopecten eccentricus s. l. of the northern Dominican Republic is a species lineage with substantial morphological variation within and among samples. The species is subdivided here into three successive chronological subspecies: *A. e. lacabrensis* n. ssp., *A. e. eccentricus*, and *A. e. caimiticus*. These subspecies are interpreted to be evolutionary stages of a single lineage, because (a) they occur in stratigraphic sequence without apparent reversals, (b) they are connected by transitional forms within the stratigraphic intervals that separate the subspecies, and (c) morphological changes within each of the first two subspecies also occur in stratigraphic sequence. That these subspecies are not merely ecophenotypes resulting from increasing depths of deposition within the measured river sections is suggested by the fact that all three subspecies occur in shallow-water facies. This facies appears to represent a fairly uniform, seagras-supporting, shallow-water marine paleoenvironment as indicated by other fossils, including benthic foraminiferans, gastropods, and other bivalves (see section on Paleoecology).

The biostratigraphic implications of the distributions of these subspecies within the Cibao Valley are discussed in the section on Biostratigraphy at the beginning of this monograph.

Occurrence.—Argopecten eccentricus eccentricus occurs in the upper Cercado and lowermost Gurabo formations, of Late Miocene age (Table 7).

Distribution.—The presence of *Argopecten eccentricus eccentricus* outside of the Dominican Republic has not yet been substantiated.

Argopecten eccentricus lacabrensis n. ssp.
Pl. 5, Figs 6-22; Table 7

Diagnosis.—Argopecten eccentricus having a posterior auricle with a deeply sigmoidal posterior margin and auricular costae that extend to this margin.

Description.—Shell not known to exceed 24 mm Ht, with length greater than height in mid- to late-ontogeny. Dorsal-ventral profile of RV commonly "humped," with change from low relative convexity in early ontogeny to higher relative convexity in late ontogeny occurring at 10-12 mm Ht; LV more convex than RV in early ontogeny, becoming less convex than RV later. Disks with 20-22 interlocking radial ribs; rib crests narrower than interspaces on both valves in early ontogeny, on RV becoming approximately equal or slightly wider than

interspaces in late ontogeny; ribs of RV sharply rounded in profile in early ontogeny, gradually becoming steep-sided trapezoidal with gently rounded, flattened, or slightly depressed or grooved crests; rib profiles of LV high and sharply rounded in early ontogeny, becoming trigonal with rounded or slightly flattened crests in later ontogeny. Commarginal lamellae commonly arcuate in low-convexity stage of early ontogeny, less commonly persisting throughout ontogeny; lamellate phases rare in stratigraphically lower forms, more common in higher forms. Right anterior auricle relatively long and narrow with deep byssal notch in early ontogeny, becoming relatively shorter with 3 or 4 radial costae in later ontogeny but remaining longer than posterior auricle. Right posterior auricle with moderately sinuate to nearly straight posterior margin with overall trend of margin forming angle with dorsal margin that ranges from slightly acute to slightly obtuse; costae of this auricle uniformly developed and persisting to posterior margin in stratigraphically lower forms but more weakly developed in stratigraphically higher forms, where dorsal costae fade out but ventral costae remain weak to margin. Disk flanks of LV possessing 1-3 fine, commonly scabrous, radial costellae in early ontogeny, fading out at 2-4 mm from beak measured along disk flank; disk flanks of RV lower than on LV, with radial costellae in early ontogeny fading earlier in ontogeny than on LV. Hinge dentition as in *Argopecten eccentricus eccentricus*.

Etymology.—Named after Arroyo La Cabra, which enters the left bank of the Río Gurabo at locality NMB 15913 (Saunders *et al.*, 1986: text-fig. 4). This locality in the Cercado Formation yielded *Argopecten eccentricus lacabrensis* n. ssp. in evolutionary stage I (see below), as did localities on the Río Gurabo immediately upstream and downstream from this site.

Type material and measurements.—Holotype: NMB G17502, 1 RV, 19.5 mm Ht, 21.2 mm L, 6.6 mm cvx (Pl. 5, Figs 6-10).

Type locality.—NMB 15909, Cercado Formation, 111-113 m above base of section, Río Gurabo.

Other material.—10,488 specimens from 50 localities in the northern Dominican Republic (Table 7). Except for 4 juvenile articulated DV, all of these are single valves.

Specimens from localities NMB 15873, 15896, and 15909 are illustrated on Pl. 5, Figs 11-22.

Remarks.—Argopecten eccentricus lacabrensis n. ssp., as discussed above under *A. e. eccentricus,* is regarded as the ancestral segment of a single lineage, the descendant segments being *A. e. eccentricus* followed by *A. e. caimiticus*. *Argopecten e. lacabrensis* n. ssp. can be subdivided into two evolutionary stages, indicated as *A. e. lacabrensis*-I and *A. e. lacabrensis*-II (abbreviated EL-I and EL-II), which differ in shape and costation of the right posterior auricle and in width of disk ribs relative to width of interspaces. In EL-I, the posterior margin of the right posterior auricle is distinctly sigmoidal with an overall trend that is approximately perpendicular to the hinge or even slightly acute (trace growth lines on posterior auricle in Pl. 5, Figs 6, 11). In EL-II, this margin is straighter with only a very shallow sinus at > 15 mm Ht and with an overall trend that forms an obtuse angle with the dorsal margin (Pl. 5, Figs 15, 19-20). In EL-I, the costae of the right posterior auricle are uniformly developed and tend to persist to the posterior margin of the auricle even in the largest specimens (Pl. 5, Figs 6, 11, 13). In EL-II, these auricular costae are evenly developed in early ontogeny, but then either all of the costae or only the dorsal costae fade out before reaching the posterior margin, generally at a radial distance from the beak of > 2.5 or 3 mm, whereas the ventral costae, although weak, persist to the margin (Pl. 5, Figs 15, 19-20).

Specimens of *Argopecten eccentricus lacabrensis* n. ssp. also vary in the degree of development of commarginal lamellae. Lamellate phases (Pl. 5, Figs 19-21) are sculptural ontogenetic phases dominated by projecting commarginal lamellae in interspaces and over the ribs. Although these phases are transient during ontogeny, they are more common in EL-II than in EL-I. In some small specimens, the entire surface can be lamellate (Pl. 5, Figs 20-21), but in some larger specimens, the lamellate phase terminates and later growth is non-lamellate (Pl. 5, Fig. 19) like that of most members of the subspecies. The two evolutionary stages also differ in the presence and extent of the disk-flank costae on the left valve in early ontogeny, those of EL-II disappearing earlier compared to EL-I.

Samples from the Río Gurabo *ca.* 118-125 m above the base of the section contain specimens that are transitional between the two evolutionary stages (Text-fig. 3, Table 7). At NMB 15903 (120 m above base of section), for example, there is variation in almost every character, including strength of costae on the right posterior auricle and depth of the right posterior auricular sinus, which in some specimens becomes obsolete early in ontogeny. All of the stratigraphically highest representatives of EL-II in the Río Gurabo (155-208 m above base of section) have a very extensive re-entry of foliated-calcite on valve interiors extending ventrally well over halfway to the pallial line, commonly to the level of the bottom of the nonstriate adductor scar on the right valve and the bottom of the undifferentiated adductor scar of the left valve (Pl. 5, Fig. 22). In the Cercado Formation on the Río Cana, both high-calcite and low-calcite forms of EL-II are present.

Comparisons.—Argopecten eccentricus lacabrensis n. ssp. differs from *A. e. eccentricus* in having a more left-convex early growth stage in which the right anterior auricle is relatively larger, narrower ribs on the right disk, and, in the stratigraphically lower form, a right posterior auricle on which the radial costae are undifferentiated and persist to a posterior auricular margin and a deeper posterior auricular sinus. *Argopecten e. lacabrensis* n. ssp. differs from *A. levicostatus* (Toula, 1909) of the Gatun and Chagres formations of Panamá (Woodring, 1982: 596) in having smaller auricles, straighter posterior auricular margins that form a less acute angle with the dorsal margin, and lower convexity of the right valve in early ontogeny.

Evolution.—See under preceding remarks and under *Argopecten eccentricus eccentricus*.

Occurrence.—The occurrences of the two evolutionary stages of *Argopecten eccentricus lacabrensis* n. ssp. are shown in Table 7. EL-I is known only from the lower Cercado Formation in the Río Gurabo section between 59 and *ca.* 120 m above the base of the section. EL-II is known from the Río Cana, Río Gurabo, and in an area *ca.* 18 km southwest of Santiago de los Caballeros (locality TU 1407). In the Río Gurabo section, EL-II succeeds EL-I, extending from *ca.* 120 m to 226 m above the base of the section, disappearing where the shallow-water Cercado sediments are gradually replaced by the deep-water Gurabo facies. Within this stratigraphic range of EL-II in the Río Gurabo section, the upper 75 m contains only the variant of EL-II that has very extensive foliated-calcite on the valve interior, extending to the level of the base of the adductor scar and nearly reaching the pallial line. This variant is the only one present in the Río Cana section and in the Santiago area at TU 1407 (Table 7).

Distribution.—Argopecten eccentricus lacabrensis n. ssp. has not been recognized outside of the Dominican Republic.

Argopecten eccentricus caimiticus (Maury, 1917a)
Pl. 6, Figs 1-7; Table 7

Pecten caimitica Maury, 1917a: 189, pl. 34, fig. 12.

Original description.—"The shell is suborbicular, slightly oblique, convex in the umbonal region but elsewhere rather compressed; surface ornamented with twenty-two narrow, rounded, radial ribs with narrower, concave interspaces; ribs and interspaces marked only by concentric, looped growth lines; ears very small, nearly equal, radially threaded. Length 20, altitude 20, semidiameter 5 mm. The species is distinguished by its more numerous ribs and very small ears" (Maury, 1917a: 189).

Description.—Shell small and gibbous, commonly < 20 mm Ht and not known to exceed 23 mm, with length and height approximately equal, rarely with height greater than length; convexity of RV exceeding that of LV beginning early in ontogeny. Disks commonly with 21-23 interlocking radial ribs, much broader on RV than on LV; profiles of ribs of RV steep-sided trapezoidal to nearly rectangular, with flattened crests much wider than interspaces beginning in early ontogeny and commonly very smooth, without medial troughs; edges of rib crests commonly with small scales formed by projecting commarginal lamellae; ribs of LV nearly trigonal with narrow, rounded crests commonly slightly rugose in early ontogeny where crossed by widely spaced commarginal lamellae; commarginal lamellae commonly present in interspaces of both valves throughout ontogeny, on LV crossing rib crests in distally concave arcs in late ontogeny; arcuate and lamellate phases absent. Auricles small and approximately equal in length; anterior auricle of RV commonly with only 3 radial costae and anterior margin highly beveled or rounded adjacent to dorsal margin; posterior margin of right posterior auricle lacking posterior sinus and with posterior margin forming obtuse angle at intersection with dorsal margin; costae of right posterior auricle well differentiated dorsoventrally, with dorsal costae fading out early in ontogeny (commonly at < 2 mm radial distance from beak) and 2 or 3 ventral costae remaining relatively strong and clustered, extending to posterior margin. Disk flanks of RV either without radial costae or with low, obscure costae; one or both disk flanks of LV having obscure, low, rounded radial costae. Foliated-calcite re-entry of RV not extensive, commonly separated from anterior margin of striate adductor scar by a dorsally projecting narrow lobe of aragonite, less commonly extending into the anterior separation between the striate and nonstriate adductor scars; foliated-calcite re-entry of LV commonly extending only to level of middle of the adductor scar or less. Arcuate and lamellate phases absent.

Type material and measurements.—Holotype, PRI 28969, 1 LV, 18.8 mm Ht, 19.2 mm L, 5.0 mm cvx (Pl. 6, Figs 1-3).

Type locality.—Maury (1917a: 189) gave the locality of her single specimen as "Zone I [eye], Rio Cana at Caimito," but see the following remarks questioning this locality.

Other material.—Approximately 700 specimens from 41 localities in the northern Dominican Republic (Table 7). All but one of these specimens are single valves.

Remarks.—Maury (1917a: 189, pl. 34, fig. 13) described a new species, *Pecten caimitica*, on the basis of a single left valve (Pl. 6, Figs 1-3) said to be from "Zone I, Rio Cana at

Caimito," but it is doubtful that this specimen is from that zone. Maury's (1917b: fold-out correlation chart) Zone I and overlying Zone H comprise her "*Aphera islacolonis* Formation," which she later named the Cercado Formation (Maury, 1919). Zone I outcrops upstream from the old crossing of the Río Cana at El Caimito in an area that Maury (1917b: 26) referred to as "Above Caimito, Orchid gorge," but she did not give its precise location. Subsequent field work by the Vokeses (E. Vokes, 1989: 62) determined that this locality might be TU 1282, "Arroyo Beyaco [or Bellaco], a tributary of the Río Cana to the east, *ca.* 1 km above the ford at Caimito on the Los Quemados-Sabaneta road." This locality (plotted by Saunders *et al.,* 1986: text-fig. 15) did not yield any pectinids and was not resampled by the NMB team. However, the nearest pectinid-bearing sample upstream (and hence stratigraphically lower because of the fairly uniform dip of the strata) is NMB 16857, 148 m above the base of the Río Cana section of Saunders *et al.* (1986: text-fig. 15), where the only *Argopecten* present is *A. eccentricus lacabrensis* n. ssp. in evolutionary stage II (see discussion under that subspecies). The nearest pectinid-bearing sample downstream (stratigraphically higher) is TU 1230, which, by extrapolation onto the Saunders *et al.* (1986: text-fig. 24) section, assuming a uniform dip, is *ca.* 200 m above the base of the section. The only *Argopecten* present at this locality, which was determined to have a fauna indicative of Maury's Zone H of the Cercado Formation by the Vokeses (see Saunders *et al.*, 1986: 65), is the same subspecies and evolutionary stage as that which occurs upstream. The single left valve of *Pecten caimitica* described by Maury, however, compares very closely to specimens that occur stratigraphically above *A. e. eccentricus* and that are regarded herein as a chronological subspecies, *A. e. caimiticus*. This subspecies first appears along the Río Cana at 228 m above the base of the section at NMB 16852 (Saunders *et al.*, 1986: text-fig. 15). This locality is downstream from El Caimito and is among the so-called "*Arca* beds" that were placed by Maury (1917b: correlation table) in her "*Sconsia laevigata* Formation," later named the Gurabo Formation (Maury, 1919).

Comparisons.—Argopecten eccentricus caimiticus is similar to *A. e. eccentricus* but smaller, more gibbous, with broader ribs lacking medial troughs on the right valve and more trigonal, somewhat rugose ribs on the left valve. Compared to the extant species *A. nucleus*, *A. e. caimiticus* has relatively smaller auricles and the costae on disk flanks are somewhat finer, forming a less complete transition from the size of costae on auricles to the size of ribs on the adjacent disk.

Evolution.—See under *Argopecten eccentricus eccentricus*.

Occurrence.—Argopecten eccentricus caimiticus occurs in the uppermost Miocene and lower Pliocene in the shallow-water phases of the Gurabo Formation in a stratigraphic position that is inferred to be above that of *A. e. eccentricus*. *Argopecten e. caimiticus* is abundant on the Río Cana beginning in the vicinity of the "*Arca* beds" 228 m above the base of the section and extending to the upper Gurabo Formation at 427 m above the base of the section (Table 7). The only occurrence in the Río Gurabo section is at 222-226 m above the base of the section (NMB 16808). Above this level, this subspecies was apparently excluded by deep-water conditions. At locality TU 1250 on the Río Verde and locality TU 1405 in the Santiago area, *A. e. caimiticus* occurs in gravity flows that carried sediments of the shallow-water Cercado facies into the Gurabo facies.

Distribution.—Argopecten eccentricus caimiticus has thus far not been recognized outside of the Dominican Republic.

Argopecten inaequalis (G. B. Sowerby I, 1850)
Pl. 6, Figs 8-14; Table 9

Pecten inaequalis G. B. Sowerby I, 1850: 52; Gabb, 1873: 256; Pilsbry, 1922: 412, pl. 45, fig. 11.

Not *Pecten inaequalis* Sowerby. Guppy, 1866: 294, pl. 18, fig. 6 [= *Pecten uselmae* Pilsbry & Johnson, 1917].

Pecten (*Aequipecten*) *inaequalis* Sowerby. Dall, 1898: 714 [in part].

Chlamys inaequalis (Sowerby). Woodring, 1925: 70.

Aequipecten inaequalis (Sowerby). Pflug, 1961: 78, pl. 24, figs 2-3.

Original description.—"Testa suborbicularis, tumidiuscula, costellis radiantibus 19, rotundatis, laevibus, subdistantibus, superne lineis decussantibus hic illic spasim notatis; interstitiis rotundatis, laevibus, aequidistantibus; alterius valvae costellis angustioribus interstitiis latioribus, laevissimus; auribus inaequalibus, radiatim costellatis" (Sowerby, 1850: 52)

Description.—Shell not known to exceed *ca.* 30 mm Ht, slightly inequilateral with posterior somewhat extended, length slightly exceeding height in large specimens, slightly less than height in smaller specimens. Convexity of valves moderately unequal, with RV convexity 21-25% Ht and LVconvexity commonly 17-18% Ht in large specimens. Disks commonly with 18-20 simple, non-branching, moderately high, interlocking radial ribs separated by interspaces of equal width; rib profiles rounded-trigonal to rounded, uncommonly with slight medial keel; commarginal lamellae commonly present in rib interspaces only in first 4-6 mm of growth, passing straight or with only minor curvature across interspaces, then becoming unevenly spaced and very flat-lying, detectible mainly as commarginal white lines against gray background; surface commonly glossy on both ribs and interspaces. Disk

flanks low and moderately steep, without radial costellae. Auricles unequal in size, with posterior longer than anterior; right anterior auricle with 3 or 4 evenly spaced radial costae that continue to margin, scrolled dorsal margin, and nearly circular anterior margin; byssal notch moderately shallow, with short, active ctenolium containing few, very small active teeth in late ontogeny located on upwardly curved flange of anterior disk flank; left anterior auricle with moderately deep byssal sinus, posterior auricles with posterior margins forming acute angle with dorsal margins; costae on left anterior and both posterior auricles weak, fading out in early ontogeny at distance from beak of 3-6 mm, except for ventralmost 1 or 2 costae, which commonly continue to margin. Hinge dentition of RV dominated by long resilial teeth bordered dorsally by sockets for correspondingly long infadorsal teeth of LV and ventrally by shallow depressions to accommodate infraresilial teeth of LV; infradorsal teeth of LV asymmetric in cross section, inclined dorsally beneath outer ligaments of RV; hinge teeth on both valves with prominent cross-ridges. (See Materials and Methods section regarding terminology of pectinid hinge dentition.) Extent of foliated-calcite re-entry on interior of RV consistently extending ventrally nearly to pallial line in late ontogeny, on RV completely underlying striate adductor scar, which is separated from nonstriate adductor scar in early ontogeny, and also underlying entire ventral margin of nonstriate scar; on LV foliated-calcite re-entry underlying entire adductor scar. Dorsal margin of adductor scar of LV evenly convex toward dorsum, lacking dorsally projecting lobe of byssal retractor scar.

Type material and measurements.—Lectotype of *Pecten inaequalis*, BMNH LL11354, 1 articulated DV missing posteroventral region, 28.3 mm Ht, designated and figured by Pflug (1961: 78, pl. 24, figs 2-3), from the Dominican Republic "Miocene." A cast of the lectotype is present in the Cenozoic Mollusk Type Collection of the Smithsonian Institution (USNM 354160).

Type locality.—The lectotype is from the Heneken Collection studied by Sowerby. For reasons stated above under *Argopecten thetidis*, the location cannot be more precise than Cibao Valley, northeastern Dominican Republic.

Other material.—207 specimens from 20 localities in the northern Dominican Republic (Table 9). All of these are single valves.

Remarks.—Argopecten inaequalis is not a highly variable species. At the same shell size, minor differences in height versus length, distance of fade-out of auricular costae from the beak, shapes of the posterior auricles, and degree of inflation of the valves can be found within single samples and do not appear to display any stratigraphic trends. A few specimens have faintly keeled ribs, but there is intergradation between this state and evenly rounded, nonkeeled ribs. The same applies to trigonal rib profiles, which in some cases approach those of some specimens of *A. thetidis* but are not as high and narrow.

Comparisons.—Argopecten inaequalis differs from *A. eccentricus s. l.* in having an extensive foliated-calcite re-entry that extends around the ventral sides of the adductor scars on both valves (Pl. 6, Fig. 9). Unlike both *A. eccentricus s. l.* and *A. thetidis*, the rib crests of *A. inaequalis* lack medial troughs. Unlike any of the other species of *Argopecten* in the Neogene of the Dominican Republic, *A. inaequalis* has a glossy external surface on which growth lamellae become exceedingly thin and flat-lying, detectible mainly as white commarginal lines on the exterior surface. The glossy surface and rounded ribs of *A. inaequalis* resemble comparable features of the extant species *A. lineolaris* (Lamarck, 1819), but the latter has much lower, nearly obsolete ribs in late ontogeny, a posterior auricular margin that forms an obtuse angle with the dorsal margin, weak or obsolescent auricular costae, and a shallower byssal notch.

Evolution.—The extensive foliated-calcite re-entry, separated striate and nonstriate adductor scars on the right valve, acute posterior auricles, and detailed configuration of auricular costae suggest that *Argopecten inaequalis* is in the same clade as *A. thetidis*. This is further indicated by the presence in a few specimens of *A. inaequalis* of lateral rib profiles with just a hint of angularity (Pl. 6, Fig. 14), as well as a hint of incipient (or vestigial) crestal troughs as indicated by deflections of growth lines on rib crests. Stratigraphic relationships suggest that *A. inaequalis* is the descendant species, although the absence of costellae on its disk flanks suggests that it evolved from *A. thetidis* before the latter developed prominently costate disk flanks, a feature that is more common in the stratigraphically higher *A. thetidis*.

The morphological features that distinguish *Argopecten inaequalis* from other late Miocene-Pliocene Caribbean *Argopecten* are similar to those that distinguish modern *A. lineolaris* from other extant Caribbean *Argopecten*. Basically, the shell smoothness, rounded ribs, and lack of projecting commarginal lamellae are characters (carried to the extreme in the genus *Amusium*) that facilitate mobility on shifting sandy or silty sea bottoms. A facility for swimming is indicated in *A. inaequalis* by its relatively thin shell, low convexity, nearly obsolete ctenolium, shallow byssal notch, adductor scars that appear to be larger than normal for *Argopecten*, and a lack of a lobate pedal retractor scar on the left valve. These

Table 9. Occurrence of *Argopecten inaequalis* in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Amp, *Amusium papyraceum*; At, *A. thetidis*; B1, Bluff 1 of Maury (1917b); Cg, *Cyclopecten guppyi*; Crp, *Cryptopecten phrygium*; Cz, *Cyclopecten zalaya* n. sp.; Dm, *Dimya* sp.; DV, matching valves; Eg, *Euvola gurabensis* n. sp.; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Ini, *Interchlamys interlineata*; Lpa, *Lindapecten paramuscosus* n. sp.; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Nn, *N. nodosus*; Pvm, *Parvamussium marmoratum*; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo								
NMB 15842	314-317.5	Gurabo	2	5	0	29.8	At, Sv	
NMB 15844	310-313.5	Gurabo	0	1	0	21.9	At, Dm	
NMB 15863	234.5-238	Gurabo	2	1	0	27.0	At, Dm	
NMB 15866	227	Gurabo	0	1	0	23.0	At, Lpa	
TU 1277	222-226	Gurabo	2	2	0	30.0	Amp	
NMB 15870	218.5	Gurabo	0	2	0	28.0	Amp, At	
Río Mao								
TU 1334	--	Mao?	5	8	0	31.0	Amp, At	
TU 1225	downstream from B1	Gurabo	1	0	0	28.0	Amp, At, Es, Lpa, Nn	
USGS 8733	downstream from B1	Gurabo	1	0	0	32.1	Crp	
USGS 8734	downstream from B1	Gurabo	0	2	0	23.0	At, Ini	
USGS 8527	downstream from B1	Gurabo	1	0	0	15.0	At	
TU 1293	B1	Gurabo	0	1	0	22.0	Amp, At	
USGS 8519	B1	Gurabo	0	1	0	18.7	Amp, At	
Río Amina area								
TU 1371	--	Gurabo?	5	6	0	18.3	Amp, Aec?, At, Eg	
TU 1436	--	Gurabo?	5	9	0	24.8	Dm	
Santiago area								
TU 1227A	--	Gurabo	15	16	0	31.0	Amp, At, Cg, Cz, Gu, Lpa, Pvm, Sv	Arroyo Zalaya, turbidity-flow lens (Vokes & D'Attilio, 1980: 52)
TU 1380	--	Gurabo?	33	44	0	26.5	Amp, At, Sv	
Road cuts								
TU 1254	--	Gurabo	11	17	0	29.0	Amp, At	
TU 1335	--	Gurabo?	3	3	0	27.0	Amp, At	
TU 1409	--	Gurabo?	1	0	0	20.0	Amp, At, Sv	

similarities, however, are analogous rather than homologous. The auricular shapes and early ontogenetic rib profiles of *A. lineolaris* suggest that it has a different ancestry, possibly lying within the *A. gibbus* (Linnaeus, 1758) stock (Waller, 1991: 34). Juvenile specimens of *A. inaequalis* (Pl. 6, Fig. 14), in which rib profiles of some specimens are angular, suggest descent from *A. thetidis*.

If *Argopecten inaequalis* is indeed descended from *A. thetidis*, it is not clear how speciation occurred, because there is good evidence that the two species were sympatric during the time of deposition of the Gurabo Formation. All but two of the 19 localities that yielded *A. inaequalis* also yielded *A. the-*

tidis. The most likely explanation is that speciation was allopatric, with a population of *A. thetidis* becoming morphologically divergent and reproductively isolated, and then spreading and overlapping ancestral populations of *A. thetidis*.

Occurrence.—Argopecten inaequalis is restricted to the Gurabo Formation (Table 9). In the Río Gurabo section, it was collected from 218 to 314-317.5 m above the base of the section. These beds are below the Miocene/Pliocene boundary, determined by Saunders *et al.* (1986: text-fig. 14) to be at *ca.* 400 m above the base of the section, and lie within nannoplankton zone NN-11. On the Río Mao, *A. inaequalis* occurs in the Gurabo Formation at Maury's Bluff 1 and downstream from Bluff 1 at least as far as Arroyo La Sibirma, 8 km (airline) south of Mao. The latter might be the youngest occurrences of the species, although the age of these beds relative to the Miocene/Pliocene boundary has not been determined. The species is unknown from the Mao Formation, the type section of which is further downstream (TU 1337, 3 km airline south of Mao) and which is in nannoplankton zone NN-16, of late middle Pliocene age (Saunders *et al.*, 1986: 32). Other occurrences are listed in Table 9.

Distribution.—Argopecten inaequalis is known with certainty only from the Gurabo Formation of the Dominican Republic.

Argopecten parathetidis n. sp.
Pl. 6, Figs 15-22; Table 10

Diagnosis.—Small, right-convex *Argopecten* with 19-21 ribs having central keel and parabolic cross section; disk flanks lacking radial costellae.

Description.—Shell not known to exceed 15 mm Ht, either equilateral or slightly extended posteroventrally, length and height approximately equal or with length slightly exceeding height. Convexity moderate, with RV commonly more convex than LV in late ontogeny. Disks with 19-21 simple, nonbranching, interlocking radial ribs separated by deep interspaces of approximately same width; rib profiles of both valves parabolic in late ontogeny, with narrow raised keel in center of crests of medial ribs or offset to anterior or posterior side of anterior or posterior ribs respectively. Commarginal lamellae in rib interspaces of both valves prominent, forming distally convex arcs across interspaces, distally concave arcs on rib flanks, and very narrow distally pointing loops on rib keels; projecting scales and secondary radial costae absent. Disk flanks moderately steep and smooth except for fine commarginal lamellae. Auricles of moderate size; anterior auricles commonly longer than posterior; right anterior auricle with 4 prominent slightly scabrous radial costae, slightly scrolled dorsal margin, rounded anterior margin, and moderately deep byssal notch and short ctenolium of 2 or 3 teeth commonly hidden beneath anterior flange of adjacent disk flank; other auricles commonly with 6 or 7 radial costae that do not fade distally, left anterior auricle with byssal sinus, posterior margins of posterior auricles with deep sinus and overall trend forming acute angle with dorsal margin. Right hinge with single strong resilial tooth on each side of resilifer, each bordered dorsally by deep socket to accommodate dorsal tooth of LV; irregular cross ridges prominent on all hinge teeth. Extent of foliated-calcite re-entry on interior of both valves very extensive in late ontogeny, filling space between striate and nonstriate adductor scars of RV and extending along ventral margin of adductor scar of LV.

Etymology.—Prefix *para-*, meaning "near," combined with species name *thetidis* to indicate a close relationship of the new species to *Argopecten thetidis*.

Holotype and measurements.—USNM 540962, 1 RV, 13.3 mm Ht, 14.0 mm L, 5.3 mm cvx (Pl. 6, Figs 15-18).

Type locality.—Locality TU 1224, road cut 6.1 km west of Los Quemados, or 3.1 km west of Río Gurabo, on road to Sabaneta, Gurabo Formation, northern Dominican Republic. This locality was not plotted by Saunders *et al.* (1986). The Vokeses, in their entry in the Tulane Locality Register, assigned it to the Gurabo Formation.

Other material.—114 specimens (62 RV, 52 LV) from 9 localities in the northern Dominican Republic (Table 10).

Remarks.—Argopecten parathetidis n. sp. exhibits a consistent morphology among the nine localities at which it was found, perhaps because these localities fall within a narrow stratigraphic range within the Lower Pliocene part of the Gurabo Formation, suggesting that there was insufficient time for evolutionary change. Pectinids associated with the new species (Table 10) include both shallow-water species (*A. eccentricus caimiticus*, *Lindapecten plurinominis*) and deeper-water forms (*A. thetidis*, *Gurabopecten uniplicatus* n. gen., n. sp.). *Dimya* sp., a deep-water indicator, as well as pycnodontinine oysters are present at the type locality, TU 1224.

Comparisons.—Argopecten parathetidis n. sp. compares most closely with the variants of *A. thetidis* that have sharply trigonal ribs and smooth disk flanks (conforming to the morphology of *Pecten oxygonum* G. B. Sowerby I, 1850, now regarded as a junior synonym of *A. thetidis*). These forms, however, attain a much larger size, and their rib profiles are trigonal rather than

parabolic and lack a distinctly differentiated keel. At the six localities (Table 10) at which *A. parathetidis* n. sp. is associated with *A. thetidis*, the latter are all of the advanced form with distinctly costellate disk flanks and grooved rib crests commonly with prominent scales along the edges of the crests.

The left valve of *Argopecten parathetidis* n. sp. (Pl. 6, Fig. 19) somewhat resembles some left valves of *A. uselmae* in which the ribs in late ontogeny are parabolic in cross section with a narrow keel on the rib crest. These also have an extensive foliated-calcite re-entry that passes along the ventral margin of the adductor scar. In these specimens of *A. uselmae*, however, the commarginals are much less prominent and do not form the tight distally pointed loops on the keels that are present in *A. parathetidis* n. sp. Furthermore, the right valves of *A. uselmae* have rounded or flattened ribs without keels, very unlike the right valves of *A. parathetidis* n. sp.

The extant species *Argopecten noronhensis* (Smith, 1885) has keeled parabolic ribs on its left valve similar to those of *A. parathetidis* n. sp., but the right valve of the former, like that of *A. uselmae*, has ribs with smooth, broad, non-keeled crests (Waller, 1973: figs 5-8).

Evolution.—Argopecten parathetidis n. sp., like *A. thetidis*, is apparently endemic to Hispaniola and is assumed to have originated there. The new species is possibly an offshoot of *A. thetidis*, which has a similarly shaped posterior auricle and extensive foliated-calcite re-entry. Some *A. thetidis* individuals have a short "*parathetidis*" phase in their ontogeny, wherein the ribs are trigonal with a central keel and with prominent looped commarginal lirae crossing the keel.

Argopecten parathetidis n. sp. is possibly ancestral to the *A. noronhensis* lineage, a relationship that is suggested by similarities in the sculpture and profiles of the ribs of left valves. Just as *A. thetidis* developed expanded rib crests possibly in response to life on fine sediment, so also *A. noronhensis*, an extant deep-water species, might have expanded the rib crests of its right valve, retaining plesiomorphic parabolic keeled ribs on the left valve.

Occurrence.—Argopecten parathetidis n. sp. occurs in the Río Cana section (NMB 16825) above the Miocene-Pliocene boundary as determined by Saunders *et al.* (1986: 23). In the Río Gurabo section, the species is known only from TU 1211 (= USGS 8546). According to Saunders *et al.* (1986, compare text-figs 4-5, and 14), this collecting station spans a stratigraphic interval that includes the Miocene-Pliocene boundary based on either the NN11-NN12 zonal boundary or the first occurrence of *Globorotalia margaritae* Bolli & Bermúdez, 1965. Along the Río Yaque del Norte, *A. parathetidis* n. sp. occurs at La Barranca in beds that were determined by Saunders *et al.* (1986: 30) to be in the upper part of the *G. margaritae* zone dated as late Early Pliocene. Localities TU 1206 and TU 1207, which also yielded *A. parathetidis* n. sp., are presumably also in the *G. margaritae* zone. The road cuts sampled by the Vokeses (TU 1222, 1224, and 1299) are not tied into stratigraphic sections, but if their elevation is higher than nearby river canyons, then they can be expected to be fairly high stratigraphically. This is corroborated by the co-occurrence of *A. parathetidis* n. sp. with advanced *A. thetidis* as well as *A. eccentricus caimiticus* at TU 1222. The same association occurs in the Santiago area at TU 1205. Saunders *et al.* (1986: 30) determined that beds in this area, as at La Barranca, are in the Pliocene. In all cases where *A. parathetidis* n. sp. is associated in the same samples with *A. thetidis*, the latter are of the advanced form with strongly costate, scabrous disk flanks.

Distribution.—Argopecten parathetidis n. sp. is thus far known only from the Cibao Valley, northern Dominican Republic.

Argopecten thetidis (G. B. Sowerby I, 1850)
Pl. 7, Figs 1-19; Table 11

Pecten thetidis G. B. Sowerby I, 1850: 52; Gabb, 1873: 256; Pilsbry, 1922: 410, pl. 44, figs 3, 6.

Pecten oxygonum G. B. Sowerby I, 1850: 52; Pilsbry, 1922: 411, pl. 45, figs 4-6; not Gabb, 1873: 256 [= *Lindapecten plurinominis* (Pilsbry & Johnson, 1917)].

Pecten exasperatus Sowerby. Guppy, 1866: 294 (not of Sowerby, 1842).

Pecten augusticostatus Gabb, 1873: 256; Pilsbry, 1922: 412, pl. 45, figs 7-8.

Pecten oxygonus Sowerby. Guppy, 1876: 532 [incorrect spelling].

Pecten (*Pecten*) *eugrammatus* Dall, 1898: 712, pl. 34, fig. 2; Ramírez, 1950: 34, pl. 7, fig. 3.

Pecten (*Aequipecten*) *oxygonum* Sowerby. Dall, 1898: 713.

Pecten (*Aequipecten*) *angusticostatus* Gabb, 1873. Dall, 1898: 714 (unjustified emendation of spelling).

Not *Pecten* (*Aequipecten*) *thetidis* Sowerby. Dall, 1898: 714-715, in part [= *Lindapecten* sp.]; Maury, 1917a: 185, pl. 34, fig. 6 [= *L. plurinominis* (Pilsbry & Johnson, 1917)]; Cooke, 1919: 138, pl. 11, figs 4-6 [= *Lindapecten* sp.].

Pecten hatoviejonis Maury, 1917a: 189, pl. 34, figs 13-14.

Not *Pecten* (*Aequipecten*) *oxygonum* Sowerby?. Cooke, 1919: 137, pl. 5, fig. 5 [= *Lindapecten* sp.].

Not *Pecten* (*Aequipecten)* sp. cf. *oxygonum* Sowerby. Cooke, 1919: 138, pl. 10, fig. 7 [= ?*Lindapecten* sp.].

Pecten thetidis pelei Pilsbry, 1922: 411, pl. 44, figs 4-5.

Chlamys thetidis (Sowerby). Woodring, 1925: 67.

Chlamys oxygonum (Sowerby). Woodring, 1925: 67.

Aequipecten thetidis (Sowerby). Pflug, 1961: 79, pl. 24, figs 4, 12 (lectotype).

Table 10. Occurrence of *Argopecten parathetidis* n. sp. in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Amp, *Amusium papyraceum*; Anq, *Antillipecten quemadosensis* n. sp.; At, *A. thetidis*; Dm, *Dimya* sp.; DV, matching valves; Eg, *Euvola gurabensis* n. sp.; Es, *E. soror*; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis s. s.*; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana								
NMB 16825	321	Gurabo	1	0	0	11.2	Amp, Anq, At, Lpl	
----------								Miocene/Pliocene boundary at least as low as 315 m (Saunders *et al.*, 1986)
Río Gurabo								
TU 1211	381-385	Gurabo	3	0	0	13.9	Ap, At, Gu, Lpa, Sv	
Río Yaque del Norte								
TU 1206	--	Gurabo?	2	0	0	12.2	Amp, At, Es, Sv	
TU 1207	--	Gurabo?	3	0	0	12.1	Amp, At	
NMB 17268	--	Gurabo?	1	1	0	11.5	Aec, Amp, Lpl	
Santiago area								
TU 1205	--	Gurabo	14	11	0	14.0	Aec, Amp, At, Es, Sv	
Road cuts								
TU 1224	--	Gurabo	24	28	0	14.9	Anq, Dm, Eg	Type locality of *A. parathetidis* n. sp.
TU 1299	--	Gurabo?	12	10	0	14.0	Anq, Lpa, Ncv	
TU 1222	--	Gurabo?	2	2	0	12.2	Aec, Amp, Anq, At, Es, Lpl	

Original descriptions.—Pecten thetidis G. B. Sowerby I, 1850: 52: "Testa orbicularis, tumida, radiatim costata, costarum marginibus quadratis, ad utrumque latus squamuliferis, squamulis minutissimis, interstitiis rugulosis; auribus inaequalilbus, radiatim costatis, costellis squamulosis."

Pecten oxygonum G. B. Sowerby I, 1850: 52: "Testa suborbicularis, subobliqua, tumida, costellis radiantibus 19, superne acutangulis, interstitiisque aequalibus lineis incrementi concinne decussatis; auribus inaequalibus, laevibus, radiatim costellatis, costellis tenuissimis."

Pecten augusticostatus Gabb, 1873: 256: "Shell small, elongated sub-circular, equilateral; ears small; base and sides regularly curved; surface marked by *ca.* twenty-three prominent, very narrow and acute ribs. Of the size and general style of *P. oxygonum*, this shell is distinguished by its peculiar ribs, which have a narrow, almost knife-like edge."

Pecten eugrammatus Dall, 1898: 713: "Shell suborbicular, convex, with twenty-one high, sharp ribs separated by V-shaped narrower interspaces, the ribs with a sharp but shallow mesial sulcus and the outer edges of the sulcus sharp and flaring; submargins smooth, ears radially threaded, inner margin deeply fluted; surface with fine, low, sharp concentric lamellae when perfect; notch small, narrow, sharp, with no ctenolium; cardinal crura well developed, sharply cross-striated; ears small. Alt. 23, lat. 24, diam. 8 mm."

Pecten hatoviejonis Maury, 1917a: 189: "Shell fan-shaped, but markedly oblique; right valve deeper and more convex than the left; ears small; ribs *ca.* twenty-one; on the proximal portion of the shell the ribs are narrow, nearly smooth, except on the posterior slope of the right valve where they are somewhat spiny; interspaces deep, concave, marked only with growth lines; suddenly more squamose sculpture develops simultaneously on both valves, the ribs become medially grooved, the interspaces develop two radial threads each, and both ribs and interspaces become decidedly squamose. Length of shell 24, altitude 23, diameter 12, semidiameter of left valve 5, of right valve 7 mm."

Pecten thetidis pelei Pilsbry, 1922: 411: In comparison to what he regarded as *Pecten thetidis s. s.*, "The ribs have wider summits, more strongly developed spinose flanges, and on the slopes of the ribs there are one or two spinose riblets. The submargins and ears have a close sculpture of spinose riblets.

Alt. and length 28, semidiam. 11 mm."

Description.—Shell not known to exceed 28 mm Ht, either equilateral or with posterior somewhat extended, length and height approximately equal. Convexity of valves moderately unequal, with RV more convex than LV. Disks commonly with 18-23 simple, nonbranching, interlocking radial ribs separated by deep interspaces; rib profiles highly variable, ranging from steep-sided trapezoidal or rectangular to sharply trigonal in late ontogeny; in forms with grooved rectangular rib crests, crests of central ribs of RV rounded in early ontogeny, becoming flattened with horizontally projecting sharp edges in mid-ontogeny, then becoming grooved medially with distally convex looped lamellae along edges of rib crests projecting upward at 45° to nearly vertical, setting off deep medial groove; rib crests of LV similar but narrower than on RV; lateral ribs narrower, commonly asymmetrically trigonal with steep sides facing anterior or posterior margins of shell. Commarginal lamellae in rib interspaces of both valves prominent, forming distally convex arcs across interspaces, sloping proximally up rib flanks before recurving slightly below edges of rib crests, then commonly forming large, distally convex scales on edges of rib crests, with each large scale formed from 2 or more commarginal lamellae present on rib flanks; commarginal lamellae of LV also prominent, commonly passing across rib crests in early ontogeny before medial grooves develop on rib crests, later commonly forming large scales along edges of crests of rectangular ribs. Secondary costae common, with one or more costae beginning in late ontogeny near base of rib flank on each side of rib, more commonly on LV than on RV. Disk flanks steep, either smooth or with low radial costellae that can be scabrous. Auricles small, with total hl *ca.* 60% L, ahl longer than phl; right anterior auricle with 3 or 4 radial costae, slightly scrolled dorsal margin, and nearly circular anterior margin; byssal notch moderately deep, with short, active ctenolium with 3 or 4 teeth in early ontogeny, reducing to 1 tooth or disappearing in late ontogeny. Right posterior auricle with 5 or 6 evenly spaced radial costae in early ontogeny, dorsal costae commonly obsolescent in later ontogeny. Left auricles with 5 or 6 radial costae crossed by commarginal lamellae; anterior margin of left anterior auricle sharply rounded with deep byssal sinus; posterior margins of posterior auricles with deep posterior sinus and overall trend of margin forming acute angle with dorsal margin. Right hinge dentition with single strong resilial tooth on each side of resilifer, with distal, central part of each tooth having slight radial depression, weaker single dorsal tooth bordering ventral side of outer-ligament groove on each side of hinge, and infradorsal socket between teeth on each side; left dentition with single infradorsal tooth on each side of resilifer fitting into infradorsal sockets of RV; apposition zones of dentition with prominent irregular vertical cross ridges. Extent of foliated-calcite re-entry on interior of RV consistently extending ventrally nearly to pallial line in late ontogeny, on RV completely underlying striate adductor scar, which is completely separated from nonstriate adductor scar in early ontogeny, and also underlying entire ventral margin of nonstriate scar; on LV foliated-calcite re-entry underlying entire adductor scar.

Type material and measurements.—Lectotype of *Pecten thetidis* Sowerby, BMNH LL11355, 1 RV, 24 mm Ht, 26 mm L, 8 mm cvx; designated, measured, and figured by Pflug (1961: 80, pl. 24, figs 4, 12), from the "Miocene" of the Dominican Republic.

Holotype of *Pecten augusticostatus* Gabb, ANSP 2866, 1 RV, 23.8 mm Ht, 24.3 mm L, from the Dominican Republic.

Syntypes of *Pecten eugrammatus* Dall, 2 RV bearing USNM 115533, 1 from Haiti, the other from the Dominican Republic. The specimen from the Dominican Republic, with "St Do" [Santo Domingo] penciled on the inside of the shell, 19.4 mm Ht, is the one illustrated by Dall (1898: pl. 34, fig. 22) and is refigured herein (Pl. 7, Fig. 1). The other right valve, 22.8 mm Ht, is possibly from Haiti, but it could also be from the Dominican Republic.

"Syntypes" of *Pecten hatoviejonis* Maury, PRI 28970, 1 RV, 22.8 mm Ht, and PRI 28971, 1 LV (Pl. 7, Figs 2-3), 22.5 mm Ht, both from Río Amina, trail between Hato Viejo and Potrero, Dominican Republic, formation not specified but presumably from Gurabo Formation. These are, in fact, matching valves and thus comprise the holotype by monotypy.

Holotype of *Pecten thetidis pelei* Pilsbry, ANSP 2853, 1 RV, 28 mm Ht, 28 mm L, 11 mm cvx, Dominican Republic, precise locality not given.

Type locality.—The material studied by Sowerby (1850) was collected in the Dominican Republic by T. S. Heneken, a British Army officer (E. Vokes, 1989: 6). Based on Moore's (1850) account of Heneken's (incorrectly spelled Heniker, see Pflug, 1961: 6) geological notes, it is clear that the collection was made in the Cibao Valley of the northeastern Dominican Republic. The brief lithological description given by Moore indicates the Cercado-Gurabo sequence, but no further details are discernible.

Other material.—1,645 specimens from 94 localities in the northern Dominican Republic (Table 11). All but 13 of these are single valves.

Remarks.—Past authors having only a limited amount of material were unaware of the great variation of external sculpture of *Argopecten thetidis* (Pl. 7, Figs 1-19) and introduced a

Table 11. Occurrence of *Argopecten thetidis* in the Cibao Valley. Localities ordered by stratigraphic level measured from base of section except for road cuts, which are ordered by locality number. Abbreviations: Aa, *Argopecten ameleus*; Ae, *A. eccentricus s. l.*; Aec, *A. eccentricus caimiticus*; Aee, *A. eccentricus eccentricus*; Ael, *A. eccentricus lacabrensis* n. ssp.; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; Anc, *Antillipecten cercadicus*; Anq, *A. quemadosensis* n. sp.; Apa, *Argopecten parathetidis* n. sp.; Caj, *Caribachlamys jungi* n. sp.; Cg, *Cyclopecten guppyi*; Cz, *C. zalaya* n. sp.; B1, Bluff 1 of Maury (1917b); B2, Bluff 2; B2/B1, between B2 and B1; Dm, *Dimya* sp.; DV, matching valves; Eg, *Euvola gurabensis* n. sp.; Es, *E. soror*; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Ini, *Interchlamys interlineata*; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis s. s.*; LV, left valve; Lt, *Leptopecten thompsoni*; Ncv, *Nodipecten colinensis vokesae*; Nn, *N. nodosus*; Pc, *Palliolum? cibaoense* n. sp.; Pvm, *Parvamussium marmoratum*; Sv, *Spathochlamys vaginula*; --, not recorded. Lettered stratigraphic levels are explained in the text.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana								
NMB 16859	361	Gurabo	1	0	0	18.9	none	
NMB 16814	349	Gurabo	1	0	0	3.9	none	
NMB 16825	321	Gurabo	1	1	0	10.0	Amp, Anq, Apa, Lpl	
----------								Miocene/Pliocene boundary at least as low as 315 m (Saunders *et al.*, 1986: 23)
Río Gurabo								
NMB 15814	403	Gurabo	13	21	0	19.7	Gu	
NMB 15964	402.5	Gurabo	9	9	0	20.6	none	
NMB 15815	402	Gurabo	2	0	0	10.4	Dm, Gu, Sv	
NMB 15934	402	Gurabo	3	4	0	19.0	Dm, Gu, Lpa	
NMB 15962	400	Gurabo	1	1	0	18.0	Dm, Gu, Lpa, Sv	
NMB 15804	399	Gurabo	2	4	0	14.2	Gu, Sv	
USGS 8549	398-400	Gurabo	3	7	0	20.0	none	
USGS 8544	397-399	Gurabo	0	2	0	22.8	Gu, Ncv	
NMB 15939	394-397	Gurabo	1	1	0	14.8	Amp, Dm, Sv	
----------								Miocene/Pliocene boundary (Saunders *et al.*, 1986: text-fig. 14)
NMB 15937	395	Gurabo	2	0	0	10.2	Dm, Sv	
TU 1210	394-396	Gurabo	3	2	0	23.3	Amp, Gu, Lpa, Ncv, Sv	
NMB 15940	393	Gurabo	1	0	0	10.0	Dm, Sv	
TU 1212	389-398	Gurabo	0	1	0	16.0	Amp, Gu	
TU 1369	388?	Gurabo	0	2	0	19.5	Amp, Gu, Lpa, Sv	
TU 1279	387-389	Gurabo	2	2	0	22.3	Es, Gu, Lpa, Sv	
NMB 15836	387-389	Gurabo	2	0	0	18.3	Gu	
TU 1278	387-389	Gurabo	2	10	0	20.5	Anq, Es, Gu, Lpa, Ncv	
NMB 15809	381-383.5	Gurabo	0	2	0	22.0	none	
TU 1211	381-385	Gurabo	16	13	0	20.1	Apa, Gu, Lpa, Sv	
TU 1231	float	Gurabo	9	6	2	24.7	Anq, Es, Lpa, Ncv	
NMB 15837	374-376	Gurabo	1	0	0	10.0	Eg, Lpa, Ncv	
NMB 15841	368-371.5	Gurabo	0	1	0	19.0	none	

Table 11 (continued).

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo (continued)								
NMB 15843	323-328	Gurabo	6	7	0	24.2	Sv	
NMB 15842	314-317.5	Gurabo	4	10	0	23.2	Ai, Sv	
NMB 15844	310-313.5	Gurabo	1	2	0	15.1	Ai, Dm	
NMB 15846	285-287	Gurabo	2	4	0	15.0	Dm, Sv	
NMB 15854	277.5	Gurabo	0	1	0	7.6	none	
TU 1215	276-386.5	Gurabo	4	1	0	21.1	Amp, Anq, Caj, Lpa, Nn	
NMB 15849	274.5	Gurabo	0	2	0	13.0	Cg, Sv	
USGS 8538	255	Gurabo	2	3	0	19.0	none	
NMB 15860	255	Gurabo	2	4	0	5.7	Cg, Sv	
NMB 15863	234.5-238	Gurabo	9	7	0	13.8	Ai, Dm	
NMB 15866	227	Gurabo	3	4	0	22.0	Ai, Lpa	
NMB 15864	224-226	Gurabo	2	4	0	20.0	none	
NMB 15869	224	Gurabo	23	36	0	21.5	Ae, Lpa, Sv	
NMB 15868	223	Gurabo	1	1	0	18.9	none	
NMB 16808	222-226	Gurabo	1	0	0	13.0	Aec, Lpa	
NMB 15867	222-225.5	Gurabo	5	2	0	23.0	none	
NMB 16810	221-223	Gurabo	9	5	1	23.8	Sv	
NMB 15865	221-223.5	Gurabo	15	14	1	21.0	Amp, Sv	
NMB 15871	220-223	Gurabo	2	6	0	21.0	Sv	
NMB 15870	218.5	Gurabo	0	1	0	16.5	Ai, Amp	
NMB 15872	211	Gurabo	1	0	0	22.2	Amp, Es	
----------								Possible unconformity accounting for missing Biozone EE
TU 1296	204-223	Gurabo	8	4	0	19.0	Lpa, Sv	Maury's Zone F, basal Gurabo Fm according to E. Vokes (1989: 18)
NMB 15880	188	Cercado	1	0	0	18.5	none	
----------								Cercado/Gurabo Fm boundary of E. Vokes (1989)
TU 1297	183-211	Cercado	1	3	0	19.7	Amp, Ael, Es, Lpl	
NMB 15884	175	Cercado	0	1	0	12.8	none	
NMB 15898	131-133	Cercado	0	2	0	18.0	Ael, Amp	
TU 1375	124-126	Cercado	0	1	1	16.1	Ael, Cg	
USGS 8739	122-126	Cercado	0	1	0	19.1	Ael, Amp	
Río Mao								
TU 1225	downstream from B1	Gurabo	4	2	0	23.8	Amp, Ai, Es, Lpa, Nn	
USGS 8734	downstream from B1	Gurabo	1	1	0	20.0	Ai, Ini	

Table 11 (continued).

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Mao (continued)								
USGS 8527	downstream from B1	Gurabo	1	0	0	15.0	Ai	
NMB 16910	B1	Gurabo	28	25	0	25.0	Aee?, Amp	
TU 1293	B1	Gurabo	33	40	0	24.6	Ai, Amp	
USGS 8519	B1	Gurabo	18	27	0	25.0	Ai, Amp	
NMB 16803	B2/B1	Cercado	1	0	0	25.5	Aee, Anc, Es, Lpl	
USGS 8522	B2/B1	Cercado	4	3	0	22.0	Aee, Lpl	
USGS 8521	B2/B1	Cercado	1	0	0	14.1	Aee, Amp, Es, Lpl	
TU 1410	B2/B1	Cercado	7	5	0	24.0	Aee, Amp, Cg, Es	
Río Amina								
TU 1219	level d	Gurabo	69	83	1	24.5	Amp, Lpa, Lpl, Sv	
USGS 8516	level d	Gurabo	16	29	0	21.8	Amp, Pc	
TU 1220	level c	Gurabo	9	10	0	24.0	Aee, Amp, Lpl	
TU 1217	level c	Gurabo	20	17	2	25.0	Amp	
NMB 16805	level c	Gurabo	1	5	0	24.0	none	
Río Amina area								
TU 1371	--	Gurabo?	10	19	0	27.8	Aec?, Ai, Amp, Eg	
TU 1412	--	Gurabo?	3	3	0	23.8	none	
Río Yaque del Norte								
TU 1206	--	Gurabo?	3	3	0	23.0	Amp, Apa, Es, Sv	
TU 1207	--	Gurabo?	23	47	1	25.4	Amp, Apa	
Río Verde								
TU 1250	--	Gurabo	13	17	0	22.9	Aec, Amp, Cg, Cz, Es, Gu, Lpa, Pvm	Gravity flows
Santiago area								
TU 1205	--	Gurabo	2	3	0	18.4	Amp, Aec, Apa, Es, Sv	
TU 1227A	--	Gurabo	40	64	0	20.8	Amp, Ai, Cg, Cz, Gu, Lpa, Pvm, Sv	Arroyo Zalaya; turbidity-flow lens (Vokes & D'Attilio, 1980: 52)
TU 1227	--	Gurabo	1	1	0	20.5	Amp, Lpl, Pvm	
USGS 8726	--	Gurabo	0	1	0	19.5	Aec, Anq, Es, Sv	Called Gurabo Fm by Vaughan *et al.* (1921: 130)
TU 1405	--	Gurabo	0	1	0	18.1	Aec, Es	Gravity flows
TU 1339	--	Gurabo?	2	2	0	19.3	Aec, Es, Lpl	
TU 1439	--	Cercado?	2	0	0	18.5	Aee, Es	
TU 1380	--	Gurabo?	10	16	0	25.5	Ai, Amp, Sv	
Road cuts								
TU 1209	--	Gurabo	4	3	0	18.8	Eg, Gu, Lpa, Ncv, Sv	
TU 1222	--	Gurabo?	1	0	0	20.3	Aec, Amp, Anq, Apa, Es, Lpl	

Table 11 (continued).

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Road cuts (continued)								
TU 1340	--	Cercado	0	1	0	22.0	Ael, Lpl, Lt	
TU 1360	--	Gurabo?	56	86	0	23.9	Amp	
TU 1254	--	Gurabo	4	4	0	24.2	Ai, Amp	
TU 1335	--	Gurabo?	0	4	0	18.1	Ai, Amp	
TU 1338	--	Gurabo	1	1	0	19.0	Amp, Eg, Gu, Lpa, Ncv	
TU 1361	--	Gurabo?	10	42	0	24.4	Amp	
TU 1409	--	Gurabo?	16	15	0	20.0	Ai, Amp, Sv	
TU 1416	--	Gurabo?	51	40	3	26.2	Lpl	
TU 1435	--	Gurabo?	20	19	1	25.7	Aa, Amp, Es, Lpl, Sv	
TU 1437	--	Gurabo?	6	6	0	22.5	Aec, Amp, Lpl	
USGS 8535	--	Gurabo	36	68	0	24.8	Amp, Es, Lpl	

number of unnecessary taxonomic names. The sharply trigonal ribs thought to characterize *Pecten oxygonum* and *P. augusticostatus* in fact intergrade with the more typical broader, medially grooved ribs of *A. thetidis* (Pl. 7, Figs 4-9). Such intergradation is evident even within single samples, as in TU 1410, where sharply trigonal ribs, trigonal ribs with crests too narrow to allow development of medial troughs, and broader ribs with medial troughs are all present (Pl. 7, Figs 4-7).

There has been substantial confusion about the meaning of the name *Pecten oxygonum*, resulting from the apparent mixing of labels and specimens in the Heneken collection that was sent by Heneken to London to be studied by Sowerby (Dall, 1898: 714; Pilsbry, 1922: 411). In his description of *P. oxygonum* as well as in his choice of the name, Sowerby (1850: 52) emphasized the acutely angular ribs, with interspaces crossed only by commarginal lamellae. Nevertheless, several authors have identified *P. oxygonum* with species similar to the extant species *Lindapecten exasperatus*, which have abundant scabrous secondary costae on both ribs and interspaces of the disk (*e.g.*, Gabb, 1873: 256; Maury, 1917a:185; Cooke, 1919: 138). This error apparently stems from a mix-up of type specimens. As noted by Dall (1898: 714), the two specimens bearing the name *P. oxygonum* in the Heneken collection are of two kinds, an articulated pair of valves having a "well-marked small rib in each furrow, coarsely squamose sculpture, and a height of forty-seven and a half millmetres," and "a single valve with the rib in the furrows obsolete or absent, the shell oblique, surface coarsely squamose." Because of the differences from the original description of *P. oxygonum* possessed by these specimens, Dall did not accept them as syntypes.

Dall's opinion is confirmed by a cast of the articulated shell in the Heneken Collection reposited in the Smithsonian collections. The cast, which came to the Smithsonian by means of a transaction between L. R. Cox of the British Museum and W. P. Woodring of the U. S. National Museum in the 1920s, is catalogd as USNM 354159. The USNM label reads "cast of type, British Museum, Geological Society of London Collection." A second label with the cast is from the British Museum (now The Natural History Museum, London). It erroneously indicates that this articulated specimen is the holotype of *Pecten oxygonum* and gives the catalog number as "Geol. Soc. Coll. 12831." Dall (1898: 714) noted that this specimen resembles a new species that he named *P.* (*Plagioctenium*) *gabbi* further on in the same monograph (p. 717, pl. 29, fig. 3). In the present study, *P. gabbi* is placed in the synonymy of *Interchlamys interlineata*, described above.

Dall (1898: 714) remarked that the Dominican Republic fossils that most closely correspond to Sowerby's description of *Pecten oxygonum* are those described by Gabb (1873: 256) as *P. augusticostatus*. Pilsbry (1922: 412) agreed that the two taxa are closely related but thought that *P. augusticostatus* "should remain distinct until connecting specimens are found." He distinguished the holotype of *P. augusticostatus*, a "left valve" (ANSP 2866, actually a right valve) from *P. oxygonum* on the basis of differences in the number of ribs (said to be 18 or 19 in *P. oxygonum*, but 22 in *P. augusticostatus*), in rib shape ("far sharper" in *P. augusticostatus*), and in disk-flank costation (disk flanks without costae in *P. oxygonum*, but with low costae on the anterior disk flank in *P. augusticostatus*). These are but minor differences, allowing *P. augusticostatus* to be re-

garded as another junior synonym of *Argopecten thetidis*.

Dall's (1898: 713) description of *Pecten eugrammatus* describes exactly the characters of *Argopecten thetidis*, with the exception of the smooth disk flanks, which are costellate in some but not all individuals of *A. thetidis*. Dall seems to have described *P. eugrammatus* only because he confounded *P. thetidis* with what is now known as *Lindapecten*, as evidenced by his statement (Dall, 1898: 714) that *P. thetidis* "is a shell much resembling the recent Florida shell which Conrad named *fuscopurpureus* ..." Dall's specimens of *P. eugrammatus* were collected by Guppy from Haiti and Santo Domingo. Two syntypes, both right valves, are cataloged under USNM 115533, although only a single specimen from Haiti is listed in the catalog for this number, and both Schuchert *et al.* (1905: 487) and Boss *et al.* (1968: 122) indicated only a single specimen. The larger of the two right valves, which is missing most of the auricles and dorsal margin, conforms to the measurements given by Dall (1898: 713) in his description; the smaller valve is more complete and conforms to the measurement given by Dall in the caption for his pl. 34, fig. 22. This latter valve (Pl. 7, Fig. 1) has "St Do" [Santo Domingo] pencilled on its inner surface and is presumably the specimen that Dall said is from the Dominican Republic. The larger valve, by default and in accord with the old USNM labels and the catalog entry for USNM 115533, is from Haiti. Both specimens have noncostate to weakly costate disk flanks and correspond to the present concept of *A. thetidis.*

In describing *Pecten hatoviejonis* from the Río Amina area, Maury (1917a: 189) was particularly impressed by the shift in external sculpture following a growth interruption, after which the rib crests become suddenly medially grooved and secondary scabrous costellae intercalate on the rib flanks (Pl. 7, Figs 2-3). However, she based her description on only one individual (matching right and left valves). Other samples from the Río Amina area lacking the growth interruption show a more gradual change and intergrade with typical *Argopecten thetidis*. The sudden change in sculpture associated with a growth interruption is a common phenomenon in the Pectinidae.

All of the characters used by Pilsbry (1922: 411) to distinguish *Pecten thetidis pelei* from the nominal subspecies vary widely within population samples. Although the presence of prominent scales on the edges of rib crests as well as distinct scabrous costellae on the disk flanks (Pl. 7, Figs 10-17) seem to be more common in samples from higher in the stratigraphic sections (in the upper Gurabo Formation), these features are still too variable and inconsistent to be of use in distinguishing chronological subspecies. Perhaps the increase in sculptural complexity in this case is ecophenotypic, occurring in deeper water deposits. Maury (1917a) had earlier recognized the same variation and chose to distinguish it by the species name *P. hatoviejonis*. (Compare Pl. 7, Fig. 2 herein to pl. 44, fig. 4 of Pilsbry, 1922.)

Comparisons.—Argopecten thetidis differs from *A. eccentricus s. l.* in having more elaborate rib crests that can be narrow and sharp, flattened with knife-like laterally projecting edges, or deeply grooved with upright edges containing looped lamellae or projecting scales. The posterior auricular margins of *A thetidis* are deeply sigmoidal and overall form an acute angle with the dorsal margin, whereas the corresponding margins of *A. eccentricus s. l.* and in particular those of *A. e. eccentricus* and *A. e. caimiticus*, are straighter, forming an obtuse angle with the dorsal margins. The adductor scars and associated foliated-calcite re-entry of the two species are markedly different. In *A. thetidis*, the striate and nonstriate adductor scars of the right valve are completely separated beginning in early ontogeny and have foliated-calcite extending between the scars as well as below the ventral margin of the nonstriate scar. In the three subspecies of *A. eccentricus*, the striate and nonstriate adductor scars of the right valve are conjoined except for a small anterior notch. The foliated-calcite re-entry might or might not fill the notch and seldom extends below the ventral margin of the nonstriate adductor scars of either valve.

Argopecten parathetidis n. sp. is smaller in size than *A. thetidis* and retains the angularity and central keel of its parabolic ribs throughout ontogeny.

Argopecten uselmae of the Mao Formation of the Dominican Republic shares extensive foliated-calcite re-entry with *A. thetidis s. l.* but differs in rib profiles, the ribs of the right valve having broad, smooth, gently rounded crests and those of the left valve narrow and rarely with a faint central keel on rib crests. These features also separate the extant species *Argopecten noronhensis* from *A. thetidis s. l.*

Evolution.—Because *Argopecten thetidis* is apparently endemic to Hispaniola and is not found elsewhere, it is assumed that it originated on this island through adaptation to the shifting sedimentary conditions on the continental shelf due to abundant terrestrial sediment input from a tectonically active source. Although sharply trigonal ribs can occur throughout the stratigraphic range of *A. thetidis*, they appear to be more common in samples from the lower part of the range, suggesting that such ribs could be ecophenotypic and associated with shallower, sandier sediments, whereas the variants with broader rib crests, more prominent scales along the edges of rib crests, and more distinct radial costellae on disk flanks could be more common in deeper, siltier sediments. From a functional point of view, the narrow, trigonal ribs might facilitate anchoring of the shell in coarser sediment, and the broader crested ribs might facilitate avoidance of sinking into finer sediments (the snowshoe effect).

The oldest occurrences of *Argopecten thetidis* in the Cibao Valley are in the upper Cercado Formation in the Río Gurabo beginning at 122-126 m above the base of the section (Table 11) in nannofossil Zone NN11 and in pectinid zone EL-II, of late Miocene age. These first appearances, however, are based on only a few specimens and are facies controlled, because stratigraphically lower strata represent depths of deposition that were probably too shallow for this species. Possibly *A. thetidis* originated by allopatric speciation from *A. eccentricus lacabrensis* n. ssp., with which it shares acute posterior auricles with deep posterior sinuses and a tendency to possess well-developed commarginal lamellae.

Occurrence.—Argopecten thetidis is most abundant in the shallower parts of the Gurabo Formation (Table 11). It was probably excluded from most of the lower Cercado Formation by conditions that were too shallow and from the uppermost Gurabo by conditions that were too deep. The species is unknown in the Mao Formation. In terms of the pectinid biozones based on *A. eccentricus* developed in the preceding section, the oldest occurrences of *A. thetidis* are in Biozone EL-II in the Cercado Formation beginning at 122-126 m above the base of the section on the Río Gurabo. These are in Zone NN11, of late Miocene age. The youngest occurrences are above the Miocene/Pliocene boundary on the Río Cana, Río Gurabo, probably on the Río Mao downstream from Bluff 1, and in the Santiago area (Table 11). The species is reported here for the first time from the southern Dominican Republic in the Río Yaque group of the Río Yaque del Sur, Azua Province (USGS 8590; see Vaughan *et al.*, 1921: 102).

Distribution.—Argopecten thetidis is unknown outside the Dominican Republic.

Argopecten uselmae (Pilsbry & Johnson, 1917)
Pl. 8, Figs 1-5

Pecten inaequalis Sowerby. Guppy, 1866: 294, pl. 18, fig. 6 (not G. B. Sowerby I, 1850).

Pecten (*Aequipecten*) *inaequalis* Sowerby. Dall, 1898: 714 (in part, not G. B. Sowerby I, 1850).

Pecten uselmae Pilsbry & Johnson, 1917: 194; Pilsbry, 1922: 412, pl. 45, fig. 9.

Pecten costaricensis Olsson, 1922: 201, pl. 18, figs 8-11.

Chlamys (*Aequipecten*) sp. cf. *uselmae* (Pilsbry & Johnson). Woodring *et al.*, 1924: 221, 242.

Chlamys (*Plagioctenium*) *uselmae* (Pilsbry & Johnson). Woodring, 1925: 69, pl. 8, figs 6-7.

Chlamys (*Plagioctenium*) *concinnata* Woodring, 1925: 70, pl. 8, fig. 8.

Chlamys (*Plagioctenium*) *mansfieldi* Woodring, 1925: 71, pl. 8, fig. 10.

Chlamys (*Plagioctenium*) *gonioides* Woodring, 1925: 71, pl. 8, figs 11-12.

Argopecten uselmae baracoensis Franco, 1983: 269, pl. 11, figs 1-2.

Original description.—"The shell is inequilateral, inequivalve, the left valve is larger, conspicuously surpassing the right through the lower margin and ends. It is strongly convex; the right valve weakly so. Sculpture of 17 rounded ribs. In the left valve these are wider than the intervals, which are deeply cut, with concave bottoms, which are closely sculptured with delicate transverse threads. In the right valve the ribs are lower, and not quite as wide as the intervals, in which the transverse striation is often weak. The submargins are smooth. Ears with several ribs. Ctenolium is very short, of three teeth, which are small in adult shells. Cardinal crura strong, vertically striate" (Pilsbry & Johnson, 1917: 194). [The authors confused the right and left valves.]

Description.—Shell not known to exceed *ca.* 30 mm Ht, either equilateral or with posterior somewhat extended, length and height approximately equal. Convexity of valves variable, commonly with RV more convex than LV, especially in late ontogeny. Disks with 16-18 simple, nonbranching, interlocking radial ribs separated by deep interspaces; ribs of RV with broadly rounded crests that slightly overhang steep, nearly vertical rib flanks; ribs of LV narrower, with broadly sloping flanks and narrow rounded crests that can be flattened or rarely with faint keel that is central on crest on central ribs but to side of crest on lateral ribs. Commarginal lamellae on RV regularly spaced and only slightly curved in rib interspaces and on lower parts of rib flanks; rib crests smooth and glossy with only obscure growth lines in ventrally concave U-shaped pattern; commarginal lamellae on LV transverse across interspaces, sloping dorsally up rib flanks, and commonly absent from rib crests except late in ontogeny. Disk flanks steep on RV, less so on LV, commonly lacking radial costae, rarely with 2 or 3 very fine, widely spaced costellae. Auricles small, with total hl *ca.* 60% L; anterior auricle slightly longer than posterior; right anterior auricle with 3 or 4 strong radial costae persisting to margin, dorsal margin slightly scrolled, anterior margin nearly circular; byssal notch moderately deep, with short active ctenolium becoming obsolete in late ontogeny. Right posterior auricle with 5 or 6 radial costae unevenly developed, dorsal costae weaker than ventral costae and commonly obsolescent in later ontogeny. Left auricles with 4 to 6 radial costae unevenly spaced and persisting to margin; left anterior auricle sharply rounded with overall trend of anterior margin forming acute angle with dorsal margin; moderately deep byssal sinus; posterior margins of posterior auricles sigmoidal, posterior sinus shallow, overall trend of margin form-

ing acute angle with dorsal margin. Hinge dentition consisting of strong resilial tooth on each side of resilifer on RV and strong infradorsal tooth on each side of resilifer of LV, crossed by vertical irregular microridges. Adductor scar of RV with nearly or completely separated striate and nonstriate components. Foliated-calcite re-entry variable, commonly filling space between adductor components on RV and forming continuous band along ventral margin of adductor scars of both valves but well separated from midventral pallial line; band of foliated-calcite ventral to adductor scars less commonly discontinuous, passing along the adductor margin from both posterior and anterior sides but not meeting.

Type material and measurements.—Holotype, ANSP 11124, 1 RV, 27.3 mm Ht, Bowden, Jamaica (figured by Pilsbry, 1922: pl. 45, fig. 9.).

Type locality.—Bowden, Jamaica, Bowden shell bed of the Bowden Formation.

Other material.—Jamaica: Bowden shell bed, Bowden Formation, 5 valves in the Woodring (1925) type collection and 152 single valves in the nontype collection of the Smithsonian Institution. Dominican Republic: NMB 16885, Río Cana, upper Mao Formation, 2 RV; TU 1216, Río Amina area, upper Mao Formation, 1 RV.

Remarks.—Pilsbry & Johnson (1917: 194) described *Pecten uselmae* in a paper dealing with fossils from the Dominican Republic only because this Bowden species had previously been identified as *P. inaequalis*, a species then known only from the Dominican Republic. Woodring (1925: 69) provided a more detailed description of the Bowden species, noting that this species "is the most abundant Bowden *Pecten*."

Woodring (1925) also named three new species of *Argopecten* [as "*Chlamys* (*Plagioctenium*)"] from the Bowden shell bed: *A. concinnatus*, *A. mansfieldi*, and *A. gonioides*. Based on the examination of type and nontype material in the Smithsonian collections identified as these species by Woodring, all three are herein regarded as junior synonyms of *A. uselmae*. In fact, Woodring himself indicated the synonymy of the first two of these on the labels of the holotypes (USNM 352784 and 352786, respectively). On the label of the holotype of the third species (USNM 352787), Woodring used pencil to indicate with a question mark that he was unsure of its synonymy with *A. uselmae*. Indeed this specimen, a left valve (13.8 mm Ht), displays a difference from the majority of specimens of *A. uselmae* in having distinct keels on the crests of its plicae (Woodring, 1925: pl. 8, fig. 11). Such keels, however, are within the range of variation of *A. uselmae,* as demonstrated by specimens in the nontype collection.

Woodring (1925: 72, pl. 8, fig. 12) wrote that his paratype of *Argopecten gonioides* (USNM 353076) is a right valve. It is in fact another left valve but is not the same species as the holotype. The paratype has strongly costate disk flanks, a posterior auricular margin that apparently formed an obtuse angle with the dorsal margin, and a foliated-calcite re-entry that extends only to the level of the middle of the adductor scar, characters that in combination suggest that it is closely related to the extant species *A. nucleus*.

The three right valves of *Argopecten uselmae* reported here are the first records of this species from the Dominican Republic. They agree well in shape, rib profile, configuration of commarginals, and pattern of foliated-calcite re-entry with *A. uselmae* from the Bowden Formation, the only detectable difference being that the rib crests of the Dominican Republic specimens are slightly narrower relative to the width of interspaces than in most of the Bowden specimens.

There is little doubt that the living counterpart of *Argopecten uselmae* is *A. noronhensis*. It is a poorly known species that ranges today from Brazil through the Antilles to the Bahamas and Bermuda, but it is unknown from the western Caribbean and Gulf of Mexico (Waller, 1973: 46). The depths at which living specimens have been taken range from 66 to 110 m, commonly associated with coarse sand and coral rubble. *Argopecten uselmae* probably was also a fairly deep-water species living in a similar habitat. In the Dominican Republic, the specimens from NMB 16885 are from the topmost beds of the Mao Formation on the Río Cana. Saunders *et al.* (1986: 22) commented that the paleoenvironment in these beds is difficult to judge because of the mixture of different kinds of sediment and fossils, possibly representing transport of shallow-water material into deeper water. They noted, however, that planktic foraminiferans are common in these beds and suggest a water depth of > 100 m.

Comparisons.—Argopecten uselmae differs from *A. inaequalis* of the Gurabo Formation in the following: (a) the rib profiles on the right valve of *A. uselmae* are nearly rectangular, with the edges of the crests slightly overhanging the interspaces, whereas those of *A. inaequalis* are rounded; (b) both valves of *A. uselmae* are more convex relative to height especially in early ontogeny; (c) raised commarginal growth lamellae are present in interspaces but not on rib crests throughout most of ontogeny in *A. uselmae*, whereas in *A. inaequalis* growth lines are barely raised above the surface even in the rib interspaces, appearing mainly as light-colored lines crossing both interspaces and ribs; (d) the auricular costae of *A. inaequalis* are more delicate and tend to fade out completely in mid-ontogeny; and (e) the left posterior auricle of *A. inaequalis* is relatively larger and forms more of an acute angle with the dorsal margin.

Argopecten uselmae differs from *A. thetidis* of the Gurabo Formation in having broader ribs and lacking elaborate grooved rib crests with raised edges, and from *A. eccentricus s. l.* of the Cercado and Gurabo formations in having smooth rib crests that overhang rib flanks and a foliated-calcite re-entry that passes along the ventral side of the adductor muscles.

Argopecten uselmae is very close to the extant species *A. noronhensis*. The latter species differs in having right rib crests that are considerably broader than the interspaces as well as sharper, knife-like horizontally directed edges along the rib crests, more pointed posterior auricles, a relative larger right anterior auricle with deeper, more acutely angular byssal notch, and left ribs with medial keels throughout ontogeny flanked by commarginal lamellae that nearly cross the rib crests except for the keels.

Argopecten borinquenensis (Hubbard, 1920) from the Neogene of Puerto Rico is morphologically intermediate between *A. uselmae* and the extant species *A. noronhensis*. The left valve of the Puerto Rican species consistently has keeled ribs, but the ribs of its right valve lack the knife-edged rib crests of *A. noronhensis* and develop a secondary riblet at the base of each right-valve rib late in ontogeny. Specimens of *A. borinquenensis* in the Smithsonian's collections are from USGS 17952, a mile east of the Arecibo lighthouse. This locality was mentioned by Monroe (1980: 63), who assigned it to the upper member of the Camuy Formation, of probable Pliocene age.

Argopecten uselmae also resembles the gibbous variant of the extant Caribbean species *A. lineolaris*, regarded by some workers as a distinct species, *A. mayaguezensis* (Dall & Simpson, 1901). Unlike *A. uselmae*, these taxa lack the overhanging right rib crests except in very early ontogeny, have smaller auricles with anterodorsal and posterodorsal margins intersecting dorsal margins at more obtuse angles, and auricular costae and disk ribs that tend to decrease in amplitude in late ontogeny, leaving a smooth and glossy shell surface. In effect, *A. lineolaris* displays features that become increasingly *Amusium*-like during ontogeny.

Woodring (1925: 70) noted the strong similarity of *Argopecten uselmae* to *A. costaricensis* Olsson, 1922, from the Moin Formation of Costa Rica, which was said to have lower ribs. Specimens of Olsson's species in the nontype collections of the Smithsonian demonstrate that it is synonymous with *A. uselmae*.

Argopecten uselmae baracoensis from the Guardarraya Formation, Upper Miocene to Pliocene, of Cuba was described on the basis of a single left valve which was said to have only 14 ribs. On the basis of the published figures, it appears that fairly prominent marginal ribs were not counted, meaning that this specimen could well be within the range of variation of typical *A. uselmae*.

Evolution.—Argopecten uselmae is likely ancestral to the extant species *A. noronhensis* and is possibly a sister species of *A. thetidis* based on shared high ribs, steep disk flanks, acute posterior auricles, and extensive foliated-calcite re-entry, but no transitional species between *A. thetidis* and *A. uselmae* have been found. Another extant species that is likely in the same clade as the *A. uselmae-noronhensis* lineage is *A. lineolaris*, another species of the tropical western Atlantic and Caribbean but also occurring in the Gulf of Mexico. Its early shell ontogeny is similar to that of *A. noronhensis*, and the two species share common aspects of color patterns, particularly the presence of discontinuous commarginal brown or reddish pigment lines on the tops of ribs. *Argopecten lineolaris* has diverged by becoming amusiiform, with a polished surface, reduced or absent commarginal lamellae, lower ribbing, small streamlined auricles, and a reduced byssal notch with obsolete ctenolium.

Occurrence.—In the Dominican Republic, *Argopecten uselmae* is known only from the Mao Formation, of Early to Middle Pliocene age.

Distribution.—Jamaica: shell beds of the lower Bowden Formation (late Middle Pliocene in age). Haiti: unnamed "Miocene" formation (but probably Pliocene), USGS 9464, northern edge of Port-au-Prince (Woodring *et al.*, 1924: 220-221); unnamed Pliocene formation, USGS 9530, arrondissement of Jacmel. Dominican Republic: Mao Formation (Pliocene). Costa Rica: Moin Formation (upper Pliocene or lower Pleistocene). Cuba: Guardarraya Formation (Pliocene).

Genus ***CHAGREPECTEN*** n. gen.

Type species.—Pecten (*Chlamys*) *cactaceus* Dall, 1898, from the Coatzacoalcos Formation of Spencer (1897: 23), Veracruz, Mexico (Dall, 1898), and the Chagres Sandsone of Panama (Woodring, 1982: 595), Upper Miocene (Collins *et al.*, 1996). Woodring (1982: 594) designated as lectotype "the immature right? valve illustrated by Dall, USNM 135058," from Tehuantepec, Mexico. It is definitely a right valve on the basis of its ctenolium and adductor scar and is figured herein (Pl. 8, Figs 6-7).

Diagnosis.—Aequipectinini close to *Cryptopecten* Dall, Bartsch, & Rehder, 1938, in having prominent vesiculate sculpture and two distinct orders of radial costae on posterior auricles; shell equiconvex and of low to moderate convexity, L exceeding Ht, disk gapes absent or very narrow; byssal notch becoming shallow and ctenolium becoming weak or obsolete in late ontogeny; radial costae in rib interspaces beginning in early ontogeny.

Etymology.—The prefix *chagre-* refers to the Chagres Formation of Panama, in which the type species, *Pecten cactaceus*, is abundant.

Remarks.—Woodring (1982: 594) placed *Pecten cactaceus* from the Upper Miocene of Mexico and Panama in the genus *Cryptopecten*, noting similarities in sculpture with extant *C. alli* Dall, Bartsch, & Rehder, 1938 [= *Pecten* (*Chlamys*) *bullatus* Dautzenberg & Bavay, 1912] from the Hawaiian Islands and *C. phrygium* from the western Atlantic. In a thorough review of *Cryptopecten* in the world's oceans, however, Hayami (1984: 90) regarded the placement of *Pecten cactaceus* in *Cryptopecten* as debatable, noting that this species differs considerably from other *Cryptopecten* in having an "undeveloped ctenolium, well-developed and persistent intercostal threads, relatively shallow byssal notch, and unusually thin shells."

In the present study, *Pecten cactaceus*, *Chagrepecten paracactaceus* n. gen., n. sp. from the Pliocene upper Gurabo and Mao formations of the Dominican Republic, and *Pecten* (*Chlamys*) *dallasi* Jordan & Hertlein, 1926, from the middle Pliocene of Baja California Sur, Mexico, are brought together into the new genus *Chagrepecten*. Although these species have the vesiculate sculpture present in *Cryptopecten*, they differ from species in that genus in the characters pointed out by Hayami (1984: 90). Their active ctenolium, although similar to that of *Cryptopecten* in early ontogeny, becomes nearly obsolete or has only weakly developed, small teeth in late ontogeny. In maturity, the byssal notch of *Chagrepecten* n. gen. is shallow, its depth, commonly less than one third the length of the right anterior auricle, whereas in *Cryptopecten* the byssal notch remains deep throughout ontogeny and its depth is usually at least half the length of the auricle. Although I would not characterize the shell of *Chagrepecten* n. gen. as being "unusually thin," it is nonetheless thinner, less convex, and more flaring than in *Cryptopecten*. The foliated-calcite reentries on the shell interior are also thinner in *Chagrepecten* n. gen. In *Cryptopecten*, the deposition of foliated-calcite ventral to the adductor scars raises these scars on a thickened platform; in *Chagrepecten* n. gen., the same depositional areas of inner foliated-calcite are present, but they scarcely elevate the adductor insertions above the inner shell surface. In well-preserved specimens of *Chagrepecten* n. gen., as in *Cryptopecten*, the commarginal lamellae that merge and form enclosed vesicles also produce a secondary surface that is of lower relief than the original surface with sharp commarginal lamellae. In essence, the more flaring shape, reduced byssal notch and ctenolium, and secondary smoothened surface are indications that *Chagrepecten* n. gen. evolved from an aequipectinoid form to more of an amussioid form, concomitant with living unattached on a soft sediment surface in deep water.

Although *Chagrepecten paracactaceus* n. gen., n. sp. in the middle Pliocene part of the Mao Formation is the geologically youngest definite member of the new genus, there is an extant species that might have branched off early from *Chagrepecten* n. gen. It is *Pecten glyptus* Verrill, 1882, which lives in the western North Atlantic from southeast of Cape Cod to the Florida Strait and in the northern Gulf of Mexico at depths from *ca.* 150-250 m. It resembles species of *Chagrepecten* n. gen. in shell outline, convexity, byssal notch, and ctenolium, as well as shell thickness and the distribution of foliated-calcite on inner shell layers. Although it also has broad, narrow-crested ribs comparable in profile and number to the fossil species of Panama and the Dominican Republic, it lacks radial costellae (except in early ontogeny), a vesiculate secondary surface, and prominent commarginal lirae. There is only a vestigial trace of the latter in the form of rows of tiny cuspate lamellae in late ontogeny. Unlike the fossil species, *P. glyptus* has prominent disk gapes.

Pecten (*Aequipecten*) *preglyptus* Olsson, 1922, from Olsson's "Gatun Formation" in Limon Province, Costa Rica, is possibly ancestral to the extant species. Olsson's species, however, is known only from the holotype (PRI 21140), a damaged and badly worn left valve (Olsson, 1922: pl. 17, figs 2, 7). Dall also noticed the resemblance between *P. cactaceus* and the extant *P. glyptus*. In his faunal list published by Spencer (1897: 24) preceding his formal description of *P. cactaceus*, Dall listed the fossil species as "*Pecten* (like *glyptus*, Verr.)."

Chagrepecten n. gen. is represented on the Pacific side of the Americas by *Pecten* (*Chlamys*) *dallasi*, from the middle Pliocene Carmen Formation and Piedras Rodadas Sandstone on the eastern side of Baja California Sur, Mexico (Durham, 1950: 65; Piazza & Robba, 1994; see the latter for a discussion of lithostratigraphic units and ages in this area).

Geographic and stratigraphic ranges.—Dominican Republic: upper Gurabo and Mao formations, Pliocene; Panama: Chagres Sandstone, Upper Miocene; Costa Rica, Limon Province, "Gatun Formation" of Olsson (1922), Pliocene?; Mexico, Veracruz: Coatzacoalcos Formation of Spencer (1897: 23); Baja California Sur, Mexico: Carmen Formation and Piedras Rodadas Sandstone, Pliocene. Inferred to have lived in water > 100 m.

Chagrepecten paracactaceus n. sp.
Pl. 8, Figs 8-20; Table 12

Diagnosis.—Chagrepecten n. gen. with 15-17 radial ribs with very narrow crests; rib crests on RV bordered by deep intercostal spaces.

Description.—Shell small, maximum known *ca.* 30 mm Ht, Ht exceeding L in early ontogeny, equilateral later, acline

to slightly prosocline, nearly equivalved and of low convexity, with convexity of RV slightly greater than LV; umbonal angle *ca.* 105-113°; disks with 15-17 simple ribs originating from 2.1-2.4 mm Ht after early prismatic stage of RV and smooth pre-radial stage of LV; rib crests of RV very narrow, bearing projecting scales spaced further apart than commarginal lamellae on rib flanks; rib flanks concave in profile in early ontogeny, becoming more gradually sloping toward shallowly rounded rib interspace later, covered by merged commarginal lamellae producing secondary surface; enclosed vesicles on rib flanks commarginally elongated and nearly perpendicular to rib crest; rib interspaces with 4 or 5 very fine radial costellae beginning by 4.5 mm Ht, increasing by intercalation to 6 or 7 costellae at distal margin; spaces between costellae bearing finely cusped lamellae that commonly merge with succeeding lamellae; left disk with similar pattern of ribs, scales, costellae, and vesicles but rib crests even narrower than on right and with additional narrow intercostal space with vesicles immediately adjacent to rib crest beginning in mid-ontogeny and persisting to margin. Disk flanks low and steep, with very faint radial costellae in late ontogeny. Auricles small relative to size of disk; anterior auricles slightly longer than posterior, total hl slightly less than half length of disk; right anterior auricle with coarsely scabrous dorsal margin bordered ventrally by 4 more finely scabrous radial costae, with additional fine costellae intercalated between costae near margin; byssal fasciole fairly broad, nearly planar in cross section, crossed by commarginal lirae, depth of byssal notch becoming shallow in late ontogeny, with depth only *ca.* ⅓ length of auricle; ctenolium becoming weakly developed in late ontogeny, consisting of few teeth obscured in planar view of valve by overhanging flange at base of anterior disk flank; posterior margin of right posterior auricle sigmoidal with overall trend forming slightly acute angle with dorsal margin, dorsal margin bearing smaller scales than on anterior dorsal margin, surface with 3 primary radial costae, dorsal costa close to dorsal margin, other two widely spaced with fine radial costellae between them; left auricles with smooth, straight dorsal margins, one pair of dorsal costae close together, and 1 or 2 additional major costae ventral to these, separated by fine radial costellae. Hinge dentition of RV consisting of long, narrow dorsal tooth on each side of resilifer, bordered ventrally by long, narrow infradorsal socket and then obscure intermediate tooth of low relief; resilial teeth low and poorly demarcated; entire hinge plate crossed by irregular vertical microcrenulations. Inner foliated-calcite layer extending ventrally from dorsal margin to level of middle of adductor scar on anterior side, passing down anterior margin of striate muscle scar into re-entry between striate and nonstriate portions of adductor and along ventral margin of adductor scar; this ventral calcite not thickened to form raised adductor platform. Internal plicae with well-developed carinate edges near margin of shell.

Etymology.—prefix *para-* from Greek, meaning "near," combined with the species name *cactaceus*, signifying close resemblance to *Pecten cactaceus*.

Holotype and measurements.—NMB G17515 (Pl. 8, Figs 8-15), a pair of matching valves, 28.2 mm Ht, 28.2 mm L, 7.5 mm cvx of articulated shell.

Type locality.—Locality NMB 15827, left bank of Río Gurabo, Mao Formation, 658-660 m above base of section (Saunders *et al.*, 1986: text-fig. 4).

Other material.—Paratypes, 6 whole or partial RV and 7 LV from 8 localities on the Río Gurabo and Río Mao, upper Gurabo and Mao formations (Table 12).

Remarks.—The rarity of this new species is probably related to its deep-water habitat in which the population was originally sparsely distributed. At TU 1292, in the upper Gurabo Formation on the Río Mao, Bold (1988: 14) noted the presence of deep-water ostracodes, and E. Vokes (1989: 18) referred to the beds at this locality as representing the deepest water of the Gurabo Formation when proceeding downstream (*i.e.*, up the section). NMB 16016 is in the Mao Formation near its base on the Río Gurabo, where Saunders *et al.* (1986: 16) referred to "badly sorted material swept into a relatively deep-water environment, probably by turbidity flows."

Comparisons.—*Chagrepecten paracactaceus* n. gen., n. sp. differs from *C. cactaceus* in having a greater number of ribs, usually 15 compared to 13, although rib counts can overlap. There is also a different pattern of secondary costation, particularly on the right valve. On the right valve of *C. cactaceus* (Pl. 8, Figs 6-7), the central rib crest is slightly wider and is not bordered on each side by an intercostal space that is significantly wider than the other intercostal spaces, and the costellae present in the rib interspaces of *C. cactaceus* are coarser and more minutely scabrous, with closed vesicles less common between the costellae. The sculptural pattern of left valves of the two species are more similar than on right valves, but in *C. paracactaceus* n. gen., n. sp., the rib crests are much narrower, and the costellae in the center of rib interspaces are finer, less scabrous, and begin much later in ontogeny (at *ca.* 20 mm Ht in *C. paracactaceus* n. gen., n. sp. compared to 5 or 6 mm in *C. cactaceus*). Closed vesicles that produce a secondary surface are more commonly present in *C. paracactaceus* n. gen., n. sp. then in *C. cactaceus*.

Evolution.—The occurrences of *Chagrepecten paracactaceus*

Table 12. Occurrence of *Chagrepecten paracactaceus* n. gen., n. sp., in the Cibao Valley. Abbreviations: Amp, *Amusium papyraceum*; Cya, *Cyclopecten acuminatus* n. sp.; Cyz, *C. zalaya* n. sp.; Dm, *Dimya* sp.; DV, matching valves; Ht, height; LV, left valve; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo								
NMB 15829	758-761	Mao	0	1	0	26	Cya, Dm	
NMB 15828	715	Mao	0	1	0	--	Cya, Dm	
USGS 8735	681-707	Mao	1	1	0	25	none	
TU 1440	671-673	Mao	1	0	0	21.3	none	Same locality as USGS 8556
USGS 8556	671-673	Mao	1	1	0	30	none	
NMB 15823	670-672	Mao	1	3	0	28	Cya, Dm	
NMB 15827	658-660	Mao	0	0	1	28.2	Cyz, Dm	Type locality of *C. paracactaceus* n. gen., n. sp.
NMB 16016	580	Mao	1	0	0	23	none	Near base of Mao Fm
Río Mao								
TU 1292	--	Gurabo	1	0	0	30	Amp	Upper Gurabo Fm

n. gen., n. sp. in the Pliocene upper Gurabo and Mao formations postdate the occurrences of *C. cactaceus* in the Chagres Formation of Panama, which is now regarded as Late Miocene in age (Collins *et al.*, 1996; Collins & Coates, 1999), and the possibly correlative Coatzacoalcos Formation of southeastern Veracruz, Mexico. It is possible, therefore, that *C. paracactaceus* n. gen., n. sp. evolved from *C. cactaceus*. (See also the remarks under *Chagrepecten* n. gen.).

Distribution.—Chagrepecten paracactaceus n. gen., n. sp. is known only from the upper Gurabo and Mao formations, Lower and Middle Pliocene, of the northern Dominican Republic.

Genus ***CRYPTOPECTEN*** Dall, Bartsch & Rehder, 1938 [emend. Hayami, 1984]

Type species.—Cryptopecten alli Dall, Bartsch, & Rehder, 1938 [= *Pecten* (*Chlamys*) *bullatus* Dautzenberg & Bavay, 1912], by original designation, Hawaiian Islands, Philippines, Japan; Late Pliocene to Recent (Hayami, 1984: 88).

Diagnosis.—"Shell comparatively small-sized for pectinids, with height subequal to length, nearly acline but tending to become slightly prosocline in later growth stages. Convexity of shell variable among species, but right valve commonly more strongly inflated than left, the reverse being the case in early growth stages. Byssal notch moderately deep, provided with several denticles of ctenolium. Wings moderate in size; anterior generally larger than posterior. Anterodorsal margin nearly straight, posterodorsal margin slightly concave, especially in later stages. Apical angle moderately large for pectinids. Disk margin scarcely gaped. Disk suborbicular, ornamented with 12 to 25 strong and simple radial ribs, and in later growth stages with a few fine threads on each interspace as well. Both lateral sides of radial ribs, and sometimes interspaces, covered with fine imbricated scales which enclose narrow hollow chambers. Wings of both valves with several radial ribs without hollow chambers. Early dissoconch marked with delicate *Camptonectes*-like striae, occurring from much earlier stage in left valve than right and disappearing before shell attains 4 mm in height. Coloration quite variable within each species, but commonly reddish brown. Left valve more darkly pigmented than right. Byssal wing of right valve almost invariably pale. Outer ligament area comparatively thin. Resilial pit small or moderate in size" (Hayami, 1984: 90).

Remarks.—In his thorough systematic revision of *Cryptopecten*, Hayami (1984) intended his emended diagnosis to apply to species such as the extant Indo-Pacific *Pecten bullatus*, *P. vesiculosus* Dunker, 1877, and *P. nux* Reeve, 1853, the extant western Atlantic *P. phrygium* Dall, 1886, and to some Neogene species from Japan, all of which have sculpture of high relief and deep byssal notches. He regarded as debatable, however, the assignment to *Cryptopecten* of species such as *Pecten cactaceus* Dall, 1898, from the Miocene of Mexico and Panama, placed in *Cryptopecten* by Woodring (1982: 594). Following Hayami's lead, I place *P. cactaceus* and a new species from the Dominican Republic in a new genus *Chagrepecten* n. gen., described above.

Geographic range.—Although *Cryptopecten* species inhabit a broad range of depths in the Indo-Pacific, from inner sublittoral to bathyal (Hayami, 1984), the type species lives in deep water, commonly at depths of 200-400 m (based on USNM collection data). The only extant species in the western Atlantic, *C. phrygium*, also lives in deep water, commonly in 90-200 m, from Cape Hatteras to Florida, the Gulf of Mexico, the Antilles, to as far south as Guiana (Hayami, 1984: 111 and USNM collection data).

Stratigraphic range.—Lower or Middle Miocene to Recent (Hayami, 1984: 16).

Cryptopecten phrygium (Dall, 1886)
Pl. 9, Figs 1-5

Pecten phrygium Dall, 1886: 217; 1889: 438, pl. 40, fig. 1.
Aequipecten (*Aequipecten*) *phrygium* (Dall). Abbott, 1954: 367.
Aequipecten phrygium (Dall). Abbott, 1974: 445.
Cryptopecten phrygium (Dall). Woodring, 1982: 595; Hayami, 1984: 110, pl. 9, figs 6-9.

Description.—Shell small, maximum known 50 mm Ht but commonly no larger than 35 mm, acline in young stages, later becoming prosocline and inequilateral with posterior somewhat more extended than anterior, Ht slightly exceeding L in early ontogeny, L > Ht later, equivalved or with RV slightly more convex than LV, with convexity of each valve moderate (cvx *ca.* 18-20% Ht), umbonal angle *ca.* 105-115°; disks with 15-18 radial ribs, averaging 17 in populations along North American coasts, but 17-21, averaging 19, in specimens from southern Antilles and Guyana shelf; ribs on RV originating at border of prismatic stage at *ca.* 1.8 mm Ht, on LV after nearly smooth preradial stage at approximately same Ht, becoming high in amplitude with deep, rounded interspaces; rib crests of RV very narrow, crossed by distally convex growth lines, sometimes forming weak scales; rib flanks deeply concave in profile and with distally concave commarginal lamellae that merge with adjacent lamellae to form bulging vesicles; floor of interspaces between edges of rib flanks crossed by distally concave commarginal lamellae that can be projecting and erect, seldom forming vesicles; medial radial costella intercalating between ribs almost at point of origin of ribs, with secondary costellae commonly increasing in number distally to 3 or 4, each separated by small distally concave lamellae, but commonly obscured by strongly projecting commarginal lamellae; rib crests of LV narrower than on RV, rarely a solid ridge, more commonly consisting of tips of vesicles alternating on each side of crest midline; sculpture of rib flanks and interspaces as on RV. Anterior auricles longer than posterior, total hl *ca.* 60% L; right anterior auricle with deep byssal notch with depth approximately half length of auricle and floored by strong active ctenolium consisting of 3 or 4 teeth, dorsal margin with strong scales, remainder of surface with 4 or 5 radial costae and much finer costellae intercalating distally; byssal fasciole well demarcated, crossed by commarginal ridges; left anterior auricle with deep byssal sinus, overall trend of anterior auricular margin forming acute angle with dorsal margin; surface of auricle with 4 or 5 major costae carrying distally pointing scales, 2 dorsal costae closely spaced, others more widely; much finer secondary costae intercalating distally; posterior margins of posterior auricles also forming acute angle with dorsal margin, surfaces with 2 closely spaced dorsal costae and 1 or 2 additional widely spaced costae, all separated by much finer intercalated costellae. Disk flanks high and steep, crossed by fine commarginal growth lines and, in early ontogeny, by microscopic antimarginal striae. Hinge dentition dominated by dorsal teeth on RV and infradorsal teeth on LV, RV with weak intermediate ridge and resilial tooth on each side; all articulating surfaces crossed by fine transverse microcrenulations. Inner foliated-calcite layer well developed, extending ventrally from dorsal margin along anterior margin of adductor scar and bordering ventral margin of scar to form elevated myophoric platform. Internal plicae with well developed carinate edges near shell margin.

Type material and measurements.—The syntypes of Dall (1886), all from the Gulf of Mexico, are in the Museum of Comparative Zoology, Harvard University. To specify a precise type locality, I herein designate the articulated shell figured by Dall (1889: pl. 40, fig. 1) as the lectotype. Dall referred to this specimen as the largest and gave its dimensions (36.5 mm Ht; 36.5 mm L; 19.0 mm hl; and umbonal angle *ca.* 100°).

Type locality.—Locality of the lectotype: "In 95 fms. [= 174 m], north of Yucatan Banks, in N. Lat. 23°32' and W. Lon. 88°5'." (Dall, 1886: 217)

Other material.—Northern Dominican Republic: Mao Formation on Río Mao: NMB 16801, 1 partial RV, 18 mm Ht (restored); USGS 8528, 2 LV fragments, maximum 22 mm Ht (restored); Gurabo Formation on Río Mao: USGS 8733, 1 LV, 14.5 mm Ht; Mao Formation on Río Gurabo: TU 1352, 4 RV, maximum 17.8 mm Ht, 1 LV, 30.1 mm Ht; Gurabo Formation on Río Cana: NMB 17009, 2 RV, 1 LV, maximum 6.9 mm Ht. Recent specimens of *Cryptopecten phrygium* in the Smithsonian collections consisting of 84 lots of the northern form (eastern and Gulf of Mexico coasts of North America) and 11 lots of the southern form (Barbados, Grenada, and the Guyana shelf) totaling *ca.* 150 specimens (single valves and articulated specimens combined).

Remarks.—Geographic variation in living *Cryptopecten phrygium* is evident in the studied material. A northern form living on the continental shelf from off of South Carolina to the Florida Keys and in the northern Gulf of Mexico is distinguished by a lower rib count from a southern form occurring in the southern Antilles and on the Guyana shelf (see preceding description). In addition, the northern form tends to be more convex and to have higher ribs and more erect commarginal lamellae in rib interspaces.

The extant species prefers water depths in the range of 90-200 m, with the total range of both live and dead specimens among the studied samples being 73-290 m. Lots containing specimens inferred to have been alive when collected are rare, suggesting that this species lives in low population densities and is probably not gregarious.

A deep-water preference is also indicated for the Dominican Republic fossil representatives of this species. Locality TU 1352, which yielded the greatest number of specimens of *Cryptopecten phrygium*, is in the upper member of the Mao Formation where gravity flows have brought lenses of coarse material into deep-water clays (E. Vokes, 1989: 11, text-fig. 4). The only other fossils associated with *C. phrygium* are *Dimya* sp. (TU 1352) and *Argopecten inaequalis* (USGS 8733), both indicators of relatively deep water. Another interesting indication is taphonomic. On the specimen from USGS 8733, the vesicles, which are well preserved, are filled with finely crystalline pyrite, suggesting that slow burial facilitated diffusion of anoxic bottom water into vesicles. Pyrite-filled vesicles are also present in some specimens of *Chagrepecten paracactaceus* n. gen., n. sp. (TU 1292 and USGS 8735).

Comparison.—The only other species that could be confused with *Cryptopecten phrygium* in the Dominican Republic Neogene is *Chagrepecten paracactaceus* n. gen., n. sp., which occupied similar deep-water depositional sites in the upper Gurabo and Mao formations. Compared to the latter species, *C. phrygium* has a deeper byssal notch that remains deep throughout ontogeny and vesicles on the left valve that slant ventrally as they approach the rib crest (Pl. 9, Fig. 1). In *C. paracactaceus* n. gen., n. sp. (Pl. 8, Fig. 13), these vesicles are transverse, approaching the rib crest at nearly a right angle. *Cryptopecten bullatus*, the extant species on the Pacific side of the Americas, differs from *C. phrygium* in being more inequilateral, having smaller auricles and a shorter hinge relative to shell length, and in lacking foliated-calcite re-entry on the shell interior as well as raised adductor scars. There is also a difference in microsculpture in early ontogeny. In very early ontogeny, *C. bullatus* has very fine antimarginal microsculpture between radial ribs at their origin, whereas this area in *C. phrygium* has only microscopic pits.

Evolution.—*Cryptopecten phrygium* is represented by too few fossil specimens to permit recognition of any evolutionary trends. On the basis of morphology, the southern form is possibly more primitive than the northern form in having a higher rib count that is more like that of *C. bullatus* of the eastern Pacific. *Cryptopecten phrygium* appears to be more derived than any Indo-Pacific *Cryptopecten* in having posterior auricles that are more pointed and therefore more removed from an *Aequipecten* outgroup.

Occurrence.—In the northern Dominican Republic, *Cryptopecten phrygium* is known to occur only in the deep-water facies of the upper Gurabo and Mao formations.

Distribution.—Cryptopecten phrygium has not previously been reported from the fossil record of the tropical American region. The author has observed specimens of *Cryptopecten* at The Natural History Museum, London, from the basal coral-rock of Barbados (Trechmann, 1937).

Genus ***GURABOPECTEN*** n. gen.

Type species.—Gurabopecten uniplicatus n. sp., from the Gurabo Formation (late Miocene and early Pliocene age), northern Dominican Republic.

Diagnosis.—Aequipectininae of small size (maximum known dimension 23 mm), slightly prosocline, Ht > L, valves of equal convexity or with LV slightly more convex than RV; hl much shorter than L; auricles small, lacking enlarged posterior dorsal costae, with shallow byssal notch and short active ctenolium; ribbing highly uneven, central sector of RV consisting of single wide plica with slightly rounded crest, steep sides, and secondary costae on crest beginning in mid-ontogeny, bordered on each side by deep, wide interspace that becomes secondarily costate in late ontogeny; central sector of LV consisting of central deep, wide interspace flanked on each side by single wide plica, with secondary costae as on RV; ribs on anterior and posterior sectors of both valves much narrower than central plicae.

Etymology.—Prefix referring to the Gurabo Formation of the northern Dominican Republic combined with *-pecten*, a common suffix used for members of the family Pectinidae.

Remarks.—The new genus *Gurabopecten* is clearly a member of the Aequipectininae, as evidenced by its pitted left preradial stage, well-developed carinae on the distal edges of internal plicae, commarginal lamellae that have normal rather than very dense spacing, and a right hinge consisting of dorsal and very strong resilial teeth. The new genus is probably de-

rived from *Argopecten*, most likely from a form similar to the co-occurring species, *A. thetidis*. This is based on the presence in *Gurabopecten* n. gen. of steep-sided plicae, flattened crests on the enlarged central plicae, steep disk flanks that are without costae early in ontogeny, and extensive foliated-calcite re-entry on the valve interiors that completely penetrates the separation between the striate and nonstriate adductor scars of the right valve. However, there is as yet no observable transition between the normal even-ribbed pattern of *A. thetidis* and the highly uneven pattern of *Gurabopecten* n. gen. There is only a hint of this transition provided by one individual among the 1,645 examined specimens of *A. thetidis* from the Gurabo Formation. This specimen, a right valve (USNM 540969, locality TU 1211; Pl. 7, Fig. 17), has an unusually low rib count (15) and has somewhat broader ribs and interspaces in the central sector than in the anterior and posterior sectors, the central rib crests becoming secondarily costate in late ontogeny.

The only other aequipectinine species that is known to develop enlarged, secondarily costate plicae, short auricles, and height greater than length is the extant species *Pecten fasciculatus* Hinds, 1845, of the tropical eastern Pacific (type locality: western coast of Panama off of Veragua, depth 31 m). It is now known to be a highly modified *Cryptopecten* that still retains the enlarged pair of dorsal costae on its posterior auricles, hinge structure, early microsculpture, and vesiculate sculpture that are typical of *Cryptopecten* (Waller, unpubl. data).

Geographic range.—Known only from the northern Dominican Republic.

Stratigraphic range.—Upper Miocene to Lower Pliocene.

Gurabopecten uniplicatus n. sp.
Pl. 9, Figs 6-16; Table 13

Diagnosis.—As for the new genus *Gurabopecten*.

Description.—Shell small, not known to exceed 23 mm Ht, distinctly prosocline with posteroventral region extended and posterior disk flank longer than anterior, Ht > L (Ht/L = 1.1-1.2), moderate cvx (cvx/L = 0.22-0.29), nearly equiconvex, short hl (hl/L = 0.5-0.6), ahl longer than phl (ahl/phl = 1.2-1.4); ventral margin commonly with slight inturning or ledging beginning in late ontogeny. Disks with radial ribs very uneven in width; central sector of RV with single, wide, nearly flat-crested, steep-sided plica bordered on each side by wide, deep interspace; anterior and posterior sectors each with 5 or 6 much smaller ribs, those next to central sector tending to merge in mid-ontogeny to produce single larger rib that is not as broad as central rib; central sector of LV with central wide, deep interspace bordered on each side by wide, round-crested plica; anterior and posterior sectors each with 4 to 6 much smaller ribs and a deeper interspace bordering each side of central sector; all ribs becoming secondarily costellate in early ontogeny but broad interspaces becoming costellate much later in ontogeny. Commarginal lamellae widely spaced, transverse across interspaces in early ontogeny but forming distally concave arcs on rib flanks and between costellae in later ontogeny. Disk flanks steep, smooth in early ontogeny but with fine radial costellae beginning in mid-ontogeny. Auricles small; right anterior auricle with rounded anterior margin and 4 or 5 radial costae; byssal notch of shallow to moderate depth bordered by active ctenolium of only 1 or 2 teeth obscured in lateral view by overhanging flange of right anterior disk flank; left anterior auricle with moderately deep byssal sinus and 5 or 6 radial costae; posterior auricles small, with concave posterior margins that meet dorsal margin at acute angle and 7 or 8 radial costae in early ontogeny, increasing in number by intercalation in mid-ontogeny. Hinge dentition strong, dominated on RV by resilial teeth, which can be centrally depressed and somewhat bifid; infradorsal teeth of LV prominent, fitting into deep sockets between resilial and dorsal teeth of RV; all teeth crossed by irregular vertical microridges. Striate and nonstriate adductor scars of RV deeply separated; adductor scar of LV with posterodorsal projection formed by scar of byssal retractor muscle. Foliated-calcite re-entry on RV completely penetrating separation between striate and nonstriate adductor scars and variably extending across valve along ventral margin of nonstriate adductor scar, remaining separated from midventral pallial line by zone of aragonite; foliated-calcite re-entry of LV commonly extending to level of ventral margin of adductor scar but not extending posteriorly along ventral margin of scar. Pigment pattern, preserved in several specimens, consisting of broad, dark diagonal bands, observed mainly on posterior sector of LV, and narrower transverse bands on posterior disk flank (Pl. 9, Fig. 11).

Etymology.—Named with reference to the single major plica in the central sector of the right valve.

Holotype and measurements.—USNM 540976 (Pl. 9, Figs 6-10), 1 RV, 18.0 mm Ht, 16.1 mm L, 8.5 mm hl, 4.9 mm cvx.

Type locality.—Locality TU 1211, left bank of Río Gurabo, second bluff below the ford on the [old] Los Quemados-Sabaneta road (= USGS 8546), *ca.* 381-385 m above base of section, Gurabo Formation, Upper Miocene, northern Dominican Republic (Saunders *et al.*, 1986: text-fig. 15).

Other material.—165 specimens from 21 localities in the

northern Dominican Republic (Table 13). All but one of these are single valves.

Remarks.—Specimens of *Gurabopecten uniplicatus* n. gen., n. sp. vary slightly in shape, although in all cases height exceeds length. The amplitude and width of the hypertrophied plicae of the central sector of each valve are fairly constant, but the spacing of the smaller ribs of the anterior and posterior sectors is more variable. These ribs can variously merge or cluster adjacent to the central sector, in some cases producing an additional enlarged plica on each side of the central sector of the right valve and a corresponding deep groove on the left valve. In rare cases (two specimens, including the holotype), a small primary riblet, originating at the boundary of the prismatic stage, can occur in the center of one of the large interspaces of the right valve (Pl. 9, Fig. 6). Its expression on the left valve is a groove down the center of the corresponding major rib (Pl. 9, Fig. 9).

Gurabopecten uniplicatus n. gen., n. sp. is interpreted as a species adapted to life on fine sediment, well within the photic zone, probably near the outer depth range of *Argopecten thetidis* and clearly in deeper water than *A. eccentricus*. *Gurabopecten uniplicatus* n. gen., n. sp. is associated with *A. thetidis* at 17 of the 21 localities (Table 13) but with the shallower-water species *A. eccentricus* at only one locality (TU 1250 on Río Verde). This latter locality, however, has several gravity-flow deposits in which specimens originally deposited in shallow water have been transported into deeper water (E. Vokes, 1989: 12). This could explain the additional association at this locality of *G. uniplicatus* n. gen., n. sp. with *Parvamussium*, a propeamussiid normally associated with deep water. Preference for a fine silt sedimentary environment is indicated by the matrix adhering to many specimens. A depth of deposition within the photic zone (< 200 m) is indicated not only by the shell pigment patterns on many specimens, particularly on left (upper) valves), but also by the presence of abundant foraminiferans of the genus *Amphistegina*. Saunders *et al* (1986: 16) characterized the paleoenvironment of that part of the Río Gurabo section in which *G. uniplicatus* n. gen., n. sp. occurs (*ca.* 285 to nearly 400 m above base of section) as having a depth of deposition "probably greater than 40 m and open ocean circulation." The stratigraphically highest specimens of *G. uniplicatus* n. gen., n. sp. collected on the Río Gurabo occur in the Gurabo Formation *ca.* 400 m above the base of section (Table 13) where there is rapid deepening of the depth of deposition to > 200 m (Saunders *et al.*, 1986: 16).

Comparisons.—*Gurabopecten uniplicatus* n. gen., n. sp. is distinguished from all other Neogene Pectinidae of the western Atlantic-Caribbean-Panamic region by way of its huge central plicae and minor lateral ribs. The distinctly pitted left beak (preradial zone) and relatively far-set commarginal lamellae, characters shared by *G. uniplicatus* n. gen., n. sp. with other members of the subfamily Aequipectininae, distinguish the species from uneven-ribbed members of the subfamily Decatopectininae Waller, 1986, which have smoother preradial zones and very close-set commarginal lamellae.

Evolution.—I have observed no stratigraphic sequence of morphologies leading to the form of *Gurabopecten uniplicatus* n. gen., n. sp. The species appears and disappears suddenly after its narrow stratigraphic range in the Gurabo Formation. The morphology of the species suggests a sister-group relationship with *Argopecten thetidis*, and the rare specimen of the latter with unevenly spaced ribs, mentioned above, lends support to this hypothesis. The absence of *Gurabopecten* n. gen. in other regions could be due to its narrow ecological range, such that similar conditions have not been preserved at localities thus far sampled, and also due to its narrow stratigraphic range, suggesting that precisely correlative deposits in nearby regions have not been sampled.

Occurrence.—*Gurabopecten uniplicatus* n. gen., n. sp. occurs almost entirely in the Gurabo Formation exposed along the Río Gurabo from *ca.* 285 to 403 m above the base of the section (Table 13). This interval extends from the Upper Miocene into the Lower Pliocene, the Miocene/Pliocene boundary occurring just below 400 m above the base of the section (Saunders *et al.*, 1986: 17).

Distribution.—*Gurabopecten uniplicatus* n. gen., n. sp. is known only from Upper Miocene to Lower Pliocene of the northeastern Dominican Republic.

Genus ***LEPTOPECTEN*** Verrill, 1897

Chlamys (Leptopecten) Verrill, 1897: 69.
Aequipecten (*Pacipecten*) Olsson, 1961: 164.

Type species of Leptopecten.—*Pecten monotimeris* Conrad, 1837, by original designation (Verrill, 1897), = *Pecten latiauratus* Conrad, 1837. Recent, northeastern Pacific, Point Reyes, California, to Cabo San Lucas, Baja California Sur (Coan *et al.*, 2000: 237).

Type species of Pacipecten.—*Pecten tumbezensis* d'Orbigny, 1846: 663, by original designation (Olsson, 1961), Recent, Gulf of California to Paita, Peru (Grau, 1959: 120).

Original diagnosis.—"Shell thin, translucent, oblique, broadly rounded, with strong, rounded radial ridges or folds, like corrugations, which appear in reverse on the interior sur-

Table 13. Occurrence of *Gurabopecten uniplicatus* n. gen., n. sp., in the Cibao Valley. Localities ordered by stratigraphic level measured from base of section except for road cuts, which are ordered by locality number. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; Anq, *Antillipecten quemadosensis* n. sp.; At, *Argopecten thetidis*; Cg, *Cyclopecten guppyi*; Cz, *C. zalaya* n. sp.; Dm, *Dimya* sp.; DV, matching valves; Eg, *Euvola gurabensis* n. sp.; Es, *E. soror*; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Pvm, *Parvamussium marmoratum*; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo								
NMB 15814	403	Gurabo	0	1	0	7.3	At	
NMB 15815	402	Gurabo	1	2	0	13.1	At, Dm, Sv	
NMB 15934	402	Gurabo	3	2	0	18.7	At, Dm, Lpa	
NMB 15962	400	Gurabo	2	2	0	12.8	At, Dm, Lpa, Sv	
NMB 15804	399	Gurabo	3	2	0	20.0	At, Sv	
USGS 8544	397-399	Gurabo	2	1	0	19.0	At, Ncv	
----------								Miocene/Pliocene boundary (Saunders *et al.*, 1986: text-fig. 14)
TU 1210	394-396	Gurabo	4	3	0	19.5	Amp, At, Lpa, Ncv, Sv	
NMV 15805	393-395	Gurabo	7	3	0	13.1	Dm, Sv	
NMB 15941	392	Gurabo	0	1	0	5.7	Cg, Dm, Sv	
TU 1212	389-398	Gurabo	1	2	0	19.0	Amp, At	
USGS 8545	388-399	Gurabo	1	0	0	9.6	none	
NMB 15942	389	Gurabo	1	0	0	8.2	Dm	
TU 1369	388?	Gurabo	5	1	0	20.1	Amp, At, Lpa, Sv	
TU 1279	387-389	Gurabo	15	1	0	22.2	At, Es, Lpa, Sv	
NMB 15836	387-389	Gurabo	1	0	0	17.8	At	
TU 1211	381-385	Gurabo	10	3	0	22.1	Apa, At, Sv	Type locality of *G. uniplicatus* n. gen., n. sp.
TU 1278	376-378	Gurabo	8	4	0	22.7	Anq, At, Es, Lpa, Ncv	
Río Verde								
TU 1250	--	Gurabo	3	2	0	16.5	Aec, Amp, At, Cg, Cz, Es, Lpa, Pvm	
Santiago area								
TU 1227A	--	Gurabo	3	0	0	16.7	Ai, Amp, At, Cg, Cz, Es, Pvm	
Road cuts								
TU 1209	--	Gurabo	27	19	1	18.8	At, Eg, Lpa, Ncv, Sv	
TU 1338	--	Gurabo	14	5	0	22.0	Amp, At, Eg, Lpa	

face. The internal ribs are not angulated by a deposit of shell, nor distinctly thickened. Margin with broad scallops. The exterior surface is covered with fine divergent camptonectes sculpture, both on the ribs and intervals. The ribs do not increase in number with age, but become broader and more flattened. Auricles large and broad, thin, corrugated. Byssal notch large and deep. Pectinidial teeth prominent. Hinge plate thin and but little differentiated. Cardinal ridge thin and small,

close to the ligament, crossed by fine incisions. The resilial pit is small, but projects beyond the thin hinge-plate in the left valve" (Verrill, 1897: 69).

Description.—Shells acline to strongly prosocline, Ht and L approximately equal, convexity of articulated shell low to moderate, ranging from moderately right-convex to equivalved to strongly left-convex; auricles large relative to size of disk, total hl approximately equal to L in juveniles, commonly < L in mature specimens; anterior auricle long and narrow, with anterior extremity commonly projecting beyond anterior extremity of disk in early ontogeny; byssal notch deep, floored by prominent active ctenolium with 4-7 teeth; posterior auricles with straight or slightly sigmoidal posterior margin commonly forming acute angle with dorsal margin. Primary radial plicae on disk with even height and spacing on both valves, commonly decreasing in amplitude toward shell margin; right anterior auricle with strong closely spaced radial costae, right posterior auricle commonly with more widely spaced costellae that can be weak or absent in later ontogeny. Hinge dentition simple, on RV consisting of very narrow dorsal teeth, resilial teeth drawn out laterally parallel to dorsal teeth, proximal end of anterior resilial tooth raised higher above hinge plate than is proximal end of posterior resilial tooth. Commarginal lamellae commonly absent or weakly developed, tending to pass straight across interspaces with slight curvature on rib flanks, uncommonly forming deep, distally concave loops on rib flanks during early ontogeny.

Remarks.—Verrill (1897: 69) based his description of *Leptopecten* on only one species, *Pecten monotimeris* Conrad, 1837. A second species described by Conrad (1837), *P. latiauratus*, which has page priority over *P. monotimeris*, differs from the latter in lacking commarginal lamellae and in having a more prosocline form, thinner shell, lower, more rounded ribs, and shorter auricles. These two putative species have broadly overlapping geographic ranges along the California coast and have been regarded by more recent authors as either subspecies (*e.g.*, Grau, 1959) or ecomorphs (*e.g.*, Coan *et al.*, 2000: 237). Clark (1971) provided evidence based on laboratory observations that their differences are under ecological control, possibly but not conclusively involving temperature relative to position in the water column.

The genus name *Leptopecten* has been applied to a wide array of Recent and extinct species living mainly in warm marine waters on both sides of the Americas, the main feature in common being the relatively large auricles, particularly the anterior auricles, the anterior extremities of which commonly project beyond the anterior extremities of the disks. The shell has a strongly prosocline pterioid shape, at least in early ontogeny, and a deep byssal notch bordered ventrally by a prominent active ctenolium that persists throughout ontogeny.

Olsson (1961: 164) subdivided *Leptopecten* by introducing a new genus-group name, *Pacipecten,* for species said to differ from *Leptopecten s. s.* in being more equilateral and having heavier, thicker valves. Upon examining many species of *Leptopecten*, however, it can be seen that equilaterality, prosoclinity, and shell thickness vary greatly. Even the ecomorphs of *L. latiauratus* mentioned above differ in shell thickness, with the lamellate form *L. latiauratus* having a thicker shell than the smooth form *L. monotimeris*. Difference in shell thickness also affects the degree to which the edges of plicae become thickened or carinate on the inner shell surface. Such internal carinae are absent in ultrathin *L. monotimeris* but present in thicker-shelled *L. latiauratus*. For these reasons, *Pacipecten* is regarded herein as a junior synonym of *Leptopecten*.

In the course of the present study, 41 nominal species and subspecies of so-called *Leptopecten* or *Pacipecten* were examined (Appendices 2-3; see Moore, 1984, for extensive application of the name *Pacipecten*), and it is concluded that there are good morphological and biogeographical reasons to subdivide *Leptopecten*, but in a different way than was done by Olsson (1961).

The name *Leptopecten* is herein restricted to those species having rounded, trigonal, or slightly flattened plicae of uniform height and spacing, commonly with commarginal lamellae only weakly developed during at least part of ontogeny and, with few exceptions, not forming deep cusps on the sides of ribs. The radial costae on at least the right posterior auricle are commonly weaker and more widely spaced than the costae on the right anterior auricle, and in some species the posterior auricular costae fade out in early ontogeny.

The name *Paraleptopecten* n. gen., described below, is applied to those species that have angular plicae commonly fringed by cuspate commarginal lamellae that are looped in distally concave curves and auricles that are densely costate. Commonly the disk plicae differ in height or spacing. On the left valve, some plicae, commonly 5, are higher and broader than others, separated by from 1-4 four narrower, lower plicae that originate slightly later than the major plicae. In some species, such as *Paraleptopecten biolleyi* (Hertlein & Strong, 1946), only a single left plica on the posterior side is higher than the others, but some individuals within this species can show the more typical pattern of 5 high ribs, at least in early ontogeny. Because the plicae of opposite valves interlock at the shell margin, the right valve has interspaces differing in depth and width, the deeper and wider interspaces corresponding to the higher and broader plicae of the left valve. *Paraleptopecten* also differs from *Leptopecten* in having more numerous and persistent radial costae on both posterior auricles and a shell that is equivalved or with the right valve more convex than the left, in contrast to *Leptopecten*, most species of which are left-

convex. The type localities and geological occurrences of species included in the two genera are listed in Appendices 2-3.

Included in *Leptopecten* are a number of species placed in *Pacipecten* by Moore (1984) that occur in the Miocene of western North America. Collectively referred to in the present study as the *L. andersoni* group (Appendix 2), these differ from *Leptopecten s. s.* in having more flaring valves, proportionately smaller auricles, a somewhat shallower byssal notch, and posterior auricular margins that commonly form an obtuse angle with the dorsal margin rather than a 90° or acute angle. Clues to their close relationship to *Leptopecten s. s.* can be seen in the early ontogeny of some species, during which the shell is more prosocline with a deeper byssal notch and proportionately larger auricles [*e.g.*, see Arnold, 1906: 82, referring to some of the young of *L. andersoni* (Arnold, 1906) as being "almost indistinguishable" from small specimens of *L. monotimeris*]. There are also similarities in rib profiles, the ribs of both *Leptopecten s. s.* and the *L. andersoni* group commonly having rounded to somewhat trigonal profiles with very weak central keels on rib crests. As in most *Leptopecten s. s.,* members of the *L. andersoni* group have a prominent, sunken byssal fasciole and posterior auricles that have weak, widely spaced costellae.

The *Leptopecten andersoni* group, which first appeared in the late Oligocene or early Miocene in the eastern Pacific, is probably the basal group from which more typical *Leptopecten* evolved, based on morphology and stratigraphic occurrence. The more aequipectinoid form of the *L andersoni* group is likely plesiomorphic compared to the unusually prosocline, pterioid form of *Leptopecten*. The oldest known member of the *L. andersoni* group is a species called "*Leptopecten*? sp." by Addicott (1972: pl. 1, fig. 11) from the lower Santos Shale of California, regarded as late Oligocene in age (Addicott, 1972: fig. 2). It is followed in the Lower Miocene by *L. subandersoni* (Loel & Corey, 1932) of southern California to Baja California Sur (Addicott, 1978: 26).

The earliest known species of *Leptopecten* on the eastern side of the Americas are closely related to one another and are all Middle Miocene in age. They are *L. gilbertharrisi* (F. & H. Hodson in Hodson *et al.*, 1927) from the Socorro Formation of northwestern Venezuela, *L. ecnomius* (Woodring, 1982) from the lower Gatun Formation of Panama, and an unnamed species from the middle part of the Thomonde Formation of Haiti (USGS 9907, cataloged as USNM 481781, data published by Woodring *et al.*, 1924: 175).

During the Late Miocene and Early Pliocene, large populations of *Leptopecten* (to judge from deposits of abundant fossils) lived in areas of probable upwelling and high productivity along the Caribbean coast of Venezuela [*Leptopecten coderensis* (Harris in Hodson *et al.*, 1927), Codore Formation] and the northern coast of the Dominican Republic [*L. thompsoni*, Cercado Formation, described below). At present, members of *Leptopecten* are common in upwelling areas along the coasts of southern California (*L. latiauratus*) and Ecuador and Peru (*L. tumbezensis*). In contrast, on the Atlantic side of the Americas, only a single species, *Leptopecten linki* (Dall, 1926), survives. It persists mainly along the Caribbean coasts of Central and South America from Honduras to Surinam with an outlier population in the Bahamas (Cosel, 1986: 118, and USNM collections). Collectively, *Leptopecten* has throughout most of its history been a warm-water genus. The northward range extension of *L. andersoni* into Washington and Oregon during the Middle Miocene occurred at the height of a Miocene warming cycle (Addicott, 1969, 1976: 104). At present, however, *L. latiauratus* lives in cool waters on the California coast as far north as Point Reyes (38.0°N) (Coan *et al.*, 2000: 237).

Geographic range.—Presently living in the eastern Pacific from southern California to Paita, Peru, and in the western Atlantic along the Caribbean coasts of Central and South America from Honduras to Surinam and the Bahamas. Fossil ranges in eastern Pacific are more extensive, from southeastern Washington to Peru. Byssate on marine vegetation or hard substrata, subtidal to 250 m.

Stratigraphic range.—Upper Oligocene to Recent on the western side of the Americas; Middle Miocene to Recent on the eastern side.

Leptopecten thompsoni (Maury, 1917a)
Pl. 9, Figs 17-21; Table 14

Pecten thompsoni Maury, 1917a (March 31): 177, pl. 34, figs 9-10; not Tang & Pantel, 2005: electronic publication without page numbers, fig. 1 [= *Argopecten eccentricus* (Gabb, 1873)].

Pecten ischnon Pilsbry & Johnson, 1917 (May 4): 194; Pilsbry, 1922: 413, pl. 44, figs 7- 9.

Original description.—"Shell thin, delicate, translucent, suborbicular, flattened, inequivalve; ribs eighteen or nineteen, rounded, a little wider than the interspaces, giving a characteristically fluted aspect to the valves; ribs and interspaces smooth except for very fine, raised, concentric growth striae; right valve exceedingly flattened with prominent ears, the anterior noticeably reflexed, deeply notched beneath and sculptured with approximately five radial riblets more or less squamose, especially that bordering the dorsal margin; a deep sulcus marks the junction of the ear with the umbonal region; posterior ear smaller, sub-triangular, its surface smooth except for concentric growth striae similar to those on the face of the valve; left valve also compressed but gently convex in the um-

bonal region; ears more nearly equal, the anterior with four to six radial threads and fine growth striae; the posterior smooth except for the striae. An average-sized right valve measures in length 20, altitude 18, semi-diameter 2; a left valve 18 x 17 x 3 mm. This species is readily distinguished by its flattened form, discrepant valves, and large, twisted right ear" (Maury, 1917a: 188).

Description.—Shell not known to exceed *ca.* 25 mm Ht, prosocline and inequilateral with posterior somewhat extended; L and Ht approximately equal; cvx of RV very low, only *ca.* 10-12% Ht; LV more convex than RV with cvx *ca.* 16% Ht but relatively greater in early ontogeny. Disks commonly with 17 radial plicae of low amplitude, broadly trigonal in profile with crests narrow and rounded or with very faint central keel; rib profiles becoming narrower and asymmetrical and bearing short, blunt scales near anterior and posterior margins, steeper sides toward lateral valve margins; edges of ribs carinate on interior near margin. Commarginal lamellae on both valves very thin, commonly not appearing until valve height > 7 mm on RV, earlier on LV, weakly developed and crowded in late ontogeny, passing across plicae and interspaces with little deflection. Anterior disk flank of RV low, steep, and without radial costellae, posterior disk flank also low but bearing 1-3 fine radial costellae; disk flanks of LV low but less steep, each bearing 1-3 fine radial costellae. Auricles relatively large compared to size of disk, total hl *ca.* 65-70% L in mature specimens, greater in juveniles; anterior hl approximately equal to posterior hl, somewhat longer in young specimens; right anterior auricle long and narrow, its anterior extremity projecting beyond anterior extremity of disk in juvenile specimens, surface with 3 or 4 strong radial costae crossed by thickened commarginal lamellae, bordered ventrally by very deep byssal notch that extends over half length of auricle and prominent active ctenolium consisting of 3-5 teeth; dorsal margin of auricle with scroll of shallow depth; entire auricle somewhat twisted outward from plane of commissure; left anterior auricle with sigmoidal anterior margin passing ventrally along deep byssal sinus and bearing 6-9 radial costae crossed by thickened commarginal lamellae; both posterior auricles flat posterior margins straight or slightly concave and forming 90° or slightly acute angle with dorsal margin; left posterior auricle with 5-6 costellae crossed by closely spaced commarginal lamellae; right posterior auricle with only very weak or obsolescent, widely spaced radial costae. Hinge dentition low and not well differentiated, dorsal teeth of RV narrow; resilial teeth broad and covered by fine irregular vertical ridges; proximal end of anterior resilial tooth projecting upward from hinge, especially noticeable in dorsal view. Adductor scars not well preserved because of dissolution of aragonite; foliated-calcite re-entry extending only to level of dorsal edge of adductor scar on both valves.

Type material and measurements.—Syntypes: PRI 28967, 1 RV (Maury, 1917a: pl. 34, fig. 9), 18.6 mm Ht, 20.0 mm L; PRI 28966, 1 LV (Maury, 1917a, pl. 34, fig. 10), 13.2 mm Ht, 13.8 mm L.

Type locality.—Maury's (1917a-b) Bluff 3, Cercado de Mao, Río Mao, northern Dominican Republic, Cercado Formation, Upper Miocene.

Other material.—The combined collections of NMB, TU, and USGS from the Dominican Republic contain 3,148 specimens, all of which are single valves (Table 14).

Remarks.—In spite of its abundance at some sites, *Leptopecten thompsoni* is remarkable in its restricted distribution. Ninety-six percent of the specimens collected from the northern Dominican Republic are from Maury's Bluffs 2 and 3 on the Río Mao (Table 14). The species is most abundant at Bluff 3 and somewhat less so in the lower beds at Bluff 2. Abundance declines rapidly in the higher beds at Bluff 2 (Beds g and h, Table 14), and the species is unknown from Bluff 1, which is up-section and represents deeper-water deposition (Saunders *et al.*, 1986: 32). In the Río Gurabo section, only two specimens were collected from one site (NMB 15920). This site is the stratigraphically lowest pectinid-bearing site in that section (55-57 m above base of section) and apparently represents very shallow-water deposition. *Leptopecten thompsoni*, like its living counterpart *L. latiauratus* in the eastern Pacific, was probably byssate throughout life, commonly attached to a variety of substrata including marine grasses or algae (Morton, 1994: 17; Coan *et al.*, 2000: 237). This interpretation is corroborated by the co-occurrence of *Argopecten eccentricus eccentricus* at virtually all of the localities on the Río Mao that yielded *L. thompsoni*.

In samples with large numbers of *L. thompsoni*, shell sizes can range from very tiny (< 4 mm Ht) to near the maximum size (25 mm) for the species. This probably indicates that the species was gregarious, as is its living counterpart, *Leptopecten latiauratus* (see Morton, 1994: 18). It might also mean that storms could have periodically swept individuals from their attachment sites and transported them for a short distance before rapid burial. Transport and rapid burial are suggested by the disparate number of right and left valves within samples (Table 14) and the lack of epifauna on valve surfaces.

Leptopecten thompsoni varies little in shell shape or convexity. Numbers of plicae on the disk vary from 15-21, but 87% of the specimens have 17 or 18 plicae and the extreme counts are very rare. Rarely an additional plica can be intercalated between primary plicae on the posterior sector of the disk.

Table 14. Occurrence of *Leptopecten thompsoni* in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Aee, *Argopecten eccentricus eccentricus*; Amp, *Amusium papyraceum*; Anj, *Antillipecten janicoensis* n. sp.; Anq, *Antillipecten quemadosensis* n. sp.; B1, Bluff 1; B2, Bluff 2; B2/B1, between B2 and B1; Cg, *Cyclopecten guppyi*; DV, matching valves; Es, *Euvola soror*; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis s. s.*; LV, left valve; Nn, *Nodipecten nodosus*; Pa, *Paraleptopecten* sp. *a*; Pc, *Palliolum? cibaoense* n. sp.; --, not recorded. Lettered stratigraphic levels are explained in the text.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo								
NMB 15920	55-57	Cercado	0	2	0	4.6	none	This is the lowest pectinid-bearing horizon on the Río Gurabo
Río Mao								
USGS 8526	B2, g-h	Cercado	1	0	0	14.0	Amp, Es, Lpl	
NMB 16931	B2, g-h	Cercado	1	0	0	11.1	Aee	
NMB 16914	B2, g/h	Cercado	1	0	0	9.5	Aee	Between levels g and h
NMB 16929	B2, f	Cercado	13	12	0	18.2	Aee, Cg, Lpl	
NMB 16928	B2, e	Cercado	91	45	0	19.9	Aee, Cg, Lpl	
NMB 16924	B2, d	Cercado	88	40	0	20.6	Aee, Cg	
NMB 16918	B2, d	Cercado	63	32	0	22.5	Aee, Cg, Pc	
NMB 16926	B2, c	Cercado	54	35	0	20.0	Aee, Cg	
NMB 16916	B2, b-f	Cercado	12	4	0	14.8	Aee, Cg	
TU 1379	B2, b-e	Cercado	225	179	0	19.5	Aee, Cg	
NMB 16915	B2, b	Cercado	42	22	0	21.2	Aee, Cg	
NMB 16927	B2, b	Cercado	128	89	0	22.1	Aee, Cg	
NMB 16923	B2, b	Cercado	24	10	0	14.3	Aee, Cg	
NMB 16917	B2, b	Cercado	22	10	0	18.0	Aee, Cg	
NMB 16922	B2, a	Cercado	53	42	0	18.8	Aee, Cg	
NMB 16912	B3	Cercado	31	15	0	20.9	Aee, Cg, Pc	Overlies NMB 16913
NMB 16913	B3	Cercado	172	141	0	24.2	Aee	Underlies NMB 16912
USGS 8525	B3	Cercado	203	157	0	20.0	Aee, Cg, Pc	
TU 1294	B3	Cercado	559	408	0	22.9	Aee, Cg, Lpl, Paa, Pc	
USGS 8529	upstream from B3	Cercado	1	1	0	9.0	Aee	
TU 1295	upstream from B3	Cercado	24	20	0	22.1	Aee	
Río Albano								
USGS 8729	--	Cercado	26	25	0	21.9	Aee	
Santiago Area								
TU 1406	--	?	1	0	0	24.2	Aec, Amp, Anj, Anq, Es, Lpa, Lpl, Nn	
Road cuts								
TU 1340	--	Cercado	15	9	0	23.0	Aee, At, Lpl	

No stratigraphic trend in rib counts was detected. The two extremes illustrated are both from the Cercado Formation at Bluff 3 (locality TU 1294, Pl. 9, Figs 17-19) or upstream on the Río Mao from Bluff 3 (TU 1295, Pl. 9, Figs 20-21).

Comparisons.—*Leptopecten thompsoni* very closely resembles the extant Caribbean species *L. linki*, which is probably in the same lineage. The latter is less prosocline and more equilateral, reaches a larger size (to 42 mm Ht), commonly has fewer than 17 plicae (15-16), these plicae being higher and more rounded with steeper sides; and its right valve is somewhat more convex relative to shell height.

Leptopecten thompsoni also closely resembles *L. maturensis* (Maury, 1925a) from the Pleistocene Matura Sand and Clay Member of the Talparo Formation at Matura, Trinidad (see Jung, 1989: 12 and Kugler, 2001: 255 for age and history of this formation) and *L. coderensis* from the early Pliocene Codore and Punta Gavilán formations of Falcón, Venezuela. Compared to *L. thompsoni*, *L. maturensis* has an even thinner shell with lower ribs, and on the inner shell surfaces the internal rib carinae are more extensive and more *Amusium*-like. *Leptopecten coderensis* is comparable to *L. thompsoni* in having a right valve of very low convexity, but the Venezuelan species reaches nearly twice the size, and the plicae of its right valve are more commonly rounded rather than trigonal. Furthermore, the right posterior auricle of *L. coderensis* is commonly without radial costellae whereas fairly strong costellae are present on the left posterior auricle. The disk flanks of *L. coderensis* are commonly noncostate, whereas those of *L. thompsoni* possess a few radial costellae, particularly on the left valve.

Pecten cercadica var. *tabaquita* Maury, 1925a, from the Tamana Formation in Trinidad, is not a subspecies of *Pecten cercadica* (assigned in the present study to the decatopectinine genus *Antillipecten* n. gen.), but rather is a *Leptopecten*. Because it is represented by only a single, rather poorly preserved right valve (PRI 898, the holotype by monotypy), it is difficult to compare reliably to other species. Nevertheless, it appears to be less prosocline and has higher ribs than *L. thompsoni* and *L. maturensis*. The specimen described by Maury (1925a: 87) as *Pecten* cf. *cercadica*, from the Brasso Formation of Trinidad (underlying the Tamana Formation), is another *Leptopecten* and is possibly the same species as that in the Tamana Formation.

Evolution.—See discussions of the genera *Leptopecten* and *Paraleptopecten*.

Occurrence.—In the Dominican Republic, *Leptopecten thompsoni* is known only from the Cercado Formation. It occurs in abundance only at Maury's Bluffs 2 and 3 and nearby localities on the Río Mao but is present at only a few localities elsewhere in the Cibao Valley (Table 14).

Distribution.—*Leptopecten thompsoni* is unknown outside the northern Dominican Republic.

Genus ***LINDAPECTEN*** Petuch, 1995

Lindapecten Petuch, 1995: 40.

Type species.—*Pecten muscosus* Wood, 1828, by original designation, Recent, Gulf of Mexico, western Atlantic from Cape Hatteras to the Florida Keys, and Brazil (based on USNM collections identified by the present author).

Original diagnosis.—"Shell equivalve, inflated; auricles equal to width of widest part of the shell; hinge line straight or slightly depressed at umbones; short [posterior] auricle generally squared-off or truncated; large [right anterior] auricle projecting, partially detached from shell; ribs ornamented with 3 rows of prominent, erect, large scalelike spines; central row of spines often larger than side rows; auricles heavily ornamented with rows of large, often comblike, spines; rib spines and auricle spines closely-packed, giving shells extremely rough-textured, prickly appearance; shells often brightly colored, usually in shades of red, reddish-brown, orange, or pink; pure yellow morphs sometimes occur; color of both valves generally equally intense" (Petuch, 1995: 40).

Description.—Shell equivalve or with LV slightly more convex than RV, moderately convex to gibbous, acline and equilateral or slightly prosocline and posteroventrally extended; anterior auricles longer than posterior, with total hl approaching or equal to L; right anterior auricle elongate, its anterior margin commonly extending beyond anterior margin of disk, byssal notch deep with strong active ctenolium, byssal fasciole sigmoidal in cross section, its raised part adjacent to disk margin commonly rugose or scabrous; left anterior auricle with deep byssal sinus; posterior auricles with moderate to deep sinus, their posterior margins forming acute angles with dorsal margin. Disk having 16-25 unbranched, rounded plicae, commonly 5 of which are higher than intervening ribs at least in early ontogeny; secondary and lower-order costae forming at variable shell heights, commonly with central costa on rib crests forming first, then intercalation of secondary costa on each side on rib crest, followed by tertiary and higher-order costae that eventually cover rib crests and interspaces; scales on plicae and costae variably developed, in some species becoming very elongate, pointed or spatulate, concave on dorsal side; enlarged scales forming either on major ribs alone or on all ribs; spacing and size of scales on primary and lower-order costae variable, either all of approximately same size and spacing or scales on primary costae much larger and more widely spaced than others; commarginal lamellae in interspaces variably developed, commonly limited to early ontogeny, uncommonly well developed throughout ontogeny; disk flanks with fine scabrous costellae; auricles radially costate; dorsal mar-

gins commonly serrate due to projecting scales. Right hinge with strong, laterally extended resilial teeth paralleling weaker dorsal teeth, proximal ends of resilial teeth commonly depressed in mid- to late ontogeny, with depressions occupied by protuberances on left hinge adjacent to resilifer; left hinge dominated by infradorsal teeth. Foliated-calcite re-entry on shell interior not covering entire intrapallial area, extending in some species to ventral margin of adductor scar; byssal retractor scar of LV moderately developed; plicae on shell interior with carinate edges near disk margin.

Remarks.—Lindapecten differs from *Aequipecten* in having a more gibbous shell, acute-angled posterior auricles, stronger laterally extended resilial hinge teeth, and in lacking disk gapes. Except in the earliest species from the Lower Miocene, *Lindapecten*, unlike *Aequipecten*, lacks tight, ventrally concave curvature of commarginal lamellae on rib flanks in early ontogeny. *Lindapecten* differs from similarly spiny species in the genus *Mimachlamys* in having anterior and posterior auricles of more equal length and hinge dentition dominated by resilial teeth that out turned laterally to be nearly parallel to the hinge.

Petuch (1995: 40) included three extant species in his new genus: *Lindapecten muscosus* (Wood, 1828), *L. acanthodes* (Dall, 1925), and *L. lindae* Petuch, 1995. He did not consider the fossil record, although he later (Petuch, 2004: 243) mentioned the presence of "*Lindapecten* species (*L. muscosus* complex)" in the Pleistocene of Florida. *Lindapecten acanthodes* is now regarded as a junior synonym of *Pecten exasperatus* (see Waller, 1991: 34, based on examination of the syntypes of *P. exasperatus* in The Natural History Museum, London). *Lindapecten lindae*, for which Petuch gave no size, is merely a juvenile of *L. muscosus* with very elongate projecting spines on its major plicae. The holotype, a pair of matching valves (CM74202), is 15.3 mm high, and the features said by Petuch to characterize his new species are all within the range of variation of juvenile *L. muscosus*. Marshall (1995: 4) placed the Patagonian scallop, *Aequipecten tehuelchus* (d'Orbigny, 1846), in *Lindapecten*. However, the deeply arcuate commarginal lamellae on rib flanks in the early ontogeny of this species, as well as its cool-temperate to cold-water occurrence, suggest that it should remain in *Aequipecten*.

Although *Lindapecten muscosus* and *L. exasperatus* have long been recognized as distinct taxa in the shell literature of the western Atlantic region, there has been persistent controversy whether these are good species or merely ecophenotypes adapted to different benthic habitats. Abbott (1974: 445) regarded them as distinct species having overlapping geographic ranges but differing in habitat preferences. *Lindapecten muscosus* was said by Abbott to range from "North Carolina to Florida and Texas to Brazil [and] Bermuda" and to be "moderately common just offshore to 90 fathoms [165 m]." The range for *L. exasperatus* was given as "Bermuda, southern Florida to the lower Caribbean ... common in shallow water on turtlegrass in soft sandy mud areas."

Study of all specimens of *Lindapecten muscosus* and *L. exasperatus* in the USNM collections as well as field work by the present author have corroborated Abbott's (1974) observations, but with some further elaboration of geographic ranges. Specimens of *L. muscosus* that were either alive or are represented by unweathered paired valves are present along the southeastern Atlantic coast of the United States from Cape Lookout southward to the Florida Keys in offshore localities ranging from 18-42 m; dead young shells have been dredged offshore from as far north as Cape Hatteras. Along the Florida Keys, *L. muscosus* is present generally as young shells on the outer (Hawk Channel) side of the Keys in depths from 5-73 m. In the Gulf of Mexico, *L. mucosus* ranges from southwest of Key West, Florida, northward and westward on the continental shelf to Texas and as far south as Campeche, Mexico, in depths ranging from 11-55 m, most commonly in 30-50 m. Only one specimen is present in USNM collections from the Caribbean, from St. Thomas, U.S. Virgin Islands (USNM 103039, depth not given). The species has also been reported from Brazil (Abbott, 1974: 445; Ríos, 1975: 206).

Lindapecten exasperatus along the eastern coast of the United States is rare north of Jupiter Inlet, Florida, but common to the south in inshore areas of eastern Florida and the Florida Keys. The species is common in Bermuda, the Bahamas, and throughout the Antilles. It extends southward along the Caribbean coasts of Central America and along the Caribbean coasts of Colombia and Venezuela. Although the geographic range of *L. exasperatus* partially overlaps that of *L. muscosus* in southern Florida, habitat preferences of the two species differ in the manner noted by Abbott (1974: 445). Along the Atlantic coast of the Florida Peninsula, *L. muscosus* occurs mainly offshore, commonly associated with coral, whereas *L. exasperatus* occurs inshore, commonly associated with grassy areas. Along the Florida Keys, *L. muscosus* occurs mainly on the deeper Hawk Channel side, whereas *L. exasperatus* again favors inshore habitats. So far as determined from the collections examined, only *L. muscosus* occurs in the northern Gulf of Mexico, where it can extend to considerable depths. The specimens from greater depths commonly have longer spines than those from shallower depths, and this difference can already appear in early ontogeny. Petuch's (1995) *L. lindae* represents this kind of variant.

The extreme spininess of some *Lindapecten muscosus* is commonly associated with cover by epifaunal sponges. It has been demonstrated that some scallops develop a mutualism with sponges, whereby the sponge benefits from an attachment site and the scallop benefits from becoming less attrac-

tive to predators because of the sponge [Bloom, 1975, with reference to *Chlamys hastata hericia* (Gould, 1850) and *C. rubida* (Hinds, 1845)]. Furthermore, Beu (1965) and Dijkstra & Marshall (2008: figs 42, 53) found that spininess increases when sponges are present on the shell surface of some New Zealand species. If the morphological differences between *L. muscosus* and *L. exasperatus* were due entirely to the presence or absence of sponge cover, however, one would expect a broader overlap of geographic ranges and more frequent co-occurrences of the two species.

The genus *Lindapecten* has a rich fossil record on both the Atlantic and Pacific sides of the Americas extending from at least the early Miocene into the early Pliocene, but since the late Pliocene, the genus has been restricted to the Atlantic side. Woodring (1982: 590) referred to this group as "strongly scabrous *Aequipecten*" and thought that its earliest representative in Panama is an unnamed species from the Caimito Formation of late Oligocene age. The three Caimito specimens available to Woodring (from USGS localities 5908 and 6024b), however, are not *Lindapecten* but rather are members of the tribe Decatopectinini Waller, 1986, based on traces of very close-set commarginal lamellae, a compressed form in early ontogeny with very steep but shallow disk flanks, knobby rather than concave-up scales in late ontogeny, and equal auricles.

Woodring (1982: 591) regarded *Aequipecten canalis* (Brown & Pilsbry, 1913) of the upper Lower Miocene La Boca Formation of Panama as another early member of his strongly scabrous group. Based on an examination of USNM material identified by Woodring, this is unlikely. *Aequipecten canalis* in early ontogeny has a *Chlamys*-like form with unequal auricles and posterior auricular margins more or less perpendicular to the hinge, slightly acute, or slightly obtuse, but without a significant posterior sinus, and the posterior auricles are definitely not pointed as in *Lindapecten* (Woodring, 1982: pl. 97, figs 4, 7; Pl. 10, Fig. 1). Furthermore, commarginals in interspaces are absent throughout ontogeny, there being instead a coarse antimarginal microsculpture present in interspaces and on disk flanks that is more like that present in chlamydinine scallops, particularly *Mimachlamys*. Scales begin in early ontogeny as tiny, narrow protuberances restricted to the centers of rib crests, unlike the more prominent transverse early scales in *Lindapecten*, and the first secondary costae to appear on either side of the central row of scales are well separated from the central row. Lastly, although hinges are not preserved or not exposed on most of the specimens from Panama, one of Woodring's hypotypes (USNM 647215) possesses an exposed right posterior hinge that has a well-developed intermediate tooth (Pl. 10, Fig. 1), a feature not observed on any *Lindapecten* species, the right hinge of which is dominated by strong, laterally extended resilial teeth. *Aequipecten canalis* closely resembles the Eocene-Recent genus *Mimachlamys* (see Waller, 1993: 229) in shape, rib pattern, and microsculpture, and I refer the species to that genus.

Mimachlamys canalis in Panama is apparently restricted to the La Boca Formation. Although Woodring (1982: 592) reported the species from the stratigraphically higher Alhajuela Formation (Middle Miocene, stratigraphically below the Gatun Formation), examination of all of Woodring's specimens from the Alhajuela established that they are *Lindapecten buchivacoanus falconensis* (F. & H. Hodson in Hodson *et al.*, 1927). The specimen that Smith (1991a: figs 3e, g) identified as "*Aequipecten canalis*" from the middle Miocene Isidro Formation of Baja California Sur, Mexico, is also *Lindapecten b. falconensis*.

A more likely candidate for an early *Lindapecten* is *L. baitoaensis* n. sp. from the upper Lower Miocene or lower Middle Miocene Baitoa Formation of the northern Dominican Republic, described below. It has aequipectinine features and is probably closely related to *Pecten* (*Aequipecten*) *chipolanus* from the Chipola Formation of Florida and *Chlamys* (*Lyropecten*) *acanikos* Gardner, 1926, from the Torreya Formation of Florida. In early ontogeny, these species closely resemble *Argopecten* in having smooth rib crests and prominent commarginal lamellae in rib interspaces but in later ontogeny differ in the presence of commarginal lamellae that extend across the tops of ribs followed by scaly secondary costae on rib crests and in interspaces (Pl. 10, Figs 2-3). The hinges of the right valves of these species are dominated by laterally extended strong resilial teeth, as in *Argopecten* and *Lindapecten* but not as in *Mimachlamys*. These three species are therefore regarded herein as primitive *Lindapecten*. There is an interesting difference among these species in the ontogenetic stage at which secondary costae begin, very late or not at all in *L. chipolanus*, late in ontogeny in *L. acanikos*, and somewhat earlier in ontogeny in *L. baitoaensis*.

In the northern Dominican Republic, *Lindapecten baitoaensis* of the Baitoa Formation is followed stratigraphically by *L. plurinominis* in the Cercado Formation, but these species are separated by a considerable stratigraphic gap (Saunders *et al.*, 1986: table 4), and it is unlikely that *L. plurinominis* is directly descended from *L. baitoaensis*. In the areas of Panama studied by Woodring, the Alhajuela and Gatun formations fill this gap, and in Venezuela, the gap is filled by the Socorro and Caujarao formations. These formations all contain the highly variable *L. buchivacoanus* species complex described by F. & H. Hodson in Hodson *et al.* (1927). Contrary to Woodring (1982: 591), *L. buchivacoanus* (F. & H. Hodson in Hodson, *et al.*, 1927) *s. s.* is not a junior synonym *of Mimachlamys canalis* and is not known to occur in the La Boca Formation. In the Alhajuela Formation, *L. buchivacoanus* is the species reported as *Aequipecten canalis* by Woodring (1982: 592), and in the

Gatun Formation it is the species that Woodring (1982: 592) incorrectly identified as *A. plurinominis*.

In their study of Venezuelan Cenozoic bivalves, F. & H. Hodson in Hodson *et al.* (1927: 29) divided the *Lindapecten buchivacoanus* complex into three subspecies: *Pecten* (*Chlamys*) *buchivacoanus s. s.*, said to be from the Oligocene; *P.* (*C.*) *b. maracaibensis* from the Miocene; and *P.* (*C.*) *b. falconensis*, also from the Miocene. The Oligocene age of the nominal subspecies, however, has been refuted on the basis of the geographic position of its type locality. Hodson & Hodson (1931: 5) described this locality (their locality number 1967) as "just southwest of La Fila del Carmen, east-southeast of Dabajuro, District of Buchivacoa, Falcón." More details were provided by Palmer (1938: 154) on the basis of a letter that she received from the Hodsons giving distances from Dabajuro as "about 10 miles east and about 4 miles south of Dabajura [*sic*]." Gamero & Díaz de Gamero (1964: 353) pointed out that this locality is in the area of outcrop of the Caujarao Formation, which is now dated as early late Miocene (Ministerio de Energía y Minas, Direccion de Geología, 1970: 672), and mentioned that *Pecten buchivacoanus s. l.* is particularly common in the Socorro Formation, which underlies the Caujarao and is of late middle Miocene age (Ministerio de Energía y Minas, Direccion de Geología, 1970: 672). H. & E. Vokes (1992:12) reached a similar conclusion, assigning the Hodsons' locality to the La Puerta Group, which is equivalent to the Socorro, Urumaco (= Caujarao), and Codore formations, ranging in age from late Middle through Late Miocene.

The morphology of *Lindapecten buchivacoanus s. l.* suggests that this species complex forms an evolutionary bridge between *L. baitoaensis* of the Early Miocene and more modern *Lindapecten* of the Late Miocene to Holocene. Like the later species, *L. buchivacoanus* has coarse, scaly, secondary costae that begin in early ontogeny. As in *L. baitoaensis*, the secondary costae are preceded by transverse ridges on the rib crests, but these ridges in *L. buchivacoanus* are coarser and become irregular before forming scales atop secondary costae. Unlike more modern *Lindapecten*, the ribs of *L. buchivacoanus s. l.* do not consistently develop three secondary costae on the rib crests, instead commonly having a central or offset groove in place of a central costa on at least some of its rib crests.

The broad geographic distribution of the *Lindapecten buchivacoanus* complex on both sides of Central America could have allowed speciation to occur independently on the two sides after seaways began to narrow. In addition to its occurrence in the middle and early late Miocene of Venezuela and Panama, members of this complex occur in strata deposited during the same time interval on the western side of the Americas. These include *Pecten sanctiludovici* Anderson & Martin, 1914 (Santa Margarita Formation, southern California), *Pecten* (*Aequipecten*) *plurinominis progresoensis* Marks, 1951 (middle Progreso Formation, Ecuador), *Pecten* (*Aequipecten*) *amenensis* Marks, 1951 (upper Progreso Formation, Ecuador), and *Chlamys* (*Chlamys*) *sua* Olsson, 1964 (unnamed "upper Neogene" formation, Ecuador).

Species that resemble extant *Lindapecten muscosus*, in the sense of having coarse, spiny sculpture, differentiated ribs (some ribs on the left valve higher and spinier than adjacent ribs), and acute posterior auricles with a deep posterior sinus, first appeared during the Pliocene on both sides of the Americas. This group includes *L. cortezianus* (Durham, 1950), originally described from the San Marcos Formation, Baja California, Mexico [= Infierno Formation, Upper Pliocene; see Carreño & Smith, 2007: 81, 87], *L. paramuscosus* n. sp., Gurabo Formation, Dominican Republic, and the extant tropical western Atlantic species *L. muscosus.* Also beginning in the late Miocene, but restricted to the Atlantic side, is the lineage that began with *L. plurinominis* and led to extant *L. exasperatus*.

Geographic range.—Presently restricted to tropical to warm temperate western Atlantic from North Carolina to Florida, Texas, the Caribbean, Bermuda, and Brazil, living just offshore to depths of *ca.* 75 m, rarely deeper, to 160 m. Fossil specimens on the western side of the Americas range from southern California to Baja California Sur, Mexico.

Stratigraphic range.—Lower Miocene to Recent in the Caribbean area; restricted to the Middle Miocene to Pliocene on western side of the Americas.

Lindapecten baitoaensis n. sp.

Pl. 10, Figs 4-12; Table 15

Diagnosis.—Lindapecten with 17-21 simple radial plicae, rarely 24-29, with secondary costae not appearing on rib flanks until 13-15 mm Ht, then persisting through ontogeny; rib crests in late ontogeny each having central groove flanked by scaly costae; hl relatively short for *Lindapecten* (60-70% L).

Description.—Shell not known to exceed 35 mm Ht, higher than long in early ontogeny, becoming slightly longer than high later, acline to slightly prosocline, equilateral or with posterior slightly extended, convexity moderate, LV more convex than RV especially in early ontogeny. Disks commonly with 17-21 simple radial plicae, rarely 24-29, approximately equal in width to interspaces or slightly wider. Commarginal lamellae present in rib interspaces but not on rib crests in early ontogeny of both valves, later crossing rib crests and becoming prominent on rib crests but disappearing in interspaces; transverse scales on some LVs appearing

earlier on 5 widely spaced plicae than on others. Secondary radial costae first appearing on rib flanks at 13-15 mm Ht, with minute scales forming where costae are crossed by commarginal lamellae; commarginal lamellae on rib crests later becoming irregular in trend and forming 2 scaly costae on rib crests with central groove; secondary costae in interspaces appearing at *ca.* 18-20 mm Ht. Disk flanks shallow, moderately sloped, with fine scaly radial costellae much finer than radials on disk but grading into radials on posterior and left anterior auricles. Auricles of moderate size relative to size of disk, anterior auricle longer than posterior, hl *ca.* 60-70% L; right anterior auricle with deep byssal notch, rugose byssal fasciole, prominent active ctenolium, and 4 or 5 scabrous radial costae; left anterior auricle not preserved; posterior auricles with *ca.* 8 scabrous primary radial costae, with finer scabrous costellae introduced by intercalation during ontogeny; posterior margins of posterior auricles each forming acute angle with dorsal margin. Right hinge dentition dominated by single prominent, laterally extended resilial tooth on each side of resilifer, bordered dorsally on each side by a socket to accommodate dorsal teeth of LV. Foliated-calcite re-entry on interior of RV extending into notch between striate and nonstriate portions of adductor scar, on LV extending ventrally to *ca.* ⅓ length of anterior margin of adductor scar.

Etymology.—Named after the village of Baitoa on the Río Yaque del Norte, Dominican Republic.

Holotype and measurements.—USNM 540987, 1 RV missing most of the anterior auricle and portions of the anterior part of the disk, 27.8 mm Ht, 25.0 mm L (incomplete), *ca.* 5 mm cvx (Pl. 10, Figs 4-5).

Type locality.—Locality TU 1226, large bluffs on east bank of the Río Yaque del Norte, just below the village of Baitoa, and above the confluence of the Río Yaque del Norte and the Río Bao. Baitoa Formation. Collected by E. H. & H. E. Vokes, 1976.

Other material.—66 specimens from 11 localities, all from the Baitoa Formation on the Río Yaque del Norte, northern Dominican Republic (Table 15). All of the specimens are single valves.

Remarks.—Although the specimen designated as the holotype is incomplete, it was selected because it displays the best preserved sculpture in late ontogeny of any of the specimens on hand. Two specimens of *Lindapecten baitoaensis* n. sp., NMB G17519 (locality NMB 16938) and NMB G17520 (locality NMB 16936), differ from all of the others in having anomalously high rib counts ranging from 24-29 (Pl. 10, Figs 11-12). These are small specimens, the largest having a restored height scarcely more than 10 mm. Most have smooth rib crests with commarginal lamellae in interspaces and look like members of *Argopecten*. That they are indeed *L. baitoaensis* n. sp. is indicated by the largest specimens, which develop scales on the lateral edges of lateral ribs, and the presence, in some specimens, of transverse lamellae on rib crests. They also develop scaly costellae on the disk flanks. Saunders *et al.* (1986: 29) commented on the part of the section that yielded the NMB samples as having "varying energy levels as suggested by frequent influxes of pebble and cobbles" and other indications of an unstable environment in very shallow water.

Comparisons.—Lindapecten baitoaensis n. sp. is closest morphologically to two species from the approximately correlative Chipola and Torreya formations of Florida, *Pecten* (*Aequipecten*) *chipolanus* Dall, 1898, and *Chlamys* (*Lyropecten*) *acanikos* Gardner, 1926, respectively. All three of these species, which I now assign to *Lindapecten*, have similar sculpture in early ontogeny but differ in numbers of ribs and the degree of development and timing of appearance of secondary radial costae. *Lindapecten chipolanus* (Pl. 10, Figs 2-3) differs from *L. baitoaensis* n. sp. in having fewer ribs (commonly 16 or 17, rarely 15 or 18), and the secondary radials on the disk of *L. chipolanus* are not as well developed in late ontogeny or can be absent. *Lindapecten acanikos* has a narrower umbonal angle and fewer ribs than does *L. baitoaensis* n. sp., and the secondary costae of *L. acanikos* appear later in ontogeny, usually with a central costa on the rib crest, whereas in *L. baitoaensis* n. sp. the rib crest has a central groove. *Lindapecten baitoaensis* n. sp. differs from *L. plurinominis*, which appears later in the Dominican Republic sections in the Cercado Formation, in having late-appearing secondary radial costation, whereas in *L. plurinominis* and in other *Lindapecten* species of the Late Miocene and later strata, secondary radials and scales appear in early ontogeny.

Evolution.—See preceding discussion of the genus *Lindapecten*.

Occurrence and distribution.—Lindapecten baitoaensis n. sp. is known only from the Baitoa Formation in the northern Cibao Valley, Dominican Republic.

Lindapecten paramuscosus n. sp.
Pl. 10, Figs 13-16; Pl. 11, Figs 1-2; Table 16

Pecten (*Aequipecten*) *thetidis* Sowerby. Cooke, 1919 (in part): 139, a specimen from USGS 5255, Santiago, Cuba, not pl. 11, figs 4-6, from Anguilla (= *Lindapecten* n. sp.?).

Table 15. Occurrences and rib counts of *Lindapecten baitoaensis* n. sp. on Río Yaque del Norte in the Cibao Valley. Stratigraphic levels are in meters, measured from the base of the drafted columnar section in text-fig. 25 of Saunders *et al.* (1986). Rib counts are followed by number of specimens with that count, regardless of valve side, in parentheses. Rib counts could not be made on specimens with parts of disk missing or covered by matrix. Abbreviations: DV, matching valves; Ht, height; LV, left valve; RV, right valve. An asterisk (*) marks the type locality.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Rib Counts
NMB 16942	72.3	Baitoa	0	1	0	5.9	21(1)
NMB 16939	70.0	Baitoa	1	0	0	9.0	20(1)
NMB 16938	66.6-69.5	Baitoa	2	2	0	10.5	27(2), 28(1)
NMB 16936	63.6-64.7	Baitoa	2	1	0	7.6	24(2), 29(1)
NMB 17290	54.5-58.4	Baitoa	6	1	0	7.1	19(6), 20(1)
NMB 17289	53.8	Baitoa	7	2	0	31.9	17(1), 18(1), 19(2), 20(1)
NMB 17288	50.4-52.8	Baitoa	4	2	0	24.0	18(4), 19(2)
NMB 17287	47.5-49.8	Baitoa	2	1	0	5.1	19(2)
NMB 17286	43.1-46.6	Baitoa	14	12	0	19.9	18(11), 19(12), 20(1)
TU 1226*	?	Baitoa	3	2	0	27.9	18(1), 19(1)
TU 1362	?	Baitoa	2	1	0	34.0	20(2), 21(1)

Diagnosis.—*Lindapecten* with pointed posterior auricles, plicae of LV differentiated in height with 5 higher and with coarser scales than others, scales on narrow rib crests larger than scales on secondary costae, commarginal lamellae prominent in interspaces, foliated-calcite re-entry on interior extensive, bordering the entire ventral margin of adductor scars in mature specimens.

Description.—Shell not known to exceed 26 mm Ht, Ht exceeding L in juveniles, equal to L in mature specimens, acline to slightly prosocline, equilateral, cvx moderate, LV more convex than RV throughout ontogeny. Disks with 17-21 plicae, most commonly 18-20, rounded to trigonal in profile, broader than interspaces on RV, narrower than interspaces on LV; 5 plicae commonly higher in elevation on LV and with coarser primary scales on crests than adjacent plicae. Commarginal lamellae in interspaces raised and prominent through most of ontogeny, gradually fading out in late ontogeny generally at > 20 mm Ht. Scales present on rib crests in early ontogeny, remaining higher than scales formed on secondary costae on rib flanks and interspaces in later ontogeny. All disk flanks with fine scabrous costellae. Right anterior auricle with deep byssal notch floored by active ctenolium with 3 or 4 teeth, byssal fasciole deeply sigmoidal in cross section with raised part adjacent to disk flank rugose, auricular surface with 4 or 5 scabrous radial costae; other auricles pointed, with deep sinuses and 7 or 8 scabrous radial costae; anterior hinge line longer than posterior (ahl/phl = 1.22 on holotype), total hl *ca.* 80% L. Right hinge dentition consisting of single dorsal tooth on each side of resilifer and a broader, higher resilial tooth drawn out laterally, commonly indented proximally giving appearance of an intermediate tooth in addition to resilial tooth. Foliated-calcite re-entry on both valves extensive, completely bordering ventral margin of adductor scar at Ht as small as 15 mm, in small shells re-entry expanding from both anterodorsal side of adductor scar and posteroventral side, later merging to completely border ventral margin of scar.

Etymology.—The prefix *para-* is combined with *muscosus* to indicate morphological proximity to *Lindapecten mucosus*.

Type material.—Holotype, USNM 540990, 1 RV, 20.8 mm Ht, 20.6 mm L(Pl. 10, Figs 13-16).

Type locality.—Locality TU 1225: Banks of Arroyo La Sabirma on west side of the Río Mao, upstream from Mao Adentro and downstream from Cercado de Mao, *ca.* 11 km by (winding) road or 8 km by airline south of Mao. Gurabo Formation, probably early Pliocene in age.

Other material.—69 specimens, all but one of which are single valves, from 24 localities in the Cibao Valley, northern Dominican Republic (Table 16).

Remarks.—In contrast to *Lindapecten plurinominis*, which lives inshore commonly associated with marine grasses, *L. paramuscosus* n. sp. lived offshore, probably associated with patch reefs or coral build-ups near the shelf edge. This is indicated by its common association with deepwater pectinids, notably *Argopecten thetidis* and *Gurabopecten uniplicatus* n.

gen., n. sp., and the deep-water bivalve *Dimya* sp. These associations, including transported coral debris, are particularly evident in the Río Gurabo section near the Miocene-Pliocene boundary, just below the level at which Saunders *et al.* (1986: 16) determined that the depth of deposition rapidly deepened. The morphology of *L. paramuscosus* n. sp. remains constant through the areas sampled.

Comparisons.—Lindapecten paramuscosus n. sp. closely resembles two other species, *L. cortezianus*, an extinct species of the late Miocene and Pliocene of the tropical eastern Pacific, and *L. muscosus*, an extant species traceable back to the late Pliocene in the tropical western Atlantic. All three species commonly have 17-20 scaly plicae and secondary costae, with the primary scales on rib crests larger than the other scales during at least early and mid-ontogeny. The posterior auricles of all three species are pointed, with the overall trend of the posterior auricular margins forming an acute angle with the dorsal margin. *Lindapecten paramuscosus* n. sp., however, is clearly separable on the basis of its prominent raised commarginal lamellae in the rib interspaces of both valves and in its extensive foliated-calcite re-entry, which in mature specimens passes completely under the adductor scar (Pl. 10, Fig. 16). Aside from these differences, *L. paramuscosus* n. sp. is remarkably close to *L. cortezianus* in having narrow rib crests with narrow primary scales as well as an ontogenetic shift from primary scales that are distinctly larger than the scales on secondary costae to a state in late ontogeny in which all scales are small. However, *L. paramuscosus* n. sp. is closer to *L. muscosus* in the nature of its byssal fasciole. In both species, the fasciole is deeply sigmoidal in cross section, the raised part adjacent to the disk flank being rugose. In *L. cortezianus*, the byssal fasciole is arched but not rugose.

Specimens that Cooke (1919: 139) identified as *Pecten* (*Aequipecten*) *thetidis* from Anguilla and Cuba belong in the genus *Lindapecten*, not in *Argopecten thetidis* (see preceding discussion of that species). The Cuban specimen (USNM 167072 from USGS 5255, Santiago, Cuba, La Cruz Formation, Pliocene) is a small right valve (17.0 mm Ht) that differs from his illustrated specimens from Anguilla (Anguilla Formation, middle Miocene) in having a distinctly narrower umbonal angle and relatively larger primary scales on rib crests compared to secondary scales. The Cuban specimen appears to be *L. paramuscosus* n. sp. based on these characters as well as its prominent commarginal lamellae in interspaces and thick foliated-calcite re-entry extending below the striate adductor scar on the shell interior. The three Anguilla specimens illustrated by Cooke (1919: pl. 11, figs 4-6) have secondary sculpture more like that on Early and Middle Miocene *L. chipolanus* and are clearly not the same species as the Cuban specimen.

Evolution.—Lindapecten paramuscosus n. sp. lies phylogenetically between *L. cortezianus* of the eastern Pacific, which first appears in the late Miocene, and the extant species *L. muscosus* of the western Atlantic, which as far as can be determined first appeared in the late Pliocene. The synapormorphy that ties *L. paramuscosus* n. sp. with *L. muscosus* is the nature of the byssal fasciole described above.

Occurrence and distribution.—In the Dominican Republic, *Lindapecten paramuscosus* n. sp. is apparently limited to the Gurabo Formation, ranging in age from very late Miocene into the early Pliocene. The species has not been observed outside of the Dominican Republic.

Lindapecten plurinominis (Pilsbry & Johnson, 1917)
Pl. 11, Figs 3-17; Table 17

Pecten oxygonum Sowerby. Gabb, 1873: 256 (Miocene, Dominican Republic); Guppy, 1876: 532 (Miocene, Dominican Republic).

Pecten (*Aequipecten*) *thetidis* Sowerby. Dall, 1898: 714 (in part; Miocene, Dominican Republic); Maury, 1917a: 185, pl. 34, fig. 6 (Miocene, Dominican Republic).

Pecten plurinominis Pilsbry & Johnson, 1917: 193 (Miocene, Dominican Republic); Pilsbry, 1922: 411, pl. 45, figs 1-2 (Miocene, Dominican Republic).

Not *Chlamys* (*Aequipecten*) *plurinominis morantensis* Woodring, 1925: 67, pl. 8, figs 4-5 (Pliocene, Jamaica) [= *Lindapecten exasperatus morantensis*)].

Not *Pecten (Aequipecten*) *plurinominis progresoensis* Marks, 1951: 60, pl. 2, fig. 8, pl. 3, figs 4-5 (Miocene, Ecuador) [probably belongs in the *Lindapecten buchivacoanus* complex].

Chlamys plurinominis (Pilsbry & Johnson), Mongin, 1968: 478, pl. 40, figs 2a-c (Miocene, Guadeloupe).

Not *Aequipecten plurinominis* (Pilsbry & Johnson), Woodring, 1982: 592, pl. 107, fig. 5, pl. 108, figs 4-6, pl. 110, fig. 3 [= *Lindapecten buchivacoanus falconensis*].

Original description.—"In this scallop there are 19 rounded ribs a little wider than their intervals, over ribs and intervals there are weak radial cords bearing thin scales, near the edge of the left valve there are three of these scaly cords upon each rib and three in each interval. Submargins [disk flanks] and ears with numerous small ribs. Ctenolium is rather long. The right valve is slightly more convex than the left" (Pilsbry & Johnson, 1917: 193).

Description.—Shell not known to exceed 33 mm Ht, L and Ht approximately equal in early ontogeny, becoming L > Ht at full size; acline to slightly prosocline, equilateral, convexity moderate, with LV more convex than RV throughout ontogeny. Disks commonly with 19-24 plicae, most commonly

Table 16. Occurrence of *Lindapecten paramuscosus* n. sp. in the Cibao Valley. Localities ordered by stratigraphic level measured from base of section except for road cuts, which are ordered by locality number. Abbreviations: Ae, *Argopecten eccentricus s. l.*; Aec, *A. eccentricus caimiticus*; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; Anj, *Antillipecten janicoensis* n. sp.; Anq, *A. quemadosensis* n. sp.; Apa, *Argopecten parathetidis* n. sp.; At, *A. thetidis*; Caj, *Caribachlamys jungi* n. sp.; Cg, *Cyclopecten guppyi*; Cz, *C. zalaya* n. sp.; Dm, *Dimya* sp.; DV, matching valves; Eg, *Euvola gurabensis* n. sp.; Es, *E. soror*; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpl, *Lindapecten plurinominis s. s.*; Lt, *Leptopecten thompsoni*; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Nn, *N. nodosus*; Pvm, *Parvamussium marmoratum*; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana								
NMB 16833	287	Gurabo	1	0	0	11.9	Aec, Lpl	
Río Gurabo								
NMB 15934	402	Gurabo	0	2	0	5.0	At, Dm, Gu	
NMB 15962	400	Gurabo	1	2	0	7.6	At, Dm, Gu, Sv	
----------								Miocene/Pliocene boundary (Saunders *et al.*, 1986)
TU 1210	394-396	Gurabo	1	1	0	20.0	Amp, At, Gu, Ncv, Sv	
TU 1369	388?	Gurabo	2	0	0	25.5	Amp, At, Gu, Sv	
TU 1279	387-389	Gurabo	2	1	0	20.0	At, Es, Gu, Sv	
TU 1211	381-385	Gurabo	5	1	0	22.8	Apa, At, Gu, Sv	
TU 1231	380-395	Gurabo?	3	0	0	21.4	Anq, At, Es, Ncv	Float in river gravel
TU 1278	376-378	Gurabo	1	0	1	21.2	Anq, At, Es, Gu, Ncv	
NMB 15838	376-378	Gurabo	0	1	0	22.0	Dm	
NMB 15837	374-376	Gurabo	1	1	0	22.9	At, Eg, Ncv	
TU 1215	276-386.5	Gurabo	1	0	0	19.0	Amp, Anq, At, Caj, Nn	
NMB 15866	227	Gurabo	1	0	0	25.0	Ai, At	
NMB 15869	224	Gurabo	1	1	0	22.2	Ae, At, Sv	
NMB 16808	222-226	Gurabo	0	1	0	26.0	Aec? At	
TU 1296	204-223	Gurabo	1	0	0	17.0	At, Sv	
----------								Cercado/Gurabo Fm boundary of E. Vokes (1989)
Río Mao								
TU 1225	?	Gurabo	1	1	0	21.0	Ai, Amp, At, Es, Nn	Type locality of *L. paramuscosus* n. sp.
Río Amina								
TU 1219	level d	Gurabo	1	0	0	25.0	Amp, At, Lpl, Sv	
Río Verde								
TU 1250	--	Gurabo	0	2	0	10.9	Aec, Amp, At, Cg, Cz, Es, Gu, Pvm	
Santiago area								
TU 1227A	--	Gurabo	0	2	0	9.2	Ai, Amp, At, Cg, Cz, Gu, Pvm, Sv	Turbidity flow

Table 16 (continued).

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Road cuts								
TU 1209	--	Gurabo	13	9	0	23.0	At, Eg, Gu, Ncv, Sv	
TU 1299	--	Gurabo?	1	0	0	16.5	Anq, Apa, Ncv	
TU 1338	--	Gurabo	3	1	0	20.9	Amp, At, Eg, Gu, Ncv	
TU 1406	--	Gurabo?	2	0	0	16.5	Aec, Amp, Anj, Anq, Es, Lt, Lpl, Nn	

21, rounded or with flattened crests, slightly broader than interspaces. Commarginal lamellae present in early ontogeny in interspaces and passing directly across rib crests, absent in later ontogeny. Later sculpture consisting of radial costae on rib crests and interspaces bearing small scales, beginning in early ontogeny as a central scaly radial costa, later (at 5-9 mm Ht) flanked by a second scaly radial costa on each side of rib (termed herein the trisquamous pattern; see Pl. 11, Figs 16-17) or lacking the central costa, with initial sculpture then consisting of a row of scales along each edge of rib crest (termed herein the bisquamous pattern; see Pl. 11, Figs 7-8); later costae intercalating on rib flanks and in interspaces, forming last in center of interspace; scales in late ontogeny all small and approximately equal in size. All disk flanks bearing fine, scaly radial costellae; right anterior disk flank very low, commonly with only a single radial costa nearly as large as neighboring anterior plica of disk. Auricles of moderate size relative to size of disk, anterior auricle longer than posterior (ahl/phl = *ca.* 1.5), hl *ca.* 70% L; right anterior auricle long and narrow with deep byssal notch, rugose byssal fasciole, prominent active ctenolium, and 5 or 6 scabrous radial costae with additional costae intercalated near margin; left anterior auricle acutely angular with deep byssal sinus and 7-9 scaly radial costae, with more costae intercalated near margin; posterior margins of posterior auricles sigmoidal, with shallow posterior sinus, overall trend perpendicular or acute to dorsal margin, and 7-9 scabrous radial costae with additional costae intercalated near margin. Right hinge dentition dominated by single, prominent, laterally extended resilial tooth on each side of resilifer, bordered dorsally on each side by a socket to accommodate dorsal teeth of LV; proximal ends of resilial teeth indented on some specimens. Foliated-calcite re-entry on interior of RV extending ⅓ to ½ of way down anterior margin of striate adductor scar, rarely entering notch between striate and nonstriate scars, on LV commonly extending only to dorsal margin of adductor scar, rarely ⅓ of way down anterior margin of scar.

Type material.—Holotype, ANSP 3236, 1 RV, illustrated by Pilsbry (1922: pl. 45, figs 1-2), 29.2 mm Ht, 28.7 mm L.

Type locality.—Miocene, probably Gurabo Formation, northern Dominican Republic.

Other material.—205 specimens, all but 5 of which are single valves, from 63 localities in the Cibao Valley, northern Dominican Republic (Table 17).

Remarks.—The two patterns of scale development, trisquamous (Pl. 11, Figs 3-12) and bisquamous (Pl. 11, Figs 13-17), have not been recognized previously in *Lindapecten plurinominis*, but they are of particular interest because of their stratigraphic distribution. On the Río Cana, the stratigraphically lowest specimens, from the upper Cercado Formation and lower Gurabo Formation, are all of the trisquamous type (Table 17). These are followed in the interval from *ca.* 250-300 m above the base of the section by specimens that display a transition between the two patterns. The transition is expressed by frequent offset of the central costa on rib crests to one side or the other, with the bisquamous condition beginning in the central sector of the disk, commonly in mid-ontogeny. In samples marked transitional (Tsq/Bsq) in Table 17, some specimens retain the trisquamous condition, whereas others in the same sample have become at least partially bisquamous. Above *ca.* 310 m above the base of the Río Cana section, at the approximate position of the Miocene-Pliocene boundary according to Saunders *et al.* (1986: 23), all specimens are of the bisquamous type. A similar stratigraphic change occurs in the Río Gurabo section, where all specimens of *L. plurinominis* in the Cercado Formation (*sensu* E. Vokes, 1989: 18) are trisquamous; those near the Cercado-Gurabo boundary are transitional; the single sample in the undisputed Gurabo Formation is bisquamous. The Gurabo sample (NMB 15878) is well below the Miocene-Pliocene boundary, which was determined by Saunders *et al.* (1986: text-fig. 14) to be nearly

Table 17. Occurrence of *Lindapecten plurinominis* in the Cibao Valley. Abbreviations: Ae, *Argopecten eccentricus s. l.*; Aec, *A. eccentricus caimiticus*; Aee, *A. eccentricus eccentricus*; Ael, *A. eccentricus lacabrensis* n. ssp.; Amp, *Amusium papyraceum*; Anc, *Antillipecten cercadicus*; Anj, *A. janicoensis* n. sp.; Anq, *A. quemadosensis* n. sp.; Ans, *Antillipecten* sp.; Apa, *Argopecten parathetidis* n. sp.; At, *A. thetidis*; Bsq, bisquamous; B1, Bluff 1 of Maury (1917b); B2, Bluff 2 of Maury (1917b), B2/B1, between Bluffs 2 and 1; B3, Bluff 3 of Maury (1917b); Cg, *Cyclopecten guppyi*; Dm, *Dimya* sp.; DV, matching valves; Ej, *Euvola jamaicensis* n. n.; frag, fragment; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lt, *Leptopecten thompsoni*; LV, left valve; Nn, *Nodipecten nodosus*; Paa, *Paraleptopecten* sp. *a*; Pc, *Palliolum? cibaoense* n. sp.; Pvm, *Parvamussium marmoratum*; Sv, *Spathochlamys vaginula*; Tsq, trisquamous; Tsq/Bsq, transitional between trisquamous and bisquamous; --, not recorded. Lettered stratigraphic intervals are explained in the text. See caption for Table 7 regarding the stratigraphic positions of the Cercado/Gurabo boundary and locality USGS 8534 on the Río Cana.

Locality	Level (m)	Formation	Sculpture	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana									
NMB 16862	383	Gurabo	Bsq	frag	0	1	24.0	Amp	
TU 1356	355-362	Gurabo	Bsq	0	0	1	24.0	Aec	
NMB 16881	352.5	Gurabo	Bsq	0	1	0	18.9	none	
NMB 16818	347	Gurabo	Bsq	0	1	0	27.0	Aec, Anq, Es	
NMB 16817	347	Gurabo	Bsq	0	1	0	9.0	Aec, Anc, Cg, Es	
NMB 16878	339	Gurabo	Bsq	1	0	0	28.5	Ae	
TU 1354	336-346	Gurabo	Bsq	1	4	2	29.7	Aec, Anq, Es, Nn	
TU 1355	?	Gurabo	Bsq	0	0	1	26.0	Nn	
NMB 16961	327	Gurabo	Bsq	1	2	0	6.5	Ae	
NMB 16825	321	Gurabo	Bsq	1	0	0	26.2	Amp, Anq, Apa, At	
NMB 16824	319	Gurabo	Bsq	1	0	0	31.2	Ae	
----------									Miocene/Pliocene boundary at least as low as 315 m (Saunders *et al.*, 1986: 23)
NMB 16828	309	Gurabo	Bsq	2	0	0	27.5	Aec, Es	
NMB 16821	306	Gurabo	Tsq/Bsq	2	6	0	28.0	Aec	
NMB 16831	287	Gurabo	Tsq	0	1	0	22.0	Aec, Es	
NMB 16833	287	Gurabo	Tsq/Bsq	5	4	0	14.9	Aec, Lpa	
NMB 16832	287	Gurabo	Tsq?	3	0	0	14.1	Aec, Dm	
NMB 16978	283	Gurabo	Tsq	0	1	0	9.4	none	
NMB 16835	252	Gurabo	Tsq/Bsq	14	9	0	28.2	Aec, Amp, Ans, Es	
NMB 16983	250	Gurabo	?	5	0	0	11.0	Aec	
NMB 16836	243	Gurabo	Tsq	1	0	0	13.5	Aec, Es	
NMB 16837	236.5	Gurabo	Tsq	5	4	0	24.9	Aec	
NMB 16838	233	Gurabo	Tsq	1	3	0	23.2	Aec, Amp, Es	
NMB 16839	231	Gurabo	Tsq	1	0	0	18.3	Aec	
NMB 16844	228 or 231	Gurabo	Tsq	2	0	0	24.6	Aec, Anj	
NMB 16852	228	Gurabo	Tsq	0	1	0	24.4	Aec	
NMB 16989	228	Gurabo	Tsq	1	1	0	9.2	Aec	
USGS 8534	200	Cercado	Tsq	1	0	0	frag	Ael	

Table 17 (continued).

Locality	Level (m)	Formation	Sculpture	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo									
NMB 15878	193	Cercado	Bsq	2	0	0	23.0	Ael, Amp, Es	
TU 1297	183-211	Cercado	Tsq	2	5	0	29.2	Ael, Amp, At, Es	
NMB 15890	175	Cercado	Tsq/Bsq	1	1	0	24.1	Ael, Amp	
NMB 15886	175	Cercado	Tsq	1	0	0	27.8	Ael, Amp	
----------									Carcado/Gurabo Fm boundary of Saunders *et al.* (1986)
NMB 15908	117-119	Cercado	Tsq	4	3	0	24.9	Ael	
TU 1359	111-118	Cercado	Tsq	5	2	0	26.0	Ael	
NMB 15909	111-113	Cercado	Tsq	5	2	0	25.1	Ael	
NMB 15911	110	Cercado	Tsq?	0	1	0	4.6	Ael	
TU 1358	102-104	Cercado	Tsq?	1	2	0	4.0	Ael, Amp, Cg	
NMB 15914	100	Cercado	Tsq	0	4	0	7.6	Ael	
TU 1376	99-102.5	Cercado	Tsq	2	2	0	12.1	Ael, Amp	
NMB 15915	99	Cercado	?	1	1	0	6.7	Ael	
TU 1377	99 and lower	Cercado	?	0	2	0	7.4	Ael	
Río Mao									
NMB 16803	B2/B1 (high)	Gurabo?	Tsq	2	1	0	31.0	Aee, Anc, At, Es	
USGS 8522	B2/B1 (low)	Cercado?	Tsq	1	1	0	13.9	Aee, At	
USGS 8521	B2/B1 (low)	Cercado?	Tsq	1	1	0	17.0	Aee, Amp, At, Es	
USGS 8526	B2, g-h	Cercado	Tsq	1	1	0	24.5	Aee, Amp, Es, Lt	
NMB 16929	B2, f	Cercado	Tsq	1	0	0	16.0	Aee, Cg, Lt	
NMB 16928	B2, e	Cercado	Tsq	1	0	0	21.5	Aee, Cg, Lt	
TU 1294	B3	Cercado	Tsq	1	0	0	10.6	Aee, Cg, Lt, Paa, Pc	
Río Amina									
TU 1219	level d	Gurabo	Bsq	1	0	0	19.9	Amp, At, Lpa, Sv	
TU 1220	level c	Gurabo	Tsq	0	1	0	28.3	Aee, Amp, At	
USGS 8518	level c	Gurabo	Tsq	2	0	0	33.0	Aee, Amp, Es	
TU 1218	level a	Gurabo	Tsq	1	0	0	11.9	Aee	
NMB 16804	level a	Gurabo	Tsq	0	1	0	22.2	Aee, Amp	
Santiago area									
TU 1227	--	Gurabo	Tsq	1	0	0	17.1	Amp, At, Pvm	
NMB 17271	--	Gurabo?	Bsq?	0	1	0	13.5	none	Arroyo Zalaya

Table 17 (continued).

Locality	Level (m)	Formation	Sculpture	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Santiago area (continued)									
USGS 8663a	--	Mao Ad.	Bsq	0	1	0	20.0	Ej	
Road cuts									
TU 1222	--	Gurabo?	Bsq	9	3	0	23.4	Aec, Amp, Anq, Apa, At, Es	
TU 1339	--	Gurabo	Bsq	2	5	0	20.1	Aec, At, Es, Nsp	
TU 1340	--	Cercado	Tsq	1	5	0	25.2	Aee, At, Lt	
TU 1406	--	Gurabo	Bsq	1	3	0	27.1	Aec, Amp, Anj, Anq, Es, Lt, Lpa, Nn	
TU 1416	--	Gurabo?	Bsq	2	3	0	30.4	At	
TU 1435	--	Gurabo?	Tsq	1	0	0	21.1	Aa, Amp, At, Es, Sv	
TU 1437	--	Gurabo?	Bsq	2	1	0	27.1	Aec, Amp, At	
USGS 8535	--	Gurabo	Bsq	3	1	0	29.2	Amp, At, Es	

400 m above the base of the section. Specimens having the bisquamous pattern also occur stratigraphically above those with the trisquamous pattern on the Río Amina (Table 17), where the single bisquamous specimen (TU 1219, Table 17) is below the base of the Pliocene as determined by Saunders *et al.* (1986: 33). No definite reversals in the stratigraphic occurrence of the two sculptural patterns have been observed in any of the river sections.

The two sculptural states of *Lindapecten plurinominis* are interpreted to be ecophenotypes rather than chronological subspecies, because specimens are nearly identical on the basis of other characters. There is also the evidence that the occurrence of the two types is correlated more with changing lithologies determined by ecological conditions than with a particular time-stratigraphic horizon such as the Miocene-Pliocene boundary. In the Río Cana section, Saunders *et al.* (1986: 22) emphasized the very shallow depth of deposition of the lower part of the Cercado Formation, including assemblages of fossils indicating nearby brackish-water conditions. The finer-grained portions of the overlying Gurabo Formation indicate only slightly deeper conditions, still probably < 50 m in depth. Whereas the trisquamous form of *L. plurinominis* is associated with siliciclastic sand, the bisquamous form tends to be associated with finer, more calcareous sediment. By analogy with its living counterpart, *L. exasperatus,* the trisquamous form probably lived in association with abundant marine grasses. The bisquamous form might have lived near the outer limits of this habitat, where the reduced scaliness of its right valve could have facilitated movement on finer, softer sediment.

Comparisons.—Lindapecten plurinominis closely resembles the extant species *L. exasperatus* in having small, more or less equally sized scales on secondary costae on ribs and interspaces. Both species lack elongated and strongly pointed posterior auricles and are generally of only moderate convexity. The primary difference is in the number of disk plicae, commonly 20-23 (rarely 19 or 24) in *L. plurinominis* but commonly only 17 or 18 , rarely 19, in *L. exasperatus*. It is on the basis of the number of ribs (commonly 19 or 20) that *Chlamys* (*Aequipecten*) *plurinominis morantensis* from the Bowden beds of Jamaica is regarded in the present study as a subspecies of *L. exasperatus*. The bisquamous sculptural variant present in *L. plurinominis* has not been observed in either *L. exasperatus s. s.* or in *L. exasperatus morantensis*.

Lindapecten buchivacoanus buchivacoanus differs from *L. plurinominis* in having stronger secondary costae and scales, a narrower umbonal angle, and an early introduction of a medial costa in interspaces. *Lindapecten b. falconensis* is more gibbous, reaches a larger size, and has a medial groove on each rib crest rather than a medial costa. *Lindapecten b. maracaibensis* resembles *L. b. falconensis* in gibbosity and size but has

a prominent medial costa in interspaces.

Three closely related species, *Lindapecten muscosus*, *L. paramuscosus* n. sp., and *L. cortezianus*, all differ from *L. plurinominis* in having more pointed auricles, particularly the posterior, ribs that are more differentiated in height on the left valve (5 ribs consistently higher than in others, especially in *L. muscosus* and *L. paramuscosus* n. sp.), fewer ribs (commonly 17 or 18), and scales on rib crests that are larger than flanking scales through most of ontogeny.

Evolution.—See preceding discussion of the genus *Lindapecten*.

Occurrence and distribution.—In the Dominican Republic, *Lindapecten plurinominis* occurs in the Cercado and Gurabo formations. Its upper limit is the Mao Adentro Limestone (basal Mao Formation), where it is represented by only a single valve (Table 17). The species has not been observed outside the Dominican Republic,

Genus ***PARALEPTOPECTEN*** n. gen.

Type species.—Chlamys (*Aequipecten*) *bavayi* Dautzenberg, 1900, Recent, Caribbean and tropical western Atlantic, from the Caribbean coast of Central America, throughout the Antilles, and southward to Uruguay (Abbott, 1974; and data from USNM collections).

Diagnosis.—Shells small, rarely exceeding 25 mm Ht, acline to moderately prosocline, Ht and L equal or with L slightly exceeding Ht, cvx of articulated shells low to moderate, ranging from equiconvex to slightly right-convex. Auricles large relative to size of disk, total hl approximately equal to L in both juveniles and adults; anterior auricle long and narrow, with anterior extremity commonly projecting beyond anterior extremity of disk throughout ontogeny; byssal notch deep, floored by prominent active ctenolium with 4-7 teeth; posterior auricles with straight or slightly sigmoidal posterior margin commonly forming acute angle with dorsal margin. Radial plicae on disk of LV commonly of uneven height and width, with 5 major plicae separated by 2-4 minor plicae; plicae of RV commonly of even height but with major interspaces deeper and wider, corresponding to interlocking major ribs of LV; less commonly plicae of both valves even in height and spacing but having angular profiles and commonly fringed by cuspate, tightly curved (distally concave) commarginal lamellae. Right anterior auricle with strong, closely spaced radial costae, right posterior auricle commonly with more widely spaced costellae that can be as strong as on anterior auricles and persist through ontogeny. Hinge dentition of RV weakly developed, consisting of very narrow, barely distinguishable dorsal teeth adjacent to ligament groove and very low, poorly demarcated resilial teeth. Commarginal lamellae commonly prominent throughout ontogeny, tending to form deep cusps on rib flanks, especially on major ribs.

Etymology.—The prefix *para-* is combined with *Leptopecten* to indicate probable phylogenetic closeness of the new genus to *Leptopecten*.

Remarks.—The fossil and Recent species that are included in *Paraleptopecten* n. gen. are listed in Appendix 3. Although *Leptopecten* and *Paraleptopecten* n. gen. are both aequipectinine genera, it is likely that they have independent origins on opposite sides of the Americas, an idea that was previously suggested by Ward & Blackwelder (1987: 140). As previously discussed under *Leptopecten*, the oldest members of that genus are in the late Oligocene or early Miocene in the eastern Pacific region. In contrast, the oldest undoubted species of *Paraleptopecten* n. gen., *P. pirabensis* (Ferreira, 1960), occurs in the Pirabas Formation of Brazil, dated as Early Miocene. Also in the same formation is a species that Ferreira (1960: 152) called "*Chlamys* (*Leptopecten*) cf. *latiaurata* (Conrad, 1837)." Based on Ferreira's figures, which show angular ribs and densely costate auricles, this species is likely also in *Paraleptopecten* n. gen.

Another Early Miocene lineage that is less likely to be in the ancestry of *Paraleptopecten* n. gen. is represented by *Pecten burnsi* Dall, 1898, of the Chipola Formation of Florida, *Pecten* (aff. *Aequipecten*) *quirosensis* Harris in Hodson *et al.*, 1927, of the late Early Miocene La Rosa Formation of the state of Zulia, Venezuela, and possibly *Pecten agronomica* Maury, 1925b, of the Early Miocene Pirabas Formation of Brazil. All of these species are strongly right convex, with even plicae. Although their posterior auricles are large and *Paraleptopecten*-like, they do not have particularly deep byssal notches. Furthermore, their ctenolium consists of very fine teeth on an out-turned flange of the disk flank, unlike the coarse-toothed, more elongate ctenolium of *Paraleptopecten* n. gen. The *P. burnsi* lineage is possibly related more closely to the *P. perplanus* stock, abundant in the Oligocene of the southeastern United States (see Glawe, 1969), a relationship previously suggested by Dall (1898: 720).

The species-level taxonomy of *Paraleptopecten* n. gen. of the Late Miocene to Early Pleistocene is confused and in need of revision, in part because past authors have not fully appreciated the degree to which rib patterns vary. Using the method of encoding rib patterns explained in the Materials and Methods section, I have identified 17 rib patterns on the disks of LVs of extant *P. bavayi* in the Smithsonian (USNM) collection of Recent mollusks (Table 18). Specimens of *P. olgensis* (Mansfield, 1939) from the middle Pliocene of Florida,

raised herein to species rank, falls within the range of variation of *P. bavayi* in terms of the rib pattern of the LV but differs from all living *P. bavayi* in lacking single medial costae in the interspaces of the RV. *Paraleptopecten olgensis* also has a narrower umbonal angle in early ontogeny and only one minor plica between the outermost major rib and shoulder of the disk flank on the anterior and posterior of the LV. *Paraleptopecten leonensis* (Mansfield, 1932) of the Pliocene Jackson Bluff Formation of Florida resembles *P. olgensis* in umbonal angle and lack of single medial costae, but differs in having only 11 ribs on the LV in the pattern /r R r R r Rc r R r R r\. *Paraleptopecten wendelli* (Tucker, 1934), from the upper Pliocene to lower Pleistocene Caloosahatchee Formation of Florida and the Waccamaw Formation of South Carolina, differs from *P. olgensis* mainly in having a single medial costae in each interspace originating in mid-ontogeny.

Some species of *Paraleptopecten* n. gen. lack the differential rib height and spacing on their LVs but have other characteristics typical of the genus, namely plicae of angular profile commonly with the rib flanks slightly undercut and covered by well-developed cuspate lamellae. In terms of rib pattern, a new species of *Paraleptopecten* n. gen. (in Appendix 3 as *P.* sp. *b*), from the Late Miocene Savaneta Glauconitic Sandstone Member of the Springvale Formation of Trinidad, is remarkably similar to *P. biolleyi* of the tropical eastern Pacific (Grau, 1959: 116) and probably reflects seaways between the Caribbean and tropical eastern Pacific that were open at that time.

Although *Paraleptopecten* n. gen. extended as far north as Virginia during the Pliocene, at present it is unknown in Florida and is restricted to more tropical regions, mainly in the Antilles and along the coasts of Central and South America.

Geographic range.—Extant in Caribbean and the tropical western Atlantic from the Lesser Antilles to Uruguay, and in the eastern Pacific from southern California to Ecuador, at depths from shallow subtidal to *ca.* 200 m; fossil in the western Atlantic from North Carolina to Brazil, Lower Miocene to Pleistocene, and in the eastern Pacific from southern California to Mexico, Upper Miocene to Recent. See Appendix 3 for details.

Stratigraphic range.—Lower Miocene to Recent on the eastern side of the Americas, Upper Miocene to Recent on the western side.

***Paraleptopecten* sp.** *a*
Pl. 11, Fig. 19

Description.—Shell small, prosocline, and slightly inequilateral with posterior somewhat extended, L and Ht approximately equal. LV with low cvx, *ca.* 25% Ht. Left disk with 18 narrow, strongly differentiated major and minor radial plicae in pattern /r r R r r R r r r Rc r r R r r R r r\; both major and minor ribs steep-sided with narrow rounded crests, fringed by projecting cuspate commarginal lamellae forming distally concave loops on rib flanks, then crossing interspaces adjacent to major ribs with more gentle distally convex curves but scarcely visible in interspaces between minor ribs; both disk flanks narrow but steep, with commarginal lamellae but without radial costellae. Auricles large relative to size of disk, left anterior auricle somewhat longer than posterior auricle and with its anterior extremity extending slightly beyond anterior disk margin, anterior margin with outward convex curvature forming acute angle with dorsal margin and moderately deep byssal sinus; posterior margin of posterior auricle also forming acute angle with dorsal margin. Both auricles of LV with radial costae, 7 on anterior auricle, 4 or 5 on posterior, crossed by projecting commarginal lamellae that tend to form small scales at intersections with costae. Left hinge simple, consisting of low, narrow infradorsal tooth on each side of resilifer crossed by coarse microridges. Adductor scar moderately large, bordered by dorsally projecting lobe indicating strong byssal retractor muscle. Foliated-calcite re-entry extending ventrally only to level of dorsal margin of adductor scar. RV unknown.

Material.—Known only from a single LV (USNM 540997) from locality TU 1294, Cercado Formation, Maury's Bluff 3, Río Mao, Dominican Republic.

Measurements.—6.6 mm Ht, 6.7 mm L, length of anterior auricle 3.0 mm, length of posterior auricle not obtainable because of missing extremity, *ca.* 0.8 mm cvx.

Remarks.—This small specimen is the only representative of *Paraleptopecten* found in the combined collections of NHB, TU, and USGS from the Dominican Republic. At TU 1294 it was hidden in a lot consisting of *ca.* 1,000 specimens of *Leptopecten thompsoni*. The possibility that the specimen was accidentally introduced into the sample was considered but then rejected because of the similarity of adhering dark mineral grains to those present in matrix adhering to *L. thompsoni* from the same locality.

Comparisons.—Based on its shape and rib pattern, *Paraleptopecten* sp. *a* is very closely related to the extant species *P. bavayi*. The rib pattern of *P.* sp. *a* is Pattern 18a, which is present in *P. bavayi* from Cuba and Puerto Rico (Table 18, Pl. 11, Fig. 18) but unknown elsewhere within the present-day geographic range of this species. *Paraleptopecten* sp. *a* differs from *P. bavayi* in having slightly higher, narrower, and more

differentiated major and minor plicae, disk flanks without radial costellae, and more prominent cuspate lamellae on the flanks of minor plicae.

Evolution.—See discussions of the genera *Leptopecten* and *Paraleptopecten* n. gen.

Occurrence.—In the Dominican Republic, *Paraleptopecten* sp. *a* is known only from a single specimen from the Cercado Formation at Maury's Bluff 3 on the Río Mao (locality TU 1294).

Distribution.—Paraleptopecten sp. *a* is unknown outside the northern Dominican Republic.

Tribe **AMUSIINI** Thiele, 1934 [emend. Waller, 2006a]

Genus ***AMUSIUM*** Röding, 1798

Amusium Röding, 1798: 128.
Pleuronectes Bronn, 1832: 624, non Linnaeus, 1758.
Pleuronectia Swainson, 1840: 388.

Type species.—Ostrea pleuronectes Linnaeus, 1758, by subsequent designation (Herrmannsen, 1846), Recent, western Indo-Pacific.

Diagnosis.—Pectininae with smooth, streamlined, broadly gaping, moderately equiconvex to slightly right-convex shells, lacking plicae throughout ontogeny on exterior but having single or paired internal carinae as well as prominent auricular buttresses; byssal notch and ctenolium becoming obsolete in early ontogeny; prismatic stage of RV limited to early ontogeny; hl short relative to L, dentition simple, with deep outer-ligament grooves on RV bordered ventrally by moderately developed dorsal teeth, resilial teeth weak or absent, intermediate teeth absent; adductor muscles commonly centralized and large relative to size of shell.

Remarks.—The genus name *Amusium* has been overused in the literature for species that have evolved a smooth, streamlined form by different phylogenetic routes (Waller, 1991: 2;

Table 18. Rib patterns in *Paraleptopecten bavayi*. Following the rib-pattern encoding system explained in the Materials and Methods section, 17 rib patterns on the LVs of extant *P. bavayi* were observed in the USNM collection of Recent mollusks. The patterns are organized by increasing total rib count. The pattern name is constructed of the total rib count (not including tertiary costae such as medial costae) followed by a letter that indicates a particular pattern with that number of ribs.

Pattern name	Pattern	Total ribs	n	%
14a	/r r R r R rr Rc r R r r R r\	14	1	1.3
14b	/r r R r R r Rc r R r r R r r\	14	1	1.3
15a	/r r R r r R r r Rc r r R r R r\	15	1	1.3
15b	/r r R r r R r Rc r R r r R r r\	15	1	1.3
16a	/r R r r R r r Rc r r R r r R r r\	16	1	1.3
16b	/r r R r R r r Rc r r R r r R r r\	16	2	2.6
16c	/r r R r r R r Rc r r R r r R r r\	16	1	1.3
17a	/r r R r r R r r Rc r r R r r R r r\	17	38	48.7
17b	/r r R r r r R r r Rc r r R r r R r\	17	1	1.3
18a	/r r R r r R r r r Rc r r R r r R r r\	18	16	20.5
18b	/r r R r r R r r r Rc r r R r r R r r\	18	1	1.3
18c	/r r R r r R r r Rc r r r R r r R r r\	18	2	2.6
19a	/r r R r r R r r r Rc r r r R r r R r r\	19	6	7.6
19b	/r r R r r r R r r r Rc r r R r r R r r\	19	1	1.3
19c	/r r R r r r R r r r Rc r r r R r r R r\	19	1	1.3
20a	/r r R r r r R r r r Rc r r r R r r R r r\	20	3	3.8
20b	/r r r R r r R r r r Rc r r R r r r R r r\	20	1	1.3
	Total valves		78	

2006b: 331). As used herein, the name applies to a group of Pectinidae that is common today in the tropical to subtropical western Indo-Pacific region, the best known species of which are *A. pleuronectes*, *A. japonicum* (Gmelin, 1791), and *A. balloti* (Bernardi, 1861). In the Early Miocene to Late Pliocene, the genus was also present in tropical and subtropical waters on both sides of the Americas, but disappeared from the American region at the end of the Pliocene. The last surviving American species is *A. mortoni* (Ravenel, 1844), which is present in late Pliocene to early Pleistocene formations in the southeastern United States, eastern Mexico, and Venezuela. So-called *Amusium papyraceum*, a species that lives today in the Gulf of Mexico and Caribbean, is neither an *Amusium* nor the species *A. papyraceum* but rather is a *Euvola* species that has independently evolved an amussioid form relatively recently, probably during the Pleistocene (Waller, 1991: 41).

The radial carinae, commonly paired, on the inner valve surfaces of *Amusium* shells are all that remain of low, rounded external plicae that were present in ancestral *Amussiopecten* Sacco, 1897 (Cox, 1927: 40; Waller, 1991: figs 5, 11). This latter genus, extinct since the Pliocene, was widely distributed in Atlantic and Pacific regions during the Late Oligocene and Miocene (Masuda, 1971b). Species of *Amussiopecten* in the Miocene of Panama that Woodring (1982: 587) referred to as *Amusium* "ribbed in the umbonal area" retain external plicae only in early ontogeny but then become smooth and closely resemble true *Amusium*. Like most *Amussiopecten*, however, at least one of these species, *Amusium sol* (Brown & Pilsbry, 1913), retains strong intermediate hinge teeth.

Extant species of *Amusium*, all of which live in the Indowest Pacific region, are tropical to subtropical, living at sublittoral to shallow shelf depths on sea bottoms of sand, muddy sand, or mud under normal marine conditions. All are highly mobile, with well-developed swimming abilities, and tend to have broad geographic distributions (Morton, 1980; Brand, 2006: 664, 711). Depths of occurrence commonly are below fair-weather wave base, ranging from 10-100 m (Brand, 2006: 664; Del Norte, 1991: 828). *Amusium balloti*, a species fished commercially off of Queensland and Western Australia, is said to prefer water temperatures of 19-24°C (Cropp, 1994: 269). The rather narrow temperature tolerance of *Amusium* could have led to its extinction in the Americas. The last occurrence of *A. mortoni* in the southeastern United States is in the late Pliocene and earliest Pleistocene Caloosahatchee Formation of southern Florida, interpreted by Petuch (2007: 117) as representing a "localized, isolated tropical marine environment" that was a refugium for many tropical taxa that had already become extinct along the eastern coast.

Geographic range.—Limited at present to tropical to subtropical western Indo-Pacific, occurring at sublittoral to shallow shelf depths on sand, muddy sand, or mud. Fossils present on the eastern side of the Americas range from Virginia to Argentina.

Stratigraphic range.—Lower Miocene to Lower Pleistocene on eastern side of the Americas; the genus is absent from the fossil record of the eastern Pacific region.

Amusium papyraceum (Gabb, 1873)
Pl. 12, Figs 1-12; Pl. 13, Figs 1-3; Table 19

Pleuronectia papyracea Gabb, 1873: 257.
Amusium papyraceum (Gabb), Dall, 1898: 718; Maury, 1917a: 190, pl. 26, fig. 22; Pilsbry, 1922: 413, pl. 43, figs 8-9; not Abbott, 1974: 443, pl. 18, fig. 5136 (= *Euvola* sp. *a* Waller, 1991: 41).

Description.—*Amusium* of moderate size, commonly 40-70 mm Ht, rarely reaching *ca.* 100 mm Ht, nearly circular in outline and of moderate convexity, with L slightly less than Ht in early ontogeny, becoming equal to or slightly exceeding Ht in later ontogeny, with broad anterodorsal and posterodorsal disk gapes between valves; RV more convex than LV and of uniform curvature in both dorsoventral and anterior-posterior directions, exterior smooth except for fine, seldom elevated, commarginal growth lines and very fine antimarginal striae; LV exterior also smooth but with broad, shallow radial trough on each side of umbonal region, causing dorsal shoulders of disk to be upturned, and rarely with very low radial undulations in anterior and/or posterior sectors of disk or across entire disk. Auricles small and hl short relative to size of disk, hinge *ca.* 33-38% L; right anterior auricle with persistent, very shallow, rounded byssal notch; ctenolium becoming obsolete early in ontogeny, at *ca.* 4-6 mm measured along auricular suture from beak to end of ctenolium; anterior margin of right anterior auricle nearly circular centrally, becoming concave ventrally in byssal notch and dorsally just below dorsal margin; posterior margin of posterior auricles convex, with overall trend forming obtuse angle with dorsal margin, not greatly incurved toward beak before intersecting dorsal margin; surfaces of all auricles lacking radial sculpture except for right anterior auricle, which has 1-3 very weak radial costellae in first few millimeters of growth. Interiors of both valves bearing radial internal carinae of variable spacing, pairing, and number, becoming less distinctly paired and fading out anteriorly and posteriorly; internal carinae of stratigraphically lower specimens tending to be in 16-24 narrow pairs with interpair spaces more than three times width of intrapair spaces in central sector; stratigraphically higher specimens with less distinct or absent pairing, especially on LV, these specimens having 45-66 single internal carinae. Adductor scars large, with posterior margins of scars nearly confluent with border

of aragonitic inner shell layer. Foliated-calcite re-entry on interior of LV of large specimens extending posteriorly along ventral margin of adductor scar, less extensive on RV, extending at least to level of ventral margin of adductor scar but not passing posteriorly beneath the scar.

Type material and measurements.—Holotype, ANSP 2864, 1 RV, 52 mm Ht, 54 mm L (measurements of Pilsbry, 1922: 413), figured by Pilsbry (1922: pl. 43, fig. 8).

Type locality.—Dominican Republic. No further details of the locality can be discerned from Gabb's (1873) original description.

Other material.—Approximately 300 specimens, approximately half of which are fragments, from 68 localities in the northern Dominican Republic (Table 19). Only 4 of these specimens are articulated shells or matching valves.

Remarks.—The number and pattern of internal carinae of *Amusium papyraceum* change from the lowest occurrence of the species in the Cercado Formation to its highest in the upper Gurabo Formation. Because the change appears to be slight and gradual, I refer to the two extremes as Morphotypes A and B rather than as subspecies or species. The two morphotypes are otherwise the same in size, shape of disk and auricles, extent of foliated-calcite re-entries on valve interiors, and the range of shell heights of the midventral margin of the outer prismatic layer of the right valve (7.5-16.2 mm).

In Morphotype A, represented by the holotype and by specimens from the Cercado Formation (Pl. 12, Figs 1-7), the internal carinae of the right valve are in narrow pairs, commonly 17-24 pairs, whereas those of the left valve are in somewhat broader pairs that are still much narrower than the interpair spaces and thus usually readily distinguishable, the pair counts being in the same range as on the right valve. In Morphotype B, typified by specimens from the upper Gurabo formation (Pl. 12, Figs 8-12), pairs of carinae are difficult to distinguish, especially on the left valve, and it is necessary to count single carinae rather than pairs. These counts are 46-66 on the right valve and 38-62 on the left. In addition, short intercalated carinae commonly occur near the margins of both valves.

The occurrences of Morphotypes A and B are shown in Table 19. In stratigraphic sections that contain *Amusium papyraceum* in sequence, Morphotype A most commonly occurs stratigraphically below Morphotype B. In the Río Gurabo section, Morphotype A is the only morphotype present in the Cercado Formation (with one possible exception at locality NMB 15886, a pair of gaping valves with interior almost filled by matrix), and is the only morphotype in the lowest sample the Gurabo Formation at 211 m above the base of the section (using the Cercado/Gurabo boundary of E. Vokes, 1989: 18). Morphotype B occurs above this point up to the highest occurrence of *Amusium* in the upper (early Pliocene) part of the Gurabo Formation at 427-431 m above the base of the section. In the Río Cana section, the exceptional Morphotype B at TU 1230 (Table 19) in the Cercado Formation is a right valve with an unusually high number (62) of single carinae with indistinct pairing, not including numerous new intercalations near the valve margin (Pl. 12, Fig. 11). The exterior, however, displays repaired marginal injuries (Pl. 12, Fig. 12), and the interior has a ring of nodules indicating that the mantle tissue was irritated during life by entrapped sediment beneath it (Pl. 12, Fig. 10). These conditions might have contributed to the high count and lack of pairing of internal carinae. On the Río Mao, Morphotype A occurs at all three of the numbered bluffs of Maury (1917a). The stratigraphically highest occurrence at Bluff 1, however, is in strata dated by Saunders *et al.* (1986: 32) as nannoplankton zone NN11 and is thus still within the late Miocene.

A third morphotype, called Morphotype C (Pl. 13, Figs 1-3), is represented by small right valves 14-22 mm in height that are clearly immature but show features that are not present in the corresponding growth stages of Morphotypes A and B. Specifically, the right valves of Morphotype C have elevated disk flanks that are sharply inturned, forming a sharp edge with the disk surface (Pl. 13, Fig. 2). The surface of the anterior disk flank is concave in cross section and in some specimens bears antimarginal ridglets. The disk flanks at corresponding sizes in Morphotype A and B are scarcely raised above the adjacent auricular surfaces and are straight or convex in cross section. Additionally, the prismatic stage of the right valve of Morphotype C is much shorter, extending to a midventral height of only *ca.* 1.2 mm, compared to 7.5-16.2 mm in Morphotypes A and B. Internal carinae in Morphotype C are barely beginning by a valve height of *ca.* 14 mm. From what little can be seen, these initial carinae have uneven spacing and no distinguishable pairing, appearing more like the carinae of Morphotype B than like those of Morphotype A. The left valves of Morphotype C, identified only by association with the right valves, do not have distinctive disk flanks and would not otherwise be identifiable as Morphotype C. Morphotype C was found only in the upper (Pliocene) part of the Gurabo Formation and can also be present in the lower Mao Formation (Table 19, locality TU 1334). Unlike *Zamorapecten maoensis* n. gen., n. sp., which also occurs this high in the section, Morphotype C lacks the distinctive concave dorsal auricular margins and umbonal sculpture.

The occurrences of the three morphotypes are clearly related to water depth as shown by their relative stratigraphic positions in sections that are known to represent increasing

Table 19. Occurrence of *Amusium papyraceum* in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Aee, *A. eccentricus eccentricus*; Ael, *A. eccentricus lacabrensis* n. ssp.; Ai, *Argopecten inaequalis*; Anj, *Antillipecten janicoensis* n. sp.; Anq, *Antillipecten quemadosensis* n. sp.; Ans, *Antillipecten* sp.; Apa, *Argopecten parathetidis* n. sp.; At, *A. thetidis*; Bsq, bisquamous; B1, Bluff 1 of Maury (1917b); B2, Bluff 2 of Maury (1917b), B2/B1, between Bluffs 2 and 1; B3, Bluff 3 of Maury (1917b); Caj, *Caribachlamys jungi* n. sp.; Cg, *Cyclopecten guppyi*; Chp, *Chagrepecten paracactaceus* n. gen., n. sp.; Cz, *Cyclopecten zalaya* n. sp.; Dm, *Dimya* sp.; DV, matching valves; Eg, *Euvola gurabensis* n. sp.; Es, *E. soror*; frag, fragment; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis plurinominis*; Lt, *Leptopecten thompsoni*; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Nn, *N. nodosus*; Pvm, *Parvamussium marmoratum*; Sv, *Spathochlamys vaginula*; --, not recorded. Morphotypes are explained in the text. See caption for Table 7 regarding stratigraphic level of TU 1230 on the Río Cana.

Locality	Level (m)	Formation	Morpho-type	RV	LV	DV	Frag	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana										
NMB 16865	431	Gurabo	B	0	0	1	10	53	none	
NMB 16862	383	Gurabo	B	0	0	0	1	--	Lpl	
NMB 16825	321	Gurabo	A	1	0	0	1	55	Anq, Apa, At, Lpl	
NMB 16835	252	Gurabo	A	0	0	0	1	--	Aec, Ans, Es, Lpl	
NMB 16838	233	Gurabo	A	0	1	0	1	60	Aec, Es, Lpl	
----------										Possible unconformity
TU 1230	200	Cercado	B	1	0	0	0	68.5	Ael, Cg, Es	
NMB 16857	148	Cercado	A	0	1	0	3	65	Ael, Cg	
Río Gurabo										
NMB 16867	427-431	Gurabo	B	0	0	0	2	--	none	
TU 1213	298-400	Gurabo	C	1	0	0	9	22	none	
TU 1212	389-398	Gurabo	?	0	1	0	0	14	At, Gu	
NMB 15939	394-397	Gurabo	?	0	1	0	0	10.6	At, Dm, Sv	
TU 1210	392-396	Gurabo	?	0	2	0	0	16.0	At, Gu, Lpa, Ncv, Sv	
TU 1369	388?	Gurabo	B?	0	1	0	0	20.1	At, Gu, Lpa, Sv	
TU 1215	286-386.5	Gurabo	C	2	0	0	0	19	Anq, At, Caj, Lpa, Nn	
NMB 15862	248-251	Gurabo	B	0	0	0	3	--	none	
TU 1277	222-226	Gurabo	B	1	0	0	3	63	Ai	
NMB 15865	221-223.5	Gurabo	B	1	0	0	1	52	At, Sv	
NMB 15870	218.5	Gurabo	B	1	1	0	0	67	Ai, At	
NMB 15872	211	Gurabo	A	0	1	0	6	65	At, Es	
----------										Cercado/Gurabo Fm boundary of E. Vokes (1989: 18)
NMB 15878	193	Cercado	A	0	1	0	0	28	Ael, Es, Lpl	
TU 1297	183-211	Cercado	A	2	0	0	0	100	Ael, At, Es, Lpl	
NMB 15883	183-185	Cercado	A	0	0	0	1	--	none	
NMB 15886	175	Cercado	B	0	0	1	0	75	Ael, Lpl	

Table 19 (continued).

Locality	Level (m)	Formation	Morpho-type	RV	LV	DV	Frag	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo (continued)										
NMB 15890	175	Cercado	?	0	0	0	1	--	Ael, Lpl	
NMB 15898	131-133	Cercado	A	1	1	0	0	40?	Ael, At	Radial undulations on LV
NMB 15905	130	Cercado	A	5	7	0	0	57	Ael	Radial undulations on LV
NMB 15899	124-126	Cercado	A	2	4	0	2	59	Ael	Radial undulations on both valves
NMB 15902	125	Cercado	A	1	0	0	0	51.0	Ael	
USGS 8739	122-126	Cercado	A	0	0	0	37	--	Ael, At	
TU 1358	102-104	Cercado	A?	0	1	0	0	21.5	Ael, Cg, Lpl	
TU 1376	99-102.5	Cercado	?	1	0	0	0	3.8	Ael, Lpl	
Río Mao										
TU 1292	--	upper Gurabo	B	1	1	0	0	27	Chp	
TU 1225	--	upper Gurabo	B?	0	1	0	0	17	Ai, At, Es, Lpa, Nn	
TU 1293	B1	Gurabo	A	2	1	0	2	50	Ai, At	
USGS 8519	B1	Gurabo	A	2	2	0	6	50	Ai, At	
NMB 16910	B1	Gurabo	A	1	2	0	5	50	Aee, At	
TU 1410	B2/B1	Cercado?	A	1	1	0	10	44	Aee, At, Cg, Es	
USGS 8521	B2/B1	Cercado?	A	0	0	0	7	--	Aee, At, Es, Lpl	
USGS 8526	B2, g-h	Cercado	A	0	0	0	3	--	Aee, Es, Lpl, Lt	
Río Amina										
TU 1371	--	Gurabo	A	1	0	0	0	20	Aec?, Ai, At, Eg	
TU 1219	level d	Gurabo	A	2	3	0	4	51	At, Lpl, Lpa, Sv	
USGS 8516	level d	Gurabo	A	0	0	0	13	--	At, Pc	
TU 1217	level c	Gurabo	B?	0	0	0	4	--	At	
TU 1220	level c	Gurabo	A	0	1	0	0	39	Aee, At, Lpl	
USGS 8518	level c	Gurabo	A	0	1	0	7	105	Aee, Es, Lpl	
NMB 16806	level b	Gurabo	A	1	2	0	0	62	Es	
NMB 16804	level a	Gurabo	A	0	0	0	3	--	Aee, Lpl	
Río Yaque del Norte										
NMB 17268	--	Gurabo	B	1	2	0	0	70	Aec?, Apa, Lpl	
TU 1206	--	Gurabo?	B	2	4	0	7	92.5	Apa, At, Es, Sv	
TU 1207	--	Gurabo?	B	1	2	0	0	61	Apa, At	

Table 19 (continued).

Locality	Level (m)	Formation	Morpho-type	RV	LV	DV	Frag	Max. Ht (mm)	Associated Pectinids	Comments
Río Verde										
TU 1250	--	Gurabo	B?	1	1	0	0	45.0	Aec, At, Cg, Cz, Es, Gu, Lpa, Pvm	
Santiago area										
TU 1205	--	Gurabo	B	2	1	0	4	70	Aec, Apa, At, Es, Sv	
TU 1227A	--	Gurabo	C	2	3	0	0	14.5	Ai, At, Cg, Cz, Gu, Lpa, Pvm, Sv	
TU 1227	--	Gurabo	C	0	1	0	0	15.0	At, Lpl, Pvm	
TU 1380	--	Gurabo?	C	2	3	0	0	19.0	Ai, At, Sv	
TU 1406	--	?	A	0	1	0	0	90	Aec, Anj, Anq, Es, Lpa, Lpl, Lt, Nn	
TU 1407	--	?	A	0	2	0	0	58	Ael, Es	
Road cuts										
TU 1222	--	?	?	1	0	0	0	35.0	Aec, Anq, Apa, At, Es, Lpl	
TU 1254	--	Gurabo	A?	0	1	0	4	52	Ai, At	
TU 1334	--	Mao?	C	2	1	0	0	24.0	Ai, At	
TU 1335	--	Gurabo?	B	1	1	0	0	45	Ai, At	
TU 1338	--	Gurabo	B	0	0	0	2	--	At, Gu, Eg, Lpa, Ncv	
TU 1360	--	Gurabo?	B	2	2	1	0	60	At	
TU 1361	--	Gurabo?	B	1	2	0	0	58.5	At	
TU 1409	--	Gurabo?	B	0	2	0	0	15	Ai, At	
TU 1435	--	Gurabo?	B	1	1	1	0	59	Ag, At, Eg, Lpl	
TU 1437	--	Gurabo?	B	2	4	0	0	68	Aec, At, Lpl	
USGS 8535	--	Gurabo	B	6	3	0	0	63	At, Es, Lpl	

depth of deposition going upward in the section (Saunders *et al.*, 1986) as well as by their faunal associations. As indicated in Table 19, Morphotype A is most commonly associated with *Argopecten eccentricus s. l.*, and *Lindapecten plurinominis*, both shallow-water pectinids that probably lived at depths < 20 m in association with marine grasses. In contrast, Morphotypes B and C are commonly associated with *Argopecten thetidis* and other deeper-water species such as *Argopecten inaequalis* and *Gurabopecten uniplicatus* n. gen., n. sp.

Comparison.—Species of American Neogene *Amusium* that lack external radial ribs on their umbones and are thus comparable to *A. papyraceum* are *A. toulae* (Brown & Pilsbry, 1911) [junior synonyms *Pecten* (*Amusium*) *luna* Brown & Pilsbry, 1913, and possibly *A. bocasense* Olsson, 1922], *A. mortoni* (junior synonym *Amusium rexmaris* Maury, 1925a), *A. darwinianum* (d'Orbigny, 1842), and *A. paris* del Río, 1992.

Based on a new examination of specimens from Panama studied by Woodring (1982), the species that he described as *Amusum toulae* from the La Boca, Alhajuela, Gatun, and Chagres formations of Panama is actually two species. One is restricted to the La Boca Formation and is identified herein as

A. aguaclarense (F. & H. Hodson in Hodson *et al.*, 1927). The latter species was described from the Agua Clara Formation of Venezuela, a stratigraphic unit that is apparently of approximately the same age as the La Boca Formation (late Early Miocene, Burdigalian). The second species included within "*A. toulae*" by Woodring is the true *A. toulae*, which does not occur in the La Boca Formation but is present in the Alhajuela, Gatun, and Chagres formations.

Morphotypes A and B of *Amusium papyraceum* differ from *A. aguaclarense*, *A. toulae*, and *A. mortoni* in the shape of the free margins of the auricles and in the extent of foliated-calcite re-entry on the shell interior. In the latter three species, the dorsal part of the free margins of the auricles sweep dorsally toward the beak to form a more obtuse angle with the dorsal margin than in *A. papyraceum*. In Panamanian *A. aguaclarense*, *A. toulae*, and *A. mortoni*, the inner aragonitic sector is broader than in *A. papyraceum*, so that the posterior margin of the adductor scar of both valves is inset from the aragonite margin posterior to the scar, whereas in *A. papyraceum* the posterior margin of the adductor scar is flush with the margin of the aragonite sector. Also, *A. papyraceum* differs from these other species in having more extensive foliated-calcite re-entries, extending to below the level of the ventral margin of the adductor scar in mature specimens, whereas in the other species, this shell layer barely extends to the mid-adductor-scar level. *Amusium aguaclarense* differs from all of the other species in the number and pattern of its internal carinae. Its right valve commonly has 8-10 broad pairs of carinae, with interpair spaces not more than approximately twice the width of intrapair spaces. Because the carinae of the left valve are on the outer sides of the paired carinae of the right valve, inter- and intrapair spaces of the left valve are the same width or nearly so, making pairs impossible to distinguish. The number of single carinae on the left valve of *A. aguaclarense* (16-20) is therefore twice the number of pairs on the right valve. *Amusium mortoni* differs from the other species in attaining a much greater maximum size (heights commonly > 100 mm, rarely exceeding 200 mm) and in having obsolete disk flanks on the left valve so that the auricular surface and adjacent disk surface are at the same level, separated only by a groove.

Amusium darwinianum and *A. paris* are two closely related species of early Late Miocene age, respectively from the Paraná and Puerto Madryn formations of Argentina (del Río, 1991, 1992). In spite of their geographic separation from the Dominican Republic, they resemble *A. papyraceum* more than do the other species discussed above. As in *A. papyraceum*, the posterior margin of the adductor scar is close to or coincident with the posterior boundary of the inner aragonitic layer, the free margins of the auricles are not greatly slanted to form high obtuse angles with the dorsal margins, and the internal carinae are in narrow pairs. The Argentine species differ in having posterior auricular margins that are slightly concave rather than convex, and in having more rapidly flaring disks. In *A. paris*, the dorsal shoulders of the disk become nearly parallel to the hinge line. The folded dorsal margins of the right auricles of *A. paris* are higher and more tightly folded than in *A. papyraceum*, and the hinge dentition of *A. paris* is more dorsoventrally compressed, the dorsal teeth being shorter and with less separation from the resilial teeth.

Evolution.—In the Miocene of the southern and western Caribbean, there appears to be an evolutionary sequence from *Amusium aguaclarense* (Early Miocene of Venezuela and Panama) to *A. toulae* (late Middle Miocene to early Pliocene of Panama) to *A. mortoni* (Early or Middle Pliocene to earliest Pleistocene of southeastern USA, Veracruz and Baja California Sur, Mexico, and Venezuela. The Mexican and Venezuelan records for *A. mortoni* have not previously been recorded. They are based on specimens from the following localities: USGS 13089, Tehuantepec area, Rodriguez Clara, Mexico; USNM 418203, hypotype of Smith (1991a: figs 3h, j, identified by her as *A. luna* from an unnamed sandstone, Punta Paredon Amarillo, northern Concepción Peninsula, Mexico); and USGS 24703, San Gregorio Formation, San Gregorio, Falcón, Venezuela. *Amusium papyraceum* is not a part of this sequence, standing apart with the Argentine species, *A. darwinianum* and *A. paris*, for the reasons given above. This relationship with Argentine species is not unexpected. Del Río (2004: 1114) provided a detailed account of dramatic biogeographic changes that occurred in the early Late Miocene, when many Caribbean and paratropical species dispersed to the Patagonian region. The morphological differences between *A. papyraceum* and *A. paris*, specifically the higher dorsal auricular folds and more flaring shape of the latter, suggest that *A. paris* is the more evolutionarily derived species.

Occurrence.—In the northern Dominican Republic, *Amusium papyraceum* occurs in the Cercado and Gurabo formations, with Morphotype A restricted to the Cercado and lower Gurabo formations and Morphotypes B (with a few exceptions) and C restricted to the upper Gurabo.

Distribution.—Based on the extensive Neogene tropical American collections in the Smithsonian collections, *Amusium papyraceum* has not been positively identified from outside the Dominican Republic.

Genus ***EUVOLA*** Dall, 1898

Pecten (*Euvola*) Dall, 1898: 694, proposed as a section of *Pecten* (*Pecten*).

Type species.—*Ostrea ziczac* Linnaeus, 1758, by original designation (Dall, 1898: 694), Recent, tropical and warm-temperate western Atlantic.

Original diagnosis.—"Left [*sic*, right] valve extremely inflated, surface polished, ribs moderate or obsolete, without radial striation, concentric sculpture inconspicuous; right [*sic*, left] valve with or without conspicuous radial and concentric sculpture, flat or concave" (Dall, 1898: 694-695).

Emended diagnosis.—Pectininae with RV moderately to deeply convex, LV flat or concave, radial ribs variable in strength, left auricles with 1-3 incipient to well-developed radial costae near dorsal margin; hinge dentition of RV dominated by dorsal teeth, prominent intermediate teeth absent, resilial teeth variably developed, commonly weak or absent.

Remarks.—Dall's (1898) concept of the "section" *Euvola* is that it consists of species of *Pecten* having obsolete or absent ribbing on the right valve as well as lacking commarginal lirae on that valve. Woodring (1925: 63) added to this concept by noting that *Pecten* (*Euvola*) differs from *Pecten s. s.* in having "only one pair of cardinal crura." Waller (1991: 38; 2006a: 25; 2007: 934) recognized that the differences between European *Pecten* (including *Oppenheimopecten* von Teppner, 1922, as a junior synonym) and American *Euvola* allow the recognition of two independent clades that have been separate at least since the middle Miocene, and in a review of the phylogeny of *Euvola* (Waller, 2007) elevated *Euvola* to genus rank. In addition to the differences in dentition (dorsal teeth of right valve dominant and intermediate teeth absent or nearly so in *Euvola,* intermediate teeth present and commonly multiple in *Pecten),* the two clades differ in the distribution of radial costae on left auricles, commonly only 2 or 3 limited to the dorsal half of the left auricles in *Euvola* but more numerous and distributed over most of the auricular surfaces in *Pecten.* The presence or absence of commarginal lamellae on the right valve is of use only at the species level. A vexing problem with the species-level taxonomy of *Euvola* is that many fossil species have been described inadequately, in some cases on the basis of only a single valve and with little attention to morphological variation.

Geographic range.—Presently ranging from North Carolina to Brazil and Bermuda and throughout the Gulf of Mexico and Caribbean on the eastern side of the Americas; from middle California to Peru and out to the Galapagos Islands on the western side, on sandy to muddy bottoms from shallow subtidal depths to *ca.* 200 m.

Stratigraphic range.—Middle Miocene to Recent.

Euvola gurabensis n. sp.
Pl. 13, Figs 4-10; Table 20

Diagnosis.—*Euvola* with RV of low to moderate convexity, LV nearly flat to slightly concave, broadly flaring with umbonal angle reaching 120°; both auricles of RV with only weak costae or none; rib crests of disk of RV bearing 2-4 low, non-scabrous costellae in late ontogeny; ribs of LV simple, rounded, without medial riblets in interspaces.

Description.—Thin shell of small size, reaching *ca.* 40 mm Ht, acline, equilateral, large specimens with L exceeding Ht, broadly flaring, umbonal angle reaching 120°; RV cvx low to moderate, *ca.* 15% Ht; LV flat to slightly concave with raised shoulders; disk gapes probably present but not observed directly. Disks with 25-28 low ribs approximately equal in width to interspaces on RV, narrower on LV; crests of right ribs becoming flattened, then bifid or subdivided by 3 or 4 low non-scabrous costae in late ontogeny; crests of left ribs remaining rounded; lateralmost ribs on RV much narrower than others, increasing in width toward central sector; lateralmost ribs on shoulders of LV lower than others except central rib on posterior shoulder higher than ribs adjacent to it. Commarginal lamellae passing straight across interspaces and rib crests, weakly developed on RV, more prominent and more widely spaced in interspaces of LV. Disk flanks of both valves narrow, curved in cross section, of approximately same width as neighboring rib interspace, steeper on LV, and without radial costellae. Prismatic stage of RV ending at at least 5 mm Ht.

Auricles approximately equal in length, total hl *ca.* 40% L; right anterior auricle with byssal notch becoming obsolete late in ontogeny, anterior margin rounded, byssal fasciole not swollen, suture along out-turned flange of anterior disk flank, surface of auricle with few very weak radial costellae in central sector in early ontogeny, fading later; free margins of left anterior auricle and both posterior auricles straight or slightly convex, with overall trends forming obtuse angles with dorsal margin, right posterior auricle commonly without radial costae, left auricles commonly with 1 weak costa or 2 well-separated weak costae in dorsal sector. Hinge dentition of RV dominated by single dorsal tooth on each side of resilifer; resilial teeth very weak or absent, intermediate teeth absent, hinge plate bearing vertical microcrenulations. Interior surface of RV not observed; that of LV having foliated-calcite re-entry extending ventrally to pallial line and extending posteriorly along ventral margin of adductor scar. Edges of ribs on shell interior carinate near valve margins; ribs on shell interior extending well inward from pallial line, crossing adductor scar.

Etymology.—Name derived from the Gurabo Formation of

the Dominican Republic.

Holotype and measurements.—USNM 541004, 1 RV with matrix-filled interior, 29 mm Ht, 32 mm L (Pl. 13, Figs 4-5).

Type locality.—Locality TU 1338: Road cut, 0.3 km west of the ford over Río Gurabo, on the Los Quemados-Sabaneta road, or 2.9 km west of Los Quemados, northern Dominican Republic.

Other material.—12 specimens from 5 localities in the northern Dominican Republic (Table 20). Two of these are fragments; the others are all single valves.

Remarks.—Euvola gurabensis n. sp. does not co-occur with *E. soror* at any of the sampled localities, although the limited amount of material of the new species leaves open the possibility that this might be due to chance. The single locality in the Río Gurabo section from which *E. gurabensis* n. sp. was collected is within the stratigraphic range of *E. soror* in the same section (compare Tables 20-21). The closest extant relative of *E. gurabensis* is *E. chazaliei* (Dautzenberg, 1900), a relatively uncommon species that lives in the tropical western Atlantic region at depths from 20-100 m, although single valves are sometimes found in sediments at shallower depths.

Comparisons.—Euvola gurabensis n. sp. differs from *E. soror* in having a thinner shell, more flaring and less convex right valve, and more numerous ribs that on the right valve are subdivided in late ontogeny by secondary radial sculpture, either a single medial groove or 2-4 low costae. The extant species *E. chazaliei* resembles *E. gurabensis* n. sp. in having a thin shell, left auricular margins forming obtuse angles with the dorsal margin, weakly developed auricular costae, and commonly > 25 ribs on its right valve. The fossil species, however, has right disk ribs that are less variable in spacing and width and that more commonly have secondary radial grooves and costae on their rib crests. The ribs of the left disk of *E. gurabensis* n. sp. are also more uniform in size and spacing and somewhat broader relative to interspaces. *Euvola coralliphila* (Olsson, 1922), from the Moin Formation, late Pliocene (Cotton, 1999: 74), of Costa Rica is very similar to and possibly a junior synonym of the extant species *E. chazaliei*. *Euvola reliquua* (Brown & Pilsbry, 1913), from the middle part of the Gatun Formation of Panama (Woodring, 1982: pl. 108, figs 1-3) of Late Miocene age (Collins *et al.*, 1996), has a relatively much more convex right valve with stronger, more rectangular ribs.

Evolution.—Euvola gurabensis n. sp. is the first definite fossil member of a subclade of thin-shelled, low-convexity *Euvola* that includes the extant species *E. chazaliei* and *E. turtoni* (E. A. Smith, 1890), the latter of St. Helena Island in the central South Atlantic. Based on the close similarity between *E. gurabensis* n. sp. and *E. soror*, the latter species could be representative of the ancestral group from which *E. gurabensis* n. sp. evolved. If this is the case, then morphological change involved decreasing convexity of the right valve, increasing irregularity in rib spacing and width, and thinning of the shell, possibly as adaptations to a change in habitat to deeper water. The time of origin of *E. gurabensis* n. sp. is unknown, although its first occurrence in the upper Gurabo Formation suggests that it was within the Pliocene. If so, the duration of the species was short, assuming that the first appearance of the extant species *E. chazaliei* in the latest Pliocene Moin Formation marks an anagenetic change from *E. gurabensis* n. sp.

Occurrence.—In the northern Dominican Republic, *Euvola gurabensis* n. sp. has thus far been found only in the upper Gurabo Formation and the upper Mao Formation in deep-water facies of Early Pliocene age (based on determination of nannofossil zone NN 15 for highest outcrops of the Mao Formation on the Río Gurabo by Saunders *et al.*, 1986: 19).

Distribution.—Euvola gurabensis n. sp. is thus far unknown outside the Dominican Republic.

Euvola jamaicensis new name
Pl. 13, Figs 11-14; Pl. 14, Figs 1-2

Pecten (*Pecten*) *barretti* Woodring, 1925: 62, pl. 7, figs 6-7, not *P. barretti* Seeley, 1861: 118, pl. 6, fig. 1, Cretaceous of England
Pecten ventonensis Cooke. Mongin, 1968: 476, pl. 40, fig. 1 (not of Cooke, 1919).

Original description.—"Shell large; dorsal margins slightly concave, diverging at an angle of *ca.* 95°; right valve strongly inflated, sculptured with 19-22 high, almost square ribs, their edges and tops slightly rounded, separated by narrower, deeply channeled interspaces; in the interspaces and on the flanks of the ribs are obscure, fine, slightly raised concentric lamellae; left valve slightly concave, sculptured with the same number of narrower square ribs, and deep, flat interspaces of the same width or slightly wider; concentric lamellae more prominent than on right valve and occasionally extending across ribs, but less conspicuous on ribs than in interspaces; submargins relatively wide and forming a deep ledge on left valve; auricles subequal, sculptured with weak radial ribs and fine concentric lamellae; interior ventral margin deeply fluted" (Woodring, 1925: 62).

Table 20. Occurrence of *Euvola gurabensis* n. sp. in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; Anq, *Antillipecten quemadosensis* n. sp.; Apa, *Argopecten parathetidis* n. sp.; At, *A. thetidis*; Dm, *Dimya* sp.; DV, matching valves; frag, fragment; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo								
NMB 15831	893	Mao	0	1	0	39	none	
NMB 15837	374-376	Gurabo	frag	0	0	--	At, Lpa, Ncv	
Río Amino area								
TU 1371	--	Gurabo?	0	frag	0	--	Aec?, Ai, At, Amp	
Road cuts								
TU 1209	--	Gurabo	5	4	0	35.2	At, Gu, Lpa, Ncv, Sv	
TU 1224	--	Gurabo	0	1	0	24.8	Anq, Apa, Dm	
TU 1338	--	Gurabo	1	0	0	29	Amp, At, Gu, Lpa, Ncv	Type locality of *E. gurabensis* n. sp.

Description.—Shell of small to moderate size, known to reach *ca.* 45 mm Ht, acline, equilateral, L exceeding Ht, moderately flaring, umbonal angle increasing during ontogeny to *ca.* 110°; RV cvx moderate to high, reaching *ca.* 33% Ht; LV slightly concave with raised shoulders; disk gapes not observed, probably narrow if present. Disk of RV with 22-23 ribs decreasing gradually in amplitude toward disk flanks, commonly twice as wide as interspaces, crests smooth except for very shallow radial troughs and beading of very low relief present on some ribs late in ontogeny, sides of ribs vertical to slightly undercut; commarginals well developed in interspaces, passing nearly straight across interspaces and up sides of ribs but ending abruptly adjacent to overhanging rib crests; disk of LV with 23-25 ribs, those on shoulders finer, lower, and more closely spaced than others, those of central sector somewhat narrower than interspaces in width, crests slightly flattened, sides steeply sloping, with barely perceptible medial radial troughs on crests developing in late ontogeny; commarginal lamellae well developed in interspaces, passing straight across ribs in early ontogeny, weakly present across ribs in some specimens in late ontogeny. Disk flanks of both valves low, moderately steep, and curved in cross section, with closely spaced commarginal growth lines but lacking radial costae. Auricles approximately equal in length; right anterior auricle with persistent shallow byssal notch, byssal fasciole raised, separated from anterior disk flank by sharp groove, active ctenolium disappearing in late ontogeny; surface of right anterior auricle with 3 or 4 radial costae in central sector, anterior margin of auricle rounded, sloping dorsally toward beak; right posterior auricle with posterior margin shallowly sigmoidal, bearing 4 or 5 moderately strong radial costae in central part, separated by deep groove from posterior disk flank; left anterior auricle with nearly straight anterior margin forming slightly obtuse angle with dorsal margin; left posterior auricle with posterior margin slightly outwardly convex, meeting dorsal margin with slightly more obtuse angle than that of anterior auricle; both left auricles with radial costae variable in number and distribution, ranging from 5 or 6 moderately strong costae distributed over entire width of auricles to fewer costae developed in dorsal part of auricle but weak or absent ventrally. Hinge dentition of RV with narrow dorsal tooth and sharply raised resilial tooth on each side of resilifer, intermediate teeth absent, hinge plate bearing vertical microcrenulations. Interior surface of RV with foliated-calcite re-entry extending only to approximately mid-adductor-scar level; re-entry on LV nearly completely covering area inside pallial line except for muscle scars. Edges of ribs on shell interior carinate near valve margins; ribs extending slightly inward from pallial line, then becoming covered by inner shell layer.

Etymology.—From Jamaica.

Holotype and measurements.—USNM 352776, 1 RV, 29.8 mm Ht, 32.2 mm L.

Type locality.—USGS Locality 2580: "Bowden Formation at Bowden, on the east side of Port Morant, in the parish of St. Thomas, lying on the south coast of Jamaica near its eastern end" (Woodring, 1925: 7).

Other material.—Jamaica: Bowden Formation, 5 LV from locality USGS 2580 in addition to the holotype, and 1 RV, 3 LV from the same locality in the collections of the University of California Museum of Paleontology (UCMP 556136-556138, 556140); August Town Formation, 1 RV, 1 partial LV in Smithsonian collections from "Vertical beds near 8 mile Windward Road, August Town Series." Dominican Republic: NMB 15830, Mao Formation on Río Gurabo, 807-810 m above base of section, 1 RV; NMB 16885, Mao Formation on Río Cana, 1,177 m above base of section, 1 RV, 1 partial LV; USGS 8663, Province of Santiago, Arroyo Las Lavas, crossing of road from Santiago to Monte Cristi, 1 RV fragment. Puerto Rico: USGS 8654, unnamed formation on south side of Vieques, 3 RV, 3 LV, and fragments; USGS 17953, upper member of Camuy Formation, northern Puerto Rico, 3 RV, 9 LV.

Remarks.—Hertlein (1936: 6) was the first to discover that *Pecten* (*Pecten*) *barretti* Woodring, 1925, is a primary junior homonym of *Pecten barretti* Seeley, 1861, a species from the Cretaceous Upper Greensand of England. Hertlein, however, did not rename Woodring's species because he regarded it as a junior synonym of *Pecten* (*Pecten*) *ventonensis* Cooke, 1919, described from the La Cruz Formation in the Santiago area of southern Cuba, a synonymy that Woodring (1928: 61) had suspected. Unfortunately both of these species are known from rather meager material, but because of morphological differences described in the comparisons that follow, it is advisable to keep these taxa separate. The junior homonym therefore requires a new name, introduced herein as *Euvola jamaicensis* n. n.

The new description of *Euvola jamaicensis* n. n. is based on specimens from both the Bowden and August Town Formations of Jamaica at the localities listed above. The left-valve paratype figured by Woodring (1925: pl. 7, fig. 7) is unusual in comparison to the other left valves in having 5 strong radial auricular costae bordered ventrally by a barely visible costa, these distributed across the dorsal two-thirds of the surface of both auricles. The auricular costae on the other left valves are weaker, fewer in number, and more concentrated in the dorsal region of the auricular surface (Pl. 14, Fig. 2, UCMP 556140). All of these left valves resemble one another in being rather thick-shelled and only slightly concave and in having similar patterns of smaller ribs clustered on the disk shoulders.

A second right valve and a partial left valve from Jamaica, not mentioned by Woodring (1925) but labeled by him as being from the "August Town series," are from "vertical beds near 8 mile, Windward Road, 10 March 1944," collector unknown. They are part of a lot consisting of large *Hyotissa haitensis* (G. B. Sowerby I, 1850) and *Spondylus bostrychites* Guppy, 1867, a small lophinine oyster, molds of a *Conus*, and an unidentified heterodont bivalve. The right valve of *Euvola* in this lot (Pl. 14, Fig. 1) is important, because it expands the morphological concept of *E. jamaicensis* n. n. It is larger than the holotype (47 mm Ht, compared to 30 mm), but like the holotype, its posterior auricle bears strong radial costae separated by a deep groove from the posterior disk flank. It has one more disk rib than the holotype but the same pattern of a single smaller lateralmost rib on each side and the same rib profile with slightly undercut rib flanks and commarginal lamellae ending abruptly at the overhang before reaching the rib crest. The left-valve fragment from the August Town locality is comparable to the left valves of *E. jamaicensis* n. n. from the Bowden shell bed. The right valve from the Mao Formation on the Río Cana (NMB 16885) in the Dominican Republic (Pl. 13, Figs 11-13) matches the holotype in valve outline, rib count, rib pattern, and number and pattern of auricular costae, but is more convex.

Comparisons.—Euvola jamaicensis n. n. closely resembles *E. caribea* (Weisbord, 1964) from the late Pliocene Mare Formation and Pleistocene Cumaná Formation of Venezuela (see Gibson-Smith, 1976: 4, regarding the age of the Mare Formation). The Venezuelan species, however, is much larger (reaching at least 85 mm Ht), has stronger auricular costae, particularly on the right anterior auricle, has higher shoulders and steeper disk flanks on its left valve, and has a much more extensive foliated-calcite re-entry on its right valve, reaching below the level of the ventral margin of the adductor scar. Weisbord (1964) had only right valves of *Pecten* (*Pecten*) *caribeus* and only left valves of a second species that he next described as *Pecten* (*Pecten*) *maiquetiensis*. Articulated specimens that I collected in the Cabo Blanco area of Venezuela prove that the latter is a junior synonym of the former.

Euvola jamaicensis n. n. differs from *E. ventonensis* in having a thicker shell, relatively more convex right valve, relatively broader right disk ribs, and more auricular costae, particularly on the right posterior auricle. Compared to extant *E. raveneli* (Dall, 1898), *E. jamaicensis* n. n. has rib interspaces on the right valve that are narrower relative to width of ribs and that have much more prominent commarginal lamellae. Furthermore, *E. raveneli* has two or three strong dorsal costae on its left auricles, whereas in *E. jamaicensis* n. n., these are weaker and more variable in number and position, and the rib crests of *E. raveneli* bear much more prominent medial grooves in late ontogeny.

Evolution.—Euvola jamaicensis n. n. essentially fills a morphological gap between earlier (Miocene) *Euvola* that had weak or absent auricular costae and relatively less convex right valves and later species that developed, beginning in the late

Table 21. Occurrence of *Euvola soror* in the Cibao Valley. Abbreviations: Aa, *Argopecten ameleus*; Aec, *Argopecten eccentricus caimiticus*; Aee, *A. eccentricus eccentricus*; Ael, *A. eccentricus lacabrensis* n. ssp.; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; Anc, *Antillipecten cercadicus*; Anj, *A. janicoensis* n. sp.; Anq, *A. quemadosensis* n. sp.; Ans, *Antillipecten* sp.; Apa, *Argopecten parathetidis* n. sp.; At, *A. thetidis*; B1, Bluff 1 of Maury (1917b); B2, Bluff 2 of Maury (1917b), B2/B1, between Bluffs 2 and 1; Cg, *Cyclopecten guppyi*; Cz, *C. zalaya* n. sp.; DV, matching valves; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lb, *Lindapecten baitoaensis* n. sp.; Lpa, *L. paramuscosus* n. sp.; Lpl, *L. plurinominis plurinominis*; Lsp, *L.* sp. undetermined; Lt, *Leptopecten thompsoni*; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Nn, *N. nodosus*; Pvm, *Parvamussium marmoratum*; Sv, *Spathochlamys vaginula*; --, not recorded. Lettered stratigraphic intervals are explained in the text. See caption for Table 7 regarding the stratigraphic positions of the Cercado/Gurabo boundary and locality USGS 8534 on the Río Cana.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana								
NMB 16815	352.5	Gurabo	1	0	0	31	none	
NMB 16817	347	Gurabo	0	1	0	28.9	Aec, Anc, Cg, Lpl	
NMB 16818	347	Gurabo	2	0	0	39	Aec, Anq, Lpl	
TU 1354	336-346	Gurabo	2	3	0	37	Aec, Anq, Lpl, Nn	
----------								Miocene/Pliocene boundary at least as low as 315 m (Saunders *et al.*, 1986: 23)
NMB 16828	309	Gurabo	0	2	0	29	Aec, Lpl	
NMB 16831	287	Gurabo	0	1	0	34	Aec, Lpl	
NMB 16835	252	Gurabo	2	12	0	40.8	Aec, Amp?, Ans, Lpl	
NMB 16836	243	Gurabo	0	1	0	32	Aec, Lpl	
NMB 16838	233	Gurabo	0	6	0	41.5	Aec, Amp, Lpl	
NMB 16842	228	Gurabo	0	1	0	25	Aec	
----------								Possible unconformity
TU 1230	*ca.* 200	Cercado	1	1	0	43.5	Ael, Amp, Cg	
Río Gurabo								
TU 1279	387-389	Gurabo	0	1	0	22	At, Gu, Lpa, Sv	
TU 1278	387-389	Gurabo	0	2	0	46.4	Anq, At, Gu, Lpa, Ncv	
TU 1231	float	Gurabo?	0	0	1	42	Anq, At, Lpa, Ncv	
NMB 15872	211	Gurabo	0	1	0	43.8	Amp, At	
----------								Cercado/Gurabo Fm boundary of E. Vokes (1989: 18)
NMB 15878	193	Cercado	0	1	0	34.5	Ael, Amp, Lpl	
TU 1297	183-211	Cercado	1	1	0	46	Ael, Amp, At, Lpl	Gurabo Fm of Saunders *et al.* (1986)), Cercado Fm of E. Vokes (1989)
Río Mao								
TU 1225	downstream from B1	Gurabo	3	1	0	37	Ai, Amp, At, Lpa, Nn	Unusual *E. soror*; see discussion
NMB 16803	B2/B1	Cercado	1	0	0	48.0	Aee, Anc, At, Lpl	
TU 1410	B2/B1	Cercado	0	1	0	42.5	Aee, Amp, At, Cg	
USGS 8521	B2/B1	Cercado	0	1	0	32.0	Aee, Amp, At, Lpl	
USGS 8526	upper B2	Cercado	1	1	0	33.7	Aee, Amp, Lpl, Lt	

Table 21 (continued).

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Amina								
USGS 8518	level c	Gurabo?	0	1	0	38	Aee, Amp, Lpl	
NMB 16806	level b	Gurabo?	0	1	0	37	Amp	
Río Yaque del Norte								
TU 1206	--	Gurabo?	1	14	0	36.1	Amp, Apa, At, Sv	
NMB 17273	--	Cercado	0	1	0	34	none	
TU 1363	--	Baitoa	1	2	0	41.2	none	
NMB 17289	--	Baitoa	0	1	0	18.3	Lb	
Río Verde								
TU 1250	--	Gurabo	2	2	0	30.2	Aec, Amp, At, Cg, Cz, Gu, Lpa, Pvm	
Santiago area								
TU 1205	--	Gurabo	0	2	0	24	Aec, Amp, Apa, At, Sv	
TU 1339	--	Gurabo?	0	4	0	35.5	Aec, At, Lpl	
TU 1405	--	Gurabo	0	1	0	16.2	Aec, At	Gravity flows (E. Vokes, 1989: 21)
TU 1406	--	?	0	9	0	38.7	Aec, Amp, Anj, Anq, Lpa, Lpl, Lt, Nn	Mixed Cercado and Gurabo formations?
TU 1439	--	?	0	1	0	34.5	Aee, At	
USGS 8702	--	Gurabo	0	1	0	33	At, Lsp	
USGS 8726	--	Gurabo	0	1	0	20	Aec, Anq, At, Sv	
Road cuts								
TU 1222	--	?	5	8	0	34.8	Aec, Amp, Anq, Apa, At, Lpl	
TU 1407	--	Cercado?	0	0	1	33.2	Ael, Amp	
TU 1435	--	Gurabo?	0	2	0	38.0	Aa, Amp, At, Lpl, Sv	
USGS 8535	--	Gurabo	0	2	0	37.0	Amp, At, Lpl	

Pliocene, greater differential convexity of valves and stronger left dorsal auricular costae.

Occurrence.—In the northern Dominican Republic, *Euvola jamaicensis* n. n. is the stratigraphically highest occurring pectinid in the combined collections made by the NMB team and the Vokeses. It is known only from the upper Mao Formation.

Distribution.—Outside the Dominican Republic, *Euvola jamaicensis* n. n. is known from the Bowden and August Town formations of Jamaica, the upper member of the Camuy Formation of Puerto Rico, an unnamed formation on Vieques Island, and an unnamed formation in Guadeloupe. All of these occurrences are Pliocene and probably not older than middle Pliocene.

Euvola soror (Gabb, 1873)
Pl. 14, Figs 3-13; Table 21

Janira soror Gabb, 1873: 257.
Pecten (*Pecten*) *soror* Gabb. Dall, 1898: 712.
Pecten soror Gabb. Pilsbry, 1922: 410, pl. 44, figs 1-2.

Original description.—"Shell sub-orbicular, nearly equilateral, very inequivalve; ears nearly equal; right valve very con-

vex, left valve concave; surface marked by *ca.* 22 square radiating ribs, crossed by fine squamose lines of growth. Length 1.9 inch" (Gabb, 1873: 257).

Description.—Thin shell of medium size, not known to exceed *ca.* 50 mm Ht, commonly in the range of 20-30 mm, acline, equilateral, with Ht and L approximately equal in smaller specimens but L exceeding Ht in large specimens; RV cvx moderately high, *ca.* 20-28% Ht; LV slightly concave in dorsoventral plane, more concave in anterior-posterior plane, with raised shoulders curving onto disk flanks; disk gapes absent. Disks with 18-24 radial ribs, most commonly 21 or 22, low to moderate in amplitude, changing from narrowly rounded in early ontogeny to more broadly rounded in later ontogeny with steeply sloping but not vertical sides and flattened crests; ribs approximately equal in width to interspaces on RV, narrower than interspaces on LV; lateralmost 1 or 2 ribs of RV narrower and lower than more central ribs; 2-5 ribs on shoulders of LV clustered and finer than central ribs. Projecting commarginal lamellae present in interspaces of RV, extending up rib flanks and crossing rib crests in early ontogeny but commonly worn on crests later, trend of lamellae straight across interspaces but slightly convex toward margin across rib crests; commarginal lamellae of LV more prominent, passing straight across interspaces and ribs, commonly curved backward and merging with preceding lamellae in some areas of disk. Disk flanks of both valves curved in cross section, those of LV lower and more tightly curved inward than on RV, both bearing fine growth lines but lacking radial costellae. Prismatic stage of RV ending at *ca.* 3 mm Ht. Auricles nearly equal in length; total hl *ca.* 40-50% L; right anterior auricle with byssal notch becoming obsolete in early ontogeny, anterior margin truncate with overall trend nearly perpendicular to dorsal margin, surface with 2-4 weak radial costae in central sector, ventral sector adjacent to disk swollen; right posterior auricular margin and both left auricular margins nearly straight, meeting dorsal margins at right angles; surface of right posterior auricle with 2 or 3 low radial costae or none; left auricles commonly with 1 or 2 weak radial costae in dorsal sector of anterior auricle and 2 or 3 in dorsal sector of posterior auricle, rarely without costae, bearing only fine commarginal growth lines. Hinge dentition of RV dominated by single dorsal tooth immediately below outer-ligament groove on each side of resilifer, resilial teeth weakly developed or absent, intermediate teeth absent, appositional area of hinge plate crossed by fine vertical microcrenulations. Interior surface with foliated-calcite re-entry on RV extending only to approximately mid-adductor-scar level, that of LV nearly complete, reaching pallial line and extending posteriorly along ventral margin of adductor scar. Edges of ribs on shell interior carinate near valve margins; ribs extending inward from margin only to pallial line in thicker shelled specimens, much further in thin-shelled variants.

Type material.—Lectotype, ANSP 2862, 1 LV, 47 mm Ht, designated by Pilsbry (1922: 410, pl. 44, figs 1-2).

Type locality.—Dominican Republic. No further details of the locality can be discerned from Gabb's (1873) original description.

Other material.—115 specimens from 40 localities in the northern Dominican Republic (Table 21). Most of these are left valves, there being only 22 right valves and two articulated specimens.

Remarks.—Many of the characters of *Euvola soror* are highly variable. The wide range of rib counts is because the weaker, lateralmost ribs have been included in the counts. These marginal ribs, particularly those on the shoulders of the left valve, are variable in number and subject to wear, meaning that determinations of their numbers could in some cases be subjective. Many left valves of *E. soror* have discontinuous patches of thin, porous, projecting commarginal lamellae that bend over toward the shell margin and merge with adjacent lamellae to form a sort of "pseudosurface." This phenomenon occurs in many genera of Pectinidae, *e.g.*, *Argopecten*, *Cryptopecten*, *Leopecten*, and *Pecten*, where its presence is variable among and within species. The minute pores in these frills result from incomplete calcification within a narrow fold of periostracum, as demonstrated by the presence of periostracum on each side of a frill, including each end of a pore (Clark, 1974).

Another kind of variation that can have some biostratigraphic utility occurs among specimens from four localities, all in the upper Gurabo Formation: NMB 16818 and TU 1354 on the Río Cana, TU 1278 on the Río Gurabo, and TU 1339 in the Santiago area. On some but not all specimens from these localities, secondary radial costellae develop on rib crests of both valves beginning at heights ranging from 20-25 mm (Pl. 14, Figs 10-13). Six or seven costellae per rib develop in the central sector, fewer on the narrower anterior and posterior ribs. The commarginal lamellae that cross the ribs are distally looped over the costellae.

Specimens of *Euvola soror* from TU 1206 from the upper Gurabo Formation of the Río Yaque del Norte display yet another variation. These specimens have thinner shells and lower ribs than others, and because of the shell thinnesss, the interior ribs extend further than usual inward from the margin. All 14 left valves from this locality have beaks that are hyaline, with commarginal lamellae beginning suddenly at a valve height varying from 4.5-7.5 mm. The surface of the hyaline phase is well enough preserved on some of the specimens to show that

there is no antimarginal or pitted microsculpture, only faint growth lines and the very low undulations marking the beginnings of radial ribbing. Once the commarginal lamellae begin to form, they merge to form a pseudosurface, the radial ribs remaining lower than is normally the case for this species.

Comparisons.—Euvola soror resembles *E. ventonensis*, originally described from the vicinity of Santiago in southern Cuba and probably from the La Cruz Formation of latest Miocene or Pliocene age. The latter species differs from *E. soror* in having more prominent and numerous auricular costae, particularly on the auricles of the right valve, and in having more strongly developed carinate edges on internal ribs. In addition, the ribs of the right valve of *E. ventonensis are* more squared, with growth lines on rib crests looping further toward the margin, and these ribs develop low transverse bulges, giving them a somewhat beaded appearance.

Compared to *Euvola barretti* (Woodring, 1925) (= *E. jamaicensis* n. n., herein), originally described from the Bowden Beds of Jamaica, *E. soror* has a right valve that is less convex relative to valve height, with ribs narrower relative to interspaces and weaker auricular costae. The left valve of *E. soror* has fewer riblets on the shoulders of its disk and more gently rounded ribs than in *E. barretti*.

Euvola gurabensis n. sp., described above, has the same shape, size, and number of ribs as *E. soror* but differs in that it is even thinner shelled, and the rib crests of its right valve are subdivided by shallow grooves, causing the ribs to appear bifid or trifid. Other species of *Euvola* that have simple ribs, such as *E. colpotus* (Woodring, 1982) from the Gatun Formation of Panama and *E. caribea* from the Cabo Blanco Group of Venezuela, differ in having much more convex right valves with stronger ribs and more prominent auricular costae.

Euvola urumaconis (Harris in Hodson *et al.*, 1927) and *E. codercola* (Harris in Hodson *et al.*, 1927), both originally described as subspecies of *E. soror* from the late Miocene of Venezuela, were elevated by Woodring (1982) to species rank. They differ from *E. soror* in reaching a much larger size (up to 70 mm height) and in having a more deeply convex right valve that is more flaring, causing length to exceed width through most of ontogeny. Both have more prominent auricular costae, particularly the dorsal costae of the left auricles. In *E. codercola*, the commarginal lamellae of the right valve remain prominent across the rib crests, and the species is unusual in developing radial costae in late ontogeny on the disk flanks of its right valve.

Evolution.—The strong resemblance between *Euvola soror* and *E. gurabensis* n. sp. and their stratigraphic relationship with the latter species succeeding the former suggest an ancestor-descendant relationship between these species in the Dominican Republic. (See above for discussion of evolution of the latter species.) The weak auricular costae of *E. soror*, as well as its simple rib pattern without medial grooves or medial ribs, is typical of the earliest species of *Euvola*. Strong right and dorsal left auricular costae occur in later species, beginning in the latest Miocene and Pliocene.

Occurrence.—In the Dominican Republic, *Euvola soror* occurs in the Baitoa, Cercado, and Gurabo formations (Table 21) in beds ranging in age from the late Early or early Middle Miocene to Early Pliocene.

Distribution.—Euvola soror has not been observed outside of the Dominican Republic.

Genus ***LEOPECTEN*** Masuda, 1971a

Leopecten Masuda, 1971a: 170.

Type species.—Pecten (*Patinopecten*) *bakeri* Hanna & Hertlein, 1927, by original designation, San Marcos Formation, Pliocene, Baja California Sur, Mexico. These rocks are now referred to the Carmen-Marquer Formation, undifferentiated (Carreño & Smith, 2007).

Diagnosis.—"Pectininae with right valve of low to moderate convexity; left valve much less convex and of changing curvature through ontogeny, flattened or concave early state followed by flat to convex final stage resulting in overall curvature from slightly concave to convex; hinge dentition simple, consisting of weak dorsal teeth and even weaker resilial teeth, intermediate teeth vestigial or absent, apposition zone of hinge ("provinculum" of Masuda, 1971a) with very fine striae perpendicular to hinge line. Disk with weak to moderately strong simple plicae ranging in cross section from triangular with carinate crest to rectangular with flattened crest. Commarginal lamellae present across disk in early ontogeny, commonly restricted to interspaces in late ontogeny. Radial costellae sometimes present on plicae and in interspaces. Right anterior auricle with few radial costae early in ontogeny, then noncostate. Right posterior auricle commonly without costae. Left auricles generally with only one or two very weak costae in dorsal half, less commonly three widely spaced costae, or with multiple costae beginning late in ontogeny after initial stage with only one or two costae. Fine columnar prismatic calcite present in early ontogeny of right valve terminating at valve height from 5.5 to 10 mm. Inner surfaces of plicae with carinate margins distally. Inner ostracum foliated, including all of nonmyostracal area inside pallial line" (Waller, 2007: 945).

Remarks.—Leopecten comprises the so-called "flat pectens" of the American Neogene that were referred to *Flabellipecten* Sacco, 1897, by Woodring (1982: 581) and others. See Waller (2007: 934-948) for a detailed review of the genus, including its separation from *Euvola*.

Geographic range.—Presently limited to the eastern Pacific, with 5 species ranging from middle California (38° N) to Peru (3° 38' S) and the Galápagos Islands at depths from *ca.* 18-230 m (Waller, 2007: 935); present in the western Atlantic during the Miocene and Pliocene from Florida, Central America, and Argentina

Stratigraphic range.—Middle Miocene to Recent.

Leopecten gatunensis (Toula, 1909)
Pl. 14, Fig. 14

Pecten (*Flabellipecten*) *gatunensis* Toula, 1909: 711, pl. 26, fig. 2 (Miocene, Panama); Woodring & Malavassi, 1961: 494, pl. 70, figs 2, 4-5 (Miocene, Costa Rica).

Pecten (*Amusium*?) *correctus* Pilsbry & Johnson, 1917: 194; Pilsbry, 1922: 413, pl. 45, fig. 13.

Pecten gatunensis Toula. Hodson *et al.*, 1927: 24, (Miocene, Venezuela).

Pecten (*Pecten*) sp. Durham, 1950: 60, pl. 7, fig. 2 (late Miocene or Pliocene, Venezuela).

Flabellipecten gatunensis gatunensis (Toula). Woodring, 1982: 584, pl. 104, figs 1-2, 10; pl. 107, figs 3, 6, pl. 110, fig. 13, pl. 113, fig. 18. See for more detailed synonymy.

Leopecten gatunensis (Toula). Waller, 2007: 936.

Original description.—"Zwei grössere Individuen, das eine wohl erhalten mit fast gleichohriger, leicht aufgewölbter Klappe, trägt 25 breite, oben flache Radialrippen und feine, aber scharf ausgeprägte Anwachslinien. Die ersteren sind durch etwas shmälere vertiefte Zwischenräume geschieden. Die von Köhler und Kobelt als *Pecten novae Zelandiae* Reeve (verbessert = *laticostatus* Gray) bezeichnete Art hat in der Art der Rippung grosse Ähnlichkeit, doch sind nur 19 Rippen vorhanden" (Toula, 1909: 711).

Description.—Medium to large size, reaching at least 100 mm Ht, acline, equilateral, with L exceeding Ht; RV cvx low, generally < 20% Ht, LV nearly flat (slightly convex in dorso-ventral direction, slightly concave in anterior-posterior direction) with raised shoulders adjacent to broad anterior and posterior disk gapes. Disks with 21-24 radial ribs, commonly low in amplitude, broader than interspaces and with flattened crests on RV, narrower than interspaces and rounded on LV, on both valves becoming narrower and tending to become obsolete near disk flanks; internal edges of ribs carinate near margin of disk. Commarginal lamellae on both valves thin but sharp, mainly present in interspaces but extending straight across rib crests in late ontogeny. Disk flanks of both valves very narrow, inturned on RV, steep on LV, without secondary costae. Auricles small relative to size of disk, anterior slightly longer than posterior; length of hinge *ca.* ⅓ L. Anterior margin of right anterior auricle sharply rounded in center, then passing with obtuse angle toward dorsal margin, recurving slightly adjacent to dorsal margin; byssal notch shallow, with ctenolium becoming obsolete in mid-ontogeny or earlier; other auricles with convex free margins forming obtuse angle with dorsal margin; all auricles commonly lacking radial sculpture, rarely 1 or 2 very fine radial costellae present on left auricles in early ontogeny. Hinge consisting of narrow dorsal and resilial teeth, intermediate teeth absent or barely discernible. Striate part of adductor scar large. Foliated-calcite re-entry on RV extending to bottom of striate adductor scar, extent on LV not determined.

Type material.—Institut für Paläontologie, Universität Wien, Austria (fide Woodring, 1982: 584). I have not been able to determine the status of the types of *Pecten gatunensis,* and the concept of the species rests on the illustration by Toula (1909: pl. 26, fig. 2).

Type locality.—"Presumably Gatun Locks excavation, Canal Zone, middle part of Gatun formation" (Woodring, 1982: 584).

Other material.—Approximately 25 specimens and fragments from Panama, Costa Rica, Venezuela, Colombia, Ecuador, and Puerto Rico in the Type and Stratigraphic Collections of the Smithsonian Institution, and 5 specimens from the Dominican Republic (localities NMB 17272 and NMB 17274, discussed below).

Remarks.—Woodring (1982) interpreted "*Flabellipecten*" *gatunensis* broadly, subdividing the species into four subspecies with a collective stratigraphic range from late Oligocene to Pliocene in the tropical American region, particularly in Panama. Three of these subspecies – *F. g. protistus* Woodring, 1982; *F. gatunensis s. s.*, and *F. g. macdonaldi* (Olsson, 1922) – were regarded as parts of a single lineage in a stratigraphic succession, whereas the fourth, *F. g. tapeinus* Woodring, 1982, was regarded as an offshoot from the main lineage. Waller (2007) presented evidence mainly from a study of hinge dentition that three of these so-called subspecies belong in *Leopecten*, not *Flabellipecten*, and reexamined phylogenetic relationships. He placed Woodring's oldest subspecies, *F. gatunensis protistus*, into the genus *Amussiopecten* (in the combina-

tion *A. protistus*) on the basis of the presence of intermediate hinge teeth as well as the fading out of radial ribs toward the ventral margin. He also determined that *F. g. tapeinus* is a junior synonym of *F. g. macdonaldi*, which was raised to species rank (as *L. macdonaldi*).

Leopecten gatunensis, as now understood, is a species that in Panama ranges from the Lower Member of the Alhajuela Formation to the middle Gatun Formation (Woodring's stratigraphic range for his *Flabellipecten gatunensis s. s.*). The middle to upper Gatun Formation has recently been dated as early Late Miocene (zone NN10 and zone N16 (= M13a), equivalent to the middle Tortonian stage of Europe) on the basis of calcareous nannoplankton and planktic foraminiferans (Collins *et al.*, 1996: 687). The Alhajuela Formation has not been precisely dated but the overlying lower Gatun Formation as been dated as zone N14 (= M11), or early Tortonian (Collins *et al.*, 1996: 676), leading to the presumption that the Alhajuela is probably late Middle Miocene in age.

Leopecten gatunensis in Panama is variable in rib amplitude (as documented by Woodring, 1982: 584) and the degree to which ribs on the disk approach the disk flanks or give way to nonribbed shoulders adjacent to the flanks. The most extreme variation occurs among the geologically oldest members of the species that occur in the lower member of the Alhajuela Formation (Woodring, 1982: pl. 110, fig. 13). Compared to more typical *L. gatunensis*, the right valve that Woodring illustrated as well as four additional right valves collected at the same locality (USGS 5906a) have narrower ribs, some of which develop 1 or 2 grooves on their crests in late ontogeny. Furthermore, the ribs continue right up to the disk flanks, there being no nonribbed shoulders as in more typical *L. gatunensis*. Close inspection with a microscope, however, revealed that the grooved rib crests are the result of repaired injuries caused by boring epifauna.

The five specimens of *Leopecten gatunensis* collected in the Dominican Republic are from two localities, NMB 17272 and NMB 17274, both on the Río Yaque del Norte. Both of these localities are in the "Arroyo López section" of Saunders *et al.* (1986: text-fig. 26), with an age indicated in their table 3 as late Miocene (lower NN11) and correlating with the lower Cercado Formation in the Río Gurabo section. Using the Neogene Time Scale of Gradstein *et al.* (2004: fig. 21.1), lower zone NN11 is late Tortonian in age and therefore somewhat younger than the youngest *L. gatunensis* in Panama. In Panama, according to Woodring (1982), *L. gatunensis s. s.* is absent in the upper part of the Gatun Formation and is replaced in the overlying Chagres Sandstone by the taxa that he called *Flabellipecten gatunensis macdonaldi* and *F. g. tapeinus* (regarded as synonyms and combined under *L. macdonaldi* by Waller, 2007: 937).

Comparisons.—*Leopecten gatunensis* resembles *Amussiopecten protistus* in having a left valve that is slightly convex to flat in a dorsoventral direction, noncostate auricles that have free margins forming obtuse angles with the dorsal margin, and low rounded ribs. In *A. protistus*, however, the ribs decline in amplitude and nearly or actually disappear during ontogeny, whereas they persist in *L. gatunensis*. Furthermore, the hinge dentition differs, that of *A. protistus* having single or even multiple intermediate teeth that are lacking in *L. gatunensis*.

Leopecten gatunensis differs from *L. macdonaldi* in the trend of the free margins of the posterior auricles, which are less obtuse relative to the dorsal margin in the latter. The left auricles of *L. gatunensis* lack radial costae, but these are invariably present in *L. macdonaldi*. The latter species also has lower ribs on the disk and a more flaring shape.

Leopecten gatunensis differs in the same way from *L. boesei* (Hanna & Hertlein, 1927), a late Miocene to early Pliocene species from the Gulf of California that resembles *L. macdonaldi* in having a nearly identical configuration of left auricular costae.

Evolution.—Both Woodring (1982) and Waller (2007) thought that *Leopecten gatunensis* evolved from *Amussiopecten protistus*. This would, however, mean that there would be an evolutionary reversal in the strength of ribs, with the distally fading ribs in the ontogeny of *Amussiopecten* becoming stronger and more ontogenetically persistent in *Leopecten*. Another possibility, however, is suggested by the variant of *L. gatunensis* in the lower member of the Alhajuela Formation described above. Its strong, narrow ribs, ribbed disk shoulders, and lack of intermediate hinge teeth suggest a relationship to *Euvola*. *Euvola* and *Leopecten* first appeared in the tropical American fossil record in the late Early or early Middle Miocene (Waller, 2007), suggesting that they could be part of one evolutionary radiation. Because both *Euvola* and *Leopecten* are extant, this might be a hypothesis that can be tested by molecular genetics, perhaps using *Amusium* as an outgroup.

Occurrence.—Lower Cercado Formation on the Río Yaque del Norte at NMB 17272 (fragments of 1 RV and 1 LV) and NMB 17274 (1 DV fragment, 1 partial RV, 1 partial LV).

Distribution.—Outside of the Dominican Republic, *Leopecten gatunensis* is thus far known from the following localities (based on USNM collections): Panama: Alhajuela and Gatun formations [see Woodring (1982) for records]. Costa Rica: unnamed Miocene formation, USGS 20001 and 21235, both in the Turrúcares district, Meseta Central, Ecuador: USGS 23490, formation not specified, Sua; USGS 23487, Angostura Formation?, Cueva Angostura. Colombia: USGS 11515, Piojó Formation, near Puerto Caiman,

Atlántico. Venezuela: formation not specified, "late Miocene or Pliocene," Puerto Cumarebo (Durham, 1950: 60); USGS 6300, formation not specified, 2.5 km south of Coro, Miranda, Falcón; USGS 6303, formation not specified, 5 km south of Coro, Miranda, Falcón; USGS 18308, formation not specified, 6 km NNE of La Vela, Colina, Falcón. Puerto Rico: USGS 21911, lower member of Ponce Formation, Urbano Magueyes, Peñueles quadrangle.

Genus ***ZAMORAPECTEN*** n. gen.

Type species.—Pecten (*Amusium*) *zamorensis* F. & H. Hodson in Hodson *et al.*, 1927, Punta Gavilán Formation, eastern end of point at Sabanas Altas, District of Zamora, State of Falcón, Venezuela. Lower Pliocene (Hodson *et al.*, 1927: 38, pl. 22, figs 1, 3-6; Pl. 15, Figs 1-6).

Diagnosis.—Small to medium-sized *Amussiopecten*-like Pectinidae, nearly equivalved, with small auricles; radial plicae on umbones beginning as fine costae of approximately same strength as commarginals, later becoming high and round, with prominent commarginals in interspaces, before gradually disappearing by *ca.* 6 mm Ht, followed by smooth exterior; coarse antimaginal ridges present on early disk flanks and bases of auricles; dorsally facing edges of auricles of both valves flattened or concave; right anterior disk flank inturned, concave in cross section, meeting disk surface along sharp edge; inner shell surface with sharp radial carinae as in *Amusium;*

Etymology.—The prefix *Zamora-* refers to the District of Zamora, State of Falcón,Venezuela, where the type species occurs.

Remarks.—The importance of *Amussiopecten* as a circumglobal tropical pectinid in the Late Oligocene to Pliocene was emphasized by Masuda (1971b) in his review of species present in North and South America. More recent studies have recognized that what was formerly called *Amussiopecten* is in fact a polyphyletic assemblage of lineages that have evolved an amusioid form by becoming more streamlined, abandoning their ribbed exterior except on the umbones, and becoming externally smooth while retaining the internal carinate edges of the radial ribs. Concomitantly, the auricles become shortened and develop more obtuse angles between their dorsal and terminal margins; the byssal notch and ctenolium become obsolete in early ontogeny; and the hinge dentition tends to become simplified, with intermediate teeth becoming weak or disappearing. A spectacular example of convergence on *Amusium* is provided by "*Amusium*" *cristatum* (Bronn, 1828) of the Mediterranean Pliocene, which looks very much like extant western Indo-Pacific species of true *Amusium* except for the presence in the fossil species of large, projecting spines along the dorsal margins of its right auricles and remnants of coarse antimarginal microsculpture along the dorsal edges of its disk and disk flanks. The detailed morphology of some members of the group represented by this convergent "*Amusium*" were first brought to light by Freneix *et al.* (1982), with later contributions by Bongrain *et al.* (1994), Baldí *et al.* (1999), Mandic (2004), and Bongrain & Cahuzac (2004). The basal members of this group from the Early and Middle Miocene (Aquitanian and Langhian) of France that have scaly secondary radial costae in addition to spines on the right dorsal auricular margins were formally named *Amussiopecten* (*Costellamussiopecten*) by Bongrain *et al.* (1994). This group was later expanded by Bongrain & Cahuzac (2004) to include species that have lost the secondary disk costae but retain the dorsal auricular spines, including "*Amusium*" *cristatum*. Bongrain & Cahuzac (2004) elevated this enlarged group to genus rank and named it *Cristatopecten*. Unfortunately, this name was stillborn in the sense that it was immediately a junior synonym of *Costellamussiopecten*, the type species of which was included in the new genus by these authors.

Bongrain & Cahuzac (2004) regarded *Amussiopecten* as a junior synonym of *Flabellipecten*, thus reverting to the old position of Depéret & Roman (1910). This matter has long been contentious, with some authors maintaining that *Amussiopecten*, as represented by its type species, *Pecten burdigalensis* Lamarck, 1806, from the Lower Miocene (Aquitanian and Burdigalian) of Europe, intergrades with *Flabellipecten*, represented by its type species *Ostrea flabelliformis* Brocchi, 1814, from the Late Pliocene of Italy, whereas others (*e.g.*, Cox, 1927; Masuda, 1971b; Waller, 1991: 38, 2006a: 25; Harzhauser *et al.*, 2007: 149) have regarded these genera as distinct. In the present study, I continue to regard *Amussiopecten* as a valid genus applicable to a group of Oligocene to Pliocene pectinids with a circumtropical distribution as described by Masuda (1971b). This distribution was achieved before the end of the Early Miocene. With the closure of the eastern gateways of the proto-Mediterranean in the Burdigalian (Harzhauser *et al.*, 2007), the Mediterranean representatives of *Amussiopecten* became isolated and failed to diversify, except to achieve large sizes and thick shells, such as in *A. burdigalensis* and *A. expansus* (G. B. Sowerby I, 1847), while tropical western Indo-Pacific and American *Amussiopecten* underwent extensive speciation.

As matters now stand, the name *Amussiopecten* applies to those members of the former *Amussiopecten s. l.* that lack scaly costae on disk or auricles and have right dorsal margins that are rounded and not spiny. The name *Costellamussiopecten* applies to "*Amussiopecten*" bearing prominent spines on the right dorsal auricular margins, the more primitive members of the group having scaly secondary costae and prominent antimar-

ginal microsculpture in early ontogeny. Finally, *Zamorapecten* n. gen. applies to forms having dorsal auricular margins that in cross section are concave, with prominent commarginals present in the interspaces of early umbonal ribs. The early ontogeny of *Zamorapecten* n. gen. suggests that it, like its European counterpart *Costellamussiopecten*, probably originated from within the Oligocene group of *Aequipecten*-like species, but the two genera likely had different ancestors that were geographically widely separated, one in the western Tethys, the other in the tropical waters of the Americas.

Geographic and stratigraphic ranges.—Pliocene, northern Venezuela and northern Dominican Republic.

Zamorapecten maoensis n. sp.
Pl. 15, Figs 7-10

Diagnosis.—Small *Zamorapecten* of nearly circular amussioid form known only from LV; umbonal sculpture limited to first 3 mm of growth, consisting of fine radial costellae crossed by commarginal lirae of nearly equal strength and with finer antimarginal microsculpture present in interspaces and on early disk flanks; radial carinae on inner surface evenly spaced.

Description.—Zamorapecten of small size, not known to exceed *ca.* 30 mm Ht, nearly circular in outline with Ht and L approximately equal, and of low cvx; umbo of LV with very fine cancellate sculpture disappearing at *ca.* 3 mm Ht, consisting of 18-20 fine radial costellae crossed by commarginal lirae of approximately equal strength, their rectangular intersections filled by fine antimarginal microsculpture that extends onto disk flanks and proximal parts of auricles; remainder of disk nearly smooth except for very low radial ridges; disk flanks low but steep, bearing antimarginal striae proximally but only commarginal growth lines distally; auricles small relative to size of disk and approximately equal in length, ratio of total hl to L *ca.* 0.43; anterior margin of left anterior auricle nearly straight, forming an angle of slightly > 90° with dorsal margin, lacking byssal sinus distally but bearing shallow byssal sinus in first couple of millimeters of ontogeny; proximal part of left anterior auricle with fine cancellate sculpture continued from umbo, consisting of 7-10 radial costellae crossed by somewhat elevated commarginal lamellae, both radials and commarginals fading away at distance of *ca.* 2 mm from beak; posterior margin of left posterior auricle nearly straight, forming an angle with dorsal margin somewhat greater than 90°, proximal part of auricle with delicate commarginals but no radials, distal part smooth; dorsal margins of both auricles flattened, becoming a dorsally facing concave trough distally. Interior with *ca.* 27-30 nearly equally spaced, strong radial carinae extending nearly to margin of valve; auricular buttress ending in low denticle well developed along base of each auricle; ventral margin of resilifer slightly undercut by umbonal cavity; adductor scar large relative to size of disk, its posterior margin confluent with posterior margin of aragonitic inner shell layer; extent of foliated-calcite re-entry not determined in holotype but extending to approximately level of dorsal margin of adductor scar in smaller specimen. RV unknown.

Etymology.—Named after the Mao Formation, northern Dominican Republic.

Type material.—Holotype (Pl. 15, Figs 7-8), 1 LV, NMB G17529, 30.3 mm Ht, 30.1 mm L.

Type locality.—Locality NMB 16122, Mao Formation, right bank of Río Gurabo *ca.* 0.5 km south of Gurabo Afuero, northern Dominican Republic, 893 m above base of Río Gurabo section. See Saunders *et al.* (1986: text-fig. 4) for precise position of locality on the river and in the stratigraphic section.

Other material.—Paratype (Pl. 15, Figs 9-10), 1 LV, 12.9 mm Ht, from locality NMB 15833, Mao Formation, right bank of Río Gurabo *ca.* 0.5 km due south of the type locality (NMB 16122), northern Dominican Republic, 895 m above base of the Río Gurabo section (Saunders *et al.*, 1986: text-fig. 4).

Remarks.—Only two specimens of *Zamorapecten maoensis* n. sp., both left valves, are present in the collections, both found by the NMB team. Although one specimen is less than half the size of the other, both show nearly identical cancellate sculpture patterns on their umbones (Pl. 15, Figs 8-9). The holotype adheres to a block of matrix, but the anterior part of the disk is broken away to reveal the imprint of internal carinae on the matrix (Pl. 15, Fig. 7).

Comparisons.—The left valve of *Zamorapecten maoensis* n. sp. closely resembles that of *Z. zamorensis* in shape of disk and auricles and the spacing and number of internal carinae. The major difference is in the umbonal sculpture. In *Z. maoensis* n. sp., the pattern is finely cancellate and disappears after the first few millimeters of growth (Pl. 15, Figs 8-9); in *Z. zamorensis,* the pattern is dominated by discrete radial ribs much stronger than the commarginal lamellae between them, and the ribs do not fade out until *ca.* 6-7 mm Ht (Pl. 15, Figs 2, 5-6). Species of *Costellamussiopecten* differ from *Z. maoensis* n. sp. in having projecting spines on their dorsal margins and lacking prominent commarginal lamellae in the interspaces of the umbonal ribs (Bongrain *et al.*, 1994: pl. 2, figs 1c-d).

Species of *Amussiopecten* differ in lacking both commarginal and antimarginal microsculpture between the umbonal ribs (Masuda, 1971b: pl. 26).

Evolution.—The earliest phase of umbonal sculpture on the left valve of *Zamorapecten zamorensis*, in the first couple of millimeters of ontogeny before the radial umbonal ribs begin to strengthen, is a cancellate pattern not unlike that found more extensively in *Z. maoensis* n. sp. The latter is therefore paedomorphic (ancestral juvenile characters appearing in adult descendant; McNamara, 1986) relative to the former and in this sense is more evolutionarily advanced. This is consistent with the stratigraphic occurrences of the two species. The Punta Gavilán Formation, which yielded *Z. zamorensis*, has been dated as Early Pliocene, *Globorotalia margaritae* Zone (Hunter, 1978), whereas the Mao Formation above 700 m above the base of the section on the Río Gurabo has been dated as Middle Pliocene, *Globorotalia miocenica* Zone (Saunders *et al.*, 1986: 19).

Occurrence and distribution.—Known only from the Mao Formation, Middle Pliocene, northern Dominican Republic.

Tribe **DECATOPECTININI** Waller, 1986

Genus ***ANTILLIPECTEN*** n. gen.

Type species.—Pecten antillarum Récluz, 1853, extant in the tropical western Atlantic, type locality Pointe-à-Pitre, Guadeloupe (Récluz, 1853: 153).

Diagnosis.—Small, nearly equivalved or slightly right-convex Decatopectinini with deep byssal notch, low to moderately strong internally carinate radial ribs, common secondary radial costae on ribs and in interspaces, weak to absent radial costae on posterior auricles, and close-set commarginal lamellae on ribs and in interspaces throughout ontogeny; hinge dentition lacking clear resilial and intermediate teeth.

Etymology.—The prefix *Antilli-* refers to the common occurrence of the new genus in the Antillean region; the suffix indicates its placement in the family Pectinidae.

Remarks.—Pecten antillarum of the tropical western Atlantic region has been assigned previously to the genera *Lyropecten* or *Bractechlamys* Iredale, 1939. The species is clearly not a *Lyropecten* in that it lacks the strong three-element dentition of that genus and differs in microsculptural features. Specifically, *P. antillarum* has typical decatopectinine close-set commarginal lamellae (defined by Waller, 1986, as 30-70 lamellae per 2-mm distance along a radius in center of disk at 10 mm height) and a nearly smooth left preradial zone, whereas *Lyropecten* (and the related genus *Nodipecten*) have only far-set commarginal lamellae and a preradial zone that is commonly pitted or with antimarginal striae (Smith, 1991b: fig. 8). *Pecten antillarum* closely resembles the Indo-Pacific decatopectinine genus *Bractechlamys* in shape and ribbing but differs from all known members of that genus in lacking intermediate hinge teeth. This difference in dentition is a persistent feature of *Antillipecten* throughout its long geologic history in the tropical western Atlantic since at least the early Oligocene.

The need for a genus-level name for this group was anticipated by Mansfield (1937: 207), who observed that his new species *Chlamys* (*Aequipecten*) *flintensis* Mansfield, 1937, is in the same group as *Pecten vaun* Cooke, 1921. Without being able to determine the section to which such species belong, Mansfield placed these species in "the section *Aequipecten*" with a query. The new genus *Antillipecten* ties these species to a larger group of tropical American Decatopectinini that possesses close-set commarginal lamellae throughout ontogeny, lacks significant radial costae on disk flanks, lacks intermediate hinge teeth, and lacks significant ledging. Based on the examination of extensive collections at the Smithsonian Institution, at least the following species in addition to the type species are assigned to *Antillipecten*, beginning with the geologically oldest: *Chlamys* (*Aequipecten*?) *flintensis* Mansfield, 1937, Suwannee Limestone (*sensu* Huddlestun, 1993: 70), early Oligocene (Vicksburgian), Florida; *Pecten anguillensis* Guppy, 1867, of Cooke (1919), Antigua Formation, late Oligocene, Antigua; *Pecten willobianus* Cooke, 1919, Antigua Formation, late Oligocene, Antigua; *Pecten guanicus* Maury, 1920, Juana Díaz Formation?, Oligocene?, Puerto Rico; *Pecten* (*Plagioctenium*?) *gardnerae* Cooke, 1919, of Mansfield (1937), not Cooke, Chattahoochee Formation, early Miocene, Florida; *Pecten* (*Chlamys*) *alumensis* Dall, 1898, Chipola Formation, late early Miocene, Florida; *Pecten vaun vaun* Cooke, 1921, Anguilla Formation, late early to early middle Miocene, Anguilla; *Pecten cercadica* Maury, 1917a, Cercado Formation, late Miocene, Dominican Republic; *Pecten gardnerae* Cooke, 1919, La Cruz Formation, Pliocene, Cuba; *Pecten vaun flabellum* Cooke, 1921, La Cruz Formation, Pliocene, Cuba; and *Chlamys* (*Chlamys*) *bellipictus* Woodring, 1925, Bowden shell bed, late Middle Pliocene, Jamaica. *Chlamys reynali* Mongin, 1968, from the Miocene of Guadeloupe is another *Antillipecten* based on the figures in Mongin (1968).

Anatipopecten Hertlein, 1936, is another decatopectinine genus restricted to the Americas. *Pecten anatipes* Morton, 1833, the type species, is confined to the early Oligocene (Vicksburgian; Huddlestun, 1993: 77) of the Gulf of Mexico Coastal Plain. It differs from *Antillipecten* in having a commonly well-developed three-element hinge dentition and

costate disk flanks, as well as enhanced development of commarginal ledging and well-developed radial costae on posterior auricles. *Chlamys* (*Lyropecten*) *incertae* Tucker-Rowland, 1938, from the upper Eocene or lowermost Oligocene of the northern Florida Peninsula, was placed in *Anatipopecten* by Nicol *et al.* (1989), but it differs from the type species in having a weaker hinge dentition and commonly absent secondary radial costae on the disk, with only very faint radial costae or none on its disk flanks. On the basis of these characters, it could equally be regarded as a very early *Antillipecten*.

Antillipecten differs from *Flexopecten*, an extant genus of the Mediterranean and eastern Atlantic, in the early ontogeny of shell microsculpture. *Flexopecten* has a pitted left beak, with pits commonly extending just beyond the start of radials, whereas *Antillipecten* has a smooth early left dissoconch followed by fine antimarginal microsculpture, which in turn abruptly terminates at the start of the close-set commarginal lamellae. Molecular genetic studies indicate that *Flexopecten* is phylogenetically closer to *Aequipecten* than to the Decatopectinini (Waller, 2006a, and references therein).

Geographic and stratigraphic ranges.—Early Oligocene to present, Caribbean and tropical western Atlantic.

Antillipecten antillarum (Récluz, 1853)
Pl. 16, Figs 1-5

Pecten antillarum Récluz, 1853 (May): 153, pl. 5, fig. 1.
Pecten fucatum Reeve, 1853 (June): species 139.
Pecten argenteus Reeve, 1853 (August): Species 168.
Pecten (*Nodipecten*) *antillarum* Récluz. Dall, 1898: 731.
Chlamys (*Chlamys*) *bellipictus* Woodring, 1925: 66, pl. 8, fig. 3.
Pecten (*Lyropecten*) *eulyratus* Bayer, 1943: 110, pl. 14, fig. 28.
Comptopallium antillarum (Récluz). Waller, 1973: 45.
Lyropecten antillarum (Récluz). Abbott, 1954: 366, pl. 34g; 1974: 448, fig. 5203; Warmke & Abbott, 1961: 169, pl. 33f; Abbott & Dance, 1982: 315.
Bractechlamys antillarum (Récluz). Waller, 1986: 40, by implication; Redfern, 2001: 212, pl. 88, fig. 869; Mikkelsen & Bieler, 2007: 144, figured on p. 145.
Decatopecten antillarum (Récluz). Dijkstra, 1994: 46.
Semipallium antillarum (Récluz). Macsotay & Campos Villarroel, 2001: 142, pl. 32, figs 1.

Description.—Shell small to moderate in size, not known to exceed 35 mm Ht, acline, Ht and L approximately equal, umbonal angle 90-99°; equivalved or with RV slightly more convex than LV, biconvexity low, < 30% Ht, hl *ca.* ⅔ L, ratio of anterior to posterior hl *ca.* 1.2-1.4. Disks with 10-13 low to moderately high, simple, rounded, unbranched ribs; ribs originating as low radial undulations in early ontogeny after early smooth zone, becoming moderately high, rounded to slightly medially carinate with low, steep sides in later ontogeny; ribs of even height and spacing in central sector, decreasing in height and width toward disk flanks, secondary radial costae originating by intercalation in mid-ontogeny, initially 1 or 2 in rib interspaces, then increasing in strength and number to 4-6 in interspaces and on rib crests; umbones of both valves smooth and glossy, on RV with initial prismatic stage extending *ca.* 1 mm from beak, on both valves glossy zone having very fine antimarginal microstructure; very close-set commarginal lamellae periodically enlarged beginning at end of glossy zone on each valve, extending straight across interspaces and rib crests but with ventrad curvature over secondary costae; projecting scales absent. Disk flanks low but steep, without radial costellae. Right anterior auricle with rounded anterior margin and deep byssal notch floored by ctenolium consisting of 4-7 small teeth; surface of auricle with 5 or 6 strong, rugose radial costae, left anterior auricle with sigmoidal anterior margin that forms acute angle with dorsal margin, byssal sinus moderately deep, radial costae weaker than on right anterior auricle, especially in early ontogeny; posterior auricular margins sigmoidal, forming acute angle with dorsal margin, costae commonly weaker than on anterior auricles. Hinge dentition consisting of moderately strong dorsal and infradorsal teeth, resilial teeth poorly differentiated, intermediate teeth absent. Striate and nonstriate adductor scars of RV separated anteriorly by shallow groove; byssal retractor attachment scar on LV forming large lobe on posterodorsal side of adductor scar. Foliated-calcite re-entry on inner surfaces of valves commonly limited to umbonal region, in some cases extending to level slightly ventral to dorsal margin of adductor scar. Edges of ribs on inner valve surfaces carinate near shell margins.

Type material and measurements.—Lectotype of *Pecten antillarum* designated by Fischer-Piette (1950: 15), DV, MNHNP, 23.7 mm Ht, 21.6 mm L. Syntypes of *Pecten fucatum*, BMNH uncataloged, 3 DV, specimen in fig. 39a of Reeve (1853), 29.0 mm Ht, 28.0 mm L, West Indies. Syntypes of *Pecten argenteus*, BMNH 1950.11.14.8-9, 2 DV, "China Sea" [erroneous], measurements of the figured specimen, 16.2 mm Ht, 15.0 mm L. Holotype of *Chlamys* (*Chlamys*) *bellipictus*, USNM 352780, RV, 6.2 mm Ht, Bowden beds, Jamaica.

Type locality.—The roads (nautical) of Pointe-à-Pitre, Guadeloupe, Lesser Antilles (Récluz, 1853:154).

Other material.—Northern Dominican Republic: NMB 15834, Mao Formation on Río Gurabo 807-810 m above base of section, fragments of 1 RV (Pl. 16, Figs 4-5). Barbados: BMNH uncataloged, Highgate, from post-coral rock at elevation of 107 m (*ca.* 350 ft), Pleistocene; USNM,

locality USGS 18382, Pine, Coral Rock at elevation of 55 m (*ca.* 180 ft), Pleistocene. Florida: USGS 26547 and 23593, Big B Ranch and Belle Glade, Palm Beach County, Bermont Formation, Pleistocene, 1 RV and 3 LV. Recent specimens in the Smithsonian collections from throughout the range of the species consisting of 102 lots containing *ca.* 350 specimens.

Remarks.—The name *Pecten antillarum* Récluz was published on May 1, 1853 (date verified by Winckworth, 1936: 154), and thus has priority over *P. fucatus* Reeve, 1853 (June) and *P. argenteus* Reeve, 1853 (August). Reeve's stated locality for *P. argenteus*, "China Sea," is erroneous.

Extant members of the species live in shallow tropical waters ranging from Bermuda (Waller, 1973) and the central eastern coast of Florida southward to the Caribbean coast of South America. They live on terrigenous or carbonate sand or rubbly bottoms, commonly near coral reefs in association with coarse reef rubble and encrusting calcareous algae. The depth range of the extant specimens studied is from the intertidal down to *ca.* 70 m, although the species is most commonly found living in water < 20 m deep. Dead shells have a much broader depth range, probably due to transport down steep reef fronts (Waller, 1973, and unpublished data from Smithsonian collections).

The morphology of *Antillipecten antillarum* is fairly constant throughout its geographic range with the exception of Cuba and Jamaica, where some specimens have higher rib counts (up to 16).

Comparisons.—Among the species of *Antillipecten*, *A. antillarum* is closest to *A. quemadosensis* n. sp. See the following description of the new species for comparisons.

Evolution.—See *Antillipecen quemadosensis* n. sp.

Occurrence.—In the northern Dominican Republic, *Antillipecten antillarum* is known only from a single locality on the Río Gurabo, NMB 15834. This collecting site is in the Mao Formation, 807-810 m above the base of the section (Saunders *et al.*, 1986: text-figs 4, 6), within the *Globorotalia miocenica* Zone and upper NN15 Zone, of early Pliocene (late Zanclean) age (Gradstein *et al.* 2004: fig. 21.1).

Distribution.—Outside of the Dominican Republic, fossil *Antillipecten antillarum* have been found in the Bermont Formation of southern Florida and the Coral Rock and younger deposits in Barbados, all of Pleistocene age, and in the Bowden shell beds of Jamaica, now regarded as late Middle Pliocene (Kohl & Robinson, 1998). I could find no specimens in the extensive Smithsonian collections from the Tamiami, Pinecrest, or Caloosahatchee formations of Florida (Upper Pliocene to early Pleistocene).

Antillipecten cercadicus (Maury, 1917a)
Pl. 16, Figs 6-10

Pecten cercadica Maury, 1917a: 188, pl. 34, fig. 11, refigured herein (Pl. 16, Figs 6-7).
Pecten gardnerae Cooke, 1919: 134, pl. 7, figs 5-6.
?*Pecten* (*Plagioctenium*) *cercadica* Maury. Hubbard, 1920: 94, pl. 13, figs 2-3.

Original description.—"Shell fan-shaped, moderately convex, fairly thick but translucent, nearly equilateral, whether equivalve or not I do not know as we found but one valve; surface sculptured with sixteen rounded, radial ribs with narrower interspaces; ribs and interspaces smooth except for fine, concentric growth lines; ears rather large, nearly equal, triangular, feebly radially threaded towards the base, otherwise smooth. Length 29, altitude 27, semidiameter 6 mm" (Maury, 1917a: 188).

Description.—Shell small, maximum known 27 mm Ht, equilateral, acline to slightly opisthocline, L slightly exceeding Ht in large specimens, Ht slightly greater than L in small specimens; umbonal angle 91-102°; both valves only moderately convex with LV more convex than RV; hinge line short (63-70% L), anterior hl slightly greater than posterior hl. Disks with 15 or 16 simple ribs originating near beak, becoming moderately high and rounded in profile, evenly spaced in central sector, decreasing in height and spacing toward anterior and posterior margins; secondary costae commonly absent, rarely with single weak costa in 1 or 2 interspaces in central sector originating at 23 mm Ht. Commarginal lamellae of close-set decatopectinine type present in interspaces of both valves, separated at regular intervals by slightly higher lamellae that pass straight across rib crests in early ontogeny; rib crests smooth in later ontogeny, projecting scales absent. Disk flanks low, steep, and smooth, lacking radial costellae. Auricles of moderate size relative to size of disk; right anterior auricle with 5 or 6 strong, somewhat scabrous radial costae, deep byssal notch, and active ctenolium with several small teeth; other auricles nearly smooth with only very weak costae that are obsolete in dorsal region; left anterior auricle with shallowly sigmoidal anterior margin forming acute angle with dorsal margin, posterior margins of posterior auricles nearly straight, also forming acute angle with dorsal margin. Hinge dentition weak, dominated by dorsal and infradorsal teeth, intermediate teeth absent. Interior of LV with well-developed byssal retractor scar adjoining adductor scar; foliated-calcite re-entry extending ventrally to top of adductor scar; edges of ribs carinate near margin of shell; interior features of RV not

accessible.

Type material and measurements.—Holotype of *Pecten cercadica*, PRI 28968 (Cornell University 36776), 1 LV, 27.0 mm Ht, 29.0 mm L (Pl. 16, Figs 6-7).

Type locality.—Bluff 2, "four miles above Cercado" (Maury, 1917b: 9), Río Mao, northern Dominican Republic, Cercado Formation. According to Saunders *et al.* (1986: 32), "Bluff 2 has given a weak determination of late Miocene, NN11 Zone, based on nannofossils (NMB sample 17329)." This NMB sample is shown in Saunders *et al.* (1986: text-fig. 31) to be from approximately the middle of the cliff section. The precise level from which Maury's specimen came was not specified by Maury (1917a, b).

Other material.—Dominican Republic: NMB 16803, between Bluffs 1 and 2, Río Mao, upper Cercado or lower Gurabo Formation, 1 RV partial.

Remarks.—Cooke (1919: 135) observed the close similarity of his new species, *Pecten gardnerae*, to the figure of *P. cercadica* provided by Maury (1917a: pl. 34, fig. 11) although noting that *P. gardnerae* has a narrower umbonal angle ("less spreading") and differently shaped auricles. He also noted that Maury did not mention any grouping of growth lines in her description of the left valve, a feature that Cooke found to be present on the left valve of *P. gardnerae*. Indeed commarginal lamellae of two orders are also present on the left-valve holotype of *P. cercadica* (Pl. 16, fig. 7). The differences in auricular shape are very minor when true outlines are observed by means of growth lines. Cooke's holotype and paratype are somewhat less flaring, their umbonal angles being respectively 91° and 95° compared to the 102° angle of *P. cercadica*, but the sculpture, microsculpture, and disk flanks of the two species are essentially identical. The weak costae in interspaces that originate on the holotype left valve of *P. cercadica* at a valve height of *ca.* 23 mm (Pl. 16, Fig. 6) are absent from the paratypic left valve of *P. gardnerae*, but this absence might well be due to the smaller size of the valve of *P. gardnerae,* which is only 22.8 mm high. The ages of *P. cercadica* and *P. gardnerae* might also be very close. Cooke (1919: 135) gave the age of *P. gardnerae* as Oligocene, but its type locality, USGS 3440, Santiago, Cuba, is in the area of outcrop of the La Cruz Formation, regarded by Bold (1975: 131) to be no older than Pliocene on the basis of ostracodes, particularly the presence of *Radimella confragosa* (Edwards, 1944). Later studies, however, have shown that the first occurrence of *Radimella* is earlier than the beginning of the Pliocene (Bold, 1988: 7; Saunders *et al.*, 1986: 23).

The only specimen other than the holotype of *Antillipecten cercadicus* collected in the Dominican Republic is the anterior half of a right valve from locality NMB 16803 (Pl. 16, Figs 8-10). This specimen is slightly smaller (26.7 mm height) than the holotypic left valve, but by superimposing the partial right valve on the holotypic left valve, it can be seen that the anterior umbonal angle and rib patterns are identical.

Comparisons.—*Antillipecten cercadicus* differs from *A. janicoensis* n. sp. in lacking well-developed secondary costae in rib interspaces. The only other species of *Antillipecten* known from the Neogene of the Dominican Republic that lacks such secondary costae is *A. microlineatus* n. sp. The latter has only 11 ribs that are broader, with more sloping sides, lacks commarginal lamellae of two orders in early ontogeny, and is inequilateral, with the posterior side extended. *Antillipecten vaun wythei* (Hertlein, 1933) from the La Cruz Formation, Pliocene, in the Santiago area of Cuba, resembles *A. cercadicus* in rib number and lack of secondary costae but differs in having lower, more rounded ribs that begin after an early non-ribbed smooth zone, and in lacking two orders of growth lines in rib interspaces and transverse lamellae on rib crests in early ontogeny.

Evolution.—The evolutionary origin of *Antillipecten cercadicus* is not clear, although it is possibly descended from smooth-ribbed late Oligocene and early Miocene species of *Antillipecten*. Within the Upper Miocene Cercado and lower Gurabo formations of the Dominican Republic, *A. janicoensis* n. sp. is possibly a sister species. See comments on evolution under that species.

Occurrence.—In the northern Dominican Republic, *Antillipecten cercadicus* is known only from the upper Cercado or lower Gurabo Formation, late Miocene, on the Río Mao.

Distribution.—Outside of the Dominican Republic, *Antillipecten cercadicus* is known from the La Cruz Formation, Pliocene, Santiago area, Cuba, from where it was described as *Pecten gardnerae* by Cooke (1919). A specimen very similar to and possibly the same as *A. cercadicus* occurs in the lower Ponce Formation of southern Puerto Rico (USGS 21911), regarded as latest Miocene to Pliocene in age by Bold (1988: 7) in that the lower part of the formation contains the basal *Radimella confragosa* [ostracode] Zone.

Antillipecten janicoensis n. sp.
Pl. 16, Figs 11-13

Diagnosis.—*Antillipecten* with equilateral, nearly equivalved shell of low biconvexity and umbonal angle of *ca.* 100°; disks with 15-17 simple, rounded, steep-sided ribs of uneven height

and spacing, and 1 or rarely 2 secondary costae originating in interspaces at 11-12 mm Ht; close-set commarginal lamellae of two orders, with major lamellae crossing rib crests.

Description.—Shell small, maximum known *ca.* 23 mm Ht, equilateral, acline, L slightly exceeding Ht, umbonal angle 98-103°, valves approximately equal and low in cvx; hinge line short, *ca.* 60% L, ratio of anterior hl to posterior hl 1.29. Disks with 15-17 simple, rounded, steep-sided ribs originating near beak; ribs of uneven height and spacing, on LV 5 ribs slightly higher than intervening ribs, lateralmost rib on each side of LV doubling by bifurcation in mid-ontogeny; secondary costae originating at 11 or 12 mm Ht, commonly only one narrow costa per interspace, rarely two. Commarginal lamellae of close-set decatopectinine type present on both ribs and interspaces, in two distinct orders in early ontogeny in interspaces with major lamellae raised and passing straight across rib crests, in late ontogeny commarginal lamellae most prominent in interspaces extending up to edges of rib crests, lower on rib crests; projecting scales absent. Disk flanks low, rounded, lacking radial costellae. Auricles of moderate size relative to size of disk; right anterior bearing radial costae but strength and number unknown, byssal notch not preserved, active ctenolium with small teeth present; left anterior auricle with 8-10 radial costae, posterior auricles with 8-10 weaker costae, becoming obsolete in dorsal sector but remaining strong in ventral sector. Left anterior auricle and posterior auricles with free margins forming acute angles with dorsal margin. Hinge dentition weak, dominated by dorsal and infradorsal teeth, intermediate teeth absent. Adductor scars not preserved or partially inaccessible. Foliated-calcite re-entry not extending beyond level of striate adductor scar. Edges of ribs on shell interior carinate near shell margin.

Etymology.—Named after the town of Jánico, with reference to the type locality on the Santiago-Jánico road, north of Jánico.

Holotype and measurements.—USNM 541015 (Pl. 16, Figs 11-12), 1 LV, 21.5 mm Ht, 23.3 mm L, 3.4 mm cvx.

Type locality.—Locality TU 1406, road cuts, Santiago-Jánico Road, 3-5 km west of junction with road to Baitoa, or 15-17 km from bridge over Río Yaque at Santiago, Dominican Republic. [The entry for this locality by Saunders *et al.* (1986: 66) incorrectly indicates "northwest of bridge." In fact it is south of the bridge.] According to the Vokes' entry in the Tulane Locality Register (at USNM), this is an exposure of the Cercado Formation. The assemblage of pectinids, however, suggest that these exposures could include some of the Gurabo Formation. The assemblage includes *Argopecten eccentricus caimiticus*, *Leptopecten thompsoni*, *Lindapecten plurinominis*, *Lindapecten paramuscosus*, *Amusium papyraceum*, *Euvola soror*, *Antillipecten quemadosensis*, and *Nodipecten nodosus*.

Other material.—Locality NMB 16844, paratypes, 1 RV (23.9 mm Ht; Pl. 16, Fig. 13) and 1 LV (14.0 mm Ht), Gurabo Formation (*Arca* beds), 228 m above base of section, Río Cana, Dominican Republic, associated in same sample with *Argopecten eccentricus caimiticus* and *Lindapecten plurinominis.*

Remarks.—The holotype is the most complete of the three specimens, although it is fragile and was broken and repaired during this study. The two specimens from NMB 16844 have better preserved shell structure and show pigment patterns not visible in the holotype. On both valves, the pattern consists of narrow white antimarginal lines on the disk flanks, some of which bifurcate just before reaching the margin of the valve. The left valve has a pattern on the disk consisting of narrow diagonal white lines that intersect to produce a chevron pattern. White pigment is also concentrated on the crests of the five high ribs. NMB 16844 is in the so-called "*Arca* beds" or "*Scapharca patricia* beds," which were placed by Saunders *et al.* (1986, text-fig. 16) in the Cercado Formation but by Maury (1917b, 1919) and Bold (1988) in the Gurabo Formation.

Comparisons.—Antillipecten janicoensis n. sp. resembles *A. cercadicus* in having commarginal lamellae of two orders, with the major lamellae forming raised transverse ridges on the rib crests in early ontogeny; the two species also have similar auricular shapes and broad umbonal angles. There is a clear difference in ribbing, however, in that *A. cercadicus* has higher, broader ribs that are evenly spaced and of uniform height and lacking well-developed costae in the interspaces. Compared to *A. quemadosensis* n. sp., *A. janicoensis* n. sp. has more ribs (15-17 compared to 10-13) as well as stronger and more numerous secondary costae in the rib interspaces.

Evolution.—Antillipecten janicoensis n. sp. is possibly ancestral to *A. quemadosensis* n. sp., which occurs stratigraphically higher in the Gurabo Formation and which, in turn, might have given rise to the extant tropical American species *A. antillarum* based on the elaboration of secondary radial costae and their spread from interspaces to rib crests. *Antillipecten cercadicus* appears to be an independent lineage that is a more plesiomorphic species than any of these, based on its lack of secondary costae.

Occurrence.—In the northern Dominican Republic the new species is known only from two well-separated collecting sites, one on the Río Cana, the other in a road cut north of

Jánico. The Río Cana site (NMB 16844), at 228 m above the base of the section, is below the first occurrence of planktic foraminiferans at 300 m, which are in turn below the possible position of the Miocene-Pliocene boundary that is at least as low as 315 m (Saunders *et al.*, 1986: 22). NMB 16844 is therefore likely to be late Miocene (NN11 Zone). Judging from the fossil assemblage, the other site (TU 1406) is likely of the same age.

Distribution.—Antillipecten janicoensis n. sp. is known only from the Upper Miocene of the northern Dominican Republic.

Antillipecten microlineatus n. sp.
Pl. 17, Figs 1-3

Diagnosis.—Antillipecten with thin, prosocline, inequilateral shell, RV more convex than LV, disk with 9-11 broad, rounded ribs that are nearly trigonal in profile in early ontogeny, rounded with sloping sides in later ontogeny, evenly spaced except for two anteriormost ribs on each valve, which are narrower and more closely spaced; surface smooth and glossy except for microscopic close-set growth lines throughout ontogeny.

Description.—Shell of medium size, restored *ca.* 45 mm Ht, prosocline, inequilateral with posterior extended, biconvexity low with RV more convex than LV, umbonal angle 94°. Ribs on disks nearly trigonal in early ontogeny, becoming narrowly rounded with gently sloping sides later, 11 on RV, 9 on LV, evenly spaced and approximately as broad as interspaces except for anteriormost two ribs on each valve, which are narrower and lower; secondary radial costae absent, commarginal lamellae of close-set decatopectinine type throughout ontogeny; surface very smooth, somewhat glossy. Anterior disk flanks low but very steep and somewhat inturned, without radial costellae or antimarginal sculpture, possessing only fine growth lines; posterior disk flanks not preserved. Auricles not preserved except for proximal end of byssal notch, which was apparently deep with active ctenolium of small teeth. Hinge and interior characters not accessible because of hard matrix between valves.

Etymology.—Named with reference to the microscopic commarginal lineations that cover the disk surfaces.

Holotype and measurements.—NMB G17535, 1 articulated DV lacking posterodorsal part and most of anterior auricles, restored 45 mm Ht, restored 48 mm L, biconvexity 10.8 mm (Pl. 17, Figs 1-3).

Type locality.—Locality NMB 15893, 150 m above base of section, Cercado Formation, Río Gurabo, Dominican Republic. The only other pectinid from this locality is *Mimachlamys blowi* n. sp.

Other material.—None.

Remarks.—Saunders *et al.* (1986: 46) described the lithology at this locality as "silt with corals" and indicated that its stratigraphic position is disconformably just below the massive conglomerate that they regarded (p. 15) as marking the base of the Gurabo Formation. They stated "The coral bed at some localities ... contains colonies of (?) poritids almost in position of growth with breakage only due to compaction *in situ*. A coral thicket of poritids with some more massive heads and with common algal balls seems to have been the environment here" (Saunders *et al.*, 1986: 15). The coral bed thickens at NMB 16184, just above 16185 (the microsample equivalent of NMB 15893), as illustrated in their pl. 1, fig. 3.

Normally an incomplete specimen lacking auricles would not be considered adequate as the sole basis for the description of a new species. In this case, however, the nature of the microsculpture and ribbing are so distinctive, and so unlike anything known from the Neogene of the Dominican Republic or elsewhere in the tropical American region, that I am confident that it is a new species.

Comparison.—Antillipecten microlineatus n. sp. differs from all other species in the genus in having a low number of broad, nearly trigonal ribs lacking secondary radial costae.

Evolution.—Nothing can be said about the phylogenetic status of this species until more material is recovered.

Occurrence and distribution.—The species is known only from the type locality at the top of the Cercado Formation, late Miocene in age.

Antillipecten quemadosensis n. sp.
Pl. 17, Figs 4-10; Table 22

Diagnosis.—Antillipecten with equilateral, slightly right-convex shell, with 10-13 evenly spaced major radial ribs; posteriormost rib of RV consisting of two smaller ribs because of bifurcation in early ontogeny; ribs high with rounded crests and steep sides; secondary costae intercalated in rib interspaces in early ontogeny but absent from rib crests throughout ontogeny; posterior margin of posterior auricles forming acute angle with dorsal margin, all auricles radially costate; byssal notch moderately deep with active ctenolium.

Description.—Shell small, not known to exceed 26 mm Ht, equilateral, acline to slightly prosocline, Ht slightly exceeding L except in latest ontogeny, when Ht and L are approximately equal; umbonal angle 92-102°; both valves only moderately convex with RV more convex than LV; hinge line short (hl/L= 0.6-0.7), anterior hl very slightly greater than posterior hl. Disks with 10-13 ribs; ribs originating as low undulations in early ontogeny after early smooth zone, becoming high, rounded, steep-sided in late ontogeny; ribs of even height and spacing in central sector, decreasing in height and width toward disk flanks; posteriormost rib of RV commonly consisting of two riblets near margin due to bifurcation early in ontogeny; secondary costae intercalating in interspaces in early ontogeny, with 3-5 in interspaces in late ontogeny; crests of major ribs rounded, without secondary costae. Commarginal lamellae of close-set decatopectinine type present on both ribs and interspaces, commonly with higher lamellae forming periodically in interspaces in early ontogeny, separating groups of finer lamellae; lamellae passing straight across ribs and interspaces but with ventrally convex curvature over tops of secondary costae; projecting scales absent. Disk flanks low, steep, lacking radial costellae. Auricles of moderate size relative to size of disk; right anterior auricle with 4 or 5 strong, slightly scabrous radial costae, broad byssal fasciole, and moderately deep byssal notch with persistent active ctenolium; left anterior auricle with from 5-9 radial costae, rounded anterior margin, and moderate deep byssal sinus; posterior auricles with 5-9 radial costae beginning in mid-ontogeny after early noncostate zone. Hinge dentition weak, dominated on RV by dorsal teeth, intermediate and resilial teeth absent. Striate and nonstriate adductor scars of RV separated on anterior side by deep groove. Foliated-calcite re-entry of RV entering adductor separation and bordering posteroventral margin of nonstriate adductor scar. Edges of ribs on shell interior carinate near shell margin. Interior features of LV not observed.

Etymology.—Named after the town of Los Quemados, Dominican Republic, a short distance east of the type locality.

Holotype and measurements.—USNM 541016 (Pl. 17, Figs 4-7), a pair of closed but slightly offset valves, 26.0 mm Ht, 24.0 mm L, paired valves 8.5 mm cvx.

Type locality.—Locality TU 1278, large arroyo on eastern side of Río Gurabo just at the ford on Los Quemados-Sabaneta Road, Gurabo Formation, Upper Miocene. Saunders *et al.* (1986: text-fig. 4) showed locality NMB 15836, which is in approximately the same position as TU 1278, as being 387-389 m above the base of the Río Gurabo section and a short distance below the Miocene-Pliocene boundary.

Other material.—19 specimens from 11 localities in the northern Dominican Republic (Table 22). All but two of these are single valves.

Remarks.—Among the limited number of specimens on hand, *Antillipecten quemadosensis* n. sp. has a fairly constant morphology with the exception of the specimens from the Guayubín area (TU 1281). The single right valve from TU 1281 has only 11 ribs, whereas right valves from other localities have 12 or 13. Similarly, left valves from other localities have 11-14 ribs, but two or the three left valves from TU 1281 have only 10; the third has 11. Furthermore, the posterior auricular costae on specimens from TU 1281 are finer and more numerous than are those on specimens from other localities.

Antillipecten quemadosensis n. sp., like its extant counterpart *A. antillarum,* probably had a broad depth range. Its association with *Argopecten thetidis* at four of the eight localities and particularly its association with *Gurabopecten uniplicatus* n. gen., n. sp., at TU 1278 indicate that the species ranged into waters > 50 m.

Comparisons.—Antillipecten quemadosensis n. sp. is closest in morphology to the extant species *A. antillarum*. The two species have the same shape and range in number of ribs but differ in rib height and distribution of secondary costae. *Antillipecten quemadosensis* n. sp. has much higher ribs that have steeper sides. Its secondary costae are limited to the rib interspaces, and the rib crests are evenly rounded and noncostate. In *A. antillarum*, costae are commonly present on the rib crests, the first expression of these rib-top costae being a very low medial ridge in the center of the crest. Additional secondary costae develop on the rib crests in later ontogeny. On some specimens, these costae are low and barely discernible under oblique light; on others they are well-developed, exemplified by specimens from St. Thomas, Virgin Islands [USNM(IZ) 103043, Pl. 16, Figs 1, 3].

Antillipecten cercadicus differs from *A. quemadosensis* n. sp. in having a broader, more flaring shell with more ribs (16 or 17) and in lacking secondary radial costae. In early ontogeny, *A. cercadicus* has raised commarginal lamellae that separate groups of close-set lamellae, the raised lamellae extending across the rib crests whereas the finer lamellae do not. *Antillipecten quemadosensis* n. sp. has lamellae of two orders in early ontogeny, but the major lamellae do not cross the rib crests.

Antillipecten janicoensis n. sp. resembles *A. quemadosensis* n. sp. in having secondary costae limited to rib interspaces. In *A. janicoensis* n. sp., however, the ribs are more numerous (15-17 compared to 10-13 in *A. quemadosensis* n. sp.) and the correspondingly narrower interspaces support fewer secondary costae, commonly only 1 or 2. *Antillipecten janicoensis* n.

sp. also differs from *A. quemadosensis* n. sp. in having more delicate posterior auricular costae, which are limited to the ventral part of each posterior auricle.

Evolution.—Antillipecten quemadosensis n. sp. is probably ancestral to the extant species, *A. antillarum*, but the number of specimens of *A. quemadosensis* n. sp. available is too small to permit detecting any stratigraphic changes in morphology. The change to *A. antillarum* occurred at least by the time of deposition of the Bowden Beds of Jamaica, the age of which is now regarded as late Middle Pliocene (late Piacenzian; Kohl & Robinson, 1998). The ancestry of *A. quemadosensis* n. sp. is poorly constrained by the specimens on hand. A possible ancestor is *A. janicoensis* n. sp., which occurs mainly or entirely in the Cercado Formation, whereas *A. quemadosensis* n. sp. occurs in the Gurabo Formation. Both species have costate interspaces, noncostate rib crests, and a doubling of the lateralmost disk ribs in early ontogeny.

Occurrence.—In the northern Dominican Republic, *Antillipecten quemadosensis* n. sp. is widely distributed among river sections and road cuts in the Gurabo and lower? Mao formations in strata determined by Saunders *et al.* (1986) to be Late Miocene to Pliocene in age.

Distribution.—Antillipecten quemadosensis n. sp. has not yet been found with certainty outside of the Dominican Republic. A careful search of the extensive collections from Neogene formations in the southeastern United States housed in the Smithsonian Institution turned up nothing. A search of the less extensive collections from the Antilles turned up only a single disk fragment from the Aymamon Formation of Puerto Rico (locality USGS 17207) of possible Middle Miocene age (Renken *et al.*, 2002: pl. 24), but both the taxonomic identity of the specimen and the age of the Aymamon Formation are uncertain.

Antillipecten sp.
Pl. 17, Fig. 11

Description.—Shell of unknown adult size, known only from juvenile LV, equilateral, acline, Ht greater than L, umbonal angle 95°, slightly convex, hinge line long, estimated reconstructed hl *ca.* 75% L, reconstructed lengths of anterior and posterior hinge lines approximately equal. Disk with 13 very low, gently rounded, simple ribs differing in height in the pattern (from anterior to posterior) r r R r r R r r Rc r R r r; anteriormost pair of ribs smaller and narrower than others, posteriormost rib flattened and possibly bifurcate distally, major ribs beginning earlier than minor ones, but all in place by 2.6 mm Ht; secondary radial costae on disk absent. Commarginal lamellae very close-set, of decatopectinine type, extending over ribs and interspaces with hint of two orders of lamellae on distal third of disk; projecting scales absent. Disk flanks low and steeply rounded, lacking radial costellae. Auricles large relative to size of disk, both with free margins forming acute angles with dorsal margin; anterior auricle with only one faint radial costella in ventral sector, no costellae detected on posterior auricle, both auricles with dense, close-set commarginal growth lines. Hinge dentition very weak, with no obvious hinge teeth; remainder of interior not accessible.

Material.—NMB 16835, Río Cana, Cercado Formation, 252 m above base of section, 1 juvenile LV, 5.7 mm Ht (Pl. 17, Fig. 11).

Measurements.—NHB G17537; 5.7 mm Ht, 5.4 mm L; locality NHB 16835.

Remarks.—This specimen occurs with a typical Cercado shallow-water assemblage that includes *Argopecten eccentricus caimiticus*, *Lindapecten plurinominis*, *Amusium papyraceum* Morphotype A, and *Euvola soror*.

Comparisons.—The single specimen of *Antillipecten* sp. was originally thought to be a juvenile of *A. cercadicus* because of its close-set commarginal growth lines of two orders, but it differs from a comparable growth stage of the left valve of that species in having fewer ribs (13 as opposed to 16) and in having ribs that are distinctly differentiated in height.

Occurrence.—Upper Cercado Formation at 252 m above the base of the section on the Río Cana (locality NHB 16835).

Distribution.—Upper Cercado Formation or lower Gurabo Formation, northern Dominican Republic.

Genus ***NODIPECTEN*** Dall, 1898

Pecten (*Nodipecten)* Dall, 1898: 695.
Chlamys (*Nodipecten*) Dall. Hertlein, 1969: N360.
Lyropecten (*Nodipecten*) Dall. Abbott, 1974: 448.
Nodipecten Dall. Smith, 1991b: 86.

Type species.—Ostrea nodosa Linnaeus, 1758, by original designation (Dall, 1898: 695), Recent, tropical western Atlantic from the Antilles southward throughout the Caribbean to Brazil (Smith, 1991b).

Original diagnosis.—"Shell like *Lyropecten*, but the ribs intermittently nodose, with more or less prominent hollow

Table 22. Occurrence of *Antillipecten quemadosensis* n. sp. in the Cibao Valley. Abbreviations: Aa, *Argopecten ameleus*; Aec, *A. eccentricus caimiticus*; Amp, *Amusium papyraceum*; Anj, *Antillipecten janicoensis* n. sp.; Apa, *Argopecten parathetidis* n. sp.; At, *A. thetidis*; Cag, *Caribachlamys guayubinensis* n. sp.; Caj, *C. jungi* n. sp.; Dm, *Dimya* sp.; DV, matching valves; Eg, *Euvola gurabensis* n. sp.; Es, *E. soror*; frag, fragment; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis plurinominis*; Lt, *Leptopecten thompsoni*; LV, left valve; Ncv, *Nodipecten colinensis vokesae*; Nn, *N. nodosus*; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana								
NMB 16818	347	Gurabo	0	2	0	18.0	Aec, Es, Lpl	
TU 1354	336-346	Gurabo	1	0	0	14.0	Aec, Es, Lpl, Nn	
NMB 16825	321	Gurabo	0	frag	0	--	Amp, Apa, At, Lpl	
Río Gurabo								
TU 1278	387-389	Gurabo	1	0	1	26.0	At, Es, Gu, Lpa, Ncv	Type locality of *A. quemadosensis* n. sp.
TU 1231	380-395?	float	0	0	1	21.2	At, Es, Lpa, Ncv	
NMB 15839	360-367	Gurabo	frag	1	0	25.0	Dm	
TU 1215	276-286.5	Gurabo	1	1	0	22.7	Amp, At, Caj, Lpa, Nn	
Río Yaque del Norte								
TU 1281	--	Mao	1	3	0	20.5	Aa, Cag	
Santiago area								
TU 1406	--	?	1	1	0	22.2	Aec, Amp, Anj, Es, Lpa, Lpl, Lt, Nn	
USGS 8726	--	Gurabo	0	1	0	22.0	Aec, At, Es, Sv	
Road cuts								
TU 1222	--	?	1	0	0	24.1	Aec, Amp, Anj, Es, Lpa, Lpl, Lt, Nn	
TU 1224	--	?	frag	0	0	--	Apa, Dm, Eg	
TU 1299	--	?	1	0	0	22.2	Apa, Lpa, Ncv	

nodes or bullae; radial striation pronounced; ears unequal, the posterior smaller, the valves often more or less oblique; imbricate surface layer sometimes very marked" (Dall, 1898: 695).

Emended diagnosis.—Monophyletic clade derived from *Lyropecten* having ledges and nodes in commarginal rows, especially pronounced on LV; nodes either open and flaring or closed, hollow, and bulbous; key ribs of LV higher and wider than neighboring ribs, commonly with a central-sector pattern of N r Nc r N or N 2r Nc 2r N; interspaces of RVcorresponding to key ribs of LV wider and deeper than neighboring interspaces; commarginal lamellae coarse, not close-set; hinge dentition consisting of three pairs of teeth (modified from Waller, 2007: 933).

Remarks.—Species of *Nodipecten* are distinguished on the basis of shell shape, rib patterns, secondary costation on disk, disk flanks and byssal fasciole, and form and distribution of flanges or nodes. (See the Methods and Materials section for an explanation of rib-pattern annotation.)

Smith (1991b) and Waller (2007) used different concepts of *Lyropecten* and *Nodipecten* in their phylogenetic interpretations. According to Smith (1991b: 48), *Lyropecten* differs from *Nodipecten* in having auricles of more equal length, a shallower byssal notch, and more regularly spaced ribs that are less diffentiated in height (*i.e.*, with less distinct key ribs). Her concept included forms with a central-sector pattern of N 2r Nc 2r N in *Lyropecten*, but including forms with a pattern of N r Nc r N in *Nodipecten*. Following this distinction, she included species such as *N. colinensis s. l.* of the Caribbean Miocene and Pliocene and the extant *N. magnificus* of the Galápagos Islands in *Lyropecten*. Waller (2007), in contrast,

regarded *Lyropecten* as the more plesiomorphic genus and distinguished *Nodipecten* on the basis of its derived characters, including repeated nodes and ledges, nodes in the form of open flanges or closed but hollow bulbs, and coarse secondary costae on disks (Waller, 2007: fig. 3, node 7). According to Waller's concept, both *N. colinensis* and *N. magnificus* belong in *Nodipecten*, not *Lyropecten*.

The evolution of *Nodipecten* has been discussed in detail by Smith (1991b), Del Río (2006), and Waller (2007), but there is still much to learn, particularly with regard to the great amount of variation shown by several species and stratigraphic correlation between the eastern and western sides of the Americas.

Geographic range.—Presently living in the western Atlantic regions from North Carolina to Florida and Bermuda, throughout the Gulf of Mexico and Caribbean, to as far south as Brazil and Ascension Island, and in the eastern Pacific from the Gulf of California to Peru, commonly offshore from shallow water to mid-shelf depths (Abbott, 1974; Coan *et al*., 2000).

Stratigraphic range.—Lower Miocene to Recent (Waller, 2007).

Nodipecten colinensis colinensis
(F. & H. Hodson in Hodson *et al.*, 1927)
Pl. 17, Figs 12-13

Pecten (aff. *Nodipecten) colinensis* F. & H. Hodson in Hodson *et al*., 1927: 33, pl. 18, figs 3, 6, pl. 19, fig. 4.
Chlamys (*Nodipecten*) *colinensis* (F. & H. Hodson in Hodson *et al*.). Mongin, 1968: 506, pl. 48, fig. 1 (reproduction of original figure by the Hodsons).
Chlamys (Nodipecten) *colinensis guadeloupensis* Mongin, 1968 (in part): pl. 43, figs 1-2.
Lyropecten (*Nodipecten*) cf. *colinensis* (F. & H. Hodson). Jung, 1971: 165, pl. 1, fig. 3.
Nodipecten clydonus Woodring, 1982: 599, pl. 101, figs 5-6.
Lyropecten colinensis colinensis (F. & H. Hodson). Smith, 1991b: 50, pl. 16, figs 5-7, pl. 19, figs 1, 3, 5.
Nodipecten colinensis (F. & H. Hodson). Del Río, 2006: 748.
Nodipecten colinensis colinensis (F. & H. Hodson). Waller, 2007: 933, fig. 3.

Original description.—"Shell averages 90-100 mm. in altitude, and is nearly equivalve, suborbicular and moderately convex. The right valve is ornamented with *ca.* 11 rather flat-topped, prominent, radially striate ribs, in addition to less well developed ribs and radial striae on the submargins; the tops of the ribs carry 3 or 4 equally spaced, coarse, radial striae; the sides of the main ribs are steep; the interspaces are approximately as wide or slightly wider than the ribs and carry 1-3 strong, radial threads; the radial ornamentation is crossed by the concentric lines of growth which swing up over the top of the ribs; at the points of intersection of the two sets of ornamentation, small beads or prominences are formed on the radial striae, but no large nodes or large imbricating scales are to be found on this valve, which easily distinguishes it from the left valve. The hinge line is straight and approximately one-half as long as the disc of the shell. The anterior ears are slightly longer than the posterior; both are radially striate with 5-6 or more, strong, radial threads which are slightly noded by the imbricate growth lines. The left valve is ornamented with *ca.* 12 main ribs in addition to the incipient ribs and striae on and near the submargins. The tops of the ribs are slightly rounded and carry 3-5 slightly scaly, radial striae; the interspaces are approximately as wide, or slightly narrower than, the ribs, and carry 1-3 strong radial threads of the same general character as those on the ribs; at periodic intervals, usually *ca.* 10-15 mm apart, there occur concentric rows of prominences, which are noticeable on all the ribs and interspacves of the left valve; the characteristic feature of this species is that every third rib on this valve bears larger nodes or very prominent scales at points of intersections with the rows of concentric prominences" (F. & H. Hodson in Hodson *et al.*, 1927: 33).

Additional description.—Nearly equiconvex, acline to slightly prosocline, anterior auricles slightly longer than posterior, byssal notch only moderately deep; RV commonly with 12-14 ribs of nearly equal height and spacing, lateralmost rib on each side becoming subdivided and barely distinguishable from coarse costae of disk flanks in late ontogeny; LV with central-sector rib plan /3n N 2n Nc 2n N 3n\ or /N 2n N 2n Nc 2n N 2n N\; nodes on key ribs closed in early ontogeny, becoming open flanges in later ontogeny; secondary costae very coarse, 3-5 on rib crests, fewer in rib interspaces, commonly with single medial costa in some interspaces in early ontogeny.

Type material and measurements.—Holotype of *Pecten colinensis*, PRI 21961, 1 articulated DV, 83 mm Ht, 97 mm L; paratypes: PRI 21954, 1 RV, and PRI 21957, 1 articulated DV.

Type locality.—Buena Vista structure at La Vela, Colina District, Falcon, Venezuela, from an outcrop of yellow sandy limestones 10 in to 2 ft[= 0.2-0.6 m] thick, with hard massive beds containing pectinids, large oysters, and very large echinoids, in a section running east-west beginning east of Taratara, Hodson field locality 115, probably from the Mataruca Limestone Member of the Caujarao Formation (data

from Smith, 1991b: 50). Wozniak & Wozniak (1987) determined that the Mataruca Limestone Member is within the *Globorotalia acostaensis* Zone, of Late Miocene age. Saunders *et al.* (1986: table 4) showed this zone as ranging through nannofossil zone NN10 and the lower half of NN11.

Other material.—Dominican Republic: NMB 17274, Río Yaque del Norte, just below Arroyo Los Cedros at López, 1 DV, 82 mm Ht (Pl. 17, Figs 12-13). Saunders *et al.* (1986: text-fig. 26) showed the position of this locality in the Arroyo López section. Their table 3 indicated that the age at this locality is Late Miocene (lower Zone NN11), correlating with the lower Cercado Formation in the Río Gurabo section.

Venezuela, Colina District, Falcon State: PRI 21954 and 21957, La Vela area, Rim Rock, east of Taratara, strike N40°W, dip 10°E, paratypes (1 RV, 1 DV); USGS 18041, north-facing slope and crest of the first ridge south of Standard Oil Company's La Vela Well No. 1, which is *ca.* 6 km N-NE of La Vela, Damsite Limestone (Caujarao Formation in current usage, Late Miocene in age), 1 RV; USGS 6296, "big oyster" limestone capping the hill (plunging anticline) just south of La Vela, 1 RV.

Panama: USNM 647127, Locality USGS 5906a, Río Chagres *ca.* 1.5 mi (2.5 km) above Alhajuela, Canal Zone, lower member of Alhajuela Formation, 1 DV, 88 mm Ht (holotype of *Nodipecten clydonus* Woodring, 1982).

Remarks.—Nodipecten colinensis colinensis is apparently restricted to strata of Late Miocene age. The single specimen on hand from the Dominican Republic is stratigraphically the lowest of the three species of *Nodipecten* that occur there. Specimens from the vicinity of the type locality near La Vela, in the state of Falcón, Venezuela, are also of Late Miocene age (Caujarao Formation). Contrary to Smith (1991b: 51) and del Río (2006: 752), I am unable to confirm any occurrences of *N. colinensis s. s.* in the Cantaure Formation of Venezuela, which is now regarded as late Early Miocene in age (Hunter, 1978). Although the Aljahuela Formation of Panama has not been precisely dated, *Nodipecten clydonus*, regarded by Smith (1991b: 50) and the present author as a junior synonym of *N. colinensis colinensis*, occurs with *Leopecten gatunensis*, an indicator of the Late Miocene (see preceding section on *L. gatunensis*).

Comparison.—Nodipecten colinensis colinensis and *N. c. vokesae* differ from *N. pittieri* (Dall, 1912) of the Venezuelan Pliocene in the rib pattern of the central sector of the left valve, N2 r Nc 2r N in *N. colinensis s. l.* and N r Nc r N in *N. pittieri*. *Nodipecten arnoldi* (Aguerrevere, 1925) of the Pliocene and Pleistocene of Venezuela also has the N r Nc r N pattern.

The two subspecies of *N. colinensis* differ only slightly from one another in the number of ribs, 12-14 in *N. c. colinensis* but commonly only 10 or 11 in *N. c. vokesae*. The difference in rib number shows up in the anterior and posterior sectors, particularly on the left valve, where an additional rib is distinguishable from the costate disk flank in *N. c. colinensis* but not in *N. c. vokesae*.

Nodipecten colinensis guadeloupensis (Mongin, 1968) as represented by its holotype has a left central sector with the pattern N r Nc r N. Both Smith (1991b: 97) and the present author place it in the synonymy of *N. pittieri*. Two other specimens illustrated by Mongin (1968: pl. 43, figs 1-2), however, have a rib pattern of N 2n Nc 2n N and, as noted by Smith (1991b: 51) are *N. c. colinensis*. Their precise stratigraphic position, however, has not been determined.

The reports of Smith (1991b: 51) of *Nodipecten colinensis colinensis* from Trinidad (Tamana Formation, Guaracara Limestone Member, late Early Miocene) and Carriacou (Carriacou Formation, late Early Miocene) have not been confirmed. A specimen of a *Nodipecten* in the Smithsonian collections from USGS 21790, Concord Quarry, Pointe-a-Pierre, Guaracara Limestone Member, Tamana Formation, is *Lyropecten dumblei* (Gardner, 1945), a species that would be expected in strata this old. Smith's (1991b) report from the Carriacou Formation of Carriacou was based on poorly preserved material not positively identified (Jung, 1971: 165, pl. 1, fig. 3). If the Carriacou specimens prove to be *N. c. colinensis*, then they are the oldest representatives of the species (Middle Miocene).

Evolution.—Smith (1991b: 51) thought that the ribbing scheme of the left valve of *Nodipecten colinensis s. l.* allied the species with what she referred to as the "*Lyropecten crassicardo-L. magnificus* stock" of Miocene to Holocene age in the eastern Pacific. In contrast, Waller (2007: 933) regarded this rib pattern as plesiomorphic in *Nodipecten* but presented evidence that the extant *N. magnificus* of the Galápagos Islands, which has the same pattern, is a recently derived species convergent in this respect. According to the phylogeny by Waller (2007: fig. 3), *N. colinensis s. l.* is drived from the base of the *Nodipecten* clade and gave rise to a Tertiary Caribbean *Nodipecten* complex that includes all of the later species. The stratigraphic position of *N. c. colinensis* relative to other *Nodipecten* species is consistent with this pattern.

Occurrence.—Nodipecten colinensis colinensis is reported for the first time from the Dominican Republic, where it occurs on the Río Yaque del Norte at a level equivalent to the lower Cercado Formation of the Río Gurabo.

Distribution.—Outside of the Dominican Republic,

Nodipecten colinensis colinensis is known from Upper Miocene strata in Venezuela (Caujarao Formation), and Panamá (lower member of Alhajuela Formation).

Nodipecten colinensis vokesae (Smith, 1991b)
Pl. 17, Fig. 14; Pl. 18, Figs 1-4; Table 23

Lyropecten colinensis vokesae Smith, 1991b: 51, pl. 16, figs 1, 3; pl. 17, fig. 3; pl. 18, figs 2-4; pl. 19, figs 2, 4.

Original description.—"Valve outlines circular to slightly longer than high. Right valve slightly more convex than left valve. Beaks project slightly beyond hinge line. Auricles subequal, costate, and lirate, anterior auricle having *ca.* 3 coarse radials. Byssal notch moderately deep. Hinge line slightly shorter than half shell length. Right valves with 10-11 ribs sculptured by moderately coarse to coarse costae crossed by lirae; wide central space space flanked by uniformly arranged to slightly grouped ribs and 1-3 coarse riblets in interspaces. Left valves flatter than right valves, with 9 ribs arranged in the scheme N 2r N_c 2r N; individuals over 1 cm high have hollow, flanged nodes on the three key ribs, 1-2 radials in interspaces. Nodes correspond to slight ledges or constrictions in the shells. Anterior and posterior shell margins have incipient radial ridges that confuse rib counts. The largest individual seen measured 9 cm high, 8.5 cm long (incomplete) (TU loc. 1209). Whole specimens tend to be longer than high" (Smith, 1991b: 51).

Type material.—Holotype of *Lyropecten colinensis vokesae*, USNM 334988, TU 1338, 2.9 km west of Los Quemados in road cut on the Los Quemados-Sabaneta road, 0.3 km west of bridge over Río Gurabo, Gurabo Formation, Dominican Republic, 1 articulated DV, 65 mm Ht, 72 mm L.

Type locality.—Locality TU 1338, 2.9 km west of Los Quemados in road cut on the Los Quemados-Sabaneta road; 0.3 km west of bridge over Río Gurabo. Gurabo Formation, upper Miocene or lower Pliocene.

Other material.—17 specimens, five of which are articulated valves, from 12 localities in the Cibao Valley, northern Dominican Republic (Table 23).

Remarks.—Nodipecten colinensis vokesae is possibly a junior synonym of *Chlamys* (*Nodipecten*) *nunezi* Torre, 1971, the type locality of which is the roof of the Galería del Confesionario, Cueva de Bellamar, Matanzas Province, Cuba (Torre, 1971: 7). This is probably in the Bellamar Member of the Canímar Formation, Lower Pliocene, *Globorotalia margaritae* Zone, N18, as indicated in Torre & Kojumdgieva (1985: 2), and thus is of approximately the same age as the upper part of the Gurabo Formation in the Dominican Republic. The problem is that Torre (1971) based his original description on only two specimens, the holotype being the anterior half of a right valve (incorrectly said to be a left valve) and another very worn specimen. His only illustration, which is of poor quality, is of the holotype. Nevertheless, Torre's figure is good enough to show that the specimen compares closely to the specimen (USNM 167122, Pl. 17, Fig. 14) from the La Cruz Formation of Cuba incorrectly identified with *N. pittieri* by Cooke (1919: 135, pl. 13, fig. 5) as well as by Torre (1971). Their rib numbers and even rib spacing on the anterior half of the disk are identical with each other and very similar to these features on the holotype of *Lyropecten colinensis vokesae*. The left valves of the Cuban species, however, are unkown, and therefore the synonymy cannot be confirmed.

Torre (1971) regarded his new species to be morphologically intermediate between *Nodipecten pittieri* and *N. nodosus*. Twenty years later, however, Smith (1991b) demonstrated the importance of the patterns of major and minor ribs, particularly in the central sector of the left valve, for distinguishing various lineages of *Lyropecten* and *Nodipecten*. Both *N. pittieri* and *N. nodosus* have a clear pattern of N r Nc r N in their left central sector, whereas *N. colinensis s. l.* has N 2r Nc 2r N.

The pectinids with which *Nodipecten colinensis vokesae* is most commonly associated, as well as its stratigraphic positions in the Río Gurabo section, indicate that it lived on the outer shelf platform. It is commonly associated with other outer-shelf pectinids such as *Argopecten thetidis* and *Gurabopecten uniplicatus* n. gen., n. sp., but not with very shallow-water species such as *Argopecten eccentricus* (Table 23). In the Río Gurabo section, *N. colinensis vokesae* disappears just at the point of rapid deepening at *ca.* 400 m above the base of the section (Saunders *et al.*, 1986: 16). This is also close to the Miocene-Pliocene boundary, but in this case, *Nodipecten* seems to be eliminated from younger strata for ecological reasons, not because of extinction.

Comparisons.—Nodipecten colinensis vokesae differs from *N. c. colinensis* in having one less rib and/or a less developed incipient rib in the anterior and posterior sectors adjacent to the disk flanks. Both subspecies have a left central-sector rib pattern of N 2r Nc 2r N, which distinguishes them from *N. pittieri*, which has N r Nc r N. See Smith (1991b: 51) for comparison with eastern Pacific Neogene species.

Evolution.—Smith (1991b: 51) observed that the pattern and number of ribs in the early ontogeny of *Nodipecten colinensis vokesae* resembles that of mature members of the nominal subspecies and therefore inferred that the former is descended from the latter. The stratigraphic position of the single speci-

men of *N. colinensis s. s.* found in the northern Dominican Republic corroborates this conclusion in that it occurs in the lower Cercado Formation, whereas all of the specimens of *N. c. vokesae* occur stratigraphically higher, in the upper Cercado and Gurabo formations. Stratigraphic occurrences elsewhere in the Caribbean region are also consistent with this hypothesis. *Nodipecten colinensis s. s.* in its type area in northern Venezuela is Late Miocene in age (see *N. colinensis s. s.*); Cuban occurrences of *N. nunezi* are Pliocene.

Occurrence.—In the Cibao Valley of the northern Dominican Republic, *Nodipecten colinensis vokesae* occurs only in the upper Cercado and lower Gurabo formations.

Distribution.—Nodipecten colinensis vokesae is thus far known from the Dominican Republic, unless *N. nunezi* of Cuba should turn out to be this subspecies (see Remarks above). Specimens identified by Smith (1991b: 51) from the Alhajuela Formation of Panama were misidentified. One specimen is probably a *Lindapecten* of the *L. buchivacoanus* complex; the other is the left valve of *N. c. colinensis*.

Nodipecten nodosus (Linnaeus, 1758)
Pl. 18, Figs 5-9; Table 24

Ostrea nodosa Linnaeus, 1758: 697, no. 164.
Pecten nodosus (Linnaeus). G. B. Sowerby II, 1842: 66, pl. 15, fig. 115.
Pecten (*Nodipecten*) *nodosus* (Linnaeus). Dall, 1898: 728.
Chlamys (*Lyropecten*) *nodosa* (Linnaeus). Tucker -Rowland, 1938: 25, pl. 2, fig. 8, not fig. 9 [= *N. pernodosus* (Heilprin, 1887)].
Lyropecten (*Nodipecten*) *nodosus* (Linnaeus). Abbott, 1954: 169.
Chlamys (*Nodipecten*) *nodosa* (Linnaeus). Mongin, 1968: 489, pl. 48, fig. 2, pl. 49, figs 1-2.
Nodipecten nodosus (Linnaeus). Smith, 1991b: 93, pl. 3, figs 3-4, 6, pl. 4, figs 3-4, pl. 7, figs 6-7, pl. 8, figs 1, 3-4, pl. 9, figs 1-2.

Original description.—"O. testa radiis. 9 nodoso-vesicularibus" (Linnaeus, 1758: species no. 164).

Additional description.—Nodipecten with moderate umbonal angle of *ca.* 90°, not greatly flaring, with L exceeding Ht and hl approximately ½ L in mature specimens; central sector of LV having rib pattern of N n Nc n N, commonly with 2 additional minor ribs on each side, lateralmost minor ribs commonly incipient yet bearing nodes; left ribs moderately high, rounded, wider than interspaces, with bulbous hollow nodes of moderate height commonly forming at regular intervals throughout ontogeny, sometimes beoming open flanges in late ontogeny; RV with 9 or 10 ribs of moderate height, broader than interspaces with rounded crests, steep-sided in early ontogeny, with weakly developed nodes; secondary radial costae present across disk and interspaces of both valves, slightly coarser in interspaces than on rib crests. Posterior auricle *ca.* ⅔ length of anterior auricle, all auricles coarsely costate.

Type material and measurements.—A lectotype was designated by Smith (1991b: 93, pl. 4, figs 3-4) as Museum Ludovicae Ulricae no. 106 [*sic*, 108] of the Linnaean Collection, University of Uppsala, Sweden. It is a pair of matching valves with dimensions, according to Smith, of 9.6 cm Ht by 9.5 cm L. Dijkstra (1999: 408, fig. 8E), in a review of the type specimens of Pectinidae described by Linnaeus, provided another figure of the lectotype and corrected the measurements to 84 mm Ht and 93 mm L [as "width"].

Type locality.—Smith (1991b: 93) pointed out that Linnaeus' original locality, "O. Africano & Indico," is erroneous and that "the holotype [*sic*, lectotype] matches material from the southern Caribbean, especially specimens from Margarita Island, Venezuela." Dijkstra (1999: 408) specified Margarita Island, Venezuela, as the type locality.

Other material.—8 specimens, 2 of which are articulated valves, from 5 localities in the Cibao Valley, northern Dominican Republic (Table 24).

Remarks.—In the studied collections from the Neogene of the Dominican Republic, *Nodipecten nodosus* is recognized mainly on the basis of two well-preserved articulated shells from only one locality, TU 1354 (Pl. 18, Figs 5-9). This locality is listed in the Tulane Locality Register as "Cañada de Zamba, a tributary on the west side of the Río Cana, approximately 2.5 km east of the village of Zamba, which is 7 km north of Cruz de Santiago (Santiago Rodriquez), on road to Guayubín; or 4.5 km (airline) below the ford at Caimito." According to Saunders *et al.* (1986: text-fig. 15), this locality is *ca.* 335-345 m above the base of the section and is in the Gurabo Formation. Based on nannofossils, it is above the Miocene-Pliocene boundary, possibly in the earliest Pliocene in Zone NN-12 (Saunders *et al.*, 1986: 22). This is apparently a shallow but clear-water phase of the Gurabo with calcareous silts and corals. A rich assemblage of pectinids from this locality includes *Argopecten eccentricus caimiticus*, *Lindapecten plurinominis* (bisquamous variant), *Euvola soror*, and *Antillipecten quemadosensis* n. sp. Specimens from other localities (TU 1215, 1225, 1355, and 1406) that could be *N. nodosus* are either worn or fragmentary. These localities are in the Gurabo Formation on the Río Gurabo and Río Mao with the exception of TU 1406, which was said by the Vokeses in the Tulane Locality Register to be in the Cercado Formation.

Table 23. Occurrence of *Nodipecten colinensis vokesae* in the Cibao Valley. Abbreviations: Amp, *Amusium papyraceum*; Anq, *Antillipecten quemadosensis* n. sp.; Apa, *Argopecten parathetidis* n. sp.; At, *A. thetidis*; DV, matching valves; Eg, *Euvola gurabensis* n. sp.; Es, *E. soror*; Gu, *Gurabopecten uniplicatus* n. gen., n. sp.; Ht, height; Lgg, *Leopecten gatunensis*; Lpa, *Lindapecten paramuscosus* n. sp.; LV, left valve; Sv, *Spathochlamys vaginula*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Gurabo								
USGS 8544	397-399	Gurabo	2	0	0	57.6	At, Gu	
NMB 15859	398	Gurabo	0	frag	0	50.0	none	Max. dimension of frag
TU 1210	394-396	Gurabo	0	0	1	?	Amp, At, Gu, Lpa, Sv	Occurrence *fide* Smith (1991b: 51)
TU 1278	387-389	Gurabo	0	0	1	40.0	Anq, At, Es, Gu, Lpa	
TU 1231	380-395?	float	0	1	2	64.0	Anq, At, Es, Lpa	See Smith (1991b: pl. 16, fig. 3, pl. 17, fig. 3)
NMB 15837	374-376	Gurabo	0	0	1	60.2	At, Eg, Lpa	
NMB 15855	274-277	Gurabo	3	0	0	61.0	none	
USGS 8539	272-279	Gurabo	1	0	0	38.5	none	
NMB 15861	258	Gurabo	1	0	0	41.2	none	
Río Yaque del Norte								
NMB 17272	--	Cercado	0	1	0	53.0	Lgg	
Road cuts								
TU 1209	--	Gurabo	0	0	0	--	At, Eg, Gu, Lpa, Sv	Occurrence of Ncv *fide* Smith (1991b: 51)
TU 1299	--	Gurabo	1	0	0	32.8	Anq, Apa, Lpa	
TU 1338	--	Gurabo	0	0	1	65.9	Amp, At, Eg, Gu, Lpa	Type locality of *N. colinensis vokesae* (Smith, 1991b: 51)

Associated species at that locality (Table 24) indicate that both formations might be represented in float.

On the basis of so little well-preserved material, nothing can be said about the variation of *Nodipecten nodosus* in the Dominican Republic Neogene. However, specimens from the early Pliocene of Venezuela identified as *N. collierensis* (Mansfield, 1932) by Smith (1991b: pl. 9, figs 3-4, pl. 10, fig. 6) appear rather to be *N. nodosus*. They show rib patterns, node development, and secondary costation comparable to the Dominican Republic specimens but differ in being less flaring and having narrower umbonal angles.

Comparison.—In the material from the Neogene of the Dominican Republic available for this study, *Nodipecten nodosus* is the only species having a central-sector rib pattern of N n Nc n N and is thus readily distinguished from *N. colinensis colinensis* and *N. c. vokesae*, in which the rib pattern is N 2r Nc 2 r N. *Nodipecten collierensis s. l.* and *N. pittieri* also have a central-sector pattern of N n Nc n N, but differ from *N. nodosus* in other characters. *Nodipecten collierensis* is a middle to late Pliocene species that ranged through the southeastern United States to the Gulf of Mexico coast of Mexico (see following discussion of evolution). It differs from *N. nodosus* in having more distinctly paired, flatter ribs on its left valve and lacking nodes on its right valve (Smith, 1991b: pl.10). *Nodipecten pittieri,* on the basis of its holotype from the late Pliocene Moín Formation of Costa Rica, is much more broadly flaring than *N. nodosus* with nodes in the form of open flanges giving way in later ontogeny to coarsely costate ribs and interspaces without nodes or flanges. Although Smith (1991b: 91) indicated that either *N. collierensis* or *N. pittieri* could be present in the Gurabo Formation of the Dominican Republic, I have found no definite trace of them in the collections on hand. *Nodipecten arnoldi*, a species in the late Pliocene to early Pleistocene of the Caribbean coastal regions of northern South America and nearby islands, has a central-sector pattern of N n Nc n N, but differs from the species mentioned above in having a much thicker, more massive shell with very coarse costae in rib interspaces.

Nodipecten nodosus, which lives today in the coastal waters

Table 24. Occurrence of *Nodipecten nodosus* in the Cibao Valley. Abbreviations: Aec, *Argopecten eccentricus caimiticus*; Ai, *A. inaequalis*; Amp, *Amusium papyraceum*; Anj, *Antillipecten janicoensis* n. sp.; Anq, *A. quemadosensis* n. sp.; At, *Argopecten thetidis*; Caj, *Caribachlamys jungi* n. sp.; DV, matching valves; Es, *Euvola soror*; Ht, height; Lpa, *Lindapecten paramuscosus* n. sp.; Lpl, *L. plurinominis plurinominis*; LV, left valve; Lt, *Leptopecten thompsoni*; --, not recorded.

Locality	Level (m)	Formation	RV	LV	DV	Max. Ht (mm)	Associated Pectinids	Comments
Río Cana								
TU 1354	336-346	Gurabo	0	0	2	65.5	Aec, Anq, Es, Lpl	
TU 1355	327-341	Gurabo	2	0	0	88.0	Lpl	
Río Gurabo								
TU 1231	380-395?	Gurabo	0	0	1	54.0	Anq, At, Es, Lpa	
TU 1215	276-386.5	Gurabo	1	0	0	32.2	Amp, Anq, At, Caj, Lpa	
Río Mao								
TU 1225	--	Gurabo	1	0	0	28.0	Ai, Amp, At, Es, Lpa	
Road cuts								
TU 1406	--	Cercado & Gurabo?	0	2	0	37.0	Aec, Amp, Anj, Anq, Es, Lpa, Lpl, Lt	

of the Antilles and along the Caribbean and Atlantic coasts of Central America and northern South America, has commonly been confused with *N. fragosus* (Conrad, 1849), which now lives along the coasts of the southeastern United States from Cape Hatteras to southern Florida and in the Gulf of Mexico from Florida to Mexico, with an outlying population in Bermuda. Both species have the N n Nc n N rib pattern in the central sector of their left valves but differ in rib spacing, rib profiles, and the degree of development of minor ribs adjacent to disk flanks. The ribs of the right valve of *N. fragosus* have flatter crests and are more distinctly paired, with wider spaces between pairs, than in *N. nodosus*. On left valves, *N. nodosus* commonly has two minor ribs between the central sector and the adjacent disk flank, with the lateralmost ribs commonly nodose. In contrast, *N. fragosus* commonly has only a single rib between the central sector and the disk flank; if a second rib is present, it commonly is difficult to distinguish from the disk flank and is not nodose. The degree of node development is highly variable in both species, but nodes can be completely absent in some specimens of *N. fragosus*.

Evolution.—Smith (1991b: 94) claimed that "*Nodipecten nodosus* evolved directly from *N. collierensis* in the late Miocene or early Pliocene." The basis for this claim are specimens identified as *N. collierensis* from the late Miocene and early Pliocene of Venezuela (Smith, 1991b: pl. 8, fig. 6, pl. 9, figs 3-4, pl. 10, fig. 6). These specimens differ from typical *N. collierensis* from the Tamiami Formation of Collier County, Florida, in having slightly more rounded, less distinctly paired ribs on the right valve and stronger somewhat broader minor ribs in the central sector of the left valve. In this sense, these specimens are closer to *N. nodosus* than is typical *N. collierensis*, and the Venezuelan specimens might indeed represent the beginning of the *N. nodosus* lineage as well as the beginning of a separate group that includes more typical *N. collierensis* of the southeastern United States, which evolved in the Gulf of Mexico and Florida, giving rise to extant *N. fragosus*.

A survey of extensive Smithsonian tropical American collections by the present author provided evidence that the separate evolutionary and geographic pathways followed by *Nodipecten nodosus* and *N. fragosus* were already in place by the middle Pliocene. Four nominal taxa occur in stratigraphic succession in the southern Florida peninsula: (a) *N. collierensis collierensis* (Mansfield, 23 March 1932) in the Ochopee Limestone Member of the Tamiami Formation (middle or late Pliocene) (Smith, 1991b: pl. 10, fig. 5, pl. 11, fig. 1); (b) *N. c. floridensis* (Tucker & Wilson, 28 March 1932) in the Buckingham Limestone (of original usage, in the type area near Buckingham) as well as in the Pinecrest beds (late Pliocene) (Smith, 1991b: pl. 8, fig. 5, pl. 10, figs 1, 3); (c) *N. pernodosus* (Heilprin, 1887) of the Caloosahatchee Formation (latest Pliocene and early Pleistocene) (Smith, 1991b: pl. 3, figs 1-2); and (d) the extant species, *N. fragosus*, present in the Bermont Formation (early to middle Pleistocene). *Nodipecten c. floridensis*, which Smith (1991b: 92) regarded as a junior synonym of *N. fragosus*, is transitional between *N. collierensis*

s. s. and *N. fragosus*. I would regard *N. c. floridensis* as a subspecies of *N. collierensis* because of intergradation with that species (exemplified by a sample of *ca.* 50 specimens from the Buckingham type area, USGS localities 22597 and 22598). The entire succession can be regarded as a clade united by flattened, steep-sided, distinctly paired ribs on the right valve and commonly only one distinct minor rib between the central sector and the disk flanks of the left valve. *Nodipecten peedeensis* (Tuomey & Holmes, 1855) from the late Pliocene of the Carolinas (Smith, 1991b: 95) is another member of this clade.

The southernmost of any member of the *Nodipecten fragosus* group is *N. collierensis floridensis* in the lower part of the Agueguexquite Formation of Veracruz, Mexico (locality TU 638). These specimens, which Smith (1991b: 100) regarded as a new species, *N. veracruzensis*, are indistinguishable from the Florida subspecies. The Agueguexquite Formation was dated as foraminiferal zone N20, Middle Pliocene (Piacenzian) and correlated with the Pinecrest beds by Akers (1974).

Occurrence.—In the northern Dominican Republic, *Nodipecten nodosus* occurs mainly in the Gurabo Formation, except for two fragments that might be from the Cercado Formation.

Distribution.—Nodipecten nodosus is presently living in the Caribbean and along the South American coast as far south as Brazil. Its Neogene fossil record reflects the same distribution, but with extensions into the eastern Pacific as reported by Smith (1991b: 94).

ACKNOWLEDGMENTS

I am particularly grateful to Peter Jung, Naturhistorisches Museum, Basel, Switzerland, for the generous loan of material and to the staff of that museum for numerous loan extensions. Emily and the late Harold Vokes of Tulane University provided important additional collections that now reside in the Smithsonian Institution. In the Department of Paleobiology, Smithsonian Institution, line drawings and photographic plates were prepared by JoAnn Sanner; the late Warren Blow and the late Barbara Bedette provided technical assistance; Scott Whittaker, Smithsonian SEM Laboratory, assisted with digital microphotography; and Jorge Santiago-Blay, Smithsonian Research Associate, translated the abstract into Spanish. Loans, specimen information, and catalog numbers were provided by: Jann Thompson, Mark Florence, and Judith Terry Smith, Department of Paleobiology, Smithsonian Institution, Washington, DC; Walter Etter and Olivier Schmidt, NMB, Basel, Switzerland; Warren Allmon and Paula Mikkelsen, PRI, Ithaca, New York; Bushra Hussaini, American Museum of Natural History, New York, New York; Timothy Pearce, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania; Mary Boyett, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts; Alan Kabat, Washington, DC, and Hermann Duque Caro, Bogotá, Colombia. Judith Terry Smith and Alan Beu reviewed the manuscript and provided suggestions for its improvement.

LITERATURE CITED

Abbott, R. T. 1954. *American Seashells*. D. Van Nostrand Company, New York**,** 541 pp.

Abbott, R T. 1974. *American Seashells. The Marine Mollusca of the Atlantic and Pacific Coasts of North America, 2nd ed.* Van Nostrand Reinhold Company, New York**,** 663 pp.

Abbott, R. T., & S. P. Dance. 1982. *Compendium of Seashells: a Color Guide to More than 4200 of the World's Marine Shells.* E. P. Dutton, New York, 411 pp.

Adams, H., & A. Adams. 1853-1858. *The Genera of Recent Mollusca, Arranged According to their Organization.* J. Van Voorst, London, in three parts: 1 (1853-1854), 484 pp; 2 (1854-1858), 661 pp; 3 (1858), 136 pls.

Addicott, W. O. 1969. Tertiary climatic change in the marginal northeastern Pacific Ocean. *Science*, 165: 583-586.

Addicott, W. O. 1972. Provincial middle and late Tertiary molluscan stages, Temblor Range, California. *Proceedings, Pacific Coast Miocene Biostratigraphic Symposium*, Pacific Section S.E.P.M. Meeting, Bakersfield, California, 1972, pp. 1-26.

Addicott, W. O. 1976. Neogene molluscan stages of Oregon and Washington. *Neogene Symposium,* Pacific Section S.E.P.M. Meeting, San Francisco, California, 1976, pp. 95-115.

Addicott, W. O. 1978. Pectinids as biochronologic indices in the Neogene of the eastern north Pacific. *Proceedings of the Second Working Group Meeting, Biostratigraphic Datum-Planes of the Pacific Neogene, IGCP Project 114, Bandung, May 30-June 1, 1977, Indonesia Geological Research and Development Centre, Special Publication,* 1: 11-23.

Aguerrevere, P. I. 1925. Description of a new *Pecten* from Venezuela, S.A. *Bulletin of the Southern California Academy of Sciences*, 24(2): 51-53.

Akers, W. H. 1972. Planktonic Foraminifera and biostratigraphy of some Neogene formations, northern Florida and Atlantic Coastal Plain. *Tulane Studies in Geology and Paleontology*, 9: 1-139.

Akers, W. H. 1974. Age of Pinecrest Beds, south Florida. *Tulane Studies in Geology and Paleontology*, 11: 119-120.

Allmon, W. 2005. Review of: *Cenozoic Seas: the View from Eastern North America* by Edward J. Petuch, 2004. *Palaios*, 20: 208-209.

Anderson, F. M. 1929. Marine Miocene and related deposits of north Colombia. *California Academy of Sciences Proceedings,* ser. 4, 18(4): 73-212.

Anderson, F. M., & B. Martin. 1914. Neocene record in the Temblor Basin, California**,** and Neocene deposits of the San Juan district, San Luis Obispo County. *California Academy of Sciences Proceedings,* ser. 4, 4: 15-112.

Arnold, R. 1906. Tertiary and Quaternary pectens of California. *United States Geological Survey Professional Paper* 47: 1-264.

Baldí, T., G. Less, & O. Mandic. 1999. Some new aspects of the lower boundary of the Egerian stage (Oligocene, chronostratigraphic scale of the Paratethys area). *Abhandlungen der Geologischen Bundensanstalt,* 56(2): 653-668.

Bayer, F. M. 1941. Notes on Florida Mollusca, with descriptions of two new varieties. *The Nautilus*, 55(2): 43-46.

Bayer, F. M. 1943. Observations on marine Mollusca, with descriptions of new species. *The Nautilus*, 56(4): 109-115.

Bernardi, M. 1861. Description d'espéces nouvelles. *Journal de Conchyliologie*, 9: 46-49.

Berry, S. S. 1957. Notices of new eastern Pacific Mollusca - I. *Leaflets in Malacology*, 1(14): 75-82.

Berry, S. S. 1968. Notices of new eastern Pacific Mollusca - VII. *Leaflets in Malacology*, 1(25): 155-158.

Beu, A. G. 1965. Ecological variation of *Chlamys dieffenbachi* (Reeve) (Mollusca, Lamellibranchiata). *Transactions of the Royal Society of New Zealand*, 7(5): 93-96.

Beu, A. G. 1995. Pliocene limestones and their scallops. Lithostratigraphy, pectinid biostratigraphy and paleogeography of eastern North Island late Neogene limestone. *Institute of Geological & Nuclear Sciences Ltd. [New Zealand],* monograph 10: 1-243.

Beurlen, K. 1944. Beiträge zur Stammesgeschichte der Muscheln. *Sitzzungsberichte der mathematisch-naturwissenschaftlichen Abteilung der Bayerischen Akademie der Wissenchasften zu München*, 1-2: 133-145.

Blackwelder, B. W. 1981. Late Cenozoic stages and molluscan zones of the U.S. middle Atlantic Coastal Plain. *Paleontological Society Memoirs*, 12: 1-34.

Bloom, S. A. 1975. The motile escape response of a sessile prey: a sponge-scallop mutualism. *Journal of Experimental Marine Biology and Ecology*, 17: 311-321.

Bold, W. A. van den. 1968. Ostracoda of the Yaque Group (Neogene) of the northern Dominican Republic. *Bulletins of American Paleontology*, 54: 1-106.

Bold, W. A. van den. 1969. Neogene Ostracoda from southern Puerto Rico. *Caribbean Journal of Science*, 9: 117-133.

Bold, W. A. van den. 1975. Ostracodes from the late Neogene of Cuba. *Bulletins of American Paleontology*, 68: 117-167.

Bold, W. A. van den. 1988. Neogene paleontology in the northern Dominican Republic. 7. The subclass Ostracoda (Arthropoda: Crustacea). *Bulletins of American Paleontology*, 94: 1-105.

Bolli, H. M., & P. J. Bermúdez. 1965. Zonation based on planktonic Foraminifera of Middle Miocene to Pliocene warm-water sediments. *Boletin Informativo, Asociación Venezolana de Geología, Minería y Petróleo*, 8(5): 119-149.

Bongrain, M., B. Cahuzac, & S. Freneix. 1994. *Amussiopecten* (*Costellamussiopecten*) *praehaueri* nov. subgen., nov. sp. (Pectinidae, Bivalvia) de l'Aquitanien basal d'Aquitaine. Considérations sur la lignée des *Costellamussiopecten*. *Revue de Paléobiologie*, 13: 97-115.

Bongrain, M., & B. Cahuzac 2004. *Cristatopecten* nov. gen. *benoisti* (Pectinidae, Bivalvia) du Chattien d'Aquitaine (France), révision systématique et réflexions sur l'origine et l'évolution *des Cristatopecten*. *Geobios*, 37: 488-515.

Born. I. von. 1778. *Index Rerum Naturalium Musei Caesarei Vindobonensis. Pars I. Testacea*. Vindobonoe, ex Officina Krausiana, Vindobonoe, 458 pp.

Boss, K. J. 1982. Mollusca. Pp 945-1166, in: *Synopsis and Classification of Living Organisms*, S. P. Parker (ed.), McGraw-Hill Book Company, New York.

Boss, K .J., J. Rosewater, & F. A. Ruhoff. 1968. The zoological taxa of William Healey Dall. *United States National Museum Bulletin* 287: 427 pp.

Brand, A. R. 2006. Scallop ecology: distributions and behaviour. Pp 651-744, in: *Scallops: Biology, Ecology and Aquaculture*, *2nd ed.*, S. Shumway & G. Parsons (eds), Elsevier, New York.

Brocchi, G. 1814. *Conchiologia Fossile Subapennina con Osservazioni Geologiche sugli Apennini e Sul Suolo Adiacente*. Stamperia Reale, Milan, Italy, pp. 241-712.

Bronn, H. G. 1828. [Description of *Pecten cristatus* Bronn n. sp.] *Zeitschrift für Mineralogie,* 2 [1827]: 542.

Bronn, H. G. 1832. *Ergebnisse meiner naturhistorisch-ökonomischen Reisen. Zweyter Theil: Skizzen und Ausarbeitungen über Italien nach einem zweiten Besuche im Jahre 1827*. Goos, Heidelberg & Leipzig, 686 pp.

Brown, A. P., & H. A. Pilsbry. 1911. Fauna of the Gatun Formation, Isthmus of Panama. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 63: 336-373.

Brown, A. P., & H. A. Pilsbry. 1913. Fauna of the Gatun Formation, Isthmus of Panama. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 64: 509-519.

Campbell, L. D. 1993. Pliocene molluscs from the Yorktown and Chowan River Formations in Virginia. *Virginia Division of Mineral Resources Publication* 127: 1-259.

Carreño, A. L., & J. T. Smith. 2007. Stratigraphy and correlation for the ancient Gulf of California and Baja California Peninsula, Mexico. *Bulletins of American Paleontology*, 371: 146 pp.

Carter, J. G. 1990. Evolutionary significance of shell microstructure in the Palaeotaxodonta, Pteriomorphia and Isofilibranchia (Bivalvia: Mollusca). Pp. 136-296, in: *Skeletal Biomineralization: Patterns, Processes and Evolutionary Trends, Vol. 1*, J. G. Carter (ed.), Van Nostrand Reinhold, New York.

Cheetham, A. H., & J. B. C. Jackson. 1996. Speciation, extinction, and the decline of arborescent growth in Neogene and Quaternary cheilostome Bryozoa of tropical America. Pp. 205-233, in: *Evolution and Environment in Tropical America*, J. B. C. Jackson, A. F. Budd, & A. G. Coates (eds), University of Chicago Press, Chicago.

Clark, G. R., II. 1971. The influence of water temperature on the morphology of *Leptopecten latiauratus* (Conrad, 1837). *The Veliger*, 13: 269-272.

Clark, G. R., II. 1974. Calcification on an unstable substrate: marginal growth in the mollusk *Pecten diegensis*. *Science*, 183: 968-970.

Coan, E.V., P. V. Scott, & F. R. Bernard. 2000. *Bivalve Seashells of Western North America.* Santa Barbara Museum of Natural History Monographs Number 2. Santa Barbara Museum of Natural History, Santa Barbara, California, 764 pp.

Collins, L. S. 1993. Neogene paleoenvironments of the Bocas del Toro Basin, Panama. *Journal of Paleontology*, 67: 699-710.

Collins, L. S., A. G. Coates, W. A. Berggren, M.-P. Aubry, & J. Zhang. 1996. The late Miocene Panama isthmian strait. *Geology*, 24: 687-690.

Collins, L. S. & A. G. Coates. 1999. A paleobiotic survey of Caribbean faunas from the Neogene of the Isthmus of Panama. *Bulletins of American Paleontology*, 357: 5-13.

Conrad, T. A. 1837. Descriptions of new marine shells, from upper California. Collected by Thomas Nuttall, Esq. *Journal of the Academy of Natural Sciences of Philadelphia*, 7(2): 227-268.

Conrad, T. A. 1849. Notes on shells, with descriptions of new genera and species. *Journal of the Academy of Natural Sciences of Philadelphia,* ser. 2, 1(3): 210-214.

Conrad, T. A. 1862. Descriptions of new genera, subgenera, and species of Tertiary and Recent shells. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 14: 284-291.

Conrad, T. A. 1865. Descriptions of new Eocene shells from Enterprise, Mississippi. *American Journal of Conchology,* 1: 137-141.

Cooke, C. W. 1919. Tertiary mollusks from the Leeward Islands and Cuba. Pp. 103-156, in*: Contributions to the Geology and Paleontology of the West Indies*, T. W. Vaughan (ed.), Carnegie Institution of Washington, Washington, DC.

Cooke, C. W. 1921. New names for West Indian pectens. *The Nautilus*, 34: 137.

Cosel, R. von. 1986. Molluscos de la region de la Cienaga Grande de Santa Marta (costa del Caribe de Colombia). *Annales del Instituto de Investigaciones Marinas de Punta de Betin [Colombia]*, 15-16: 79-370.

Costa, F. H. A., R. H. Nehm, & C. S. Hickman. 2001. Neogene paleontology of the northern Dominican Republic. 22. The family Neritidae (Mollusca: Gastropoda). *Bulletins of American Paleontology*, 359: 47-71.

Cotton, M. A. 1999. Neogene planktic foraminferal biochronology of the southern Central American isthmus. In: *A Paleobiotic Survey of Caribbean Faunas from the Neogene of the Isthmus of Panama*, L. S. Collins & A. G. Coates (eds). *Bulletins of American Paleontology*, 357: 61-80.

Cox, L. R. 1927. Neogene and Quaternary Mollusca from the Zanzibar Protectorate. Pp. 113-102, in: *Report on the Paleontology of the Zanzibar Protectorate*, A. M. Davies, L. R. Cox, G. M. Stockley, C. J. Stubblefield, & E. I. White, Government of the Zanzibar Protectorate.

Cox, L. R., 1969. General features of Bivalvia. Pp. N2-N129, in: *Treatise on Invertebrate Paleontology, Part N, Mollusca 6, Bivalvia, Vol. 1*, R. C. Moore (ed.), Geological Society of America, Boulder, Colorado, and University of Kansas, Lawrence.

Cronin, T. M., L. M. Bybell, R. Z. Poore, B. W. Blackwelder, J. C. Liddicoat, & J. E. Hazel. 1984. Age and correlation of emerged Pliocene and Pleistocene deposits, U.S. Atlantic Coastal Plain. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 47: 41-51.

Cronk, Q. C. B. 1992. Relict floras of Atlantic islands: patterns assessed. *Biological Journal of the Linnean Society*, 46: 91-103.

Cronk, Q. C. B. 1997. Islands: stability, diversity, conservation. *Biodiversity and Conservation,* 6: 477-493.

Cropp, D. A. 1994. Hatchery production of western Australian scallops. *Memoirs of the Queensland Museum*, 36: 269-275.

Crosse, H. 1885. Nomenclatura generica e specifica di alcune conchiglie mediterranee, pel Marchese di Monterosato. *Journal de Conchiliologie*, 33: 149-142.

Cuvier, G. L. C. F. C. 1797. *Tableau Élémentaire de l'Histoire Naturelle des Animaux*. Paris, 710 pp.

Dall, W. H. 1881. Reports on the results of dredging under the supervision of Alexander Agassiz, in the Gulf of Mexico and in the Caribbean Sea, 1877-79, by the U.S. Coast Survey steamer "Blake," Lieutenant-commander C. D. Sigsbee, U.S.N., and Commander J. R. Bartlett, U.S.N., commanding. XV. Preliminary report on the Mollusca. *Bulletin of the Museum of Comparative Zoology*, 9(2): 3-144.

Dall, W. H. 1886. Reports on the results of dredging, under the supervision of Alexander Agassiz, in the Gulf of Mexico (1877-78) and in the Caribbean Sea (1879-80), by the U.S. Coast Survey Steamer "Blake," Lieut.-Commander C. D. Sigsbee, U.S.N., and Commander J. R. Bartlett, U.S.N., commanding. XXIX. Report on the Mollusca. Part I. Brachiopoda and Pelecypoda. *Bulletin of the Museum of Comparative Zoology*, 12(6): 171-318.

Dall, W. H. 1889. A preliminary catalog of the shell-bearing marine mollusks and brachiopods of the southeastern coast of the United States, with illustrations of many of the species. *Bulletin of the United States National Museum*, 37: 1-232.

Dall, W. H. 1897. New west American shells. *The Nautilus*, 11(8): 85-86.

Dall, W. H. 1898. Contributions to the Tertiary fauna of Florida with especial reference to the Silex beds of Tampa and the Pliocene beds of the Caloosahatchie River, including in many cases a complete revision of the generic groups treated of and their

American Tertiary species. Part IV. I. Prionodesmacea: *Nucula* to *Julia*. II. Teleodesmacea: *Teredo* to *Ervilia*. *Transactions of the Wagner Free Institute of Science of Philadelphia*, 3(4): 571-947.

Dall, W. H. 1908. Reports on the dredging operations off the west coast of Central America to the Galapagos, to the west coast of Mexico, and in the Gulf of California, in charge of Alexander Agassiz, carried by the U. S. Fish Commission steamer "Albatross", from October 1904 to March 1905, Lieut. Commander L. M. Garrett, U.S.N. commanding. XIV. The Mollusca and Brachiopoda. *Bulletin of the Museum of Comparative Zoology*, 43(6): 205-487, 22 pls.

Dall, W. H. 1912. New species of fossil shells from Panama and Costa Rica. *Smithsonian Miscellaneous Collections*, 59(2): 1-10.

Dall, W. H. 1924. Supplement to the Report of the Canadian Arctic Expedition, 1913-18, Volume VIII, Part A, Mollusks, Recent and Pleistocene (1919). Pp. 31A-35A, in: *Report of the Canadian Arctic Expedition, 1913-18*, F. A. Acland, Ottawa, Canada.

Dall, W. H. 1925. Notes on the nomenclature of some of our east American species of *Pecten* with descriptions of new species. *The Nautilus*, 38: 112-120.

Dall, W. H. 1926. A new pecten from Colombia. *Proceedings of the Biological Society of Washington*, 39: 61.

Dall, W. H., P. Bartsch, & H. A. Rehder. 1938. A manual of the Recent and fossil marine pelecypod mollusks of the Hawaiian Islands. *Bernice P. Bishop Museum Bulletin*, 153: 1-233.

Dall, W. H., & C. T. Simpson. 1901. The Mollusca of Porto Rico. *United States Fish Commission Bulletin* 1 (for 1900): 351-524.

Dautzenberg, P. 1900. Croisières du yacht *Chazalie* dans l'Atlantique. Mollusques. *Mémoires de la Société Zoologique de France*, 13: 145-265.

Dautzenberg, P., & A. Bavay. 1912. Les Lamellibranches de l'Expedition du Siboga. Partie systematique. 1. Pectinidés. Pp. 127-167, in: *Siboga-Expeditie,*, vol. 34 (monograph 34b), M. Weber (ed.), Brill, Leiden.

de Huelbes A., J. 1988. *Chlamys cruciana* (Bivalvia: Pectinidae) en los sedimentos de la Formación La Cruz de los alrededores de la Ciudad de Santiago de Cuba. *Revista Tecnológica [Havana]*, 18(3): 30-39.

del Norte, A. G. C. 1991. Philippines. Pp 825-834, in: *Scallops: Biology, Ecology and Aquaculture*, S. Shumway (ed.), Elsevier, New York.

del Río, C. J. 1991. Revisión sistemática de los bivalvos de la Formacion Paraná (Mioceno medio) – Provincia de Entre Ríos – Argentina. *Academia Nacional de Ciencias Exactas, Físicas y Naturales, Monografia* 7: 1-93.

del Río, C. J. 1992. Middle Miocene bivalves of the Puerto Madryn Formation, Valdes Peninsule, Chubut Province, Argentina (Nuculidae – Pectinidae). Part 1. *Palaeontographica, Abteilung A, Palaozoologie-Stratigraphie*, 225: 1-58.

del Río, C. J. 2004. Tertiary marine molluscan assemblages of eastern Patagonia (Argentina): a biostratigraphic analysis. *Journal of Paleontology*, 78: 1097-1122.

del Río, C. J. 2006. El género *Nodipecten* Dall (Bivalvia, Pectinidae) en el Neógeno de la Patagonia (Argentina). *Ameghiniana*, 43: 745-756.

Depéret, C., & F. Roman. 1910. Monographie des Pectinidés Néogènes de l'Europe & des régions voisines. II. Genre *Flabellipecten* Sacco, 1897. *Mémoires de la Société de France, Paléontologie*, 18(2): 105-138.

Dijkstra, H. H. 1994. De Pectinidae en Propeamussiidae van de A.B.C.-Eilanden. Pp. 44-52, in: *De Horen en Zijn Echo,* M. Coomans-Eustatia, R. Moolenbeek, W. Los, & P. Prins (eds), Stichting Libri Antillliani, Bloemendaal, The Netherlands.

Dijkstra, H. H. 1999. Type specimens of Pectinidae (Mollusca: Bivalvia) described by Linnaeus (1758-1771). *Zoological Journal of the Linnean Society*, 125: 383-443.

Dijkstra, H. H., & S. Gofas. 2004. Pectinoidea (Bivalvia: Propeamussiidae and Pectinidae) from some northeastern Atlantic seamounts. *Sarsia*, 89: 33-78.

Dijkstra, H. H., & B. A. Marshall. 2008. The Recent Pectinoidea of the New Zealand region (Mollusca: Bivalvia: Propeamussiidae, Pectinidae and Spondylidae). *Molluscan Research*, 28(1): 1-88.

Donovan, S. K. 1998. An introduction to the Bowden Shell Bed, southeast Jamaica. *Contributions to Tertiary and Quaternary Geology (Leiden)*, 35: 3-8.

Dunker, G. 1877. Mollusca nonnula nova maris Japonici. *Malakozoologische Blätter*, 24: 67-75.

Durham, J. W. 1950. Megascopic paleontology and marine stratigraphy, in 1940 E. W. Scripps Cruise to the Gulf of California, pt. II. *Geological Society of America Memoir* 43: 1-216.

Eberzin, A. G. 1960. Molliuski – pantsirnye, dvustvorchatye, lopatonogie. Pp 1-300, in: *Osnovy Paleontologii*, Yu. A. Orlov (ed.), USSR Academy of Science, Moscow.

Edwards, R .E. 1944. Ostracoda from the Duplin marl (U. Miocene) of North Carolina. *Journal of Paleontology*, 18: 505-528.

Etherington, T. J. 1931. Stratigraphy and fauna of the Astoria Miocene of southwest Washington. *University of California Publications, Bulletin of the Department of Geological Sciences*, 20(5): 31-142.

Ferreira, C. S. 1960. Contribuiçao á paleontologia do estado do Pará. Revisao da família Pectinidae da formaçao Pirabas (Mioceno inferior), com a discriçao de novas espécies. VI. Mollusca-Pelecypoda. *Arquivos do Museu Nacional (Brazil)*, 50: 135-165.

Férussac, A. E. De. 1822. *Tableaux Systématiques des Animaux Mollusques*. A. Bertrand, Paris, 111 pp.

Fischer, P. H. 1880-1887. *Manuel de Conchyliologie et de Paléontologie Conchyliologique ou Histoire Naturelle des Mollusques Vivants et Fossiles*. F. Savy, Paris, xxix + 1369 pp.

Fischer-Piette, E. 1950. Liste des types décrits dans le Journal de Conchyliologie et conservés dans la collection de ce journal. *Journal de Conchyliologie*, 90: 8-23.

Forbes, E. 1844. Report on the Mollusca and Radiata of the Aegean

Sea, and on their distribution, considered as bearing on geology. *British Association for the Advancement of Science, Report for 1843*: 130-193.

Franco, G. L. 1983. Nuevas subespecies de bivalvos del Neógeno de Cuba oriental. Pp. 267-271, in: *Contribucion a la Geología de Cuba Oriental*, Anonymous (ed.), Editorial Científico-Técnica, Havana.

Freiheit, J. R., & D. H. Geary. 2009. Neogene paleontology of the northern Dominican Republic. 23. Strombid gastropods (genera *Strombus* and *Lobatus*; Mollusca: Gastropoda: Strombidae) of the Cibao Valley. *Bulletins of American Paleontology*, 376: 1-54.

Freneix, S., S. Calzada, & E. Fatton. 1982. *Amussiopecten baranensis* (Almera & Bofill, 1897) = *Amussiopecten destefanii* (Ugollini, 1903), bivalve du Miocène de Catalogne. Remarques sur le genre *Amussiopecten*. *Geobios*, 15(2): 181-198.

Gabb, W. M. 1873. On the topography and geology of Santo Domingo. *American Philosophical Society Transactions*, n. s., 15: 49-259.

Gamero, G., & L. Díaz de Gamero. 1964. Estudio de una sección de referencia de las formaciones Cerro Pelado y Socorro en la región de Saladillo, Estado Falón. *Boletin Informativo, Asociación Venezolana de Geología, Minería y Petróleo*, 7: 329-367.

Gardner, J. 1926. The molluscan fauna of the Alum Bluff group of Florida. Part 1. Prionodesmacea and Anomalodesmacea. *United States Geological Survey Professional Paper* 142-A: 64 pp., 15 pls.

Gardner, J. 1945. Mollusca of the Tertiary formations of northeastern Mexico. *Geological Society of America Memoir* 11: 1-332.

Gibbard, P. L., M. J. Head, M. J. C. Walker, & the Subcommission on Quaternary Stratigraphy. 2010. Formal ratification of the Quaternary System/Period and the Pleistocene Series/Epoch with a base at 2.58 Ma. *Journal of Quaternary Science*, 25(2): 96-102.

Gibson-Smith, J. 1976. A new taxon in the genus *Charonia* (Mollusca: Gastropoda) from the Pliocene of Venezuela, and its implications. *Boletin Informativo, Asociación Venezolana de Geología, Minería y Petróleo*, 10: 1-15.

Glawe, L. N. 1969. *Pecten perplanus* stock (Oligocene) of the southeastern United States. *Geological Survey of Alabama Bulletin* 91: 1-179.

Gmelin, J. F. 1791. *Caroli Linnaei Systema Naturae per Regna Tria Naturae. 13th ed., Aucta, Reformata, Vermes Testacea.* Lipsiae,1(6): 3021-2910 [for dating, see Hopkinson, 1907, and Kabat & Petit, 1988].

Gould, A. A. 1850. The shells from the United States Exploring Expedition. *Boston Society of Natural History, Proceedings*, 3: 275-278, 309-312, 343-348.

Gradstein, F. M., J. G. Ogg, & A. G. Smith. 2004. *A Geologic Time Scale 2004.* Cambridge University Press, Cambridge, UK, 589 pp.

Grau, G. 1959. Pectinidae of the eastern Pacific. *Allan Hancock Pacific Expeditions*, 23: 308 pp.

Gregorio, A. de. 1884. Nota intorno ad alcune nuove Conchiglie mioceniche di Sicilia. *Naturalista Siciliano,* 3: 119-120.

Guppy, R. J. L. 1866. On the Tertiary Mollusca of Jamaica. *Quarterly Journal of the Geological Society of London*, 22: 281-295.

Guppy, R. J. L. 1867. On the Tertiary fossils of the West-Indies, with especial reference to the classification of the Kainozoic rocks of Trinidad. *Scientific Association of Trinidad, Proceedings*, 1(3): 145-176 [reprinted 1921, *Bulletins of American Paleontology*, 35: 14-55].

Guppy, R. J. L. 1876. On the Miocene fossils of Haiti. *Quarterly Journal of the Geological Society of London*, 32: 516-532.

Hanna, G. D. 1926. Paleontology of Coyote Mountain, Imperial County, California. *California Academy of Sciences Proceedings*, ser. 4, 13(10): 151-156.

Hanna, G. D., & L. G. Hertlein. 1927. Expedition of the California Academy of Sciences to the Gulf of California in 1921; geology and paleontology. *California Academy of Sciences Proceedings*, ser. 4, 16(6): 137-156.

Harzhauser, M., A. Kroh, O. Mandic, W. E. Piller, U. Göhlich, M. Reuter, & B. Berning. 2007. Biogeographic responses to geodynamics: a key study all around the Oligo-Miocene Tethyan Seaway. *Zoologischer Anzeiger*, 246: 241-256.

Hayami, I. 1984. Natural history and evolution of *Cryptopecten*, a Cenozoic-Recent pectinid genus. *University Museum, University of Tokyo, Bulletin* 24: 1-149.

Heilprin, A. 1887. Additional species from the Pliocene deposits of the Caloosahatchie (Supplement). Pp. 131-134, in: *Explorations of the West Coast of Florida and in the Okeechobee Wilderness with Special Reference to the Geology and Zoology of the Floridian Peninsula*. *Transactions of the Wagner Free Institute of Philadelphia, Philadelphia*, 1 [reprinted 1964, Paleontological Research Institution, Ithaca, New York].

Herrmannsen, A. N. 1846-1847. *Indicis Generum Malacozoarum Primordia . . . Praetermittuntur Cirripedia, Tunicata, et Rhizopoda*, vol. 1. Cassel, 637 pp.

Hertlein, L. G. 1933. Three preoccupied names in the Pectinidae. *The Nautilus*, 47(2): 62-63.

Hertlein, L. G. 1935. The Templeton Crocker Expedition of the California Academy of Sciences, 1932. *Proceedings of the California Academy of Sciences*, ser. 4, 21(25): 301-328.

Hertlein, L. G. 1936. Three new sections and rectifications of some specific names in the Pectinidae. *The Nautilus*, 5: 24-27.

Hertlein, L. G. 1966. Pliocene fossils from Rancho El Refugio, Baja California, and Cerralvo Island, Mexico. *California Academy of Sciences Proceedings*, ser. 4, 30(14): 265-284.

Hertlein, L. G. 1969. Family Pectinidae Rafinesque, 1815. Pp. N348-N373, in: *Treatise on Invertebrate Paleontology, Part N, Mollusca 6, Bivalvia*, R. C. Moore (ed.), Geological Society of America, Boulder Colorado, and University of Kansas Press, Lawrence.

Hertlein, L. G., & A. M. Strong. 1946. Eastern Pacific expeditions

of the New York Zoological Society. XXXIV. Mollusks from the west coast of Mexico and Central America. Part III. *Zoologica, Scientific Contributions of the New York Zoological Society*, 31(2): 53-76.

Hinds, R. B. 1844-1845. *The Zoology of the Voyage of the H. M. S. Sulphur, Under the Command of Capt. Sir Edward Belcher, ... During the Years 1836-42. Vol. 2 [Mollusca]*. Smith, Elder & Company, London, 72 pp.

Hodson, F., & H. K. Hodson. 1931. Some Venezuelan mollusks. *Bulletins of American Paleontology*, 59: 1-46, 24 pls.

Hodson, F., H. K. Hodson, & G. D. Harris. 1927. Some Venezuelan and Caribbean mollusks. *Bulletins of American Paleontology*, 49: 1-160.

Hopkinson, J. 1907. Dates of publication of the separate parts of Gmelin's edition (13th) of the "Systema Naturae" of Linnaeus. *Proceedings of the Zoological Society of London*, 1907(49): 1035-1037.

Hubbard, B. 1920. Tertiary Mollusca from the Lares District. *New York Academy of Sciences Survey of Porto Rico and the Virgin Islands,* 3(2): 79-164.

Huddlestun, P. F. 1993. A revision of the lithostratigraphic units of the Coastal Plain of Georgia. The Oligocene. *Georgia Geological Survey Bulletin*, 105: 152 pages.

Hunter, V. F. 1978. Foraminiferal correlation of Tertiary mollusc horizons of the southern Caribbean area. *Geologie en Mijnbouw*, 57: 193-203.

International Commission on Zoological Nomenclature [ICZN]. 1999. *International Code of Zoological Nomenclature, 4th ed.* International Trust for Zoological Nomenclature, London, 306 pp.

Iredale, T. 1929. Mollusca from the continental shelf of eastern Australia. *Records of the Australian Museum Sydney*, 74(4): 157-189.

Iredale, T. 1939. *Great Barrier Reef Expedition, 1928-29, Science Reports*, 5(6), Mollusca, Part 1: 425 pp.

Issel, A. 1869. *Malacologia del Mar Rosso, Richerche Zoologiche et Paleontologiche*. Biblioteca Malacologia, Pisa, Italy, 387 pp.

Jordan, E. K., & L. G. Hertlein. 1926. Contribution to the geology and paleontology of the Tertiary of Cedros Island and adjacent parts of Lower California. *California Academy of Sciences Proceedings*, ser. 4, 15(14): 409-464.

Jung, P. 1969. Miocene and Pliocene mollusks from Trinidad. *Bulletins of American Paleontology,* 55: 293-657.

Jung, P. 1971. Fossil mollusks from Carriacou, West Indies. *Bulletins of American Paleontology*, 61: 147-262.

Jung, P. 1986. Neogene paleontology in the northern Dominican Republic. 2. The *genus Strombina* (Gastropoda: Columbellidae). *Bulletins of American Paleontology*, 90: 1-42.

Jung, P. 1989. Revision of the *Strombina*-group (Gastropoda: Columbellidae), fossil and living. Distribution, biostratigraphy, and systematics. *Schweizerische Paläontologische Abhandlungen,* 111: 298 pp.

Kabat, A. R., & R. E. Petit. 1988. The two printings of J. F. Gmelin's *Systema Naturae*, 13th edition (1788-96). *The Nautilus*, 102: 164-166.

Kier, P. M., R. E. Grant, & E. L. Yochelson. 1965. Whitening fossils. Pp. 453-456, in: *Handbook of Paleontological Techniques*, B. Kummel & D. Raup (eds), W. H. Freeman and Company, San Francisco.

Kohl, B., & E. Robinson. 1998. Foraminifera and biostratigraphy of the Bowden shell bed, Jamaica, West Indies. Pp. 29-46, in: *The Pliocene Bowden Shell Bed, Southeast Jamaica*, S. K. Donovan, *Contributions to Tertiary and Quaternary Geology*, 35(1-4): 29-46.

Kugler, H. G. (edited by H. M. Bolli & M. Knappertsbusch). 2001. *Treatise on the Geology of Trinidad. Part 4: The Paleocene to Holocene Formations.* Museum of Natural History Basel, Basel, Switzerland, 309 pp.

Lamarck, J. B. P. 1806. Suite des mémoires sur les fossiles des environs de Paris, [genre LXXV – genre LXXVII]. Pp. 347-355, in: *Mémoires sur les Fossiles des Environs de Paris, Comprenant la Détermination des Espèces qui Appartiennent aux Animaux Marins sans Vertèbres, et don't la Plupart sont Figurés dan la Collection des Vélins du Muséum*. *Annales du Muséum National d'Histoire Naturelle*, 8.

Lamarck, J. B. P. 1816. *Histoire Naturelle des Animaux sans Vertèbres*, 2. Verdière, Paris, 568 pp.

Lamarck, J. B. P. 1819. *Histoire Naturelle des Animaux sans Vertèbres*, 6(1), A. Belin, Paris, 353 pp.

Landau, B, G. Vermeij, & C. Marques da Silva. 2008. Southern Caribbean Neogene palaeobiogeography revisited. New data from the Pliocene of Cubagua, Venezuela. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 257: 445-461.

Laskey, J. 1811. Account of North British Testacea. *Memoirs of the Wernerian Natural History Society*, 1: 370-417.

Linares, O. J. 2004. Bioestratigrafía de la fauna de mamíferos de las formaciones Socorro, Urumaco y Codore (Mioceno medio-Plioceno temprano) de la región Urumaco, Falcón, Venezuela. *Paleobiología Neotropical (Contribuciones Ocasionales Editada por el Laboratorio de Paleobiología, Universidad Simón Bolívar, Caracas, Venezuela)*, 1: 1-26.

Linnaeus, C. 1758. *Systema Naturae per Regna Tria Naturae . . . Editio Decima, Reformata 1 (Regnum Animale)*. Salvii, Stockholm, 824 pp.

Locard, A. 1898. *Expéditions Scientifiques du Travailleur et du Talisman Pendant les Années 1880, 1881, 1882, 1883*. Masson, Paris, 515 pp.

Loel, W., & W. H. Corey. 1932. The Vaqueros Formation, lower Miocene of California. I. Paleontology. *University of California Publications, Bulletin of the Department of Geological Sciences*, 22(3): 31-410.

Lovén, S. 1846-1847. Index Molluscorum litora Scandinaviae occi-

dentalia hatitantium. *Ofversigt af Kongliga Vetenskaps-Akademiens Förhhandligar*, 3(5-6): 134-161, 182-204.

MacNeil, F. S. 1967. Cenozoic pectinids of Alaska, Iceland and other northern regions. *United States Geological Survey Professional Paper* 553: 1-57.

Macsotay, O., & R. Campos Villarroel. 2001. *Moluscos Representativos de la Plataforma de Margarita, Venezuela*. Editora Rivolta, Valencia, Venezuela, 280 pp.

Mandic, O. 2004. Pectinid bivalves from the Grund Formation (Lower Badenian, Middle Miocene, Alpine-Carpathian Foredeep) – taxonomic revision and stratigraphic significance. *Geologica Carpathica*, 55: 129-146.

Mansfield, W. C. 1932. Pliocene fossils from limestone in southern Florida. *United States Geological Survey Professional Paper* 170-D: 43-49.

Mansfield, W. C. 1937. Mollusks of the Tampa and Suwannee Limestones of Florida. *State of Florida, Department of Conservation, Geological Bulletin* 15: 1-334.

Mansfield, W. C. 1939. Notes on the upper Tertiary and Pleistocene mollusks of peninsular Florida. *State of Florida Department of Conservation, Geological Bulletin* 18: 1-75.

Marks, J. G. 1951. Miocene stratigraphy and paleontology of western Ecuador. *Bulletins of American Paleontology*, 33: 1-162.

Marshall, C.P. 1995. Recent changes in the Pectinidae Part 2. *American Conchologist*, 23(3): 4, 12.

Masuda, K. 1971a. On some *Patinopecten* from North America. *Transactions and Proceedings of the Palaeontological Society of Japan*, n. s., 83: 166-178.

Masuda, K. 1971b. *Amussiopecten* from North America and northern South America. *Transactions and Proceedings of the Palaeontological Society of Japan*, n. s., 84: 205-224.

Mattson, P. H. 1984. Caribbean structural breaks and plate movements. Pp. 131-152, in: *The Caribbean-South American Plate Boundary and Regional Tectonics*, W. E. Bonini, R. B. Hargraves, & R. Shagam (eds.), *Geological Society of America Memoir* 162.

Maury, C. J. 1917a. Santo Domingo type sections and fossils. Part 1. Mollusca. *Bulletins of American Paleontology*, 29: 1-251.

Maury, C. J. 1917b. Santo Domingo type sections and fossils. Part 2. Stratigraphy. *Bulletins of American Paleontology*, 30: 1-62.

Maury, C. J. 1919. A proposal for two new Miocene formational names. *Science*, 50: 591.

Maury, C. J. 1920. Tertiary Mollusca from Porto Rico. *New York Academy of Sciences, Scientific Survey of Porto Rico and the Virgin Islands,* vol. 3, part 1, 77 pp.

Maury, C. J. 1925a. A further contribution to the paleontology of Trinidad (Miocene horizons). *Bulletins of American Paleontology*, 10: 1-250.

Maury, C. J. 1925b. Fosseis terciarios do Brasil com discripçao de novas formas cretaceas. *Monographias do Serviço Geologico e Mineralogico do Brasil*, 4: 1-711.

McNamara, K. J. 1986. A guide to the nomenclature of heterochrony. *Journal of Paleontology*, 60:. 4-13.

McNeill, D. F., J. S. Klaus, C. C. Evans, & A. F. Budd. 2008. An overview of the regional geology and stratigraphy of the Neogene deposits of the Cibao Valley, Dominican Republic. Pp. 21-45, in: *Evolutionary Stasis and Change in the Dominican Republic Neogene*, R. H. Nehm, & A. F. Budd (eds), Springer Science, The Netherlands.

Meek, F. B. 1864. Checklist of the invertebrate fossils of North America: Cretaceous and Jurassic. *Smithsonian Miscellaneous Collections*, 177: 5-16, 31-34.

Mikkelsen, P. M., & R. Bieler. 2007 ("2008"). *Seashells of Southern Florida: Living Marine Mollusks of the Florida Keys and Adjacent Regions. Bivalves.* Princeton University Press, Princeton, New Jersey, 503 pp.

Milne-Edwards, H., & J. Haime. 1848. Recherches sur les polypiers. Quatrième mémoire. Monographie des Astreides. *Annales des Sciences naturelles, ser. 3, Zoologie*, 10: 209-320.

Ministerio de Energía y Minas, Dirección de Geología. 1970. Léxico estratigráfico de Venezuela, 3rd ed. *Boletín de Geología, Publicación Especial,* 12: 828 pp.

Ministerio de Energía y Minas, Dirección de Geología. 1997. Léxico estratigráfico de Venezuela, 2nd ed. *Boletín de Geología, Publicación Especial*, 4: 756 pp.

Mongin, D. 1968. Les pectinidés du Miocène de la Guadeloupe (Antilles Francaises). *Bulletins of American Paleontology*, 54: 471-510.

Monroe, W. H. 1980. Geology of the middle Tertiary formations of Puerto Rico. *United States Geological Survey Professional Paper* 953: 93 pp.

Monterosato, T. A. di. 1884. *Nomenclatura Generica e Specifica de Alcune Conchiglie Mediterranee*. Palermo, 152 pp.

Monterosato, T. A. di. 1889. Coquilles marines Marocaines. *Journal de Conchyliologie*, 37: 20-40, 112-121.

Monterosato, T. A. di. 1899. Revision de quelques *Pecten* des mers d'Europe. *Journal de Conchyliologie*, 47: 182-193.

Moore, E .J. 1963. Miocene marine mollusks from the Astoria Formation in Oregon. *United States Geological Survey Professional Paper* 419: 109 pp.

Moore, E. J. 1984. Tertiary marine pelecypods of California and Baja California: Propeamussiidae and Pectinidae. *United States Geological Survey Professional Paper* 1228-B: 112 pp,

Moore, J. C. 1850. On some Tertiary beds in the Island of San Domingo: from notes by J. S. Heneken, Esq., with remarks on the fossils. *Quarterly Journal of the Geological Society of London*, 6: 39-44.

Mörch, O. A. L. 1852. *Catalogus Conchyliorum quae Reliquit D. Alphonso d'Aquirra et Gadea Comes di Yoldi. Fasc. 1. Cephalophora.* Typus Ludovici Kleini, Hafniae [Copenhagen], 170 pp.

Morton, B. 1980. Swimming in *Amusium pleuronectes* (Bivalvia: Pectinidae). *Journal of Zoology*, 190: 373-404.

Morton, B. 1994. The biology and functional morphology of

Leptopecten latiauratus (Conrad, 1837): an 'opportunistic' scallop. *The Veliger*, 37(1): 5-22.

Morton, S.G. 1833. Supplement to the "Synopsis of the Organic Remains of Ferruginous Sand Formation of the United States" contained in vols. 17 and 18 of this Journal. *American Journal of Science*, ser. 1, 23(2): 288-294.

Müller, O. F. 1776. *Zoologiae Danicae Prodromus, seu Animalium Daniae et Norvegiae Indigenarum Characteres, Nomina, et Synonyma Imprimis Popularium*. Copenhagen, 281 pp.

Nehm, R. H. 2001. Neogene paleontology in the northern Dominican Republic. 21. The genus *Prunum* (Gastropoda: Marginellidae). *Bulletins of American Paleontology*, 359: 7-46.

Nicol, D., D. S. Jones, & J. W. Hoganson. 1989. *Anatipopecten* and the *Rotularia vernoni* Zone (Late Eocene) in peninsular Florida. *Tulane Studies in Geology and Paleontology*, 22(2): 55-59.

Nordsieck, F. 1969. *Die europäischen Meeresmuscheln (Bivalvia) vom Eismeer bis Kapverden, Mittelmeer und Schwarzes Meer*. Gustav Fischer, Stuttgart, Germany, 256 pp.

Ockelmann, K. W. 1965. Developmental types in marine bivalves and their distribution along the Atlantic coast of Europe. Pp. 25-35, in: *Proceedings of the First European Malacological Congress (London, September 17-21, 1962),* L. R. Cox & J. F. Peake (eds), Conchological Society of Great Britain and Ireland and the Malacological Society of London, London.

Olsson, A. A. 1922. The Miocene of northern Costa Rica. Part 2. Class Pelecypoda. *Bulletins of American Paleontology,* 9: 171-288.

Olsson, A. A. 1932. Contributions to the Tertiary paleontology of northern Peru: Part 5. The Peruvian Miocene. *Bulletins of American Paleontology*, 68: 1-272.

Olsson, A. A. 1961. *Mollusks of the Tropical Eastern Pacific, Particularly from the Southern Half of the Panamic-Pacific Faunal Province (Panama to Peru). Panamic-Pacific Pelecypoda*. Paleontological Research Institution, Ithaca, New York, 574 pp.

Olsson, A. A. 1964. *Neogene Mollusks from Northwestern Ecuador*. Paleontological Research Institution, Ithaca, New York, 256 pp.

Olsson, A. A., & A. Harbison. 1953. Pliocene Mollusca of southern Florida with special reference to those from north Saint Petersburg with special chapters on the Turridae by William G. Fargo and Vitrinellidae and fresh-water mollusks by Henry A. Pilsbry. *Academy of Natural Sciences of Philadelphia Monographs,* 8: 1-457.

d'Orbigny, A. D. 1842. Mollusques. in: *M. Ramon de la Sagra, Histoire Physique, Politique et Naturelle de l'Ile de Cuba, Atlas*, A. Bertrand, Paris, 28 pls.

d'Orbigny, A. D. 1846. Mollusques. Lamellibranches. Pp. 489-758, in: *Voyage dans l'Amérique Méridionale*, vol. 5, Paris, Strasbourg.

Palmer, K. V. W. 1938. Miocene spondyli from the southern United States and tropical America. *Palaeontographica Americana*, 8: 1-18, pls. 1-3.

Petuch, E. J. 1995. Molluscan discoveries from the tropical western Atlantic region. *La Conchiglia (International Shell Magazine)*, 27(275): 36-41.

Petuch, E. J. 2004. *Cenozoic Seas. The View from Eastern North America*. CRC Press, Boca Raton, Florida, 308 pp.

Petuch, E. J. 2007. *The Geology of the Everglades and Adjacent Areas*. CRC Press, Boca Raton, Florida, 212 pp.

Pflug, H. D. 1961. Mollusks aus dem Tertiär von St. Domingo. *Acta Humboldtiana, Series Geologica et Palaeontologica*, 1: 107 pp..

Piazza, M., and E. Robba. 1994. Pectinids and oysters from the Pliocene Loreto Basin (Baja California Sur, Mexico). *Rivista Italiana di Paleontologia e Stratigrafia*, 100: 33-70.

Pilsbry, H. A. 1922. Revision of W. M. Gabb's Tertiary Mollusca of Santo Domingo. *Proceedings of the Academy of Natural Sciences of Philadelphia,* 73: 305-435.

Pilsbry, H. A., & C. W. Johnson. 1917. New Mollusca of the Santo Domingan Oligocene. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 69: 150-202.

Powell, C .L., II. 1985. Bivalve molluscan paleoecology of northern exposures of the marine Neogene Imperial Formation in Riverside County, California. *Western Society of Malacologists Annual Report,* 17 (for 1984): 29-32.

Powell, C. L., II. 1986. *Stratigraphy and Bivalve Molluscan Paleontology of the Neogene Imperial Formation in Riverside County, California.* Unpublished MS Thesis, Department of Geology, San Jose State University, California, 324 pp

Powell, C. L., II, J. A. Barron, A. M. Sarna-Wojcicki, J. C. Clark, F. A. Perry, E. E. Brabb, & R. J. Fleck. 2007. Age, stratigraphy, and correlations of the Late Neogene Purisima Formation, central California Coast Ranges. *United States Geological Survey Professional Paper* 1740: 1-32.

Puslednik, L., & J. M. Serb. 2008. Molecular phylogenetics of the Pectinidae (Mollusca: Bivalvia) and effect of increased taxon sampling and outgroup selection on tree topology. *Molecular Phylogenetics and Evolution*, 48: 1178-1188.

Rafinesque, C. S. 1815. *Analyse de la Nature ou Tableau de l'Univers du des Corps Organisés.* Press of Jean Barravecchia, Palermo, 225 pp.

Ramírez, R. 1950. Descripción de algunos moluscos del Mioceno del Valle del Cibao de la República Dominicana. *Publicaciones de la Universidad de Santo Domingo*, ser. 4, 70(1): 3-39.

Ravenel, E. 1844. Descriptions of some new species of fossil organic remains, from the Eocene of South Carolina. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 2(5): 96-98.

Récluz, M. C. 1853. Description de coquilles nouvelles (g. *Pecten*, *Tellina* et *Natica*). *Journal de Conchyliologie*, 4: 152-156.

Redfern, C. 2001. *Bahamian Seashells: a Thousand Species from Abaco, Bahamas*. Bahamian Seashells.com, Boca Raton, Florida, 280 pp.

Reeve, L. A. 1853 [1852-1853]. Monograph of the genus *Pecten*. In: *Conchological Iconica; or, Illustrations of the Shells of Moluscos Animals,* vol. 8, L. A. Reeve (ed.), 35 pls. (pls. 1-8, November

1852; 9-12, December 1852; 13-16, February 1853; 17-20, April 1853; 28-28, May 1853; 29-32, June 1853; 33-35, August 1853).

Renken, R. A., W. C. Ward, I. P. Gill, F. Gómez-Gómez, J. Rodríguez-Martínez, & others. 2002. Geology and hydrology of the Caribbean islands – aquifer system of the Commonwealth of Puerto Rico and the U.S. Virgin Islands. *United States Geological Survey Professional Paper* 1419: 139 pp.

Richards, H. G. 1968. Catalog of invertebrate fossil types at the Academy of Natural Sciences of Philadelphia. *Academy of Natural Sciences of Philadelphia, Special Publication* 8: 1-222.

Ríos, E. C. 1975. *Brazilian Marine Mollusks Iconography*. Fundaçao Universidade do Rio Grande, Centro de Ciencias do Mar, Museu Oceanográfico, Rio Grande, Brazil, 331 pp.

Risso, A 1826. *Histoire Naturelle des Principales Productions de l'Europe Méridionale et Particuliérement de Celles des Environs de Nice et des Alpes Maritimes,* vol. 1. F.-G. Levrault, libraire, Paris and Strasbourg, 446 pp.

Röding, P. F. 1798. *Museum Boltenianum sive Catalogus Cimeliorum e Tribus Regnis Naturae quae Olim Collegerat Joa. Fried. Bolten, M. D., p. d., Pars Secunda Continens Conchylia sive Testacea Univalvia, Bivalvia et Multivalvia.* Typis Johan Christi Trapii, Hamburg, Germany.

Rouault, A. 1850. Description des fossiles du Terraine Éocène des environs de Pau. *Mémoires de la Société geologique de France,* ser. 2, 3: 457-502.

Sacco, F. 1897. *I Molluschi dei Terreni Terziarii del Piemonte e Della Ligura*, Pt. 24, (Pectinidae). Carlo Clausen, Torino, 74 pp.

Saunders, J. B., P. Jung, & B. Biju-Duval. 1986. Neogene paleontology in the northern Dominican Republic. 1. Field surveys, lithology, environment, and age. *Bulletins of American Paleontology*, 89: 1-79.

Schuchert, C., W. H. Dall, T. W. Stanton, & R. S. Bassler. 1905. Catalog of the type and figured specimens of fossils, minerals, rocks and ores in the Department of Geology, United States National Museum. Part I. Fossil invertebrates. *Bulletin of the United States National Museum*, 53(1): 1-704.

Schultz, O. 2001. *Catalogus Fossilium Austriae*, vol. 1, part 1. Österreichischen Akademie der Wissenschaften, Vienna, 379 pp., 56 pls.

Seeley, H. 1861. Notes on Cambridge paleontology. I. Some new Upper Greensand bivalves. *Annals & Magazine of Natural History*, ser. 3, 7: 116- 124.

Smith, E. A. 1885. Report on the Lamellibranchiata. *Report on the Scientific Results of the Voyage of the H. M. S. Challenger During the Years 1873-76, Zoology,* 13(35): 341 pp.

Smith, E. A. 1890. Report on the marine molluscan fauna of the island of St. Helena. *Proceedings of the Scientific Meetings of the Zoological Society of London*, 1890(2): 247-317.

Smith, J. T. 1984. Miocene and Pliocene marine mollusks and preliminary correlations, Vizcaino Peninsula to Arroyo La Purisima, northwestern Baja California Sur, Mexico. Pp 197-217, in*: Geology of the Baja California Peninsula,* V. A. Frizzell, Jr. (ed.), *Pacific Coast S.E.P.M.,* 39.

Smith, J. T. 1991a. Cenozoic marine mollusks and paleogeography of the Gulf of California. Pp. 637-666, in: *The Gulf and Peninsular Province of the Californias*, J. P. Dauphin & B. R. T. Simoneit (eds), *American Association of Petroleum Geologists Memoir* 47: 637-666.

Smith, J. T. 1991b. Cenozoic giant pectinids from California and the Tertiary Caribbean Province: *Lyropecten*, "*Macrochlamis*", *Vertipecten*, and *Nodipecten* species. *United States Geological Survey Professional Paper* 1391: 155 pp.

Sowerby, G. B., I. 1835. Characters of new genera and species of Mollusca and Conchifera, collected by Mr. Cuming. Genus *Pecten. Proceedings of the Zoological Society of London*, 2 (1835): 109-110.

Sowerby, G. B., I. 1847. Descriptions of figures, plates XV-XX. Pp. 417-422, in: *On the Age of the Tertiary Beds of the Tagus, with a Catalog of the Fossils*, James Smith. *Quarterly Journal of the Geological Society of London*, 3(1).

Sowerby, G. B., I. 1850. Descriptions of new species of fossil shells found by J. S. Heniker [*sic*, Heniken] Esq., in: *On Some Tertiary Beds in the Island of San Domingo: From Notes by J. S. Heniker, Esq., with Remarks on the Fossils*, by J. C. Moore. *Quarterly Journal of the Geological Society of London*, 6: 39-53.

Sowerby, G. B., II. 1842. Monograph of the genus *Pecten*. In: *Thesaurus Conchyliorum; or, Monographs of Genera of Shells*, G. B. Sowerby II (ed.), 1(2): 45-82.

Spencer, J. W. W. 1897. Great changes of level in Mexico and the interoceanic connections. *Geological Society of America Bulletin* 9: 13-34.

Spieker, E. M. 1922. The paleontology of the Zoritos Formation of the north Peruvian oil fields. *Johns Hopkins University Studies in Geology*, 9: 1-196.

Stewart, R. B. 1930. Gabb's California Cretaceous and Tertiary type lamellibranchs. *Academy of Natural Sciences of Philadelphia, Special Publications*, 3: 1-314.

Swainson, W. 1840. *A Treatise on Malacology or Shells and Shell-fish*. The Cabinet Cyclopedia, Natural History, Longman, London, 420 pp.

Sykes, E. R., E. A. Smith, & G. C. Crick (eds). 1898. *Zoological Record. Part 7: Mollusca*, 34 (1897). London, 78 pp.

Tang, C., & J. H. Pantel. 2005. Combining morphometric and paleoecological analyses: examining small-scale dynamics in species-level and community-level evolution. *Palaeo-Electronica,* 8(2): unpaginated.

Távora, A., & J. M. Garrafielo Fernandes. 1999. Estudio de los foraminiferos de la Formación Pirabas (Mioceno Inferior), estado de Pará, Brasil y su correlación con faunas del Caribe. *Revista Geológica de América Central*, 22: 63-74.

Teppner, W. von. 1922. Pars 15. Lamellibranchiata tertiaria.

"Anisomyaria." Pp. 67-296, in: *Fossilium Catalogus, I: Animalia*, C. Diener (ed.), W. Junk, Berlin.

Theroux, R. B., & R. L. Wigley. 1983. Distribution and abundance of east coast bivalve mollusks based on specimens in the National Marine Fisheries Service Woods Hole collection. *National Oceanic and Atmospheric Administration Technical Report,* NMFX SSRF-768: 1-172.

Thiele, J. 1934. *Handbuch der systematischen Weichtierkunde*, 2(3). Fischer, Jena, Germany, pp. 779-1022.

Torre, A. de la. 1971. Nueva especie de Pectinidae y notas sobre la distribución estratigráfica de *Chlamys* (*Nodipecten*) *pittieri* (Dall) en Cuba. *Ciencias, Universidad de la Habana, ser. 4 (Ciencias Biológicas)*, 13: 1-15.

Torre, A. de la, & E. Kojumdgieva. 1985. Asociaciones y niveles faunales de moluscos del Plioceneo-Cuaternario del occidente de Cuba, y sus implicaciones estratigráficas. *Reporte de Investigación del Instituto de Geología y Paleontología, Academia de Ciencias de Cuba*, 5: 1-19.

Toula, F. 1909. Eine jungtertiäre Fauna von Gatun am Panama-Kanal. *Geologischen Reichsanstalt, Jahrbuch,* 58: 637-760.

Trechmann, C. T. 1937. The base and top of the coral-rock in Barbados. *Geological Magazine*, 74: 337-359.

Tucker, H. I. 1934. Some Atlantic coast Tertiary Pectinidae. *The American Midland Naturalist*, 15: 612-621.

Tucker, H. I., & D. Wilson. 1932. Some new or otherwise interesting fossils from the Florida Tertiary. *Bulletins of American Paleontology*, 65: 41-62.

Tucker-Rowland, H. I. 1938. The Atlantic and Gulf coast Tertiary Pectinidae of the United States. Section 3. Systematic descriptions. *Mémoires de Musée Royal d'Histoire Naturelle de Belgique*, ser. 2, 13: 1-76.

Tuomey, M., & F. S. Holmes. 1855-1856. *Pleiocene Fossils of South Carolina*. Russell and Jones, Charleston, South Carolina, 152 pp.

Vaughan, T. W., C. W. Cooke, D. D. Condit, C. P. Ross, W. P. Woodring, & F. C. Calkins. 1921. A geological reconnaissance of the Dominican Republic. *Geological Survey of the Dominican Republic, Memoirs*, 1: 1-268.

Verrill, A. E. 1873. Brief contributions to zoology, from the Museum of Yale College. No. 23. Results of recent dredging expeditions on the coast of New England. *American Journal of Science and Arts*, ser. 3, 5: 1-16.

Verrill, A. E. 1882. Catalog of marine Mollusca added to the fauna of New England during the past ten years. *Transactions of the Connecticut Academy*, 5(2): 447-587.

Verrill, A. E. 1884. Second catalog of Mollusca, recently added to the fauna of the New England coast and the adjacent parts of the Atlantic, consisting mostly of deep sea species, with notes on others previously recorded. *Transactions of the Connecticut Academy*, 6(1): 139-294.

Verrill, A. E. 1885. Third catalog of Mollusca, recently added to the fauna of the New England coast and the adjacent parts of the Atlantic, consisting mostly of deep-sea species, with notes on others previously recorded. *Transactions of the Connecticut Academy*, 6(2): 395-452.

Verrill, A. E. 1897. A study of the family Pectinidae, with a revision of the genera and subgenera. *Transactions of the Connecticut Academy of Sciences*, 10: 41-96.

Vokes, E. H. 1979. The age of the Baitoa Formation, Dominican Republic, using Mollusca for correlation. *Tulane Studies in Geology and Paleontology*, 15(4): 105-116.

Vokes, E. H. 1989. Neogene paleontology in the northern Dominican Republic. 8. The family Muricidae (Mollusca: Gastropoda). *Bulletins of American Paleontology*, 97: 1-94.

Vokes, E. H., & A. d'Attilio. 1980. *Pygmaepterys*, a newly described taxon of Muricidae (Mollusca: Gastropoda), with the description of three new species from the Cenozoic of the western Atlantic. *Tulane Studies in Geology and Paleontology*, 16(2): 45-54.

Vokes, H. E. 1989. Neogene paleontology in the northern Dominican Republic. 9. The family Cardiidae (Mollusca: Bivalvia). *Bulletins of American Paleontology*, 97: 97-141, 154-160.

Vokes, H. E., & E. H. Vokes. 1992. Neogene paleontology in the northern Dominican Republic. 12. The genus *Spondylus* (Bivalvia: Spondylidae). *Bulletins of American Paleontology*, 102: 5-13.

Waller, T. R. 1969. The evolution of the *Argopecten gibbus* stock (Mollusca: Bivalvia), with emphasis on the Tertiary and Quaternary species of eastern North America. *Paleontological Society, Memoir 3* [*Journal of Paleontology*, 43(5, supplement)]: 125 pp.

Waller, T. R. 1972a. The Pectinidae (Mollusca: Bivalvia) of Eniwetok Atoll, Marshall Islands. *The Veliger*, 14(3): 221-264.

Waller, T. R. 1972b. The functional significance of some shell microstructures in the Pectinacea (Mollusca: Bivalvia). *International Geological Congress. 24th Session, Montreal, Canada, Section 7, Paleontology*: 48-56.

Waller, T. R. 1973. The habits and habitats of some Bermudian marine mollusks. *The Nautilus*, 87(2): 31-52.

Waller, T. R. 1978. Morphology, morphoclines and a new classification of the Pteriomorphia (Mollusca: Bivalvia). Pp. 345-365, in: *Evolutionary Systematics of Bivalve Molluscs*, C. M. Yonge & T. E. Thompson (eds), *Philosophical Transactions of the Royal Society of London, B, Biological Sciences,* 284.

Waller, T. R. 1981. Functional morphology and development of veliger larvae of the European oyster, *Ostrea edulis* Linné. *Smithsonian Contributions to Zoology*, 328: 1-70.

Waller, T. R. 1984. The ctenolium of scallop shells: functional morphology and evolution of a key family-level character in the Pectinacea (Mollusca: Bivalvia). *Malacologia*, 25(1): 203-219.

Waller, T. R. 1986. A new genus and species of scallop (Bivalvia: Pectinidae) from off Somalia, and the definition of a new tribe Decatopectinini. *The Nautilus*, 100: 39-46.

Waller, T. R. 1991. Evolutionary relationships among commercial scallops (Mollusca: Bivalvia: Pectinidae). Pp. 1-73, in: *Scallops: Biology, Ecology and Aquaculture*, S. E. Shumway (ed.), Elsevier, New York.

Waller, T. R. 1993. The evolution of "*Chlamys*" (Mollusca: Bivalvia: Pectinidae) in the tropical western Atlantic and eastern Pacific. *American Malacological Bulletin*,10: 195-249.

Waller, T. R. 1995. The misidentified holotype of *Argopecten circularis* (Bivalvia: Pectinidae). *The Veliger*, 38: 298-303.

Waller, T. R. 2006a. New phylogenies of the Pectinidae (Mollusca: Bivalvia): reconciling morphological and molecular approaches. Pp. 1-44, in: *Scallops: Biology, Ecology and Aquaculture*, 2nd ed., S. E. Shumway & G. J. Parsons (eds), Elsevier, Amsterdam.

Waller, T. R. 2006b. Phylogeny of families in the Pectinoidea (Mollusca: Bivalvia): importance of the fossil record. *Zoological Journal of the Linnean Society*, 148: 313-342.

Waller, T. R. 2007. The evolutionary and biogeographic origins of the endemic Pectinidae (Mollusca: Bivalvia) of the Galápagos Islands. *Journal of Paleontology*, 81: 929-950.

Ward, L. W. 1992. Molluscan biostratigraphy of the Miocene, middle Atlantic Coastal Plain of North America. *Virginia Museum of Natural History Memoir* 2: 1-159.

Ward, L. W., & B. W. Blackwelder. 1975. *Chesapecten*, a new genus of Pectinidae (Mollusca: Bivalvia) from the Miocene and Pliocene of eastern North America. *United States Geological Survey Professional Paper* 861: 1-24.

Ward, L. W., & B. W. Blackwelder. 1987. Late Pliocene and early Pleistocene Mollusca from the James City and Chowan River formations at the Lee Creek Mine. Pp 113-283, in: *Geology and Paleontology of the Lee Creek Mine, North Carolina, II*, C. E. Ray (ed.), *Smithsonian Contributions to Paleobiology*, 61.

Warmke, G. L., & R. T. Abbott. 1961. *Caribbean Seashells*. Livingston Publishing Company, Narberth, Pennsylvania, 346 pp.

Weisbord, N. E. 1964. Late Cenozoic pelecypods from northern Venezuela. *Bulletins of American Paleontology*, 45: 1-564.

Whittaker, J. E. 1988. *Benthic Cenozoic Foraminifera from Ecuador*. British Museum (Natural History), London, 194 pp.

Winckworth, R. 1932. The British marine Mollusca. *Journal of Conchology*, 19(7): 211-252.

Winckworth, R. 1936. *Journal de Conchyliologie*: dates of publication. *Proceedings of the Malacological Society of London*, 22: 153-156.

Wood, W. 1828. *Supplement to the Index Testaceologicus; or, Catalog of Shells, British and Foreign*. Wood, London, 59 pp.

Woodring, W. P. 1925. Miocene mollusks from Bowden, Jamaica. Pelecypods and scaphopods. *Carnegie Institution of Washington Publication* 366: 222 pp.

Woodring, W. P. 1928. Miocene mollusks from Bowden, Jamaica. Part II. Gastropods and discussion of results. *Carnegie Institution of Washington Publication* 385: 564 pp.

Woodring, W. P. 1966. The Panama land bridge as a sea barrier. *Proceedings of the American Philosophical Society*, 110(6): 425-433.

Woodring, W. P. 1974. The Miocene Caribbean faunal province and its subprovinces. *Verhandlungen der Naturforschenden Gesellschaft in Basel*, 84(1): 209-213.

Woodring, W. P. 1982. Geology and paleontology of Canal Zone and adjoining parts of Panama. Description of Tertiary mollusks (pelecypods: Propeamussiidae to Cuspidariidae; additions to families covered in P306-E; additions to gastropods; cephalopods). *United States Geological Survey Professional Paper* 306-F: 541-759.

Woodring, W. P., J. S. Brown, & W. S. Burbank. 1924. *Geology of the Republic of Haiti*. Republic of Haiti, Department of Public Works and Geological Survey of the Republic of Haiti, Port-au-Prince, 631 pp.

Woodring, W. P., & E. Malavassi V. 1961. Miocene Foraminifera, mollusks, and a barnacle from the Valle Central, Costa Rica. *Journal of Paleontology*, 35: 489-497.

Wozniak, J., & M. H. Wosniak. 1987. Bioestratigrafia de la región nor-central de la serranía de Falcón, Venezuela nor-occidental. *Boletín de Geología Memoria (Caracas)*, 16(28): 101-139.

APPENDICES

Appendix 1. Localities Not Listed by Saunders *et al.* (1986)

Data are from Tulane University (TU) and the United States Geological Survey (USGS) Locality Registers unless otherwise indicated.

TU 638. 14.0 mi [22.5 km] east of junction of side road into Coatzacoalcos, Vera Cruz, Mexico, on Mexico Highway 180; road cut on northern side of road. Agueguexquite Formation.

USGS 2580. Road-cut at foot of a hill on which stood a house occupied by Capt. L. D. Baker, on eastern side of Port Morant, parish of St. Thomas, on southern coast of Jamaica near its eastern end. Bowden Formation. J. B. Henderson and C. T. Simpson, collectors, 1894 [data from Woodring, 1925: 7].

USGS 3536. Southern side of city of Santiago, Cuba, along trocha in small escarpment separating Terrace I from Terrace 2 of coastal shelf 20-foot level, brownish, yellowish marl with masses of *Porites*. T. W. Vaughan, collector, 1901.

USGS 3440. Northeastern portion of Santiago, Cuba. Fossils in marl on hillside. T. W. Vaughan, collector, 1901.

USGS 3441. East of La Cruz near railroad crossing of road to Morro, Cuba. T. W. Vaughan, collector, 1901.

USGS 3443. Northeastern portion of Santiago, Cuba. Marls at foot of the hill. T. W. Vaughan, collector, 1901.

USGS 3446. First deep cutting on railroad east of La Cruz, Cuba, near Santiago. T. W. Vaughan, collector, 1901.

USGS 5255. Santiago de Cuba, received by USNM 20 January 1910. Collector not stated.

USGS 5906a. Banks of Chagres River ⅛ to ¼ mi above Alhajuela, Panama Canal Zone. D. F. MacDonald, collector, May, 1911. [Woodring (1925: 733) said of this locality, "Lower member of Alhajuela Formation... Madden Basin."]

USGS 5908. Creamy limestone a mile or less north of New Frijoles on the relocated line of the Panama Railroad, Panama Canal Zone. D. F. MacDonald, May 1911.

USGS 6024b. From limestone above foraminiferal marl at Agua Salad bridge *ca.* ⅓ mi north of New Frijoles on relocated line of Panama Railroad, Panama Canal Zone. D. F. MacDonald and T. W. Vaughan, collectors, 1911. [Woodring (1982: 727) gave for this locality, "Caimito Formation, Gatun Lake area ... shallow-water facies."]

USGS 6300. Middle horizon of "Coro series," from limestone and sandstone formation back of red house, ½ mi up Río Coro from dam site, 2.5 mi south of Coro, state of Falcón, Venezuela. Ralph Arnold and party, collectors, 1912.

USGS 6303. Middle "Coro series," ¼ mi northwest of Isiro, 5 mi south of Coro, state of Falcon, Venezuela, four-foot bed of very fossiliferous sandstone and shale, stratigraphically above the coal seam. Ralph Arnold, collector, 1912.

USGS 8439. Toro sandstone. Río Cana Quebrada region, province of Colon, Panama. A. Olsson, collector, 1919. [Woodring (1982: 737) said of this locality, "Chagres Sandstone proper."]

USGS 8518. Left bank of Río Amina, *ca.* ½ mi above crossing at Potrero, next horizon below USGS 8516, province of Santiago, Dominican Republic. T. W. Vaughan and C. W. Cooke, collectors, 2 May 1919.

USGS 8529. Near top of bluff on right side of Río Mao *ca.* 5/8 mi by trail N 40° E of Bulla and *ca.* 1 mi above the ford El Paso de los Perros, province of Santiago, Dominican Republic. T. W. Vaughan, C. W. Cooke, and D. D. Condit, collectors, 5 May 1919.

USGS 8535. Road from Caimito to Gurabo Adentro, *ca.* ½ mi west of Las Caobas, Distrito de Monte Cristi, Dominican Republic. T. W. Vaughan and C. W. Cooke, collectors, 10 May 1919.

APPENDIX 2. SPECIES INCLUDED IN *LEPTOPECTEN*

Species included in *Leptopecten* Verrill, 1897, arranged by region and alphabetically by species. Superscript 1 = *Leptopecten andersoni* group.

Eastern Pacific region

Leptopecten andersoni andersoni (Arnold, 1906)[1]. Type locality: Zayante Creek, Santa Cruz County, California: "Temblor" stage (Moore, 1984: B45). Geographic range: middle California to Baja California Sur, Mexico (Moore, 1984: B45). Age: late Early to early Middle Miocene (age of "Temblor" given by Smith, 1991b: fig. 1).

Leptopecten andersoni barkerianus (Arnold, 1906)[1]. Type locality: Barker's Ranch, Kern County, California: Temblor Formation (Moore, 1984: B45). Geographic range: middle and southern California (Moore, 1984: B45). Age: late Early to early Middle Miocene (age of "Temblor" given by Smith, 1991b: fig. 1).

Leptopecten andersoni clemonensis (Etherington, 1931)[1]. Type locality: Grays Harbor County, southwestern Washington: Astoria (?) Formation (Moore, 1963: 67). Geographic range: Washington and Oregon (Addicott, 1976: 104). Age: Newportian molluscan stage, middle Miocene (Addicott, 1976: 104).

Leptopecten andersoni subandersoni (Loel & Cory, 1932)[1]. Type locality: San Luis Obispo County, California: Vaqueros Formation (Moore, 1984: B45). Geographic range: southern California to Baja California Sur, Mexico (Moore, 1984: B45). Age: late Oligocene to late Early Miocene, based on formations listed by Moore (1984: B45) and ages of these formations given by Smith (1991a: fig. 13A).

Leptopecten camerella (Berry, 1968) = *L. latiauratus.*

Leptopecten cracens (Olsson, 1964). Type locality: Telembi, Ecuador: Angostura Formation (Olsson, 1964). Geographic range: Ecuador. Age: zone N16, Late Miocene (age of Angostura Formation given by Whittaker, 1988).

Leptopecten latiauratus (Conrad, 1837). Type locality: subtidal near San Diego and Santa Barbara, California (Moore, 1984: B44). Geographic range: living from "Point Reyes, California (38.0°N), to Cabo San Lucas, Baja California Sur (22.9°N), in intertidal pools to 250 m" (Coan *et al.*, 2000: 237). Age: Late Miocene (based on age of oldest part of Purisima Formation given by Powell *et al.*, 2007) to present. Habitat: "in intertidal pools to 250 m. Usually byssally attached to eelgrass, rocks, or algae. Also collected attached to pelagic red crabs" (Coan *et al.*, 2000: 237).

Leptopecten nelsoni (Olsson, 1932). Type locality: Quebrada Tucillal at Zorritos, Department of Tumbez, Peru, Tumbes Formation. Geographic range: northwestern Peru. Age: Late Miocene.

Leptopecten praevalidus (Jordan & Hertlein, 1926). Type locality: southeast of Bahía Tortola, Baja California Sur, Mexico: Almejas Formation. Geographic range: Baja California Sur (Moore, 1984: B43). Age: Late Miocene (Smith, 1984: fig. 3).

Leptopecten tumbezensis (d'Orbigny, 1846). Type locality: Tumbez, Peru, extant. Geographic range: Gulf of California to Paita, Peru (Grau, 1959: 120); fossil, Baja California Sur, Mexico, in Infierno and Salada formations (Moore, 1984: B49). Age: Pliocene to present (Moore, 1984: B49). Habitat: "from just below low tide to *ca.* 70 fathoms [128 m] ... usually found in mud, occasionally sandy mud or sand" (Grau, 1959: 120).

Leptopecten woodringi (Spieker, 1922). Type locality: corrected by Olsson (1932: 82) to Tumbes Formation, probably Quebrada Tucillal, Zorritos, Peru. Age: Late Miocene (Olsson, 1932: 37).

Western Atlantic region

Leptopecten atlanticola (Anderson, 1929). Type locality: northern slope of Tuberá [*sic*, Tubará] Mountain, Atlántico, Caribbean Colombia, horizon P, near middle of Tubará group (Anderson, 1929). Geographic range: known only from type locality. Age: early Pliocene (Hunter, 1978).

Leptopecten coderensis (Harris in Hodson *et al.*, 1927). Type locality: north 65 m from third quebrada north of Codore de Dentro, north of Urumaco, District of Democracia, state of Falcon, Venezuela (based on label with holotype, PRI 21956), probably the Codore Formation, which outcrops in this area (Ministerio de Energía y Minas, 1970). Geographic range: districts of Democracia, Colina, and Falcón, State of Falcón, northwestern Venezuela. Age: early Pliocene, based on age determination for the Codore Formation (Ministerio de Energía y Minas, 1997).

Leptopecten coderensis willistoni (Harris, F. Hodson, & H. Hodson in Hodson *et al.*, (1927) = *L. coderensis.*

Leptopecten ecnomius Woodring, 1982. Type locality: Transisthmian Highway, 09°21'N + 335 m, 79°49'W, Panama, lower part of Gatun Formation (Woodring, 1982: 595). Geographic range: Panama (Woodring, 1982). Age: lower part of Gatun dated as latest Middle to earliest Late Miocene, 11.8 to 11.4 MA (Collins & Coates, 1999).

Leptopecten gilbertharrisi (F. & H. Hodson in Hodson *et al.*, 1927). Type locality: Cují sec., SE of Urumaco and NNW of Agua Clara, District of Miranda, Falcón, Venezuela, Socorro Formation (based on label with holotype, PRI 21967). Geographic range: districts of Democracia, Miranda, Colina, and Buchivacoa, State of Falcón, Venezuela (Hodson *et al.*, 1927: 28). Age: Middle Miocene, based on age of Socorro Formation (Linares, 2004: 5).

Leptopecten gilbertharrisi democracianus (F. & H. Hodson in Hodson *et al.*, 1927) = *L. gilbertharrisi*.

Leptopecten linki (Dall, 1926). Type locality: northern coast of Colombia, Department of Antioquia, in raised terraces probably of late Pleistocene age (Dall, 1926). Geographic range: Caribbean coasts of Central and South America from Honduras to Surinam with an outlier population in the Bahamas (Cosel, 1986: 118, and USNM collections). Age: Pleistocene to present. Habitat: in shallow water on bottoms of muddy sand or fine sand, commonly in relatively turbid water, often near mouths of rivers or estuarine regions with brackish water, but always on beaches open to the sea, apparently not tolerating reduced salinity (Cosel, 1986: 118, translated from Spanish).

Leptopecten maturensis (Maury, 1925a). Type locality: Matura Bay, east of Matura Ward, northeastern St. Andrew County, Trinidad (based on label of syntypes, PRI 900 and 901), "Matura beds" (Matura Sand and Clay Member of the Talparo Formation; Kugler, 2001: 255). Geographic range: Trinidad. Age: early Pleistocene (Kugler, 2001: correlation chart #37).

Leptopecten tabaquita (Maury, 1925). Type locality: "8½ miles on the Tabaquite Road near the Tabaquite oil field, Trinidad, Tamana Formation." See Kugler, 2001: 262, regarding inaccuracy in Maury's locality description. Geographic range: Trinidad. Age: early Late Miocene (Kugler, 2001: correlation chart #37).

Leptopecten thompsoni (Maury, 1917a). Type locality: Bluff 3, Cercado de Mao, Río Mao, Dominican Republic, Cercado Formation. Geographic range: northern Dominican Republic. Age: late Late Miocene, nannofossil zone NN11 (Saunders *et al.*, 1986: table 3).

APPENDIX 3. SPECIES INCLUDED IN *PARALEPTOPECTEN*

Species included in *Paraleptopecten* n. gen. arranged by region and alphabetically by species. Junior synonyms are in brackets.

Eastern Pacific region

Paraleptopecten bellilamellatus (Arnold, 1906). Type locality: Pacific Beach, San Diego, California, San Diego Formation (Moore, 1984: B43). Geographic range: middle California to Baja California Sur, in Merced, San Diego, Almejas, and Purisima formations (Moore, 1984: B43). Age: late Miocene to Pleistocene. See Carreño & Smith (2007) regarding stratigraphic refinements of the "Purisima Formation."

Paraleptopecten biolleyi (Hertlein & Strong, 1946). Type locality: 10°55'45"N, 85°49'05"W, Port Parker, Costa Rica, 22 m. Geographic range: Punta Abreojos, western Baja California and Coronados Islands, Gulf of California southward to Ecuador (Grau, 1959: 116). Age: known only from extant specimens. Habitat: normal marine shallow shelf, 7 to *ca.* 200 m, sand or mud bottoms (Grau, 1959:. 116).

[*Paraleptopecten euterpes* (Berry, 1957)] = *Paraleptopecten velero* (Hertlein, 1935). Type locality: 6-10 fathoms [= 11-18 m], off of Acapulco, western coast of Mexico. Geographic range: known only from type locality. Age: known only from extant specimens. Habitat: shallow shelf.

Paraleptopecten palmeri (Dall, 1897). Type locality: "near the head of the Gulf of California" (Dall, 1897: 85), extant. Geographic range: extant specimens known only from the Gulf of California, Concepción Bay north to San Felipe Bay (Grau, 1959: 114); fossil specimens occur in Riverside County, California, in the upper member of the Imperial Formation (Powell, 1985). Age: Pliocene to present. Habitat: low tide to 50 fathoms [91 m], on rock, sand, sandy mud, or mud bottoms (Grau, 1959: 114).

Paraleptopecten velero (Hertlein, 1935). Type locality: 3-9 fathoms [= 5-16 m], Bahía Honda, Veragua, Panama. Geographic range: extant specimens occur from Las Animas Bay, Gulf of California, to Puna, Gulf of Guayaquil, Ecuador (Grau, 1959: 115); fossil specimens have been reported from the Imperial Formation in Riverside County, California (Powell, 1986: 102). Age: Pliocene to present. Habitat: "Recorded in 3 to 40 fathoms [= 5 to 73 m] . . . Found on rock, gravelly sand, sand, and mud bottoms" (Grau, 1959: 115).

Western Atlantic region

Paraleptopecten sp. *a* Waller, herein. Type locality: Bluff 3, Cercado de Mao, Río Mao, Dominican Republic, Cercado Formation. Geographic range: known only from type locality. Age: late Late Miocene, nannofossil zone NN11 (Saunders *et al.,* 1986: table 3).

[*Paraleptopecten auroraensis* (Ward & Blackwelder, 1987)] = *P. wendelli* (Tucker, 1934). Type locality: USGS 25357, Lee Creek phosphate mine on right bank of Pamlico River, 5.5 mi north of Aurora, Beaufort County, North Carolina, Bed E of James City Formation (Ward & Blackwelder, 1987: 140, based on locality of holotype; the type locality was erroneously given as "Clewiston, Florida, Caloosahatchee Formation"). Geographic range: Beaufort County, North Carolina: Chowan River and James City formations (Ward & Blackwelder, 1987: 141). Age: late Pliocene and early Pleistocene (Ward & Blackwelder, 1987: fig. 12).

Paraleptopecten sp. *b* Waller, herein. Type locality: USGS 20428, Boutakoff's Brechin Castle Estate, Saveneta River area, Trinidad: Savaneta Glauconitic Sandstone Member of the Springvale Formation. Geographic range: type locality and vicinity. Age: Late Miocene, based on age determination for the Savaneta Glauconitic Sandstone Member (Hunter, 1978: 200; Jung, 1989: 12; Kugler, 2001: correlation chart 37).

Paraleptopecten bavayi (Dautzenberg, 1900). Type locality: coasts of Venezuela and Caribbean Colombia. Geographic range: living in Bahamas, Antilles, Caribbean coasts of Central and South America southward to Uruguay (Abbott, 1974: 447; USNM collections). Age: extant. Habitat: normal marine shallow shelf, common at depths from 5-30 m, ranging to 82 m (USNM collections).

[*Paraleptopecten desultorius* (Weisbord, 1964)] = *P. bavayi* (Dautzenberg, 1900). Type locality: on hillside above western bank of Quebrada Mare Abajo, Mare Formation (Weisbord, 1964: 146). Geographic range: known only from vicinity of Quebrada Mare Abajo, Venezuela. Age: middle to late Pliocene, based on age of Mare Formation (Jung, 1989: 20, and references therein).

[*Paraleptopecten irremotis* (Olsson & Harbison, 1953)] = *P. olgensis* (Mansfield, 1939). Type locality: Clewiston, Florida, formation not specified (locality possibly erroneous, because rock matrix matches that of the Buckingham Limestone exposed near Olga, on the Caloosahatchee River, Florida). Geographic range: described only from type locality and the vicinity of St. Petersberg, Florida. Age: Pliocene.

[*Chlamys* (*Leptopecten*) cf. *latiaurata* (Conrad), Ferreira (1960)] = *Paraleptopecten* sp. Pirabas Formation, Brazil.

Paraleptopecten leonensis (Mansfield, 1932). Type locality: lower bed at Jackson Bluff, Leon County, Florida, Jackson Bluff Formation. Geographic range: Leon County, Florida; Porters Landing, Savannah River, George; possibly Raysors Bridge, Edisto River, South Carolina; Zone 2 of Yorktown Formation, Hampton, Virginia. Age: middle Pliocene, based on determination of age of Jackson Bluff Formation as planktic formaniferal zone N20 by Akers (1974).

[*Leptopecten leonensis* Campbell, 1993], *non* Mansfield, 1932 = *Paraleptopecten olgensis* (Mansfield, 1939). Type locality: "basal Zone 2 [Yorktown Formation], Gloucester County and Piankatank River, Virginia" (Campbell, 1993: 24). Geographic range: see *P. olgensis*. Age: middle Pliocene.

Paraleptopecten olgensis (Mansfield, 1939). Type locality: "dredged from the Caloosahatchee River, 2 miles above Olga [Lee County, Florida]" (Mansfield, 1939: 51), Buckingham Limestone. Geographic range: southern Florida to southeastern Virginia. Age: Pliocene.

Paraleptopecten pirabensis (Ferreira, 1960). Type locality: Fazenda, ilha de Fortaleza, baía de Pirabas, municipality of Salinópolis, Pará, Brazil, Pirabas Formation. Geographic range: known only from Brazil. Age: Early Miocene, planktic foraminiferal zones N4 and N5, based on age of Pirabas Formation according to Távora and Fernandes (1999).

Paraleptopecten rutamensis (Jung, 1969). Type locality: Matura, Trinidad, Matura Sand and Clay Member of the Talparo Formation. Geographic range: known only from the type locality. Age: Pleistocene, based on age of the Matura Sand and Clay Member (Jung, 1989: 12).

Paraleptopecten wendelli (Tucker, 1934). Type locality: Ft. Denaud, Florida, "Caloosahatchie [*sic*] Pliocene" (Tucker, 1934: 612).

[*Paraleptopecten wilsoni* (Campbell, 1993)] = *Paraleptopecten leonensis* (Mansfield, 1932). Type locality: Wilson's Pit, Hampton, Virginia, Zone 2 of Yorktown Formation. Geographic range: see *P. leonensis*. Age: middle Pliocene, based on age determination of upper Yorktown Formation by Cronin *et al.* (1984).

[*Leptopecten* sp. Blackwelder, 1981] = *Paraleptopecten olgensis* (Mansfield, 1939). Type locality: 0.1 km below mouth of Wilton Creek, left bank of Piankatank River, Glebe Neck, Middlesex County, Virginia, upper Yorktown Formation. Geographic range: see *Paraleptopecten olgensis*. Age: middle Pliocene.

Paraleptopecten sp. = *Leptopecten* cf. *latiauratus* of Ferreira (1960). Type locality: Igarapé Xibé, colônia Pedro Teixeira, municipality of Capanema, Pará, Brazil: Pirabas Formation. Geographic range: known only from Brazil. Age: Early Miocene, planktic foraminiferal zones N4 and N5, based on age of Pirabas Formation according to Távora & Fernandez (1999).

PLATES

PLATE 1

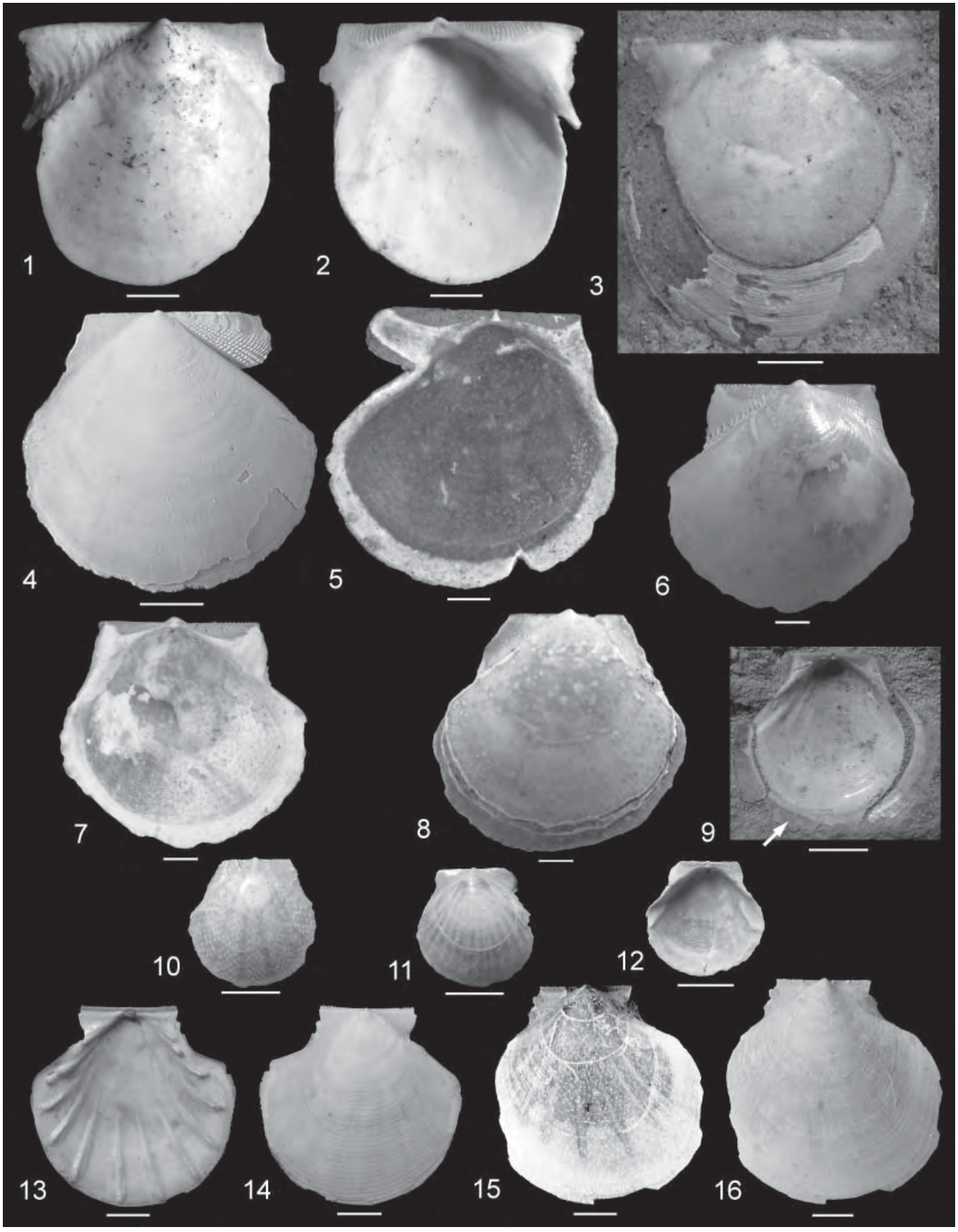
Figure Page

1-3. *Cyclopecten acuminatus* n. sp. Scale bars = 0.5 mm. 18
1-2. Holotype, NMB G17491, locality NMB 15829: Río Gurabo, Mao Formation, 758-761 m above base of section. Left valve, missing periphery of disk, exterior (1) and interior (2).
3. NMB G17492, locality NMB 15828: Río Gurabo, Mao Formation, 715 m above base of section. Right valve, exterior.

4-8. *Cyclopecten guppyi* (Dall, 1898). Scale bars = 0.5 mm. 19
4. USNM 540936, locality TU 1294: Río Mao, Bluff 3, Cercado Formation. Right valve, exterior.
5. NMB G17493, locality NMB 16922: Río Mao (Arroyo Bajon), Cercado Formation, level a. Right valve, interior.
6-7. USNM 540937, locality TU 1294: same as Fig. 4. Left valve, exterior (6) and interior (7).
8. USNM 540938, locality TU 1410: Río Mao, Cercado Formation, between Bluffs 1 and 2. Left valve, exterior showing repeated repaired injuries.

9-12. *Cyclopecten zalaya* n. sp. Scale bars = 2 mm. 23
9. NMB G17494, locality NMB 15827: Río Gurabo, Mao Formation, 658-660 m above base of section. Left valve, interior showing marginal band of foliated-calcite (arrow).
10. Holotype, USNM 540939, locality TU 1227A: Cañada Zalaya, upper Gurabo Formation. Left valve, uncoated to show pigment pattern.
11. USNM 540940, locality TU 1227A: same as Fig. 10. Right valve, uncoated to show pigment pattern.
12. USNM 540941, locality TU 1227A: same as Fig. 10. Right valve, interior showing internal ribs.

13-16. *Parvamussium marmoratum* (Dall, 1881). Scale bars = 2 mm. 25
13-14. USNM 540942, locality TU 1227: Cañada Zalaya, upper Gurabo Formation. Right valve, interior (13) and exterior (14).
15-16. USNM 540943, locality TU 1227: same as Fig. 13. Left valve, uncoated, showing pigment pattern (15) and coated, showing radial costellae (16).


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

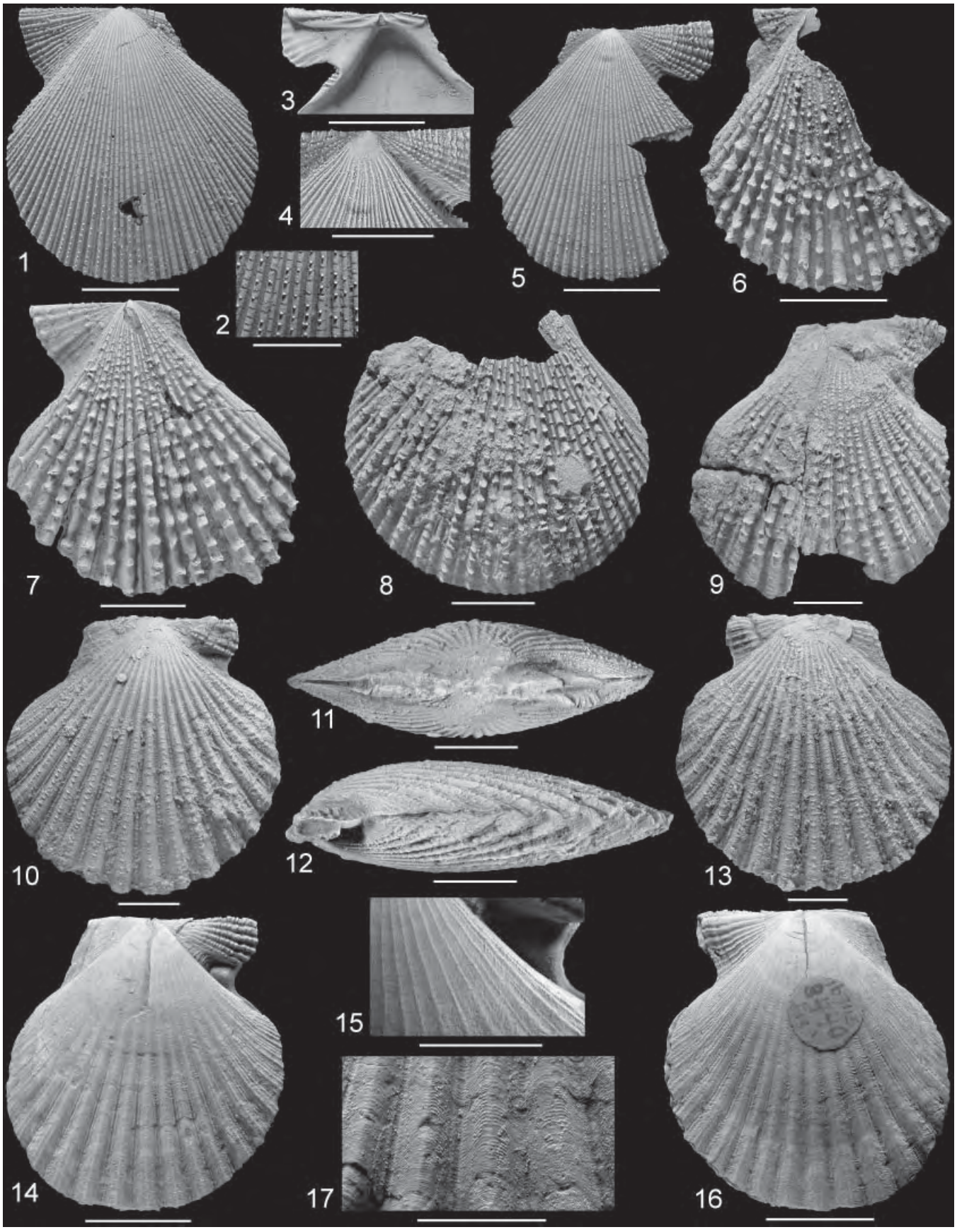

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

PLATE 2

Figure Page

1-5. *Caribachlamys jungi* n. sp. Scale bars = 3 mm (2, 4), 5 mm (1, 3, 5). 28
1-2. Holotype, NMB G17495, locality NMB 16934: Río Gurabo, Gurabo Formation, 274-277 m above base of section. Left valve, exterior (1) and detail of sculpture (2).
3-5. USNM 540948, locality TU 1215: Río Gurabo, Gurabo Formation, 276-384 m above base of section. Right valve, hinge (3), detail of dorsal region (4), and exterior (5).

6-9. *Caribachlamys guayubinensis* n. sp. Scale bars = 5 mm (6), 10 mm (7-9). 27
6. USNM 540946, locality TU 1281: southern side of Río Yaque near Guayubín, Mao Adentro Limestone. Left valve, exterior.
7. Holotype, USNM 540944, locality TU 1438: road cut near Guayubín, Mao Adentro Limestone. Left valve, exterior.
8. USNM 540945, locality TU 1245: road cut near Guayubín, Mao Adentro Limestone. Left valve, exterior.
9. USNM 540947, locality TU 1438: same as Fig. 7. Right valve, exterior.

10-13. *Interchlamys interlineata* (Gabb, 1873). USNM 540949, locality TU 1245: same as Fig. 8. Articulated shell, right exterior (10), dorsal (11), anterior (12), and left exterior 13. Scale bars = 10 mm. 31

14-17. *Interchlamys jacobiana* (Cooke, 1919). Scale bars = 5 mm (15, 17), 10 mm (14, 16). 32
14-16. Holotype, USNM 167115, locality USGS 3440: La Cruz Formation, Santiago, Cuba. Articulated shell, right exterior (14), detail of anterodorsal exterior showing antimarginal striae (15), and left exterior (16).
17. NMB G17496, locality NMB 17277: Río Yaque del Norte, southern end of Angostura Gorge at base of limestones. Right valve, detail of ventral exterior.

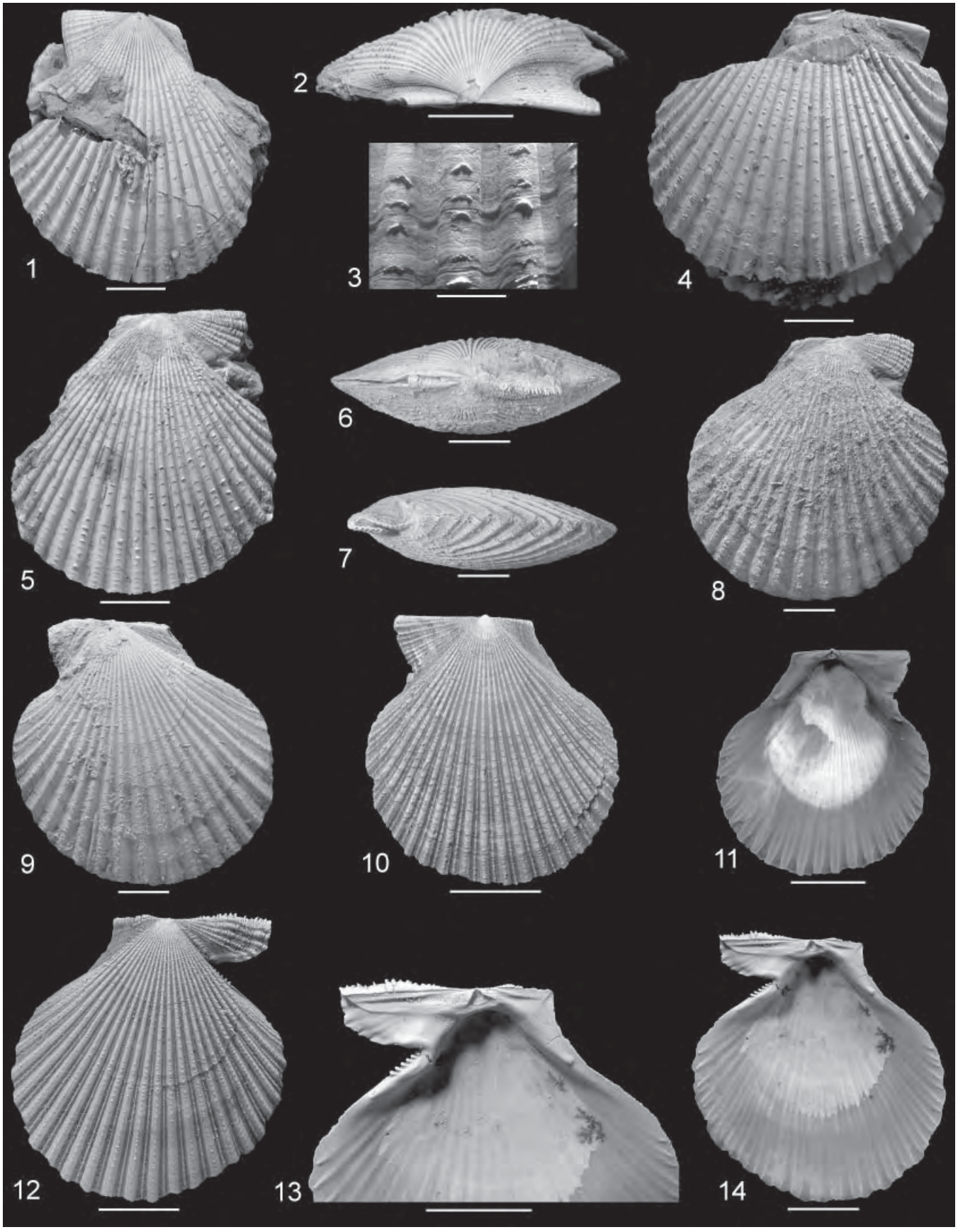
PLATE 3

Figure — Page

1-5. *Mimachlamys blowi* n. sp. Scale bars = 3 mm (3), 10 mm (1-2, 4-5). 34
1-4. NMB G17498, locality NMB 15893: Río Gurabo, Cercado Formation, 150 m above base of section. Offset matching valves, left exterior (1), dorsal of left valve (2), detail of right exterior near ventral margin (3), and right exterior (4).
5. Holotype, NMB G17497, locality NMB 15893: same as Fig. 1. Right valve, exterior.

6-9. *Mimachlamys vokesorum* n. sp. Holotype, USNM 540950, locality TU 1245: road cut near Guayubín, Mao Adentro Limestone. Articulated shell, dorsal (6), anterior (7), right exterior (8), and left exterior (9). Scale bars = 10 mm. 35

10-14. *Spathochlamys vaginula* (Dall, 1898). Scale bars = 5 mm. 36
10-11. USNM 474660, locality TU 1410: Río Mao, Cercado Formation, between Bluffs 1 and 2. Left valve, exterior (10) and interior (11).
12-14. USNM 540951, locality TU 1409: road cut south of Mao, Gurabo Formation. Right valve, exterior (12), hinge (13), and right interior (14).


1
2
3
4
5
6
7
8
9
10
11
12
13
14

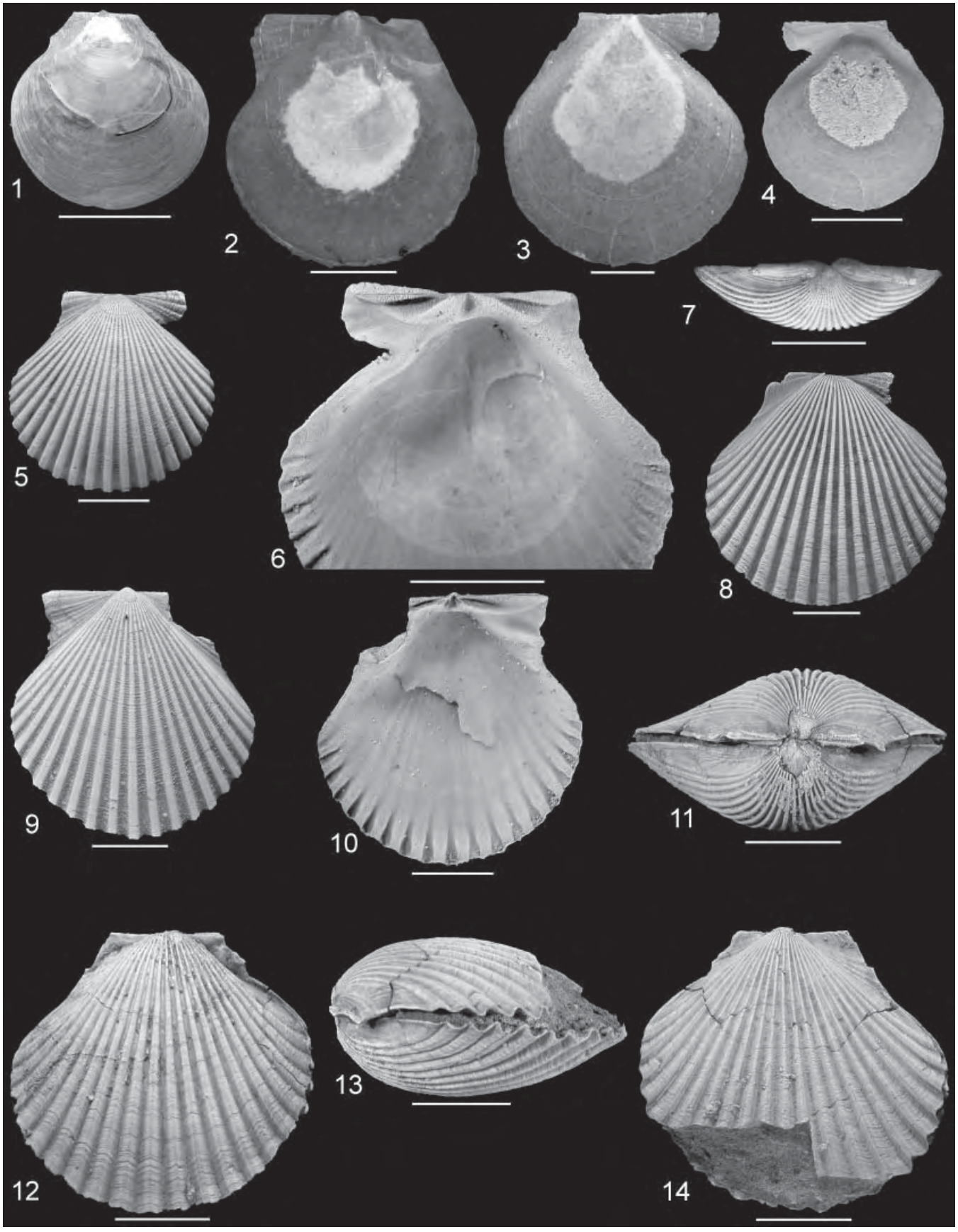

1
2
3
4
5
6
7
8
9
10
11
12
13
14

PLATE 4

Figure Page

1-4. *Palliolum*? *cibaoense* n. sp. Scale bars = 1 mm (2-3), 2 mm (4), 5 mm (1). 39
1. Holotype, USNM 540952, locality USGS 8516: Río Amina, Gurabo Formation, level d. Left valve, exterior.
2. USNM 540953, locality USGS 8525: Río Mao, Bluff 3, Cercado Formation. Left valve, exterior.
3-4. NMB G17499, locality NMB 16912: Río Mao, Bluff 3, Cercado Formation. Right valve, exterior (3), interior (4).

5-10. *Argopecten ameleus* (Woodring, 1925). Scale bars = 5 mm. 41
5-7. Holotype, USNM 352785, Bowden Formation, Jamaica. Right valve, exterior (5), interior (6), and dorsal (7).
8. USNM 540954, locality TU 1435: southern side of Río Yaque del Norte west of Santiago, upper Gurabo? Formation. Right valve, exterior.
9-10. USNM 540955, locality TU 1281: southern side of Río Yaque near Guayubín, Mao Adentro Limestone. Left valve, exterior (9) and interior (10).

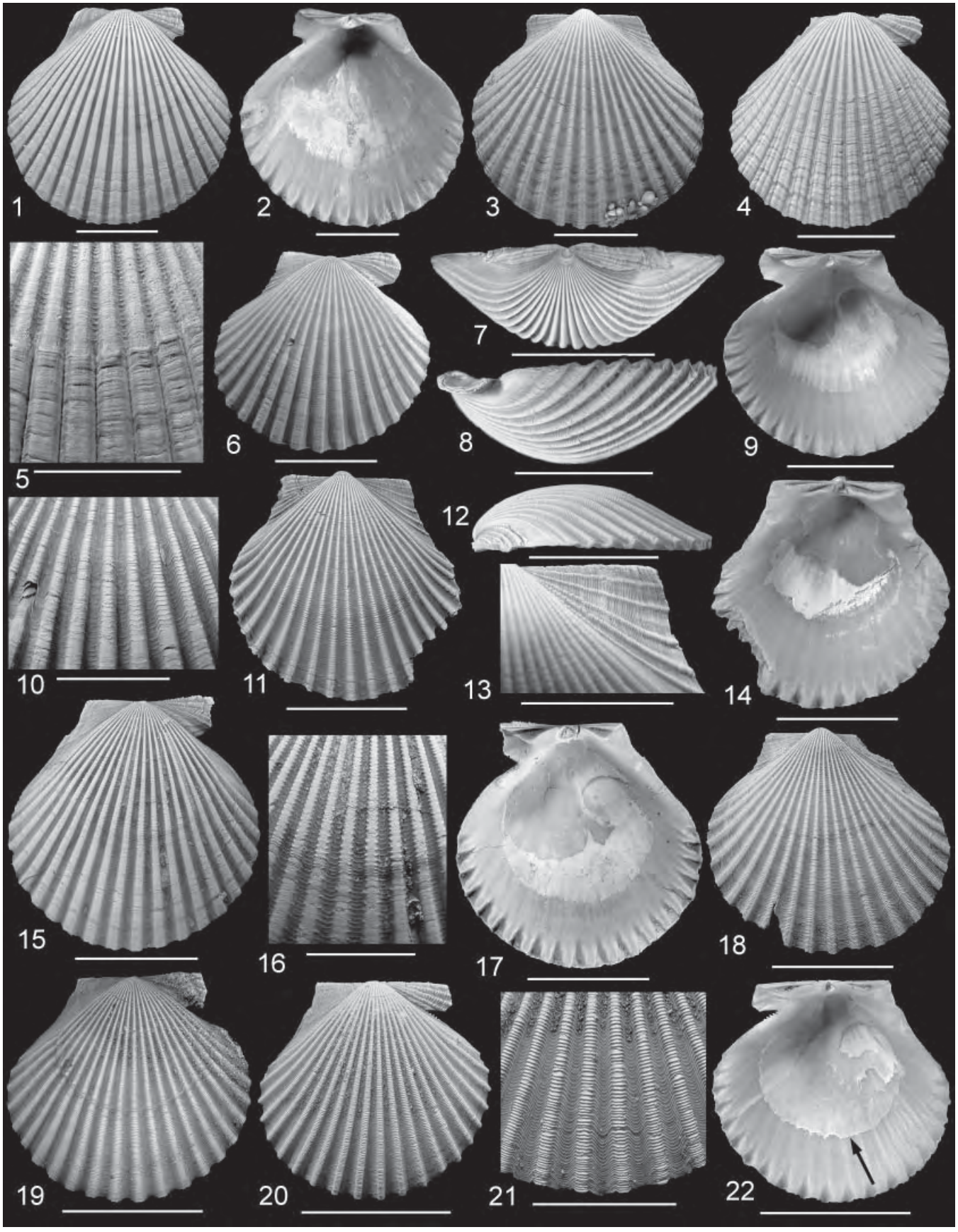
11-14. *Argopecten eccentricus eccentricus* (Gabb, 1873). USNM 540956, locality TU 1218: Río Amina, lower Gurabo Formation, level a. Articulated shell, dorsal (11), right exterior (12), anterior (13), and left exterior (14). Scale bars = 10 mm. 42

PLATE 5

Figure Page

1-5. *Argopecten eccentricus eccentricus* (Gabb, 1873). Scale bars = 5 mm (5), 10 mm (1-4). 42
1-2. NMB G17500, locality NMB 16912: Río Mao, Bluff 3, Cercado Formation. Right valve, exterior (1) and interior (2).
3. NMB G17501, locality NMB 16912: same as Fig. 1. Left valve, exterior.
4-5. USNM 540957, locality TU 1439: road cut south of Santiago, Gurabo Formation? Right valve, exterior (4) and detail of ontogenetic change in sculpture (5).

6-22. *Argopecten eccentricus lacabrensis* n. ssp. Scale bars = 5 mm (10, 13, 16, 21), 10 mm (6-9, 11-12, 14-15, 17-20, 22). 49
6-10. Holotype, NMB G17502, locality NMB 15909: Río Gurabo, Cercado Formation, 111-113 m above base of section. Right valve, exterior (6), dorsal (7), anterior (8), interior (9), and detail of exterior (10).
11-14. NMB G17503, locality NMB 15909: same as Fig. 6. Left valve, exterior (11), anterior (12), detail of posterior auricle (13), and interior (14).
15-17. NMB G17504, locality NMB 15896: Río Gurabo, Cercado Formation, 135 m above base of section. Right valve, exterior (15), detail of exterior (16), and interior (17).
18. NMB G17505, locality NMB 15896: same as Fig. 15. Left valve, exterior.
19. NMB G17506, locality NMB 15896: same as Fig. 15. Right valve of lamellate form, exterior.
20-22. NMB G17507, locality NMB 15873, Río Gurabo, Gurabo Formation, 208 m above base of section. Right valve of lamellate form with extensive foliated-calcite re-entry, exterior (20), detail of exterior (21), and interior showing extent of foliated-calcite re-entry (22, arrow).


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

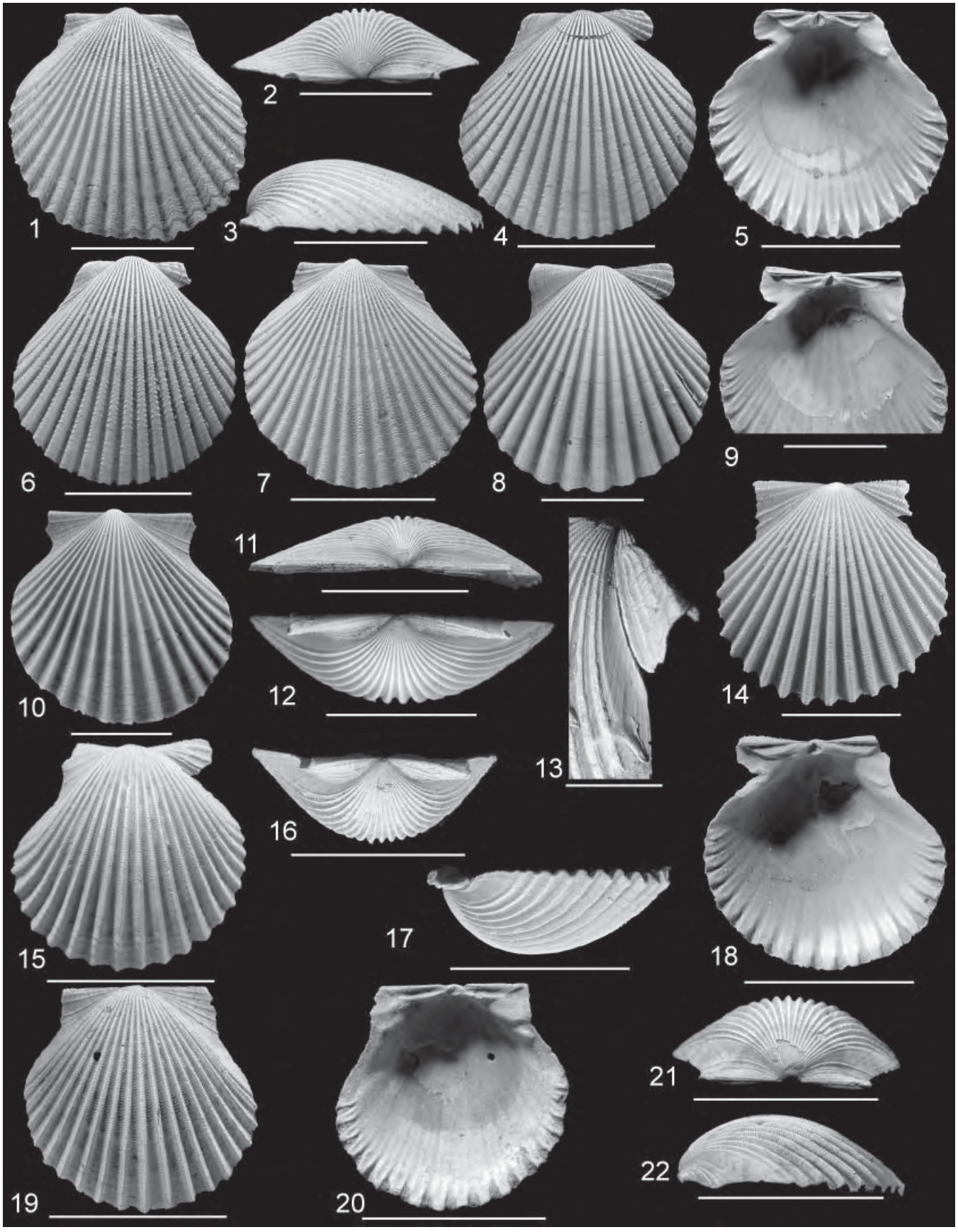

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

PLATE 6

Figure Page

1-7. *Argopecten eccentricus caimiticus* (Maury, 1917). Scale bars = 10 mm. 51
1-3. Holotype, PRI 28969, Río Cana, Orchid Gorge above Caimito, Zone I of Maury (1917). Left valve, exterior (1), dorsal (2), and anterior (3).
4-5. NMB G17508, locality NMB 16835: Río Cana, Cercado Formation, 252 m above base of section. Right valve, exterior (4) and interior (5).
6. NMB G17509, locality NMB 16835: same as Fig. 4. Right valve, exterior.
7. NMB G17510, locality NMB 16835: same as Fig. 4. Left valve, exterior.

8-14. *Argopecten inaequalis* (G. B. Sowerby I, 1850). Scale bars = 5 mm (13-14), 10 mm (8-12). . . 52
8-9, 12. USNM 540958, locality TU 1380: road cut south of Santiago, Gurabo Formation? Right valve, exterior (8), interior (9), and dorsal (12).
10-11. USNM 540959, locality TU 1380: same as Fig. 8. Left valve, exterior (10) and dorsal (11).
13. USNM 540960, locality TU 1436: road cut 5 km north of junction at El Limpio on road from Piedra Gorda to Cuesta Arriba. Right valve, oblique view of anterior disk flank.
14. USNM 540961, locality TU 1380: same as Fig. 8. Right valve, exterior.

15-22. *Argopecten parathetidis* n. sp. Scale bars = 10 mm. 55
15-18. Holotype, USNM 540962, locality TU 1224: road cut 6.1 km west of Los Quemados, Gurabo Formation. Right valve, exterior (15), dorsal (16), anterior (17), and interior (18).
19-22. USNM 540963, locality TU 1224: same as Fig. 15. Left valve, exterior (19), interior (20), dorsal (21), and anterior (22).

PLATE 7

Figure Page

Argopecten thetidis (G. B. Sowerby I, 1850). Scale bars = 10 mm. 56

1. Lectotype of *Pecten eugrammatus* Dall, 1898, USNM 115533, from the Neogene of the Dominican Republic, precise locality unknown. Right valve, exterior.

2-3. Syntypes of *Pecten hatoviejonis* Maury, 1917, Río Amina, trail between Hato Viejo and Potrero, Dominican Republic, probably Gurabo Formation.
2. PRI 28970, right valve, exterior.
3. PRI 28971, left valve, exterior.

4-5. Variant with sharp-crested ribs, USNM 540964, locality TU 1410: Río Mao, Cercado Formation, between Bluffs 1 and 2. Right valve, exterior (4) and ventral rib profile (5).

6-7. Variant with slightly broader rib crests, USNM 540965, locality TU 1410: same as Fig. 4. Right valve, ventral rib profile (6) and right valve exterior (7).

8-9. More typical variant with medial troughs on rib crests, NMB G17511, locality NMB 15865: Río Gurabo, Gurabo Formation, 221-223.5 m above base of section. Right valve, exterior (8) and ventral rib profile (9).

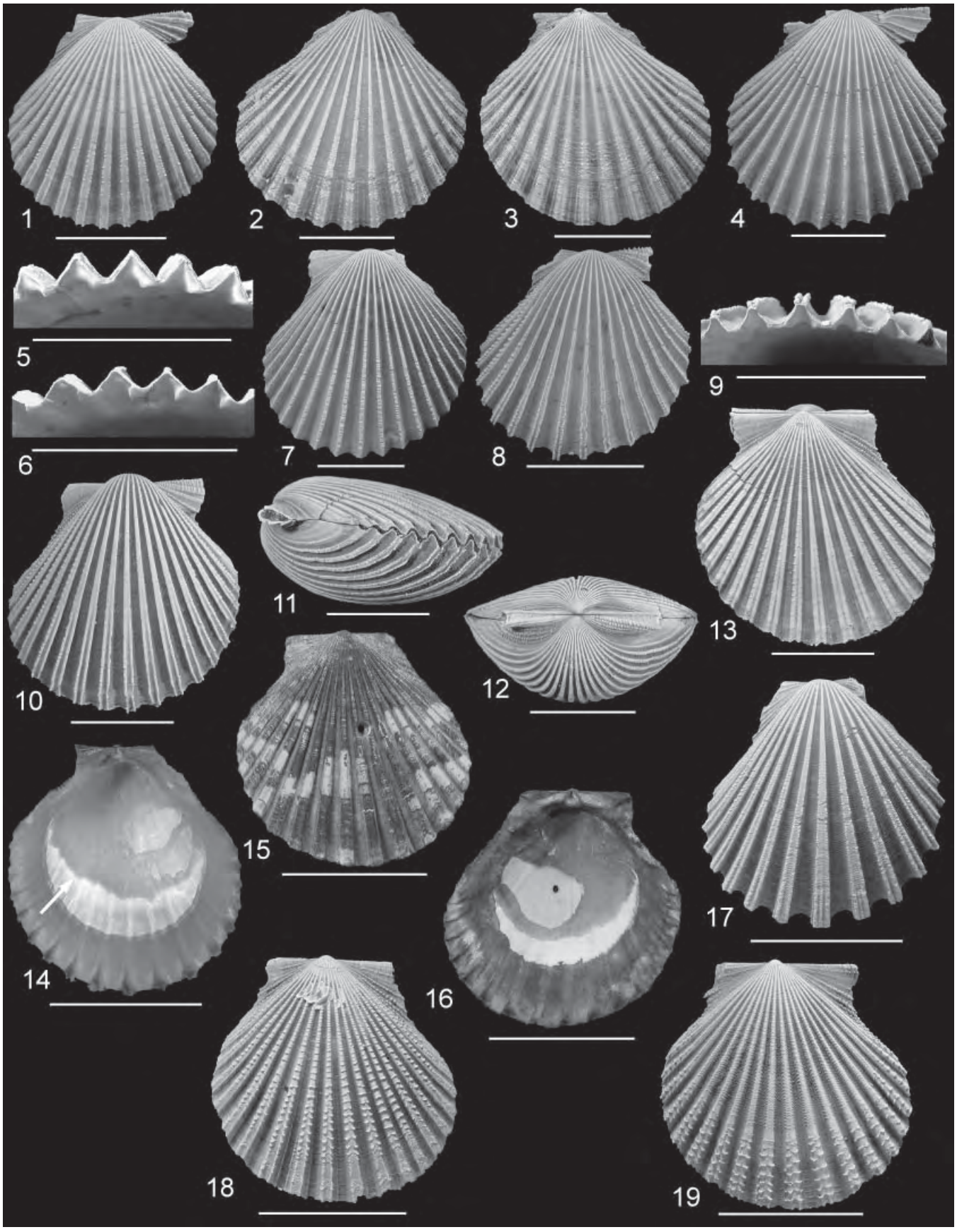
10-13. Variant from upper part of stratigraphic range, USNM 540966, locality TU 1416: road cut on new Los Quemados-Sabaneta road, 1 km east of Las Caobas, Gurabo Formation. Articulated shell, right exterior (10), anterior (11), dorsal (12), and left exterior (13).

14-16. Locality USGS 8519: Río Mao, Bluff 1, Gurabo Formation.
14. USNM 540967, interior of right valve, uncoated to show foliated-calite re-entry (arrow).
15-16. USNM 540968, left valve, uncoated to show external pigment pattern (15) and internal foliated-calcite re-entry (16).

17. Variant with low rib count and uneven rib spacing, USNM 540969, locality TU 1211: Río Gurabo, Gurabo Formation, 381-385 m above base of section. Right valve, exterior.

18. NMB G17512, locality NMB 15871: Río Gurabo, Gurabo Formation, 220-223 m above base of section. Left valve, exterior, showing ontogenetic change in sculpture.

19. NMB G17513, locality NMB 15865: Río Gurabo, Gurabo Formation, 221-223.5 m above base of section. Left valve, exterior, showing ontogenetic change in sculpture.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

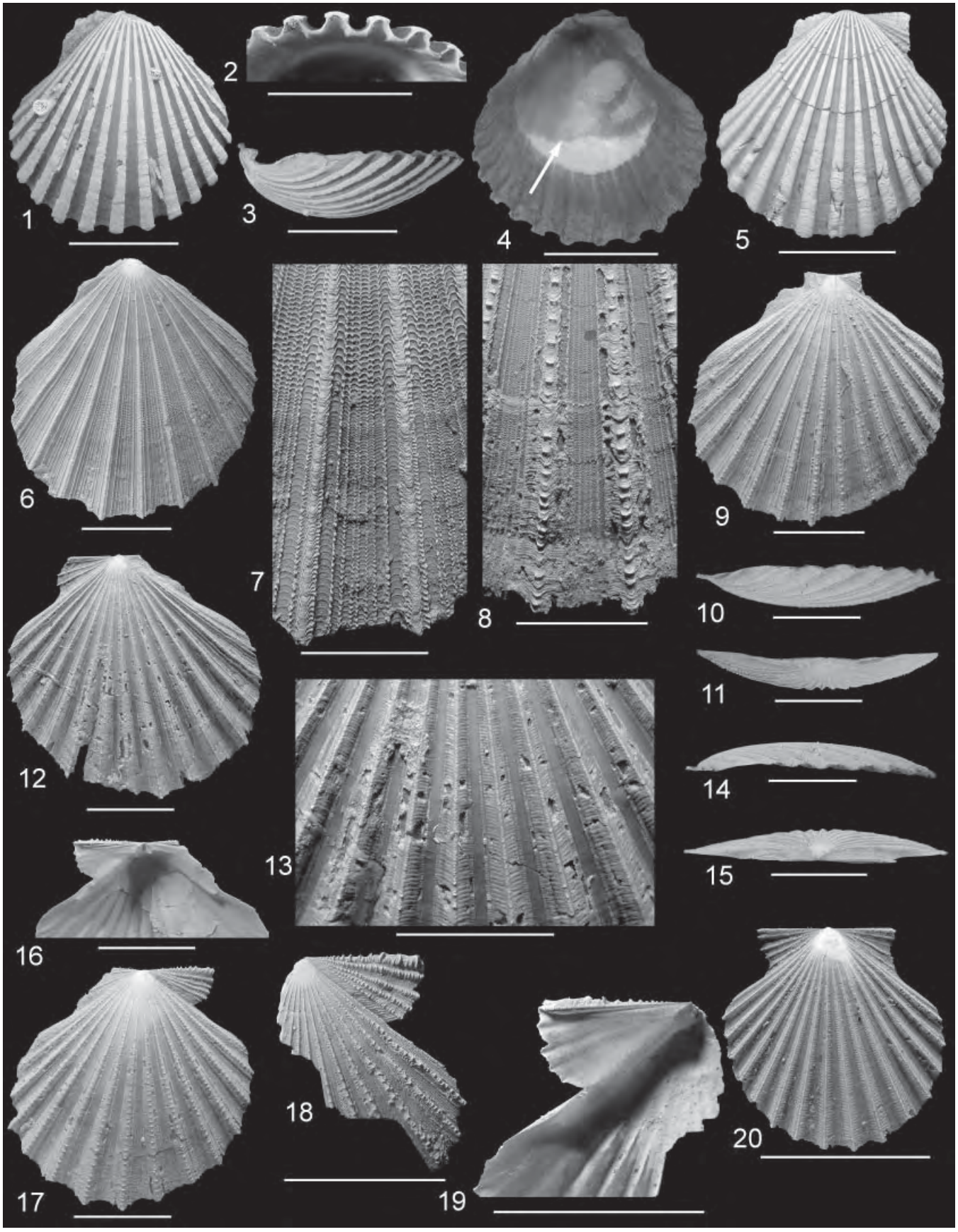

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

PLATE 8

Figure Page

1-5. *Argopecten uselmae* (Pilsbry & Johnson, 1917). Scale bars = 10 mm. 64
1-4. NMB G17514, locality NMB 16885: Río Cana, Mao Formation, 1,177 m above base of section. Right valve, exterior (1), ventral rib profile (2), anterior (3), and interior (4), uncoated to show foliated-calcite re-entry (arrow).
5. USNM 540970, locality TU 1216: southern side of Río Yaque del Norte, road cut, 27 km west of Santiago. Right valve, exterior.

6-7. *Chagrepecten cactaceus* (Dall, 1898). USNM 135058, lectotype designated by Woodring (1982: 594). Right valve, exterior (6) and detail of sculpture (7). Scale bars = 5 mm (7), 10 mm (6). . . 66

8-20. *Chagrepecten paracactaceus* n. gen., n. sp. Scale bars = 5 mm (8), 6 mm (13), 10 mm (9-12, 14-20). . . 67
8-15. Holotype, NMB G17515, locality NMB 15827: Río Gurabo, Mao Formation, 658-660 m above base of section. Disarticulated pair of matching valves.
8-11. Right valve, detail of sculpture (8), exterior (9), anterior (10), and dorsal (11).
12-15. Left valve, exterior (12), detail of sculpture (13), anterior (14), and dorsal (15).
16-17. USNM 540971, locality USGS 8556: Río Amina, Gurabo Formation, level d. Right valve, dorsal interior (16) and exterior (17).
18-19. NMB G17516, locality NMB 16016: Río Gurabo, base of Mao Formation, 580 m above base of section. Partial right valve showing obsolete ctenolium, exterior (18) and interior (19).
20. NMB G17517, locality NMB 15823: Río Gurabo, Mao Formation, 670-672 m above base of section. Left valve, exterior.

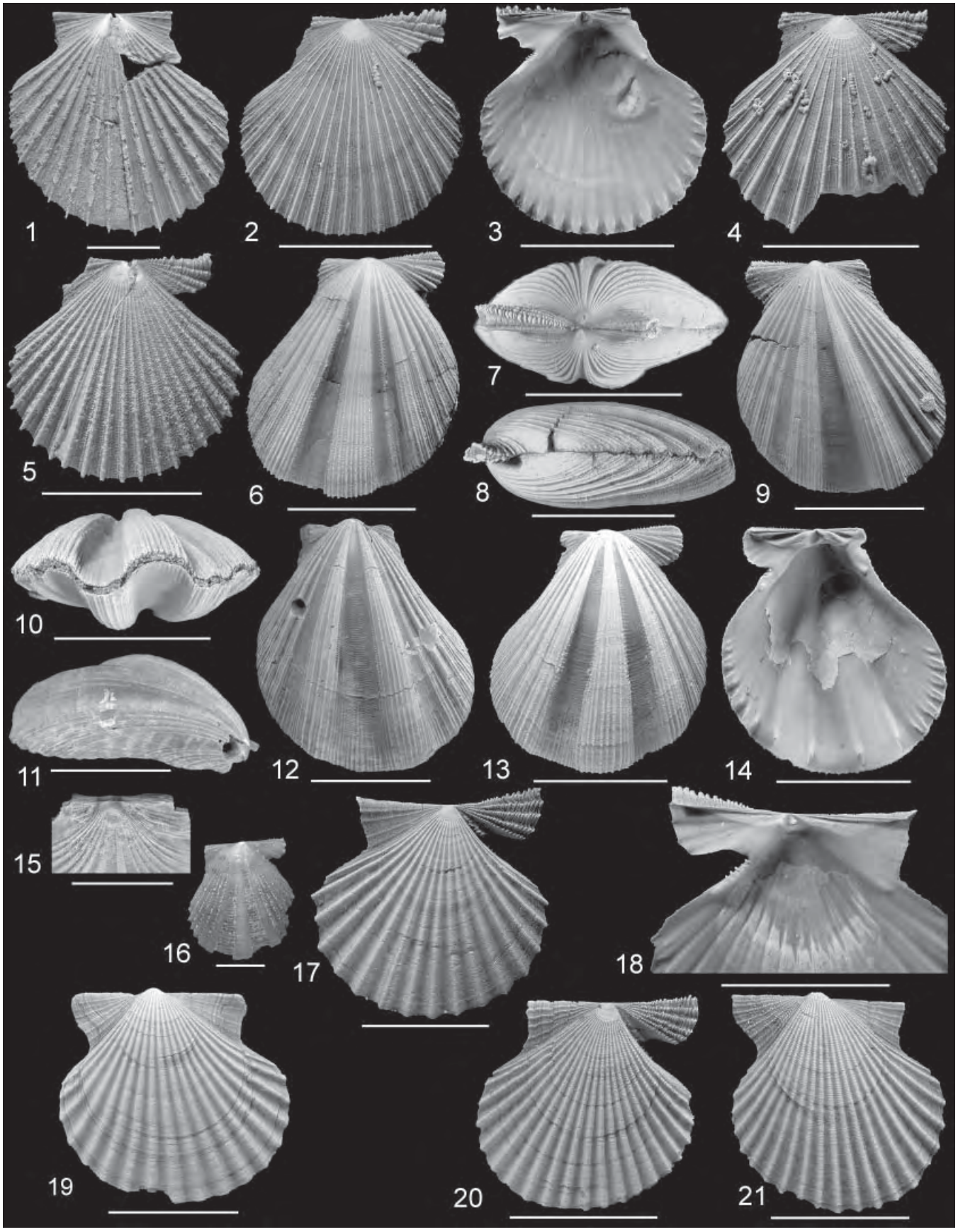
PLATE 9

Figure Page

1-5. *Cryptopecten phrygium* (Dall, 1886), locality TU 1352: Río Gurabo, Mao Formation, 895 m above base of section. Scale bars = 10 mm. 70
1. USNM 540972. Left valve, exterior.
2-3. USNM 540973. Right valve, exterior (2) and interior (3).
4. USNM 540974. Right valve, exterior.
5. USNM 540975. Variant with coarse sculpture, right valve, exterior.

6-16. *Gurabopecten uniplicatus* n. gen., n. sp. Scale bars = 2 mm (16), 5 mm (15), 10 mm (6-14). . . . 72
6-10. Holotype, USNM 540976, locality TU 1209: road cut, 2 km west of Los Quemados, Gurabo Formation. Articulated shell, right exterior (6), dorsal (7), anterior (8), left exterior (9), and ventral (10).
11-12. USNM 540977, locality TU 1211: Río Gurabo, Gurabo Formation, 381-385 m above base of section. Left valve, uncoated oblique view of posterior (11), to show pigment pattern, and planar view of exterior (12).
13-14. USNM 540978, locality TU 1211: same as Fig. 11. Right valve, exterior (13) and interior (14).
15. USNM 540979, locality TU 1211: same as Fig. 11. Left valve, oblique view of umbo, lightly coated to show preradial pitting.
16. USNM 540980, locality TU 1227a: Cañada Zalaya, upper Gurabo Formation. Juvenile right valve, uncoated exterior.

17-21. *Leptopecten thompsoni* (Maury, 1917). Scale bars = 10 mm. 76
17-18. USNM 540981, locality TU1294: Río Mao, Bluff 3, Cercado Formation. Right valve, exterior (17) and interior (18).
19. USNM 540982, locality TU 1294: same as Fig. 17. Left valve, exterior.
20. USNM 540983, locality TU 1295: road cuts *ca.* 3 km east of crossing of Río Mao at Bulla, Cercado Formation. Variant with higher lamellae, right valve, exterior.
21. USNM 540984, locality TU 1295: same as Fig. 20. Variant with higher lamellae, left valve, exterior.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

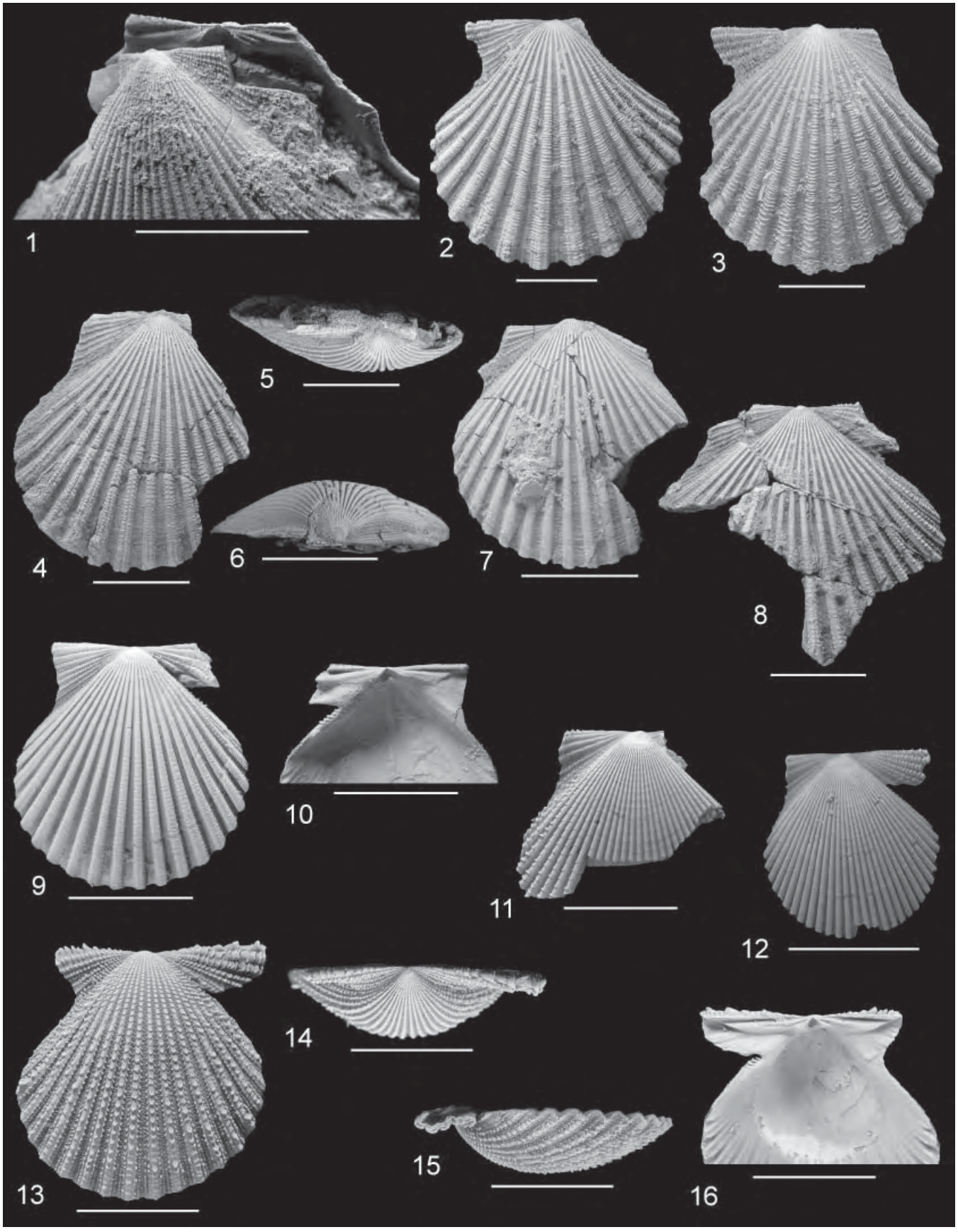

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

PLATE 10

Figure Page

1. *Mimachlamys canalis* (Brown & Pilsbry, 1913). USNM 647215, also figured by Woodring (1982: pl. 97, fig. 4), locality USGS 23652: Gaillard Cut, Canal Zone, Panama, La Boca Formation. Offset matching valves showing left exterior and right hinge. Scale bar = 10 mm. 81

2-3. *Lindapecten chipolanus* (Dall, 1898). Scale bars = 5 mm. 83
2. USNM 540985, locality USGS 2212: Chipola River, Florida, Chipola Formation. Right valve, exterior.
3. USNM 540986, locality USGS 2212: same as Fig. 2. Left valve, exterior.

4-12. *Lindapecten baitoaensis* n. sp. Scale bars = 5 mm (11-12), 10 mm (4-10). 82
4-5. Holotype, USNM 540987, locality TU 1226: Río Yaque del Norte, between Baitoa and confluence with Río Bao, Baitoa Formation. Right valve, exterior (4) and dorsal (5).
6-7. USNM 540988, locality TU 1226: same as Fig. 4. Left valve, dorsal (6) and exterior (7).
8. USNM 540989, locality TU 1362: trail on bluff downstream from Baitoa, Baitoa Formation. Right valve, exterior.
9-10. NMB G17518, locality NMB 17286: Río Yaque del Norte, Lopez section, Baitoa Formation. Right valve, exterior (9) and hinge (10).
11. NMB G17519, locality NMB 16938: Rio Yaque del Norte, Lopez section, Baitoa Formation. Partial right valve, exterior.
12. Multiribbed variant, NMB G17520, locality NMB 16936: Río Yaque del Norte, Lopez section, Baitoa Formation. Right valve, exterior.

13-16. *Lindapecten paramuscosus* n. sp. Holotype, USNM 540990, locality TU 1225: Río Mao at Arroyo Sabirma (well downstream from Bluff 1), Gurabo Formation. Right valve, exterior (13), dorsal (14), anterior (15), and interior (16). Scale bars = 10 mm. 83

PLATE 11

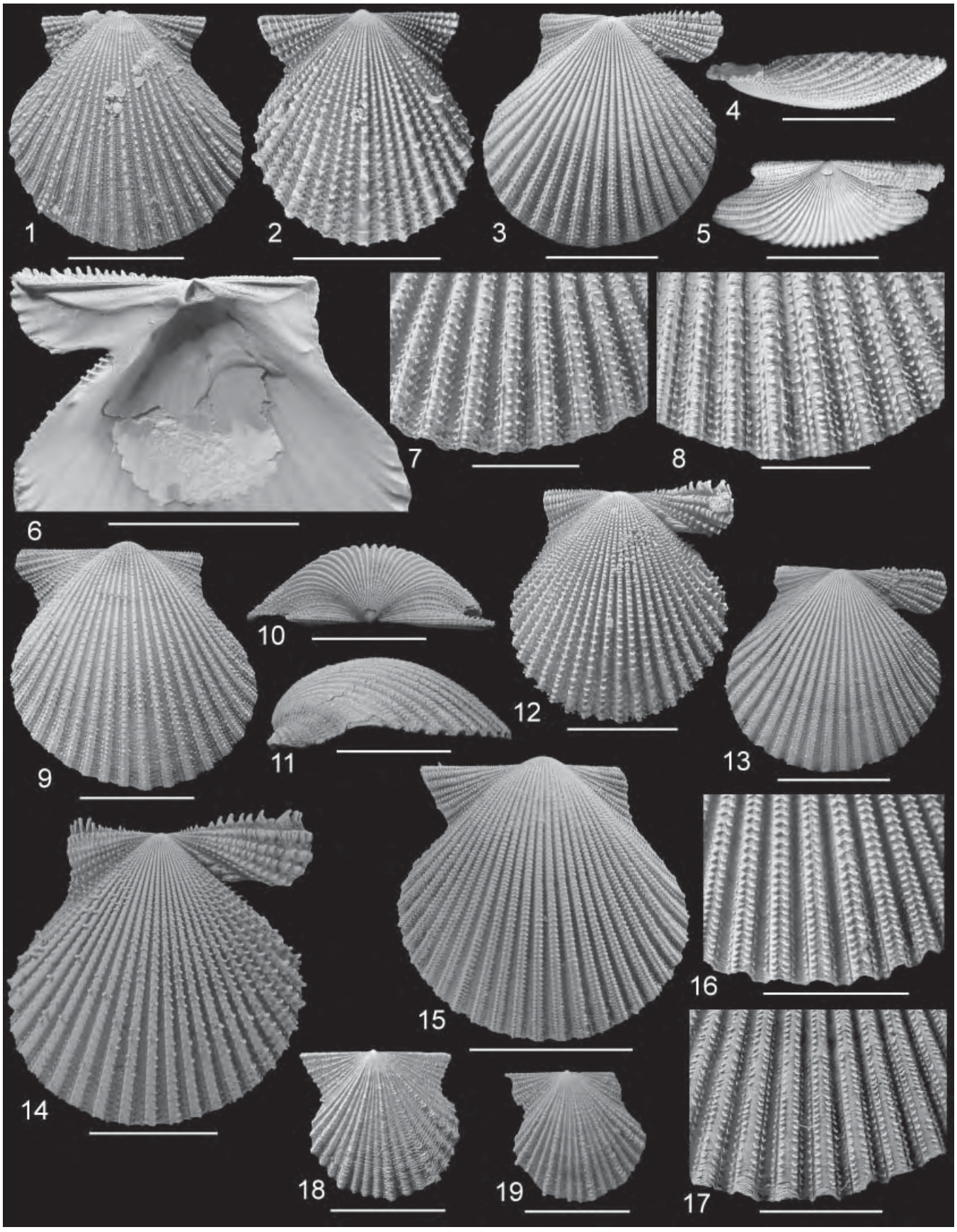
Figure Page

1-2. *Lindapecten paramuscosus* n. sp. Scale bars = 5 mm (2), 10 mm (1). 83
1. USNM 540991, locality TU 1209: road cut, 2 km west of Los Quemados, Gurabo Formation. Left valve, exterior.
2. USNM 540992, locality TU 1227A: Cañada Zalaya, upper Gurabo Formation. Juvenile left valve, exterior.

3-17. *Lindapecten plurinominis* (Pilsbry & Johnson, 1917). Scale bars = 5 mm (7-8, 12, 16-17), 10 mm (3-6, 9-11, 13-15). 85
3-7. NMB G17521, locality NMB 15909: Río Gurabo, Cercado Formation, 111-113 m above base of section. Trisquamous variant, right valve, exterior (3), anterior (4), oblique dorsal (5), interior (6), and detail of exterior (7).
8-11. NMB G17522, locality NMB 15909: same as Fig. 3. Trisquamous variant, left valve, detail of exterior (8), exterior (9), dorsal (10), and anterior (11).
12. USNM 540993, locality TU 1294: Río Mao, Bluff 3, Cercado Formation. Trisquamous variant, juvenile right valve, exterior.
13, 16. USNM 540994, locality TU 1222: road cut 4.5 km north of plaza in Moncion, on road to Los Quemados, Gurabo? Formation. Bisquamous variant, right valve, exterior (13), detail of exterior (16).
14. USNM 540995, locality TU 1416: road cut on new Los Quemados-Sabaneta road, 1 km east of Las Caobas, Gurabo Formation. Bisquamous variant, right valve, exterior.
15, 17. USNM 540996, locality TU 1222: same as Fig. 13. Bisquamous variant, left valve, exterior (15), detail of exterior (17).

18. *Paraleptopecten bavayi* (Dautzenberg, 1900). USNM(IZ) 1136352. North of Mayaguez Docks, Puerto Rico, Recent. Left valve, exterior. Scale bar = 5 mm. 92

19. *Paraleptopecten* sp. *a*. USNM 540997, locality TU 1294: Río Mao, Bluff 3, Cercado Formation. Left valve, exterior. Scale bar = 5 mm. 92


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

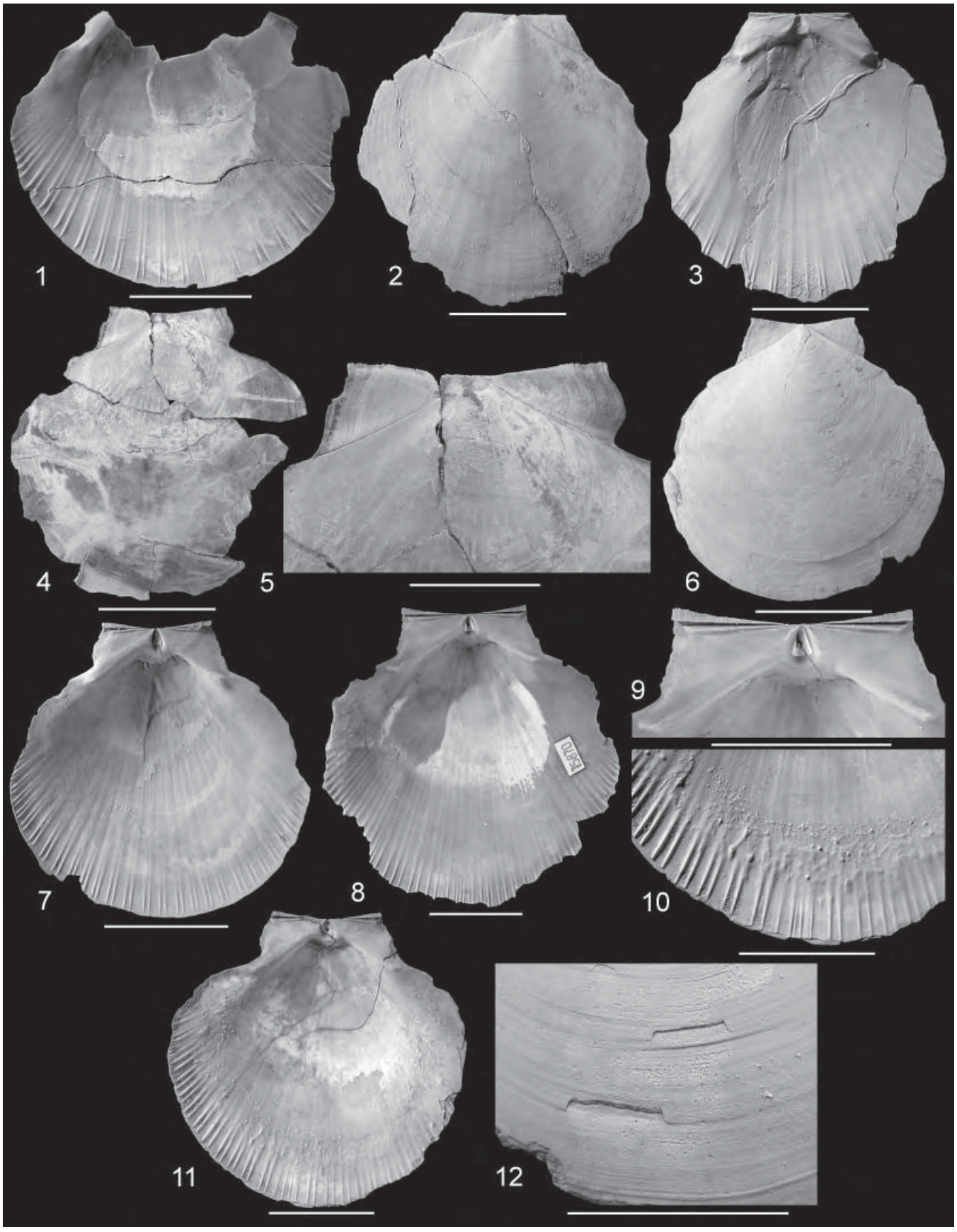

1
2
3
4
5
6
7
8
9
10
11
12

PLATE 12

Figure Page

Amusium papyraceum (Gabb, 1873). Scale bars = 20 mm (1-3, 5-12), 40 mm (4). 94

1. USNM 540998,locality TU 1219: Río Amina, level d, Gurabo Formation. Morphotype A, right valve, interior.

2-3. USNM 540999, locality TU 1219: same as Fig. 1. Morphotype A, left valve, exterior (2) and interior (3).

4-5. USNM 541000, locality TU 1297: Río Gurabo, 183-211 m above base of section, Gurabo Formation. Morphotype A, right valve, exterior (4) and detail of dorsal exterior (5).

6-7. USNM 541001, locality TU 1297: same as Fig. 4. Morphotype A, right valve, exterior (6) and interior (7).

8-9. NMB G17523, locality NMB 15870: Río Gurabo, 218.5 m above base of section, Gurabo Formation. Morphotype B, right valve, interior (8) and detail of hinge (9).

10-12. USNM 541002, locality TU 1230: Río Cana, *ca.* 200 m above base of section, Cercado Formation. Morphotype B, right valve, ventral interior showing repairs by mantle (10), interior of entire valve (11), and ventral exterior showing repaired injuries (12).

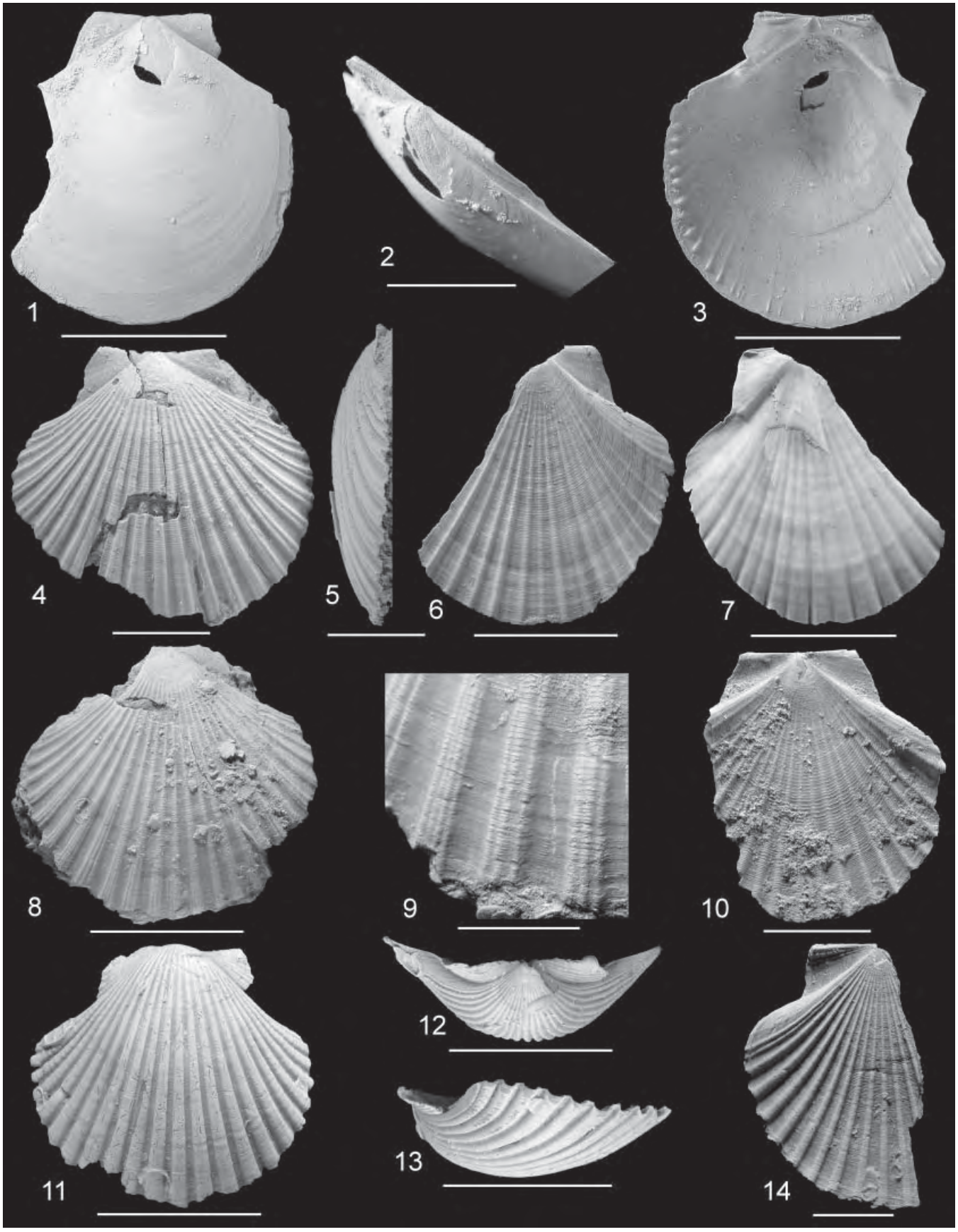
PLATE 13

Figure Page

1-3. *Amusium papyraceum* (Gabb, 1873). USNM 541003, locality TU 1380: road cut south of Santiago, Gurabo? Formation. Morphotype C, right valve, exterior (1), oblique view of anterior disk flank (2), and interior (3). Scale bars = 5 mm (2), 10 mm (1, 3). 94

4-10. *Euvola gurabensis* n. sp. Scale bars = 5 mm (9), 10 mm (4-5, 10), 20 mm (6-8). 100
4-5. Holotype, USNM 541004, locality TU 1338: road cut near Río Gurabo, 2.9 km west of Los Quemados, Gurabo Formation. Right valve, exterior (4) and anterior (5).
6-7. NMB G17524, locality NMB 15831: Río Gurabo, 893 m above base of section, Mao Formation. Partial left valve, exterior (6) and interior (7).
8-9. USNM 541005, locality TU 1209: road cut, 2 km west of Los Quemados, Gurabo Formation. Right valve:, exterior (8) and detail of exterior showing tripartite ribs (9).
10. USNM 541006, locality TU 1224: road cut 6.1 km west of Los Quemados, Gurabo Formation. Left valve, exterior.

11-14. *Euvola jamaicensis* n. n. Scale bars = 10 mm (14), 20 mm (11-13). 101
11-13. NMB G17525, locality NMB 16885: Río Cana, Mao Formation, 1,177 m above base of section. Right valve, exterior (11), dorsal (12), and anterior (13).
14. NMB G17526, locality NMB 16885: same as Fig. 11. Left valve, exterior.


1
2
3
4
5
6
7
8
9
10
11
12
13
14

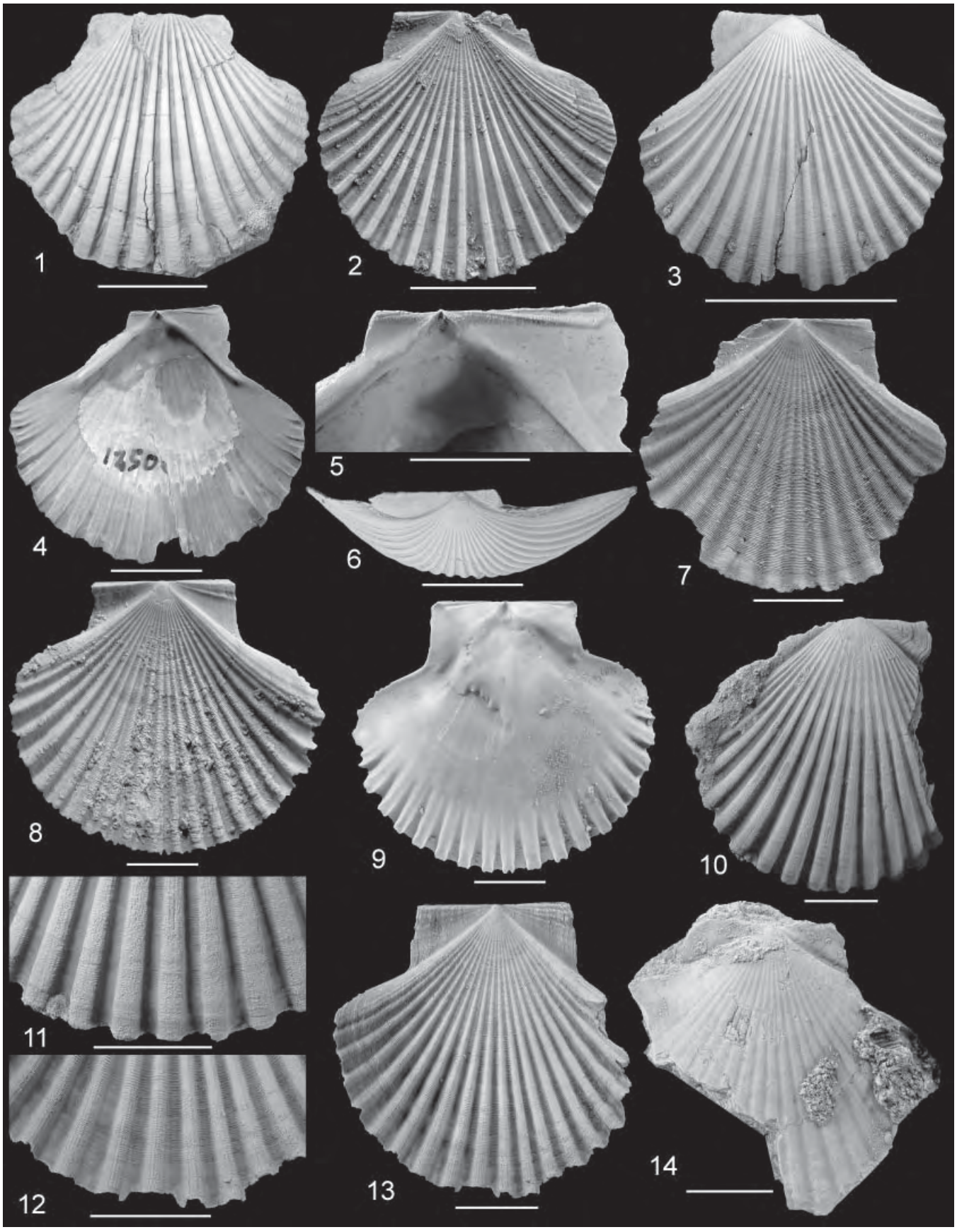

1
2
3
4
5
6
7
8
9
10
11
12
13
14

PLATE 14

Figure Page

1-2. *Euvola jamaicensis* n. n. Scale bars = 20 mm. 101
1. USNM 541007, August Town Series, Jamaica. Right valve, exterior.
2. UCMP 556140. Bowden beds, Jamaica. Left valve, exterior.

3-13. *Euvola soror* (Gabb, 1873). Scale bars = 5 mm (5), 10 mm (4, 6-13), 20 mm (3). 105
3-6. USNM 541008, locality TU 1250: Río Verde, *ca.* 10 km north of La Vega, Gurabo Formation. Right valve, exterior (3), interior (4), detail of hinge (5), and dorsal (6).
7. USNM 541009, locality TU 1250: same as Fig. 3. Left valve, exterior.
8-9. USNM 541010, locality TU 1435: southern side of Río Yaque del North west of Santiago, upper Gurabo Formation? Left valve, exterior (8) and interior (9).
10-11. NMB G17527, locality NMB 16818: Río Gurabo, 347 m above base of section, Gurabo Formation. Right valve, exterior (10), and detail of sculpture showing radial costellae (11).
12-13. USNM 541011, locality TU 1339: road cuts 13.1 km south of bridge over Río Yaque del Norte at Santiago, on road to Jánico. upper Gurabo Formation. Left valve, detail of sculpture showing radial costellae (12) and exterior (13).

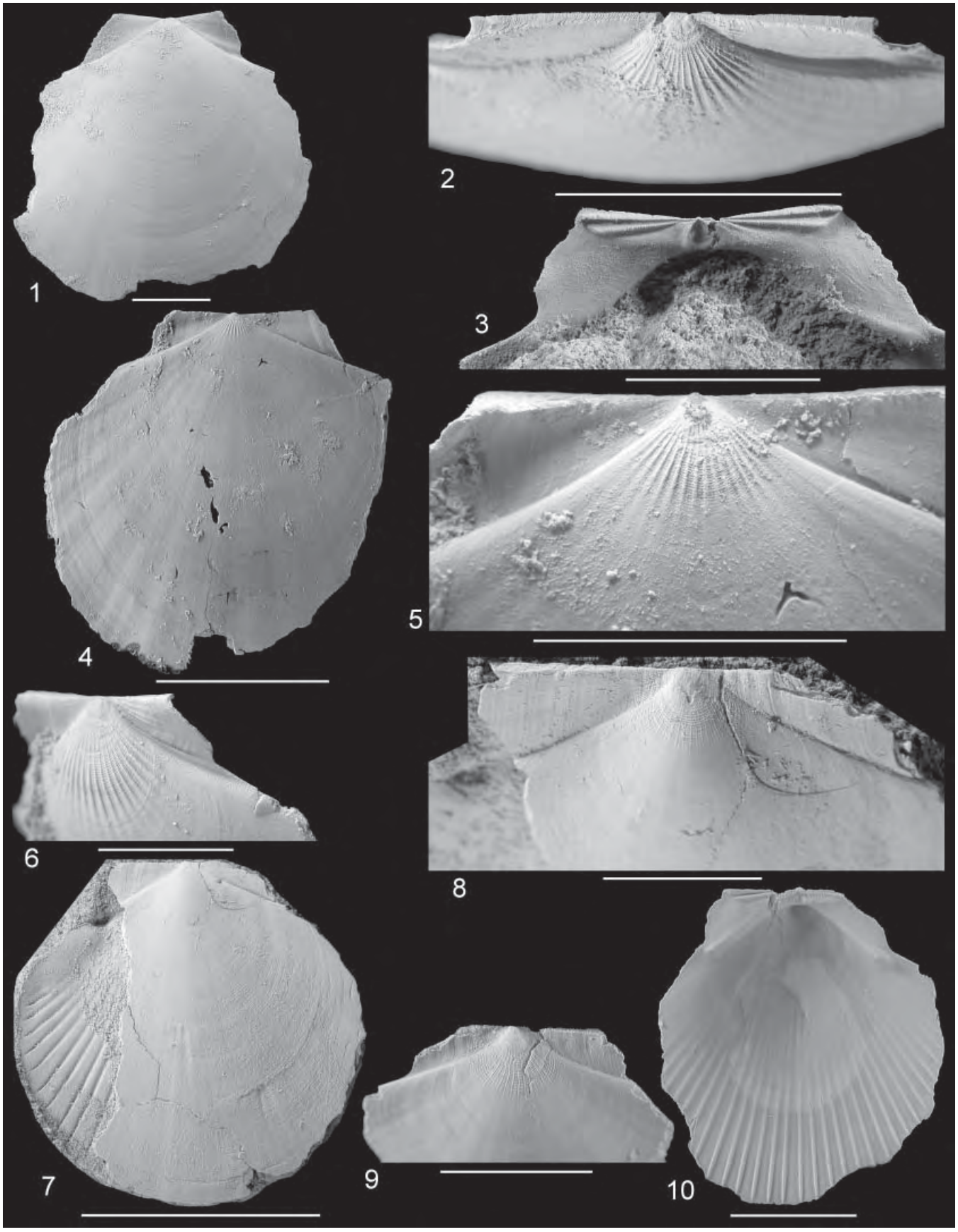
14. *Leopecten gatunensis* (Toula, 1909). NMB G17528, locality NMB 17274: Río Yaque del Norte, just below Arroyo Los Cedros at López, Cercado Formation. Right valve, exterior. Scale bar = 10 mm. 108

PLATE 15

Figure Page

1-6. *Zamorapecten zamorensis* (F. & H. Hodson in Hodson *et al.*, 1927). Locality USGS 11074: Punta Zamuro, Distrito Acosta, State of Falcón, Venezuela. Zamuro Beds. Scale bars = 5 mm (6), 10 mm (1-3, 5), 20 mm (4). 110
1-3. USNM 541012. Right valve, exterior (1), dorsal (2), and hinge (3).
4-5. USNM 541013. Left valve, exterior (4) and detail of dorsal region (5).
6. USNM 541014. Right valve, oblique view of umbo showing anterior disk flank.

7-10. *Zamorapecten maoensis* n. sp. Scale bars = 5 mm (8-10), 20 mm (7). 111
7-8. Holotype, NMB G17529, locality NMB 16122: Río Gurabo, 893 m above base of section, Mao Formation. Left valve, exterior (7), partly broken away to show imprint of internal carinae, and detail of dorsal region (8).
9-10. NMB G17530, locality NMB 15833: Río Gurabo, 895 m above base of section, Mao Formation. Left valve, dorsal region (9) and interior (10).


1
2
3
4
5
6
7
8
9
10

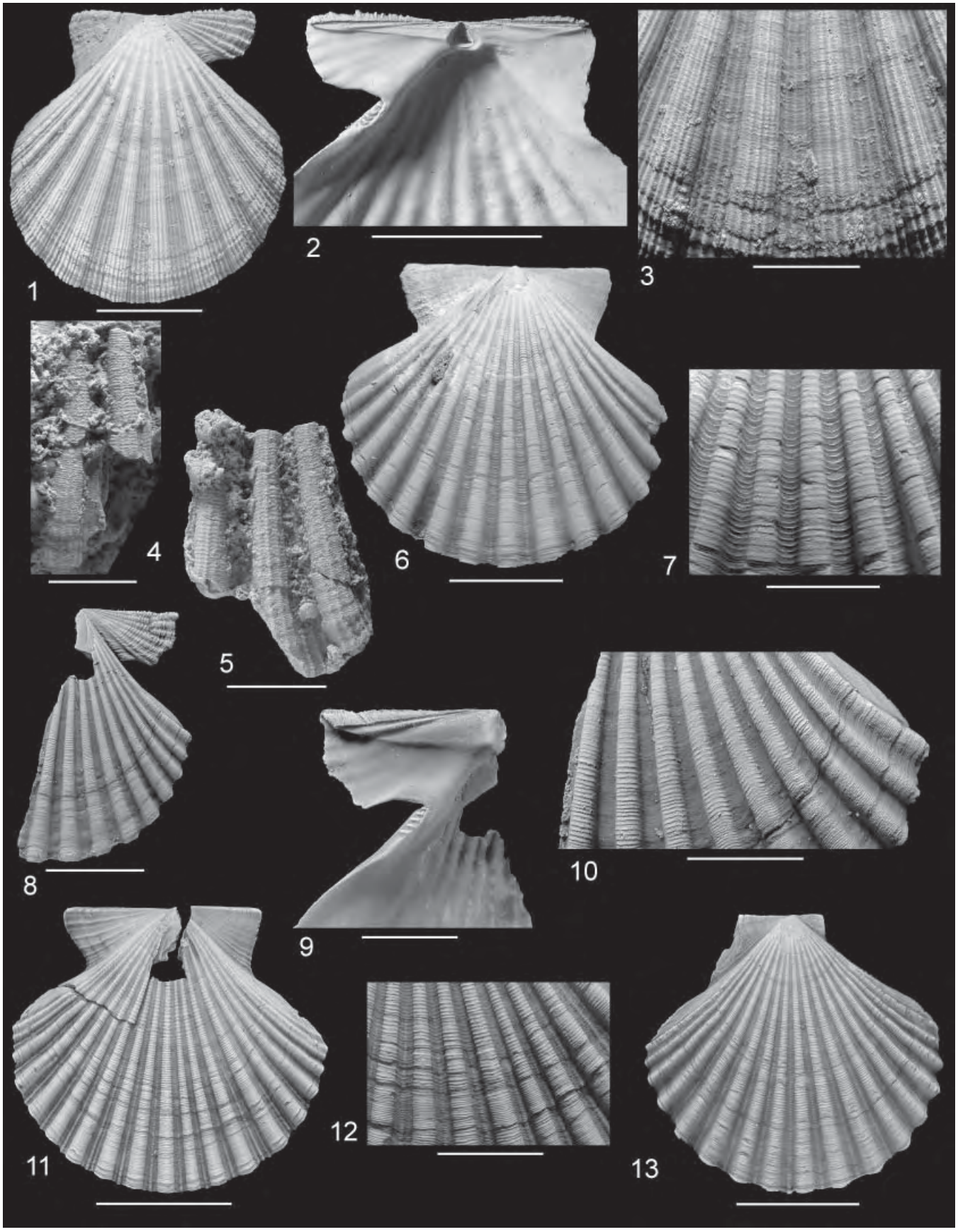

1
2
3
4
5
6
7
8
9
10
11
12
13

PLATE 16

Figure Page

1-5. *Antillipecten antillarum* (Récluz, 1853). Scale bars = 5 mm (3-5), 10 mm (1-2). 113
1-3. USNM(IZ) 103043, St. Thomas, Virgin Islands, Recent. Right valve, exterior (1), hinge (2), and detail of sculpture (3).
4. NMB G17531, locality NMB 15834: Río Gurabo, 807-810 m above base of section, Mao Formation. Fragment of right valve, exterior.
5. NMB G17532, locality NMB 15834: same as Fig. 4. Fragment of right valve, exterior.

6-10. *Antillipecten cercadicus* (Maury, 1917). Scale bars = 5 mm (7, 9-10), 10 mm (6, 8). 114
6-7. Holotype, PRI 28968, Río Mao, Bluff 2, Cercado Formation. Left valve, exterior (6) and detail of sculpture (7).
8-10. NMB G17533, locality NMB 16803: Río Mao, between Bluffs 1 and 2, upper Cercado or lower Gurabo Formation. Partial right valve, exterior (8), hinge (9), and detail of sculpture (10).

11-13. *Antillipecten janicoensis* n. gen., n. sp. Scale bars = 5 mm (12), 10 mm (11, 13). 115
11-12. Holotype, USNM 541015, locality TU 1406: roadcut 15-17 km southwest of Santiago on Santiago-Jánico road, Cercado? Formation. Left valve, exterior (11) and detail of sculpture (12).
13. NMB G17534, locality NMB 16844: Río Cana, 228 m above base of section, *Arca* beds, lower Gurabo Formation. Right valve, exterior.

PLATE 17

Figure — Page

1-3. *Antillipecten microlineatus* n. gen., n. sp. Holotype, NMB G17535, locality NMB 15893: Río Gurabo, Cercado Formation, 150 m above base of section. Articulated shell, right exterior (1), detail of sculpture of right exterior (2), and left exterior (3). Scale bars = 5 mm (2), 20 mm (1, 3). 117

4-10. *Antillipecten quemadosensis* n. gen., n. sp. Scale bars = 5 mm (6), 10 mm (10), 20 mm (4-5, 7-9). . . 117

4-7. Holotype, USNM 541016, locality TU 1278: Río Gurabo, 387-389 m above base of section, Gurabo Formation. Articulated shell, right exterior (4), anterior (5), detail of left exterior (6), and left exterior (7).

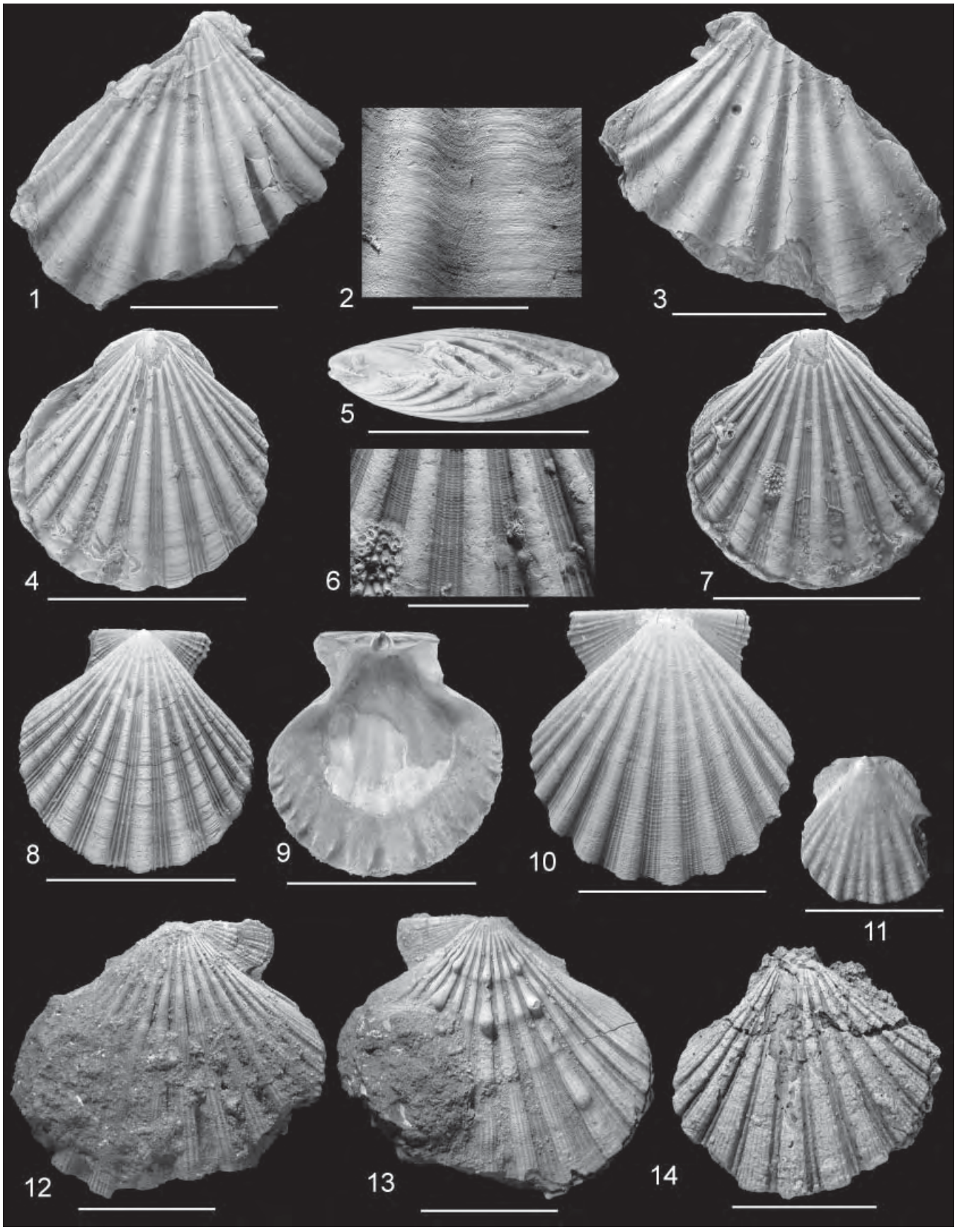
8-9. NMB G17536, locality NMB 15839: Río Gurabo, 360-367 m above base of section, Gurabo Formation. Left valve, exterior with anterior auricle incomplete (8) and interior (9).

10. USNM 541017, locality TU 1281: southern side of Río Yaque near Guayubín, Mao Adentro Limestone. Left valve, exterior.

11. *Antillipecten* sp. NMB G17537, locality NMB 16835: Río Cana, 252 m above base of section, Cercado Formation. Juvenile left valve, exterior. Scale bar = 5 mm. 119

12-13. *Nodipecten colinensis colinensis* (F. & H. Hodson in Hodson *et al.*, 1927). NMB G17538, locality NMB 17274: Río Yaque del Norte, just below Arroyo Los Cedros at López, Cercado Formation. Articulated shell, right exterior (12) and left exterior (13). Scale bars = 40 mm. 121

14. *Nodipecten colinensis vokesae* (Smith, 1991b). *Pecten pittieri* of Cooke (1919), not of Dall (1912), USNM 167122, locality USGS 3468: Gorge of Yumurí River below Iglesia Mte. Serrato, Matanzas Province, Cuba. Right valve, exterior. Scale bar = 40 mm. 123


1
2
3
4
5
6
7
8
9
10
11
12
13
14

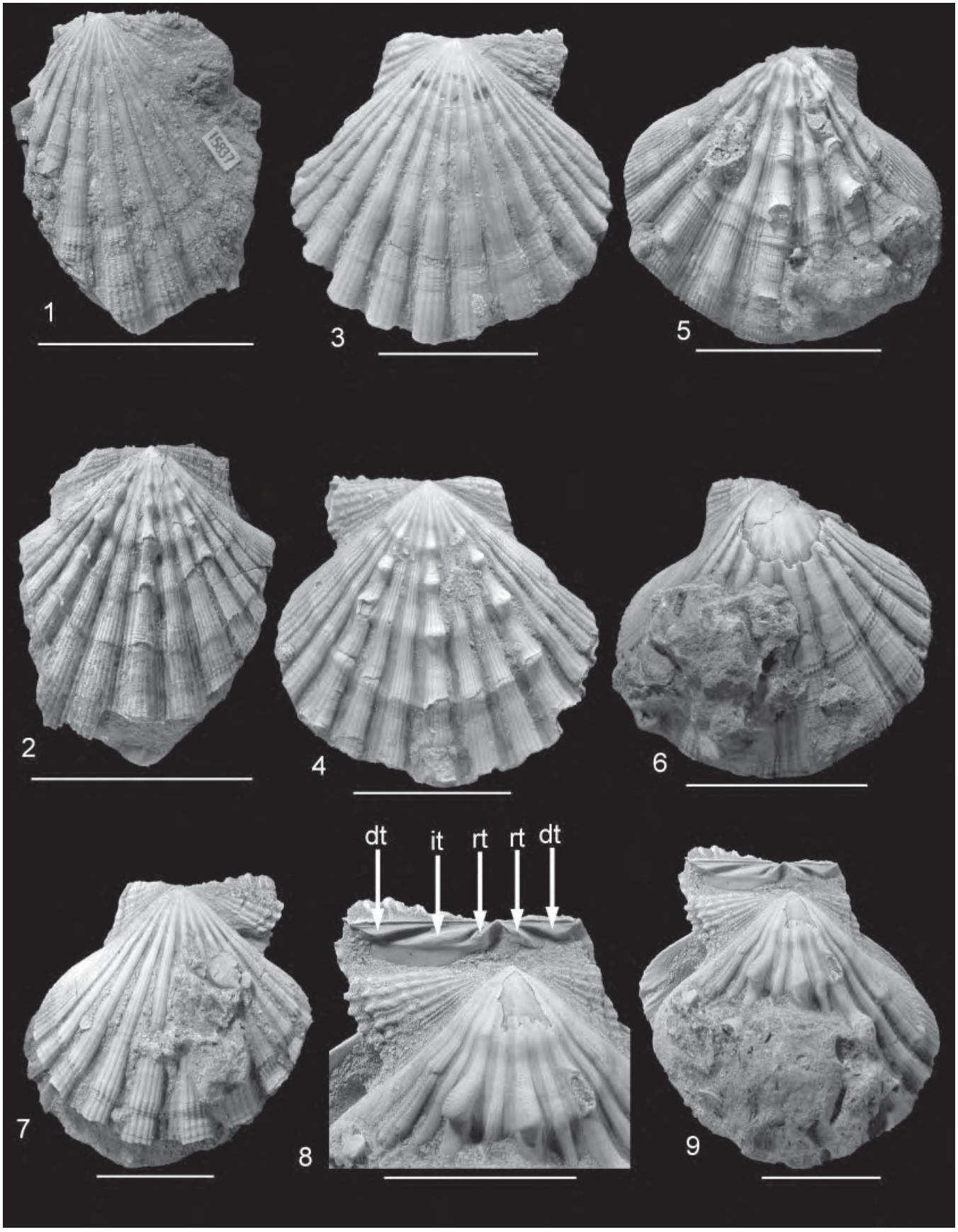

1
3
5
2
4
6
dt
it
rt
rt
dt
7
8
9

PLATE 18

Figure Page

1-4. *Nodipecten colinensis vokesae* (Smith, 1991b). Scale bars = 20 mm (3-4), 40 mm (1-2). 123
1-2. NMB G17539, locality NMB 15837: Río Gurabo, 374-376 m above base of section, Gurabo Formation. Incomplete articulated shell with offset valves, right exterior (1) and left exterior (2).
3-4. USNM 541018, locality TU 1278: Río Gurabo, 387-389 m above base of section, Gurabo Formation. Articulated shell, right exterior (3) and left exterior (4).

5-9. *Nodipecten nodosus* (Linnaeus, 1758), locality TU 1354: Río Cana, 336-346 m above base of section, Gurabo Formation. Scale bars = 20 mm (7-9), 40 mm (5-6). 124
5-6. USNM 541019. Articulated shell, left exterior (5) and right exterior (6).
7-9. USNM 541020. Articulated shell with offset valves, right exterior (7), detail of right hinge (8) showing dorsal teeth (dt) anterior intermediate tooth (it), and resilial teeth (rt), and left exterior (9).

INDEX

Note: Page numbers are in light face; plate numbers are in **bold face** type; pages on which principal discussions occur are in italics.

Abbott (1954) 2, 17, 70, 113, 124
Abbott (1974) 24-26, 37, 70, 80, 91, 94, 113, 119, 121, 140
Abbott & Dance (1982) 113
acanikos
  Chlamys (*Lyropecten*) 81, 83
  Lindapecten 81, 83
acanthodes, *Lindapecten* 80
acuminatus, *Cyclopecten* 7, 18, 19, 24, 69, **1**
Adams, H. & A. (1858) 17
Addicott
  (1969) 76
  (1972) 76
  (1976) 76, 138
  (1978) 2, 76
Aequipecten
  canalis 81
  inaequalis 52, 64
  phrygium 70
  tehuelchus 80
  thetidis 56
  (*Aequipecten*) *phrygium* 70
  (*Pacipecten*) 73
Aequipectinini 40, 65
agronomica, *Pecten* 91
Agua Clara Formation 99
aguaclarense, *Amusium* 99
Agueguexquite Formation 127, 137
Aguerrevere (1925) 122
aidei
  Interchlamys 31-32
  Pecten interlineatus 30-31
Akers
  (1972) 15
  (1974) 127, 140
Alhajuela Formation 81, 98-99, 109, 122-124, 138
alli, *Cryptopecten* 67, 69
Allmon (2005) 15
Almejas Formation 138-139
almirantensis, *Cyclopecten* 24
alumensis, *Pecten* (*Chlamys*) 112
ameleus
  Argopecten 15, 28, 38, *41-42*, 59, 104, 120, **4**
  Chlamys (*Plagioctenium*) 41
amenensis, *Pecten* (*Aequipecten*) 82
Amusium 5, 7, 16, 53, *93-94*, 109-110
  aguaclarense 99
  balloti 94
  bocasense 98
  darwinianum 98-99
  japonicum 94
  lucidum marmoratum 25
  luna 98-99
  mortoni 94, 98-99
  papyraceum 7, 9-13, 16, 20, 22, 26, 29, 38, 40-41, 44, 54, 57, 59, 69, 74, 78, 86, 88, *94-99*, 102, 104, 116, 119-120, 125-126, **12-13**
    Morphotype A 12-13, *95*-99, 119, **12**
    Morphotype B 12-13, *95*-99, **12**
    Morphotype C 29, *95*-96, 98, **13**
  paris 98-99
  pleuronectes 94
  rexmaris 98
  sol 94
  toulae 98-99
  (*Parvamussium*) *spendulum* 27
  (*Propeamusium*)
    marmoratum 25
    striatulum 25
Amussiopecten
  burdigalensis 110
  expansus 110
  protistus 109
  (*Costellamussiopecten*) 110
Amussium (*Parvamussium*) 25
Anadara (*Larkinia*) *patricia* 13
anatipes, *Pecten* 112
Anatipopecten 112-113
Anderson
  (1929) 139
  & Martin (1914) 82
andersoni
  andersoni, *Leptopecten* 138
  barkerianus, Leptopecten 138
  clemonensis, *Leptopecten* 138
  subandersoni, *Leptopecten* 138
  Leptopecten 76, 138
Angostura
  Formation 109, 138
  Gorge 4, 14, 30, 33, 145
Anguilla 32, 83, 85, 112
  Formation 32, 85, 112
anguillensis, *Pecten* 112
angusticostatus, Pecten (*Aequipecten*) 56
ANSP [Academy of Natural Sciences, Philadelphia, Pennsylvania, USA] catalog numbers
  2846 32
  2853 58
  2854 43
  2862 106
  2864 95
  2866 58, 62
  11124 65
Antigua 112
  Formation 112
antillarum
  Antillipecten 7, 9, 15, *113-114*, 116, 118-119, **16**
  Bractechlamys 112-113
  Comptopallium 113
  Decatopecten 113
  Lyropecten 112-113
  Pecten 112-114
    (*Nodipecten*) 113
  Semipallium 113
Antilles 26, 65, 70-71, 80, 91-92, 113, 119, 126, 140
Antillipecten n. gen. *112-113*
  antillarum 7, 9, 15, *113-114*, 116, 118-119, **16**
  bellipictus 112-113

cercadicus 15, 44, 59, 88, 104, *114-115*, 116, 118-119, **16**
janicoensis n. sp. 44, 78, 86, 88, 96, 104, *115-117*, 118-120, 126, **16**
microlineatus n. sp. 115, *117*, **17**
quemadosensis n. sp. 29, 38, 44, 57, 59, 74, 78, 86, 88, 96, 102, 104, 114, 116, *117-119*, 120, 124-126, **17**
reynali 112
sp. 44, 88, 96, 104, *119*, **17**
vaun
flabellum 112
vaun 112
wythei 115
willobianus 112
aotus, *Cyclopecten* 21-22
Aphera islacolonis
Formation 52
Zone 12
Araya Peninsula 31
Arca beds 12, 44, 52, 116, 173
Arctinula 17
argenteus, *Pecten* 113-114
Argentina 94, 99, 108
Argopecten 40-41
ameleus 15, 28, 38, *41-42*, 59, 104, 120, **4**
borinquenensis 66
eccentricus 7, 8, 9, 13, 16, 38, 43-44, 49, 53, 59, 63, 66, 73, 76, 86, 88, 98, 123
assemblage 7, 9-11
caimiticus 8-13, 20, 22, 26, 38, 43-44, 49-50, *51-52*, 54-57, 59, 63, 74, 78, 86, 88, 96, 102, 104, 116, 119-120, 126, **6**
biozone 13
eccentricus 10, 13-14, 20, 38, 40-41, *42-49*, 50-52, 59, 63, 77-78, 88, 96, 104, **4**, **5**
biozone 13-14
lacabrensis n. ssp. 8-10, 13, 20, 44, *49-51*, 52, 59, 64, 88, 96, 104, **5**
biozone 13
subassemblage 7-10, 12
gibbus stock 54
inaequalis 7, 10, 22, 26, 38, 44, *52-55*, 59, 65, 71, 74, 86, 96, 98, 102, 104, 126, **6**
lineolaris 53-54, 66
mayaguezensis 66
noronhensis 56, 63, 65-66
nucleus 42, 49, 52, 65
parathetidis n. sp. 38, 44, *55-56*, 57, 59, 63, 86, 88, 96, 102, 104, 120, 125, **6**
thetidis 7-11, 13, 16-17, 20, 22, 26, 29, 37-38, 40-42, 44, 48, 53-55, *56-64*, 66, 72-74, 84-86, 88, 96, 98, 102, 104, 118, 120, 123, 125-126, **7**
uselmae 15, 42, 56, 63, *64-66*, **8**
baracoensis 64, 66
Arnold (1906) 76, 138-139
Arroyo Bajón 10, 11, 43, 142
Arroyo Beyaco [or Bellaco] 52
Arroyo La Cabra 50
Arroyo La Sibirma 55
Arroyo López 14-15, 109, 122
Arroyo Los Cedros 122, 169, 174
Arroyo Zalaya 10, 23-24, 39, 54, 61, 89
asperrimus, Pecten 34
Astoria Formation 138
Atlantic Coastal Plain 40
Atlantic Ocean
eastern 17, 34, 37, 39, 40, 113
northwestern 37
western 7, 17, 21, 24, 26-27, 29, 31, 34, 36-37, 41, 66-67, 69-70, 73, 76, 79-82, 85, 91-92, 100-101, 108, 112-113, 119, 121, 126, 139-140
atlanticola, Leptopecten 139
August Town
Formation 103, 105
Series 169
augusticostatus, Pecten 56-58, 62
auroraensis, Paraleptopecten 140
Australia 94
Austria, Institut für Paläontologie, Universität Wien 108
Aymamon Formation 119
Bahamas 65, 76, 80, 139-140
Baitoa 11, 48, 83, 116, 161
Formation 2, 11-12, 14-15, 81, 83-84, 105, 107, 161
baitoaensis, *Lindapecten* 12, 15, 81, *82-83*, 84, 104, **10**
Baja California 30-31, 67, 73, 76, 81-82, 99, 107, 138-139
bakeri, *Pecten* (*Patinopecten*) 107
Baldí, Less, & Mandic (1999) 110
balloti, *Amusium* 94
baracoensis, *Argopecten uselmae* 64, 66
Barbados 70-71, 113-114
barkerianus, *Leptopecten andersoni* 138
barretti
Euvola 107
Pecten 101, 103
Pecten (*Pecten*) 14, 101, 103
bavayi
Chlamys (*Aequipecten*) 91
Paraleptopecten 91-93, 140, **11**
Bayer
(1941) 28
(1943) 113
Bellamar Member 123
bellilamellatus, *Paraleptopecten* 139
bellipictus, Chlamys (Chlamys) 112-113
benedicti
Pecten 36
Spathochlamys 16, 37
Bermont Formation 114, 126
Bermuda 27, 65, 80, 82, 100, 114, 121, 126
Bernardi (1861) 94
Berry
(1957) 139
(1968) 138
Beu
(1965) 81
(1995) 2
Beurlen (1944) 17
Biju-Duval, Bernard 2
biolleyi, *Paraleptopecten* 75, 92, 139
Blackwelder (1981) 140
Bloom (1975) 81
Blow, Warren 34, 127
blowi, *Mimachlamys 34-35*, 36, 117, **3**
Bluff 1 4, 10-11, 13-14, 20, 38, 44, 48, 54-55, 59, 64, 77-78, 88, 95-96, 104, 115, 142, 146, 154, 161, 173
Bluff 2 4, 10-11, 13-15, 20, 38, 40-41, 43-44, 48-49, 59, 77-79, 88, 96, 104, 115, 142, 146, 154, 173
Bluff 3 4, 10-11, 13-15, 40-41, 43, 49, 77-79, 88, 92-93, 96, 139-140,

142, 149, 158, 162
BMNH [The Natural History Museum, London, U.K.] catalog numbers
LL11354 53
LL11355 58
Bocas del Toro basin 24
bocasense, *Amusium* 98
boesei, *Leopecten* 109
Bold
(1968) 12-13
(1969) 33
(1975) 30, 34, 115
(1988) 9, 12-13, 15, 31, 44, 46, 68, 115-116
Bolli & Bermúdez (1965) 56
Bongrain
& Cahuzac (2004) 110
et al. (1994) 110-111
borinquenensis, *Argopecten* 66
Born (1778) 42
Boss
(1982) 17
et al. (1968) 63
bostrychites, *Spondylus* 103
Bowden
Formation 16, 19, 21, 23-24, 28, 36-37, 42, 65-66, 102-103, 105, 149
shell beds 14-15, 24, 27-28, 36, 42, 65, 90, 103, 107, 112-114, 119, 169
Bractechlamys antillarum 112-113
Brand (2006) 94
Brasso Formation 79
Brazil 26-27, 36, 41, 65, 79-80, 82, 91-92, 100, 119, 121, 127, 140
Brocchi (1814) 110
Bronn
(1828) 110
(1832) 25, 93
Brown & Pilsbry
(1911) 49, 98
(1913) 22, 81, 94, 98, 101
buchivacoanus
buchivacoanus
Lindapecten 81
Pecten (*Chlamys*) 82
falconensis
Lindapecten 81, 85, 90
Pecten (*Chlamys*) 82
maracaibensis
Lindapecten 82
Pecten (*Chlamys*) 82
species complex, *Lindapecten* 81-82, 85, 124
Buckingham Limestone 126, 140
bullatus
Cryptopecten 67, 71
Pecten (*Chlamys*) 67, 69
burdigalensis
Amussiopecten 110
Pecten 110
burnsi, *Pecten* 91
cactaceus
Chagrepecten 68-69, **8**
Pecten 67-69
(*Chlamys*) 66
caimitica, *Pecten* 51-52
caimiticus, *Argopecten eccentricus* 8-13, 15, 20, 22, 26, 38, 43-44, 49-50, *51-52*, 54-57, 59, 63, 74, 78, 86, 88, 96, 102, 104, 116, 119-120, 124, 126, **6**
Caimito 4, 51-52, 124, 138
Formation 81, 138
California 66, 30-31, 36, 40-41, 73, 75-76, 82, 92, 100, 103, 108, 138-139
Caloosahatchee Formation 92, 94, 114, 126, 140
Caloosahatchian province 16
camerella, Leptopecten 138
Campbell (1993) 140
Camuy Formation 15, 66, 103, 105
Cañada de Zamba 124
Cañada Zalaya 10, 142, 158, 162
canalis
Aequipecten 81
Mimachlamys 81, **10**
Canímar Formation 123
Cantaure Formation 122
Cape Cod 67
Cape Hatteras 70, 79-80, 126
Cape Lookout 80
Caribachlamys 27
guayubinensis n. sp. 14, *27-28*, 29, 36, 120, **2**
imbricata 28
jungi n. sp. *28-30*, 59, 86, 96, 120, 126, **2**
mildredae 28
paucirama 29
sentis 27, 29, 30
Caribbean 3, 14, 16, 25, 27, 29, 36, 41, 49, 53, 65-66, 74, 76, 79-80, 82, 91-92, 94, 99-100, 113-114, 119-122, 124-127, 139-140
Plate 2
caribea, *Euvola* 103, 107
caribeus, *Pecten* (*Pecten*) 103
caribphile 16
Carmen Formation 67, 107
Carreño & Smith (2007) 82, 107, 139
Carriacou 122
Formation 122
CAS [California Academy of Sciences, San Francisco, California, USA] 6
Caujarao Formation 81-82, 121-123
Caya Agua Formation 24
Central America 80, 82, 91, 108, 126
cercadica
tabaquita, *Pecten* 79
Pecten 79, 112, 114-115
(*Plagioctenium*) 114
cercadicus, *Antillipecten* 15, 44, 59, 88, 104, *114-115*, 116, 118-119, **16**
Cercado de Mao 4, 77, 84, 139-140
Cercado
facies 16, 52
fauna 12-13, 119
Formation 2, 7-10, 12-16, 20-21, 23-24, 35, 37, 39-41, 44-52, 60-62, 64, 66, 76-79, 81, 83, 87-93, 95, 96-97, 104-105, 107, 109, 112, 115-117, 119, 122, 124-127, 139-140
Cercado-Gurabo
boundary 8, 12-13, 86-88, 95-96, 104
sequence 16, 58
Chagrepecten n. gen. *66-67*
cactaceus 67-69, **8**
dallasi 67
paracactaceus n. sp. 18, 22, *67-69*, 71, 96, **8**
paracactaceus assemblage 7, 9-10, 12
Chagres Sandstone 57, 66-67, 69, 98-99, 109, 138

Chattahoochee Formation 112
chazaliei, *Euvola* 101
Cheetham & Jackson (1996) 7
Chipola Formation 15, 81, 83, 91, 112, 161
chipolanus
Lindapecten 15, 81, 83, 85, **10**
Pecten (*Aequipecten*) 81, 83
Chlamydinae 27
Chlamys
cruciana 31-32
hastata hericia 81
inaequalis 57
mediacostata grewingki 30
oxygonum 56
reynali 112
rubida 81
thetidis 56
(*Aequipecten*)
bavayi 91
plurinominis morantensis 85, 90
(*Chlamys*)
bellipictus 112-113
sua 82
vaginulus 36
(*Leptopecten*) 73, 91, 140
(*Lyropecten*)
acanikos 81, 83
incertae 113
interlineatus 31
nodosa 124
(*Nodipecten*)
colinensis 121
guadeloupensis 121
nodosa 124
nunezi 123
(*Palliolum*?) *guppyi* 19
(*Plagioctenium*)
ameleus 41
concinnata 64
gonioides 64
mansfieldi 64
Chowan River Formation 140
cibaoense, *Palliolum*? 20, *39-40,* 41, 44, 59, 78, 88, **4**
circularis, Pecten **40**
Clark
(1971) 75
(1974) 106
clemonensis, *Leptopecten andersoni* 138
clydonus, *Nodipecten* 121-122
CM [Carnegie Museum] catalog number
74202 80
Coan *et al.* (2000) 40, 73, 75-77, 121, 138
Coatzacoalcos Formation 66, 67, 69
Cocos Island 24
cocosensis, *Cyclopecten* 24
codercola, *Euvola* 107
coderensis
willistoni, *Leptopecten* 139
Leptopecten 76, 79, 139
Codore Formation 76, 79, 82, 139
colinensis
colinensis
Lyropecten 121
Nodipecten 14, 16, *121-123*, 124-125, **17**
guadeloupensis
Chlamys (*Nodipecten*) 121
Nodipecten 122
vokesae
Lyropecten 121, 123
Nodipecten 15, 29, 38, 54, 57, 59, 74, 86, 96, 102, 104, 120, 122, *123-124*, 125, **17-18**
Chlamys (*Nodipecten*) 121
Lyropecten (*Nodipecten*) 121
Nodipecten 120-124
Pecten 121
collierensis
floridensis, *Nodipecten* 126, 127
Nodipecten 125-126
Collins
(1993) 24
& Coates (1999) 69, 139
et al. (1996) 66, 69, 101, 109
Colombia 80, 108, 109, 124, 139, 140
Colombian-Venezuelan-Trinidad subprovince 16
colpotus, *Euvola* 107
Comptopallium antillarum 113
concinnata, *Chlamys* (*Plagioctenium*) 64
confragosa, *Radimella* 30, 115
Conrad
(1837) 74-75, 91, 138
(1849) 126
(1862) 5
(1865) 40
Cooke
(1919) 14-15, 30-33, 56, 62, 83, 85, 101, 103, 112, 114-115, 123
(1921) 14, 34, 112
Cooke, C. W. 2, 40
coralliphila, *Euvola* 101
Cordillera
Central 2
Septentrional 2, 14
correctus, *Pecten* (*Amusium*?) 108
cortezianus, *Lindapecten* 82, 85, 91
Coscinaraea 14, 33
Cosel (1986) 76, 139
Costa *et al.* (2001) 7, 21
Costa Rica 21, 24, 66-67, 101, 108-109, 125, 139
costaricensis, *Pecten* 64, 66
Costellamussiopecten 110-111
Cotton (1999) 101
Cox
(1927) 94, 110
(1969) 3
Cox, L. R. 62
cracens, *Leptopecten* 138
Crassadomini 27
Cristatopecten 110
cristatum, "*Amusium*" 110
crocus, Dimarzipecten 32
Cronin *et al.* (1984) 140
Cronk
(1992) 16
(1997) 16
Cropp (1994) 94
Crosse (1885) 37
cruciana, *Chlamys* 31-33

crucianus, *Pecten* (*Plagioctenium*) 30-32
Cryptopecten *69-70*
alli 67, 69
bullatus 67, 69, 71
cactaceus 66-69
phrygium 7, 9-10, 22, 54, 67, 69, *70-71*, **9**
Cuba 14-15, 30-35, 66, 83, 85, 92, 103, 107, 112, 114-115, 123-124, 137-138
Cuesta Arriba 42, 153
Cumaná Formation 103
Cuvier (1797) 17
Cyclopecten *17-18*
acuminatus 7, *18-19*, 24, 69, **1**
almirantensis 24
aotus 21, 22
cocosensis 24
defuniak 22
fenestratus 17
guppyi 7, 10, 12, *19-23*, 24, 26, 38, 40-41, 44, 54, 59, 74, 78, 86, 88, 96, 104, **1**
hoskynsi 17
nanus 17, 21-23
oligolepis 22, 23
pustulosus 17
thalassinus 24
zalaya n. sp. 7, 10-12, 18-22, *23-24*, 26, 44, 54, 59, 69, 74, 86, 96, 104, **1**
Dabajuro 82
Dall
(1881) 7, 25-26
(1886) 7, 24-26, 37, 69-70
(1889) 70
(1897) 139
(1898) 5, 7, 15-16, 19, 31, 36, 40, 42-43, 52, 56-58, 62-64, 66, 69, 83, 85, 91, 94, 99-100, 103, 105, 112-113, 119-120, 124
(1908) 24
(1912) 122
(1924) 37
(1925) 80
(1926) 76, 139
& Simpson (1901) 66
et al. (1938) 66-67, 69
dallasi
Chagrepecten 67
Pecten (*Chlamys*) 67
darwinianum, *Amusium* 98-99
Dautzenberg
(1900) 91, 101, 140
& Bavay (1912) 67, 69
Decatopecten antillarum 113
Decatopectinini 81, 112-113
defuniak, *Cyclopecten* 22
de Huelbes (1988) 31-32
del Norte (1991) 94
del Río
(1991) 99
(1992) 98-99
(2004) 99
(2006) 121-122
democracianus, *Leptopecten gilbertharrisi* 139
Depéret & Roman (1910) 110
desultorius, *Paraleptopecten* 140
Dijkstra
(1994) 113
(1999) 124
Gofas (2004) 17
Dimarzipecten 32, 37
Dimya 7, 9, 18, 20, 22, 37, 38, 44, 54-55, 57, 59, 69, 71, 74, 85-86, 88, 96, 102, 120
Dominican Republic project 2, 29
Donovan (1998) 24
dumblei, *Lyropecten* 122
Dunker (1877) 69
duodecimlamellatus, *Pecten* (*Pleuronectes*) 25
Durham (1950) 67, 82, 108, 110
Eberzin (1960) 37
EC evolutionary stage 44-45, 48
eccentricus
caimiticus, Argopecten 8-13, 20, 22, 26, 38, 43-44, 49-50, *51-52*, 54-57, 59, 63, 74, 78, 86, 88, 96, 102, 104, 116, 119-120, 126, **6**
eccentricus, *Argopecten* 10, 13-14, 20, 38, 40-41, *42-49*, 50-52, 59, 63, 77-78, 88, 96, 104, **4-5**
lacabrensis, *Argopecten* 8-10, 13, 20, 44, *49-51*, 52, 59, 64, 88, 96, 104, **5**
Argopecten 8-9, 13, 16, 38, 43-44, 49, 53, 59, 63, 66, 73, 76, 86, 88, 98, 123
ecnomius, *Leptopecten* 76, 139
Ecuador 36, 76, 82, 92, 108-109, 138-139
Edwards (1944) 30, 115
EE biozone 38, 45, 60
El Caimito 52
El Limpio 42
EL-II Biozone 13, 64
Etherington (1931) 138
eugrammatus, *Pecten* (*Pecten*) 56-58, 63
eulyratus, Pecten (*Lyropecten*) 113
Europe 100, 109-111
euterpes, *Paraleptopecten* 139
Euvola *99-100*
barretti 107
caribea 103, 107
chazaliei 101
codercola 107
colpotus 107
coralliphila 101
gurabensis n. sp. 9, 38, 44, 54, 57, 59, 74, 86, 96, *100-101*, 102, 107, 120, 125, **13**
jamaicensis n. name 9, 14-15, 88, *101-105*, 107, **13-14**
raveneli 103
reliquua 101
soror 12, 20, 22, 26, 38, 44, 57, 59, 74, 78, 86, 96, 101, 104, *105-107*, 116, 119-120, 124-126, **14**
sp. *a* 94
turtoni 101
urumaconis 107
ventonensis 15, 101, 103, 107
ziczac 100
exasperatus
morantensis, Lindapecten 85, 90
Lindapecten 14, 62, 80-82, 85, 90
Pecten 56, 80
excentricus
Pecten 42
(*Plagioctenium*) 42
expansus, *Amussiopecten* 110

fasciculatus, *Pecten* 72
fenestratus, *Cyclopecten* 17
Ferreira (1960) 91, 140
Férrusac (1822) 17
Fischer-Piette (1950) 113
flabelliformis
Flabellipecten 110
Ostrea 110
Flabellipecten
flabelliformis 110
gatunensis gatunensis 108-109
gatunensis macdonaldi 109
gatunensis protistus 108
gatunensis tapeinus 109
Flexopecten 113
Florida 15-16, 22-23, 28-31, 36, 37, 41, 63, 70, 80-83, 91-92, 94, 108, 112-114, 121, 126-127, 140
Keys 71, 79-80
Strait 67
Forbes (1844) 17
fragosus, *Nodipecten* 126-127
France 110
Franco (1983) 64
Freiheit & Geary (2009) 2
Freneix *et al*. (1982) 110
fucatum, *Pecten* 113
Gabb (1873) 7, 10, 12, 30-32, 42-43, 52, 56-57, 62
gabbi, *Pecten* (*Plagioctenium*) 31, 62
Galápagos Islands 36-37, 100, 108, 120, 122
Gamero & Díaz de Gamero (1964) 82
Gardner
(1926) 19, 22-23, 81, 83
(1945) 122
gardnerae
Pecten 112, 114-115
(*Plagioctenium*) 112
Gatun
Formation 15, 22, 49, 51, 76, 81-82, 98-99, 101, 107-109
of Olsson 67
gatunensis
gatunensis
Flabellipecten 108
Leopecten 108-109
macdonaldi, *Flabellipecten* 108-109
protistus, *Flabellipecten* 108
tapeinus, *Flabellipecten* 108-109
"*Flabellipecten*" 108
Leopecten 14-16, 33, *108-110*, 122, 125, **14**
Pecten 108
(*Flabellipecten*) 108
Gibson-Smith (1976) 103
gilbertharrisi
democracianus, *Leptopecten* 139
Leptopecten 76, 139
Glawe (1969) 91
Globigerinatella insueta Zone 15
Globorotalia
acostaensis Zone 122
exilis Subzone 15
margaritae Zone 10, 24-25, 56, 112, 123
miocenica Zone 15, 112, 114
glyptus, Pecten 67
Gmelin (1791) 28, 94
gonioides, *Chlamys* (*Plagioctenium*) 64
Gould (1850) 81
Gradstein *et al*. (2004) 6, 10, 16, 109, 114
Grau (1959) 24, 73, 75, 92, 138-139
Gregorio (1884) 25
Grenada 70
groenlandicus, *Similipecten* 17
guanicus, *Pecten* 112
Guaracara Limestone Member 122
Guardarraya Formation 66
Guadeloupe 15, 32, 85, 105, 112-113
Guayubín 14, 28, 30-32, 36, 42, 118, 124
guayubinensis, *Caribachlamys* 14, *27-28*, 29, 36, 120, **2**
Gulf of California 36, 40, 73, 100, 121, 138-139
Gulf of Mexico 16, 25-26, 29, 36, 41, 65-67, 70-71, 79-80, 94, 100, 112, 125-126
Gulf of Panama 24
Guppy
(1866) 52, 56, 64
(1867) 103, 112
(1876) 56, 85
guppyi
Chlamys (*Palliolum*?) 19
Cyclopecten 7, 10, 12, *19-23*, 24, 26, 38, 40-41, 44, 54, 59, 74, 78, 86, 88, 96, 104, **1**
Pecten (*Pseudamusium*) 19
Pseudamussium 19
gurabensis, *Euvola* 9, 38, 44, 54, 57, 59, 74, 86, 96, *100-101*, 102, 107, 120, 125, **13**
Gurabo
Afuero 111
facies 10, 16, 26, 51-52, 64
Formation 2, 7-10, 12-16, 20-24, 26-27, 29-30, 33, 35, 37-42, 44-49, 52, 54-55, 57-74, 82, 84-91, 95-102, 104-107, 115-120, 123-127
Hills 14, 32
Gurabopecten n. gen. *71-72*
uniplicatus n. sp. 7, 10, 16-17, 20, 22, 26, 37-38, 44, 54-55, 57, 59, 71-*73*, 74, 84, 86, 96, 98, 102, 104, 118, 120, 123, 125, **9**
assemblage 8, 12
Guyana 70-71
haitensis, *Hyotissa* 103
Haiti 58, 63, 66, 76
Hanna
(1926) 30
& Hertlein (1927) 107, 109
Harzhauser *et al*. (2007) 110
hastata hericia, *Chlamys* 81
Hato Viejo 56
hatoviejonis, *Pecten* 56-58, 63
Hawaiian Islands 67, 69
Hayami (1984) 67, 69-70
Heilprin (1887) 124, 126
Heneken collection 53, 58, 62
Herrmannsen (1846) 93
Hertlein
(1933) 115
(1935) 139
(1936) 103, 112
(1966) 30
(1969) 25, 119
& Strong (1946) 75, 139
Hinds (1845) 72, 81
Hispaniola 2, 56, 63

Fault zone 2
Hodson
& Hodson (1931) 82
et al. (1927) 14, 30, 33, 76, 81-82, 91, 99, 107-108, 110, 121, 139
holotype 18, 23, 25, 27-29, 32-33, 35, 40, 42-43, 50-51, 55, 58, 62, 65, 67-68, 72-73, 79-80, 83-84, 87, 95, 101-103, 111, 113, 115-118, 121-123
Honduras 76, 139
Hopkinson (1907) 131
hoskynsi, *Cyclopecten* 17
Hubbard (1920) 66, 114
Huddlestun (1993) 112
Hunter (1978) 112, 122, 139-140
Hyalopecten undatum 37
Hyotissa haitensis 103
ICZN [International Code of Zoological Nomenclature] 26, 43
imbricata, *Caribachlamys* 28
imbrifer, *Palliolum* 37
Imperial Formation 139
inaequalis
Aequipecten 52
Argopecten 7, 10, 22, 26, 38, 44, *52-55*, 59, 65, 71, 74, 86, 96, 98, 102, 104, 126, **6**
Chlamys 52
Pecten 52-53, 64-65
(*Aequipecten*) 52, 64
incertae, *Chlamys* (*Lyropecten*) 113
incomparabile, *Palliolum* 37
incomparabilis, *Pecten* 37
Indian Ocean 34
Indo-Pacific 7, 16, 34, 69-71, 93-94, 110, 112
Interchlamys n. gen. *30-31*
aidei 31-32
interlineata 7, 14-15, 30-*33, 37, 54, 59, 62,* **2**
jacobiana 14-15, 30-31, *32-34*, **2**
interlineata, Interchlamys 7, 14-15, 30-*33, 37, 54, 59, 62,* **2**
interlineatus
aidei, *Pecten* 30-31
Chlamys (*Lyropecten*) 31
Pecten 30-31
Pecten (*Chlamys*) 31
Iredale
(1929) 30, 34
(1939) 112
irradians, *Pecten* 42
irremotis, *Paraleptopecten* 140
ischnon, *Pecten* 76
Isidro Formation 81
islahispaniolae, *Nemocardium* (*Microcardium*) 10
Issel (1869) 12
Italy 25, 110
Jackson Bluff Formation 16, 37, 92, 140
jacobiana, *Interchlamys* 14-15, 30-31, *32-34*, **2**
jacobianus, Pecten (*Aequipecten*) 30, 32
Jamaica 14-16, 19, 23-24, 27-28, 36-37, 42, 65-66, 85, 90, 102-103, 105, 107, 112-114, 119
jamaicensis, *Euvola* 9, 14-15, 88, *101-105,* 107, **13-14**
James City Formation 140
Janico 116-117
janicoensis, *Antillipecten* 44, 78, 86, 88, 96, 104, *115-117*, 118-120, 126, **16**
Janira soror 105
japonicum, *Amusium* 94
Jordan & Hertlein (1926) 67, 138
Juana Díaz Formation 112
Jung
(1969) 149
(1971) 121-122
(1986) 13
(1989) 79, 140
Jung, P. 2, 29, 127
jungi, *Caribachlamys 28-30*, 59, 86, 96, 120, 126, **2**
Kabat & Petit (1988) 131
Kier *et al.* (1965) 6
Kohl & Robinson (1998) 15, 24, 28, 42, 114, 119
Kugler (2001) 79, 139-140
La Barranca 4, 11, 56
La Boca Formation 22, 81, 98-99
lacabrensis, *Argopecten eccentricus* 8-10, 13, 20, 44, *49-51*, 52, 59, 64, 88, 96, 104, **5**
La Cruz Formation 15, 30-35, 85, 103, 107, 112, 115, 123
La Fila del Carmen 82
La Puerta Group 82
La Rosa Formation 91
Lamarck
(1806) 110
(1816) 7
(1819) 34, 53
Landau *et al.* (2008) 15
landi, *Mimachlamys* 34, 35
Laskey (1811) 17
latiauratus
Leptopecten 73, 75-77, 138, 140
Pecten 73, 75
lectotype 19, 29, 36, 43, 53, 56, 58, 66, 70, 106, 113, 124
leonensis
Leptopecten 140
Paraleptopecten 92, 140
Leopecten 107-108
boesei 109
gatunensis 14-16, 33, *108-110*, 122, 125, **14**
gatunensis 108-109
leptaleum, *Palliolum* 37
Leptopecten 73-76
andersoni 76, 138
andersoni 138
barkerianus 138
clemonensis 138
group 76, 138
subandersoni 138
atlanticola 139
camerella 138
coderensis 76, 79, 139
willistoni 139
cracens 138
ecnomius 76, 139
gilbertharrisi 76, 139
democracianus 139
latiauratus 73, 75-77, 138, 140
leonensis 92, 140
linki 76, 79, 139
maturensis 79, 139
monotimeris 73, 75-76
nelson 138
praevalidus 138
subandersoni 76, 138

tabaquita 79, 139
thompsoni 7, 10, 14, 20, 40-41, 44, 59, *76-79*, 86, 88, 92, 96, 104, 116, 120, 126, 139, **9**
subassemblage 7, 10
tumbezensis 73, 76, 138
woodringi 138
Linares (2004) 139
lindae, *Lindapecten* 80
Lindapecten *79-82*
acanikos 81, 83
acanthodes 80
baitoaensis n. sp. 12, 15, 81-*83*, 84, 104, **10**
buchivacoanus
buchivacoanus 81
falconensis 81, 85, 90
species complex 81-82, 85, 124
chipolanus 15, 81, 83, 85, **10**
cortezianus 82, 85, 91
exasperatus 14, 62, 80-82, 85, 90
morantensis 85, 90
lindae 80
muscosus 79-82, 85, 91
paramuscosus n. sp. 10, 12-13, 20, 22, 26, 29, 38, 44, 54, 57, 59, 74, 78, 82, *83-85*, 86, 88, 91, 96, 102, 104, 116, 120, 125, 126, **10**, **11**
plurinominis 7, 9, 10, 13, 20, 26, 38, 41, 44, 55-57, 59, 78, 81-84, *85-91*, 96, 98, 104, 116, 119-120, 124, 126, **11**
progresoensis 82, 85
sp. 56
sua 82
lineolaris, *Argopecten* 53, 54, 66
linki, *Leptopecten* 76, 79, 139
Linnaean Collection, University of Uppsala, Sweden 124
Linnaeus (1758) 7, 17, 34, 54, 93, 100, 119, 124
Locard (1898) 17
Loel & Corey (1932) 76, 138
López 4, 14-15, 122
Los Quemados 52, 55, 72, 101, 118, 123
Lovén (1846) 37
lucidum marmoratum, *Amussium* 25
luna, *Amusium* 98-99
Lyropecten
antillarum 112-113
colinensis
colinensis 121
vokesae 121, 123
crassicardo-magnificus stock 122
dumblei 122
magnificus 122
(*Nodipecten*)
colinensis 121
nodosus 124
macdonaldi
Flabellipecten gatunensis 108-109
Leopecten 109
MacNeil (1967) 2
Macsotay & Campos Villarroel (2001) 113
magnificus
Lyropecten 122
Nodipecten 5
maiquetiensis, *Pecten* (*Pecten*) 103
Mandic (2004) 2, 110
Mansfield
(1932) 30, 92, 125-126, 140
(1937) 112
(1939) 91, 140
mansfieldi, *Chlamys* (*Plagioctenium*) 64
Mao Adentro 4, 10, 28, 84
Limestone 14, 28, 31-32, 34-36, 42, 91
Mao Clay Member 10
Mao Formation 2, 7, 9-10, 15, 18-19, 21-22, 24, 28, 30, 32, 34-36, 42, 54-55, 63-71, 91, 95, 98, 101-103, 105, 111-114, 119-120
maoensis, *Zamorapecten* 79, 95, *111-112*, **15**
Mare Formation 103, 140
Marks (1951) 82, 85
marmoratum
marmoratum, Parvamussium 26
pourtalesianum, Parvamussium 26
striatulum, Parvamussium 26
Amussium lucidum 25
Parvamussium 7, 10-12, 20, 22, *25-27*, 38, 44, 54, 59, 74, 86, 88, 96, 104, **1**
Marquer Formation 107
Marshall (1995) 80
Massachusetts 25, 36, 41, 127
Masuda
(1971a) 7, 107
(1971b) 94, 110, 112
Mataruca Limestone Member 121-122
Matura
beds 139
Sand and Clay Member 79, 139-140
maturensis, *Leptopecten* 79, 139
Maury
(1917a) 2, 6-7, 8, 10, 15, 31, 36, 42-43, 51, 56-57, 62-63, 76-77, 85, 94-95, 112, 114, 139
(1917b) 2, 12-14, 44, 52, 54, 59, 77, 88, 96, 104, 115-116
(1919) 12, 44, 52, 116
(1920) 112
(1925a) 79, 98, 139
(1925b) 91
mayaguezensis, *Argopecten* 66
McNamara (1986) 112
McNeill *et al.* (2008) 2, 16
mediacostata grewingki, *Chlamys* 30
mediacostatus mediacostatus, *Pecten* 30
Mediterranean 39, 110, 113
Merced Formation 139
Mexico 30, 31, 66-67, 69, 80-82, 92, 94, 99, 107, 125-127, 137-139
microlineatus, *Antillipecten* 115, *117*, **17**
Mikkelsen & Bieler (2008) 17, 113
mildredae, *Caribachlamys* 28
Milne-Edward & Haime (1848) 14
Mimachlamydini 30-31, 34, 36
Mimachlamys *34*
blowi n. sp. *34-35*, 36, 117, **3**
canalis 81, **10**
landi 34-35
varia 34
vokesorum n. sp. 28, 31, *35-36*, **3**
Ministerio de Energía y Minas, Direccion de Geología (1970) 82, 139
minor, *Similipecten* 17
Miocene-Pliocene boundary 8-9, 11, 14, 30, 33, 56, 85, 87, 90, 117, 118, 123-124
Mörch (1852) 13

Moin Formation 66, 101, 125
molecular genetic 27, 109, 113
Mongin (1968) 15, 31-32, 85, 101, 112, 121-122, 124
monotimeris
Leptopecten 75-76
Pecten 73, 75
Monroe (1980) 33, 66
Montastrea 33
Monterosato
(1884) 3, 37
(1889) 12, 40
(1899) 40
Moore, E.
(1963) 138
(1984) 30, 75-76, 138-139
Moore, J. (1850) 58
Morocco 39
Morton, B.
(1980) 94
(1994) 77
Morton, S. (1833) 112
mortoni, *Amusium* 94, 98-99
Müller (1776) 5, 37
muscosus
Lindapecten 79-82, 85, 91
Pecten 79
Museum of Comparative Zoology (MCZ), Harvard University, Cambridge, Massachusetts 25, 70, 127
nanus
Cyclopecten 17, 21-23
Similipecten 17
National Museum of Natural History, Smithsonian Institution 2, 6, 14, 26, 53, 62, 65-66, 70, 91, 99, 103, 108, 112, 114, 119, 122, 126-127
Naturhistorisches Museum Basel [Switzerland] 2, 6, 127
Nehm (2001) 8, 9, 12
nelsoni, *Leptopecten* 138
Nemocardium (*Microcardium*) *islahispaniolae* 10
Neritina 7
new genera
Antillipecten 112-113
Chagrepecten 66-67
Gurabopecten 71-72
Interchlamys 30-31
Paraleptopecten 91-92
Zamorapecten 110-111
new name
Euvola jamaicensis 9, 14-15, 88, *101-105,* 107, **13-14**
New Zealand 81
new species
Antillipecten
janicoensis 115-117
microlineatus 117
quemadosensis 117-119
Argopecten parathetidis 55-56
Caribachlamys
guayubinensis 27-28
jungi 28-30
Chagrepecten paracactaceus 67-69
Euvola gurabensis 100-101
Gurabopecten uniplicatus 72-73
Lindapecten
baitoaensis 82-83
paramuscosus 83-85
Mimachlamys
blowi 34-35
vodesorum 35-36
Palliolum? *Cibaoense* 39-40
Zamorapecten maoensis 111-112
new subspecies
Argopecten eccentricus lacabrensis 49-51
Newportian molluscan stage 138
Nicol *et al.* (1989) 113
NMB [Naturhistorisches Museum Basel, Switzerland] catalog numbers
G17491 18, **1**
G17492 **1**
G17493 **1**
G17494 **1**
G17495 29, **2**
G17496 **2**
G17497 35, **3**
G17498 35, **3**
G17499 **4**
G17500 **5**
G17f01 **5**
G17502 50, **5**
G17503 **5**
G17504 **5**
G17505 **5**
G17506 **5**
G17507 **5**
G17508 **6**
G17509 **6**
G17510 **6**
G17511 **7**
G17512 **7**
G17513 **7**
G17514 **8**
G17515 68, **8**
G17516 **8**
G17517 **8**
G17518 **10**
G17519 83, **10**
G17520 83, **10**
G17521 **11**
G17522 **11**
G17523 **12**
G17524 **13**
G17525 **13**
G17526 **13**
G17527 **14**
G17528 **14**
G17529 111, **15**
G17530 **15**
G17531 **16**
G17532 **16**
G17533 **16**
G17534 **16**
G17535 117, **17**
G17536 **17**
G17537 119, **17**
G17538 **17**
G17539 **18**
NMB [Naturhistorisches Museum Basel, Switzerland] locality numbers
15804 38, 59, 74
15805 38, 74
15809 59

15814 9, 59, 74
15815 38, 59, 74
15823 18, 69, 157
15827 22, 68, 69, 142, 157
15828 18, 69, 142
15829 9, 18, 69, 142
15830 9, 103
15831 9, 102, 166
15833 9, 111, 170
15834 9, 113-114, 173
15835 38
15836 59, 74, 118
15837 59, 86, 102, 125, 177
15838 86
15839 120, 174
15841 59
15842 38, 54, 60
15843 38, 60
15844 54, 60
15846 38, 60
15849 20, 38, 60
15854 60
15855 29, 125
15859 125
15860 20, 38, 60
15861 125
15862 96
15863 54, 60
15864 60
15865 38, 60, 96, 154
15866 54, 60, 86
15867 60
15868 60
15869 38, 60, 86
15870 54, 60, 96, 165
15871 38, 60, 154
15872 60, 96, 104
15873 8, 45, 50, 150
15874 8, 13, 45
15876 45
15878 45, 87, 89, 96, 104
15880 60
15881 45
15882 45
15883 96
15884 60
15886 45, 89, 95-96
15890 45, 89, 97
15893 35, 117, 146, 174
15894 45
15895 46
15896 46, 50, 150
15897 46
15898 46, 60, 97
15899 46, 97
15900 46
15901 46
15902 46, 97
15903 46, 50
15904 46
15905 46, 97
15906 20, 46
15907 46
15908 46, 89
15909 46, 50, 89, 150, 162
15910 46
15911 46, 89
15912 46
15913 46, 50
15914 46, 89
15915 46, 89
15916 46
15918 8, 46
15920 77-78
15934 59, 74, 86
15935 22
15937 38, 59
15939 38, 59, 96
15940 38, 59
15941 20, 38, 74
15942 74
15962 38, 59, 74, 86
15964 59
16016 68-69, 157
16122 9, 111, 170
16184 117
16185 117
16802 47
16803 46, 61, 89, 104, 115, 174
16804 47, 89, 97
16805 61
16806 97, 105
16808 8, 13, 45, 52, 60, 86
16809 38
16810 38, 60
16814 59
16815 104
16817 20, 44, 88, 104
16818 44, 88, 104, 106, 120, 169
16819 44
16821 44, 88
16824 44, 88
16825 56, 57, 59, 88, 96, 120
16828 44, 88, 104
16831 44, 88, 104
16832 44, 88
16833 8, 44, 86, 88
16835 44, 88, 96, 104, 119, 153, 174
16836 44, 88, 104
16837 44, 88
16838 44, 88, 96, 104
16839 45, 88
16842 9, 43, 45, 104
16843 45
16844 45, 88, 116-117, 173
16852 45, 52, 88
16857 20, 45, 52, 96
16858 44
16859 59
16862 88, 96
16865 96
16866 9, 44
16867 96
16878 44, 88
16881 88
16885 15, 65, 103, 157, 166

16910 39, 61, 97
16912 20, 41, 47, 49, 78, 149-150
16913 47, 49, 78
16914 47, 49, 78
16915 20, 47, 78
16916 20, 47, 78
16917 20, 47, 49, 78
16918 7, 20, 41, 47, 49, 78
16922 20, 47, 49, 78, 142
16923 20, 47, 78
16924 20, 47, 49, 78
16926 20, 47, 49, 78
16927 20, 47, 78
16928 20, 47, 49, 78, 89
16929 20, 47, 78, 89
16930 47, 49
16931 43, 47, 78
16932 20, 47, 49
16934 29, 145
16936 83-84, 161
16938 83-84, 161
16939 84
16942 84
16943 14
16949 14
16958 15
16961 44, 88
16972 44
16976 44
16978 88
16983 44, 88
16984 44
16986 45
16989 45, 88
16993 45
17005 9, 20, 45
17009 10, 22, 70
17268 11, 48, 57, 97
17271 89
17272 108-109, 125
17273 105
17274 14, 108-109, 122, 169, 174
17277 14, 30, 33, 145
17286 84, 161
17287 84
17288 84
17289 84, 105
17290 84
17312 10
17316 14, 33
17317 14
17329 115
N4 Zone 140
N5 Zone 140
N7 Zone 15
N8 Zone 15
N10 Zone 15
N14 Zone 109
N16 Zone 109, 138
N17 Zone 36
N18 Zone 123
N19/N20 Zone 36
N20 Zone 127, 140
NN10 Zone 109, 122
NN11 Zone 14, 16, 56, 64, 95, 109, 115, 117, 122, 139-140
NN12 Zone 14, 56
NN13 Zone 16
NN15 Zone 114
Nodipecten *119-121*
clydonus 121-122
colinensis 120-124
colinensis 14, 16, *121-123*, 124-125, **17**
guadeloupensis 122
vokesae 15, 29, 38, 54, 57, 59, 74, 86, 96, 102, 104, 120, 122-*124*, 125, **17-18**
collierensis 125-126
floridensis 126-127
fragosus 126-127
magnificus 5
nodosus 9, 16, 44, 54, 59, 78, 86, 96, 104, 116, 120, 123-*127*, **18**
nunezi 124
peedeensis 127
pernodosus 124, 126
pittieri 122-123, 125
veracruzensis 127
nodosa
Chlamys
(*Lyropecten*) 124
(*Nodipecten*) 124
Ostrea 119, 124
nodosus
Lyropecten (*Nodipecten*) 124
Nodipecten 9, 16, 44, 54, 59, 78, 86, 96, 104, 116, 120, 123-*127*, **18**
Pecten 124
(*Nodipecten*) 124
Nordsieck (1969) 40
noronhensis, *Argopecten* 56, 63, 65-66
North Carolina 27, 36, 80, 82, 92, 100, 121, 140
Norway 39
nucleus, *Argopecten* 42, 49, 52, 65
nunezi
Chlamys (*Nodipecten*) 123
Nodipecten 124
nux
Cryptopecten 69
Pecten 69
Oak Grove Sand 23
Ochopee Limestone Member 126
Ockelmann (1965) 23
olgensis, *Paraleptopecten* 91-92, 140
oligolepis, *Cyclopecten* 22-23
Olsson
(1922) 21-22, 24, 64, 66-67, 98, 101, 108
(1932) 138
(1961) 73, 75
(1964) 82, 138
& Harbison (1953) 140
opercullariformis, *Pecten* 49
d'Orbigny
(1842) 98
(1846) 73, 80, 138
Orchid Gorge 52
Oregon 76, 138
ornatus? var. *vaginulus*, *Pecten* (*Chlamys*) 36
Ostrea
flabelliformis 110

nodosa 119, 124
oxygonum
Chlamys 56
Pecten 55-57, 62, 85
(*Aequipecten*) 56
oxygonus, *Pecten* 56
Pacific Ocean
eastern 7, 24, 31, 36-37, 40-41, 71-73, 76-77, 85, 91-92, 94, 108, 121-123, 137-138, 139
western 7, 16, 24, 93-94, 110
Pacipecten tumbezensis 73
paciphile 16
Palliolinae 27, 37
Palliolini 37, 39
Palliolum 37
imbrifer 37
incomparabile 37
leptaleum 37
reticulum 37
ringnesia 37
striatum 37
subimbrifer 37
tigerinum 37
undatum 37
Palliolum? *cibaoense* n. sp. 20, *39-40,* 41, 44, 59, 78, 88, **4**
Palmer (1938) 82
palmeri, *Paraleptopecten* 139
Panama 14-15, 22, 24, 49, 51, 66-67, 69, 72, 76, 81-82, 94, 98-99, 101, 107-109, 122-124, 138-139
papyracea, *Pleuronectia* 94
papyraceum, *Amusium* 7, 9-13, 16, 20, 22, 26, 29, 38, 40-41, 44, 54, 57, 59, 69, 74, 78, 86, 88, *94-99*, 102, 104, 116, 119-120, 125-126, **12-13**
Morphotype A 12-13, *95*, 96-99, 119, **12**
Morphotype B 12-13, *95*, 96-99, **12**
Morphotype C 29, *95*-96, 98, **13**
paracactaceus, *Chagrepecten* 7, 9-10, 12, 18, 22, 67-69, 72, 96, **8**
Paraguaná Peninsula 31
Paraleptopecten n. gen. *91-92*
auroraensis 140
bavayi 91-93, 140, **11**
bellilamellatus 139
biolleyi 75, 92, 139
desultorius 140
euterpes 139
irremotis 140
leonensis 92, 140
olgensis 91-92, 140
palmeri 139
pirabensis 91, 140
rutamensis 140
sp. *a* 20, 41, 44, 78, 88, *92-93,* 140, **11**
sp. *b* 92, 140
velero 139
wendelli 92, 140
wilsoni 140
paramuscosus, *Lindapecten* 10, 12-13, 20, 22, 26, 29, 38, 44, 54, 57, 59, 74, 78, 82-*85*, 86, 88, 91, 96, 102, 104, 116, 120, 125-126, **10-11**
Paraná Formation 99
parathetidis, *Argopecten* 38, 44, *55-56*, 57, 59, 63, 86, 88, 96, 102, 104, 120, 125, ***6***
paris, *Amusium* 98, 99
Parvamussium 25
marmoratum 7, 10-12, 20, 22, *25-27*, 38, 44, 54, 59, 74, 86, 88, 96, 104, **1**
pourtalesianum 26
striatulum 26
pourtalesianum
marmoratum 26
pourtalesianum 26
striatulum 26
patricia
Anadara (*Larkinia*) 13
Scapharca 44, 116
paucirama, *Caribachlamys* 29
Pecten
agronomica 91
anatipes 132
anguillensis 112
antillarum 112-114
argenteus 113-114
asperrimus 34
augusticostatus 56-58, 62
barretti 101, 103
benedicti 36
burdigalensis 110
burnsi 91
cactaceus 66-69
caimitica 51, 52
cercadica 79, 112, 114-115
tabaquita 79
circularis 40
colinensis 121
costaricensis 64, 66
eccentricus 42-43
exasperates 56, 80
excentricus 42
fasciculatus 72
fucatum 113
gardnerae 112, 114-115
gatunensis 108
glyptus 67
guanicus 112
hatoviejonis 56-58, 63
inaequalis 52-53, 64-65
incomparabilis 37
interlineatus 30-31
aidei 30-31
irradians 42
ischnon 76
latiauratus 73, 75
mediacostatus mediacostatus 30
monotimeris 73, 75
muscosus 79
nodosus 124
nux 69
opercullariformis 49
oxygonum 55-57, 62, 65
oxygonus 56
perplanus stock 91
phrygium 69-70
pustulosus 17
sanctiludovici 82
sentis 27
solidulus 40
soror 105
thetidis 56-58, 63

pelei 56-58, 63
thompsoni 76
tumbezensis 73
uselmae 52, 64-65
vaginulus 36
vaun 112
flabellum 112
vaun 112
ventonensis 15, 101, 103
ventricosus 40
willobianus 112
(*Aequipecten*)
amenensis 82
angusticostatus 56
chipolanus 81, 83
jacobianus 30, 32
inaequalis 52, 64
oxygonum 56
plurinominis progresoensis 82, 85
preglyptus 67
quirosensis 91
thetidis 56, 83, 85
(*Amusium*) *zamorensis* 110
(*Amusium*?) *correctus* 108
(*Chlamys*)
alumensis 112
buchivacoanus
buchivacoanus 82
maracaibensis 82
bullatus 67, 69
cactaceus 66
dallasi 67
interlineatus 31
ornatus? var. *vaginulus* 36
(*Euvola*) 99, 100
(*Flabellipecten*) *gatunensis* 108
(*Lyropecten*)
eulyratus 113
tamiamiensis 30
(*Nodipecten*)
antillarum 113
nodosus 124
(*Palliolum*) 37
(*Patinopecten*) *bakeri* 107
(*Pecten*)
barretti 14, 101, 103
caribeus 103
eugrammatus 56-58, 63
maiquetiensis 103
soror 105
ventonensis 103
(*Plagioctenium*)
cercadica 114
crucianus 30-31, 33
excentricus 42
gabbi 31, 62
gardnerae 112
(*Pleuronectes*) *duodecimlamellatus* 25
(*Pseudamusium*) *guppyi* 19
Pectinidae 2-5, 7-12, 15-16, *27*, 37, 63, 71, 73, 94, 105, 110, 112, 124
Pectininae 27, 40, 93, 100, 107
peedeensis, *Nodipecten* 127
pelei, *Argopecten thetidis* 56-58, 63
pernodosus, *Nodipecten* 124, 126
Peru 40, 41, 73, 76, 100, 108, 121, 138
Petuch
(1995) 15, 79-80
(2004) 15-16, 80
(2007) 94
Pflug (1961) 52-53, 56, 58
phrygium
Aequipecten 70
(Aequipecten) 70
Cryptopecten 7, 9-10, 22, 54, 67, 69-*71*, **9**
Pecten 70
Piazza & Robba (1994) 67
Piedra Gorda 42
Piedras Rodadas Sandstone 67
Pilsbry
(1922) 2, 31-32, 42-43, 52, 56-57, 62-65, 76, 85, 87, 94-95, 105-106, 108
& Johnson (1917) 2, 7, 15, 52, 56, 64-65, 76, 85, 108
Pinecrest
beds 126-127
Formation 31, 114
Pirabas Formation 91, 140
pirabensis, *Paraleptopecten* 91, 140
pittieri, *Nodipecten* 122-123, 125
Plagioctenium 40
Pleuronectes 93
pleuronectes
Amusium 94
Ostrea 93
Pleuronectia 93
plurinominis
morantensis, Chlamys (*Aequipecten*) 85, 90
progresoensis
Lindapecten 82, 85
Pecten (*Aequipecten*) 82, 85
Lindapecten 7, 9-10, 13, 20, 26, 38, 41, 44, 55-57, 59, 78, 81-84, *85-91*, 96, 98, 104, 116, 119-120, 124, 126, **11**
Ponce Formation 15, 33-34, 110, 115
Porites 33, 137
Potrero 40, 58, 138
Dam section 4, 14
pourtalesianum
marmoratum, *Amusium (Propeamusium*) 25
striatulum, *Amusium* (*Propeamusium*) 25
Parvamussium 26-27
Propeamussium 25
Powell II
(1985) 139
(1986) 139
et al. (2007) 138
praevalidus, *Leptopecten* 138
preglyptus, *Pecten* (*Aequipecten*) 67
PRI [Paleontological Research Institution, Ithaca, New York, USA] catalog numbers
898 79
900 139
901 139
21140 67
21954 121-122
21957 121-122
21961 121
28965 43

28966 77
28967 77
28969 51, **6**
28970 58, **7**
28971 58, **7**
36776 115
Progreso Formation 82
Propeamussiidae 2, 5-9, 12, 15-17, 23, 25, 37
Propeamussium pourtalesianum 25
protistus
Amussiopecten 109
Flabellipecten gatunensis 108
Pseudamussium guppyi 19
Puerto Madryn Formation 99
Puerto Rico 14-15, 33-34, 66, 92, 103, 105, 108, 110, 112, 115, 119
Punta Gavilán Formation 79, 110, 112
Purisima Formation 138-139
Puslednik & Serb (2008) 27
pustulosus
Cyclopoecten 17
Pecten 17
pycnodontinine oysters 55
quemadosensis, *Antillipecten* 29, 38, 44, 57, 59, 74, 78, 86, 88, 96, 102, 104, 114, 116-*119*, 120, 124-126, **17**
quirosensis, *Pecten* (aff. *Aequipecten*) 91
Radimella
confragosa 30, 115
Zone 115
Rafinesque (1815) 2, 17, 27, 40
Ramírez (1950) 56
Ravenel (1844) 94
raveneli, *Euvola* 103
Récluz (1853) 7, 112-113
Redfern (2001) 113
Reeve (1853) 27, 29, 37, 40, 69, 113-114
reliquua, *Euvola* 101
Renken *et al.* (2002) 119
reticulum, *Palliolum* 37
reynali
Antillipecten 112
Chlamys 112
rexmaris, Amusium 98
Richards (1968) 47
ringnesia, *Palliolum* 37
Río Albano 4, 48, 78
Río Amina 10-12, 14-15, 39-41, 47-48, 54, 58, 61, 63, 65, 86, 89-90, 97, 105, 138
Río Bao 4, 83
Río Cana 9-10, 13-15, 20, 22, 44-45, 50-52, 56-57, 59, 64-65, 70, 86-88, 90, 95-96, 103-104, 106, 116-117, 119-120, 124, 126, 138
Río Gurabo 7-10, 12-15, 18, 20, 22, 29-30, 35, 38, 45-46, 50-52, 54-57, 59-60, 64, 68-70, 72-74, 77-78, 85-87, 89, 95-97, 101-104, 106, 109, 111-114, 117-118, 120, 122-126
Río Mao 10-11, 13-15, 20, 28, 36, 39-41, 43, 46-49, 54-55, 60-61, 64, 68-70, 77-79, 84, 86, 89, 92-93, 95-96, 104, 115, 124, 126, 138-140
Río Verde 12, 21-22, 26, 48, 52, 61, 74, 86, 98, 105
Río Yaque del Norte 11, 14-15, 30, 33, 39, 42, 48, 56-57, 61, 83-84, 97, 105-106, 109, 116, 120, 122, 125
Río Yaque del Sur 64
Ríos (1975) 80
Risso (1826) 37
Röding (1798) 5, 30, 93
Rouault (1850) 7
rubida, *Chlamys* 81
rutamensis, *Paraleptopecten* 140
Sabaneta 28-29, 32, 36, 52, 55, 72, 101, 118, 123
Sacco (1897) 25, 94, 108
Saint Helena 101
Saint Thomas 19, 42, 80, 102, 118, 137
Salada Formation 138
Samba hills 14, 28, 36
sanctiludovici, Pecten 82
San Diego Formation 139
San Gregorio Formation 99
San Marcos Formation 82, 107
Santa Margarita Formation 82
Santiago, Cuba 15, 30, 32-34, 83, 85, 103, 107, 115
Santiago (Santiago de los Caballeros), Dominican Republic 11, 14-15, 21-22, 26, 32, 39, 42, 48, 51-52, 54, 56-57, 61, 64, 74, 78, 86, 89-90, 98, 103, 105-106, 116, 120
Santos Shale 76
Saunders *et al.* (1986) 2-4, 7-16, 18, 20, 22, 24, 28-31, 33, 35, 38, 40, 42-45, 50, 52, 55-57, 59, 65, 68, 72-74, 77, 81, 83-90, 95, 98, 101, 104, 109, 111-112, 114-119, 122-124, 137, 139-140
Saunders, John 2
Savaneta Glauconitic Sandstone Member 92, 140
Scapharca patricia beds 44, 116
Schuchert *et al.* (1905) 63
Schultz (2001) 21
Sconsia
laevigata Formation 12, 44, 52
Zone 12-13
Seeley (1861) 101, 103
Semipallium antillarum 111
sentis
Caribachlamys 29, 30
Pecten 27
Septentrional Fault zone 2
Siderastrea 33
Similipecten
groenlandicus 17
minor 17
similis 17
similis, *Similipecten* 17
Smaragdia viridis 7
Smith, E. A.
(1885) 56
(1890) 101
Smith, J. T.
(1984) 138
(1991a) 81, 99, 138
(1991b) 2, 5, 15, 112, 119-127, 138
Socorro Formation 76, 81-82, 139
sol, *Amusium* 94
solidulus, *Pecten* 40
soror
Euvola 12, 20, 22, 26, 38, 44, 57, 59, 74, 78, 86, 96, 101, 104-*107*, 116, 119-120, 124-126, **14**
Janira 105
Pecten 105
(*Pecten*) 105
South America 76, 92, 110, 114, 125-127, 139-140
South Carolina 71, 92, 140
Sowerby I
(1835) 5, 40
(1847) 110

(1850) 7, 9, 13, 52, 55-58, 62, 64, 103
Sowerby II (1842) 14, 17, 40, 56, 124
Spathochlamys 36
benedicti 16, 37
vaginula 7, 11, 13, 16, 20, 22, 26, 32, *36-37*, 38, 44, 48, 54, 57, 59, 74, 86, 88, 96, 102, 104, 120, 125, **3**
sp. *a*, *Paraleptopecten* 20, 41, 44, 78, 88, *92-93*, **11**
sp. *b*, *Paraleptopecten* 92, 140
Spencer (1897) 66-67
spendulum, *Amusium* (*Parvamussium*) 27
Spieker (1922) 138
Spondylus bostrychites 103
Springvale Formation 92, 140
striatulum, *Amusium* (*Propeamussium*) 25-26
striatum, *Palliolum* 37
Strombina 13
sua
Chlamys (*Chlamys*) 82
Lindapecten 82
subandersoni
Leptopecten 76
andersoni 138
subimbrifer, *Palliolum* 37
Surinam 76, 139
Suwannee Limestone 112
Swainson (1840) 93
Sykes *et al.* (1898) 17
tabaquita
Leptopecten 139
Pecten cercadica 79
Talparo Formation 79, 139-140
Tamana Formation 79, 122, 139
Tamiami Formation 31, 37, 114, 126
tamiamiensis
Interchlamys 31
Pecten (*Lyropecten*) 30
Tang & Pantel (2005) 76
tapeinus, *Flabellipecten gatunensis* 108-109
Távora & Garrafielo Fernandes (1999) 140
Tehuantepec 66, 99
tehuelchus, *Aequipecten* 80
Temblor
Formation 138
stage 138
Teppner (1922) 27, 100
Texas 80, 82
thalassinus, *Cyclopecten* 24
Theroux & Wigley (1983) 24
thetidis
Aequipecten 56
Argopecten 7-11, 13, 16-17, 20, 22, 26, 29, 37, 38, 40-42, 44, 48, 53-55, *56-64*, 66, 72-74, 84-86, 88, 96, 98, 102, 104, 118, 120, 123, 125-126, ***7***
Chlamys 56
Pecten 56
Thiele (1934) 17, 93
Thomonde Formation 76
thompsoni
Leptopecten 7, 10, 14, 20, 40-41, 44, 59, *76-79*, 86, 88, 92, 96, 104, 116, 120, 126, 139, **9**
Pecten 76
tigerinum, *Palliolum* 37
Torre
(1971) 123
& Kojumdgieva (1985) 123
Torreya Formation 81, 83
Toula (1909) 14, 49, 51, 108
toulae, *Amusium* 98-99
Trechmann (1937) 71
Trinidad 16, 79, 92, 122, 139-140
Tubará group 139
Tucker
(1934) 92, 140
& Wilson (1932) 31, 126
Tucker-Rowland (1938) 31, 113, 124
TU [Tulane University, New Orleans, Louisiana, USA] locality numbers
638 127, 137
1205 11, 39, 48, 56-57, 61, 98, 105
1205-1207 11
1206 11, 39, 56-57, 61, 97, 105-106
1207 11, 56-57, 61, 97
1209 39, 61, 74, 87, 102, 123, 125, 158, 162, 166
1210 38, 59, 74, 86, 96, 125
1211 9, 38, 56-57, 59, 72, 74, 86, 154, 158
1212 59, 74, 96
1213 96
1215 29, 60, 86, 96, 120, 124, 126, 145
1216 15, 65, 157
1217 61, 97
1218 14, 47, 89, 149
1219 39, 40, 61, 86, 89-90, 97, 165
1220 47, 61, 89, 97
1222 48, 56-57, 61, 90, 98, 105, 120, 162
1224 55-57, 102, 120, 153, 166
1225 54, 60, 84, 86, 97, 104, 124, 126, 161
1226 84, 161
1227 7, 10, 26, 61, 89, 98, 142
1227A 10, 21-22, 24, 26, 39, 54, 61, 74, 86, 98, 142, 158, 162
1230 20, 44-45, 52, 95-96, 104, 165
1231 8, 59, 86, 104, 120, 125-126
1245 14, 28, 32, 35-36, 145-146
1250 12, 21-22, 24, 26, 48, 52, 61, 73-74, 86, 98, 105, 169
1254 54, 62, 98
1277 54, 96
1278 59, 74, 86, 104, 106, 118, 120, 125, 174, 177
1279 38, 59, 74, 86, 104
1281 14, 28, 42, 118, 120, 145, 149, 174
1282 52
1292 10, 68-69, 71, 97
1293 54, 61, 97
1294 20, 41, 47, 78, 89, 92-93, 142, 158, 162
1295 47, 78, 158
1296 12, 38, 60, 86
1297 12, 45, 60, 89, 96, 104, 165
1299 56-57, 87, 120, 125
1334 54, 95, 98
1335 54, 62, 98
1337 55
1338 62, 74, 87, 98, 101-102, 123, 125, 166
1339 48, 61, 90, 105-106, 169
1340 48, 62, 78, 90
1352 9, 70-71, 158
1354 44, 53, 88, 104, 106, 120, 124, 126, 177
1355 58, 88, 124, 126
1356 44, 88

1357 26, 27
1358 20, 46, 89, 97
1359 46, 89
1360 62, 98
1361 62, 98
1362 84, 161
1363 105
1369 38, 59, 74, 86, 96
1371 12, 48, 54, 61, 97, 102
1373 46
1375 20, 46, 60
1376 46, 89, 97
1377 46, 89
1378 46
1379 20, 47, 78
1380 39, 54, 61, 98, 153, 166
1382 48
1405 48, 52, 61, 105
1406 48, 78, 87, 90, 98, 105, 116-117, 120, 124, 126, 173
1407 48, 51, 98, 105
1409 39, 54, 62, 98, 146
1410 20, 37, 39, 47, 61-62, 97, 104, 142, 146, 154
1412 12, 61
1416 62, 90, 154, 162
1418 45
1419 46
1435 39, 42, 62, 90, 98, 105, 149, 169
1436 54, 153
1437 48, 62, 90, 98
1438 14, 28, 32, 145
1439 48, 61, 105, 150
1440 69
Tulane University 2, 6, 26, 127, 137
Tumbes Formation 138
tumbezensis
Leptopecten 76, 138
Pacipecten 73
Pecten 73
Tuomey & Holmes (1855) 127
turtoni, *Euvola* 101
UCMP [Museum of Paleontology, University of California, Berkeley, California, USA] catalog numbers
556136-556138 108
556140 103, 169
undatum
Hyalopecten 37
Palliolum 37
uniplicatus, *Gurabopecten* 7, 10, 16-17, 20, 22, 26, 37-38, 44, 54-55, 57, 59, 71-*73*, 74, 84, 86, 96, 98, 102, 104, 118, 120, 123, 125, **9**
United States Geological Survey (USGS) 2, 4, 6, 137
Uruguay 91-92, 140
Urumaco Formation 82, 139
urumaconis, *Euvola* 107
uselmae, *Argopecten* 15, 42, 56, 63-*66*, **8**
USGS [United States Geological Survey at Smithsonian Institution, Washington, DC, USA] locality numbers
2580 19, 102-103, 137
3436 33
3440 30, 32-33, 115, 137, 145
3441 32, 137
3443 33, 137
3446 33, 137
5255 83, 85, 138
5906a 109, 122, 138
5908 81, 138
6024b 81, 138
6300 110, 138
6303 110, 138
8439 138
8516 40-41, 61, 97, 138, 149
8518 12, 47, 89, 97, 105, 138
8519 54, 61, 97, 154
8521 47, 61, 89, 97, 104
8522 47, 61, 89
8525 20, 41, 47, 78, 149
8526 47, 78, 89, 97, 104
8527 54, 61
8528 70
8529 47, 78, 138
8534 44-45, 88, 104
8535 62, 90, 98, 105, 138
8538 60
8539 29, 125
8539-8543 29
8544 59, 74, 125
8545 74
8546 56, 72
8548 38
8549 59
8556 69, 157
8590 64
8654 103
8663 14, 103
8663a 90
8702 105
8724 14, 32
8726 39, 48, 61, 105, 120
8729 48, 78
8733 54, 70-71
8734 54, 61
8735 69, 71
8737 45
8738 45
8739 46, 60, 97
9464 66
9530 66
9907 76
11515 109
13089 99
17207 119
17952 66
17953 103
18041 122
18308 110
20001 109
21235 109
21790 122
21911 33, 110, 115
23487 109
23490 109
24703 99
USNM [National Museum of Natural History, Smithsonian Institution, Washington, DC, USA] catalog numbers
103039 80
103043 118, **16**
115533 58, 63, **7**

135058 66, **8**
135779 19, 24
167072 85
167110 33
167115 33, **2**
167116 33
167122 123, **17**
334988 123
352776 102
352784 65
352785 42, **4**
352787 65
353076 65
353223 19
354159 62
354160 53
418203 99
481781 76
647127 122
647215 81, **10**
752646 26
vaginula, *Spathochlamys* 7, 11, 13, 16, 20, 22, 26, 32, *36-37*, 38, 44, 48, 54, 57, 59, 74, 86, 88, 96, 102, 104, 120, 125, **3**
vaginulus
Chlamys (*Chlamys*) 36
Pecten 36
velero, *Paraleptopecten* 139
Vaqueros Formation 138
varia, *Mimachlamys* 34
Vaughan *et al.* (1921) 14, 28, 39, 44-45, 61, 64
Vaughan, T. Wayland 2, 40, 137-138
vaun
flabellum
Antillipecten 112
Pecten 112
vaun
Antillipecten 112
Pecten 112
wythei, *Antillipecten* 115
Pecten 112
Venezuela 14, 16, 30-31, 76, 79-82, 91, 94, 99, 103, 107-108, 110-111, 121-126, 138-140, 170
ventonensis
Euvola 103, 107
Pecten 15, 101, 103
ventricosus, *Pecten* 40
veracruzensis, *Nodipecten* 127
Verrill
(1873) 17
(1882) 67
(1884) 37
(1885) 37
(1897) 16, 17, 36-37, 73, 75, 138
Virgin Islands (US) 80, 118, 173
Virginia 92, 94, 140
viridis, *Smaragdia* 7
Vokes, E.
(1979) 12, 15
(1989) 2, 7-8, 10, 12-13, 24, 26, 29, 38, 45, 52, 58, 60, 68, 71, 73, 86-87, 95-96, 104-105
& d'Attilio (1980) 24, 26, 39, 54, 61
Vokes, E. H. 2, 35, 83, 127
Vokes, H.
(1989) 28
& E. Vokes (1992) 32, 42, 82
Vokes, H. E. 2, 35, 83, 127
vokesae, Nodipecten colinensis 15, 29, 38, 54, 57, 59, 74, 86, 96, 102, 104, 120, 122-*124*, 125, **17-18**
Vokeses 2, 29, 52, 55-56, 105, 124
vokesorum, *Mimachlamys* 28, 31, *35-36*, 246, **3**
Waccamaw Formation 92
Waller
(1969) 3, 41
(1972a) 3
(1972b) 5, 17
(1973) 37, 56, 65, 113-114
(1978) 17, 27
(1981) 23
(1984) 3
(1986) 3, 5, 74, 81, 112-113
(1991) 3, 5, 34, 54, 80, 93-94, 100, 110
(1993) 7, 16, 27-30, 34, 36-37, 81
(1995) 40
(2006a) 27, 37, 93, 100, 113
(2006b) 5, 25
(2007) 5, 16, 37, 100, 107-109, 120-122
Ward
(1992) 37
& Blackwelder
(1975) 2
(1987) 91, 140
Warmke & Abbott (1961) 113
Washington [state] 76, 138
Weisbord (1964) 103, 140
wendelli, *Paraleptopecten* 92, 140
West Indian subprovince 16
Whittaker (1988) 138
willistoni, *Leptopecten coderensis* 139
willobianus
Antillipecten 112
Pecten 112
wilsoni, *Paraleptopecten* 140
Winckworth
(1932) 17
(1936) 114
Wood (1828) 79-80
Woodring
(1925) 14-15, 19, 27, 36, 41-42, 52, 56, 64-66, 85, 100-103, 107, 112-113, 137, 138
(1928) 103
(1966) 16
(1974) 16
(1982) 22, 51, 66-67, 69-70, 76, 81-82, 85, 94, 98, 101, 107-109, 121-122, 138-139
& Malavassi (1961) 108
et al. (1924) 64, 66, 76
Woodring, W. P. 65, 67
woodringi, *Leptopecten* 138
Wozniak & Wozniak (1987) 122
Yorktown Formation 140
zalaya, *Cyclopecten* 7, 10-12, 18-22, *23-24*, 26, 44, 54, 59, 69, 74, 86, 96, 104, **1**
Zamba Hills 28
Zamorapecten n. gen. *111-112*
maoensis n. sp. 79, 95, *111-112*, **15**

zamorensis 111-112, **15**
zamorensis
Pecten (*Amusium*) 110
Zamorapecten 111-112, ***15***
ziczac
Euvola 100
Ostrea 100
Zones of Maury
A-F 14
D 13, 29
H 52

PREPARATION OF MANUSCRIPTS

Bulletins of American Paleontology, the oldest continuously published, peer-reviewed paleontological journal in the Americas, seeks significant, larger monographs (> 50 printed pages, minimum 100 manuscript pages) in paleontological subjects or in neontological subjects that are strongly relevant to paleontological problems. Most contributions focus on systematics, placed in biostratigraphic, biogeographic, paleoenvironmental, paleoecological, and/or evolutionary contexts. Contributions have historically focused on fossil invertebrates, but papers on any taxon of any age are welcome. Emphasis is placed on manuscripts for which high-quality photographic illustrations and the large quarto format are desirable. Both single- and multi-authored (contributed proceedings) volumes are invited.

Submissions are welcome from authors of any institutional or organizational affiliation. Publication costs of the Bulletins are heavily subsidized by PRI, but authors are asked to pay illustration charges ranging from $35 per text-figure to $120 per full-page plate.

Manuscripts must be submitted as electronic copy (preferably pdf) in English, prepared in one of the more widely used word-processing programs. Each manuscript should include Abstract, Introduction, Materials and Methods, Results (flexible format), Discussion, Acknowledgments, Literature Cited, Appendices, Index (subjects only), Tables, Figure and Plate Captions, Text-figures and Plates. The abstract should be informative and include all new taxa, combinations, and taxonomic decisions (*e.g.*, selection of lectotypes); an additional abstract in a second language can be included when appropriate in view of the content or authors. All measurements should be metric, and authories and dates of all species-level taxa must be provided when first mentioned in the text (although citations need not be included in the Literature Cited). Repositories of types and voucher specimens should be indicated, and nomenclature must be in accordance with the relevant *International Code of Nomenclature*. All abbreviations and acronyms used in the paper must be explained. Particular care should be paid to formatting the Literature Cited (see full "Instructions" for examples). Comprehensiveness of the Index is at the discretion of the author(s). Illustrations should be prepared as high-resolution, black-and-white digital images, prearranged on plates as appropriate; color reproduction is available but at a substantially higher cost, which must be borne by the author. Low-resolution images are acceptable for initial submission. After review, final submission should include the original (word-processor) text file(s), plus separate table files and a high-resolution image file for each text-figure and plate.

The full "Instructions for Authors" should be consulted during manuscript preparation, and are available from the Editor or online at http://www.museumoftheearth.org/publications/bookstore.php?page=Info_Authors.

PALEONTOLOGICAL
RESEARCH INSTITUTION
1259 Trumansburg Road
Ithaca, New York 14850 U. S. A.

ISSN 0007-5779

ISBN: 978-0-87710-494-0
9 780877 104940 56000
US $60.00