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Neogene Paleontology in the Northern Dominican Republic

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by

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CONTENTS

LIST OF ILLUSTRATIONS AND TABLES

NEOGENE PALEONTOLOGY IN THE NORTHERN DOMINICAN REPUBLIC 16. THE FAMILY CORBULIDAE (MOLLUSCA: BIVALVIA)

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ABSTRACT

Corbulid bivalves (Myacea: Corbulidae) are an important constituent of fossiliferous Neogene sediments of the Cibao Valley, northern Dominican Republic. Six corbulid species referred to five subgenera within the genus *Corbula* are described and figured (*Bothrocorbula, Caryocorbula, Juliacorbula, Panamicorbula,* and *Varicorbula*). One species is new, *Corbula* (*Panamicorbula*) *canae*. This is the first description of a fossil *Panamicorbula* species and the first description of a *Panamicorbula* species outside of the eastern Pacific. The distribution of Dominican corbulids is strongly influenced by paleoenvironmental conditions such as salinity, depth, and bioclastic fabric. Corbulids are most common in Miocene sediments that were deposited predominantly in shallow-marine waters. *Corbula* (*Caryocorbula*) *sericea* Dall, 1898 has the widest stratigraphic and geographic distribution within the study area and is especially abundant in brackish-water and very shallow-marine deposits. *Corbula* (*Bothrocorbula*) *viminea* Guppy, 1866b is also common in shallow-marine and brackish-water deposits. *Corbula* (*Varicorbula*) *sanctidominici* Maury, 1925 occurs predominantly in shallow-marine sediments, whereas *Corbula* (*Panamicorbula*) *canae* n. sp. is restricted to brackish-water deposits of the Upper Miocene Cercado Formation in the Río Cana section. *Corbula* (*Caryocorbula*) *dominicensis* Gabb, 1873b and *Corbula* (*Juliacorbula*) *fossilis* Pilsbry, 1922 are rare. *Corbula dominicensis* is apparently restricted to the upper Lower to lower Middle Miocene Baitoa Formation of the Río Yaque del Norte section, and *C. fossilis* is found in Upper Miocene sediments of the Cercado and Gurabo Formations. Dominican corbulid species show close morphologic affinities to species of the Pliocene Bowden Formation of Jamaica, Neogene units of the Caribbean coast of Central America such as the Gatun Formation and sediments of the Limón Basin, Miocene and Pliocene deposits of Trinidad, and Miocene to Pleistocene sediments of Florida.

RESUMEN

Los bivalvos corbúlidos (Myacea: Corbulidae) constituyen una parte importante de los sedimentos fosilíferos del Neógeno en el Valle de Cibao al norte de la República Dominicana. A continuación, se describe y se dibuja seis especies pertenecientes a cinco subgéneros dentro del género *Corbula,* es decir, *Bothrocorbula, Caryocorbula, Juliacorbula, Panamicorbula,* y *Varicorbula. Corbula* (*Panamicorbula*) *canae* forma una nueva especie. Por primera vez se describe la especie fósil *Panamicorbula* y es la primera vez que se describe la especie *Panamicorbula* fuera del Pacífico este. La distribución de corbúlidos dominicanos está influenciada fuertemente por condiciones paleoambientales tales como la salinidad, profundidad de agua y fábrica bioclástica. Los corbúlidos se encuentran más comúnmente en aquellos sedimentos del Mioceno depositados predominantemente en aguas marinas someras. Dentro del la zona de estudio, *Corbula* (*Caryocorbula*) *sericea* Dall, 1898 muestra tener la distribución estratigráfica y geográfica más amplia y abunda sobre todo en agua salobre y en depósitos marinos de agua muy someras. *Corbula* (*Bothrocorbula*) *viminea* Guppy, 1866b también se encuentra comúnmente en depósitos marinos de agua somera y en depósitos de agua salobre. *Corbula* (*Varicorbula*) *sanctidominici* Maury, 1925 aparece en sedimentos marinos de poca profundidad mientras que *Corbula* (*Panamicorbula*) *canae,* n. sp. se encuentra restringida a depósitos de agua salobre en la formación Cercado del Mioceno superior en la sección del Río Cana. *Corbula* (*Caryocorbula*) *dominicensis* Gabb, 1873b y *Corbula* (*Juliacorbula*) *fossilis* Pilsbry, 1922 son poco frecuentes. Aparetmente, *C. dominicensis* queda restringida entre la parte superior del Mioceno inferior y la parte inferior del Mioceno intermedio de la formacio Baitoa en la sección del Río Yaque del Norte. *Corbula fossilis* se encuentra en los sedimentos de las formaciones Cercado y Gurabo con edad del Mioceno superior. Las especies de corbúlidos dominicanos muestran una afinidad morfológica a las especies de la formación Bowden del Plioceno en Jamaica, a las unidades Neógenas de la costa caribeña de centroamérica tales como la formación Gatun y los sedimentos de la cuenca Limón, a los depósitos de edad Miocena y Pliocena en Trinidad y a los sedimentos de Florida que comprenden desde el Mioceno hasta el Pleistoceno.

INTRODUCTION

This work is one of a series of taxonomic monographs on Neogene fossils of the Cibao Valley in the northern Dominican Republic (Text-fig. 1). Saunders *et al.* (1986) provide detailed information on measured sections and samples, and a general biostratigraphic framework. The units studied include the upper Lower to lower Middle Miocene Baitoa, Upper Miocene Cercado, Upper Miocene to Lower Pliocene Gurabo, and Lower Pliocene Mao Formations. Although not highly diverse, corbulid bivalves occur throughout the stratigraphic section. They are most abundant, however, in brackish-water and shallow-

marine sediments, which are typical of Miocene deposits in the study area.

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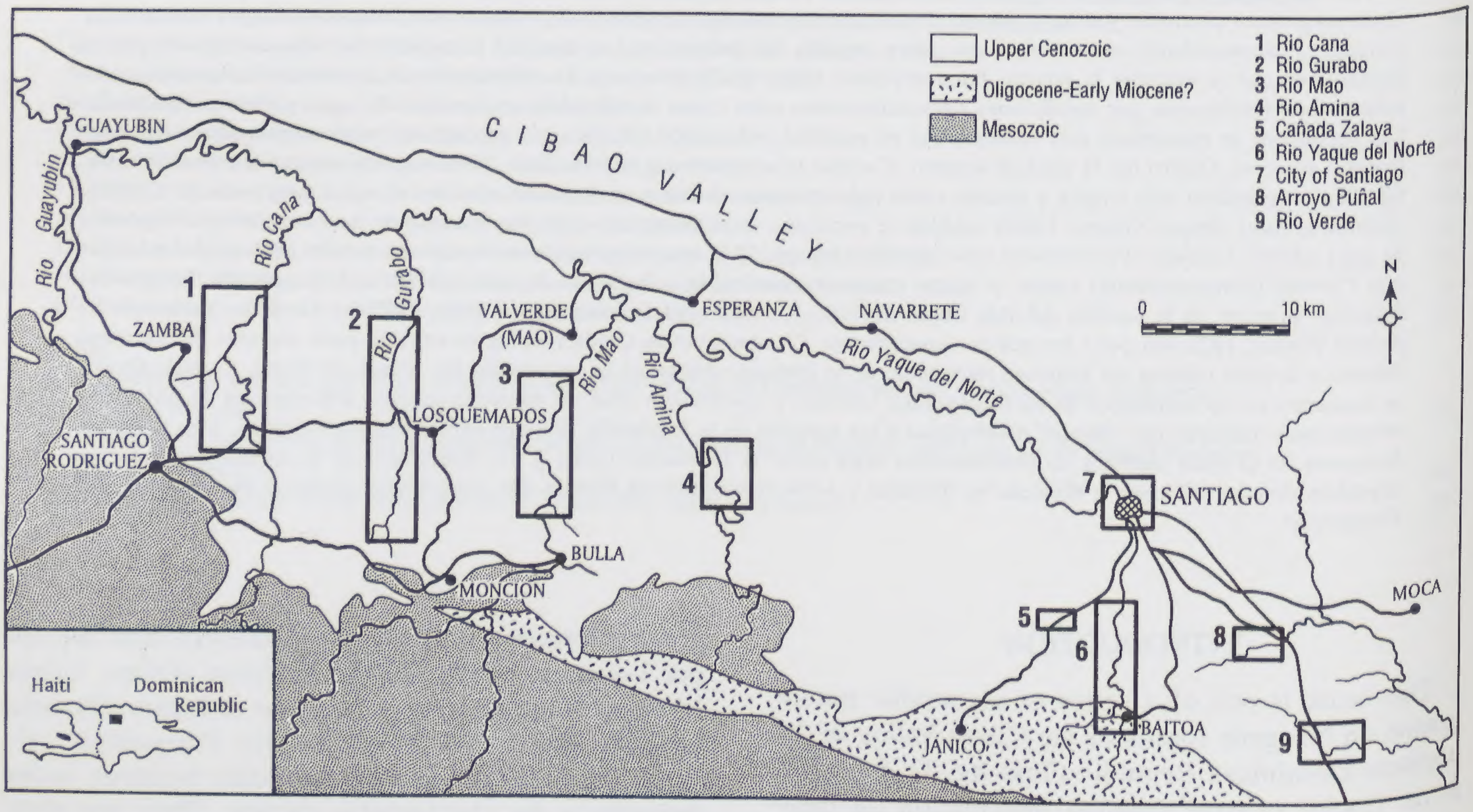
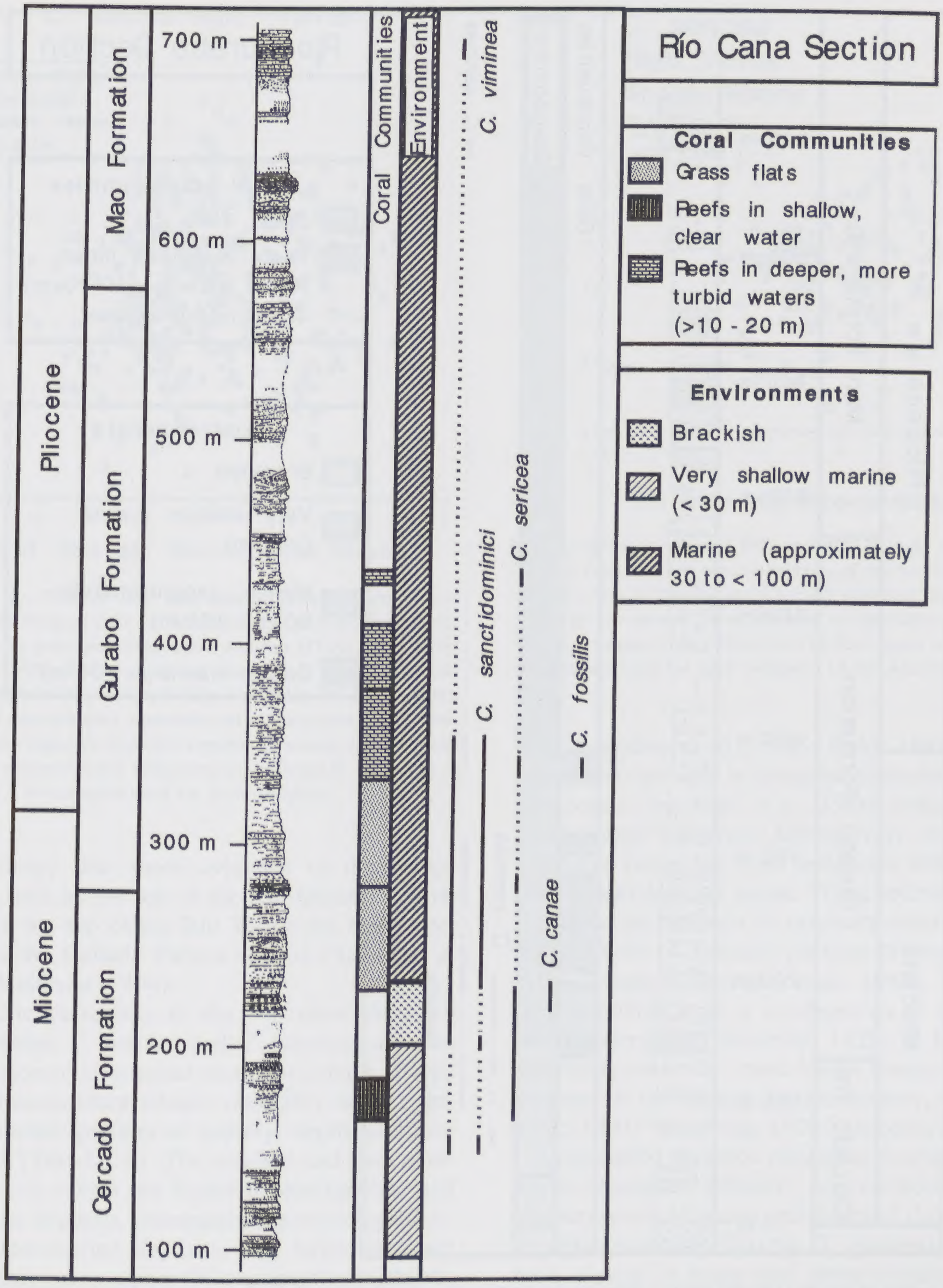
I am especially grateful for the generosity and assistance of Peter Jung, of the Naturhistorisches Museum Basel, Switzerland and Emily Vokes of Tulane University who provided long-term loans of extensive collections. A number of other institutions generously lent samples and specimens, and I would like to thank Warren Allmon of the Paleontological Research Institution; Thomas Waller, Warren Blow, and Jann Thompson of the United States National Museum of Natural History, Smithsonian Institution; Gary Rosenberg and Elana Benamy of the Academy of Natural Sciences of Philadelphia; Silvard Kool of the Museum of Comparative Zoology, Harvard University; Paul Taylor and Paul Jeffery of The Natural History Museum, London (British Museum, Natural History); and Klaus Westphal of the Museum of Geology, University of Wisconsin-Madison. Thanks also to Juan Lorenzo for translating the abstract, and to Emily Vokes, Jay Schneider, and John Kruger for reviewing the manuscript. This research was supported by the National Science Foundation (EAR-9316363), Sigma Xi, the Paleontological Society, and the Geological Society of America.

BIOSTRATIGRAPHY AND PALEOECOLOGY

Within the study area (Text-fig. 1), it is possible to trace changes in corbulid species distributions and intraspecific variability in a number of stratigraphic sections that record the interplay of paleoenvironment, time, and geography. Anderson (1994) documents in detail the relationship of corbulid species distributions and intraspecific variability to paleoenvironmental conditions in these sediments and those findings are reviewed here. Distributions of the most common species, *Corbula* (*Caryocorbula*) *sericea, Corbula* (*Bothrocorbula*) *viminea, Corbula* (*Varicorbula*) *sanctidominici,* and *Corbula* (*Panamicorbula*) *canae,* track paleoenvironmental conditions, and represent migrations into and out of the study area over time rather than speciation and extinction events (Anderson, 1994). Corbulid abundance and diversity reflect a preference for marginal-marine and shallow to intermediate marine habitats (< 100 m), which is compatible with habitat distributions of living corbulids. This correspondence of species distributions to paleoenvironmental conditions causes a temporal pattern in species distributions because paleoenvironmental conditions changed systematically through time in the study area (Saunders *et al.*, 1986). In the study area, corbulids are most abundant and diverse in Miocene marine sediments deposited primarily in shallow (approximately



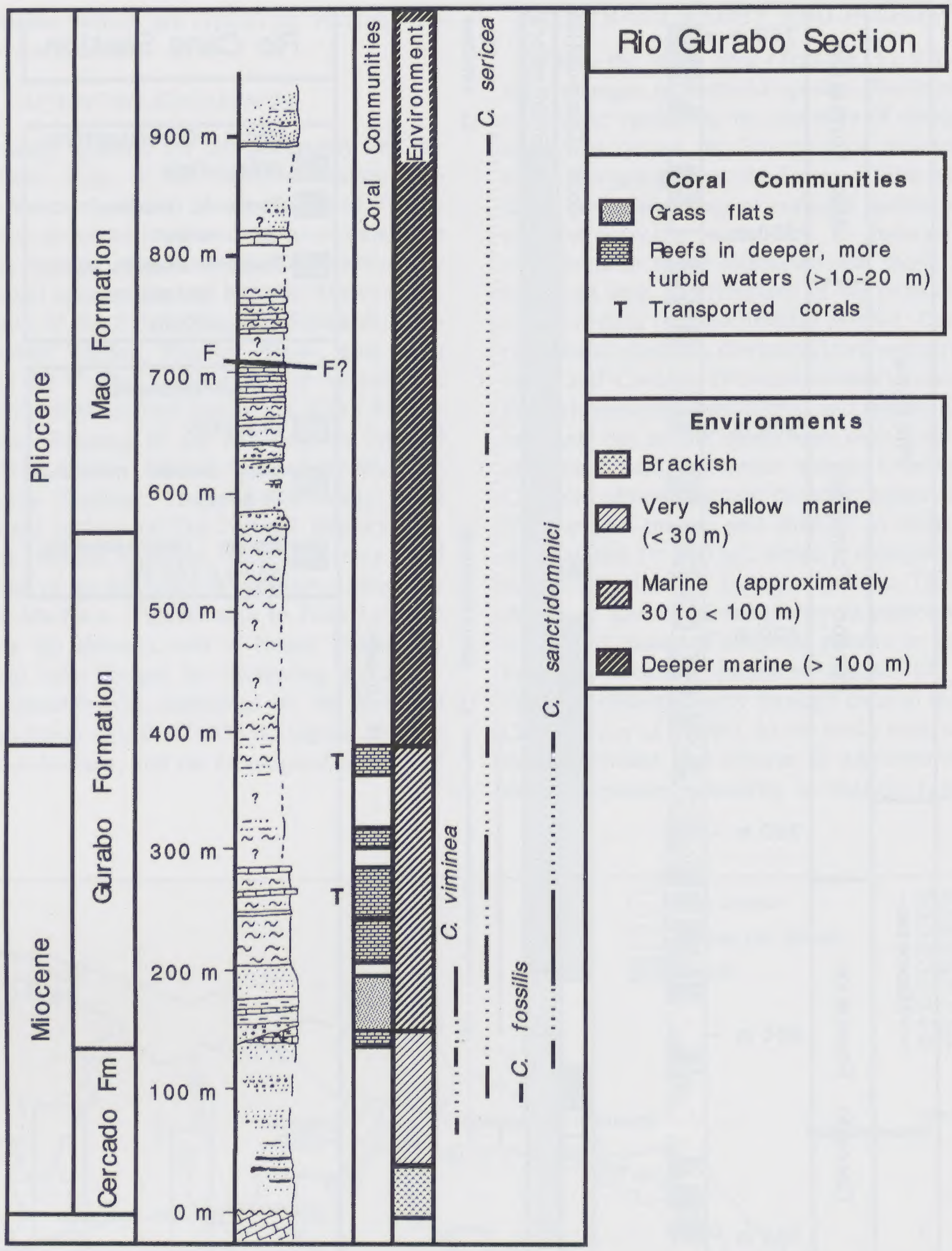
Text-figure 1.—Index map of areas investigated in the Cibao Valley, Dominican Republic (after Saunders et al., 1986).



Text-figure 2.—Part of the Río Cana section showing the stratigraphic distributions of *Corbula* species. Coral communities are based on average linkage cluster analysis of coral assemblages from Budd *et al.* (1996). Criteria used to distinguish environmental categories are outlined in Appendix 1.

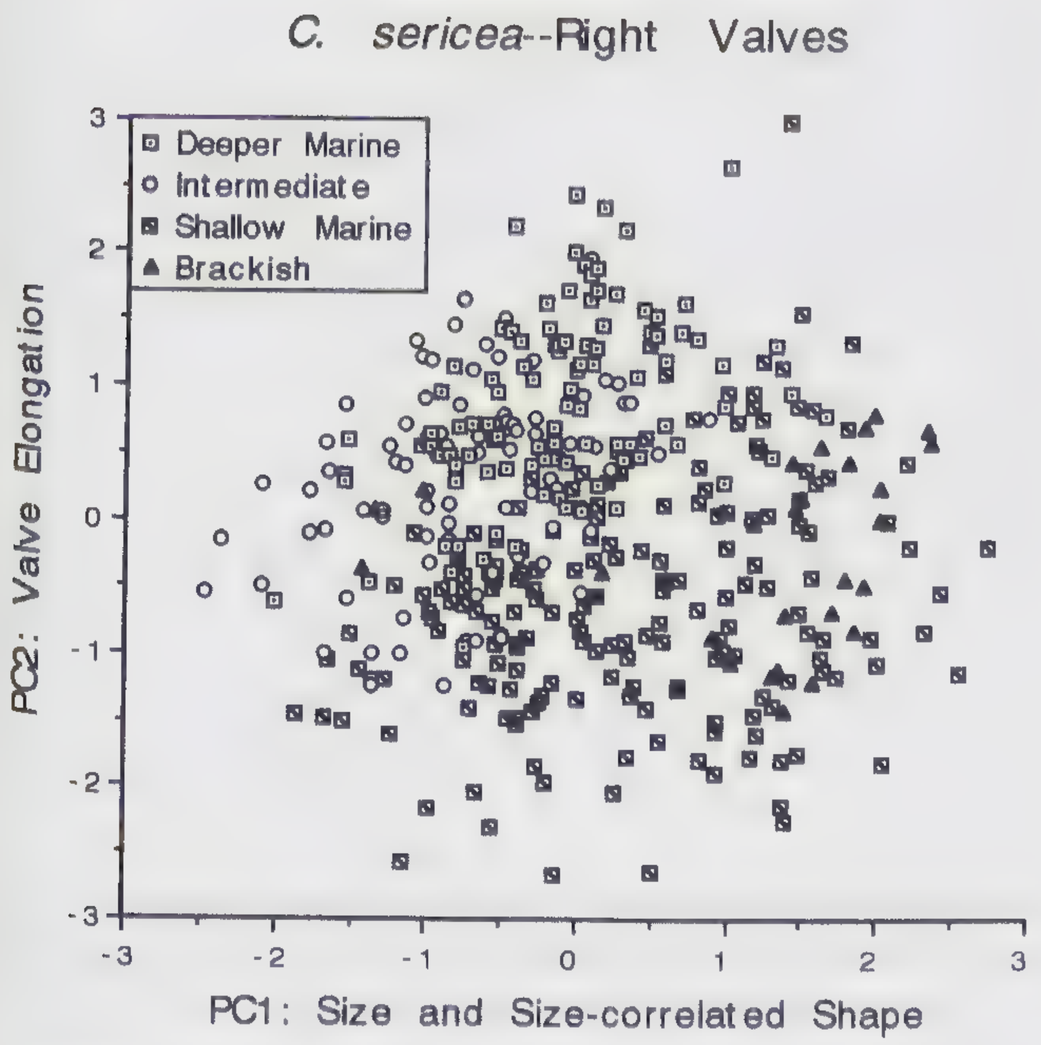
0–30 m) to intermediate depths (approximately 30–100 m), whereas corbulids are much less common and diverse in Pliocene sediments deposited in deeper marine (> 100 m) waters (Text-figs. 2, 3; see Appendix 1 for criteria used to construct these paleoenvironmental categories).

Slight differences in environmental preferences exist among Dominican Republic corbulid species. *Corbula sericea* is most abundant in brackish-water and shallow-marine to intermediate-marine deposits, although it is conspicuously absent from sediments deposited in grass-flat habitats such as the lower part of the Gurabo

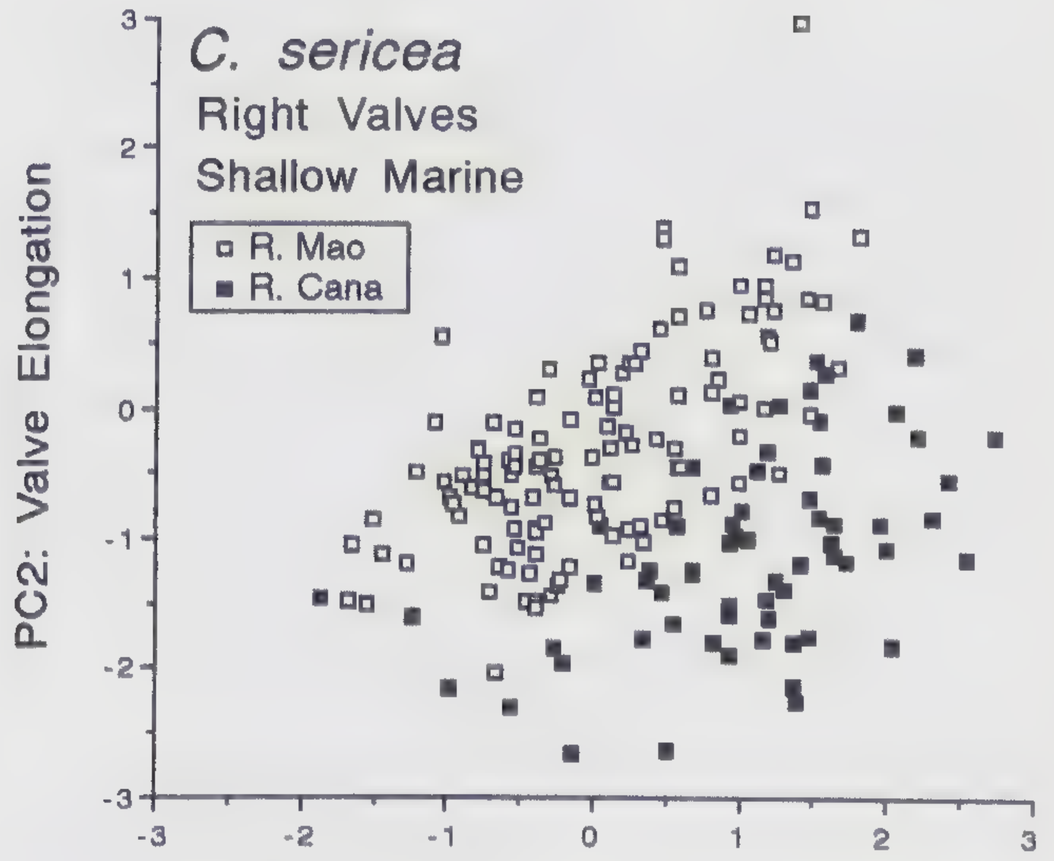


Text-figure 3.—Part of the Río Gurabo section showing the stratigraphic distributions of *Corbula* species. Coral communities are based on average linkage cluster analysis of coral assemblages from Budd *et al.* (1996). Criteria used to distinguish environmental categories are outlined in Appendix 1.

Formation in the Río Cana section (Text-fig. 2; Anderson, 1994). *Corbula viminea* also occurs in brackish-water and shallow-marine to intermediate-marine deposits in the study area, whereas *C. sanctidominici* occurs primarily in shallow- to intermediate-marine sediments (Text-figs. 2, 3). *Corbula canae* only occurs in brackish-water deposits of the Río Cana section, which were probably deposited in or near a mangrove swamp (Text-fig. 2; Anderson, 1994). *Corbula sericea* and *C. sanctidominici* also occur in deeper marine sediments



Text-figure 4.—Plot of first and second principle component scores (PC1 and PC2) of right valves of *Corbula sericea*. Procedures and results of the principal components analysis (PCA) are outlined in Anderson (1994). PC1 (explaining about 55 % of the variance) represents size and size-correlated shape variability. PC2 (explaining about 16 % of the variance) represents valve elongation, more elongate valves have negative principle component scores. Criteria used to distinguish environmental categories are outlined in Appendix 1. See Appendix 2 for samples used for each category.



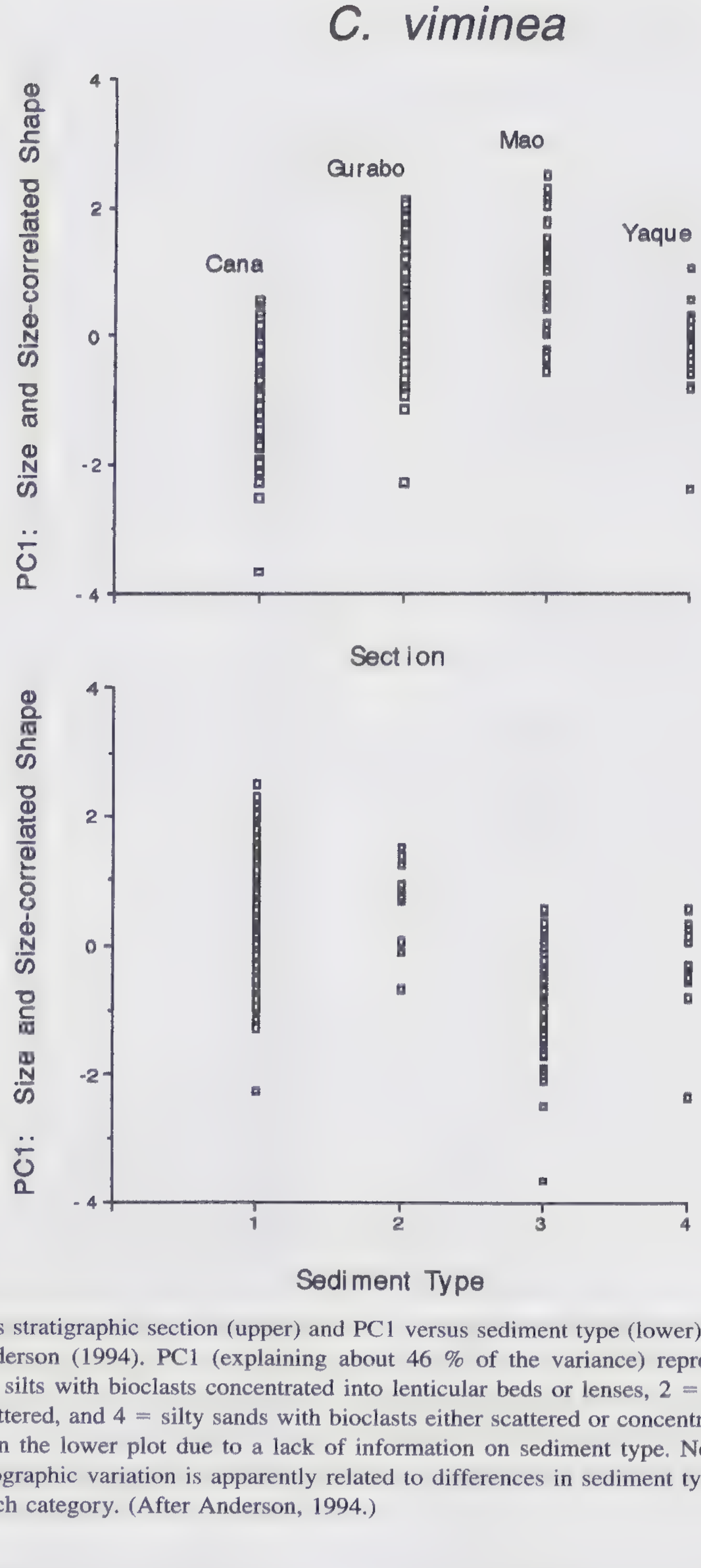
Text-figure 5.—Plot of PC1 and PC2 of right valves of *Corbula sericea* from shallow-marine deposits of the Río Cana and Río Mao sections, where this species is locally abundant. Size and shape differences are related to differences in bioclastic fabric. This plot shows a subset of data illustrated in Text-figure 4. See Appendix 2 for samples used for each category. (After Anderson, 1994.)

(>100 m deep) that show evidence of downslope movement, such as the top of the Río Gurabo section (Text-fig. 3), the top of the Río Yaque del Norte section, and in the Cañada Zalaya section (Saunders *et al.*, 1986; Anderson, 1994).

Intraspecific variability in the two most abundant corbulid species, *C. sericea* and *C. viminea,* are also related to paleoenvironmental factors. *Corbula sericea* shows continuous morphologic variability along a paleoenvironmental gradient of salinity, depth, and bioclastic fabric (Text-fig. 4). The smallest and least elongate *C. sericea* valves are found in intermediate and deeper marine deposits. Intermediate morphologies occur in shallow-marine deposits, and larger (but not more elongate) valves generally occur in brackish-water deposits. A few valves categorized as "brackish-water" from the López section of the Río Yaque del Norte, however, do not fit this trend (triangles with negative values on the first principle component axis [PC1 < 0] in Text-fig. 4). This anomaly is caused by difficulties in assigning these sediments to an environmental category because of conflicting environmental interpretations based on different faunal components. Even though the ostracode and foraminiferal faunas of the López section indicate deposition in brackish waters (Saunders *et al.*, 1986; Bold, 1988), these sediments also are rich in irregular echinoids and massive reef corals (Saunders *et al.*, 1986) indicating a significant marine influence. Alternatively, the other brackish-water valves are from sediments with an unambiguous brackish-water signal. These sediments of the Río Cana section are rich in brackish-water mollusks, including beds of *Anadara patricia* (Sowerby, 1850) (= "*Arca*" beds of Saunders *et al.*, 1986). This species is closely related to or is a subspecies of *Anadara grandis* (Broderip and Sowerby, 1829), a Recent species inhabiting intertidal mud banks bordering mangrove swamps in the eastern Pacific (Maury, 1922; Olsson, 1932, 1961; Woodring, 1973; Saunders *et al.*, 1986).

Geographic variation related to bioclastic fabric also can be discerned within *C. sericea* from roughly contemporaneous Miocene sediments of the Río Cana and Río Mao sections (Text-fig. 5; Anderson, 1994). *Corbula sericea* is larger and more elongate in the Río Cana section, where it occurs mainly in silts with bioclasts concentrated in lenses. In the Río Mao section, *C. sericea* is smaller and less elongate, and occurs in lenticular beds rich in bioclasts with a silty matrix.

Variation in *C. viminea* shows a morphologic cline from west to east in contemporaneous sediments, with variability related to sediment type and bioclastic fabric (Text-fig. 6; Table 1; Anderson, 1994). *Corbula viminea* is relatively small in the west (Río Cana section, where it occurs in pebbly shell beds), whereas to the



Text-figure 6.—Plot of PC1 versus stratigraphic section (upper) and PC1 versus sediment type (lower) for *Corbula viminea*. Procedures and results of PCA are outlined in Anderson (1994). PC1 (explaining about 46 % of the variance) represents size and size-correlated shape variability. Sediment types are: 1 = silts with bioclasts concentrated into lenticular beds or lenses, 2 = silts with bioclasts concentrated into burrows, 3 = silts with bioclasts scattered, and 4 = silty sands with bioclasts either scattered or concentrated. Two valves from the Río Yaque del Norte section are not included in the lower plot due to a lack of information on sediment type. Note clinal variation from west to east (Río Cana to Río Mao section). Geographic variation is apparently related to differences in sediment type among sections (see Table 1). See Appendix 2 for samples used for each category. (After Anderson, 1994.)

east (Río Gurabo and Río Mao sections, where it occurs in lenticular-, burrow-, or lens-shaped shell concentrations within silts) it becomes progressively larger. Valves from the Río Yaque del Norte section are from older deposits of the Baitoa Formation and do not follow this trend. Morphological differences among the four sediment-type/bioclastic-fabric categories are significant using the nonparametric Kruskal-Wallis analysis of variance ($H=103$, $df=3$, $p < 0.005$).

In summary, both abundance of particular corbulid species within their stratigraphic ranges and total ranges within stratigraphic sections are controlled by paleoenvironmental factors. In addition, intraspecific morphologic variability in *C. sericea* and *C. viminea* corresponds strongly with specific paleoenvironmental conditions. Although aspects of intraspecific variability in both species are related to bioclastic fabric, taphonomic processes do not control the morphologic variability observed (Anderson, 1994). Morphologic

Table 1.—*Corbula viminea* valves from various sediment types for each stratigraphic section. Sediment type categories are based on descriptions in Saunders *et al.* (1986) and on personal observation. Categories are: 1) silts with bioclasts in lenticular beds or lenses, 2) silts with bioclasts filling burrows, 3) silts with mollusks dispersed in matrix, 4) silty sands with bioclasts dispersed or concentrated. Samples used are listed in Appendix 2.

	sediment type			
section	*1*	*2*	*3*	*4*
Cana	14	0	98	0
Gurabo	88	11	0	0
Mao	44	0	0	0
Yaque[1]	0	0	8	15

[1] Two valves from this section were not included in the analysis because sediment type was unknown.

change within these species over time is relatively minor or is a side effect of systematic changes in environmental conditions.

BIOGEOGRAPHY

In tropical America (including the Caribbean Sea, eastern Pacific Ocean, and western Atlantic Ocean), Miocene to Recent corbulid faunas are nearly identical at the subgenus level, except for a few apparently endemic, low-diversity taxa. Widespread and abundant subgenera include *Varicorbula* Grant and Gale, 1931 (*Notocorbula* Iredale, 1930 of some authors) and *Caryocorbula* Gardner, 1926, and to a lesser extent *Bothrocorbula* Gabb, 1873a and *Juliacorbula* Olsson and Harbison, 1953. Endemic subgenera typically inhabit the Recent Panamic-Pacific province and include *Serracorbula* Olsson, 1961 and *Tenuicorbula* Olsson, 1932 (also found in the Tertiary of Peru, Venezuela, and Trinidad). *Panamicorbula* Pilsbry, 1932 was first described from the Recent Panamic-Pacific province, but also is reported from the Miocene of the Pacific coast of Costa Rica (Punta Judas; Seyfried *et al.*, 1985), the Miocene Cercado Formation of the Dominican Republic (Anderson, 1991, 1994), and the Pliocene l'Enfer and Springvale Formations of Trinidad (see p. 19).

Dominican corbulid species show affinities to a number of other Miocene to Pleistocene faunas. The Pliocene Bowden Formation of Jamaica shares two species with the Dominican fauna, *Corbula viminea* and *C. sericea,* and contains a species of *Varicorbula, Corbula* (*Varicorbula*) *heterogena* Guppy (in Dall, 1898), that is morphologically very similar to *C. sanctidominici. Corbula viminea* and *C. sericea* also are reported from Neogene deposits of the Limón Basin, Costa Rica (Dall, 1898; Olsson, 1922). In addition, the following units all contain a number of corbulid species with strong affinities to Dominican corbulids: Miocene and Pliocene sediments of Trinidad (including the Manzanilla, Springvale, l'Enfer Formations; Maury, 1925; Jung, 1969), the Miocene Gatun Formation of Panama (Woodring, 1982), Upper Miocene Santa Rosa beds of Veracruz, Mexico (Perrilliat [1984], who assigns these beds to the Agueguexquite Formation; E. Vokes [1989] states, however, that this formation only occurs farther north, near Coatzacoalcos, and is Pliocene), and Miocene to Pleistocene sediments of Florida (Dall, 1898; Gardner, 1928; Olsson and Harbison, 1953).

ABBREVIATIONS OF REPOSITORY INSTITUTIONS

The following abbreviations for repository institutions are used in this paper:

ANSP: Academy of Natural Sciences, Philadelphia, PA, U.S.A.
IGM: Instituto de Geología, Ciudad Universitaria de México, D.F., México
BMNH: The Natural History Museum, London, England, U.K. (British Museum, Natural History)
NMB: Naturhistorisches Museum Basel, Switzerland
PRI: Paleontological Research Institution, Ithaca, NY, U.S.A.
TU: Tulane University, New Orleans, LA, U.S.A.
USNM: United States National Museum of Natural History, Washington, DC, U.S.A.
UW: Museum of Geology, University of Wisconsin-Madison, Madison, WI, U.S.A.

SYSTEMATIC PALEONTOLOGY

INTRODUCTION

All species described here are assigned to the genus *Corbula*; other supraspecific taxa are considered subgenera, following Vaught (1989). All subgenera share the same basic hinge structure and differ primarily in shape, ornamentation, and the degree of disparity in size, shape, and ornamentation of the left and right valves. A majority of species described here are abundant enough to incorporate intraspecific variation into interpretations of species boundaries (see also Anderson, 1991, 1994 for quantitative treatments). Variability is considered intraspecific if it can be related to size differences (presumably ontogenetic) and/or to changes in paleoenvironmental conditions. In comparison to this approach, the taxonomy of living corbulids has been more typological because taxonomic and systematic studies have not incorporated potential phenotypic variation caused by ontogenetic, environmental, or geographic factors.

Only forms considered identical to described species are listed in the synonymy. A question mark (?) before an item in a synonymy indicates that material was insufficient to confirm conspecific status. The abbreviation "sp." indicates that the described species could be identified to the subgenus but not to the specific level. *Diagnoses* are used both for species and for supraspecific categories and indicate the diagnostic features of a particular taxon. *Descriptions* are used for species only, and outline overall species morphology. The *Remarks* section provides information on the particular taxon described, and may include a taxonomic discussion, taphonomic and paleoenvironmental information, and geologic and geographic ranges (ranges for supraspecific taxa only). The *Comparisons* section outlines differences between the species being described and morphologically similar species. Detailed locality information for Dominican Republic samples is listed in the *Occurrence* section, whereas the *Distribution* section is a more general statement of a species' geographic and stratigraphic distribution inside and outside the Dominican Republic. A question mark (?) after a formation indicates that synonymy is uncertain.

SYSTEMATICS

Family **CORBULIDAE** Lamarck, 1818

Diagnosis.—Small- to moderate-sized sturdy shells (length typically 2 cm or less), inequilateral, and generally strongly inflated. Slightly to strongly inequivalved in size and shape; left valves smaller than right valves. Hinge simple with anterior cardinal tooth in right valve and socket in left valve. Resilifer present behind hinge; typically a projecting chondrophore in left valve that corresponds to socket-like resilifer in right valve. Pallial sinus small to obsolete. (See H. Vokes, 1945; Moore, 1969.)

Subfamily **CORBULINAE** Lamarck, 1818

Diagnosis.—Left valve typically slightly smaller than right valve. Chondrophore in left valve present in most species, fitting into socket-like resilifer in right valve. Posterior typically rostrate. (See H. Vokes, 1945; Moore, 1969.)

Genus **CORBULA** Bruguière, 1797

Corbula Bruguière, 1797, pl. 230.
Corbula Lamarck, 1799, p. 89.
Aloidis Megerle von Mühlfeldt, 1811, p. 67.

Type species.—*Corbula sulcata* Lamarck, 1801; by subsequent designation, Schmidt (1818); Recent, Senegal.

Diagnosis.—Shell sturdy, moderately inflated, inequilateral and inequivalved; left valve smaller. Shells smooth to concentrically ribbed. Hinge with cardinal tooth in right valve and cardinal socket in left valve. In type species, socket-like resilifer present behind dentition in both valves; in most species, however, left valve with chondrophore and right valve with socket-like resilifer. (See H. Vokes, 1945.)

Remarks.—The generic name *Corbula* was first used in Bruguière (1797) in a plate title, and the name is generally credited to him, although he did not describe the genus. Lamarck (1799) first described *Corbula* but did not specify a type. Schmidt (1818) subsequently designated *Corbula sulcata* as type (see Stewart, 1930). *Aloidis* Megerle von Mühlfeldt (1811) is a synonym of *Corbula* (H. Vokes, 1945, 1980). Unlike most other members of the genus, the type species, *Corbula* (*Corbula*) *sulcata,* has no chondrophore in the left valve; the resilium instead is received in a socket-like resilifer behind the cardinal socket.

Geologic range of the genus is Cretaceous to Recent (Moore, 1969). The genus is found worldwide in tropical to temperate waters that range from marine to brackish salinities (Boss, 1982). Some species are tolerant of waters low in dissolved oxygen (Lewy and Samtleben, 1979).

Subgenus **BOTHROCORBULA** Gabb, 1873a

Bothrocorbula Gabb, 1873a, p. 274, pl. 10, figs. 3, 3a.

Type species.—*Corbula viminea* Guppy, 1866b; by monotypy. Pliocene, Bowden Formation, Jamaica.

Diagnosis.—Shell moderately large and thickened. Valves subequal, with coarse concentric ribs and fine radial striations. Characteristic deep lunular depression in front of umbos. Right valve hinge with cardinal tooth in front of socket-like resilifer. Left valve hinge with cardinal socket in front of chondrophore. (See Gabb, 1873a; Gardner, 1926; H. Vokes, 1945.)

Remarks.—This subgenus ranges from Miocene to Pleistocene in Florida, the West Indies, and eastern Central America (see p. 13–14). It is found in sediments deposited in shallow-marine and marginal-marine waters. The Miocene-to-Recent taxon *Hexacorbula* Olsson, 1932 closely resembles *Bothrocorbula* but lacks a lunular pit.

Corbula (Bothrocorbula) viminea Guppy, 1866b
Plate 1, figures 1–8, 10, 11, 13, 14

Corbula viminea Guppy, 1866b, p. 293, pl. 18, fig. 11; Olsson, 1922, p. 270, pl. 28, fig. 25.
Corbula (*Bothrocorbula*) *viminea* Guppy. Maury, 1917, p. 233–234, pl. 39, figs. 20, 21; 1925, p. 108–109, pl. 19, fig. 19; Pilsbry, 1922, p. 428; Woodring, 1925, p. 189–190, pl. 26, figs. 5–8; Ramírez, 1950, p. 38–39, pl. 7, fig. 9; Anderson, 1994, figs. 2.1–2.4.

Diagnosis.—Species characterized by relatively large size, prominent lunule, thick valves, coarse concentric ribs, fine radial striations, evenly rounded anterior margin, and evenly rounded to slightly sinuous ventral margin.

Description.—Valves moderately large, subequal in size and shape. Right valve slightly larger than left, only overlapping left ventrally. Valve thickness widely variable, although variability in part preservational because valve inner layers tend to slough off. Valves elongate-ovate with rostrum and arcuate keel. On some valves, posterior slope has midline depression parallel to keel. Continuous variation seen in expression of rostrum and ventral margin, ranging from subdued rostrum and evenly rounded ventral margin, to short posteriorly-pointing rostrum and evenly rounded ventral margin, to short ventrally-pointing rostrum and gently sinuous ventral margin (concave just anterior of rostrum). Valve ornamented with coarse concentric ribs that die out before reaching keel. Fine concentric and radial striations superimposed on coarse ribs, and especially visible between ribs. Posterior slope and nepionic shell with fine concentric striations, but lacking radial and coarse concentric ribs.

Both valves with deep lunule anterior of umbo. Lunule larger and deeper in left valve, encompassing entire hinge plate. Right valve hinge with large, triangular, hooked-shaped, cardinal tooth and posterior socket-like, broadly-open resilifer. Broad short ridge descends from resilifer roof and extends across part of hinge plate. Hinge plate surface depressed at resilifer. Left valve hinge with deep, triangular, hook-shaped anterior socket and broad posterior chondrophore. Hinge plate strongly sinuous resulting in obliquely-oriented cardinal socket. Dorsal surface of chondrophore with anterior and posterior ridges separated by midline trough. Posterior ridge more prominent and with denticle. Adductor muscle scars relatively large and thickened; posterior scar circular, anterior scar ovate. Pallial sinus obsolete.

Type Material.—Syntypes: BMNH 64088 (left valve), BMNH 64099 (right valve). Right valve figured by Guppy (1866b, Pl. 18, fig. 11) Both valves are figured here (Pl. 1, figs. 3, 6).

Type locality.—"Miocene" (= Bowden Formation, Pliocene), Jamaica. The type locality is here restricted to TU 705: type locality of Bowden Formation (Pliocene), Bowden, Parish of St. Thomas, Jamaica (fide H. Vokes, 1989).

Material.—Measured and/or figured specimens: NMB G 14103, 14104, 14105, 14106, 14107, 14108, 14109, 14110. Other specimens (over 600 valves) are cataloged by locality, which are listed in the Occurrence section.

Table 2.—Measurements of *Corbula* (*Bothrocorbula*) *viminea.* Figures are in mm.

	valve	*length*	*height*	*width*
BMNH 64088: syntype (Pl. 1, fig. 3)	right	19.1	13.9	6.3
BMNH 64099: syntype (Pl. 1, fig. 6)	left	15.1	10.3	5.0
USNM 115648: (figured by Woodring, 1925)	right	17.5	12.0	4.8
PRI 919: (figured by Maury, 1917)	left	14.0	9.6	4.1
PRI 919: (figured by Maury, 1917)	right	15.5	10.6	4.8
NMB G 14103: (Pl. 1, fig. 14); NMB locality 16923	left	15.9	11.8	4.9
NMB G 14104: (Pl. 1, fig. 13); NMB locality 16923	right	17.4	12.3	6.0
NMB G 14105: (Pl. 1, fig. 11); NMB locality 15900	left	15.3	11.3	5.4
NMB G 14106: (Pl. 1, fig. 10); NMB locality 15900	right	16.3	11.5	6.0
NMB G 14107: (Pl. 1, fig. 8); TU locality 1230	left	14.1	9.7	5.0
NMB G 14108: (Pl. 1, fig. 7); TU locality 1230	right	14.2	9.9	5.2
NMB G 14109: (Pl. 1, figs. 2, 5); TU locality 1364	left	13.3	9.3	3.8
NMB G 14110: (Pl. 1, figs. 1, 4); TU locality 1364	right	14.0	9.7	4.8

Remarks.—This is a common species in upper Miocene shallow-marine and brackish-water deposits of the Río Cana, Río Gurabo, Río Mao, Río Yaque del Norte, and Río Amina sections. It is typically found in silty shell beds or thin shell-rich stringers interbedded with silts. This species also is found in bioclast-rich sediment filling burrows, scattered in silts, and in pebbly and conglomeratic layers. Woodring (1925) states that Dominican forms of *C. viminea* are smaller and slightly more elongate than Jamaican forms.

Comparison.—*Corbula* (*Bothrocorbula*) *wilcoxii* Dall, 1898, a Pleistocene species from the Caloosahatchee and Bermont formations of southern Florida (Anderson, unpublished data), shows some morphologic overlap with *C. viminea. Corbula viminea* tends to be slightly larger and has a more evenly rounded anterior margin than *C. wilcoxii.* The valve margin of *C. wilcoxii* typically is flattened into a short horizontal ledge anterior of the beak, resulting in a projecting anterior. Although the two species typically are distinct, intermediate forms can be found in both species.

Corbula (*Bothrocorbula*) *synarmostes* Dall, 1898 of the Miocene Chipola Formation of Florida is smaller and has a much smaller lunule than *C. viminea. Corbula* (*Bothrocorbula*) *radiatula* Dall, 1898 of the Miocene Oak Grove Formation of Florida is also smaller

than *C. viminea,* has a reduced lunule, and more pronounced radial ornament.

Occurrence.—This species was collected from the following areas (see Saunders et al., 1986 for locality information):

Río Cana: Cercado Formation: TU 1230, and NMB 16835, 16836, 16837, 16838, 16839, 16844, 16857, 16988, 16989, 16993, 17005. Lower Gurabo Formation: NMB 16831, 16832, 16833, 16820. Upper Gurabo Formation: TU 1354, and NMB 16817–16819, 16824. Mao Formation (Mao Adentro Limestone Member): NMB 16873.

Río Gurabo: Cercado Formation: TU 1359, 1373, 1377, 1419, and NMB 15896, 15900, 15901, 15903, 15904, 15906, 15907, 15908, 15910. Lower Gurabo Formation: TU 1297, 1298, and NMB 15876, 15878, 15882, 15887.

Río Mao: Cercado Formation: TU 1294, and NMB 16913 (all correspond to Maury's Bluff 3); NMB 16915, 16917, 16918, 16923, 16924, 16926, 16927, 16928 (all Arroyo Bajón); NMB 16914, 16930, 16932 (all Maury's Bluff 2).

Río Amina: Gurabo Formation: TU 1412.

Río Yaque del Norte: Baitoa Formation: TU 1226, 1363, 1364, and NMB 16935, 16936, 16938, 17286, 17288, 17289 (all López section). Unnamed formation: TU 1445 (Angostura).

Distribution.—Upper Lower to lower Middle Miocene Baitoa, Upper Miocene Cercado, Upper Miocene to Lower Pliocene Gurabo, and Lower Pliocene Mao Formations, Dominican Republic; Miocene Thomonde and Las Canobas Formations (?), Haiti (see Guppy, 1876; Woodring et al., 1924; Woodring, 1925); Pliocene Bowden Formation, Jamaica; Pliocene Río Banano Formation, Costa Rica.

Subgenus **CARYOCORBULA** Gardner, 1926

Caryocorbula Gardner, 1926, p. 46.

Type species.—*Corbula alabamiensis* Lea, 1833, by original designation. Middle Eocene (Claibornian Stage) of Alabama.

Diagnosis.—Small- to moderately-sized, moderately thickened valves. Left valve slightly smaller than right. Shells typically elongate, with posterior keel and rostrum. Valves with moderately coarse concentric ribs; some also with fine radial striations. Right valve hinge with anterior cardinal tooth and posterior socket-like resilifer. Left valve hinge with anterior cardinal socket and posterior chondrophore. (See Gardner, 1926.)

Remarks.—*Caryocorbula* includes most American species assigned to *Cuneocorbula* Cossmann, 1886 by a number of authors (*e.g.*, Dall, 1898; Maury, 1917). Its geologic range is Eocene to Recent in North and South America and East Asia (Moore, 1969). *Caryocorbula* species inhabit shallow-marine to marginal-marine environments.

Corbula (Caryocorbula) dominicensis Gabb, 1873b

Plate 1, figures 9, 12; Plate 2, figures 1, 2, 4, 5

Corbula dominicensis Gabb, 1873b, p. 247; Pilsbry, 1922, p. 427, pl. 46, figs. 12, 13.

?*Corbula* (*Cuneocorbula*) *dominicensis* Gabb. Maury, 1917, p. 232, pl. 39, figs. 14, 15.

Diagnosis.—Species characterized by elongate shape and sculpture of concentric, closely-spaced, moderately coarse ribs and no radial striations. Also distinguished from other Dominican corbulids by relatively uninflated valves, moderately thickened shell, and large size.

Description.—Right and left valves subequal in size and shape; right valve slightly larger than left. Umbos slightly anterior of valve midline. Greatest convexity of ventral margin anterior of umbo in left valve but even with or anterior of umbo in right valve. Valves not strongly inflated and shells not greatly thickened. Sculpture consists of concentric, closely-spaced, flat-topped ribs with steep dorsal and more gradual ventral slopes. Ribs do not split and double towards posterior keel as described by Pilsbry (1922). Radial sculpture absent. Nepionic shell somewhat distinct, with very fine concentric ribs. Posterior region of valve with sharp arcuate keel and small rostrum. Left valve hinge with anterior, large, triangular socket that opens ventrally. Broad chondrophore posterior of cardinal socket, continuous with dorsal margin, and with midline cleft. Right valve hinge with anterior, large, hook-shaped, triangular cardinal tooth. Widely open socket-like resilifer present posterior of cardinal tooth. Long furrows for reception of left valve located anterior and posterior of, and continuous with, right valve hinge. Adductor muscle scars large and thickened; posterior scar circular, anterior scar ovate. Very small pallial sinus present.

Type Material.—Lectotype: ANSP 2691 (articulated shell). Specimens figured by Pilsbry (1922, p. 427, pl. 46, figs. 12, 13), who designated the lectotype, which is now lost (G. Rosenberg, pers. comm., 1993).

Type locality.—None designated. It is here designated as NMB 17281: Baitoa Formation (upper Lower to lower Middle Miocene), López section, Río Yaque del Norte, Dominican Republic.

Material.—Measured and/or figured specimens: NMB G 14111, 14112, 14113. Other specimens (four right valves, two left valves, three articulated shells, one internal mold, and two left valve fragments) are cataloged by locality, which are listed in the Occurrence section.

Table 3.—Measurements of *Corbula* (*Caryocorbula*) *dominicensis*. Figures are in mm.

specimen	*valve*	*length*	*height*	*width*
ANSP 2691: lectotype (figured by Pilsbry, 1922)	articulated	14.6	9.0	6.0[1]
PRI 29033: (figured by Maury, 1917; refigured in Pl. 2, fig. 3)	left	13.4	8.6	3.3
PRI 29033: (figured by Maury, 1917; refigured in Pl. 2, fig. 6)	right	12.6	8.6	3.2
NMB G 14112: (Pl. 2, figs. 2, 5); TU locality 1226	left	13.6	8.2	3.1
NMB G 14113: (Pl. 2, figs. 1, 4); TU locality 1226	right	14.2	9.0	4.0
NMB G 14111: (Pl. 1, figs. 9, 12); NMB locality 17281	articulated	15.3	9.2	6.9[1]

[1] diameter of articulated shell.

Measurements.—See Table 3.

Remarks.—This is a rare species found in conglomerates or conglomeratic lenses containing mollusks. In this study, it was found only in the upper Lower to lower Middle Miocene Baitoa Formation of the Río Yaque del Norte section (see Saunders *et al.*, 1986). Maury (1917), however, reports *C. dominicensis* from the upper Miocene Cercado Formation of the Río Cana Section (Zone H of the Río Cana at Caimito; equivalent to TU 1230 [Saunders *et al.*, 1986; H. Vokes, 1989]). Maury's specimens (refigured in Pl. 2, figs. 3, 5) differ from the Baitoa Formation specimens in several ways. Maury's specimens are smaller, less elongate, have a more centrally located umbo, more strongly arcuate keel, larger posterior slope, and coarser concentric ribs. Smaller specimens from the Baitoa Formation closely resemble Maury's specimens, but with the limited material available, it was not possible to unite or separate the specimens from the two formations.

Comparison.—*Corbula* (*Caryocorbula*) *democracia* F. Hodson, in Hodson and Hodson, 1931, from the Miocene of Falcón, Venezuela is much larger (holotype length is 22.5 mm), is less elongate, has a more convex ventral margin, and has coarser concentric ribs than *C. dominicensis*. *Corbula* (*Caryocorbula*) *prenasuta* Olsson, 1964 of the lower and middle Gatun Formation (Upper Miocene) of Panama and the Upper Miocene Angostura Formation of Ecuador is about the same size as *C. dominicensis* but is more strongly rostrate with the rostrum located in a more dorsal position on the posterior margin, and has a more strongly arcuate keel, giving the rostrum a twisted appearance. *Corbula* (*Caryocorbula*) *dominicensis veracruzana* Perrilliat, 1984 from the Upper Miocene Santa Rosa beds, Veracruz, Mexico more closely resembles *C. democracia* than *C. dominicensis* s. s., and probably is not a subspecies of *C. dominicensis*.

Occurrence.—This species was collected from the following areas (see Saunders *et al.*, 1986 for locality information):

Río Yaque del Norte: Baitoa Formation: TU 1226, and NMB 17281, 17283.

Distribution.—Upper Lower to lower Middle Miocene Baitoa, Upper Miocene Cercado (?) Formations, Dominican Republic.

Corbula (Caryocorbula) sericea Dall, 1898
Plate 2, figures 7–21

Corbula lavaleana Orbigny. Gabb, 1873b, p. 247; 1881, p. 371.
Corbula (*Corbula*) *sericea* Dall, 1898, p. 848–849; 1900, pl. 36, fig. 8; Woodring, 1925, p. 186–187, pl. 25, figs 19–22.
Corbula (*Cuneocorbula*) *cercadica* Maury, 1917, p. 232–233, pl. 39, figs. 16, 17.
Corbula (*Cuneocorbula*) *caimitica* Maury, 1917, p. 233, pl. 39, figs. 18, 19.
Corbula sericea Dall. Pilsbry, 1922, p. 427.
Corbula (*Caryocorbula*) *cercadica* Maury. Anderson, 1994, figs. 1.1–1.5.

Diagnosis.—Species characterized by small, inflated, elongate-ovate to subtriangular valves with relatively fine, closely and evenly spaced concentric ribs, and very fine radial striations.

Description.—Shells small to moderately sized; moderately inflated. Valves thin to relatively thick, variability in part preservational. Left and right valves subequal in size and shape; right valve larger and slightly less elongate than left. Umbo at or slightly anterior of valve midline. Keel nearly straight to arcuate. Valve shape varies from triangular to elongate ovate; elongate valves more rostrate. Ornament of closely spaced concentric ribs. Fine radial ribs present but variably expressed. Radial striations present, beaded under magnification.

Right valve hinge with anterior, large, triangular, hook-shaped, cardinal tooth, and posterior, large, widely open, socket-like resilifer. Ridge bisects roof of resilifer, as in *C. viminea*. Long furrow present on either side of right valve hinge for reception of left valve's thickened dorsal margin. Posterior furrow continuous with resilifer. Left valve hinge with anterior, large, triangular, cardinal socket and broad posterior chondrophore. Anterior half of chondrophore's dorsal surface concave, posterior half convex. Small denticle present at posterior edge of chondrophore. Adductor muscle scars slightly thickened. Posterior scar circular; anterior scar ovate. Pallial sinus small to obsolete.

Type Material.—Lectotype: USNM 135655 (right valve). Lectotype designated by Woodring (1925). Specimen figured by Dall (1900, Pl. 36, fig. 8) and Woodring (1925, Pl. 25, figs. 19, 20), and refigured here (Pl. 2, fig. 7).

Type locality.—USGS locality 2692: track ballast

Table 4.—Measurements of *Corbula* (*Caryocorbula*) *sericea*. Figures are in mm.

specimen	*valve*	*length*	*height*	*width*
USNM 135655: lectotype (Pl. 2, fig. 7)	right	5.3	4.0	2.0
PRI 29035[1]: (figured by Maury, 1917; refigured in Pl. 2, fig. 9)	left	5.6	3.9	2.0
PRI 29035[1]: (figured by Maury, 1917; refigured in Pl. 2, fig. 8)	right	6.6	4.6	2.3
NMB G 14114: (Pl. 2, fig. 17); NMB locality 16928	left	5.6	4.0	1.8
NMB G 14115: (Pl. 2, fig. 16); NMB locality 16928	right	6.1	4.5	2.1
NMB G 14116: (Pl. 2, fig. 19); NMB locality 15869	left	4.2	2.9	1.4
NMB G 14117: (Pl. 2, fig. 18); NMB locality 15869	right	4.9	3.2	1.6
NMB G 14118: (Pl. 2, figs. 11, 15); NMB locality 16848	left	7.5	4.7	2.4
NMB G 14119: (Pl. 2, figs. 10, 14); NMB locality 16848	right	7.0	5.0	3.0
NMB G 14120: (Pl. 2, fig. 13); NMB locality 16855	left	7.1	4.6	2.3
NMB G 14121: (Pl. 2, fig. 12); NMB locality 16855	right	8.1	4.8	2.7
NMB G 14122: (Pl. 2, fig. 21); TU locality 1227A	left	5.6	3.9	2.0
NMB G 14123: (Pl. 2, fig. 20); TU locality 1227A	right	6.0	4.2	2.3

[1] Mislabeled as cotypes (syntypes) of *Corbula* (*Cuneocorbula*) *caimitica* but are *Corbula* (*Cuneocorbula*) *cercadica* illustrated in pl. 39, figs. 16, 17 of Maury 1917). The syntypes of *Corbula* (*Cuneocorbula*) *caimitica* are apparently lost (W. Allmon, pers. comm., 1994).

for railroad 1.5 miles west of Limón, Costa Rica. The source of the aggregate is USGS locality 2694: *in situ* Limón Reef (= Moín Formation, Pliocene).

Material.—Measured and/or figured specimens: NMB G 14114, 14115, 14116, 14117, 14118, 14119, 14120, 14121, 14122, 14123. Additional material: UW 1863/25, 1863/26. Other specimens (thousands of valves) are cataloged by locality, which are listed in the Occurrence section.

Measurements.—See Table 4.

Remarks.—This species is locally abundant in Upper Miocene shallow-marine (< 30 m) and brackish-water deposits of the Río Cana, Río Gurabo and Río Mao sections. It also occurs in Miocene and Pliocene intermediate and deeper marine (> 30 to + 100 m) sediments of the Río Cana, Río Gurabo, Cañada Zalaya, Río Amina, Río Verde, and Río Yaque del Norte sections. *Corbula sericea* is found in a variety of sediment types in the study area although it predominantly occurs scattered in silts and in shell beds with a silty matrix.

Corbula sericea is morphologically variable, although most shape variation is highly correlated with size. Size and size-correlated shape, in turn, are continuous and are closely related to paleoenvironmental conditions (Anderson, 1994). Specimens from very shallow marine deposits of the Río Mao have a subtriangular valve outline (Pl. 2, figs. 16, 17). Average height to length ratio (H:L) is 0.72 (all height to length ratios for *C. sericea* reported here are based on data from Anderson, 1994). The ventral margin of these forms is directed upward at a slight angle in both directions from the midline. There is no invagination of the ventral margin in association with the keel or rostrum. The rostrum is very subdued to nearly absent and is directed downward. Most forms have an evenly rounded dorsal margin, although in some, the umbo is somewhat set off and projecting.

Specimens from very shallow marine sediments of the Río Cana section (Pl. 2, figs. 12, 13) tend to be larger and more elongate (average H:L = 0.63) than those of the Río Mao section. In addition, the rostrum in Río Cana specimens is located in a more dorsal position on the posterior margin, and it tends to point posteriorly rather than ventrally. As a result, valves have an ovate outline. Convexity of the keel varies, but most specimens have a slightly sinuous keel. The dorsoanterior slope is nearly straight, and the highest point of the valve is located more anteriorly than in the Río Mao specimens.

Brackish water forms from the Río Cana section (Pl. 2, figs. 10, 11, 14, 15) also are large, ovate, and elongate (average H:L = 0.68), although not as elongate as valves from very shallow-marine deposits of the Río Cana. In addition, the dorsoanterior slope is more rounded than in very shallow-marine forms. The rostrum is moderately expressed to obsolete, and when present, is directed ventrally. The ventral margin is strongly rounded, and the keel less sinuous than in shallow-marine forms of the Río Cana section.

Valves from intermediate and deeper marine deposits of the Río Gurabo, Río Mao, Río Cana, and Río Yaque del Norte sections tend to be smaller than those of other paleoenvironments but are very similar in shape to the Río Mao specimens. For these deeper water forms (Pl. 2, figs. 18, 19), H:L is 0.72 to 0.73 on average. Pliocene valves of deeper marine deposits of the Cañada Zalaya section (Pl. 2, figs. 20, 21) are similar in both size and shape to other deeper water forms, except that the ventral margin tends to be flatter.

Comparison.—Jung (1969) noted that small caryocorbulids of the Miocene and Pliocene of Trinidad were oversplit and considered *Corbula smithiana* Maury, 1912, and possibly *C. caribaea pergrata* Maury, 1925 and *C. daphnis* Maury, 1925, to be junior synonyms of *C. helenae* Maury, 1912. Although it is similar in shape to Río Cana morphologies of *C.*

sericea, C. helenae has a larger maximum size (up to 13 mm long), is more elongate, is less inflated, can be more coarsely sculptured, can have more prominent radial striations, and tends to have a more bulbous and projecting anterior. The species *C. manzanillensis* Maury, 1925 of the Miocene Manzanilla Formation of Trinidad is very small, has coarser ribs at comparable sizes, is strongly triangular, and less elongate than *C. sericea.*

Corbula (*Caryocorbula*) *oropendula* Olsson, 1922 has coarser sculpture, has a straighter keel and more ventrally located rostrum, is more elongate, and has a more strongly and evenly rounded ventral margin than *C. sericea. Corbula* (*Caryocorbula*) *oropendula dolicha* Woodring, 1982 is similar in shape to *C. oropendula* but has finer sculpture. *Corbula* (*Caryocorbula*) *oropendula stena* Woodring (1982) is much more rounded, tends to be smaller, and its rostrum creates a more prominent notch in the ventral margin than seen in *C. sericea.*

Occurrence.—This species was collected from the following areas (see Saunders *et al.*, 1986 for locality information):

Río Cana: Cercado Formation: TU 1230, and NMB 16838, 16839, 16841, 16843, 16844, 16845, 16846, 16848, 16850, 16851, 16853, 16854, 16855, 16856, 16986, 16987, 16988, 16989, 16990, 16993, 17001, 17003. Lower Gurabo Formation: NMB 16832. Upper Gurabo Formation: TU 1354, and NMB 16865, 17009.

Río Gurabo: Cercado Formation: TU 1277, 1419, and NMB 15900, 15904, 15910, 15911, 15912, 15925. Lower Gurabo Formation: TU 1211, 1215, 1278, and NMB 15842, 15846, 15854, 15860, 15863, 15864, 15869, 15871, 15873, 15882, 15936, 15937, 15941, 15944, 15945, 15947, 16808, 16809, 16810, 15836, 15835, 15952. Upper Gurabo Formation: TU 1210, and NMB 15933, 15935, 15939, 15964, 15966, 15969, 15805, 15804, 15814, 15815. Mao Formation: TU 1352, and NMB 15822, 15827, 15832, 15833.

Río Mao: Cercado Formation: TU 1294, and NMB 16912, 16913, 17269 (all correspond to Maury's Bluff 3 (1917)); NMB 16915, 16916, 16917, 16918, 16922, 16923, 16924, 16926, 16927, 16928 (all Arroyo Bajón); NMB 16914, 16929, 16930, 16931, 16932 (all Maury's Bluff 2); NMB 16802 (located between Bluff 1 and 2); TU 1293, and NMB 16910 (all Bluff 1), and TU 1225 (down stream and up section from Bluff 1).

Río Amina: Gurabo Formation: TU 1219, 1411, 1412.

Cañada Zalaya: Gurabo Formation: TU 1227, 1227A, 1453, 1453A.

Río Verde: Gurabo Formation: TU 1250.

Río Yaque del Norte: Baitoa Formation: TU 1226. Unnamed Formation: NMB 17273 (Arroyo López), NMB 17278 (Angostura). Gurabo Formation: TU 1403, 1405, 1448, 1449 (La Barranca), TU 1206 (Santiago).

Distribution.—Upper Lower to lower Middle Miocene Baitoa, Upper Miocene Cercado, Upper Miocene to Lower Pliocene Gurabo, and Lower Pliocene Mao Formations, Dominican Republic; Pliocene Bowden Formation, Jamaica; Pliocene Moín Formation, Costa Rica; Miocene Gatun Formation (?), Panama (see Brown and Pilsbry, 1911).

Subgenus **JULIACORBULA** Olsson and Harbison, 1953

Juliacorbula Olsson and Harbison, 1953, p. 148–149.

Type species.—*Corbula aequivalvis* Philippi, 1836 (= *Corbula cubaniana* Orbigny, 1846; = *Corbula knoxiana* Adams, 1852b); by original designation. Recent, West Indies.

Diagnosis.—Shell small- to medium-sized, nearly equivalved. Subrectangular with strong keel and sharply truncated posterior. Well-defined escutcheon located behind beak. Hinge as in *Caryocorbula.* (See Olsson and Harbison, 1953; Olsson, 1961.)

Remarks.—*Juliacorbula* differs from *Caryocorbula* in shape and in the presence of an escutcheon. The type species was originally designated as *C. cubaniana,* which generally is agreed to be a junior synonym of *C. aequivalvis* (see McLean, 1951; Weisbord, 1964; Rios, 1975). The geologic range of *Juliacorbula* is Miocene to Recent in the West Indies, eastern Pacific, Central and South America, and Florida (Moore, 1969; Olsson and Harbison, 1953). Members of this group inhabit shallow-marine environments.

Corbula (Juliacorbula) fossilis Pilsbry, 1922
Plate 2, figures 22–26

Corbula contracta Say. Gabb, 1873b, p. 247.
Corbula knoxiana fossilis Pilsbry, 1922, p. 427, pl. 46, fig. 14.
?*Corbula* (*Cuneocorbula*) *cubaniana* Orbigny. Maury, 1925, p. 103–104, pl. 20, figs. 2–4.
?*Juliacorbula aequivalvis* (Philippi). Jung, 1969, p. 410–411, pl. 39, figs. 11–15.
Corbula (*Juliacorbula*) *aequivalvis* Philippi. Perrilliat, 1984, p. 17, pl. 16, figs. 1–4.

Diagnosis.—Species characterized by straight to slightly concave ventral margin, strongly angled posterior margin, strong keel and rostrum, and subtrapezoidal shape.

Description.—Valves relatively small, subtrapezoidal, and moderately inflated. Ventral margin flattened

to slightly concave at midline. Dorsoanterior margin also slightly concave in front of umbo. Directly posterior of beak, valve margin planar, gently sloping ventrally (sloping more steeply in left valves) to rostrum so that rostrum nearly as high as entire valve. Posterior of rostrum, valve margin nearly planar and vertical. Keel sharp and gently sinuous. Valve ornament of relatively coarse ribs with steep dorsal and gentle ventral slopes. Faint radial striations present on umbo.

Right valve hinge with moderately projecting, triangular, hook-shaped, cardinal tooth directly beneath beak. Posterior socket-like resilifer present beneath umbo. Hinge plate strongly sinuous, making resilifer nearly obsolete. Posterior of hinge, long L-shaped furrow present on right valve's posterior margin for reception of left valve. Left valve hinge with large, triangular, cardinal socket beneath beak and posterior broad chondrophore. Dorsal surface of chondrophore with anterior, midline and posterior ridges; small denticle present at end of posterior ridge. Adductor muscle scars large and moderately thickened; anterior scar ovate, posterior scar circular. Pallial sinus obsolete.

Type Material.—Holotype: ANSP 2689 (right valve). Figure by Pilsbry (1922, Pl. 46, fig. 14) and refigured here (Pl. 2, figs. 22, 23).

Type locality.—None designated. It is here designated as NMB 15914: Cercado Formation (Upper Miocene), Río Gurabo, Dominican Republic.

Material.—Measured and/or figured specimens: NMB G 14124, 14125.

Measurements.—See Table 5.

Remarks.—This rare species is found in shell-rich sediments with a silty matrix.

Comparison.—Species of *Juliacorbula* from the Tertiary of Trinidad (Maury, 1925; Jung, 1969) are very similar to the Dominican species, although the posterior slope is nearly vertical in the Trinidad specimens and more oblique in Dominican forms. It is not possible at this time to determine whether this difference is of taxonomic significance because of the paucity of material. *Corbula* (*Juliacorbula*) *scutata* Gardner, 1943 of the Florida Pleistocene is very similar to *C. fossilis* but has coarser ribs, a more arched and less sinuous keel, a less concave dorsoanterior margin, and can be more elongate. The Pleistocene to Recent *C. aequivalvis* Philippi, 1836 (=*C. knoxiana* C. B. Adams, =*C. cubaniana* Orbigny) may be a peramorphic descendent of *C. fossilis*. Smaller specimens of *C. aequivalvis* overlap in morphology with *C. fossilis*. *Corbula aequivalvis* differs from *C. fossilis*, however in attaining a larger size, having a more rounded ventral margin that shows its greatest convexity anterior of the midline, not having a concave dorsoanterior margin, being more elongate, having a more sinuous keel, and tending to have finer ribs.

Table 5.—Measurements of *Corbula* (*Juliacorbula*) *fossilis*. Figures are in mm.

specimen	*valve*	*length*	*height*	*width*
ANSP 2689: holotype (Pl. 2, figs. 22, 23)	right	8.7	6.1	2.7
ANSP uncat.: paratype (Pl. 2, fig. 24)	left	8.4	5.8	2.8
ANSP uncat.: paratype	left	6.7	4.4	1.8
NMB G 14124: (Pl. 2, fig. 26); NMB locality 15914	right	5.7	4.1	1.6
NMB G 14125: (Pl. 2, fig. 25); NMB locality 16817	right	5.6	3.7	1.4
USNM 306431: (figured in Perrilliat, 1984); IGM locality 2851	left	8.7	6.8	2.2
PRI 870: (figured in Maury, 1925)	left	6.2	4.3	1.9
PRI 871: (figured in Maury, 1925)	right	7.4	5.1	2.3
PRI 872: (figured in Maury, 1925)	right	7.9	6.0	2.7

Occurrence.—This species was collected from the following areas (see Saunders et al., 1986 for locality information):

Río Cana: Upper Gurabo Formation: NMB 16817.

Río Gurabo: Cercado Formation: NMB 15914.

Distribution.—Upper Miocene Cercado, Upper Miocene to Lower Pliocene Gurabo Formations, Dominican Republic; Upper Miocene Santa Rosa beds, Veracruz, Mexico; Lower Pliocene Melajo Clay Member of the Springvale Formation(?), Pliocene Point Courbaril Sand and Clay Member of the l'Enfer Formation (?), Pliocene Matura Sand and Clay Member of the Talparo Formation (?), Trinidad.

Subgenus **PANAMICORBULA** Pilsbry, 1932

Panamicorbula Pilsbry, 1932, p. 105.

Type species.—*Potamomya inflata* Adams, 1852a (=*P. aequalis* Adams, 1852a, =*P. trigonalis* Adams, 1852a, = *Corbula macdonaldi* Dall, 1912); by original designation. Recent, Pacific Coast of Panama.

Diagnosis.—Valves moderately large and inflated but relatively thin, not rostrate. Surface smooth or with very fine concentric ribs. Hinge of right valve with anterior cardinal tooth and posterior socket-like resilifer. Left valve hinge with anterior cardinal socket and posterior chondrophore. (See Pilsbry, 1932; H. Vokes, 1945; Olsson, 1961.)

Remarks.—Contrary to the original description, no lateral teeth are present. What Pilsbry (1932) described as long laterals in the right valve are actually buttresses for grooves that receive the dorsal margin of the left valve (H. Vokes, 1945; Moore, 1969). Living *Panamicorbula* are found in the Panamic Province (eastern

Pacific; Mazatlán to Peru) in brackish water (Pilsbry, 1932; Olsson, 1961). The subgenus is reported as abundant but poorly preserved from Middle Miocene sediments at Punta Judas, Pacific Coast, Costa Rica (Seyfried et al., 1985). It is also present in USNM collections (with U.S. Geological Survey locality numbers) of the Lower Pliocene l'Enfer Formation (USGS 21842, USGS 20433) and Lower Pliocene Springvale Formation (USGS 20421, USGS 21083, USGS 20423) of Trinidad.

Corbula (Panamicorbula) canae, new species
Plate 3, figures 1–10

Corbula (*Panamicorbula*) aff. *C. inflata* (C. B. Adams). Anderson, 1994, fig. 3.1.

Diagnosis.—Species characterized by roughly triangular shape, thin valves, fine concentric ribs, and left and right valves subequal in size and shape.

Description.—Valves relatively large (maximum length about 15 mm), inflated, and thin. Left and right valves subequal in size and shape; right valve slightly larger. Valve height shows positive allometry relative to valve length; larger valves more triangular, whereas smaller valves more quadrate. Ventral margin most convex anterior of midline, whereas umbo located at midline. Ventral margin of right valve rounded, of left valve slightly sinuous. Valve ornament of very fine, closely-spaced, concentric ribs. Radial ribs absent. Arcuate keel and subtle rostrum present. Right valve hinge with large, anterior, triangular, hook-shaped, cardinal tooth. Posterior, socket-like resilifer present beneath beak and opening ventrally. Elongate furrow present on both sides of right valve hinge for reception of left valve. Left valve hinge with large, anterior, triangular, cardinal socket and broad posterior chondrophore. Chondrophore continuous with valve margin and not strongly projecting. Low anterior, midline, and posterior ridges present on dorsal surface of chondrophore. Adductor muscle scars large but not thickened. Posterior scar circular; anterior scar ovate. Pallial sinus obsolete.

Etymology of name.—Name after Río Cana.

Type Material.—Holotype: NMB G 14126 (articulated shell). Figured in Plate 3, figures 1, 2.

Type locality.—NMB 16845: Cercado Formation (Upper Miocene), Río Cana, Dominican Republic. Paratypes are from NMB 16841, a nearby locality in the same lithologic unit.

Material.—Measured and/or figured specimens: NMB G 14126, 14127, 14128, 14129, 14130, 14131, 14132. Other specimens (11 articulated shells, 32 right valves, and 20 left valves) are cataloged by locality, which are listed in the Occurrence section.

Table 6.—Measurements of *Corbula* (*Panamicorbula*) *canae*. Figures are in mm.

specimen	*valve*	*length*	*height*	*width*
NMB G 14126: holotype (Pl. 3, figs. 1, 2); NMB locality 16845	articulated	14.4	11.8	9.6[1]
NMB G 14127: paratype (Pl. 3, figs. 6, 7); NMB locality 16841	left	12.2	9.9	3.6
NMB G 14128: paratype (Pl. 3, fig. 8); NMB locality 16841	left	13.5	10.4	4.3
NMB G 14129: paratype (Pl. 3, fig. 5); NMB locality 16841	right	13.9	11.2	4.8
NMB G 14130: paratype (Pl. 3, figs. 3, 4); NMB locality 16841	right	12.4	10.2	3.4
NMB G 14131: (Pl. 3, fig. 9); NMB locality 16841	left	8.3	7.0	2.3
NMB G 14132: (Pl. 3, fig. 10); NMB locality 16841	right	7.1	5.5	1.5

[1] diameter of articulated shell.

Measurements.—See Table 6.

Remarks.—This is the first description of a fossil *Panamicorbula* species and the first description of a Caribbean *Panamicorbula.* This species is restricted to the "*Arca*" beds of the Upper Miocene Cercado Formation Río Cana section (see Saunders et al., 1986). It is found in interbedded shelly silts and silty clays, and in shell beds. Living representatives of *Panamicorbula* are restricted to the Pacific coast of Central America where they inhabit mangrove swamps and areas near the mouths of streams (Pilsbry, 1932; H. Vokes, 1945; Keen, 1971). *Corbula canae* apparently had similar environmental preferences because it occurs in sediments deposited in or near mangrove swamps (Anderson, 1994).

Comparison.—*Corbula* (*Panamicorbula*) *inflata* (Adams, 1852a) (synonyms: *C. aequalis* [Adams, 1852a], *C. trigonalis* [Adams, 1852a], and *C. macdonaldi* Dall, 1912) is much larger than *C. canae* and differs somewhat in shape. The ventral margin of *C. inflata* (Adams, 1852a) is flatter and is most convex near the valve midline, the keel is less arcuate, and the rostrum is absent.

Occurrence.—This species was collected from the following areas (see Saunders et al., 1986 for locality information):

Río Cana: Cercado Formation: NMB 16843, 16845, 16990, 16841, 16993, 16987, 16989, 16840, 16844, 16852, and 16842.

Distribution.—Upper Miocene Cercado Formation, Dominican Republic.

Corbula (Panamicorbula) sp.
Plate 3, figure 11

Diagnosis.—Small uninflated valves (< 6.5 mm) of *Panamicorbula* with rectangular shape.

Table 7.—Measurements of *Corbula* (*Panamicorbula*) sp. Figures are in mm.

specimen	*valve*	*length*	*height*	*width*
NMB G 14133: (Pl. 3, fig. 11); NMB locality 16990	right	5.4	4.0	1.3

Material.—Measured and/or figured specimens: NMB G 14113. Other specimens (15 right valves, and 4 left valves) are cataloged by locality, which are listed in the Occurrence section.

Measurements.—See Table 7.

Remarks.—These are small, apparently immature valves of a *Panamicorbula* species. Although these valves may be small individuals of *Corbula* (*Panamicorbula*) *canae,* the small number of valves for comparison and lack of intermediates makes assignment uncertain. These valves co-occur with *C. canae* in interbedded shelly silts and silty clays, and shell beds dominated by *Anadara patricia* in the upper part of the Upper Miocene Cercado Formation of the Río Cana section.

Comparison.—Valve shape of *Corbula* (*Panamicorbula*) sp. resembles *Caryocorbula,* but these valves are not as inflated as *Caryocorbula,* and the resilifer of the right valve opens ventrally (as in *Panamicorbula*). These valves differ from *Corbula* (*Panamicorbula*) *canae* in that they are small, much less inflated, and rectangular (rather than triangular) in shape.

Occurrence.—This species was collected from the following areas (see Saunders *et al.*, 1986 for locality information):

Río Cana: Cercado Formation: NMB 16845, 16990, 16993, 16987, 16989, 16846, 16852, 16986.

Distribution.—Upper Miocene Cercado Formation, Dominican Republic.

Subgenus **VARICORBULA** Grant and Gale, 1931

Varicorbula Grant and Gale, 1931, p. 420, footnote 1.

Type species.—*Tellina gibba* Olivi, 1792; by original designation. Recent, west coast of Europe and Mediterranean Sea.

Diagnosis.—Valves small to moderate in size with right and left valves strongly unequal in size, shape, and ornamentation. Right valve larger, more inflated and relatively higher; left valve smaller, more elongate, and much less inflated. Right valves with strongly expressed concentric ribs. Left valves with fine, widely spaced, radial ribs and fine concentric growth-lines; thicker concentric ribs may be present on beak and umbo. Right valve hinge with anterior cardinal tooth and posterior socket-like resilifer. Left valve hinge with anterior cardinal socket and posterior chondrophore.

Remarks.—Some workers (Stenzel *et al.*, 1957; Weisbord, 1964; Jung, 1969) consider *Varicorbula* to be a junior synonym of *Notocorbula* Iredale, 1930. Woodring (1982), however, advocated continued use of *Varicorbula* until the type species of *Notocorbula* was better known. Stenzel *et al.* (1957) state that the nepionic shells evident in both valves of the type species, *Corbula* (*Notocorbula*) *vicaria* (Iredale, 1930), can be seen in a more subdued form in *C. gibba* (Olivi, 1792), the type species of *Varicorbula,* and use this trait as a basis for synonymy. *Corbula vicaria,* however, does apparently differ from *C. gibba* in that left and right valves are subequal in size and shape, whereas *Varicorbula* is strongly inequivalved. Therefore, *Varicorbula* is used here.

The geologic range of *Varicorbula* is Eocene to Recent in eastern North America, Europe, and the eastern and western Pacific (Moore, 1969). *Varicorbula* species inhabit marine waters and can locally dominate the benthic fauna (*e.g.*, Yonge, 1946).

Corbula (Varicorbula) sanctidominici Maury, 1925

Plate 3, figures 12–18

Corbula disparilis Orbigny. Gabb, 1873b, p. 247.
Corbula vieta Guppy. Pilsbry, 1922, p. 427.
Corbula (*Aloidis*) *vieta* Guppy. Maury, 1917, p. 231–232, pl. 39, fig. 13.
Corbula (*Aloidis*) *sancti-dominici* Maury, 1925, p. 98–99, pl. 19, fig. 2.
Corbula (*Varicorbula*) *vieta* Guppy. Anderson, 1994, fig. 3.2.

Diagnosis.—Species characterized by highly inflated right valve with concave dorsoanterior slope, evenly rounded ventral margin, relatively narrow and anteriorly directed umbo, and near absence of rostrum and keel. Left valve characterized by quadrate shape and uninflated umbo.

Description.—Shells of moderate size. Valves strongly inequivalved in size, shape, and ornamentation. Right valve larger, greatly inflated, and subtriangular. Right valve also with very subtle to obsolete keel and rostrum, evenly spaced moderately coarse flat-topped concentric ribs, and evenly convex ventral margin. Valve shape varies with size. Small right valves inflated with concave dorsoanterior slope, umbo directed anteriorly, and obsolete keel. Inflation increases, dorsoanterior slope becomes less concave, and umbo becomes more dorsally oriented with increasing size. Subtle keel and slight rostrum also develop as size increases.

Left valves more elongate and quadrate, and much less inflated than right. Left valves with faint, concentric growth lines and widely spaced and slightly more distinct radial striations. Radial striations absent on posterior slope. Small left and right valves (2–3 mm

in length) very similar in shape, but radial ribs more prominent on left valves and concentric ribs more prominent on right valves. As size increases, left valves become more quadrate and keel become more strongly expressed.

Hinge of right valve with small, blunt, anterior cardinal tooth directly beneath beak and posterior, broad, socket-like resilifer that extends slightly beneath beak. Resilifer, appears reduced because hinge plate concave. Subsidiary denticle may occur above cardinal tooth, formed by projection of valve margin beneath beak. Furrows present on either side of right valve hinge for reception of left valve. Left valve hinge with an anterior small subtriangular socket, and posterior broad chondrophore. Dorsal surface of chondrophore with prominent anterior ridge, more subdued midline ridge, and posterior ridge with small denticle. Posterior portion of chondrophore projects strongly upward and may be visible externally. Muscle scars not thickened. Posterior scar circular; anterior scar ovate. Pallial sinus obsolete.

Type Material.—Holotype: PRI 903 (right valve). Figured by Maury (1917, Pl. 39, fig. 13; 1925, Pl. 19, fig. 2), and refigured here (Pl. 3, fig. 12).

Type locality.—Río Cana at Caimito, Dominican Republic (designated by Maury, 1925). The type locality is here restricted to TU 1230: Cercado Formation (Upper Miocene), Río Cana, Dominican Republic (fide Jung, 1986).

Material.—Measured and/or figured specimens: NMB G 14134, 14135, 14136, 14137. Other specimens (over 1,100) are cataloged by locality, which are listed in the Occurrence section.

Measurements.—See Table 8.

Remarks.—*Corbula sanctidominici* typically occurs scattered in silts and in bioclastic beds with a silty matrix. This species also occurs in bioclast-rich lenses and burrow-fills within silts.

The literature for Caribbean Neogene and Quaternary *Varicorbula* is complex. Of primary concern here are whether *Corbula* (*Varicorbula*) *sanctidominici* is a junior synonym of 1) *C. vieta* Guppy, 1866a, a species originally described from the Miocene Manzanilla Formation of Trinidad, or 2) *C. operculata* Philippi, 1848 (=*C. disparilis* Orbigny, 1846?), a Recent Atlantic species. Gabb (1873b) placed *Varicorbula* from the Dominican Republic in *C. disparilis* and also considered *C. vieta* to be a junior synonym of *C. disparilis.* Recent specimens of *Varicorbula* of the western Atlantic represent a taxonomic quandary, and they have been variously assigned to *Corbula disparilis* Orbigny, 1846?; *C. operculata* Philippi, 1848; and *C. philippii* Smith, 1885 (see Weisbord, 1964 and Woodring, 1982 for discussion). The synonymy of these names is not controversial, although authors differ on which is senior. Woodring (1982) states that Orbigny's illustration is poor and the dates of publication controversial; the imprinted date is 1846, although the probable publication date is 1853 (Keen, 1971). Those who doubt the 1846 publication date use *C. operculata* Philippi, 1848 for this species. However named, the Recent species appears distinct from *C. vieta* s. s. and *C. sanctidominici,* because it attains a larger maximum size, is more elongate in shape with gentler anterior and posterior dorsal slopes, has coarser ribs, and has a stronger rostrum and keel.

Pilsbry (1922), in his revision of Gabb's Dominican species, concurs with Dall (1898) that *C. vieta* and *C. disparilis* are not synonymous, and assigned Gabb's specimens to *C. vieta.* Maury (1917) first placed her Dominican *Varicorbula* in *C. vieta,* but later (Maury, 1925) considered her Dominican form to be distinct, and named it *C. sanctidominici.* Maury (1925) stated that her Dominican specimen was larger (10 mm long, 10 mm high compared to 6 mm × 6 mm for *C. vieta* from the type area), more inflated, and had more numerous (about 26 rather than about 25) and more closely spaced ribs. Maury (1925), however, did not place Gabb's (1873b) Dominican *Varicorbula* specimens in synonymy with *C. sanctidominici,* stating they are either *C. vieta* or *C. sanctidominici.*

The type material of *C. vieta* (USNM 115650; left valves of *C. vieta* were assigned to *Erycina tensa* Guppy, 1866a, USNM 115652) are not well preserved, and the margins of the larger right valve are not complete, making comparison difficult. *Corbula vieta* from the type locality shows the same size range as Dominican varicorbulids, but tends to be more elongate, have a wider umbo, less concave dorsoanterior slope, and stronger keel.

The material from this study agrees well with Gabb's (1873b) material (ANSP 2690) from the Dominican Republic. Maury's type (PRI 903) of *C. sanctidominici* is, however, somewhat unusual for Dominican *Varicorbula.* Her specimen is a right valve that is

Table 8.—Measurements of *Corbula* (*Varicorbula*) *sanctidominici.* Figures are in mm.

specimen	*valve*	*length*	*height*	*width*
PRI 903: holotype (Pl. 3, fig. 12)	right	9.5	9.6	5.1
NMB G 14135: (Pl. 3, figs. 13, 18); NMB locality 16837	right	7.8	7.9	4.6
NMB G 14134: (Pl. 3, figs. 16, 17); NMB locality 16837	left	4.6	4.0	1.7
NMB G 14136: (Pl. 3, fig. 14); TU locality 1250	right	5.5	5.4	2.6
NMB G 14137: (Pl. 3, fig. 15); TU locality 1250	right	4.4	4.1	2.0

unusually large and coarsely ribbed. Unfortunately, the ventral margin is not intact so it is difficult to determine original valve shape, a diagnostic feature. Nevertheless, the traits that Maury noted as diagnostic for *C. sanctidominici* seem to be correlated with size in Dominican *Varicorbula.* Therefore, I place both my material and Gabb's Dominican material in *C. sanctidominici.*

Comparison.—*Corbula* (*Varicorbula*) *sanctianderaea* Maury (1925) of the Miocene Manzanilla Formation of Trinidad has a left valve with a very convex beak that is subequal in size to the right valve's beak. In addition, the right valve of *C. sanctianderaea* is relatively more elongate and subequilateral with a wider umbo and stronger rostrum than *C. sanctidominici.*

Corbula heterogena Guppy (in Dall, 1898) of the Pliocene Bowden Formation of Jamaica is very similar in size and shape to *C. sanctidominici.* In *C. heterogena,* however, the umbos of the right valve are less elevated and prominent, and are not as strongly directed anteriorly because the dorsoanterior margin is less concave. Therefore, in *C. sanctidominici* the right valve umbo appears narrower and more set off from the ventral portion of the valve. In addition, the right valve of *C. heterogena* is more elongate and has a stronger rostrum and keel. The left valves of *C. heterogena* are more inflated and have more prominent beaks.

Woodring (1982) assigns specimens of the Miocene and Pliocene of Panama and Costa Rica to *Corbula* (*Varicorbula*) *disparilis.* He also considered *C. waltonensis* Gardner, 1928 from the Miocene of Florida a junior synonym of *C. disparilis,* thus allowing much morphologic variation in the species. Woodring's (1982) figured specimens are very similar to *C. heterogena.* These Central American forms differ from *C. sanctidominici* in having a stronger rostrum and keel, beaks directed dorsally rather than anteriorly, and a somewhat sinuous rather than straight ventral margin.

Occurrence.—This species was collected from the following areas (see Saunders *et al.*, 1986 for locality information):

Río Cana: Cercado Formation: TU 1230, and NMB 16835, 16838, 16837, 16842, 16857, 17005. Lower Gurabo Formation: NMB 16828, 16832, 16833, 16834. Upper Gurabo Formation: TU 1354, and NMB 16817, 16818, 16959, 16824.

Arroyo Ballaco: Cercado Formation: TU 1420.

Río Gurabo: Cercado Formation: NMB 15895, 15896, 15906, 15900. Lower Gurabo Formation: TU 1215, 1277, 1211, and NMB 15846, 15860, 15863, 15864, 16810, 15869, 15871, 15873, 15874, 15878, 15882, 15836, 15944, 15952, 15954. Upper Gurabo Formation: TU 1210, and NMB 15804, 15805.

Río Mao: Cercado Formation: NMB 16927, 16915, 16926, 16924 (all correspond to Arroyo Bajón); NMB 16929, 16914 (all Maury's Bluff 2); TU 1410, and NMB 16802 (between Maury's Bluff 1 and 2); TU 1293, NMB 16910 (Maury's Bluff 1); TU 1225 (downstream of Maury's Bluff 1).

Cañada Zalaya: Gurabo Formation: TU 1227, 1227a, 1453, 1453a.

Río Yaque del Norte: Baitoa Formation: TU 1363, and NMB 16938 (all López section). Unnamed Formation: NMB 17273 (Arroyo López). Gurabo Formation: TU 1449, 1448, 1405, 1403 (La Barranca); TU 1206 (Santiago).

Río Verde: Gurabo Formation: TU 1250.

Distribution.—Upper Lower to lower Middle Miocene Baitoa, Upper Miocene Cercado, Upper Miocene to Lower Pliocene Gurabo Formations, Dominican Republic.

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APPENDIX 1

Criteria used to distinguish four environmental categories, based on the paleoenvironmental interpretations of Saunders *et al.* (1986) and Bold (1988) primarily using macrofossil and microfossil assemblages.

Brackish: Characterized by mollusks such as *Larkinia, Mytilus,* and *Melongena, Anadara patricia,* and brackish-water ostracodes.

Shallow: Depths approximately 0–30 m. Characterized by shallow-marine benthic foraminifera (*Amphistegina,* soritids, miliolids), shallow-marine mollusks (*Pachycrommium, Stigmaulux, Anadara, Tellina, Strombina*) and shallow-marine ostracodes (*Cytherella, Radimella, Caudites, Proteoconcha, Loxoconcha, Paracytheridea*). Planktonic foraminifera and calcareous nannofossils are absent.

Intermediate: Depths approximately 30–100 m. Characterized by abundant and diverse assemblage of shallow-water ostracodes, benthic foraminifera, corals, mollusks (including *Strombus, Oliva, Polystira,* and *Lyria*), and a few planktonic foraminiferal species.

Deep: Depths > 100 m. Characterized by rich assemblage of planktonic foraminifera, high ratios of planktonic to benthic foraminifera, deep water ostracodes (e.g., *Krithe*), and pteropods.

APPENDIX 2

Samples used for analyses illustrated in Text-figures 4–6. Samples selected to provide broad stratigraphic coverage. Abbreviations are as follows:

Section = Stratigraphic section; Cana = Río Cana; Gurabo = Río Gurabo; Mao = Río Mao; Yaque = Río Yaque del Norte; Zalaya = Cañada Zalaya.

Formation = Geologic Formation. If blank, Saunders *et al.* (1986) did not assign.

Age = Geologic age.

Environment = Environmental category (for *Corbula sericea*). See Appendix 1 for criteria used to distinguish categories.

Sed. Type = Sediment type (for *Corbula viminea*). Categories are: 1 = silts with bioclasts in lenticular beds or lenses; 2 = silts with bioclasts filling burrows; 3 = silts with mollusks dispersed in matrix; 4 = silty sands with bioclasts dispersed or concentrated.

Valves = Number of valves used in each sample. If a sample contained less than 30 valves (left or right) all were measured. For *C. sericea,* if a sample contained more than 30 right valves, 30 were randomly selected. For *C. viminea,* if a sample contained more than 30 left or right valves, 30 of each were randomly selected. All selected valves were measured but due to missing data on less than pristine valves, not all may have been incorporated into the principal components analyses (PCA).

Corbula (Caryocorbula) sericea

section	*sample*	*formation*	*age*	*environment*	*valves*
Cana	NMB 16865	Gurabo	Pliocene	Intermediate	3
Cana	NMB 17009	Gurabo	Pliocene	Intermediate	4
Cana	NMB 16848	Cercado	Miocene	Brackish	25
Cana	TU 1230	Cercado	Miocene	Shallow	15
Cana	UW 1863/27	Cercado	Miocene	Shallow	22
Cana	NMB 16855	Cercado	Miocene	Shallow	27
Gurabo	NMB 15833	Mao	Pliocene	Deep	7
Gurabo	TU 1352	Mao	Pliocene	Deep	10
Gurabo	NMB 15805	Gurabo	Pliocene	Deep	24
Gurabo	NMB 15842	Gurabo	Miocene	Intermediate	10
Gurabo	NMB 15846	Gurabo	Miocene	Intermediate	10
Gurabo	NMB 15863	Gurabo	Miocene	Intermediate	12
Gurabo	NMB 16810	Gurabo	Miocene	Intermediate	17
Gurabo	NMB 15869	Gurabo	Miocene	Intermediate	21
Gurabo	NMB 15911	Cercado	Miocene	Shallow	1
Gurabo	NMB 15912	Cercado	Miocene	Shallow	1
Mao	NMB 16910		Miocene	Intermediate	5
Mao	NMB 16802		Miocene	Intermediate	7
Mao	NMB 16929		Miocene	Shallow	24
Mao	NMB 16928		Miocene	Shallow	25
Mao	UW 1863/25		Miocene	Shallow	25
Mao	UW 1863/26		Miocene	Shallow	23
Mao	NMB 16913		Miocene	Shallow	23
Yaque	TU 1206		Pliocene	Deep	16
Zalaya	TU 1227A		Pliocene	Deep	27
Yaque	TU 1403		Pliocene	Deep	16
Yaque	NMB 17278		Miocene	Shallow	2
Yaque	NMB 17273		Miocene	Brackish	3

Corbula (Bothrocorbula) viminea

section	*sample*	*formation*	*age*	*sed. type*	*valves*
Cana	NMB 16833	Gurabo	Miocene	3	28
Cana	NMB 16832	Gurabo	Miocene	3	5
Cana	NMB 16837	Cercado	Miocene	3	9
Cana	NMB 16838	Cercado	Miocene	3	3
Cana	TU 1230	Cercado	Miocene	3	53
Cana	NMB 16857	Cercado	Miocene	1	10
Cana	NMB 17005	Cercado	Miocene	1	4
Gurabo	NMB 15878	Gurabo	Miocene	1	4
Gurabo	TU 1297	Gurabo	Miocene	2	7
Gurabo	NMB 15882	Gurabo	Miocene	2	4
Gurabo	NMB 15906	Cercado	Miocene	1	47
Gurabo	NMB 15900	Cercado	Miocene	1	37
Mao	NMB 16915		Miocene	1	4
Mao	NMB 16917		Miocene	1	14
Mao	NMB 16923		Miocene	1	21
Mao	NMB 16927		Miocene	1	1
Yaque	TU 1445		Miocene	—	2
Yaque	NMB 16938	Baitoa	Miocene	3	5
Yaque	NMB 16936	Baitoa	Miocene	3	1
Yaque	NMB 16935	Baitoa	Miocene	4	1
Yaque	NMB 17289	Baitoa	Miocene	4	2
Yaque	TU 1364	Baitoa	Miocene	4	9
Yaque	TU 1363	Baitoa	Miocene	4	2
Yaque	NMB 17288	Baitoa	Miocene	3	2
Yaque	NMB 17286	Baitoa	Miocene	4	1

PLATES

EXPLANATION OF PLATE 1

Figure — Page

1–8, 10, 11, 13, 14. **Corbula (Bothrocorbula) viminea** Guppy, 1866b 12

1, 4. Hypotype. NMB G 14110; from locality TU 1364: Río Yaque del Norte, upper Lower to lower Middle Miocene Baitoa Formation. Right valve: 1. interior, × 4⅓; 4. exterior, × 4. Length, 14.0 mm; height, 9.7 mm; width, 4.8 mm.

2, 5. Hypotype. NMB G 14109; from locality TU 1364: Río Yaque del Norte, upper Lower to lower Middle Miocene Baitoa Formation. Left valve: 2. interior, × 4⅓; 5. exterior, × 4⅔. Length, 13.3 mm; height, 9.3 mm; width, 3.8 mm.

3. Syntype. BMNH 64088. Bowden Formation, Jamaica. Right valve exterior. Length, 19.1 mm; height, 13.9 mm; width, 6.3 mm; × 3.

6. Syntype. BMNH 64099. Bowden Formation, Jamaica. Left valve exterior. Length, 15.1 mm; height, 10.3 mm; width, 5.0 mm; × 3.

7. Hypotype. NMB G 14108; from locality TU 1230: Río Cana, Upper Miocene Cercado Formation. Right valve exterior. Length, 14.2 mm; height, 9.9 mm; width, 5.2 mm; × 4.

8. Hypotype. NMB G 14107; from locality TU 1230: Río Cana, Upper Miocene Cercado Formation. Left valve exterior. Length, 14.1 mm; height, 9.7 mm; width, 5.0 mm; × 4⅓.

10. Hypotype. NMB G 14106; from locality NMB 15900: Río Gurabo, Upper Miocene Cercado Formation. Right valve exterior. Length, 16.3 mm; height, 11.5 mm; width, 6.0 mm; × 3.

11. Hypotype. NMB G 14105; from locality NMB 15900: Río Gurabo, Upper Miocene Cercado Formation. Left valve exterior. Length, 15.3 mm; height, 11.3 mm; width, 5.4 mm; × 3.

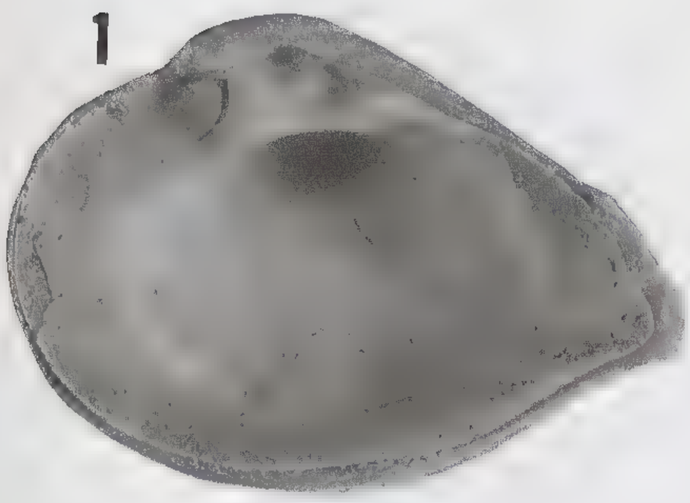
13. Hypotype. NMB G 14104; from locality NMB 16923: Río Mao, Upper Miocene Cercado Formation (Maury's Bluff 3). Right valve exterior. Length, 17.4 mm; height, 12.3 mm; width, 6.0 mm; × 4.

14. Hypotype. NMB G 14103; from locality NMB 16923: Río Mao, Upper Miocene Cercado Formation (Maury's Bluff 3). Left valve exterior. Length, 15.9 mm; height, 11.8 mm; width, 4.9 mm; × 4.

9, 12. **Corbula (Caryocorbula) dominicensis** Gabb, 1873b 14

9, 12. Hypotype. NMB G 14111; from locality NMB 17821: Río Yaque del Norte, upper Lower to lower Middle Miocene Baitoa Formation. Articulated shell: 9. right side; 12. left side. Length, 15.3 mm; height, 9.2 mm; width, 6.9 mm; × 4⅓.

1



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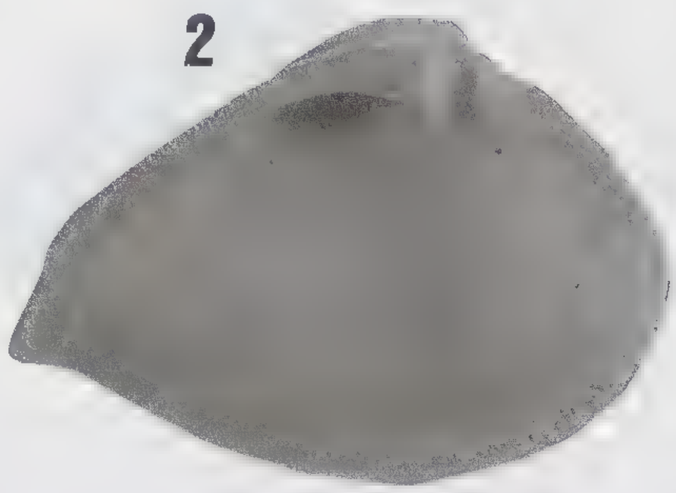

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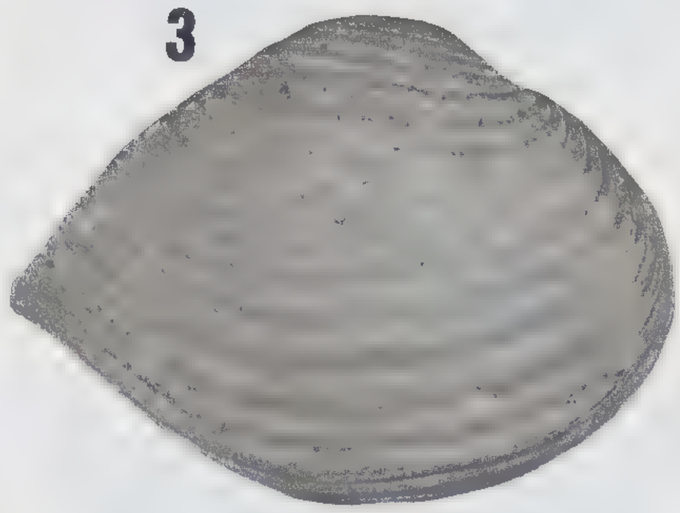

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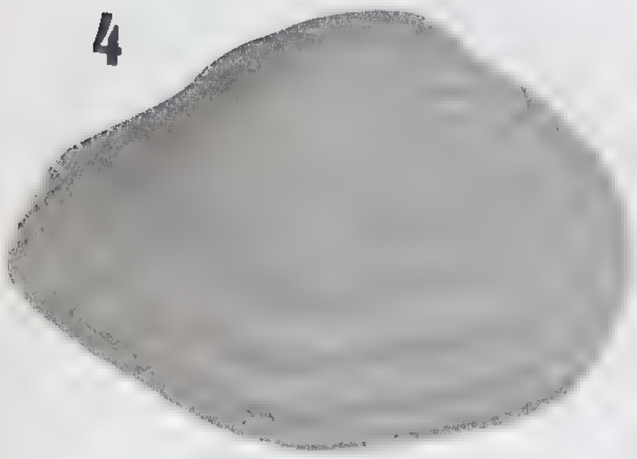

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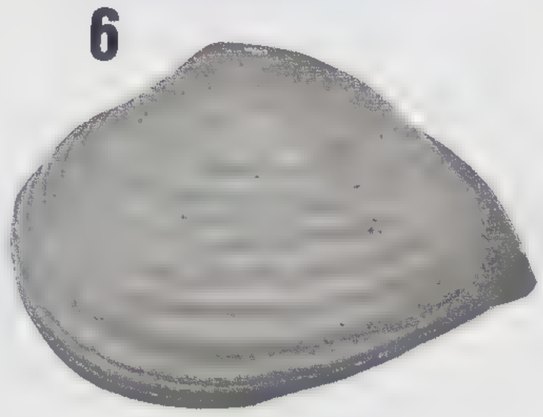

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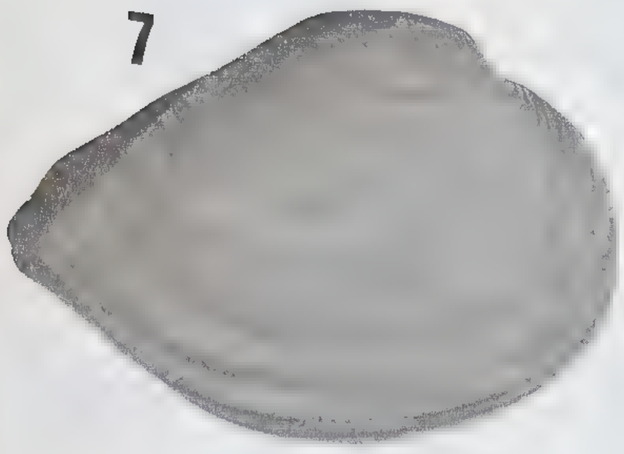

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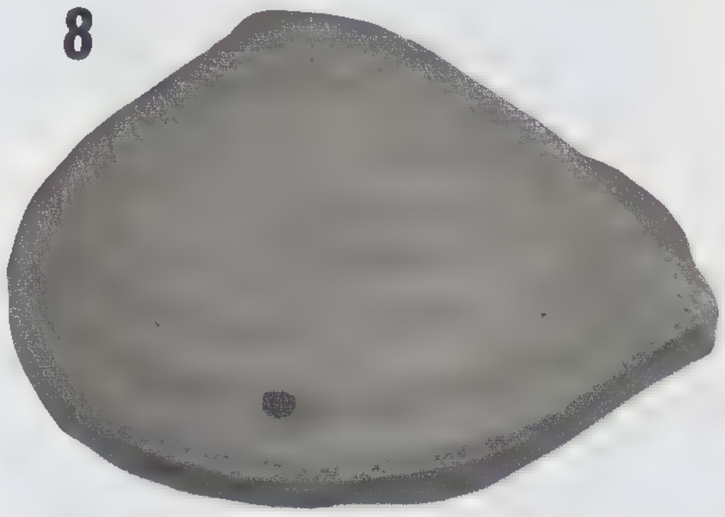

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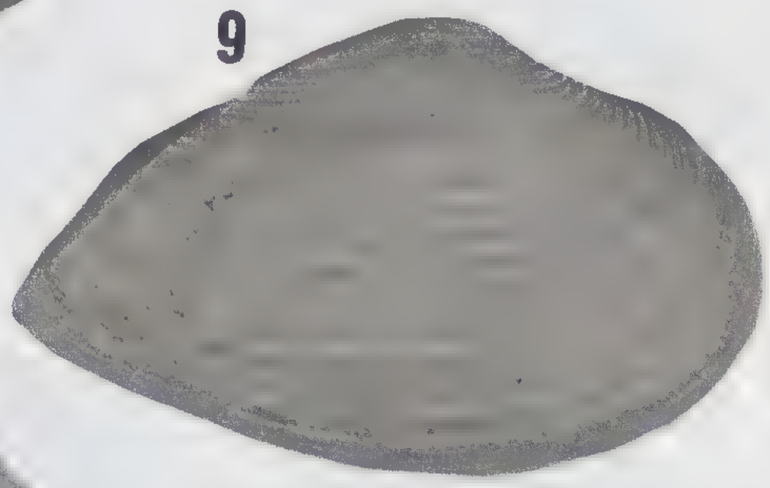

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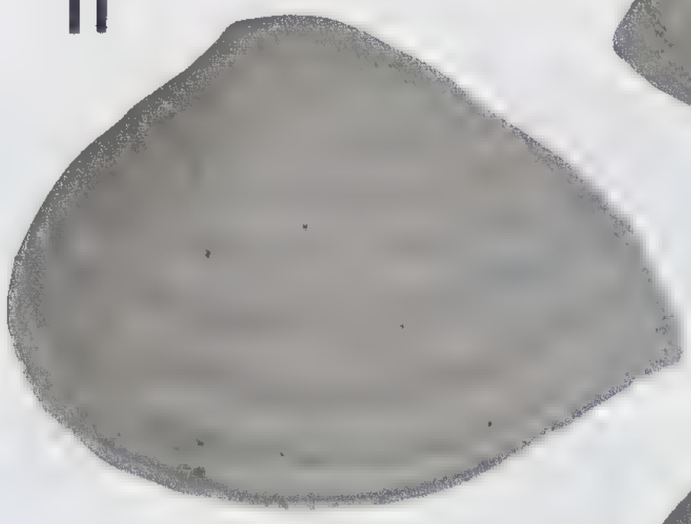

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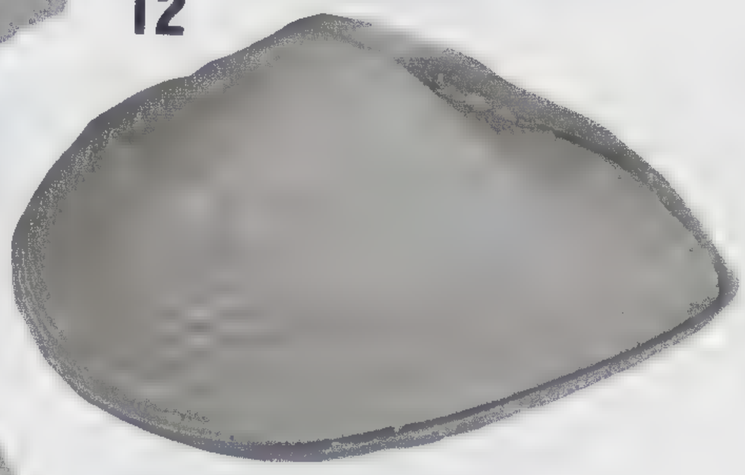

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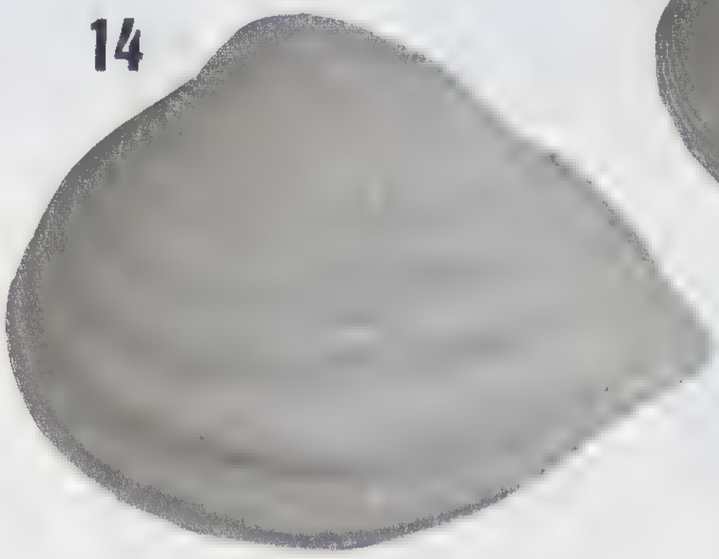

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EXPLANATION OF PLATE 2

Figure — Page

1, 2, 4, 5. **Corbula (Caryocorbula) dominicensis** Gabb, 1873b 14

1, 4. Hypotype. NMB G 14113; from locality TU 1226: Río Yaque del Norte, upper Lower to lower Middle Miocene Baitoa Formation. Right valve: 1. interior; 4. exterior. Length, 14.2 mm; height, 9.0 mm; width, 4.0 mm; × 4⅓.

2, 5. Hypotype. NMB G 14112; from locality TU 1226: Río Yaque del Norte, upper Lower to lower Middle Miocene Baitoa Formation. Left valve: 2. interior; 5. exterior. Length, 13.6 mm; height, 8.2 mm; width, 3.1 mm; × 4⅓.

3, 6. **?Corbula (Caryocorbula) dominicensis** Gabb, 1873b 14

3. Hypotype. PRI 29033. Río Cana, Upper Miocene Cercado Formation; figured in Maury (1917). Left valve exterior. Length, 13.4 mm; height, 8.6 mm; width, 3.3 mm; × 4⅓.

6. Hypotype. PRI 29033. Río Cana, Upper Miocene Cercado Formation; figured in Maury (1917). Right valve exterior. Length, 12.6 mm; height, 8.6 mm; width, 3.2 mm; × 4⅓.

7–21. **Corbula (Caryocorbula) sericea** Dall, 1898 15

7. Lectotype. USNM 135655. Moín Formation, Limón, Costa Rica. Right valve exterior. Length, 5.3 mm; height, 4.0 mm; width, 2.0 mm, × 4⅓.

8. Syntype of *Corbula* (*Cuneocorbula*) *cercadica* Maury, 1917 (mislabeled as *Corbula* (*Cuneocorbula*) *caimitica* Maury, 1917). PRI 29035. Río Mao, Upper Miocene Cercado Formation (Maury's Bluff 3). Right valve exterior. Length, 6.6 mm; height, 4.6 mm; width, 2.3 mm; × 4⅓.

9. Syntype of *Corbula* (*Cuneocorbula*) *cercadica* Maury, 1917 (mislabeled as *Corbula* (*Cuneocorbula*) *caimitica* Maury, 1917). PRI 29035. Río Mao, Upper Miocene Cercado Formation (Maury's Bluff 3). Left valve exterior. Length, 5.6 mm; height, 3.9 mm; width, 2.0 mm; × 5⅔.

10, 14. Hypotype. NMB G 14119; from locality NMB 16848: Río Cana, Upper Miocene Cercado Formation. Right valve: 10. interior, × 4⅓; 14. exterior, × 5⅔. Length, 7.0 mm; height, 5.0 mm; width, 3.0 mm.

11, 15. Hypotype. NMB G 14118; from locality NMB 16848: Río Cana, Upper Miocene Cercado Formation. Left valve: 11. interior, × 4⅓; 15. exterior, × 5⅔. Length, 7.5 mm; height, 4.7 mm; width, 2.4 mm.

12. Hypotype. NMB G 14121; from locality NMB 16855: Río Cana, Upper Miocene Cercado Formation. Right valve exterior. Length, 8.1 mm; height, 4.8 mm; width, 2.7 mm; × 5⅔.

13. Hypotype. NMB G 14120; from locality NMB 16855: Río Cana, Upper Miocene Cercado Formation. Left valve exterior. Length, 7.1 mm; height, 4.6 mm; width, 2.3 mm; × 5⅔.

16. Hypotype. NMB G 14115; from locality NMB 16928: Río Mao, Upper Miocene Cercado Formation (Arroyo Bajón). Right valve exterior. Length, 6.1 mm; height, 4.5 mm; width, 2.1 mm; × 5⅔.

17. Hypotype. NMB G 14114; from locality NMB 16928: Río Mao, Upper Miocene Cercado Formation (Arroyo Bajón). Left valve exterior. Length, 5.6 mm; height, 4.0 mm; width, 1.8 mm; × 6⅓.

18. Hypotype. NMB G 14117; from locality NMB 15869: Río Gurabo, Upper Miocene part of Gurabo Formation. Right valve exterior. Length, 4.9 mm; height, 3.2 mm; width, 1.6 mm; × 6⅓.

19. Hypotype. NMB G 14116; from locality NMB 15869: Río Gurabo, Upper Miocene part of Gurabo Formation. Left valve exterior. Length, 4.2 mm; height, 2.9 mm; width, 1.4 mm; × 6⅓.

20. Hypotype. NMB G 14123; from locality TU 1227A: Cañada Zalaya, Lower Pliocene part of Gurabo Formation. Right valve exterior. Length, 6.0 mm; height, 4.2 mm; width 2.3 mm; × 5⅔.

21. Hypotype. NMB G 14122; from locality TU 1227A: Cañada Zalaya, Lower Pliocene part of Gurabo Formation. Left valve exterior. Length, 5.6 mm; height, 3.9 mm; width 2.0 mm; × 5⅔.

22–26. **Corbula (Juliacorbula) fossilis** Pilsbry, 1922 17

22, 23. Holotype. ANSP 2689; Dominican Republic (locality unknown). Right valve: 1. exterior, 2. interior. Length, 8.7 mm; height, 6.1 mm; width, 2.7 mm; × 4.

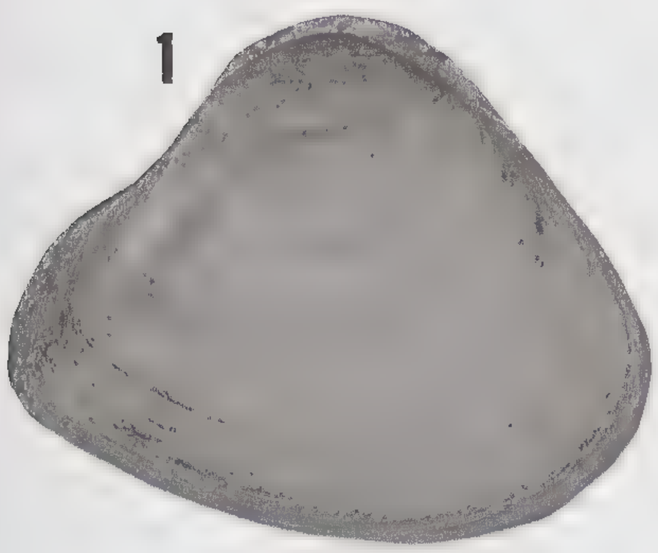
24. Paratype. ANSP uncataloged; Dominican Republic (locality unknown). Left valve exterior. Length, 8.4 mm; height, 5.8 mm; width, 2.8 mm; x 5⅓.

25. Hypotype. NMB G 14125; from locality NMB 16817: Río Cana, Lower Pliocene part of Gurabo Formation. Right valve exterior. Length, 5.6 mm; height, 3.7 mm; width, 1.4 mm; × 7⅓.

26. Hypotype. NMB G 14124; from locality NMB 15914: Río Gurabo, Upper Miocene Cercado Formation. Right valve exterior. Length, 5.7 mm; height, 4.1 mm; width, 1.6 mm; × 6⅔.

EXPLANATION OF PLATE 3

1



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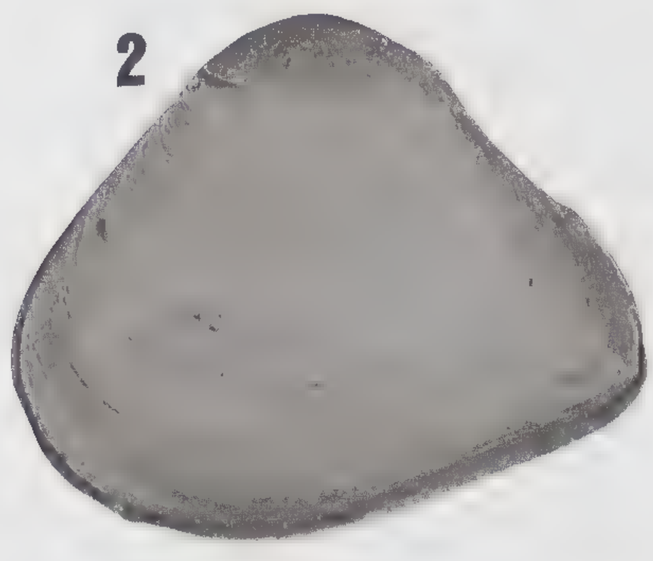

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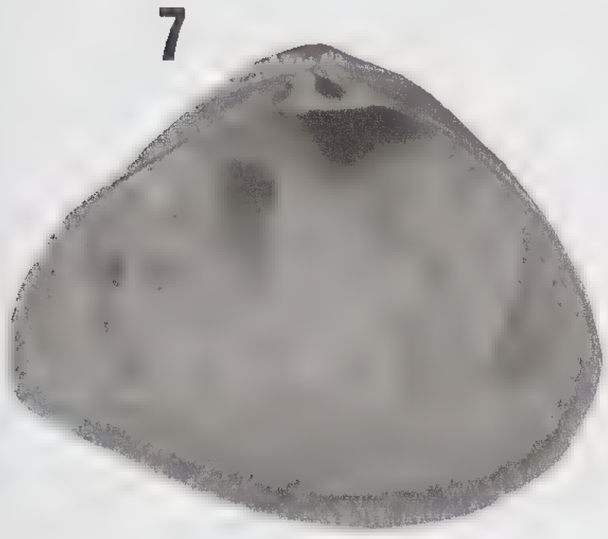

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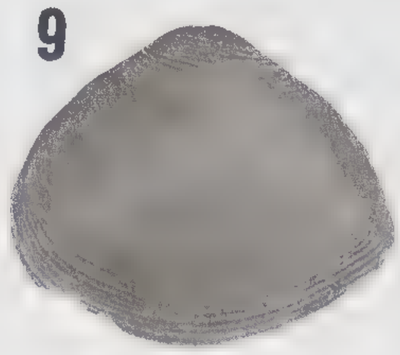

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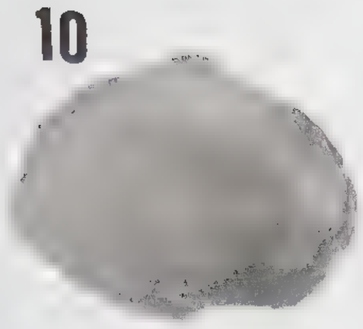

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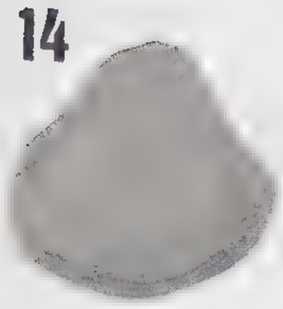

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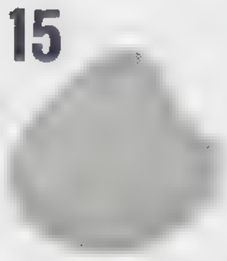

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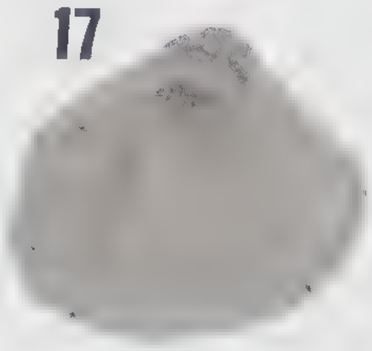

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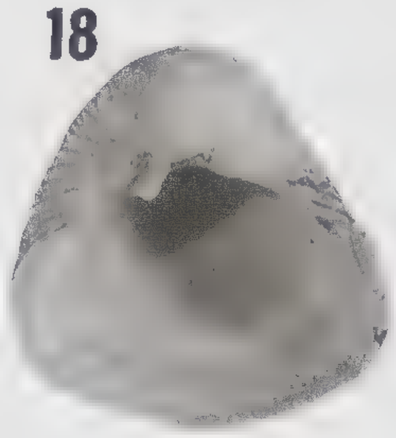

INDEX

Note: Page numbers are in light face; plate numbers are in **bold** face type; pages on which principal discussion occur are in *italics.*

NEOGENE PALEONTOLOGY IN THE NORTHERN DOMINICAN REPUBLIC. 17. THE FAMILIES CUSPIDARIIDAE AND VERTICORDIIDAE (MOLLUSCA: BIVALVIA)

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ABSTRACT

Seven species belonging to two genera of Cuspidariidae and two genera of Verticordiidae are described and figured. Five of them occur in the Neogene sections of the Dominican Republic and their stratigraphic occurrences are given. Two species of the verticordiid genus *Trigonulina* are known from the Recent fauna only: one from the Western Atlantic, the other from the Eastern Pacific. The latter is described as new (*T. pacifica* n. sp.). The two living species are discussed herein for comparative purposes. Out of the five fossil species, only two are well represented (*Cardiomya islahispaniolae* and *Trigonulina bowdenensis*). The remaining three species are known from very few specimens.

RESUMEN

Se describen siete especies pertenecientes a dos géneros de la familia Cuspidariidae y a dos géneros de la familia Verticordiidae. Cinco de ellas se encuentran representadas en las secciones del Neogeno de la República Dominicana; se indican sus ámbitos estratigráficos. Dos especies de verticordidos del género *Trigonulina* solamente se conocen de la fauna actual. *T. pacifica* habita en el Pacífico Oriental y se describe aqui por primera vez; la otra habita en el Atlántico Occidental. Ambas se mencionan con propósitos comparativos. De las cinco especies fósiles, apenas dos estan bien representadas (*Cardiomya islahispaniolae* y *Trigonulina bowdenensis*). El material existente de las restantes tres especies es muy escaso.

INTRODUCTION

This paper is a further contribution to the series of taxonomic studies dealing with Neogene fossils from sections situated in the Cibao Valley of the northern Dominican Republic (Text-fig. 1). The project and the framework within which these studies are being carried out have been outlined by Saunders *et al.* (1982) and Saunders *et al.* (1986). Jung (1986, p. 5) listed the most important early collections of molluscs from this area. The material of Cuspidariidae and Verticordiidae available for this paper is not rich. I nevertheless thought it worthwhile studying these two families especially considering the facts that (1) illustrations of these groups in literature are generally rather poor, and (2) the method of scanning electron microscopy allows to produce good illustrations.

As is the case for all the contributions to this series, the material studied has been collected from measured sections. The geographic location of the investigated areas is shown in Text-figure 1. For detailed information as to geographic locations and stratigraphic position of all the collecting stations, as well as to the general biostratigraphic framework and the ages, the reader is referred to the paper by Saunders *et al.* (1986). Formational names have been used with care, because correlations of the sections are not certain.

ACKNOWLEDGMENTS

The material on which this paper is based was collected during field work carried out in the years 1978, 1979, and 1980 as part of the project referred to above. The field work was made possible by a grant from the Swiss National Science Foundation (Grant 2.646-0.76). The financial help and the assistance in the field provided by Institut Français du Pétrole are gratefully acknowledged.

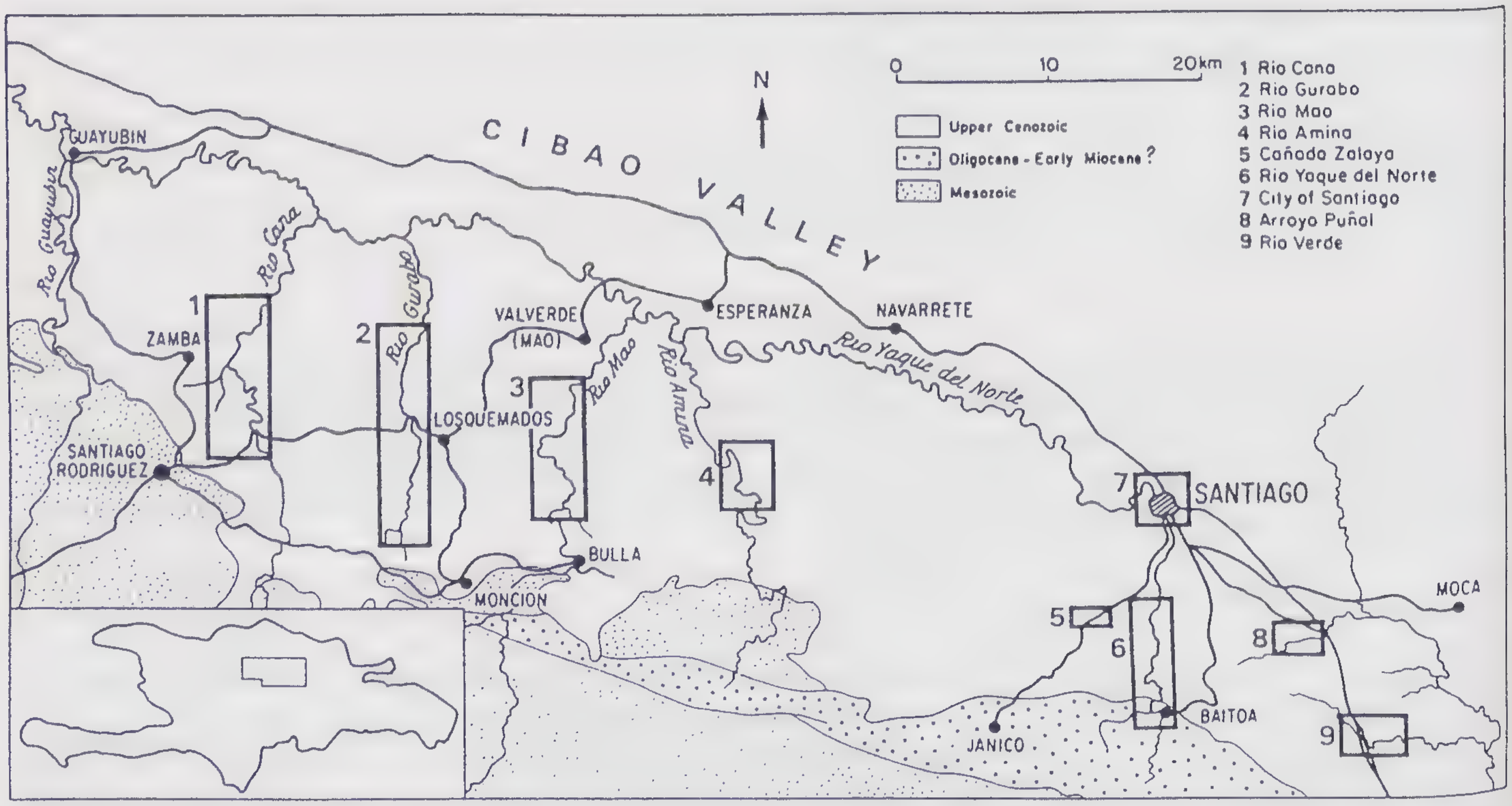
I am indebted to the following persons for the loan of specimens under their care: Gary Rosenberg, Academy of Natural Sciences, Philadelphia, PA, U.S.A.; Alan Kabat, Mark Florence, Jann Thompson, Warren Blow, all of the National Museum of Natural History, Washington, DC, U.S.A.; Kathie Way, The Natural History Museum, London, England; James McLean, Los Angeles County Museum, Los Angeles, CA, U.S.A.

Eugene Coan, Palo Alto, CA, U.S.A., offered useful comments and information on parts of the manuscript, which are gratefully acknowledged.

In addition, I am grateful to Richard Guggenheim, Marcel Düggelin, and Daniel Mathys, all of the Scanning Electron Microscope Laboratory, University of Basel as well as to Severino Dahint, photographer at the Naturhistorisches Museum Basel, Switzerland.

BIOSTRATIGRAPHY AND PALEOBIOGEOGRAPHY

A total of seven species belonging to two genera of Cuspidariidae and two genera of Verticordiidae is discussed in this paper. Two species of the verticordiid genus *Trigonulina* are known from the recent fauna



Text-figure 1.—Index map showing location of investigated areas in the Cibao Valley, Dominican Republic (after Jung, 1986, Text-fig. 1).

only, one from the Western Atlantic, the other from the Eastern Pacific. They have been included here for comparative purposes.

The stratigraphic occurrences of the remaining five species are plotted in Text-figures 2–7. The species are not continuously present through a given sequence of sediments, but their occurrences are spotty (Jung and Petit, 1990, p. 88; Jung, 1994, p. 6). The five species occur in the following sections:

Río Gurabo section (Text-figs. 2, 3):

Cardiomya islahispaniolae (Maury, 1917)
Cardiomya distira (Dall, 1903)
Haliris jamaicensis (Dall, 1903)
Trigonulina bowdenensis (Dall, 1903)

Río Cana section (Text-fig. 4):

Cardiomya islahispaniolae (Maury, 1917)
Plectodon granulatus (Dall, 1881)
Trigonulina bowdenensis (Dall, 1903)

Río Mao section (Text-figs. 5–7):

Cardiomya islahispaniolae (Maury, 1917)

Arroyo Zalaya:

Cardiomya distira (Dall, 1903)
Haliris jamaicensis (Dall, 1903)

Arroyo Babosico near La Barranca, Río Yaque del Norte:

Cardiomya distira (Dall, 1903)

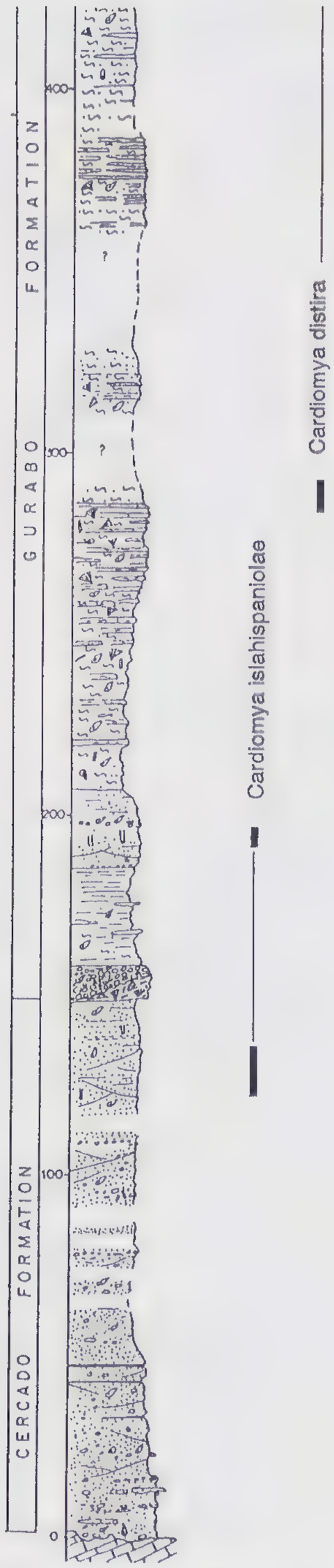
Río Verde:

Trigonulina bowdenensis

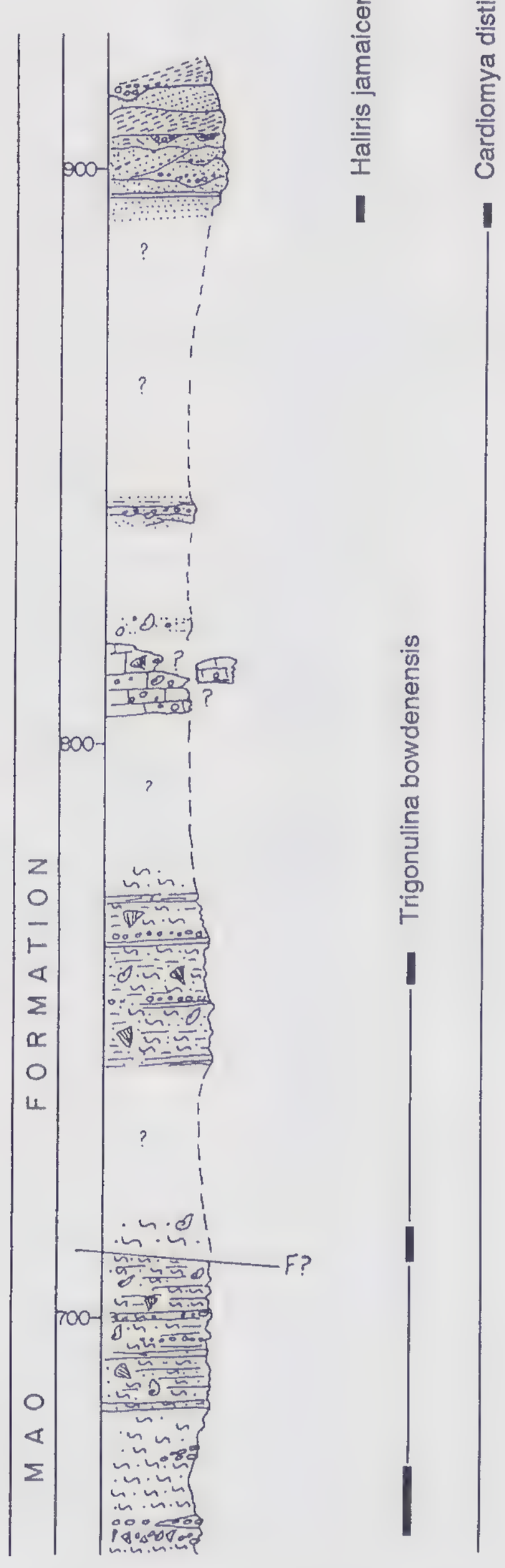
As can be seen from the above lists *Cardiomya islahispaniolae* occurs in the sections of Río Gurabo, Río Cana, and Río Mao. *Trigonulina bowdenensis* has been found in the sections of Río Gurabo, Río Cana, and Río Verde. *Cardiomya distira* is recorded from the sections of Río Gurabo, Arroyo Zalaya, and Arroyo Babosico; *Haliris jamaicensis* from the sections of Río Gurabo and Arroyo Zalaya, whereas *Plectodon granulatus* is restricted to the Río Cana section.

The representation of these five species in the various sections is rather uneven. Four species occur in the Río Gurabo section, three in the Río Cana section, two in Arroyo Zalaya, and a single species in the sections of Río Mao, Arroyo Babosico, and Río Verde.

The numerical representation of the five species in the Dominican deposits is uneven as well. *Trigonulina bowdenensis* is represented by 80, *Cardiomya islahispaniolae* by 52 Dominican specimens. On the other hand *Cardiomya distira* is represented by only eight, *Haliris jamaicensis* by three, and *Plectodon granulatus* by a single specimen. The three latter species therefore are very rare.



Text-figure 2.—Columnar section of Río Gurabo showing occurrences of species dealt with herein (after Saunders *et al.*, 1986, Text-fig. 6). Numbers in second column from left refer to thickness in m.

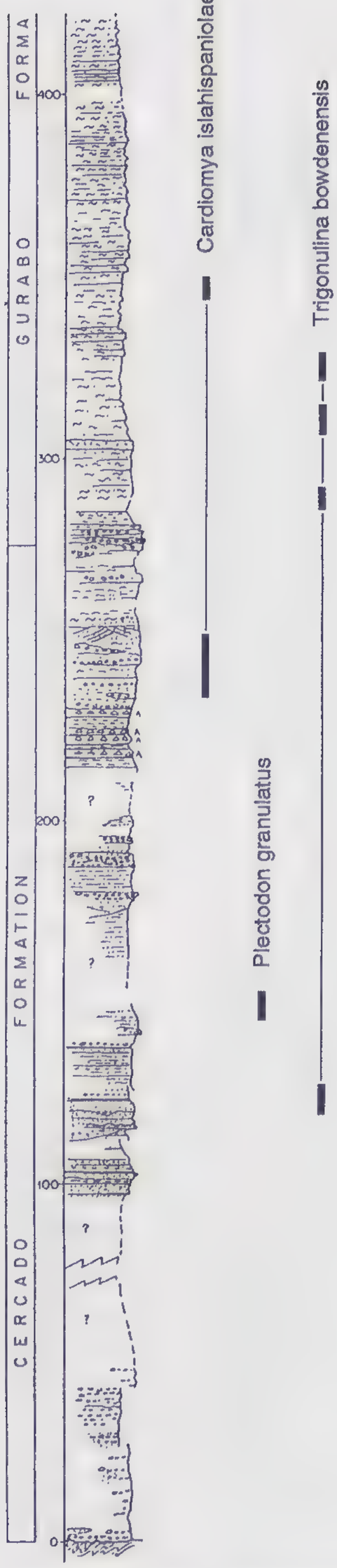


Text-figure 3.—Río Gurabo: upper part of columnar section showing occurrences of species dealt with herein (after Saunders *et al.*, 1986, Text-fig. 6). Numbers in second column from left refer to thickness in m.

Of the five species mentioned above, only *Cardiomya islahispaniolae* is endemic to the Neogene of the Dominican Republic, Three species, namely *Cardiomya distira, Haliris jamaicensis,* and *Trigonulina bowdenensis,* also occur in the early Pliocene Bowden Formation of Jamaica, and *Plectodon granulatus* is known from the middle Miocene Shoal River Formation of Florida, the Pliocene of Florida, and from the Recent fauna of the Western Atlantic.

ABBREVIATIONS OF REPOSITORY INSTITUTIONS

ANSP: Academy of Natural Sciences, Philadelphia, PA, U.S.A.

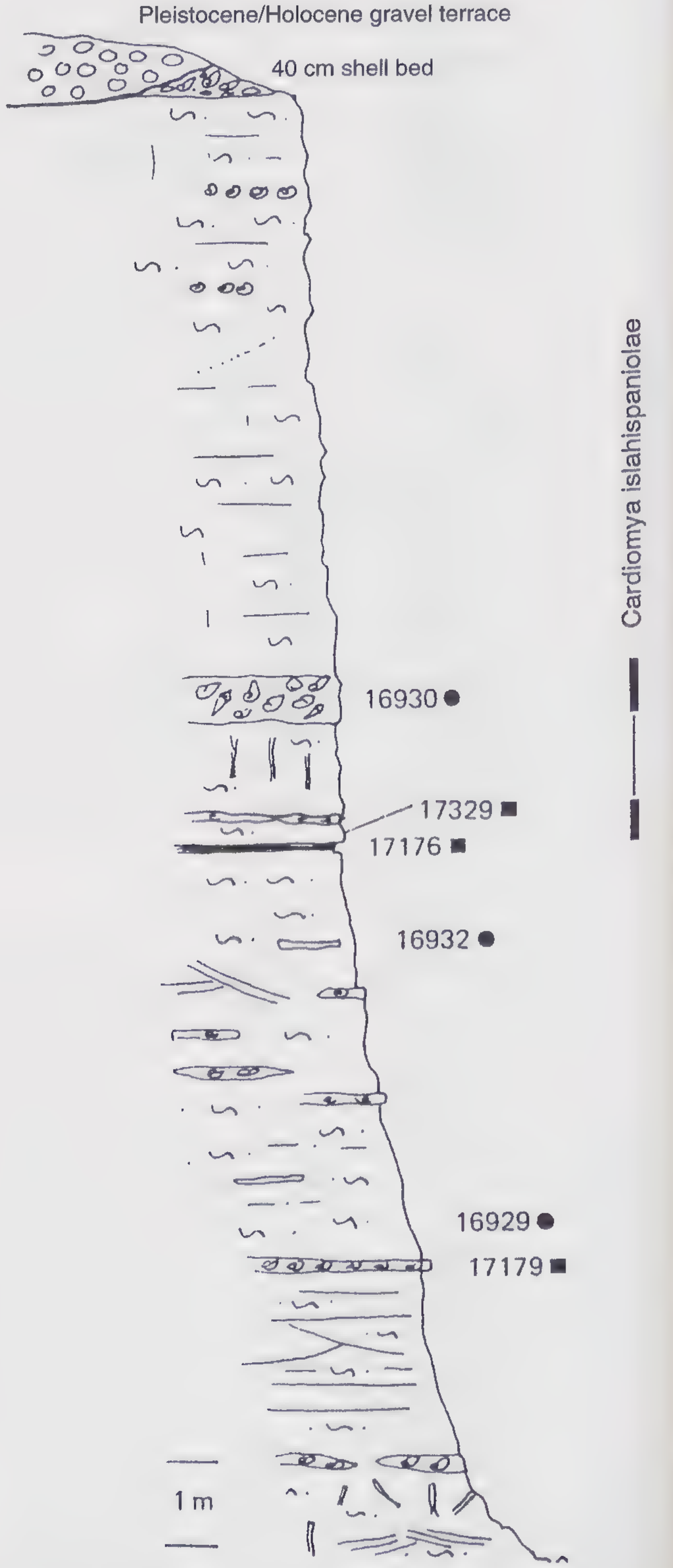


Text-figure 4.—Columnar section of Río Cana showing occurrences of species dealt with herein (after Saunders *et al.,* 1986, Text-fig. 16). Numbers in second column from left refer to thickness in m.

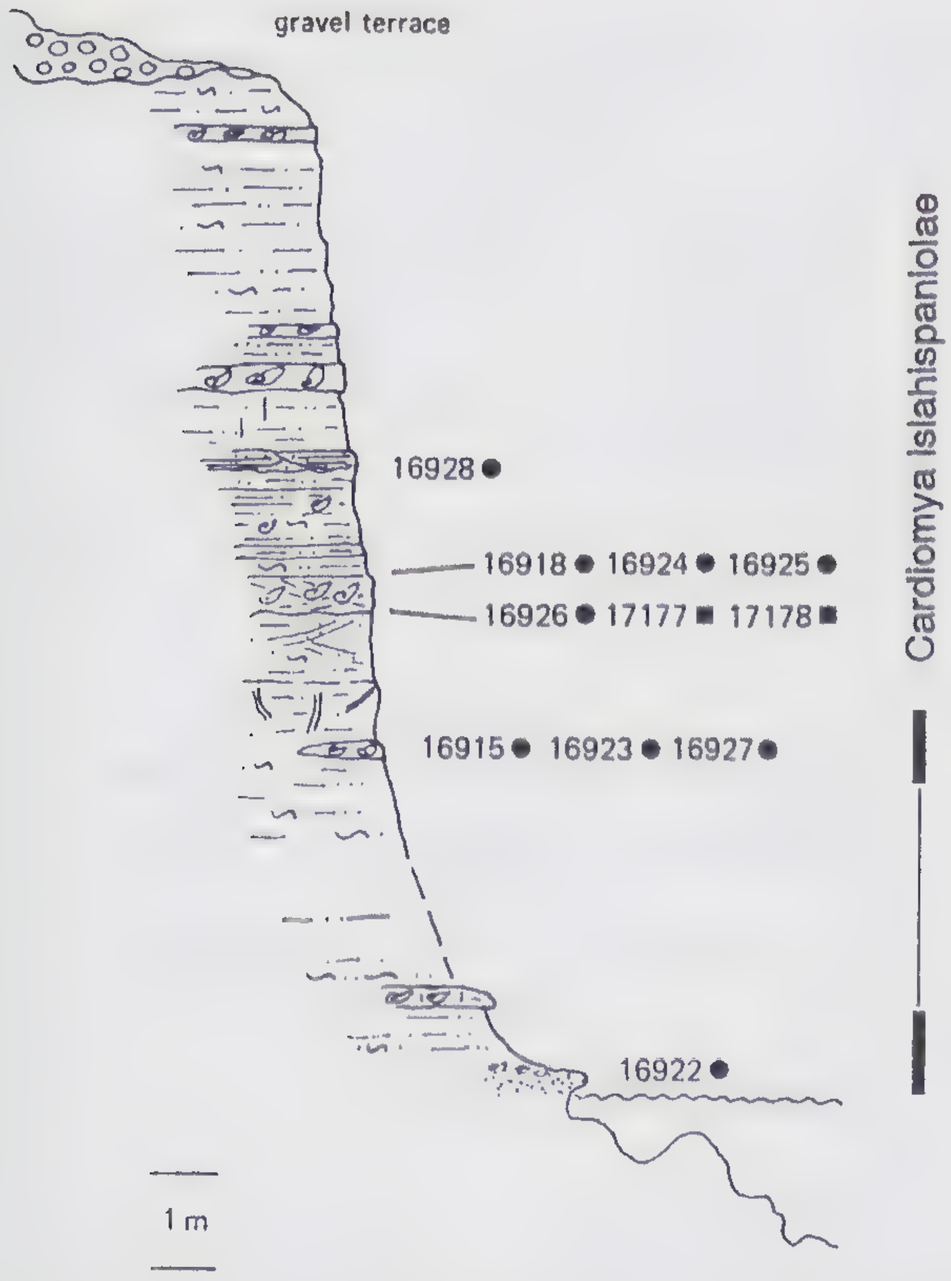
BMNH: British Museum (Natural History), London, England, now The Natural History Museum, London.

LACM: Los Angeles County Museum of Natural History, Los Angeles, CA, U.S.A.

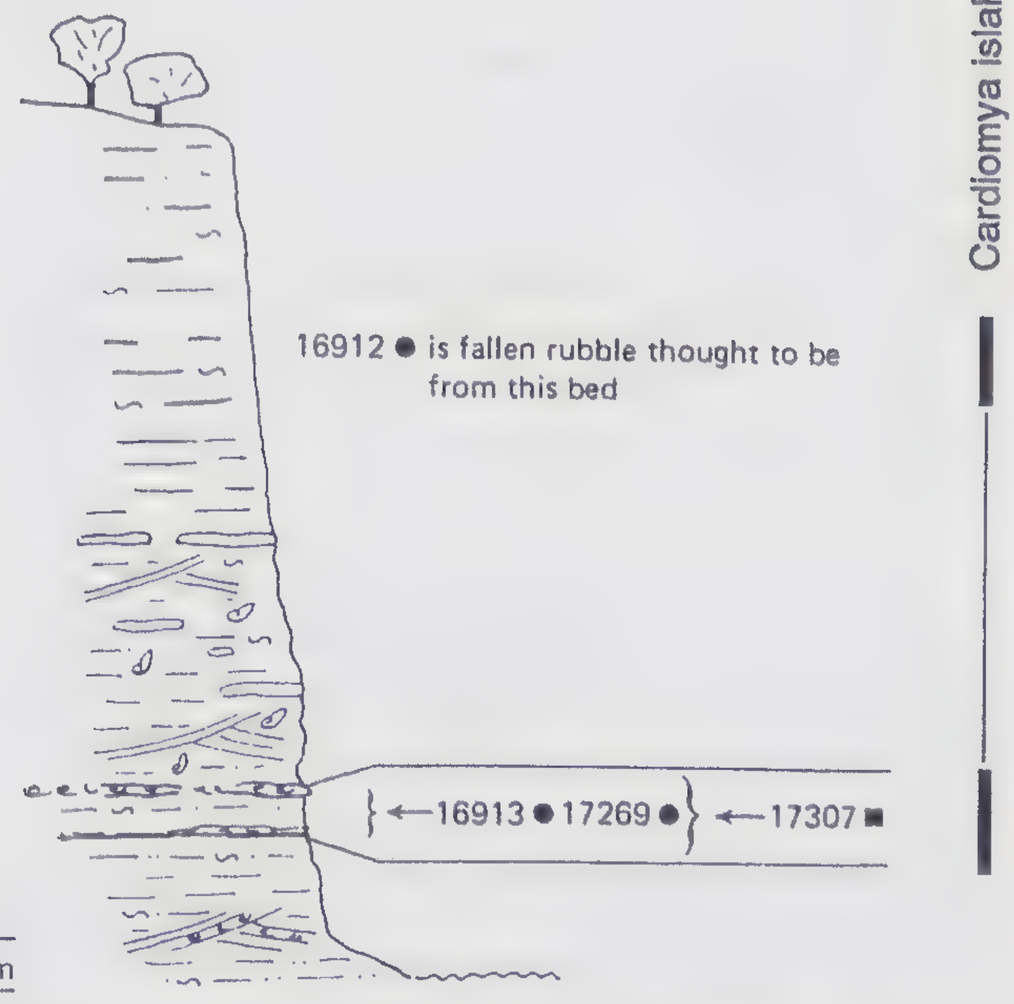
NMB: Naturhistorisches Museum Basel, Switzer-



Text-figure 5.—Section exposed in Maury's Bluff 2 on Río Mao showing occurrence of *Cardiomya* (*Cardiomya*) *islahispaniolae* (Maury, 1917) and stratigraphic positions of NMB localities: black squares represent localities collected for microfossils and lithologic analyses; black circles represent localities collected for macrofossils (after Saunders *et al.,* 1986, Text-fig. 31).



Text-figure 6.—Section exposed at mouth of Arroyo Bajón on Río Mao showing occurrence of *Cardiomya* (*Cardiomya*) *islahispaniolae* (Maury, 1917) and stratigraphic positions of NMB localities: black squares represent localities collected for microfossils and lithologic analyses; black circles represent localities collected for macrofossils (after Saunders *et al.*, 1986, Text-fig. 32).



Text-figure 7.—Section exposed at the downstream (eastern) end of Maury's Bluff 3 on Río Mao showing occurrence of *Cardiomya* (*Cardiomya*) *islahispaniolae* (Maury, 1917) and stratigraphic positions of NMB localities: black square represents a locality collected for microfossils and lithologic analyses; black circles represent localities collected for macrofossils (after Saunders *et al.*, 1986, Text-fig. 33).

land (the letter G after NMB stands for bivalves).

PRI: Paleontological Research Institution, Ithaca, NY, U.S.A.

TU: Tulane University, New Orleans, LA, U.S.A.

USNM: United States National Museum of Natural History, Smithsonian Institution, Washington, DC, U.S.A.

SYSTEMATIC PALEONTOLOGY

INTRODUCTION

The basis for the preparation of this paper has been the combined collections of the Naturhistorisches Museum Basel and Tulane University. All of the figured specimens of Cuspidariidae and Verticordiidae derived from these collections are deposited in the Naturhistorisches Museum Basel. It was originally planned to examine and refigure the type specimens of all the species of Cuspidariidae and Verticordiidae occurring in the Dominican Republic Neogene as well as the type specimens of species which were most important for comparative purposes.

However, this plan has not been carried out for various reasons. As mentioned below under *Cardiomya islahispaniolae,* the holotype of that species is badly broken (Fast, 1978, p. 80) and therefore could not be refigured. In addition the type specimens of four species of Cuspidariidae and Verticordiidae described by Dall (1903) from the early Pliocene Bowden Formation of Jamaica have been available to me: *Cardiomya craspedonia,* which does not occur in the Dominican Republic, and *Cardiomya distira, Haliris jamaicensis,* and *Trigonulina bowdenensis,* which occur in the Dominican Republic as well. The type lots of all these four species consist of three specimens each. All those specimens are glued to a piece of black paper. I tried to remove the specimens from the black paper using various chemicals in an attempt to dissolve the glue but without success. Lectotypes of all four species have been selected, but they are not refigured herein.

Although the amount of material available for this study is mentioned under each species, a summary of the number of lots and specimens of each species is given in Table 1.

As mentioned above, three of the species discussed herein are also known from the Bowden Formation of

Table 1.—Numbers of lots and specimens of each of the seven species of Cuspidariidae and Verticordiidae dealt with in this paper.

taxon	*number of lots*	*number of specimens*
Cardiomya (Cardiomya) islahispaniolae	20	50
Cardiomya (Bowdenia) distira	8	47
Plectodon granulatus	11	22
Haliris jamaicensis	4	10
Trigonulina ornata	6	1049
Trigonulina pacifica	23	1840
Trigonulina bowdenensis	32	112
Total	104	3130

Table 2.—Number of specimens available from the Neogene of the Dominican Republic and from the Bowden Formation of Jamaica.

species	*specimens from Dominican Republic*	*specimens from Bowden, Jamaica*
Cardiomya islahispaniolae	50	0
Cardiomya distira	8	39
Plectodon granulatus	1	0
Haliris jamaicensis	3	7
Trigonulina bowdenensis	80	32

Jamaica, but their numerical representation differs greatly from that in the Dominican Republic. Table 2 gives the number of specimens of the five fossil species available from the Dominican Republic and from Bowden, Jamaica.

A short discussion of species concepts has been given by Jung (1986, p. 9; 1989, p. 37), and definitions of the headings used in the following systematic part may be found in Jung (1989, p. 35) and in Jung and Petit (1990, p. 93). They are not repeated here.

SYSTEMATICS

Family **CUSPIDARIIDAE** Dall, 1886

Genus **CARDIOMYA** A. Adams, 1864

Cardiomya A. Adams, 1864, p. 208

Type species (by monotypy).—Neaera gouldiana Hinds, 1843. Recent, seas of Japan.

Diagnosis.—Shell of small to medium size, rostrate. Sculpture consisting of radial ribs. Radial sculpture often restricted to main shell disc or continuing over the rostrum as well. There may be secondary radial ribs. Left hinge with a subumbonal chondrophore but no teeth. Right hinge with a subumbonal chondrophore and one or two lateral teeth. Posterior lateral tooth usually prominent.

Remarks.—Cardiomya not only includes Neogene, Pleistocene (Grant and Gale, 1931), and Recent species but also a number of species from deposits of Eocene and Oligocene age (Durham, 1944; Gardner, 1945; Harris, 1919; Meyer and Aldrich, 1886; Turner, 1938; Vokes, 1939). According to the Treatise on Invertebrate Paleontology (p. N854) the oldest record dates back to the late Cretaceous. The stratigraphic range of *Cardiomya* is therefore late Cretaceous to Recent.

Subgenus **CARDIOMYA** sensu stricto

Cardiomya (Cardiomya) islahispaniolae (Maury, 1917)

Plate 1, figures 1–6; Plate 2, figures 1–4; Text-figure 8

Neaera alternata d'Orbigny. Gabb, 1873, p. 248.
Neaera ornatissima d'Orbigny. Gabb, 1873, p. 248; Guppy, 1876, p. 530.
Cuspidaria islahispaniolae Maury, 1917, p. 196, pl. 26, fig. 20.
Cuspidaria ornatior Pilsbry and Johnson, 1917, p. 195; Pilsbry, 1922, p. 414, pl. 38, figs. 11, 12.
Cuspidaria gabbi Pilsbry and Johnson, 1917, p. 195; Pilsbry, 1922, p. 415, pl. 38, fig. 10.

Description.—Shell of medium size (up to 9 mm in length), delicate, rostrate. Umbos prosogyrate, placed almost centrally. Sculpture consisting of numerous radial ribs. Posteriormost rib more prominent than the others, forming a small carina marking the boundary between main shell disc and rostrum. In addition to this small carina there may be one or more ribs just anterior to it which are more prominent than all the other ribs on the main shell disc and have wider interspaces. There may be a few secondary radial ribs. Except for the more prominent posterior ribs the radial ribs are usually well developed only on the ventral part of the main shell disc. Dorsal part of the main shell disc is smooth or sculptured by concentric growth lines. The rostrum is smooth or sculptured by growth lines. There may be an indication of a radial rib near its postero-dorsal margin, where the growth lines are coarser and more prominent. Left hinge with a subumbonal chondrophore but no teeth; margin bent in a dorsal direction anteriorly and posteriorly. Right hinge with a subumbonal chondrophore and a prominent posterior lateral tooth; antero-dorsal margin bent slightly upwards.

Holotype of C. islahispaniolae.—PRI 28904. This is a right valve which is badly broken according to Fast (1978, p. 80) and Warren Allmon (written communication, September 22, 1993).

Dimensions of holotype of C. islahispaniolae.—Length 9 mm; height 6 mm (Maury, 1917, p. 196).

Type locality of C. islahispaniolae.—Bluff 3 of Maury on Río Mao, Dominican Republic. Cercado Formation (late Miocene). This includes NMB localities 16912, 16913, 17269, and 17307 (Saunders *et al.* 1986, text-figs. 29, 33).

Holotype of C. ornatior.—ANSP 2790. This is the specimen (a left valve) figured by Pilsbry (1922, pl. 38, fig. 12).

Dimensions of holotype of C. ornatior.—Length 5.0 mm; height 2.9 mm.

Type locality of C. ornatior.—"Santo Domingo". No further details are available.

Paratype of C. ornatior.—ANSP 79015. This is the specimen (a left valve) figured by Pilsbry (1922, pl. 38, fig. 11).

Dimensions of paratype of C. ornatior.—Length 4.8 mm; height 2.7 mm.

Holotype of C. gabbi.—ANSP 2791. This is the specimen (a left valve) figured by Pilsbry (1922, pl. 38, fig. 10).

Dimensions of holotype of C. gabbi.—Length 8.0 mm; height 5.3 mm.

Type locality of C. gabbi.—"Santo Domingo". No further details are available.

Paratype of C. gabbi.—ANSP 79016.

Dimensions of paratype of C. gabbi.—Length 7.4 mm; height 5.2 mm.

Remarks.—The 40 available specimens (some of which are incomplete) show variability in rostrum shape and radial sculpture. The rostrum may be relatively long and narrow, or it may be shorter, thus giving the impression of greater width. In some specimens only the posteriormost radial rib is more prominent than the others. In other specimens there may be up to four more prominent radial ribs with wider interspaces. This variability of the radial sculpture obviously has been the reason for the introduction of the names *ornatior* and *gabbi* by Pilsbry and Johnson (1917, p. 195).

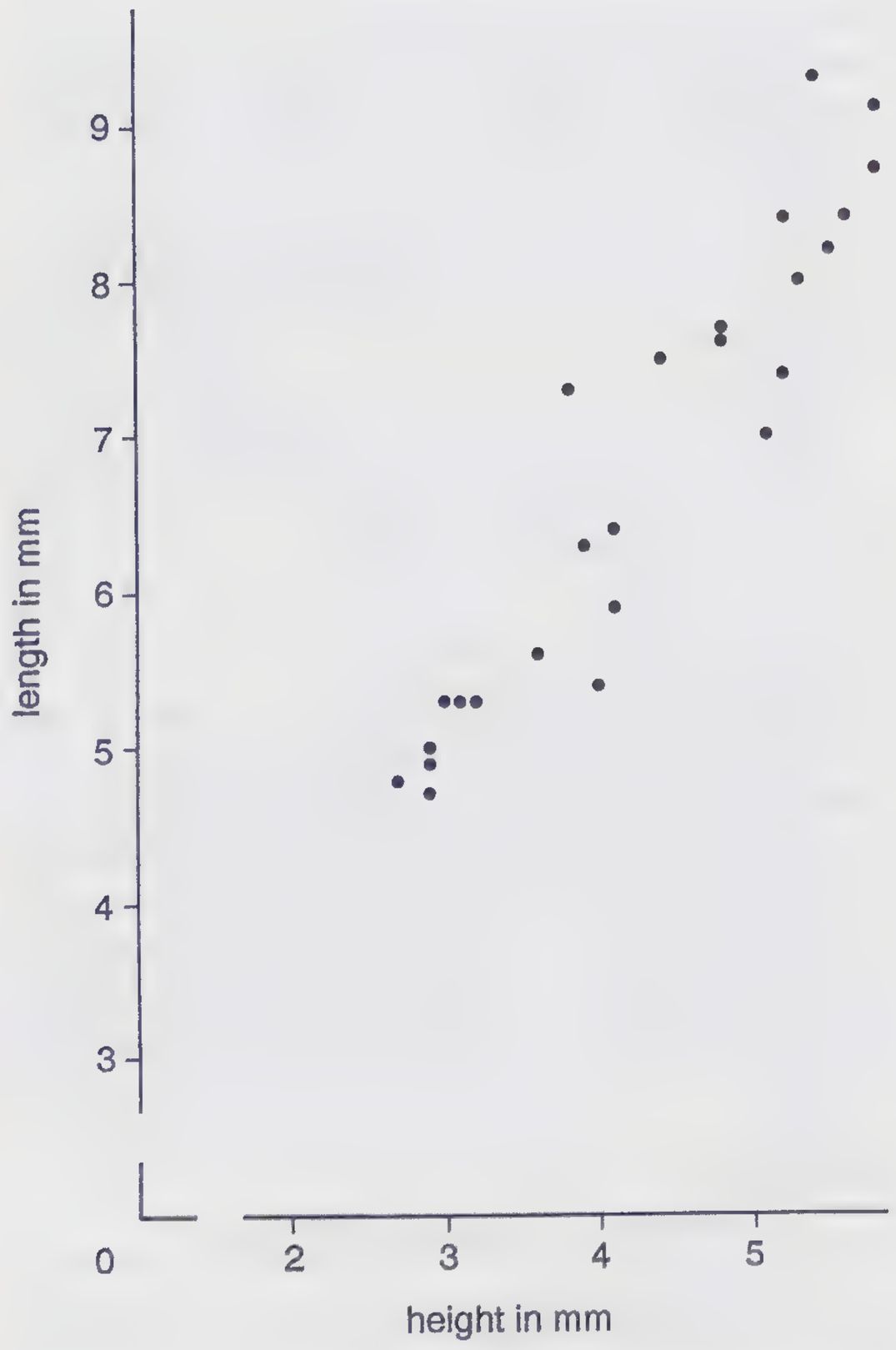
As mentioned in the introduction to the systematic paleontology, the type specimens of four species of Cuspidariidae and Verticordiidae described by Dall (1903) from the early Pliocene Bowden Formation of Jamaica are available. Three of them occur in the Dominican Republic as well: *Cardiomya* (*Bowdenia*) *distira, Haliris jamaicensis,* and *Trigonulina bowdenensis.* For each of these species a lectotype has been selected (see under those species). The same is done for the fourth species, *Cardiomya* (*Cardiomya*) *craspedonia,* which does not occur in the Dominican Republic but is compared with *C. islahispaniolae.* As is the case for the other three species the type lot of *C. craspedonia* consists of three specimens, which had been glued to a piece of black paper and cannot be removed from it without risk of damage. The type specimens of *C. craspedonia* (all left valves) are:

1. Lectotype: USNM 135691. Length 4.5 mm; height 2.7 mm. This is the specimen figured by Dall (1903, pl. 57, fig. 17) and Woodring (1925, pl. 10, fig. 20).
2. Paralectotype: USNM 482409. Length 3.6 mm; height 2.3 mm. This is the specimen figured by Woodring (1925, pl. 10, fig. 22).
3. Paralectotype: USNM 482410. Length 4.3 mm; height 2.8 mm. This is the specimen figured by Woodring (1925, pl. 10, fig. 21).

Comparisons.—*C. islahispaniolae* is similar but nevertheless clearly distinct from *C. craspedonia* Dall (1903, p. 1506, pl. 57, fig. 17) from the early Pliocene Bowden Formation of Bowden, Jamaica. It is not only considerably larger (practically twice as large) than *C. craspedonia,* but *C. craspedonia* has more numerous secondary radial ribs on the main shell disc. In addition the rostrum of *C. craspedonia* is proportionately shorter.

Material.—20 lots with a total of 50 specimens as listed below:

1. 1 spec., ANSP 2790: holotype of *C. ornatior*; "Santo Domingo".
2. 1 spec., ANSP 79015: paratype of *C. ornatior*; "Santo Domingo".
3. 1 spec., ANSP 2791: holotype of *C. gabbi*; "Santo Domingo".
4. 1 spec., ANSP 79016: paratype of *C. gabbi*; "Santo Domingo".
5. 1 spec., NMB locality 16912: Río Mao, Bluff 3 of Maury; Cercado Formation (late Miocene).
6. 4 spec., NMB locality 16913: Río Mao, Bluff 3 of Maury; Cercado Formation (late Miocene).
7. 2 spec., NMB locality 16915: Río Mao, Arroyo Bajón; Cercado Formation (late Miocene).
8. 1 spec., NMB locality 16917: Río Mao, Arroyo Bajón; Cercado Formation (late Miocene).
9. 1 spec., NMB locality 16922: Río Mao, Arroyo Bajón; Cercado Formation (late Miocene).
10. 1 spec., NMB locality 16923: Río Mao, Arroyo Bajón; Cercado Formation (late Miocene).
11. 2 spec., NMB locality 16929: Río Mao; Cercado Formation (late Miocene).
12. 1 spec., NMB locality 16930: Río Mao, Bluff 2 of Maury; Cercado Formation (late Miocene).
13. 1 spec., NMB locality 15878: Río Gurabo; lower part of Gurabo Formation (late Miocene).



Text-figure 8.—Length/height diagram of *Cardiomya* (*Cardiomya*) *islahispaniolae* (Maury, 1917).

14. 5 spec., NMB locality 15903: Río Gurabo; upper part of Cercado Formation (late Miocene).
15. 1 spec., NMB locality 15906: Río Gurabo; uppermost part of Cercado Formation (late Miocene).
16. 3 spec., NMB locality 15907: Río Gurabo; uppermost part of Cercado Formation (late Miocene).
17. 2 spec., NMB locality 16817: Río Cana, Cañada de Zamba; lower part of Gurabo Formation (early Pliocene).
18. 12 spec., NMB locality 16837: Río Cana; uppermost part of Cercado Formation (late Miocene).
19. 1 spec., NMB locality 16838: Río Cana; uppermost part of Cercado Formation (late Miocene).
20. 10 spec., TU locality 1294 (= NMB locality 18556): Río Mao, Bluff 3 of Maury; Cercado Formation (late Miocene).

Measurements.—Plotted in Text-figure 8.

Occurrence.—This species is recorded from the following areas: Río Mao: Cercado Formation (late Miocene): NMB localities 16912, 16913, TU locality 1294 (= Bluff 3 of Maury); 16915, 16917, 16922, 16923 (all Arroyo Bajón); 16929, 16930 (= Bluff 2 of Maury) (Saunders *et al.*, 1986, text-figs. 29, 30, table 3). Río Gurabo; lower part of Gurabo Formation (late Miocene): NMB locality 15878. Upper part of Cercado Formation (late Miocene): NMB localities 15903, 15906, 15907 (Saunders *et al.*, 1986, text-figs. 4, 6).

Río Cana; lower part of Gurabo Formation (early Pliocene): NMB locality 16817. Uppermost part of Cercado Formation (late Miocene): NMB localities 16837, 16838 (Saunders *et al.*, 1986, text-figs. 15, 16).

Distribution.—Not known from outside the Dominican Republic.

Subgenus **BOWDENIA** Dall, 1903

Bowdenia Dall, 1903, p. 1504.

Type species (*by original designation and monotypy*).—*Cuspidaria* (*Bowdenia*) *distira* Dall. Bowden, Jamaica. Bowden Formation (Pliocene).

Diagnosis.—Shell small (around 3 mm in length), rostrate. Umbos prosogyrate, almost centrally placed. Sculpture of fine, more or less well developed radial ribs. Rostrum well set off from main shell disc by a more prominent radial rib. Ventral margin of main shell disc evenly rounded. Hinge of left valve consisting of an inconspicuous posterior lateral tooth situated just behind a cavity to receive the posterior cardinal tooth of the right valve, which in turn is situated behind the subumbonal chondrophore. Hinge of right valve consisting of a subumbonal chondrophore, a weakly developed anterior cardinal tooth, and a prominent posterior cardinal tooth. Postero-dorsal margin of left valve somewhat thickened to fit the groove of the postero-dorsal margin of the right valve.

Remarks.—So far the type species of *Bowdenia, B. distira* Dall, is the only species assigned to this subgenus. *Bowdenia* is therefore known only from the Pliocene Bowden Formation of Bowden, Jamaica, and the late Miocene part of the Gurabo Formation, Dominican Republic (see below).

Cardiomya (Bowdenia) distira (Dall, 1903)

Plate 3, figures 1–5; Plate 4, figures 1–5;
Text-figure 9

Cuspidaria (*Bowdenia*) *distira* Dall, 1903, p. 1506, pl. 57, fig. 16; Woodring, 1925, p. 91, pl. 11, figs. 1–5.

Description.—Shell small (around 3 mm in length), delicate, rostrate. Umbos prosogyrate, placed almost centrally. Sculpture consisting of fine radial ribs, which may be fairly well developed, but sometimes hardly recognizable. Rostrum well set off from main shell disc by a more prominent radial rib. The concave

part of the rostrum of the left valve sometimes carrying a few fine radial riblets, but corresponding area of right valve does not. Concave part of rostrum adjoining postero-dorsal margin carrying three or four ribs. Ventral margin of main shell disc evenly rounded. Growth lines usually more clearly developed on right valve. Hinge of left valve consisting of an inconspicuous posterior lateral tooth behind a cavity to receive the posterior cardinal tooth of right valve. This cavity is situated behind the subumbonal chondrophore. Hinge of right valve consisting of a subumbonal chondrophore, a weakly developed anterior cardinal tooth, and a prominent posterior cardinal tooth. Postero-dorsal margin of left valve somewhat thickened to fit groove of postero-dorsal margin of right valve.

Lectotype (*selected herein*).—USNM 135692. This is the specimen figured by Dall (1903, pl. 57, fig. 16) and Woodring (1925, pl. 11, fig. 1), a left valve.

Dimensions of lectotype.—Length 3.3 mm; height 2.5 mm.

Type locality.—Bowden, Jamaica. Bowden Formation (early Pliocene).

Paralectotype.—USNM 482411. This is the specimen figured by Woodring (1925, pl. 11, figs. 2, 3), a left valve.

Dimensions of paralectotype USNM 482411.—Length 3.1 mm; height 2.3 mm.

Paralectotype.—USNM 482412. This is the specimen figured by Woodring (1925, pl. 11, figs. 4, 5), a right valve.

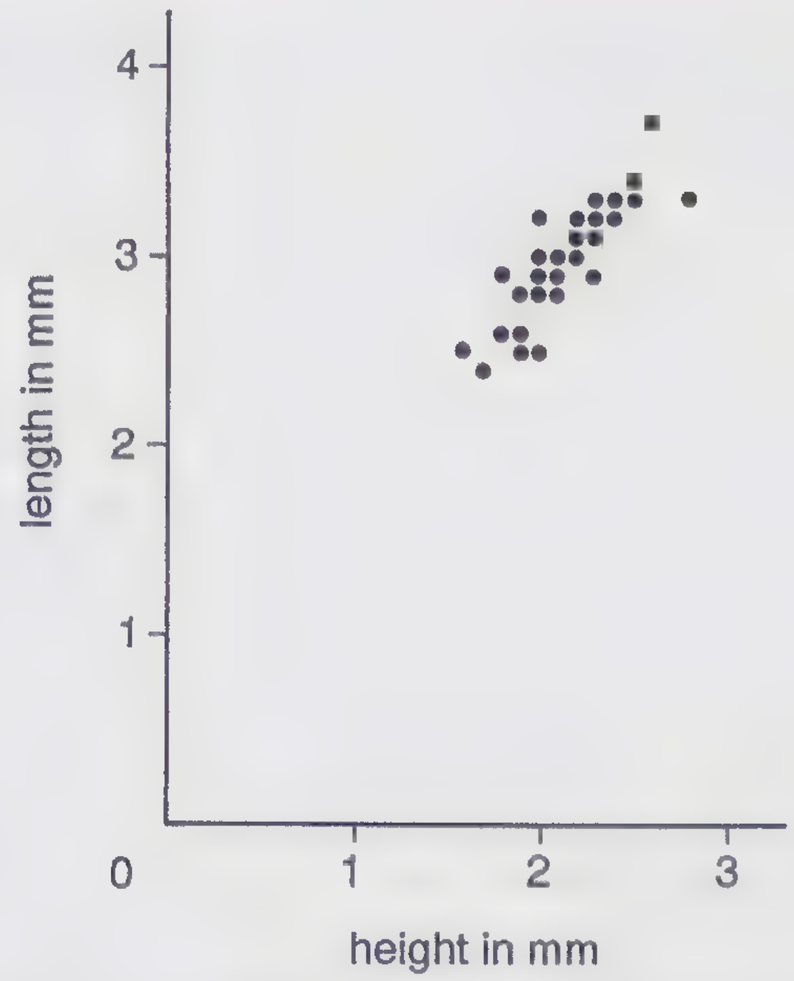
Dimensions of paralectotype USNM 482412.—Length 3.0 mm; height 2.0 mm.

Remarks.—The type lot of this species consists of the lectotype and the two paralectotypes. All three specimens are glued to a piece of black paper. Originally I intended to remove the specimens from the black paper in order to refigure the exterior of the lectotype and to figure its interior. Various chemicals have been used in an attempt to dissolve the glue but without success. The lectotype is therefore not refigured. Instead several topotypes are figured (Pl. 3, fig. 5; Pl. 4, figs. 1–5).

The Dominican Neogene has yielded eight specimens of this species. As hinted at in the above description there is some variability in the development of the radial ribs. They may be stronger or weaker. Sometimes they are evenly developed over the entire main shell disc, sometimes they are restricted to the ventral part of the main shell disc.

Comparisons.—As *Cardiomya* (*Bowdenia*) *distira* is the only species of the subgenus known no comparisons can be made.

Material.—Eight lots with a total of 47 specimens as listed below:



Text-figure 9.—Length/height diagram of *Cardiomya* (*Bowdenia*) *distira* (Dall, 1903).

1. 3 spec., USNM 135692 (lectotype) and two paralectotypes (USNM 482411, 482412). Bowden, Jamaica. Bowden Formation (early Pliocene).
2. 1 spec., NMB locality 15846: Río Gurabo, Dominican Republic. Latest Miocene part of Gurabo Formation (Pl. 3, figs. 1–4).
3. 5 spec., TU locality 1227A (= NMB locality 18582): Arroyo Zalaya, Dominican Republic; *Globorotalia margaritae* zone (early Pliocene).
4. 1 spec., TU locality 1352 (= NMB locality 18584): Río Gurabo, Dominican Republic; middle Pliocene part of Mao Formation.
5. 1 spec., TU locality 1403 (= NMB locality 18586): Arroyo Babosico near Río Yaque del Norte at La Barranca; upper part of *Globorotalia margaritae* zone (late early Pliocene).
6. 33 spec., NMB locality 10635: Bowden, Jamaica. Bowden Formation (early Pliocene).
7. 1 spec., NMB locality 11146: Bowden, Jamaica. Bowden Formation (early Pliocene).
8. 2 spec., NMB locality 17617: Bowden, Jamaica. Bowden Formation (early Pliocene).

Measurements.—Plotted in Text-figure 9.

Occurrence.—Río Gurabo section: latest Miocene part of Gurabo Formation: NMB locality 15846 (Saunders *et al.*, 1986, text-figs. 4, 6); middle Pliocene part of Mao Formation: TU locality 1352. *Globorotalia margaritae* zone (early Pliocene) of Arroyo Zalaya (TU locality 1227A) and Arroyo Babosico (TU locality 1403).

Distribution.—Bowden Formation (early Pliocene) of Bowden, Jamaica. Latest Miocene part of Gurabo

Formation; *Globorotalia margaritae* zone (early Pliocene); middle Pliocene part of Mao Formation, northern Dominican Republic.

Genus **PLECTODON** Carpenter, 1864

Plectodon Carpenter, 1864, pp. 611, 638.

Type species (*by original designation and monotypy*).—*Plectodon scaber* Carpenter, 1864, pp. 611, 638. Recent, Catalina Island, California, to Santa Inez Bay, east coast of Baja California, Mexico (Palmer, 1958, p. 80). Throughout the Gulf of California and south to Panama and the Galápagos Islands, Ecuador, in 20 to 250 m (Keen, 1971, p. 302).

Diagnosis.—Shell of medium to large size (up to 24 mm in length), rostrate, moderately delicate. Antero-ventral margin evenly rounded. Exterior surface of shell covered by pustules. Resilium situated posterior to the umbo. Dorsal margin of left valve twisted just anterior to the umbo forming a small, toothlike projection. No lateral teeth in left valve. Right hinge with an anterior and a posterior lateral tooth.

Remarks.—The holotype of *P. scaber* (USNM 592441) unfortunately is broken into several fragments (see also Palmer, 1958, p. 80). Originally it was mounted on a piece of glass. The fragmentation probably happened when the specimen was removed from the glass. Other material of *P. scaber* is figured here (Pl. 2, figs. 5–8) for comparison with *P. granulatus*.

The stratigraphic range of the genus *Plectodon* is given as Pliocene to Recent (Dall, 1903, p. 1507). The single right valve from the Dominican Republic described below has been collected from sediments of late Miocene age, and the single valve from the middle Miocene Shoal River Formation of Florida reported by Gardner (1926, p. 64) as *Cuspidaria* (*Plectodon*) cf. *granulata* Dall extend the range of *Plectodon* from middle Miocene to Recent.

Plectodon granulatus (Dall, 1881)

Plate 2, figures 9, 10; Plate 5, figures 1–4; Plate 6, figures 1–4; Plate 7, figures 1–4; Text-figure 10

Neaera granulata Dall, 1881, p. 111.
Leiomya (*Plectodon*) *granulata* Dall. Dall, 1886, p. 300, pl. 3, fig. 8; Dall, 1889, p. 66, pl. 3, fig. 8.
Cuspidaria (*Plectodon*) *granulata* Dall. Dall, 1903, p. 1507.
? *Cuspidaria* (*Plectodon*) cf. *granulata* Dall. Gardner, 1926, p. 64.
Cuspidaria (*Plectodon*) *scabrata* Olsson and Harbison, 1953, p. 67, pl. 1, fig. 2.
Plectodon granulatus (Dall, 1881). Knudsen, 1982, p. 136.

Description.—Shell of medium size (up to 18 mm in length), rostrate, moderately delicate. Antero-ventral margin evenly rounded. Umbos prosogyrate. Exterior surface of shell covered by pustules. In the umbonal area there are fewer or no pustules; instead the growth lines are more clearly developed. Resilium located behind the umbo and somewhat toward the interior of the shell. Dorsal margin of the left valve twisted just in front of the umbo, forming a small, toothlike projection. No lateral teeth in left valve. Right hinge with an anterior and a posterior lateral tooth.

Lectotype (*selected herein*).—USNM 63193 (Pl. 2, figs. 9, 10).

Dimensions of lectotype.—Length 11.3 mm; height 6.7 mm.

Type locality.—Off Sombrero Island, Leeward Islands, Lesser Antilles, in 132 m (72 fathoms).

Remarks.—Lot USNM 63193 contains three specimens, the syntypes of *P. granulatus*. The specimen chosen as the lectotype is the left valve figured by Dall (1886, pl. 3, fig. 8). One of the paralectotypes is a right valve, the other paralectotype is also a left valve like the lectotype, but is considerably smaller. The two paralectotypes are USNM 887025 (*ex* USNM 63193).

The Dominican Neogene so far has yielded a single specimen of this species, a right valve. It is not quite complete: its postero-dorsal margin is somewhat damaged (Pl. 5, fig. 1). Unfortunately this unique specimen has been broken during handling for scanning electron microscopy (Pl. 5, fig. 3). Olsson and Harbison (1953, p. 67) state that their *P. scabratus* from the Pliocene of Fort Thompson, Florida, is less "narrow" than Recent specimens of *P. granulatus*. It is not clear, however, what is meant by "narrow". It probably refers to the ratio of height to length. In that respect there is some variability in *P. granulatus*. Two Recent specimens of *P. granulatus* are figured here for comparison (Pl. 6, figs. 1–4; Pl. 7, figs. 1–4).

Comparisons.—The only other species of *Plectodon* is the Recent Eastern Pacific *P. scaber* Carpenter (1864, pp. 611, 638) (for figures see Schenck, 1945, pl. 67, figs. 1–4; Palmer, 1958, pl. 6, figs. 6–8; Keen, 1971, p. 302, fig. 786; and Pl. 2, figs. 5–8). The main differences between the two species is size. *P. scaber* is considerably larger; it actually may be twice as large as *P. granulatus*.

Material.—Twelve lots with a total of 22 specimens as listed below:

1. 1 spec., NMB locality 16857: Río Cana, Dominican Republic; Cercado Formation (late Miocene).
2. 1 spec., USNM 63193: lectotype. Recent; Sombrero Island, Leeward Islands, Lesser Antilles, 72 fms.; Blake Coll.
3. 2 spec., USNM 887025: paralectotypes. Recent; Sombrero Island, Leeward Islands, Lesser Antilles, 72 fms.; Blake Coll.
4. 1 spec., USNM 63194: Recent; Barbados, 100 fms.

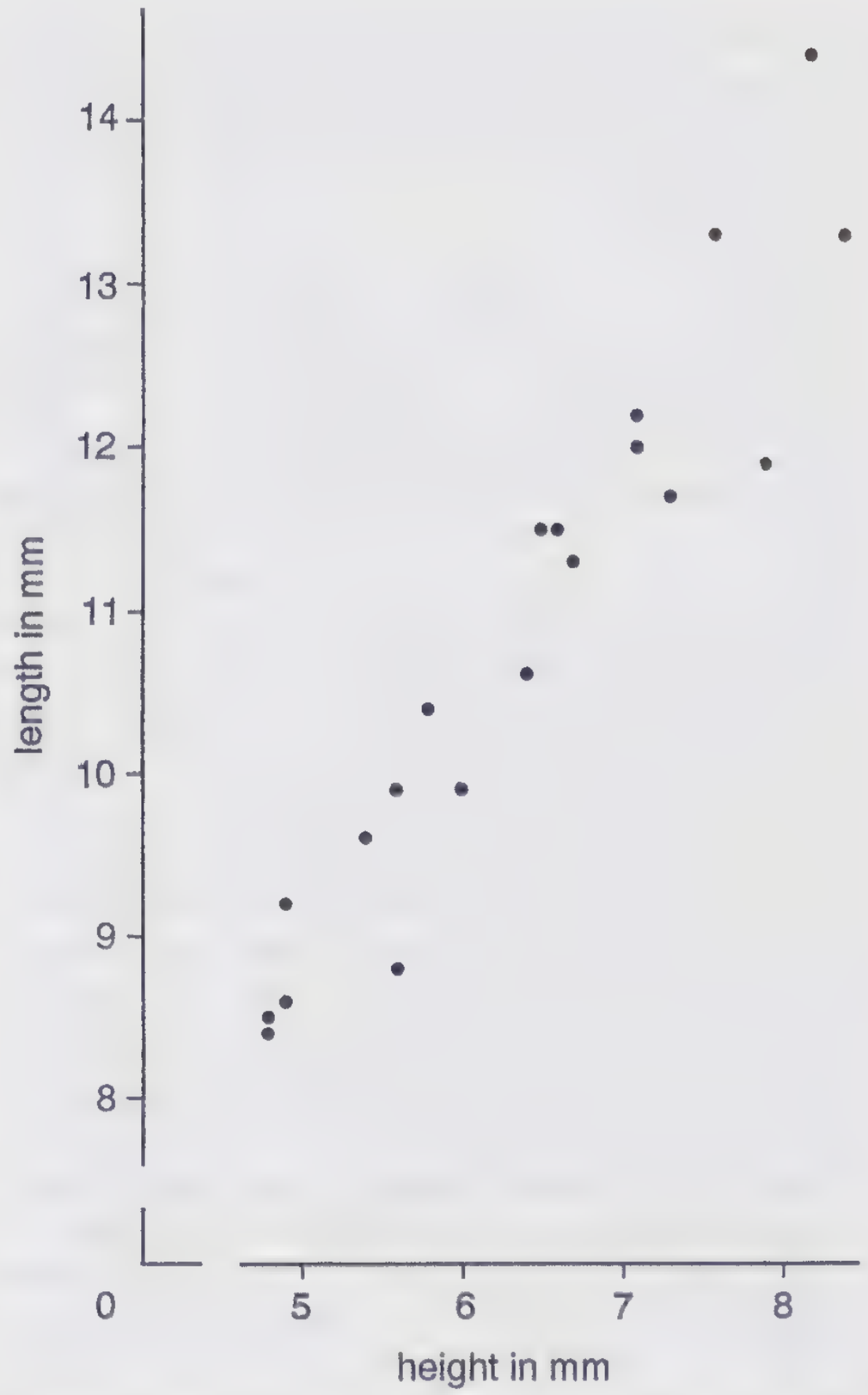
5. 6 spec., USNM 94214: Recent; Station 2648: off Cape Florida, 84 fms., sand.
6. 3 spec., USNM 667843: Recent; Station 1306: Campeche Bank off Yucatan, Mexico (22°10′N, 91°40′W), 42 fms., sand.
7. 1 spec., USNM 667668: Recent; Station 470: Campeche Bank off Yucatan, Mexico (22°30′N, 90°15′W), 46 fms., sand.
8. 1 spec., USNM 157815: Recent; Station 2404: between Mississippi Delta and Cedar Keys, Gulf of Mexico; 60 fms., sand.
9. 1 spec., USNM 64003: Recent; Station 2646: off Cape Florida; 85 fms.
10. 3 spec., USNM 97157: Recent; Station 2646: 5 miles off Cape Florida, Gulf of Mexico; 85 fms., sand.
11. 1 spec., USNM 157986: Recent; Station 2646: Recent; off Cape Florida, Gulf of Mexico; 85 fms., sand.
12. 1 spec., USNM 667737: Recent; Station 1241: Campeche Bank off Yucatan, Mexico (20°15′N, 92°10′W), 32 fms., sand.

Measurements.—Plotted in Text-figure 10.

Depth range.—From 37 to 274 m (Knudsen, 1982, p. 137).

Occurrence.—Cercado Formation (late Miocene) of Río Cana section: NMB locality 16857 (Saunders *et al.*, 1986, text-figs. 15, 16).

Distribution.—Shoal River Formation (middle Miocene), Florida? Cercado Formation (late Miocene), northern Dominican Republic. Pliocene, Florida. Recent, southern Florida and Gulf of Mexico throughout the West Indies.



Text-figure 10.—Length/height diagram of *Plectodon granulatus* (Dall, 1881).

Family **VERTICORDIIDAE** Stoliczka, 1871

Genus **HALIRIS** Dall, 1886

Haliris Dall, 1886, p. 287.

Type species (*by original designation*).—*Verticordia fischeriana* Dall, 1881. Recent, Gulf of Mexico. North Carolina to Gulf of Mexico to Barbados (Abbott, 1974, p. 563).

Diagnosis.—Shell small (up to 7 mm in length), globose. Umbos strongly prosogyrate. Lunule somewhat depressed. Ventral margin evenly rounded or somewhat angulated near its middle. Entire surface sculptured by numerous radial ribs. No secondary radial ribs. Surface granulated. Interior surface nacreous, its ventral margin fluted. Hinge of left valve consisting of a hardly recognizable, subumbonal cardinal tooth and (only in fully adult shells) an inconspicuous posterior lateral tooth. Hinge of right valve with a prominent, subumbonal cardinal tooth and a posterior lateral tooth.

Remarks.—Numerous Recent specimens of the type species, *H. fischeriana,* are available. Some of them are figured (Pl. 8, figs. 1–6) for comparison with *H. jamaicensis.* The stratigraphic range of the genus is Eocene to Recent.

Haliris jamaicensis (Dall, 1903)

Plate 9, figures 1–6; Plate 10, figures 1–4

Verticordia (*Haliris*) *jamaicensis* Dall, 1903, p. 1511; Woodring, 1925, p. 93, pl. 11, figs. 9–11.

Description.—Shell small (up to less than 5 mm in length), globose. Umbos strongly prosogyrate. Lunule depressed. Ventral margin slightly angulated near its middle. Surface sculptured by 23 to 26 radial ribs; interspaces narrower on anterior part of shell. Whole surface granulated. Inner surface nacreous, its ventral margin fluted. Hinge of left valve consisting of a hardly recognizable, subumbonal cardinal tooth and (only in fully adult shells) an inconspicuous, posterior lateral

tooth. Hinge of right valve with a prominent, subumbonal cardinal tooth and a posterior lateral tooth.

Lectotype (*selected herein*).—USNM 135686. This is the specimen figured by Woodring (1925, pl. 11, fig. 10), a right valve.

Dimensions of lectotype.—Length 4.5 mm; height 4.7 mm.

Type locality.—Bowden, Jamaica. Bowden Formation (early Pliocene).

Paralectotype.—USNM 482413. This is the specimen figured by Woodring (1925, pl. 11, fig. 9), a right valve.

Dimensions of paralectotype USNM 482413.—Length 3.8 mm; height 3.8 mm.

Paralectotype.—USNM 482414. This is the specimen figured by Woodring (1925, pl. 11, fig. 11), a left valve.

Dimensions of paralectotype USNM 482414.—Length 3.3 mm; height 3.1 mm.

Remarks.—The lectotype of *H. jamaicensis* is the largest of the 10 available specimens. Its height is greater than its length. In all the other specimens the length is greater (or the same as) than the height.

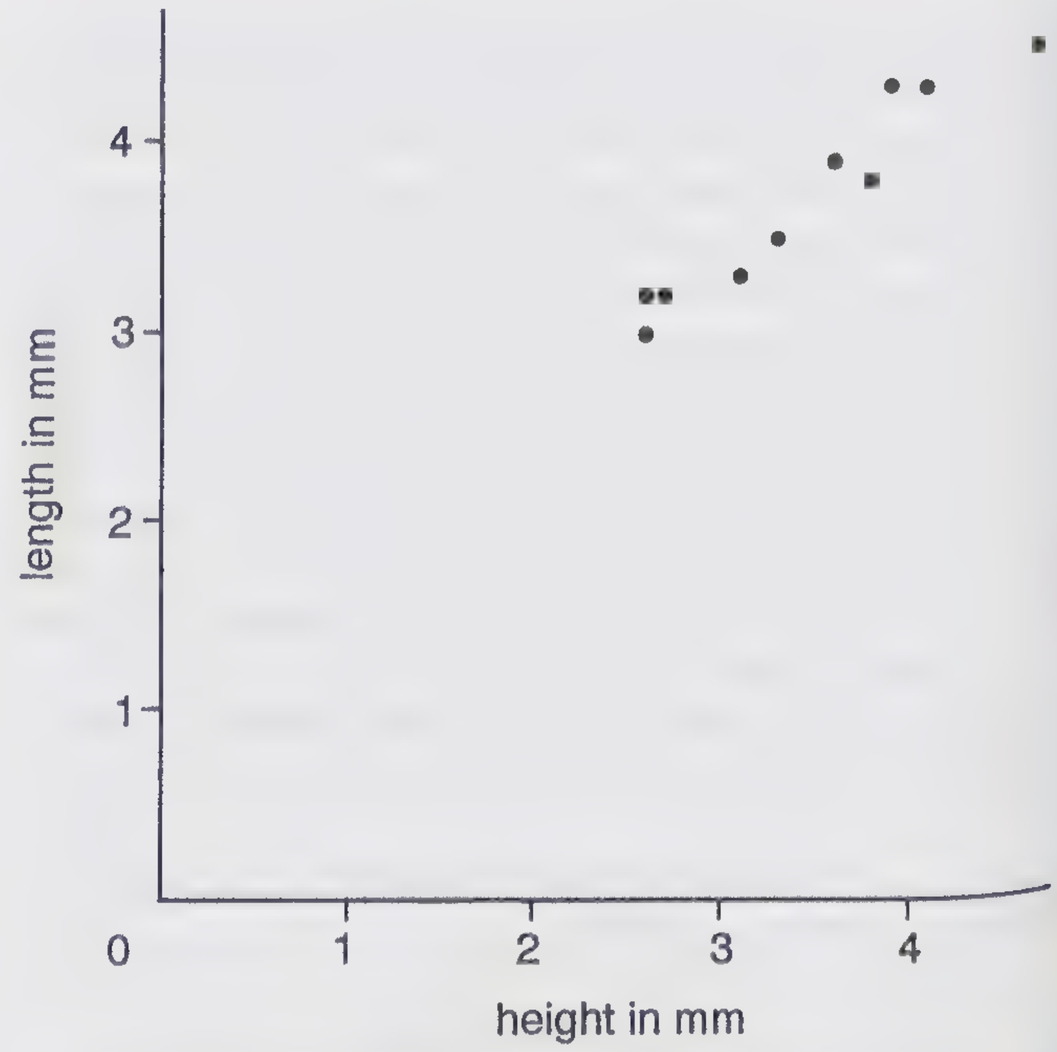
The type material of this species consists of the lectotype and the two paralectotypes mentioned above. All three specimens are glued to a piece of black paper. As explained under *Cardiomya* (*Bowdenia*) *distira* it has not been possible to remove the specimens from the black paper. Therefore the lectotype is not refigured here.

Woodring (1925, p. 93) mentioned a fragment from the early Pliocene Bowden Formation of Jamaica that is almost three times as large as the specimens listed below under "Material". More specimens from Bowden would be needed in order to be able to identify the fragment mentioned above.

Comparisons.—*H. jamaicensis* is obviously closely related to the living *H. fischeriana* (Dall) (1881, p. 106), the type species of the genus. *H. fischeriana* is larger than *H. jamaicensis* and has more radial ribs. In addition the ventral margin is evenly rounded in *H. fischeriana* but somewhat angulated in *H. jamaicensis*.

Material.—Four lots with a total of only ten specimens as listed below:

1. 2 spec., NMB locality 15832: Río Gurabo, Dominican Republic; middle Pliocene part of Mao Formation.
2. 1 spec., TU locality 1227A (= NMB locality 18582): Arroyo Zalaya, Dominican Republic; *Globorotalia margaritae* zone (early Pliocene).
3. 4 spec., NMB locality 10635: Bowden, Jamaica; Bowden Formation (early Pliocene).
4. 3 spec., USNM 135686 (lectotype) and two paralectotypes (USNM 482413, 482414). Bowden, Jamaica; Bowden Formation (early Pliocene).



Text-figure 11.—Length/height diagram of *Haliris jamaicensis* (Dall, 1903).

Measurements.—Plotted in Text-figure 11.

Occurrence.—*Globorotalia margaritae* zone (early Pliocene) of Arroyo Zalaya: TU locality 1227A and middle Pliocene part of Mao Formation of Río Gurabo section: NMB locality 15832 (Saunders *et al.*, 1986, text-figs. 4, 6).

Distribution.—Bowden Formation (early Pliocene) of Bowden, Jamaica. Early Pliocene *Globorotalia margaritae* zone and middle Pliocene part of Mao Formation, Dominican Republic.

Genus **TRIGONULINA** d'Orbigny, 1842

Trigonulina d'Orbigny, 1842 (see also d'Orbigny, 1845?, p. 327).

Type species (*by monotypy*).—*Trigonulina ornata* d'Orbigny, 1842 (see also d'Orbigny, 1845?, p. 327). Recent, Massachusetts to Florida and the West Indies, Bermuda, Brasil (Abbott, 1974, p. 563).

Diagnosis.—Shell small (up to almost 6 mm in length), oval. Umbos low, strongly prosogyrate. Lunule deeply depressed. Sculpture consisting of few, widely spaced, high, and narrow radial ribs projecting beyond ventral margin. On the posterior slope there is a large area without radial ribs. Interior surface nacreous, its ventral margin fluted. Ligament internal. No teeth in left valve. Right valve with a strong, projecting, subumbonal, cardinal tooth and a groove along postero-dorsal margin to receive postero-dorsal margin of left valve.

Remarks.—The Spanish edition of Ramón de la Sagra's *Historia física, política y natural de la Isla de Cuba,* volume 5 (molluscs) of the second part (natural history), is dated 1845. On page 327, where *Trigonulina* and its type species, *T. ornata,* are described, the date is given as 1846. According to Aguayo (1943, p. 38) publication of this edition appears to have started in 1844 already and was probably completed only in 1853. Aguayo is quoting the Spanish edition as of 1845?, to which the present author is adding [1844-1853?] in the "References Cited". Dall (1889, p. 18) did not have access to the Spanish edition.

Both Dall (1889, p. 18) and Aguayo (1943, p. 38) commented on the dates of publication of the French edition. Both authors state that the atlas was published in 1842. The figures of *T. ornata* given in this atlas (pl. 27, figs. 30–33) are an indication as defined in Article 12b(7) of the International Code of Zoological Nomenclature (third edition, 1985).

Trigonulina is here used as a full genus, whereas Abbott (1974, p. 563) and Woodring (1925, p. 92) treated it as a subgenus of *Verticordia* J. Sowerby (1812–1846, p. 68, pl. 639, 1844 [for date of publication of plate 639 see Renevier, 1855, and Sykes, 1906]. On the other hand Keen (1971, p. 302) considered *Trigonulina* as a synonym of the subgenus *Verticordia s.s.* The type species of *Verticordia* is *V. cardiiformis* J. Sowerby (1812–1846, p. 68, pl. 639, 1844) from the Pliocene of England. The original figure shows that the 13 radial ribs are evenly distributed over the entire shell disc. In *Trigonulina,* however, there is a space without radial ribs on the postero-dorsal slope.

T. ornata d'Orbigny, the type species of *Trigonulina,* is not only reported from Western Atlantic waters, but is also said to occur in the Eastern Pacific (Keen, 1971, p. 302). Having looked at a number of lots from both oceans I come to the conclusion that they are distinct and that the species from the Eastern Pacific therefore needs a name. For this reason these two living species are briefly discussed and compared below.

The stratigraphic range of *Trigonulina* is Eocene to Recent.

Trigonulina ornata d'Orbigny, 1842

Plate 11, figures 1–4; Plate 12, figures 1–4; Text-figures 12, 13

Trigonulina ornata d'Orbigny, 1842, pl. 27, figs. 30–33; 1845?, p. 327.

Verticordia caelata Verrill, 1882, p. 566; 1884, p. 278, pl. 30, figs. 9, 9a.

Verticordia (*Trigonulina*) *ornata* D'Orbigny. Dall, 1886, p. 290 (part). Dall and Simpson, 1901, p. 498 (part). (For further citations see Dall, 1886.)

Verticordia (*Trigonulina*) *ornata* (Orbigny, 1842). Abbott, 1974, p. 563, fig. 6158.

Verticordia ornata (Orbigny, 1846). Knudsen, 1982, p. 128 (part). For additional citations see this publication.

Verticordia ornata (Orbigny, 1842). Rios, 1985, p. 282, pl. 99, fig. 1390 (part).

Description.—Shell small (up to 5 mm in length), oval. Umbos low, strongly prosogyrate. Lunule deeply impressed in both valves, but more so in left valve. Sculpture consisting of eight to twelve high, narrow, radial ribs anterior to the unsculptured posterior slope projecting beyond the ventral margin. Surface of perfectly preserved valves covered by minute pustules forming rows parallel to the ribs. Interior surface nacreous, its ventral margin fluted. No teeth in left valve. Right valve with a strong, subumbonal, cardinal tooth and a groove along postero-dorsal margin to receive postero-dorsal margin of left valve.

Holotype.—BMNH Cat. no. 493; Reg. no. 1854.10.4.557, a left valve.

Dimensions of holotype.—Length 2.6 mm; height 2.3 mm.

Type locality.—"Jamaica" (from sand). This is the only information given with the original description.

Remarks.—The holotype of *T. ornata* is at hand. Its ventral margin is somewhat damaged. It is a left valve. It is the specimen figured in an idealized way and in mirror-image by d'Orbigny (1842, pl. 27, figs. 30, 31). His Figure 31 shows the interior of the valve with a hinge without teeth, a hinge typical for left valves. The holotype is one of the rare cases of a specimen having only eight radial ribs in front of the posterior slope. Due to its imperfect preservation it is not refigured here.

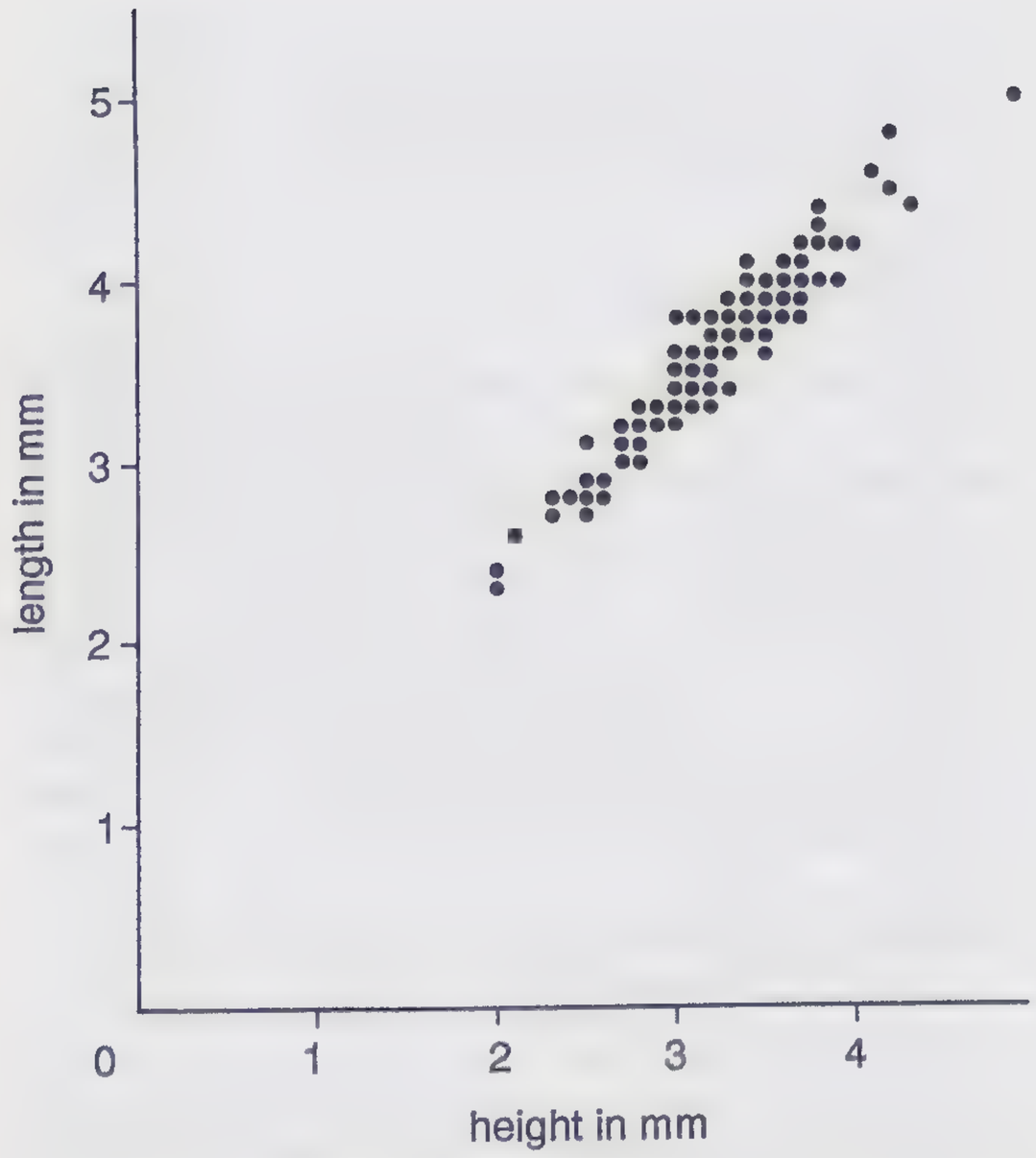
As listed under "Material", six lots with 1049 specimens have been used for the description given above. Out of these 1049 specimens 190 valves have been measured (Text-fig. 12) and their ribs in front of the unsculptured posterior slope counted (Text-fig. 13). As indicated in the description the range of the number of ribs is eight to twelve. However, the extremes are rare (Text-fig. 13); there are only three valves with eight ribs, eight valves with nine ribs, and twelve valves with twelve ribs. In other words one should really describe *T. ornata* as having ten or eleven ribs.

The original description of *Verticordia caelata* Verrill was based on a single right valve with eleven ribs.

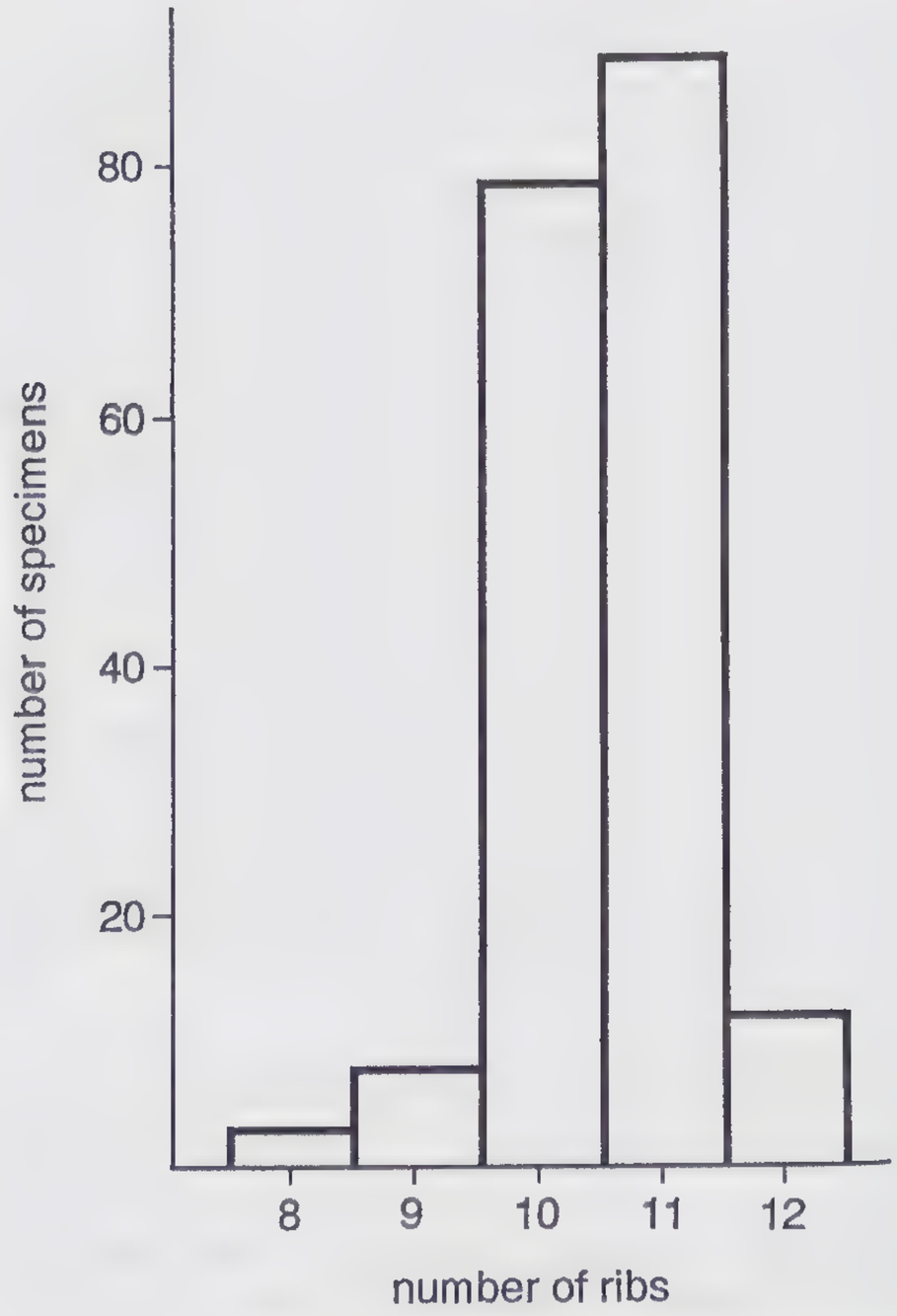
Comparisons.—Comparative remarks are given below under *T. pacifica* and *T. bowdenensis.*

Material.—Six lots with a total of 1049 specimens as listed below (quoted from specimen labels):

1. 439 spec., USNM 444664: Eolis Station 368: off Ajax Reef, Florida; 80–100 fms.



Text-figure 12.—Length/height diagram of *Trigonulina ornata* d'Orbigny, 1842.



Text-figure 13.—Histogram showing rib number distribution of *Trigonulina ornata* d'Orbigny, 1842.

2. 54 spec., USNM 444479: Eolis Station 178: off Fowey Light, Florida; 68 fms.
3. 3 spec., USNM 63214: off Hatteras; 15–124 fms.
4. 172 spec., USNM 444514: Eolis Station 311: off Govt. cut, Miami, Florida; 75 fms.
5. 337 spec., USNM 444665: Eolis Station 370: off Ajax Reef, Florida; 70–90 fms.
6. 44 spec., USNM 444653: Eolis Station 363: off Fowey Light, Florida; 85 fms.

Measurements.—Plotted in Text-figure 12.

Depth range.—From 5 to 850 m (Knudsen, 1982, p. 128) and 15 to 1256 m (Hertlein and Grant, 1972, p. 344).

Distribution.—Massachusetts to Florida and the West Indies, Bermuda, Brazil (Abbott, 1974, p. 563) or from about 42°N to about 30°42′S (Knudsen, 1982, p. 128). So far *T. ornata* has not been reported as a fossil.

Trigonulina pacifica, new species
Plate 2, figures 11, 12; Plate 13, figures 1–4;
Plate 14, figures 1–4; Text-figures 14, 15

Verticordia ornata (d'Orbigny). Grant and Gale, 1931, p. 266, pl. 13, fig. 4 (part).

Verticordia (*Verticordia*) *ornata* (Orbigny, 1846). Keen, 1971, p. 302, fig. 789 (part).

Verticordia (*Trigonulina*) *ornata* d'Orbigny. Hertlein and Grant, 1972, p. 344, pl. 43, figs. 23, 26, 27, 31.

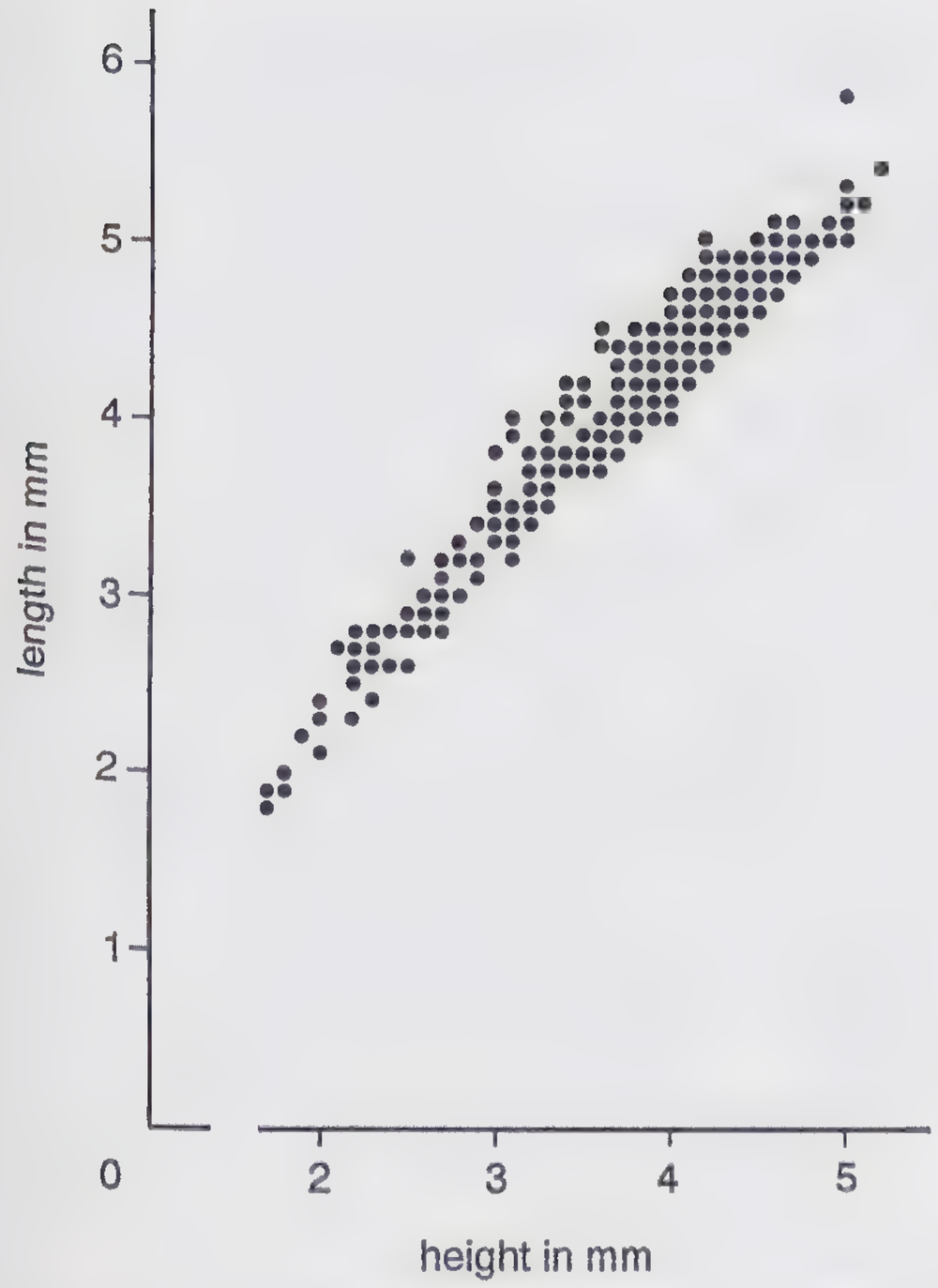
Description.—Shell small (up to almost 6 mm in length), oval. Umbos low, strongly prosogyrate. Lunule deeply impressed in both valves, but more so in left valve. Sculpture consisting of six to 12 high, narrow radial ribs anterior to the unsculptured posterior slope projecting beyond the ventral margin. Surface of perfectly preserved valves covered by minute, not closely spaced pustules forming rows parallel to the ribs. Interior surface nacreous, its ventral margin fluted. No teeth in left valve. Right valve with a strong, subumbonal, cardinal tooth and a groove along postero-dorsal margin to receive the postero-dorsal margin of left valve.

Holotype.—LACM 2718 (Pl. 2, figs. 11, 12).

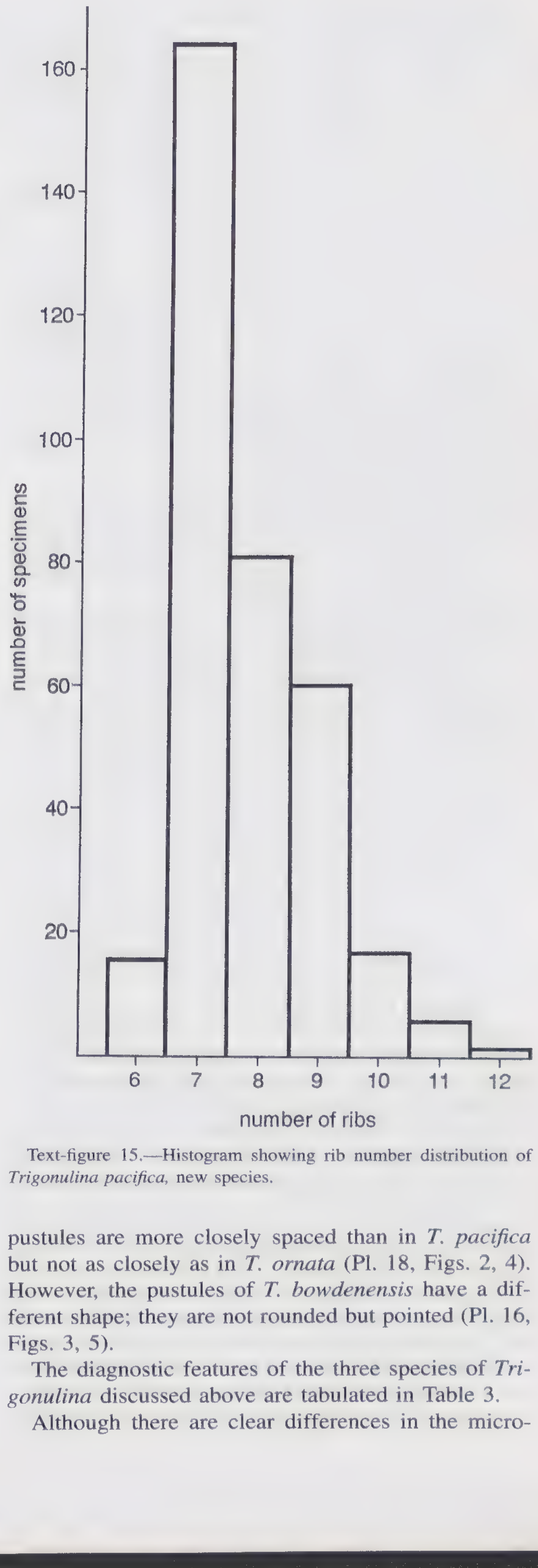
Dimensions of holotype.—Length 4.8 mm; height 4.2 mm.

Type locality.—(quoted from specimen label) LACM 65-6.22: 0.4–0.7 miles 110 to 132 degrees T from Ship Rock, Santa Catalina Island, California Channel Islands, California (33°27′N, 118°30′W). Depth: 82 m.

Remarks.—The basis for the above description consists of the 23 lots with 1840 specimens listed under "Material". A total of 320 specimens have been measured (Text-fig. 14) and their ribs in front of the ribless



Text-figure 14.—Length/height diagram of *Trigonulina pacifica,* new species.



Text-figure 15.—Histogram showing rib number distribution of *Trigonulina pacifica,* new species.

posterior slope counted (Text-fig. 15). The range of the number of ribs as given in the description is six to 12. But again—as in *T. ornata*—the extremes are rare: there are only 16 valves with six ribs, 17 valves with 10 ribs, six valves with 11 ribs, and a single valve with 12 ribs. It is therefore appropriate to say that the great majority of the valves has seven to nine ribs.

The ribs of *T. pacifica* as a rule are high and narrow. But sometimes there are exceptions with lower and somewhat broader ribs.

Comparisons.—T. pacifica reaches larger dimensions than the Recent West Indian *T. ornata* d'Orbigny and has fewer radial ribs. In addition the general outline of the shell is more rounded or oval in *T. ornata,* and the area without ribs on the posterior slope of *T. ornata* is wider than that of *T. pacifica. T. pacifica* is considerably larger than *T. bowdenensis* Dall from the early Pliocene Bowden Formation of Jamaica but has about the same number of radial ribs.

The microsculpture of *T. ornata* and *T. pacifica* are clearly different. In both species the microsculpture consists of rounded pustules, which are aligned in rows parallel to the ribs; but in *T. ornata* they are much more closely spaced (Pl. 12, Figs. 2, 4; Pl. 14, Figs. 2, 4). In *T. bowdenensis* on the other hand the pustules are more closely spaced than in *T. pacifica* but not as closely as in *T. ornata* (Pl. 18, Figs. 2, 4). However, the pustules of *T. bowdenensis* have a different shape; they are not rounded but pointed (Pl. 16, Figs. 3, 5).

The diagnostic features of the three species of *Trigonulina* discussed above are tabulated in Table 3.

Although there are clear differences in the micro-

Table 3.—Diagnostic features of the three species of *Trigonulina* dealt with herein. Numbers of measured specimens: *T. ornata*: 190; *T. pacifica*: 320; *T. bowdenensis*: 79.

	maximum length	*maximum height*	*mean ratio length/ height*	*ribless area on posterior slope*	*range of number of ribs*	*most frequent number of ribs*	*microsculpture*		*depth range (in m)*
							spacing of pustules	*form of pustules*	
T. ornata	5.0	4.9	1.13	wide	8–12	11	close	rounded	5–1256
T. pacifica	5.8	5.2	1.09	narrower	6–12	7	wide	rounded	18–168
T. bowdenensis	4.0	3.5	1.16	wide	7–10	10	not wide	pointed	—

sculpture of these species, considerably more numerous, well preserved specimens should be looked at in the scanning electron microscope in order to determine the range of variability of the microsculpture.

Material.—23 lots with a total of 1840 specimens as listed below (lots arranged from north to south) (quoted from specimen labels):

1. 3 spec., paratypes. LACM 63-50.12: 60 m, Humpback Rock, off Hopkins Marine Station, Pacific Grove, Monterey Bay, California (36°38′N, 121°54′W). Leg. J.H. McLean, R/V Tage, 26 November 1963.
2. 3 spec., paratypes. LACM 41-80.19: 99–102 m, mud, sand and shell, 1.5 mi NW of Cavern Pt., Santa Cruz Id., California Channel Ids., California (34°04′N, 119°34.4′W). Leg. R/V Velero III (AHF 1300-41), 12 April 1941. Ex AHF.
3. 2 spec., paratypes. LACM 40-164.20: 27–91 m, sand and gravel, Anacapa Passage, W of Anacapa Id., California Channel Ids., California (33°59.0′N, 119°32.1′W). Leg. R/V Velero III (AHF 1190-40), 30 October 1940. Ex AHF.
4. 1 spec., paratype. LACM 41-74.19: 62–75 m, sand and shell, 0.5 mi S of Gull Id., Santa Cruz Id., California Channel Ids., California (33°56.5′N, 119°49.6′W). Leg. R/V Velero III (AHF 1294-41), 11 April 1941. Ex AHF.
5. 8 spec., holotype and 7 paratypes. LACM 65-6.22: 82 m, 0.4–0.7 mi 110 to 132 degrees T from Ship Rock, Santa Catalina Id., California Channel Ids., California (33°27′N, 118°30′W). Leg. R. Reimer et al., R/V Velero IV, 13 February 1965. Ex AHF.
6. 4 spec., paratypes. LACM 41-25.17: 75 m, shell, mud and gray sand, 4 mi N of Islas Todos Santos, Pacific Coast, Baja California, Mexico (31°53.3′N, 116°48.3′W). Leg. R/V Velero III (AHF 1245-41), 24 February 1941. Ex AHF.
7. 12 spec., paratypes. LACM 75-93.17: 27 m, gravel and shell, W of Isla Smith, Bahía de los Angeles, Gulf of California, Mexico (29°04′N, 113°33′W). Leg. Gale Sphon, D.K. Mulliner, 10 October 1975.
8. 21 spec., paratypes. LACM 76-2.21: 18–22 m, sand and gravel, W of Isla Smith, Bahía de los Angeles, Gulf of California, Mexico (29°03.7′N, 113°31.0′W). Leg. Gale Sphon, D.K. Mulliner, 10–16 May 1976.
9. 25 spec., paratypes. LACM 71-158.38: 31–37 m, shelly sand, Kellett Channel, S of Isla Cedros, Pacific Coast, Baja California, Mexico (27°57.0′N, 115°08.5′W). Leg. J.H. McLean, P.I. LaFollette, R/V Searcher, 20 October 1971.
10. 24 spec., paratypes. LACM 78-120.18: 43–55 m, sandy, off Isla Danzante, Bahía Escondido, Gulf of California, Baja California Sur, Mexico (25°46′N, 111°15′W). Leg. D. Mulliner, G. Sphon, 6 November 1978.
11. 384 spec., paratypes. USNM 211469: off La Paz, Baja California, Mexico; 9½–10 fms.
12. 623 spec., paratypes. USNM 211458: off La Paz, Baja California, Mexico; 26½ fms.
13. 591 spec., paratypes. USNM 151959: near La Paz, off Baja California, Mexico; 9½–10 fms.
14. 13 spec., paratypes. LACM 66-23.22: 27–37 m, sand, off Punta Arena de la Ventana, Gulf of California, Baja California Sur, Mexico (24°04′N, 109°49′W). Leg. J.H. McLean, P. M. Oringer, L. Marincovich, 8 April 1966.
15. 6 spec., paratypes. LACM 66-22.40: 18–55 m, sand and shell, directly off anchorage at Bahía de los Muertos, Gulf of California, Baja California Sur, Mexico (23°58′N, 109°46′W). Leg. J.H. McLean et al., 8 April 1966.
16. 6 spec., paratypes. LACM 66-17.62: 18–37 m, sand, between Rancho El Tule and Rancho Palmilla, Gulf of California, Baja California Sur, Mexico (22°58′N, 109°45′W). Leg. J.H. McLean, P.M. Oringer, 5 April 1966.
17. 10 spec., paratypes. LACM 38-5.9: 37–73 m, Bahía Banderas, Jalisco, Mexico (20°40′N, 105°25′W). Leg. G. Willett, 14 February 1938.
18. 31 spec., paratypes. LACM 34-2.20: 26–33 m, sand, nullipores, Bahía Braithwaite, Isla Socorro, Islas Revilla Gigedo, Mexico (18°42.5′N, 110°56.22′W). Leg. R/V Velero III (AHF 129-34), 3 January 1934. Ex AHF.

19. 8 spec., paratypes. LACM 38-9.11: 73–128 m, Bahía Guatulco, Oaxaca, Mexico. Leg. G. Willett, 7 March 1938.
20. 11 spec., paratypes. LACM 72-13.26: 37 m, mud, 0.5 to 1.5 mi W Roca Vagares, Bahía Juanillo, Guanacaste Prov., Costa Rica (10°57.47′N, 85°45.3′W). Leg. D. Cadien, P.I. LaFollette, R/V Searcher (Searcher 393), 14 February 1972.
21. 27 spec., paratypes. LACM 72-54.45: 37 m, off Bahía Herradura, Puntarenas Prov., Costa Rica (9°38.8′N, 84°40.8′W). Leg. J.H. McLean, W. Bussing, R/V Searcher (Searcher 451, 457), 10 March 1972.
22. 15 spec., paratypes. LACM 72-53.27: 21 m, sand, anchorage in Bahía Herradura, Puntarenas Prov., Costa Rica (9°37.97′N, 84°40.5′W). Leg. J.H. McLean, R/V Searcher, 9 March 1972.
23. 12 spec., paratypes. LACM 72-57.33: 21 m, sand, anchorage inside small islet 1.5 km S Punta Quepos, Puntarenas Prov., Costa Rica (9°22.72′N, 84°09.68′W). Leg. J.H. McLean, R/V Searcher, 11 March 1972.

Measurements.—Plotted in Text-figure 14.

Depth range.—From 18 to 168 m (Keen, 1971, p. 302).

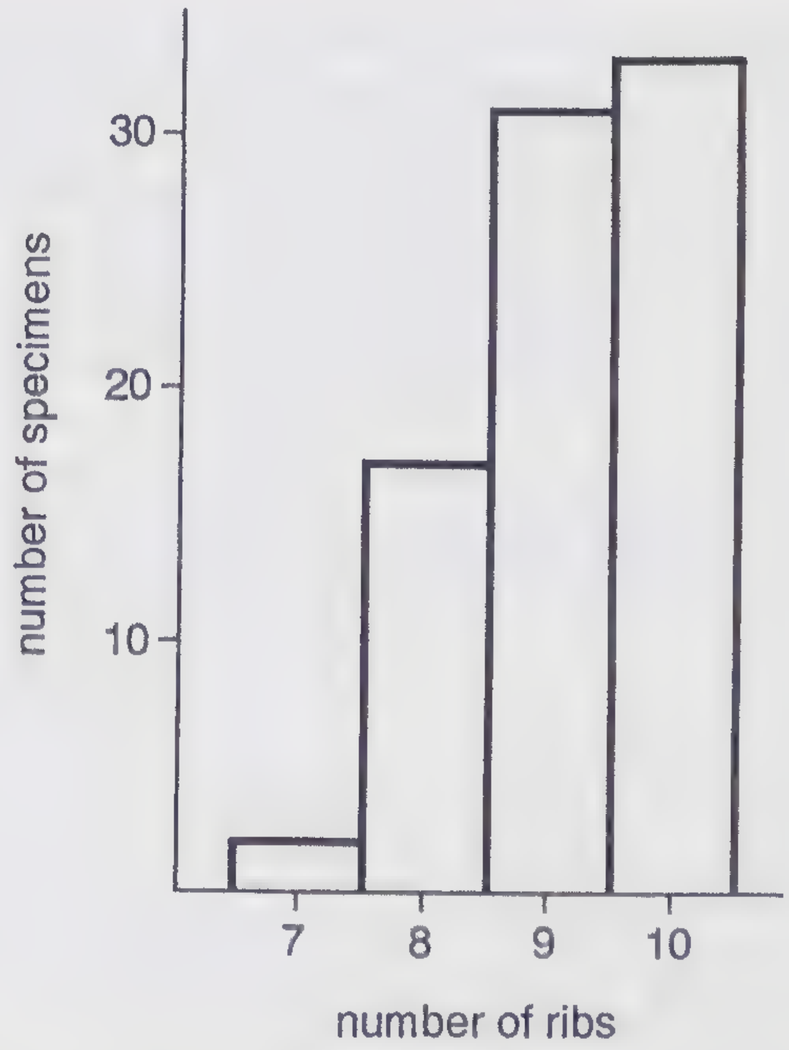
Distribution.—Pliocene of San Diego, California (Hertlein and Grant, 1972, p. 344); Pleistocene of California (Grant and Gale, 1931, p. 266). Recent from Catalina Island, California, through the Gulf of California, south to Peru and the Galápagos Islands (Keen, 1971, p. 302) or from about 34°N to 12°S (Knudsen, 1982, p. 128). The record from Monterey Bay (lot 1) extends the distribution to the north to almost 37°N.

Trigonulina bowdenensis (Dall, 1903)

Plate 15, figures 1–4; Plate 16, figures 1–5; Plate 17, figures 1–4; Plate 18, figures 1–4;
Text-figures 16, 17

Verticordia (*Trigonulina*) *bowdenensis* Dall, 1903, p. 1512; Woodring, 1925, p. 92, pl. 11, figs. 6–8.

Description.—Shell small (up to 4 mm in length), oval to rotund. Umbos low, strongly prosogyrate. Lunule more deeply impressed in left valve. Sculpture consisting of seven to 10 high, narrow, radial ribs anterior to unsculptured posterior slope, which project beyond ventral margin. Surface of perfectly preserved valves covered by minute, pointed pustules forming rows parallel to ribs. Along postero-dorsal margin there are two closely spaced, narrow ribs. Interior surface nacreous, its ventral margin fluted. No teeth in left valve. Right valve with a strong, subumbonal, cardinal tooth and a groove along postero-dorsal margin to receive postero-dorsal margin of left valve.



Text-figure 16.—Histogram showing rib number distribution of *Trigonulina bowdenensis* (Dall, 1903).

Lectotype (*selected herein*).—USNM 135689. This is the specimen figured by Woodring (1925, pl. 11, fig. 6), a left valve.

Dimensions of lectotype.—Length 3.1 mm; height 2.8 mm.

Type locality.—Bowden, Jamaica. Bowden Formation (early Pliocene).

Paralectotype.—USNM 482415. This is the specimen figured by Woodring (1925, pl. 11, fig. 7), a left valve.

Dimensions of paralectotype USNM 482415.—Length 2.7 mm; height 2.4 mm.

Paralectotype.—USNM 482416. This is the specimen figured by Woodring (1925, pl. 11, fig. 8), a right valve.

Dimensions of paralectotype USNM 482416.—Length 3.0 mm; height 2.5 mm.

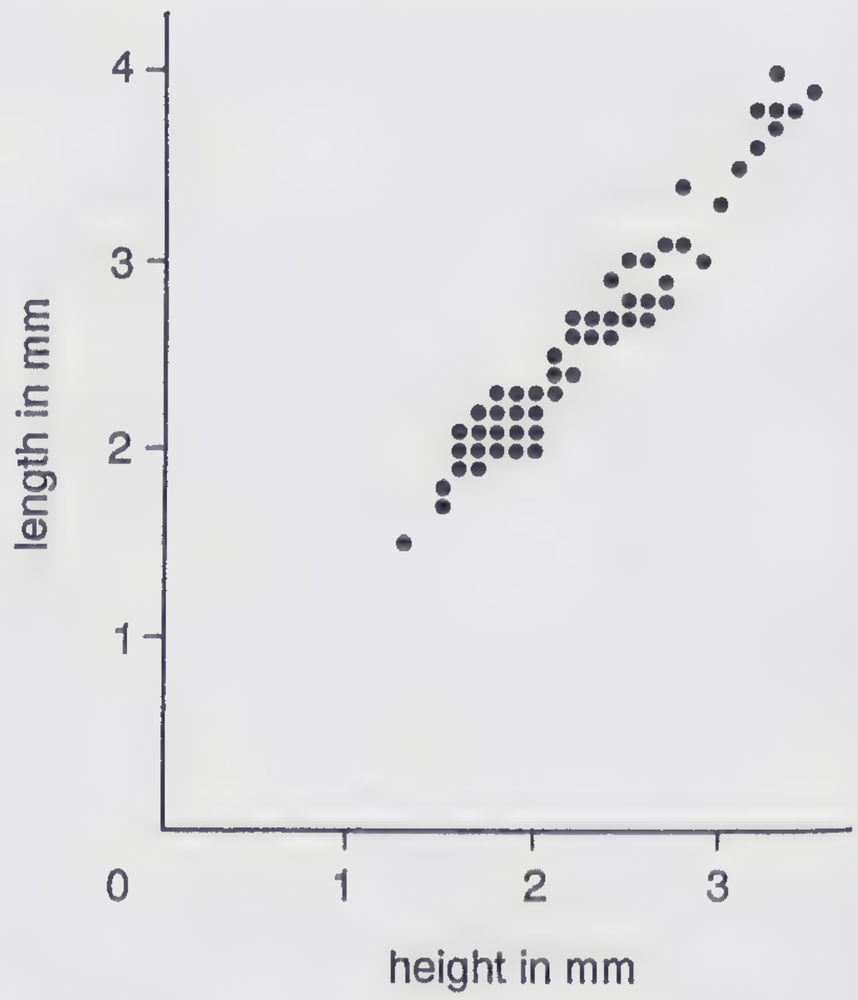
Remarks.—The type material of this species consists of the lectotype and the two paralectotypes mentioned above. All three specimens are glued to a piece of black paper. As explained under *Cardiomya* (*Bowdenia*) *distira,* it has not been possible to remove the specimens from the black paper. The lectotype is therefore not refigured here.

As hinted at in the above description, there is some variability as to the number of radial ribs. The large majority of the specimens at hand has eight to 10 radial ribs. Only two valves out of the 90 available specimens have only seven radial ribs (Text-fig. 16). One is from Jamaica, the other from the Dominican Republic.

Comparisons.—The Recent Caribbean *T. ornata* d'Orbigny is larger than *T. bowdenensis* and has more radial ribs. The Recent Eastern Pacific *T. pacifica* has about the same number of radial ribs as *T. bowdenensis* but reaches even larger dimensions than *T. ornata* (see also "Comparisons" under *T. pacifica*).

Material.—32 lots with a total of 112 specimens as listed below:

1. 1 spec., NMB locality 16802: Río Mao; Cercado Formation (late Miocene).
2. 2 spec., TU locality 1293 (= NMB locality 18583): Río Mao, Bluff 1 of Maury; late Miocene.
3. 1 spec., NMB locality 15804: Río Gurabo; Gurabo Formation (early Pliocene).
4. 1 spec., NMB locality 15823: Río Gurabo; Mao Formation (early Pliocene).
5. 2 spec., NMB locality 15828: Río Gurabo; Mao Formation (early to middle Pliocene).
6. 5 spec., NMB locality 15829: Río Gurabo; Mao Formation (middle Pliocene).
7. 12 spec., NMB locality 15846: Río Gurabo; Gurabo Formation (late Miocene).
8. 1 spec., NMB locality 15849: Río Gurabo; Gurabo Formation (late Miocene).
9. 6 spec., NMB locality 15863: Río Gurabo; Gurabo Formation (late Miocene).
10. 1 spec., NMB locality 15864: Río Gurabo; Gurabo Formation (late Miocene).
11. 2 spec., NMB locality 15865: Río Gurabo; Gurabo Formation (late Miocene).
12. 1 spec., NMB locality 15869: Río Gurabo; Gurabo Formation (late Miocene).
13. 1 spec., NMB locality 15937: Río Gurabo; Gurabo Formation (early Pliocene).
14. 1 spec., NMB locality 15945: Río Gurabo; Gurabo Formation (late Miocene).
15. 1 spec., NMB locality 15962: Río Gurabo; Gurabo Formation (early Pliocene).
16. 1 spec., NMB locality 16031: Río Gurabo; Mao Formation (early Pliocene).
17. 2 spec., NMB locality 16034: Río Gurabo; Mao Formation (early Pliocene).
18. 1 spec., TU locality 1210 (= NMB locality 18579): Río Gurabo; Gurabo Formation (early Pliocene).
19. 2 spec., TU locality 1211 (= NMB locality 18580): Río Gurabo; latest Miocene part of Gurabo Formation.
20. 2 spec., TU locality 1215 (= NMB locality 18581): Río Gurabo; Gurabo Formation (late Miocene).
21. 6 spec., NMB locality 16817: Río Cana; Gurabo Formation (early Pliocene).



Text-figure 17.—Length/height diagram of *Trigonulina bowdenensis* (Dall, 1903).

22. 3 spec., NMB locality 16818: Río Cana; Gurabo Formation (early Pliocene).
23. 4 spec., NMB locality 16824: Río Cana; Gurabo Formation (early Pliocene).
24. 1 spec., NMB locality 16828: Río Cana; Gurabo Formation (late Miocene).
25. 1 spec., NMB locality 16832: Río Cana; Gurabo Formation (late Miocene).
26. 2 spec., NMB locality 16833: Río Cana; Gurabo Formation (late Miocene).
27. 1 spec., NMB locality 16961: Río Cana; Gurabo Formation (early Pliocene).
28. 1 spec., NMB locality 17026: Río Cana; Cercado Formation (late Miocene).
29. 10 spec., TU locality 1354 (= NMB locality 18585): Río Cana, Cañada de Zamba; Gurabo Formation (early Pliocene).
30. 5 spec., TU locality 1250 (= NMB locality 18558): Río Verde; Gurabo Formation (late Miocene or early Pliocene).
31. 29 spec., NMB locality 10635: Bowden, Jamaica; Bowden Formation (early Pliocene).
32. 3 spec., USNM 135689 (lectotype) and two paralectotypes (USNM 482415, 482416). Bowden, Jamaica; Bowden Formation (early Pliocene).

Measurements.—Plotted in Text-figure 17.

Occurrence.—This species is recorded from the following areas:

Río Mao: Cercado Formation (late Miocene): NMB locality 16802, TU locality 1293 (Saunders *et al.*, 1986, text-fig. 29).

Río Gurabo: late Miocene part of Gurabo Formation: NMB localities 15846, 15849, 15863, 15864, 15865, 15869, 15945 and TU localities 1211, 1215. Early Pliocene part of Gurabo Formation: NMB localities 15804, 15937, 15962, and TU locality 1210. Mao Formation (early Pliocene and early to middle Pliocene): NMB localities 15823, 15828, 15829, 16031, 16034. For location see Saunders *et al.*, 1986, text-figs. 4–6).

Río Cana: Cercado Formation (late Miocene): NMB locality 17026. Late Miocene part of Gurabo Formation: NMB localities 16828, 16832, 16833. Early Pliocene part of Gurabo Formation: NMB localities 16817, 16818, 16824, 16961, and TU locality 1354 (Saunders *et al.*, 1986, text-figs. 15, 16).

Río Verde: Gurabo Formation: TU locality 1250 (Saunders *et al.*, 1986, text-fig. 38).

Distribution.—Bowden Formation (early Pliocene) of Bowden, Jamaica. Cercado Formation (late Miocene), late Miocene and early Pliocene parts of Gurabo Formation, and Mao Formation (early Pliocene and early to middle Pliocene), Dominican Republic.

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PLATES

EXPLANATION OF PLATE 1

1. NMB G 14145. NMB locality 15907: Río Gurabo, Dominican Republic; uppermost part of Cercado Formation (late Miocene). Exterior of right valve. Length 9.3 mm; height 5.4 mm.
2, 3. NMB G 14144. NMB locality 16923: Río Mao, Arroyo Bajón, Dominican Republic; Cercado Formation (late Miocene). Right valve. 2. Enlargement of hinge, ×30. 3. Interior. Length 8.4 mm; height 5.2 mm.
4, 5. NMB G 14146. NMB locality 15903: Río Gurabo, Dominican Republic; upper part of Cercado Formation (late Miocene). Left valve. 4. Interior. 5. Enlargement of hinge, ×30. Length 8.7 mm; height 5.8 mm.
6. NMB G 14147. NMB locality 16929: Río Mao, Dominican Republic; Cercado Formation (late Miocene). Exterior of left valve. Length 7.6 mm; height 4.8 mm.


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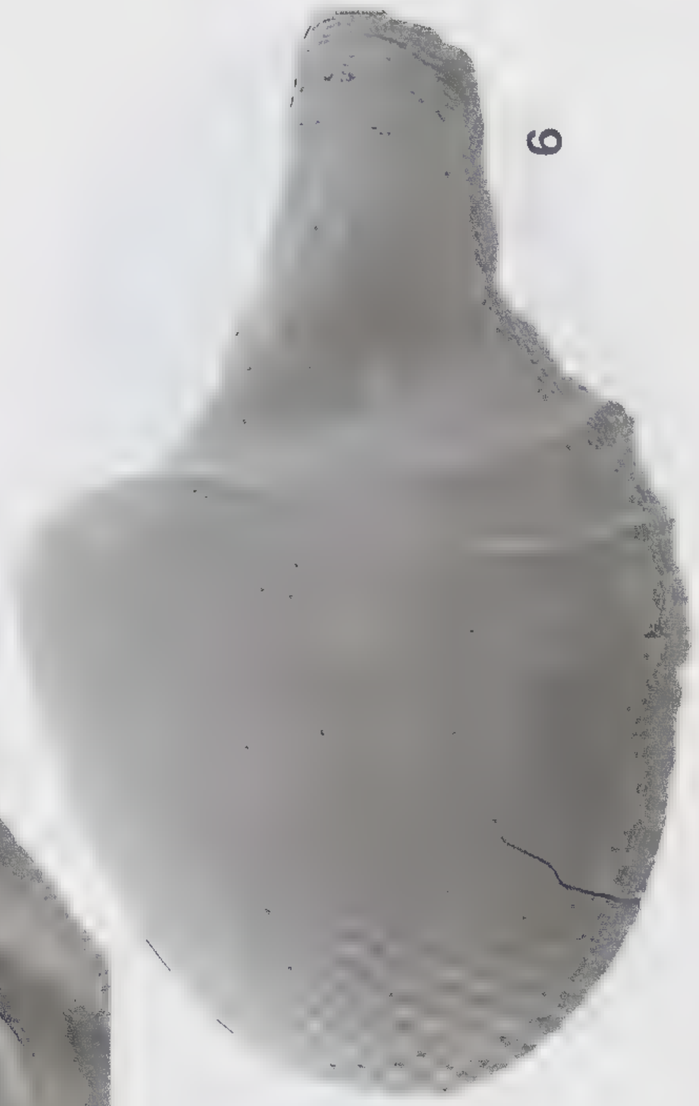
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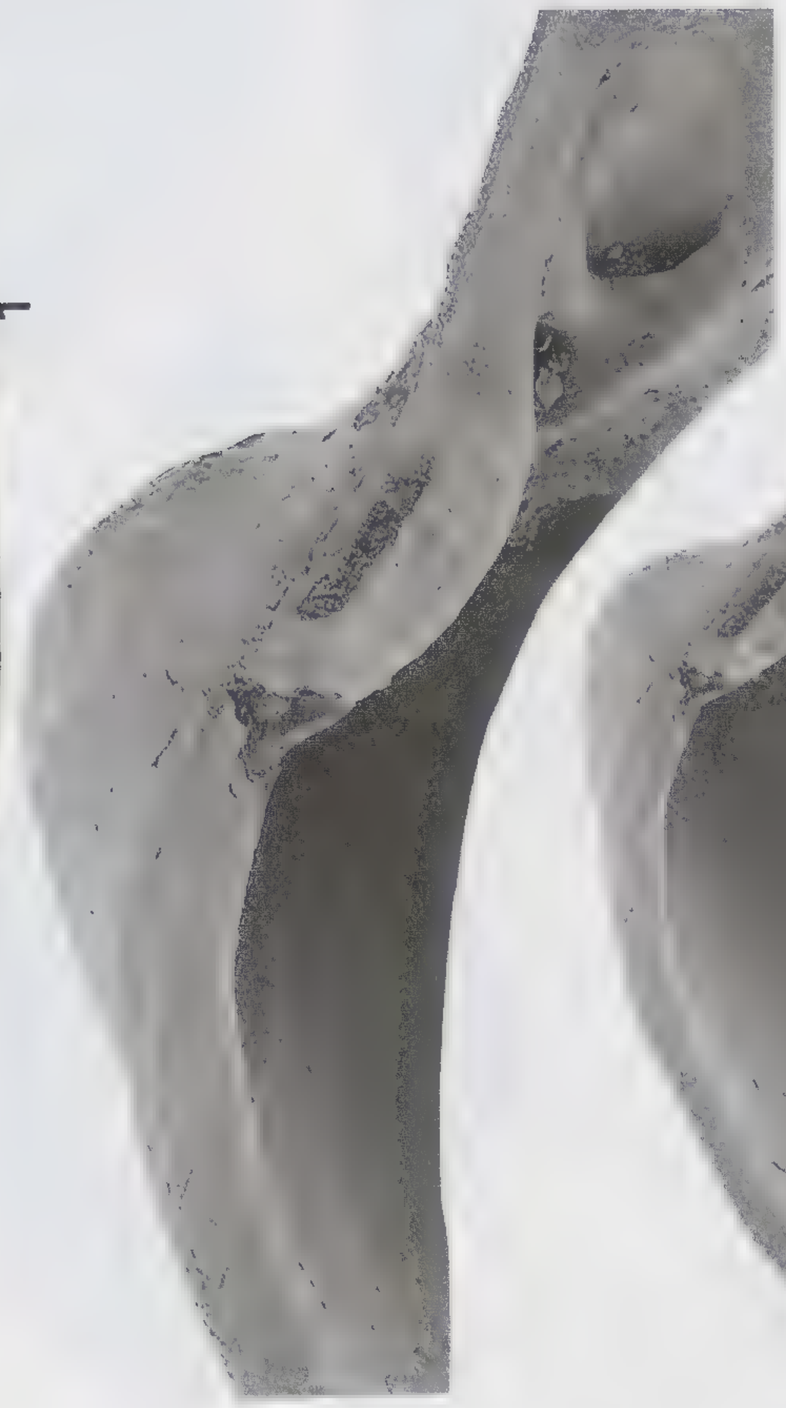
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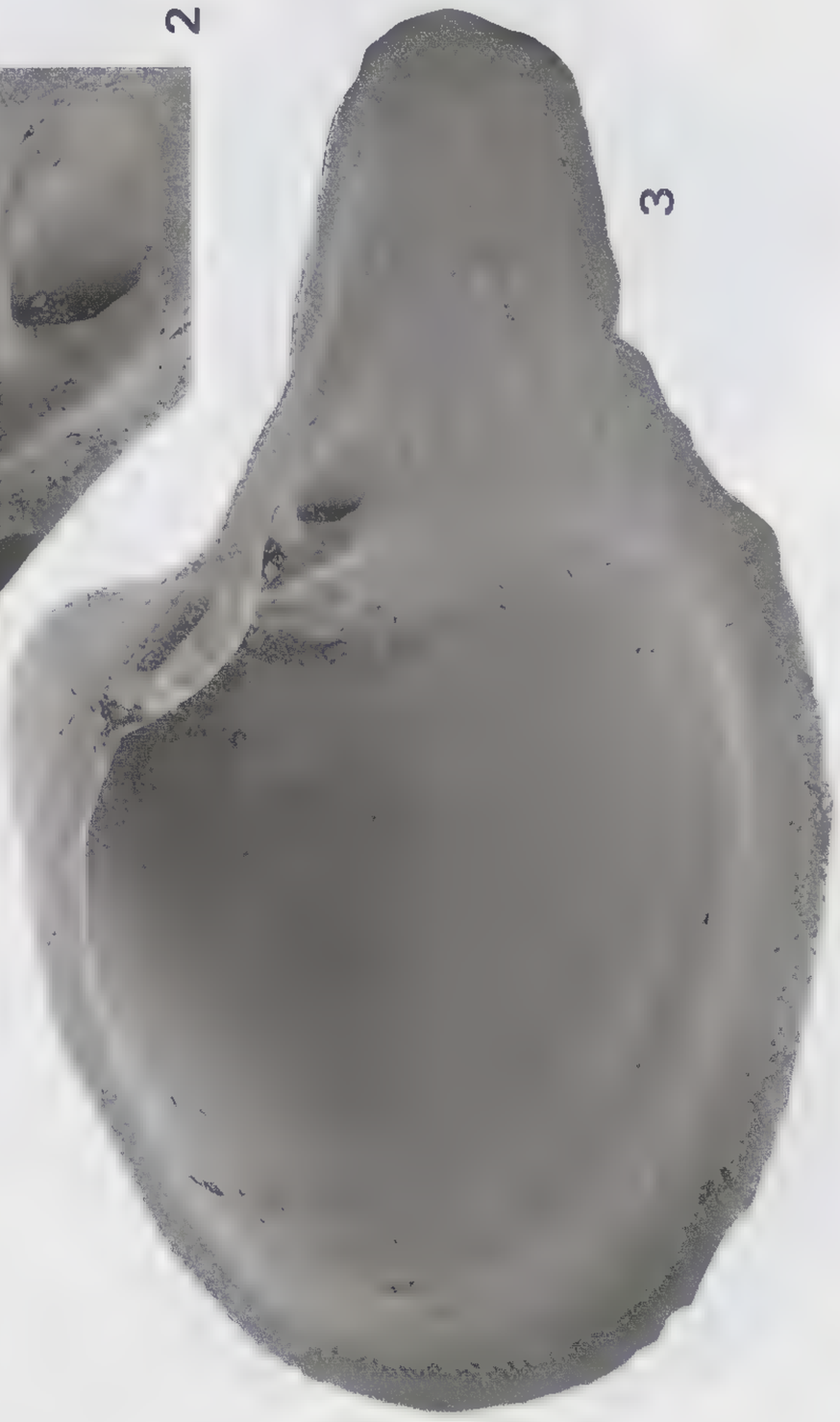
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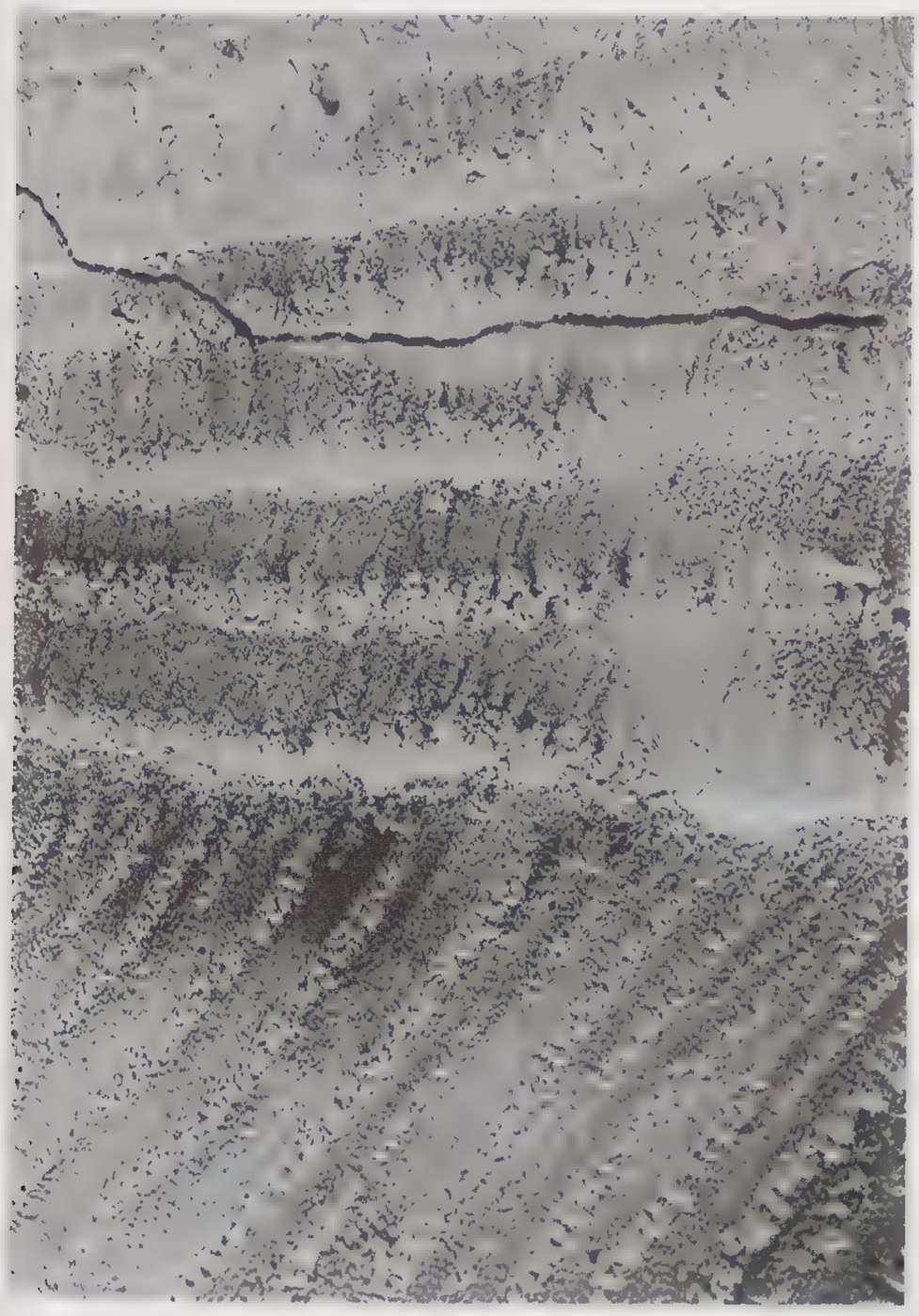
EXPLANATION OF PLATE 2

EXPLANATION OF PLATE 3

Figure

1–4. NMB G 14139. NMB locality 15846 Río Gurabo, Dominican Republic; latest Miocene part of Gurabo Formation. Incomplete right valve. 1. Exterior; 2. Enlargement of sculpture, ×120; 3. Interior; 4. Enlargement of hinge, ×60. Length 2.7 mm; height 2.2 mm.

5. NMB G 14140. NMB locality 10635: Bowden, Jamaica; type locality of Bowden Formation (early Pliocene). Interior of right valve. Length 3.2 mm; height 2.0 mm.



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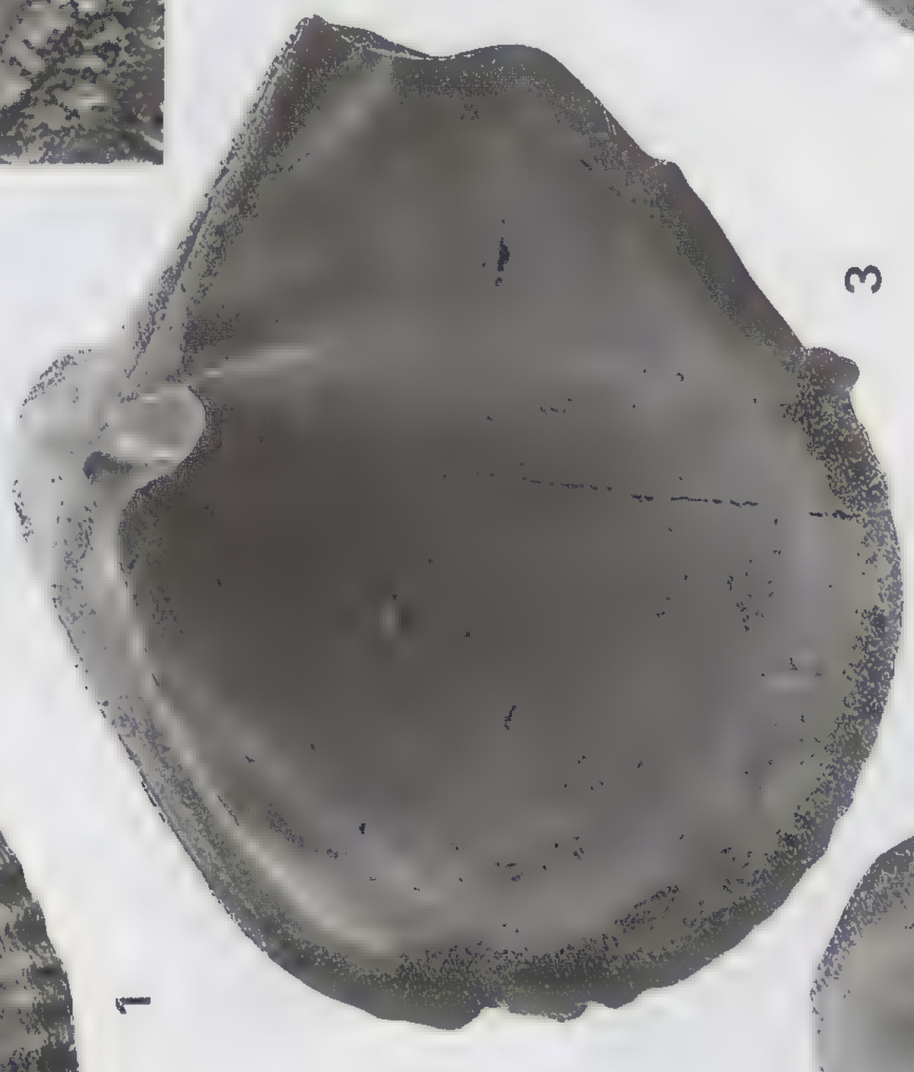

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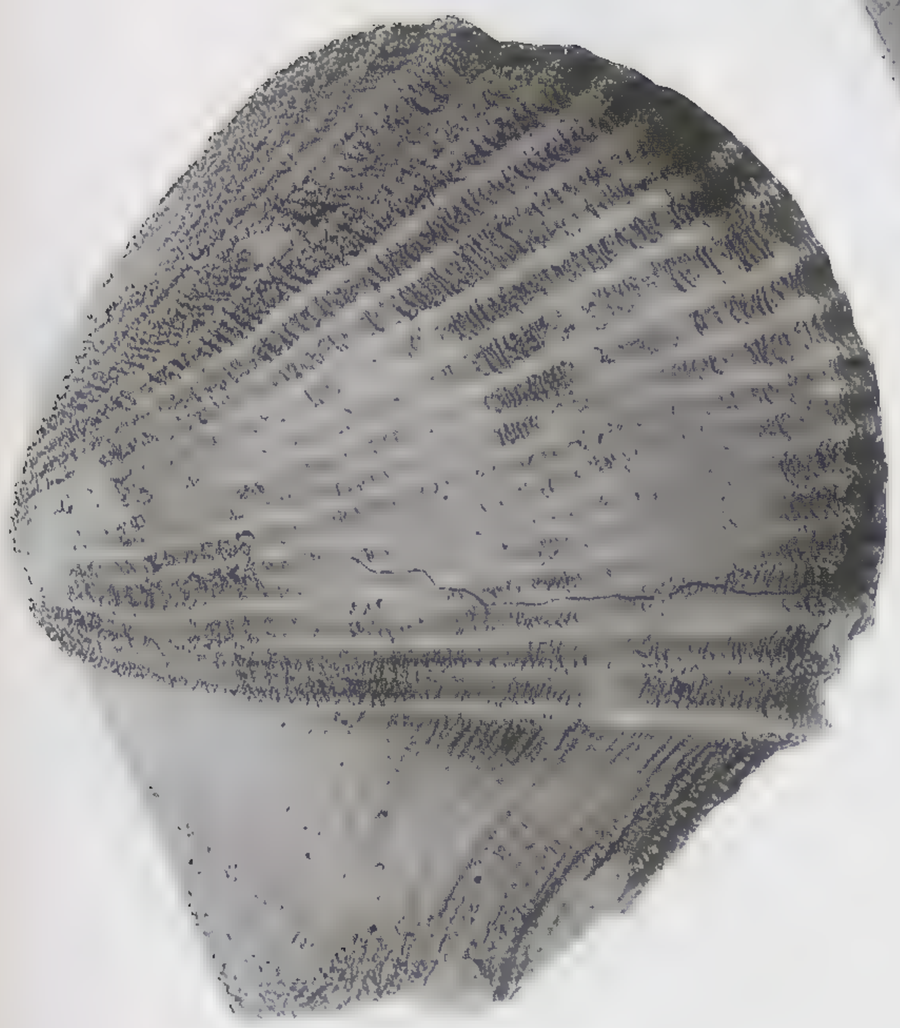

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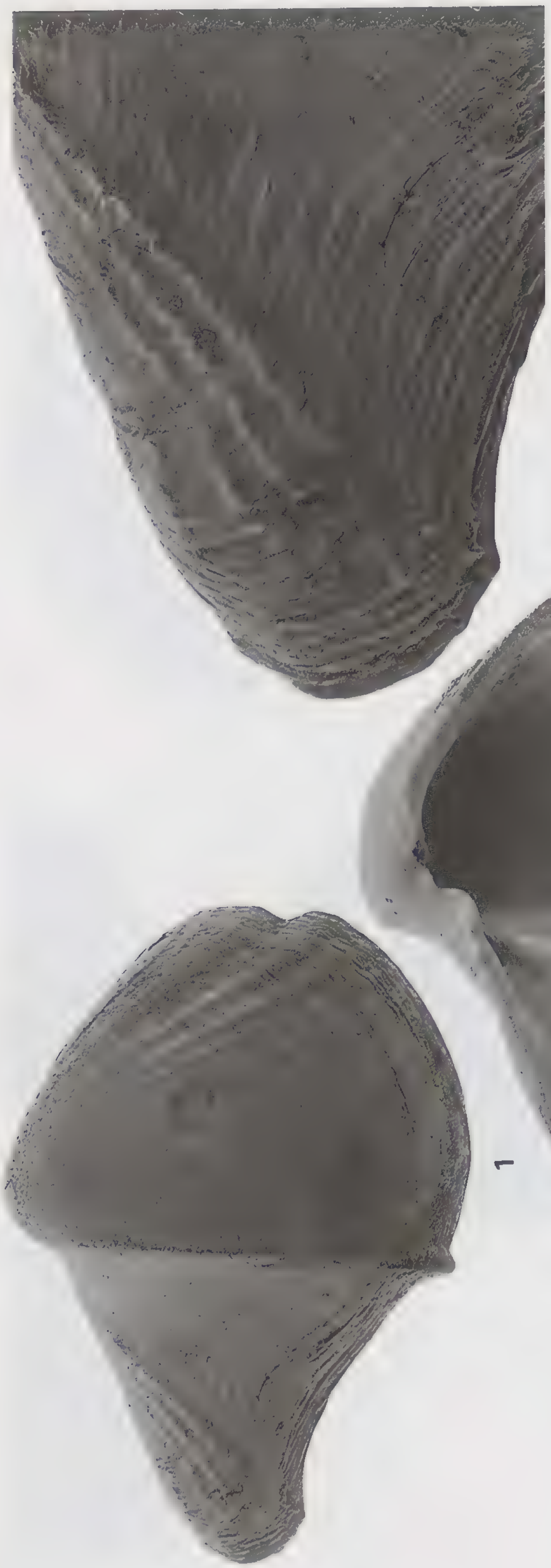
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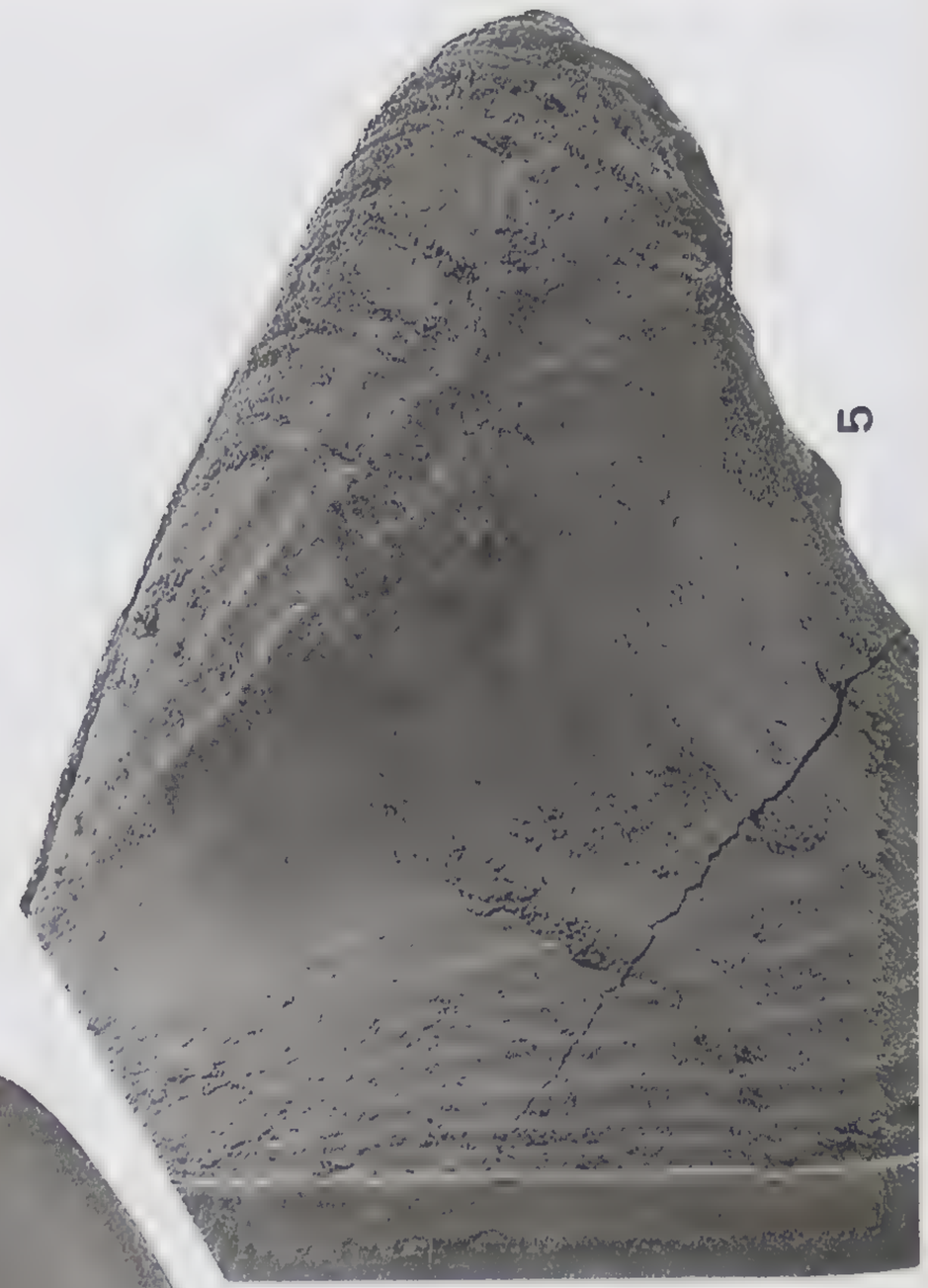
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EXPLANATION OF PLATE 4

Figure

All specimens from NMB locality 10635: Bowden, Jamaica; type locality of Bowden Formation (early Pliocene).

1, 2. NMB G 14141. Right valve. 1. Exterior; 2. Enlargement of rostrum, ×90. Length 3.0 mm; height 2.0 mm.

3. NMB G 14142. Interior of left valve. Length 2.9 mm; height 2.3 mm.

4, 5. NMB G 14143. Left valve. 4. Exterior; 5. Enlargement of rostrum, ×65. Length 3.3 mm; height 2.3 mm.

Explanation of Plate 5

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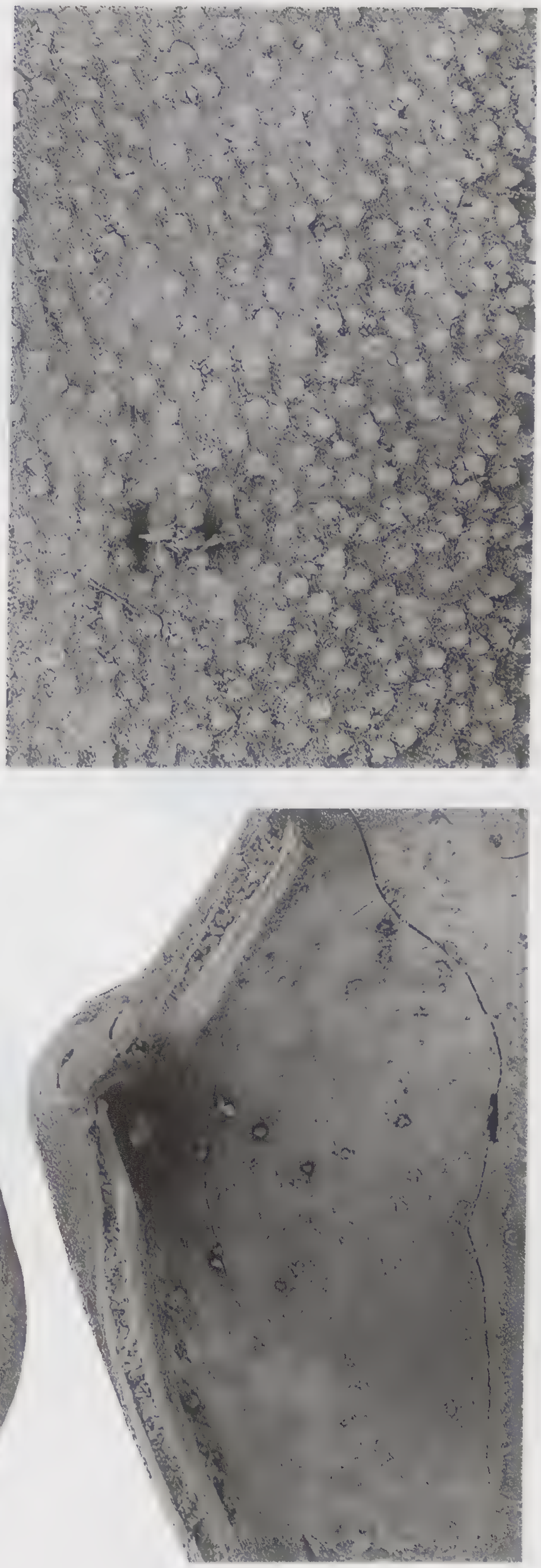

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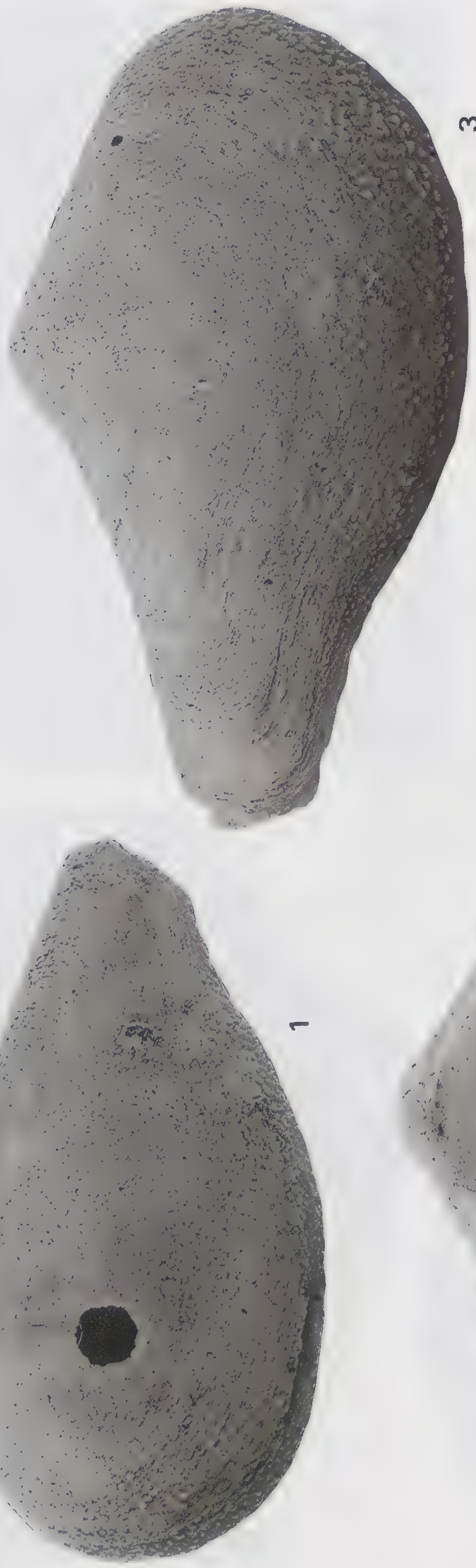
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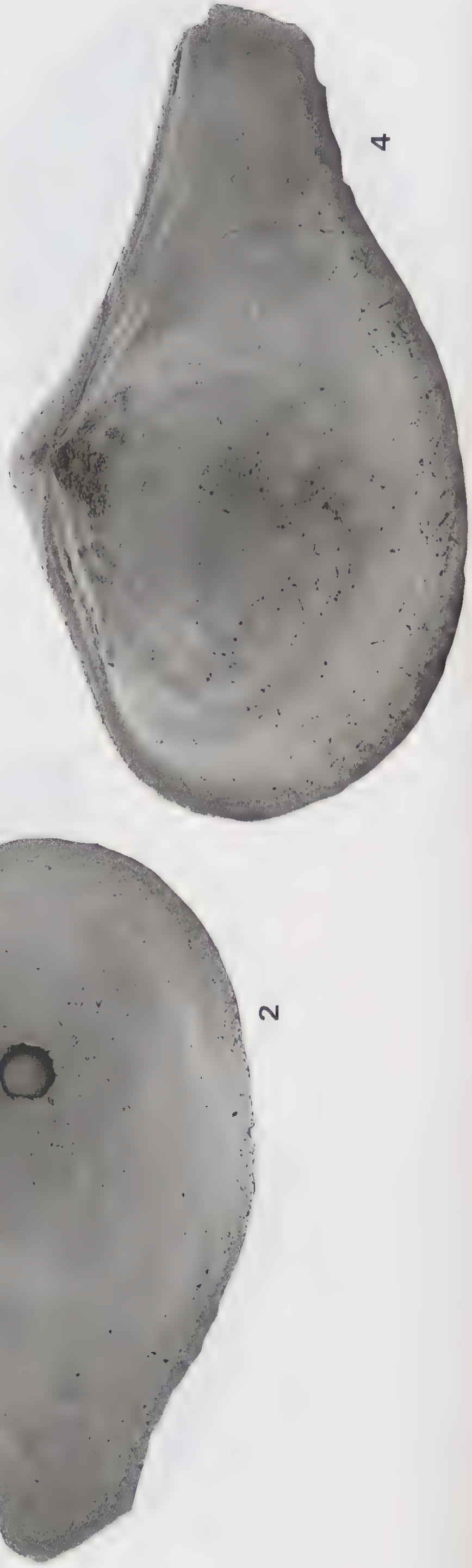
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EXPLANATION OF PLATE 6

Figure

USNM 94214. Recent. Station 2648: off Cape Florida, 84 fms., sand.

1, 2. Left valve. 1. Exterior; 2. Interior. Length 8.8 mm; height 5.6 mm.

3, 4. Right valve. 3. Exterior; 4. Interior. Length 11.5 mm; height 6.5 mm.

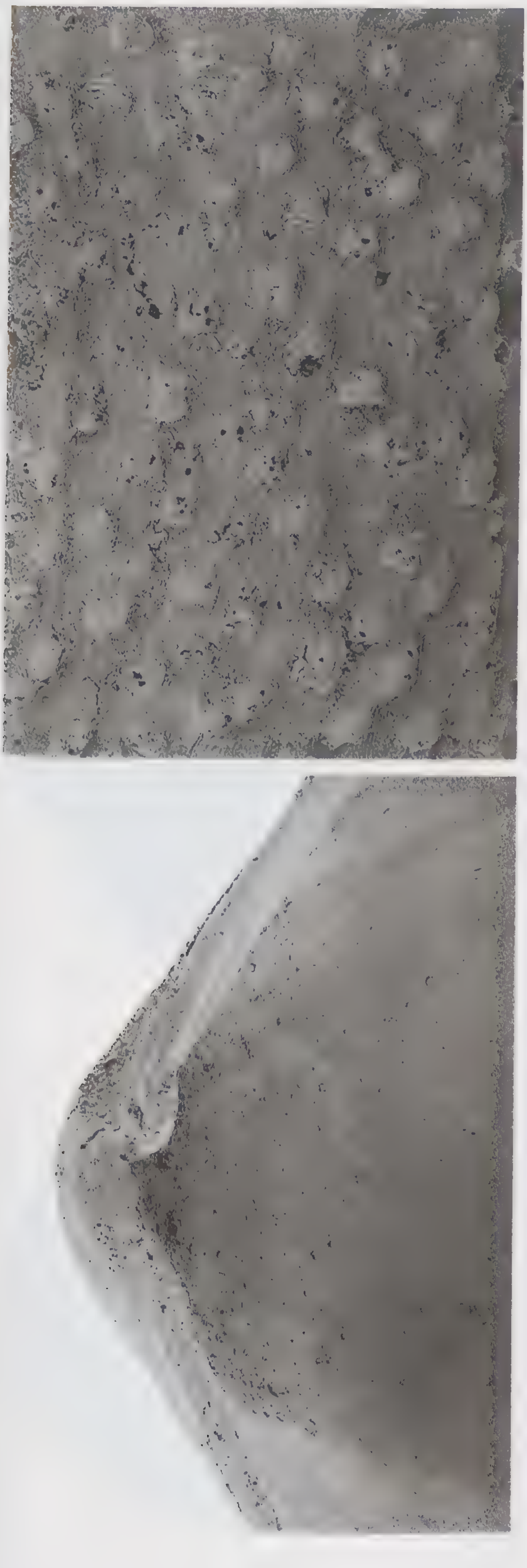
EXPLANATION OF PLATE 7

Figure — Page

1–4. *Plectodon granulatus* (Dall, 1881) 46

USNM 94214. Recent. Station 2648: off Cape Florida, 84 fms., sand.

1. Enlargement of left hinge (×30) of specimen shown on Plate 6, figure 2.
2. Enlargement of right hinge (×20) of specimen shown on Plate 6, figure 4.
3, 4. Enlargement of sculpture of right valve shown on Plate 6, figure 3. 3. Near center of shell disc, ×60; 4. Towards rostrum, ×50.



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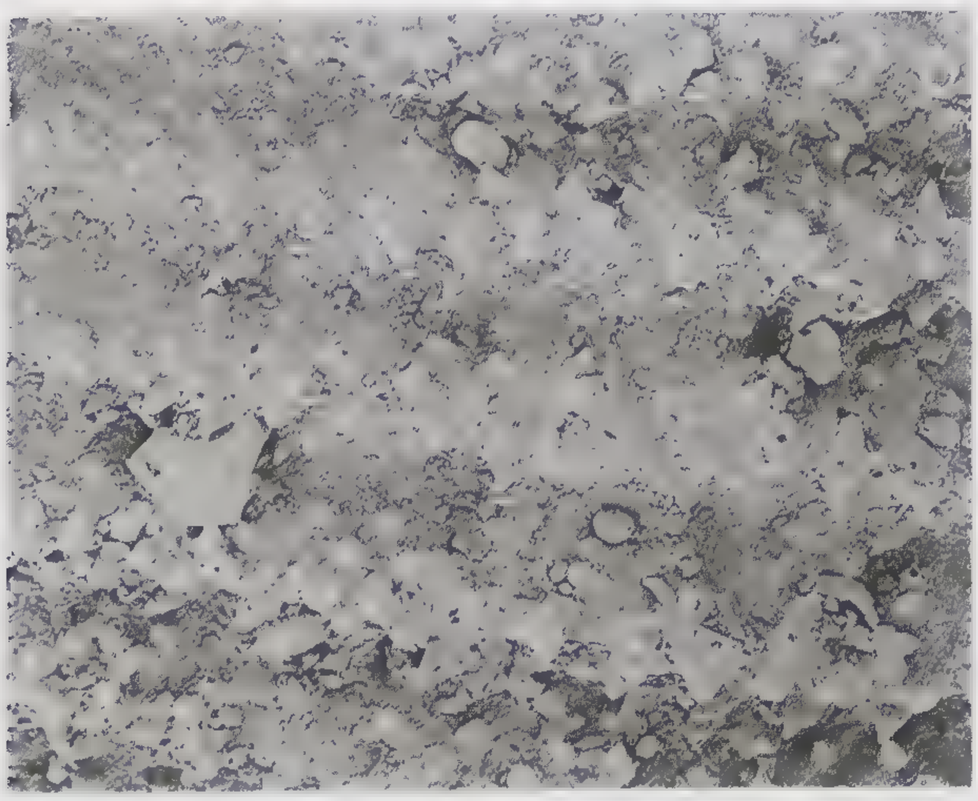

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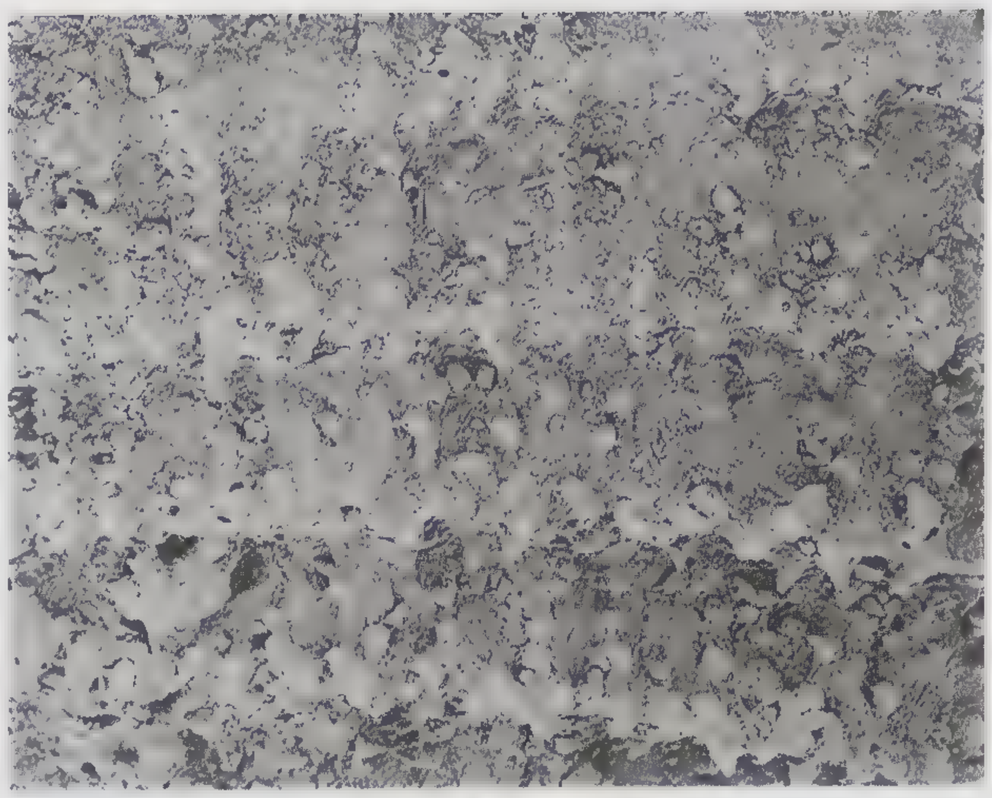

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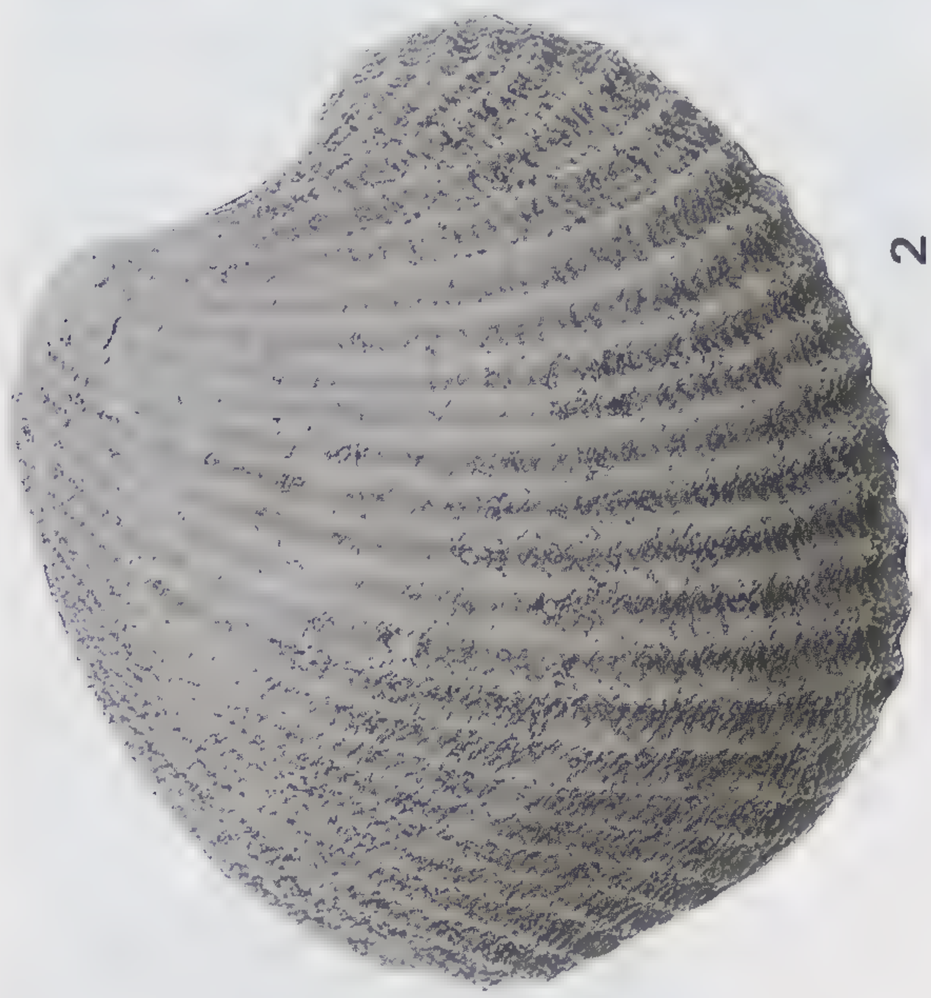

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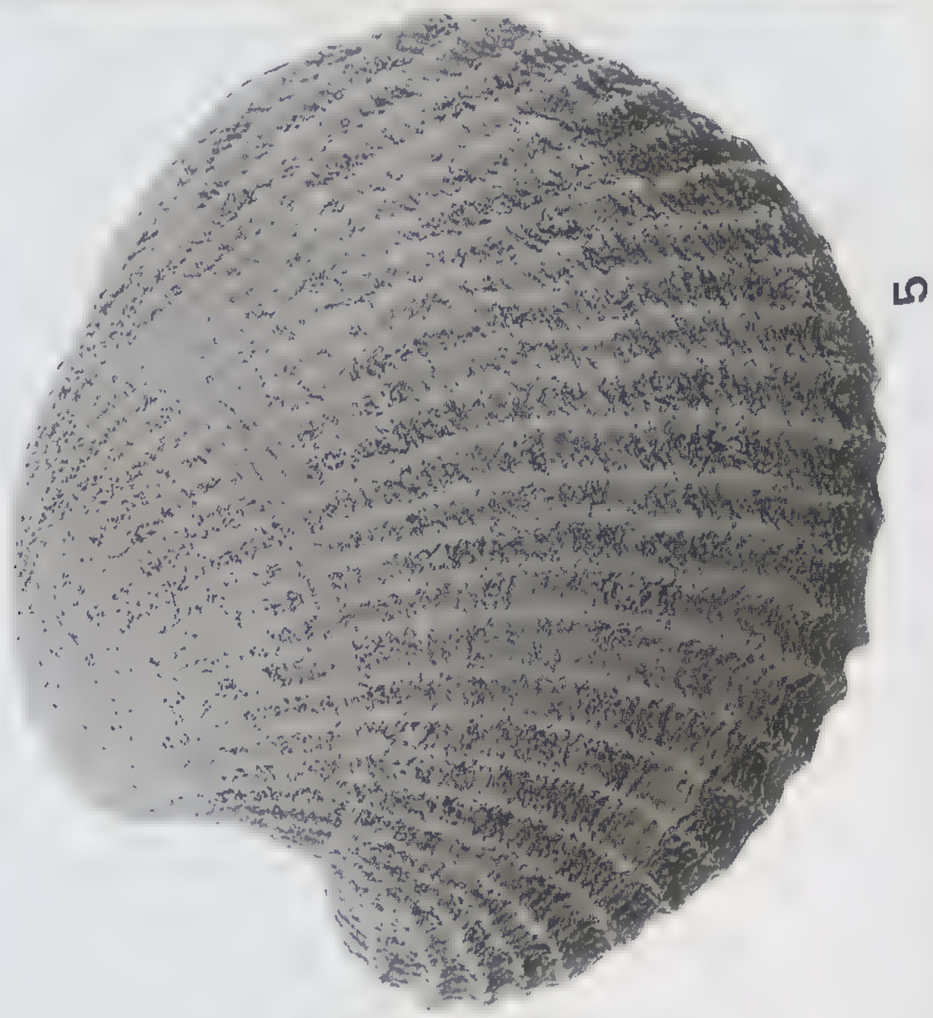

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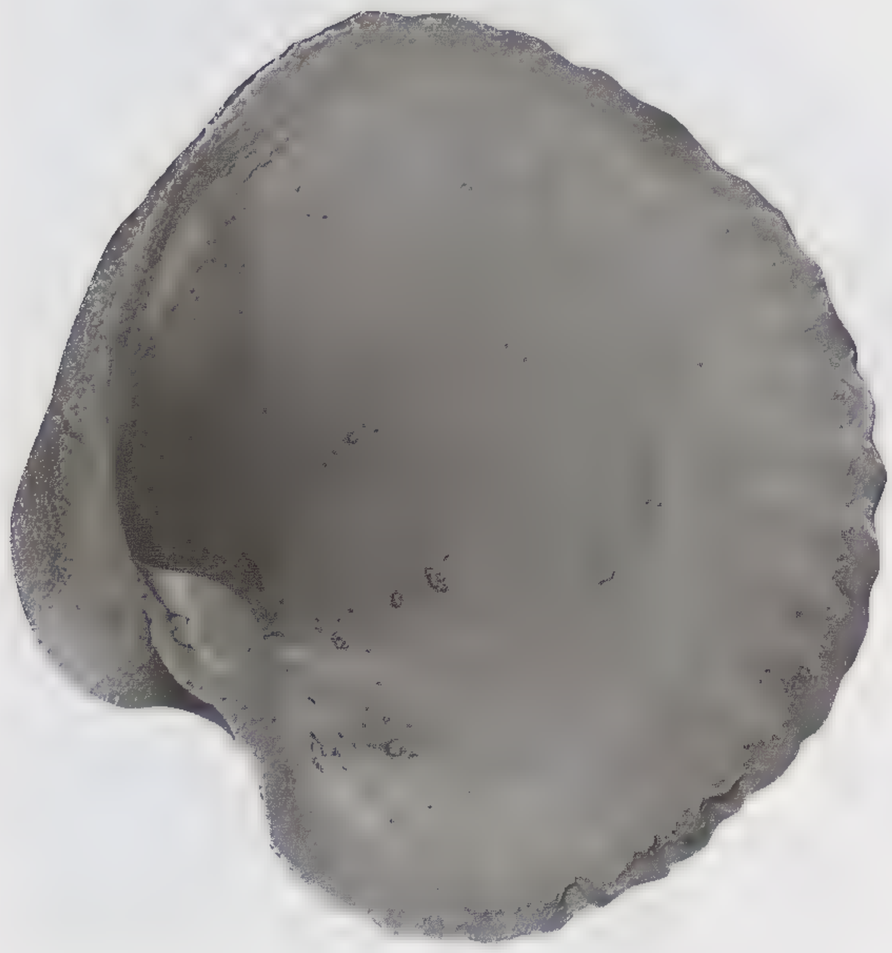

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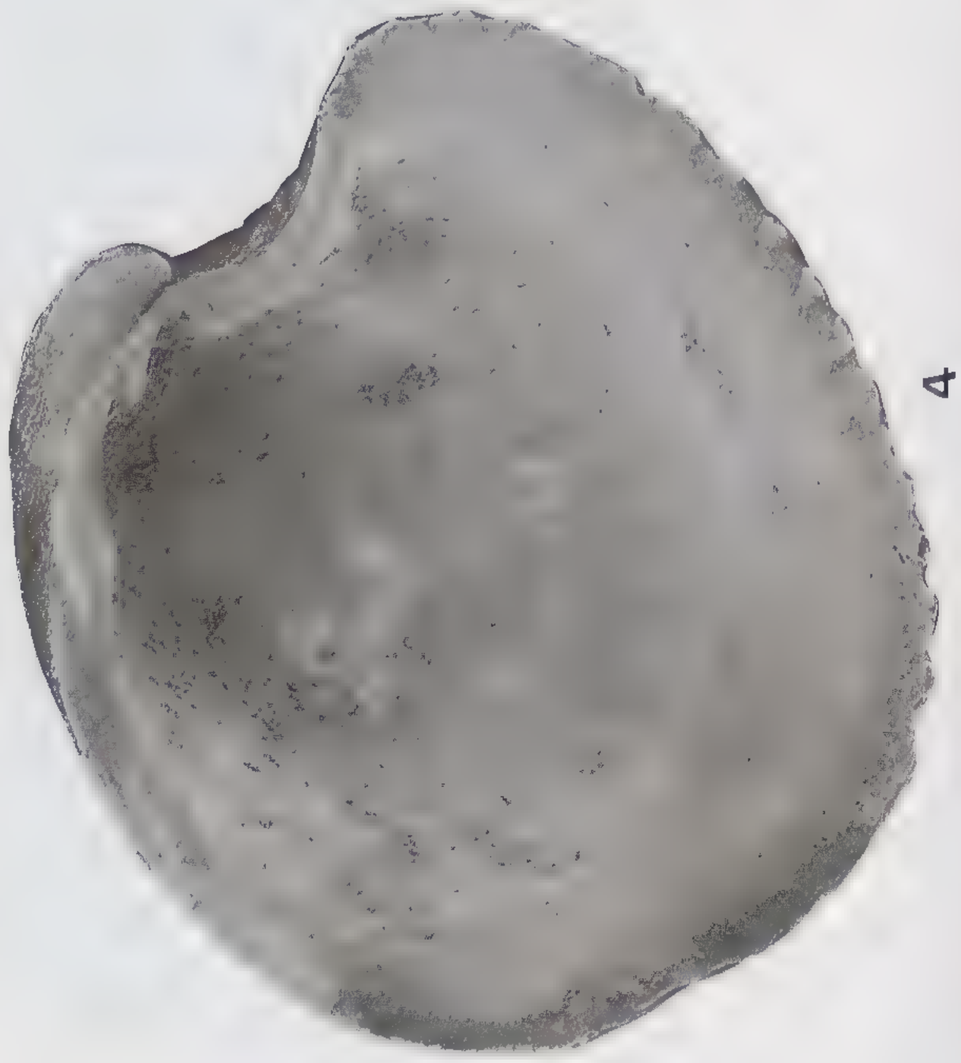

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EXPLANATION OF PLATE 8

Figure

USNM 444416. Recent. Eolis Station 370: off Ajax Reef, Florida, 70–90 fms.

1. Interior of right valve. Length 6.0 mm; height 5.6 mm.
2, 3. Exterior of right valve. Length 6.1 mm; height 5.7 mm. 3. Enlargement of sculpture, ×50.
4. Interior of left valve. Length 6.1 mm; height 5.6 mm.
5, 6. Exterior of left valve. Length 6.4 mm; height 5.8 mm. 6. Enlargement of sculpture, ×50.

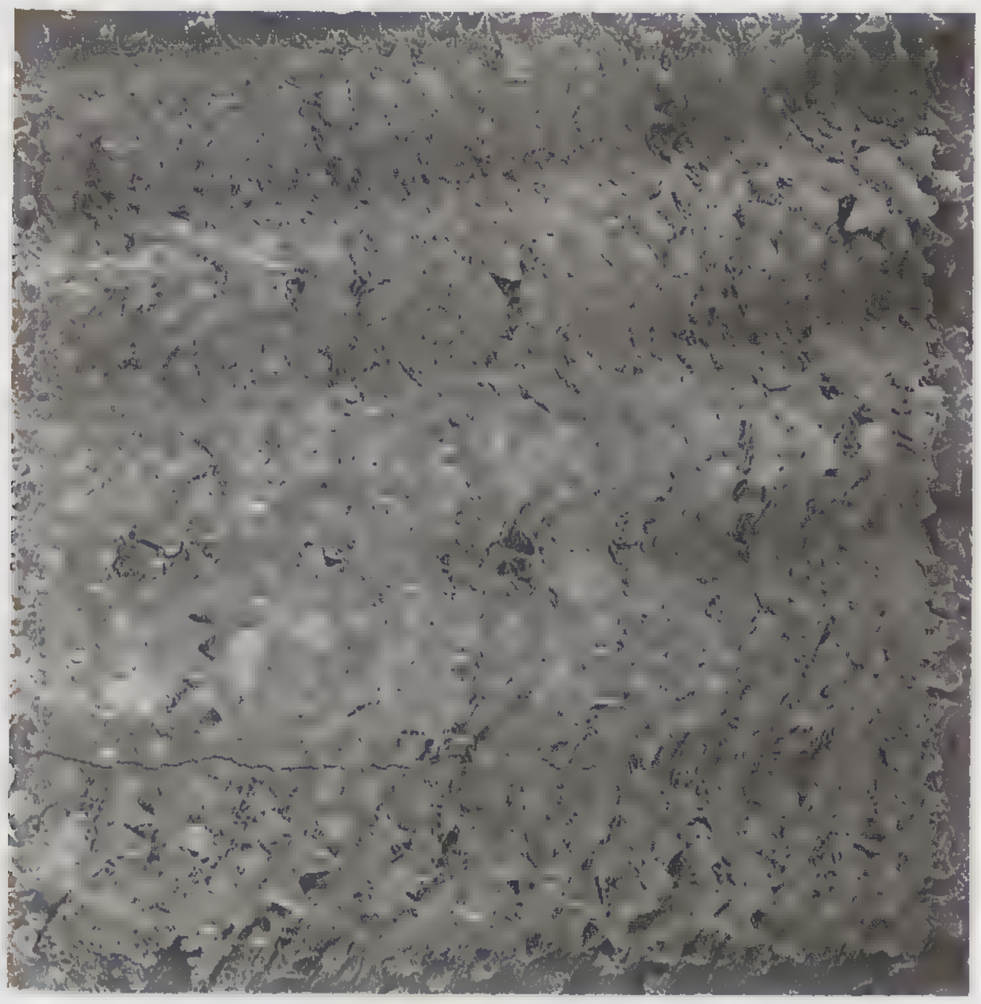
EXPLANATION OF PLATE 9

Figure — Page

1–6. *Haliris jamaicensis* (Dall, 1903) 47

1–3. NMB G 14148. NMB locality: 15832: Río Gurabo, Dominican Republic; middle Pliocene part of Mao Formation. Right valve. 1. Interior; 2. Exterior; 3. Enlargement of sculpture, ×60. Length 4.3 mm; height 4.1 mm.

4–6. NMB G 14149. NMB locality 10635: Bowden, Jamaica; Bowden Formation (early Pliocene). Right valve. 4. Exterior; 5. Interior; 6. Enlargement of hinge, ×40. Length 4.3 mm; height 3.9 mm.



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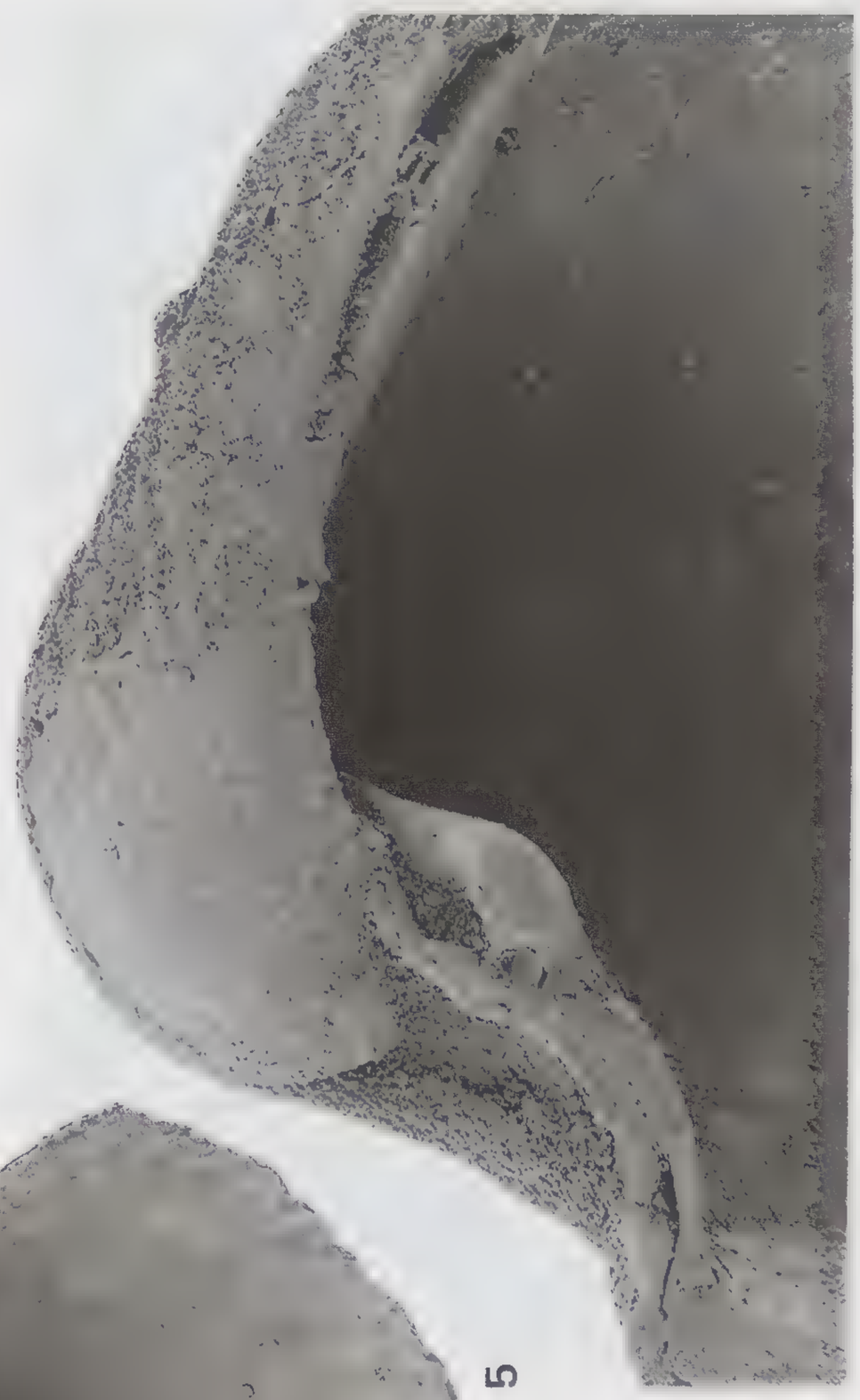

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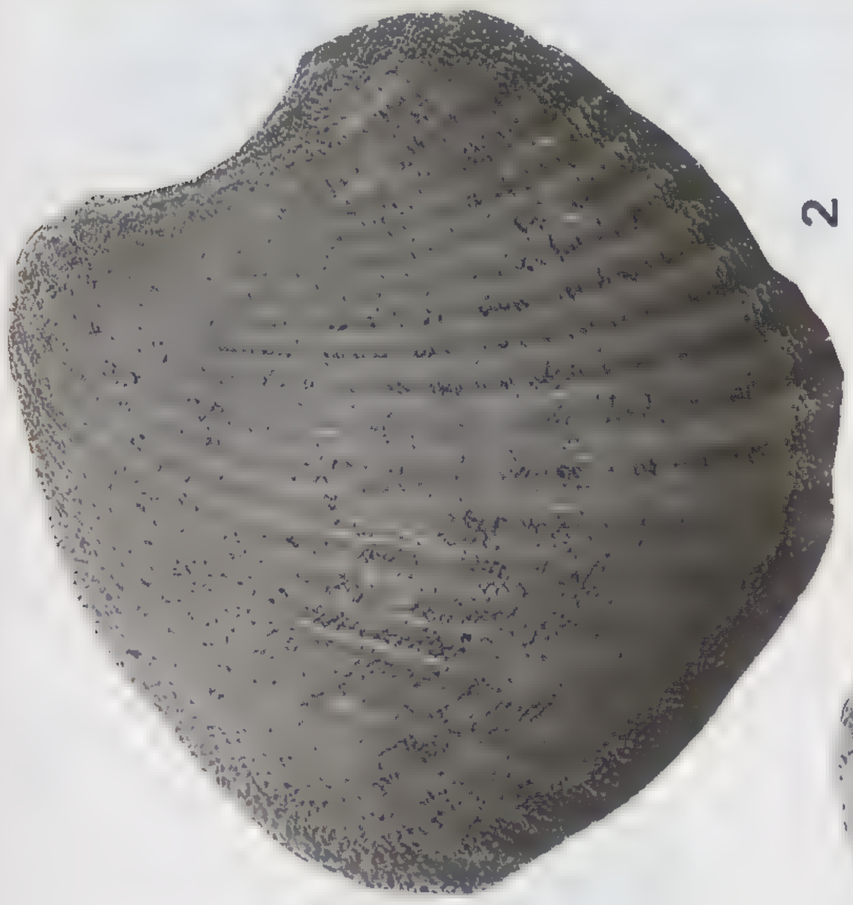

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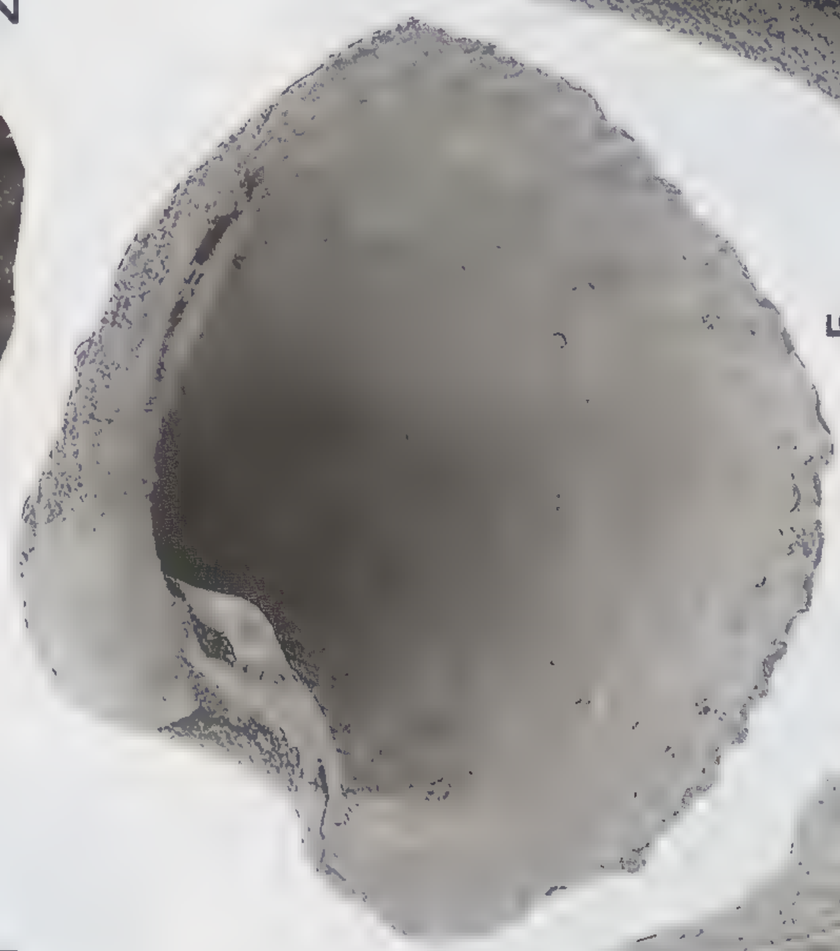

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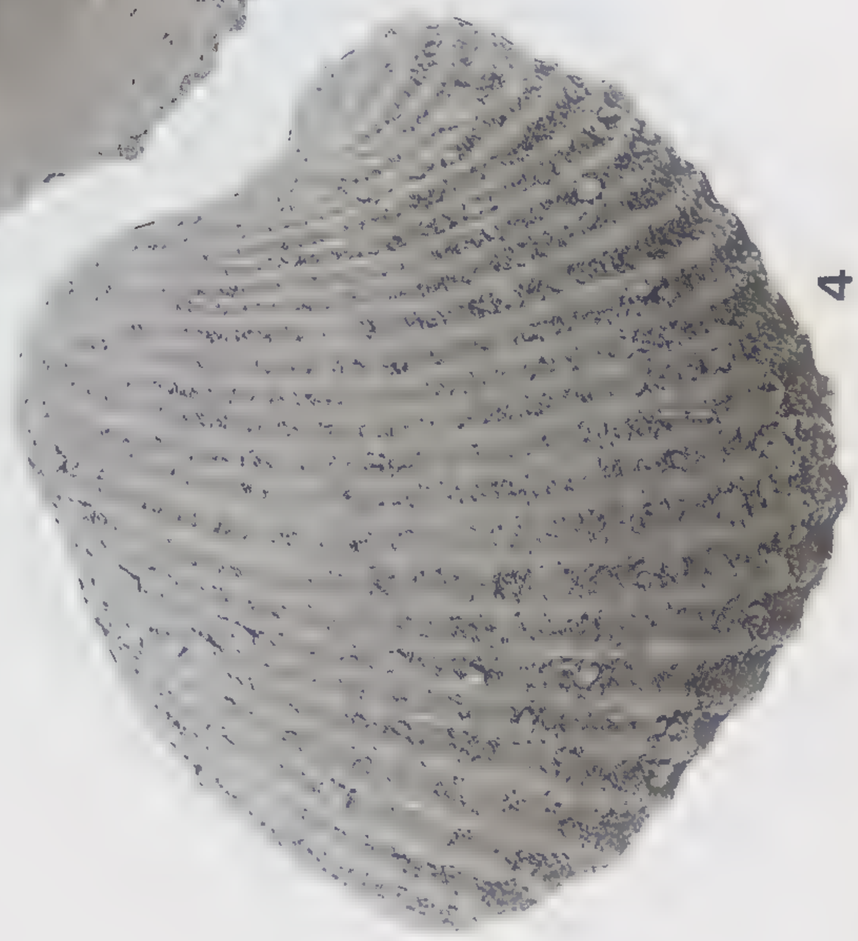

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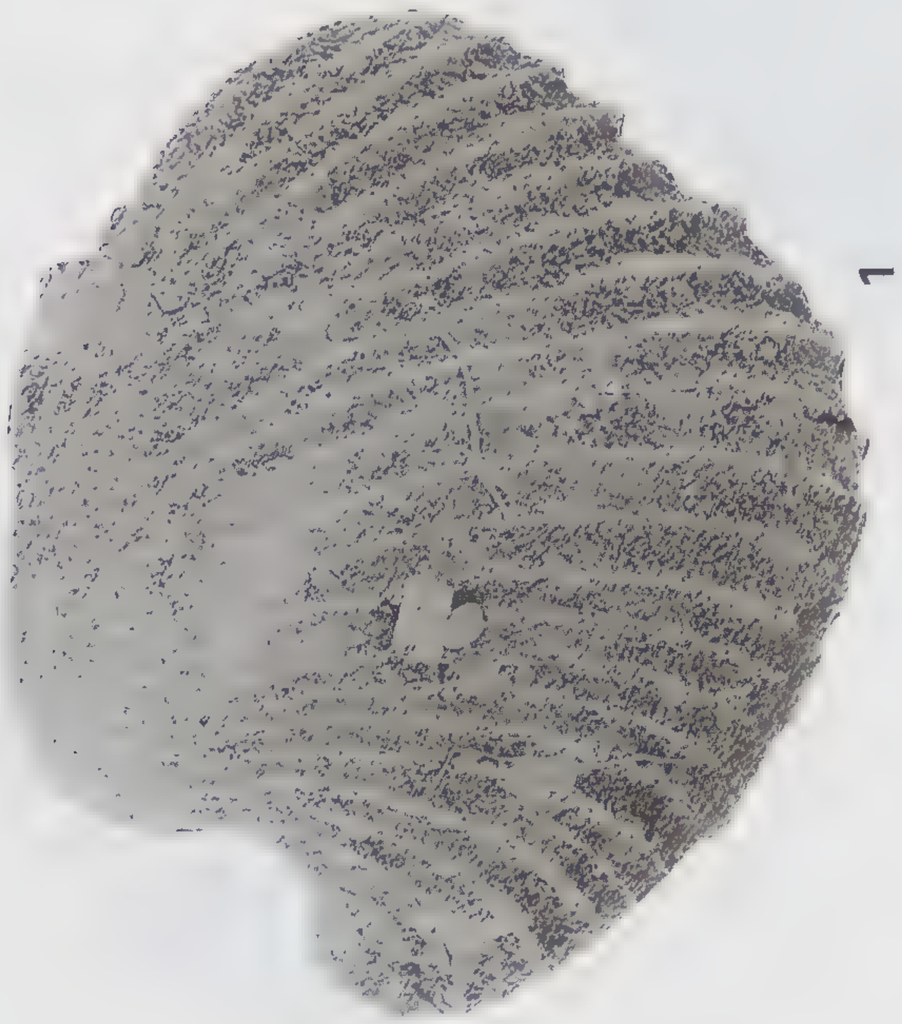

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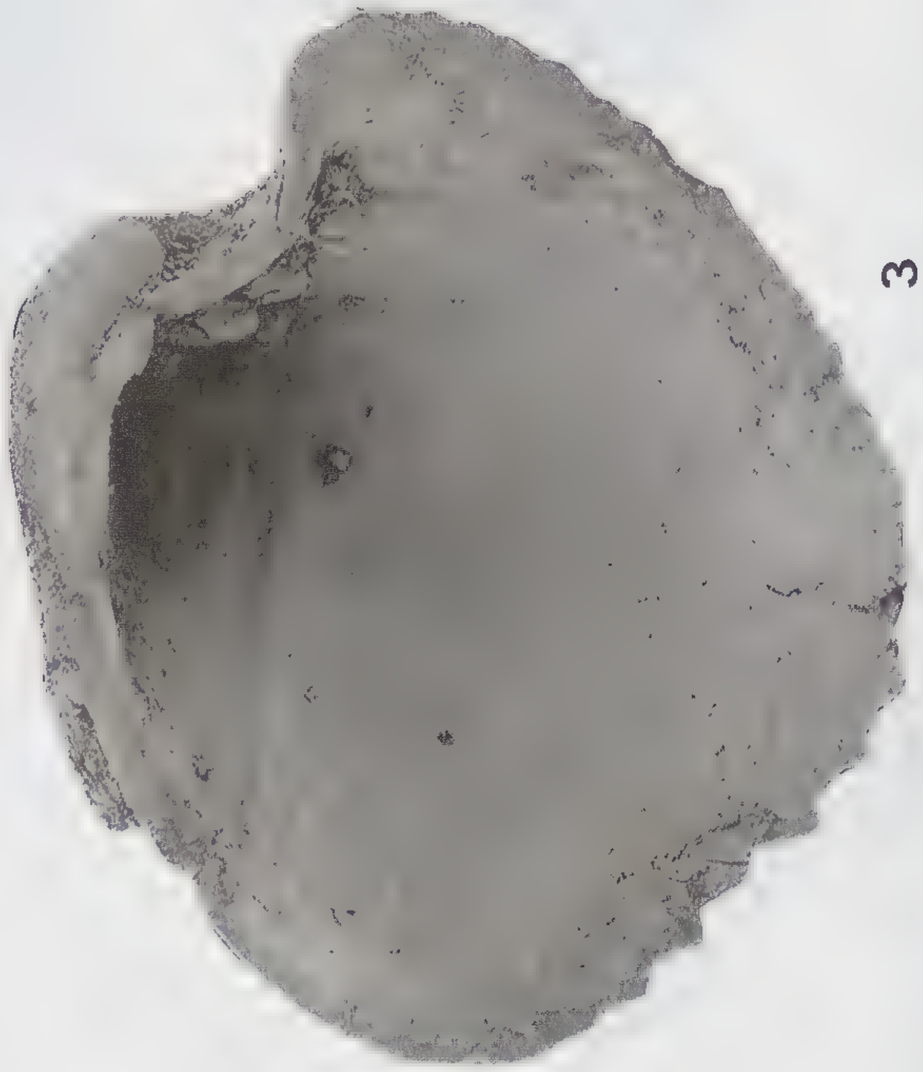

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EXPLANATION OF PLATE 10

Figure

NMB G 14158. NMB locality 10635: Bowden, Jamaica; Bowden Formation (early Pliocene). Left valve. 1. Exterior; 2. Enlargement of sculpture, ×100; 3. Interior; 4. Enlargement of hinge, ×50. Length 3.2 mm; height 2.6 mm.

EXPLANATION OF PLATE 11

Figure — Page

1–4. *Trigonulina ornata* d'Orbigny, 1842 49

USNM 444479. Recent. Eolis Station 178: off Fowey Light, Florida, 68 fms.

1, 2. Interior of right valve. Length 4.2 mm; height 3.8 mm. 2. Enlargement of hinge, ×45.

3, 4. Interior of left valve. Length 3.4 mm; height 3.2 mm. 4. Enlargement of hinge, ×55.

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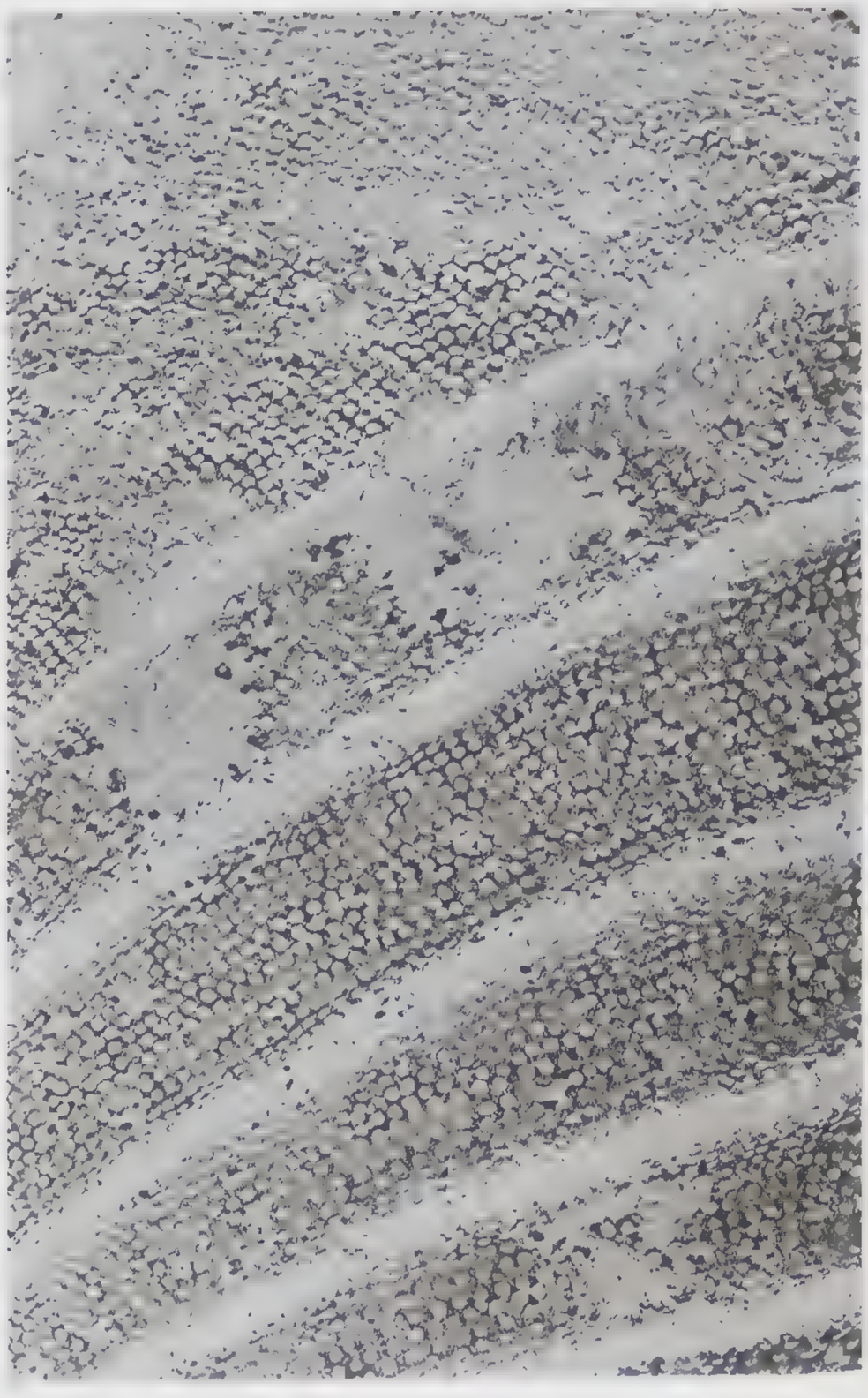

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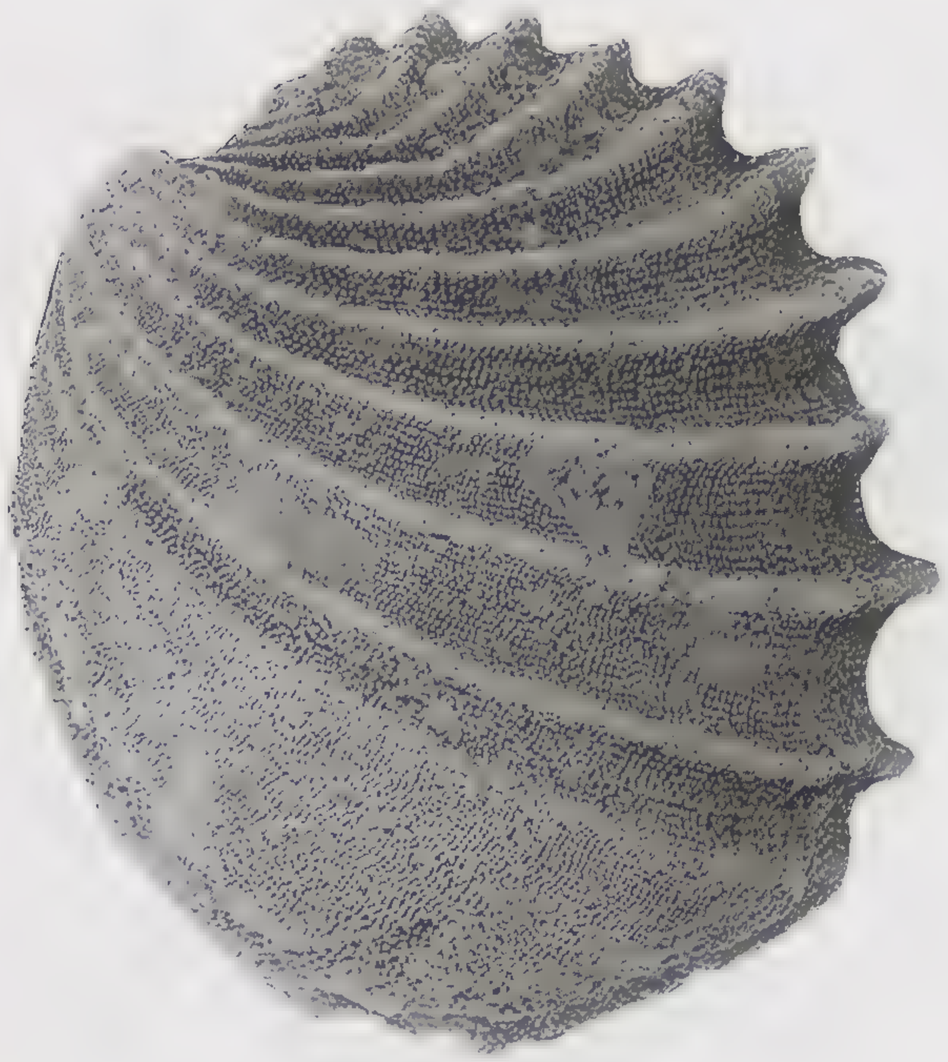

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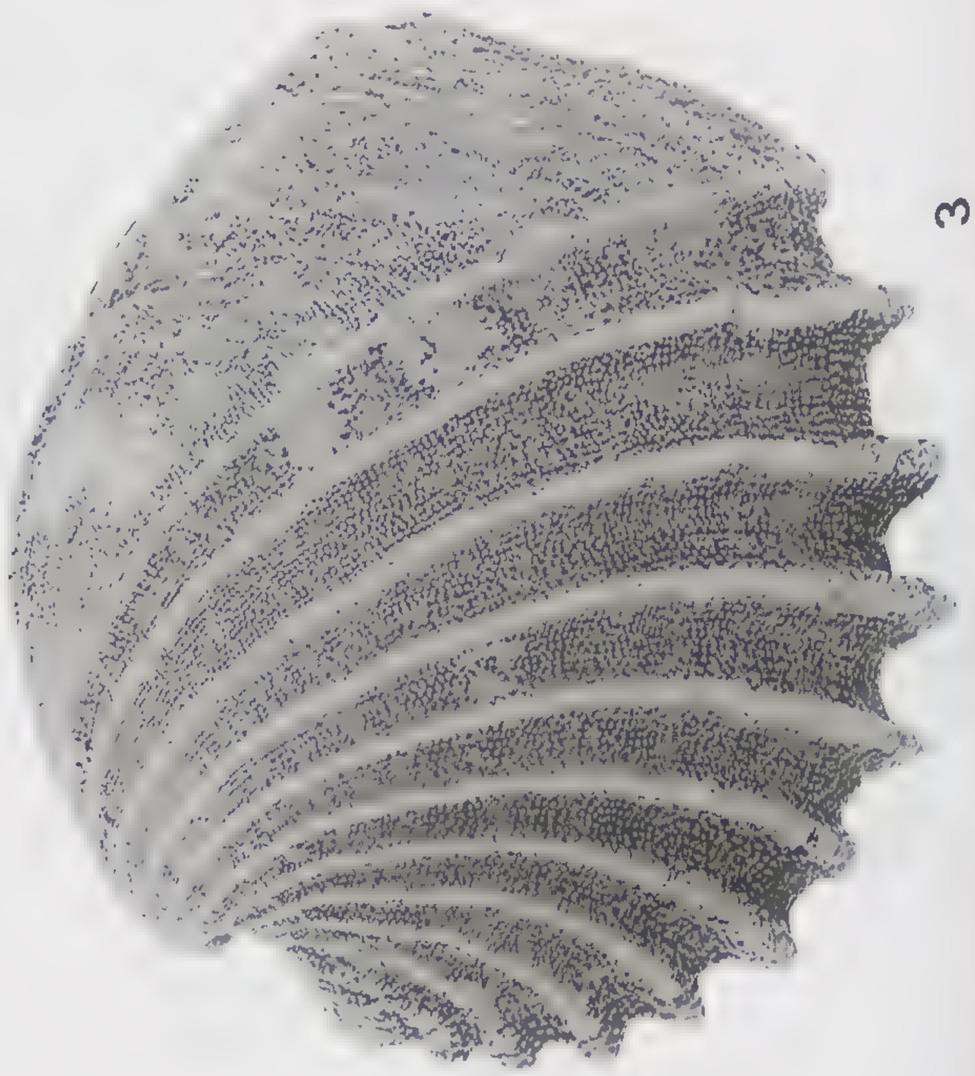

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EXPLANATION OF PLATE 12

Figure

1–4. *Trigonulina ornata* d'Orbigny, 1842 . . . . . Page 49

USNM 444479. Recent. Eolis Station 178: off Fowey Light, Florida, 68 fms.

1, 2. Exterior of right valve. Length 3.7 mm; height 3.3 mm. 2. Enlargement of sculpture, ×50.

3, 4. Exterior of left valve. Length 4.0 mm; height 3.6 mm. 4. Enlargement of sculpture, ×50.

EXPLANATION OF PLATE 13

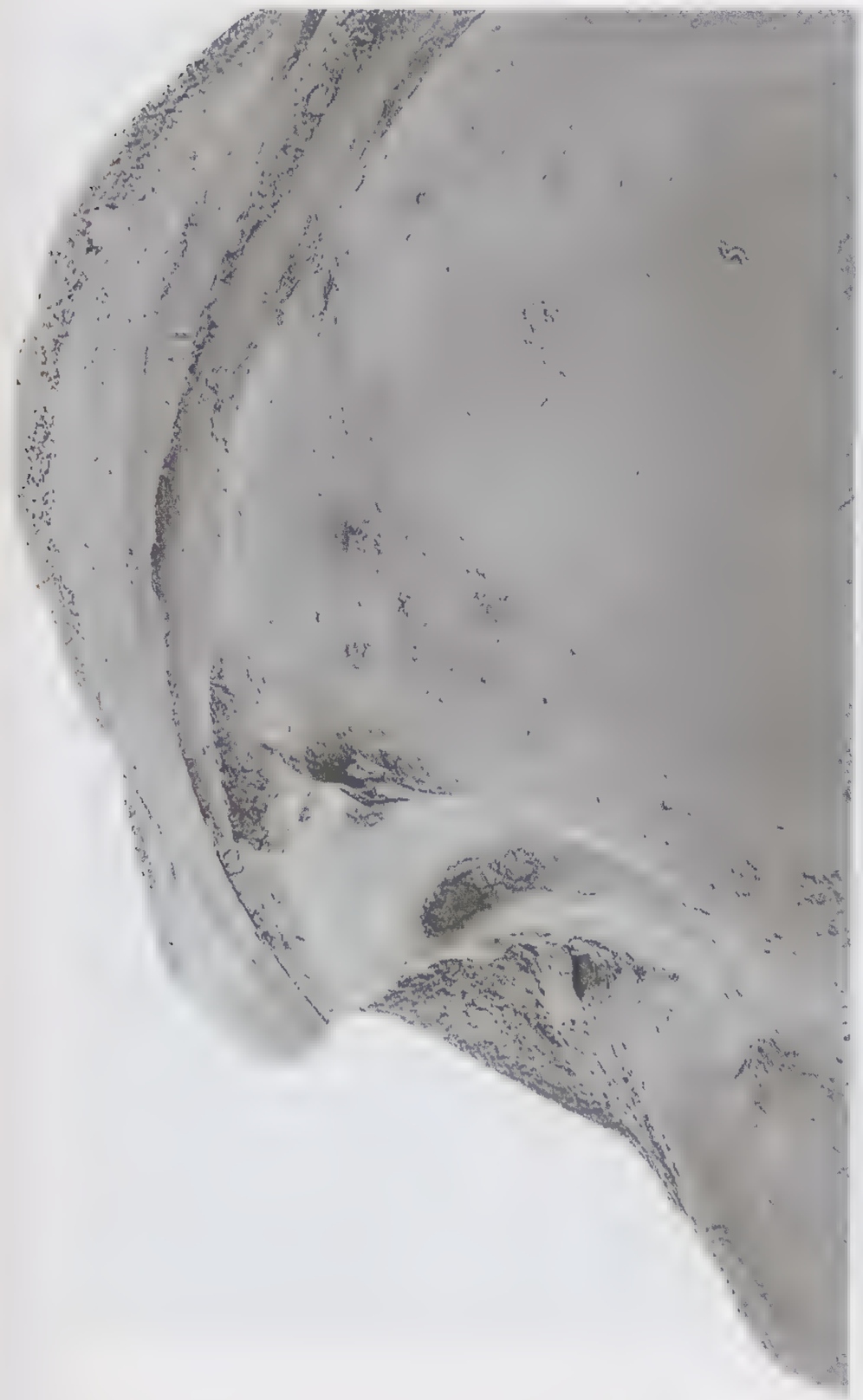
Figure | Page

1–4. *Trigonulina pacifica,* new species. 50

USNM 211469. Recent, off La Paz, Baja California, Mexico; 9½–10 fms.

1, 2. Interior of right valve. Length 4.8 mm; height 4.7 mm. 2. Enlargement of hinge, ×35.

3, 4. Interior of left valve. Length 4.7 mm; height 4.3 mm. 4. Enlargement of hinge, ×40.



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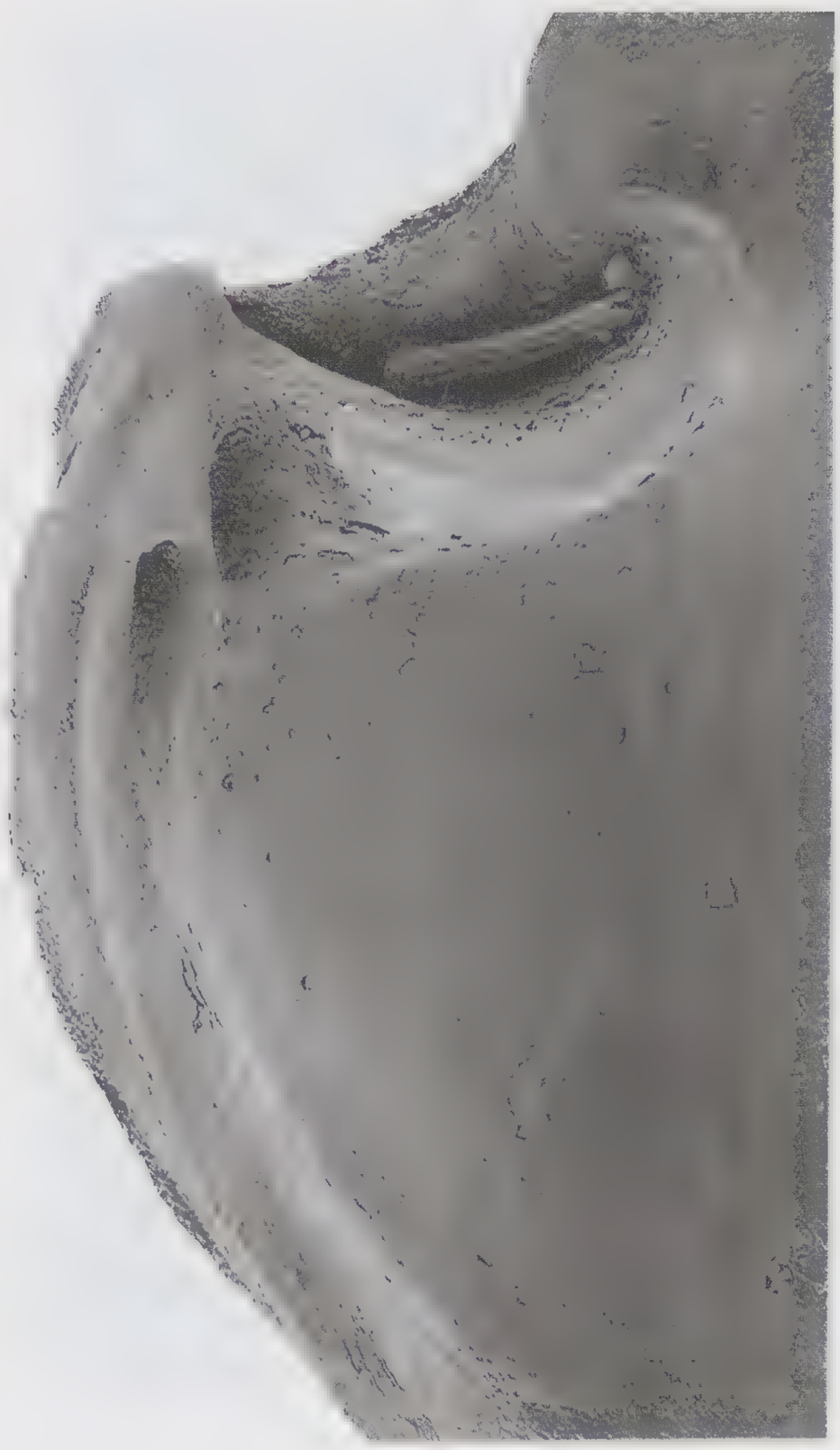

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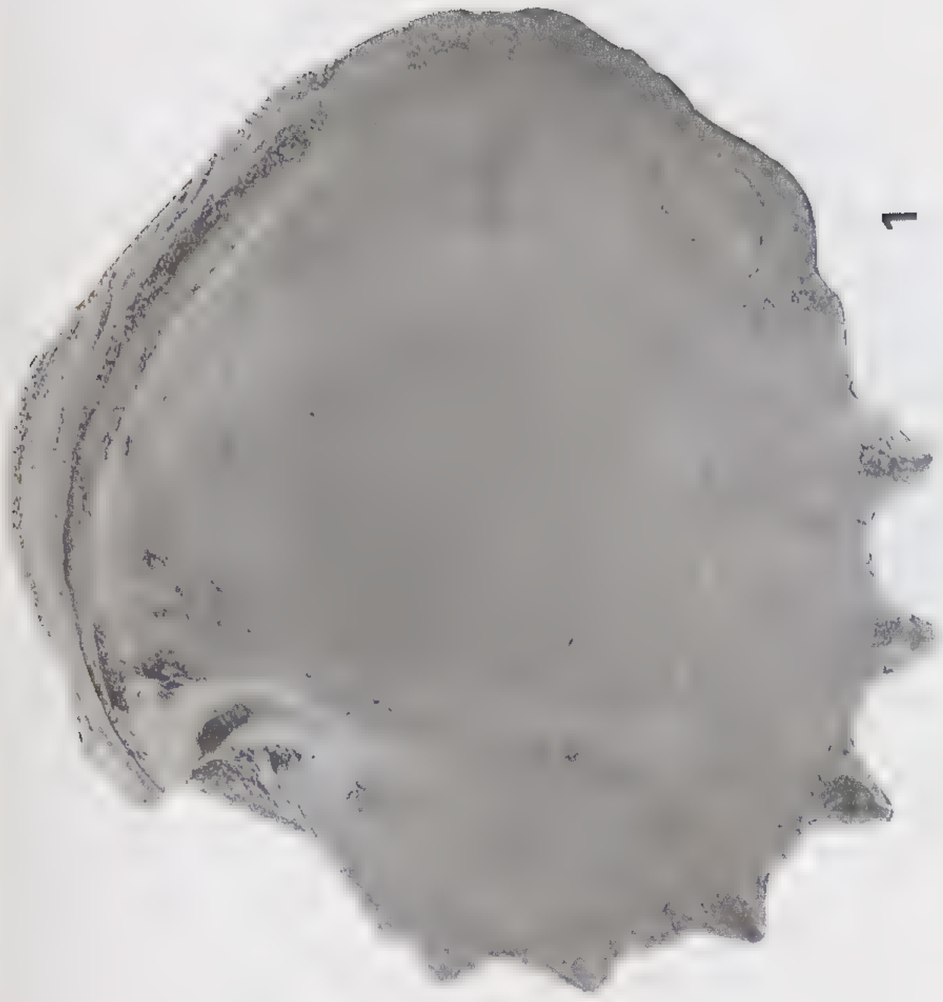

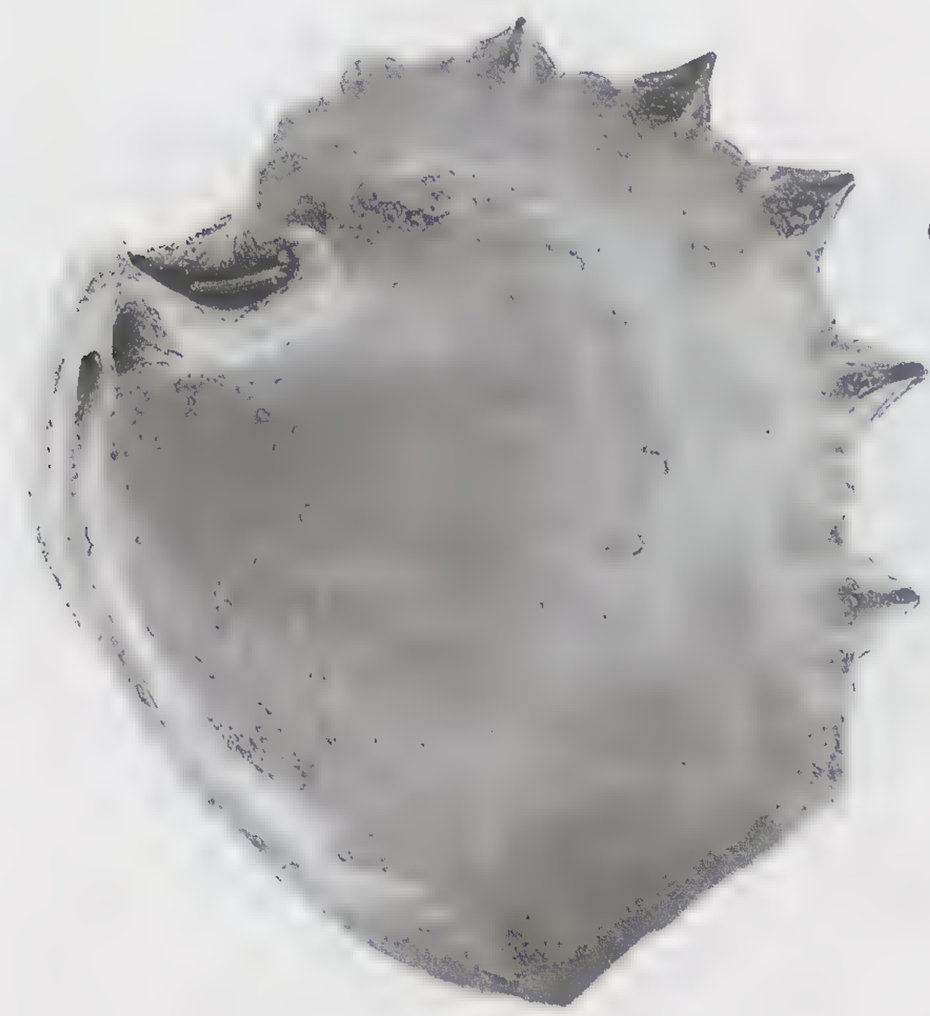

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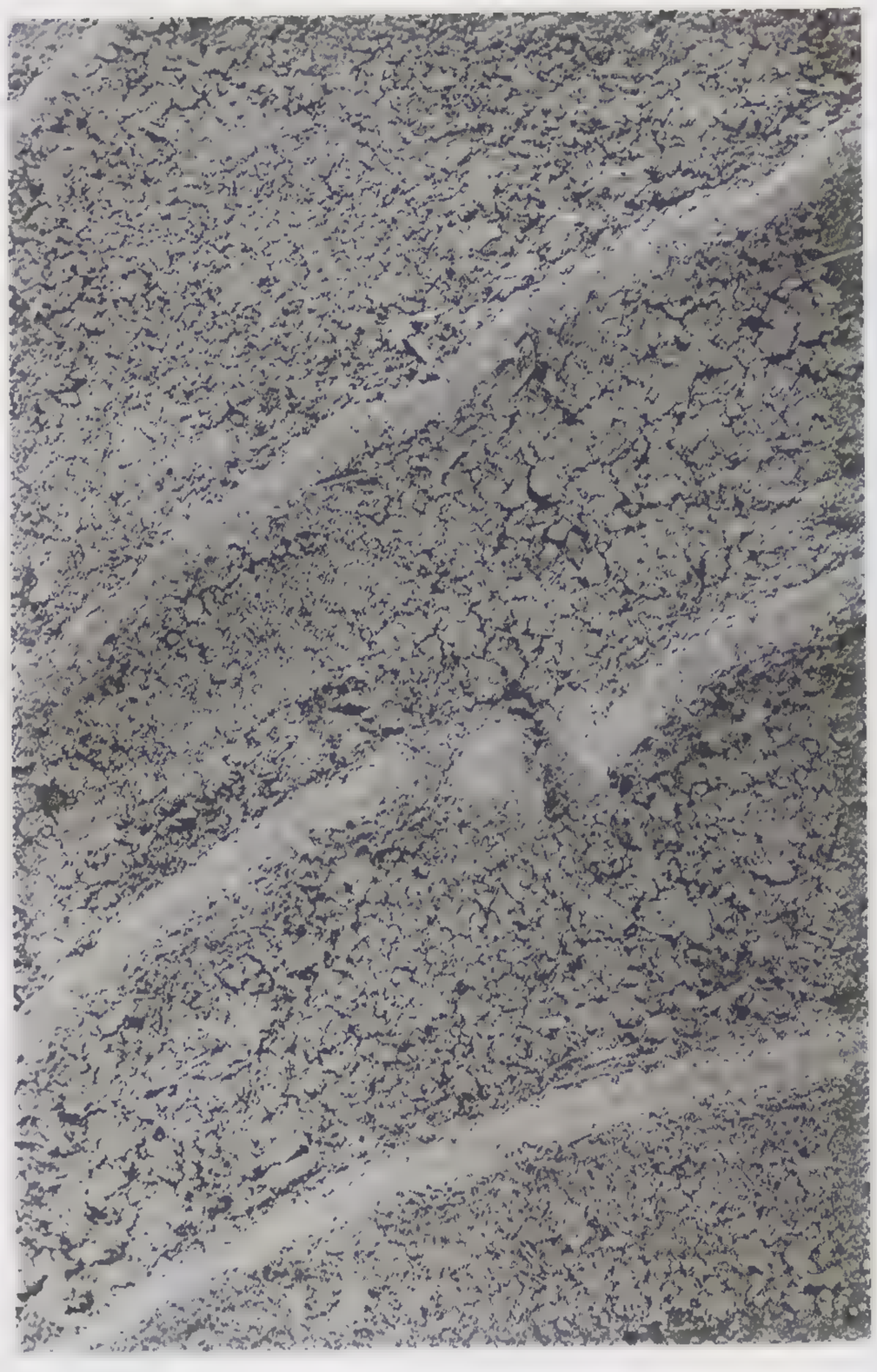

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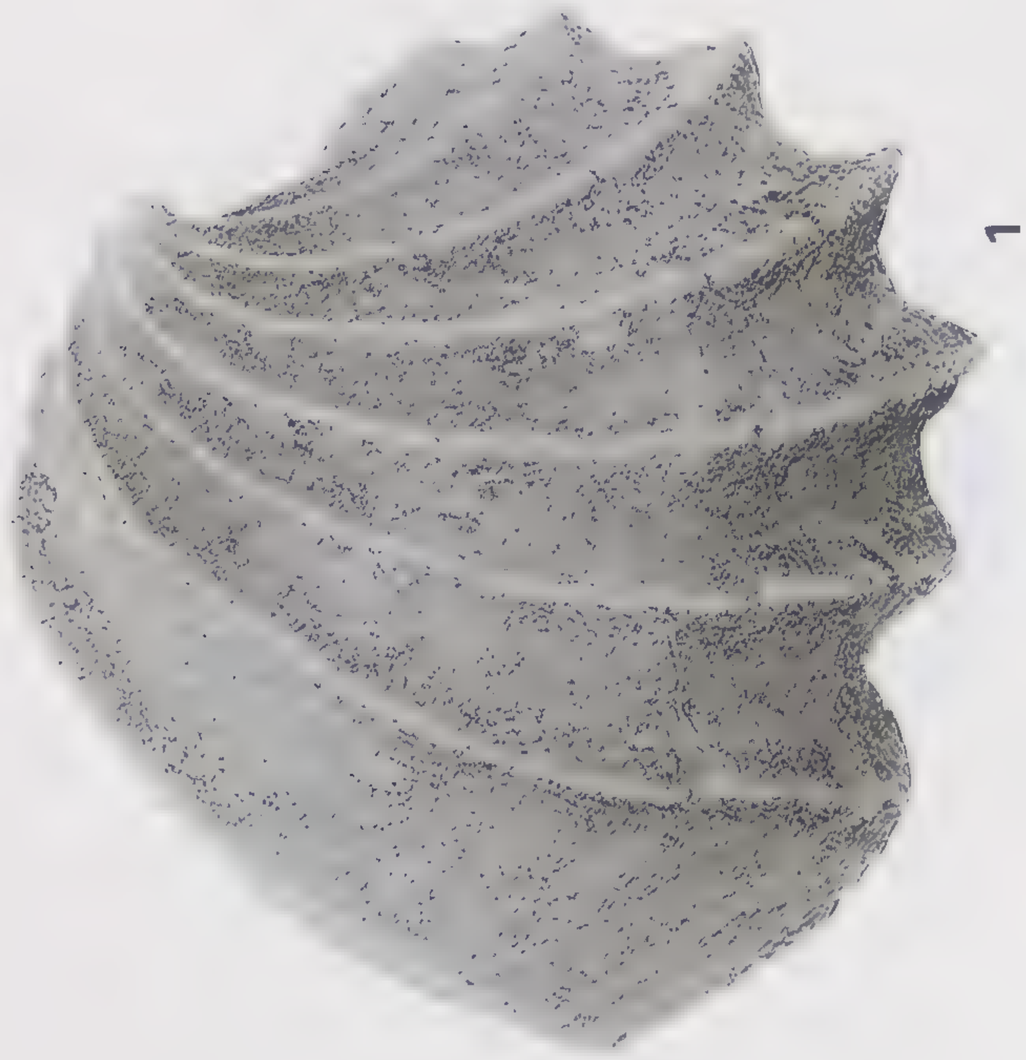

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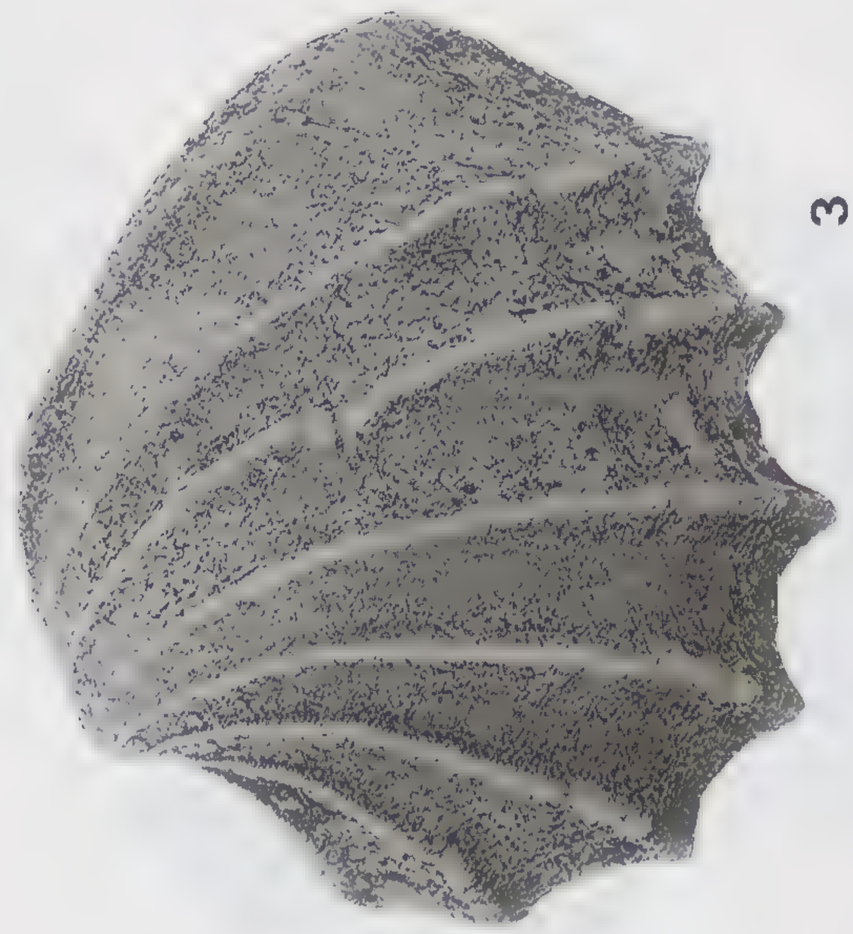


3

EXPLANATION OF PLATE 14

Figure

USNM 211469. Recent, off La Paz, Baja California, Mexico; 9½–10 fms.

1, 2. Exterior of right valve. Length 5.1 mm; height 4.9 mm. 2. Enlargement of sculpture, ×50.

3, 4. Exterior of left valve. Length 4.5 mm; height 4.0 mm. 4. Enlargement of sculpture, ×50.

Explanation of Plate 15

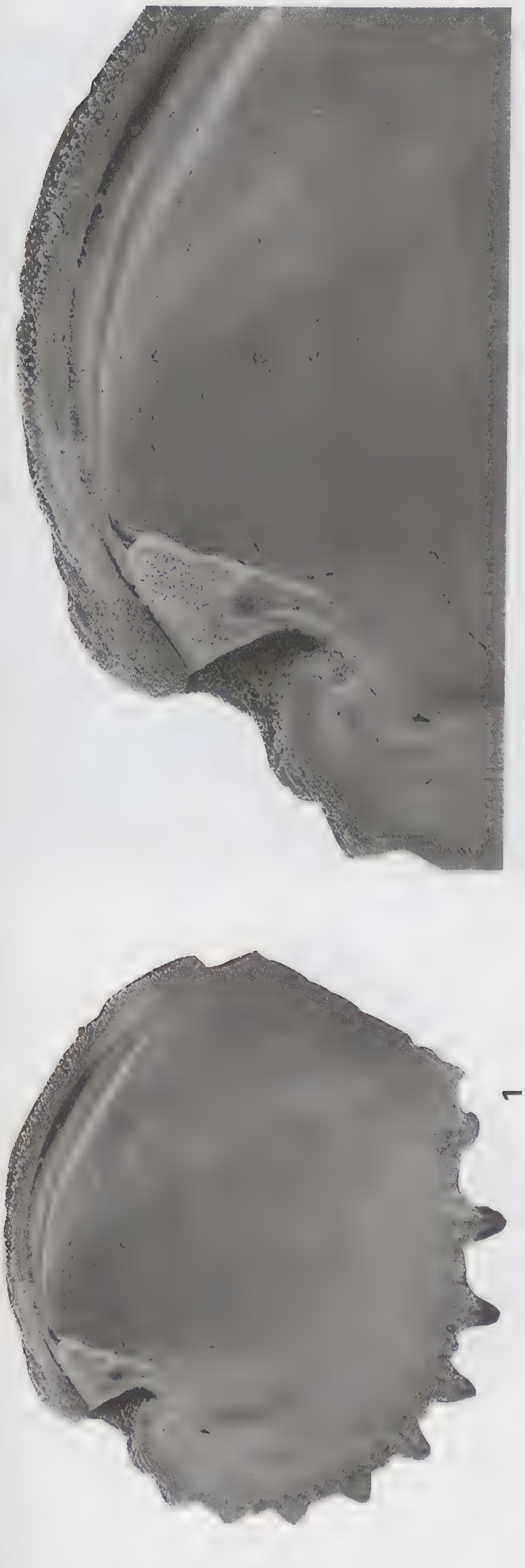
Figure — Page

1–4. *Trigonulina bowdenensis* (Dall, 1903). 53

NMB locality 15846: Río Gurabo; Gurabo Formation (late Miocene).

1, 2. NMB G 14151. Interior of right valve. Length 3.5 mm; height 3.1 mm. 2. Enlargement of hinge, ×40.

3, 4. NMB G 14153. Interior of left valve. Length 3.3 mm; height 3.0 mm. 4. Enlargement of hinge, ×50.



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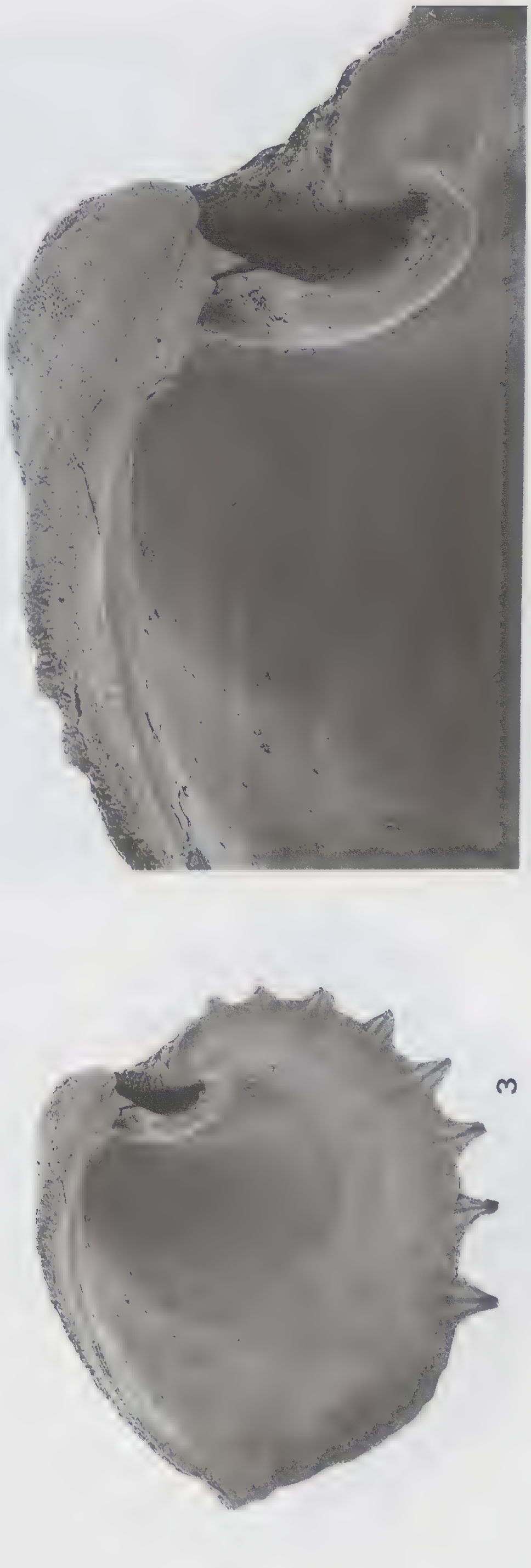

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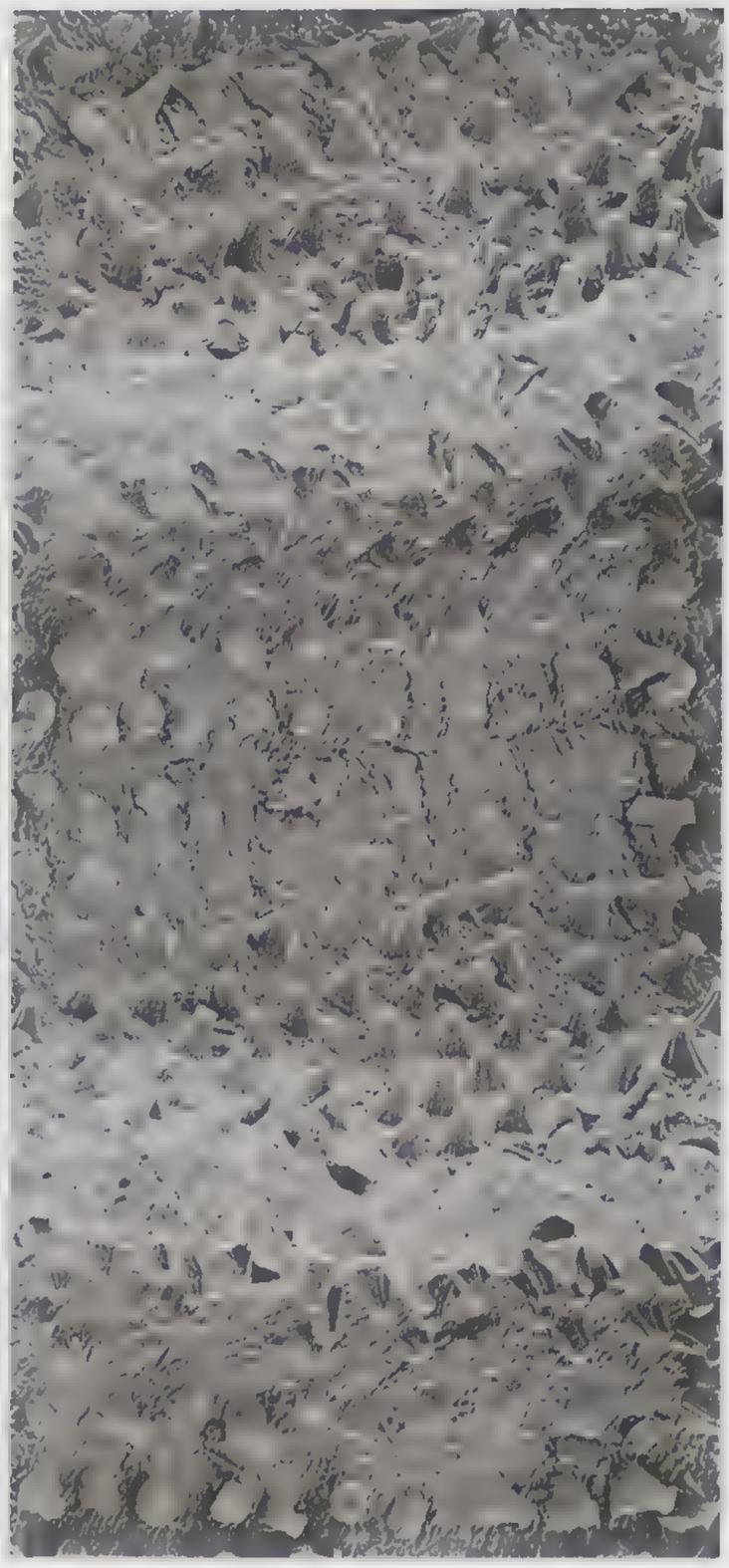

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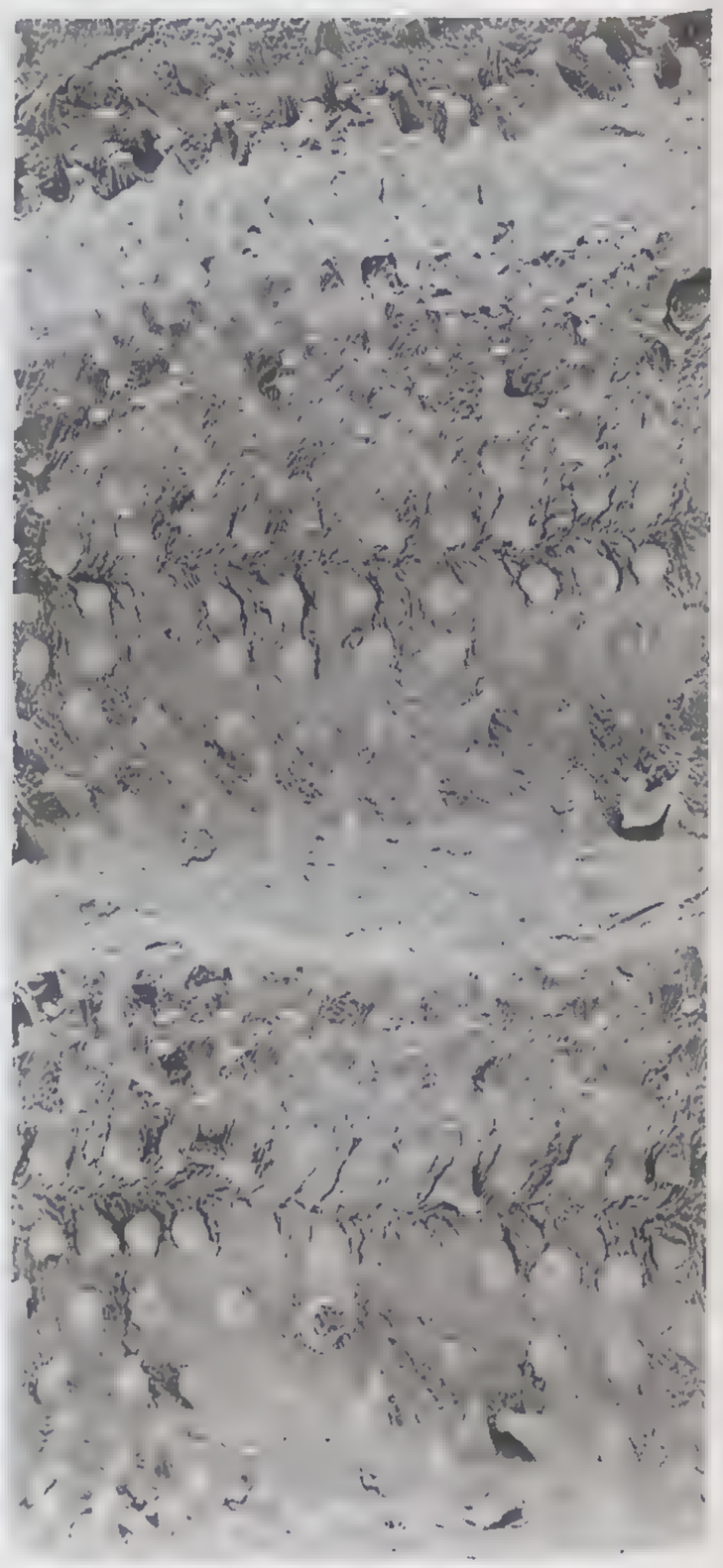

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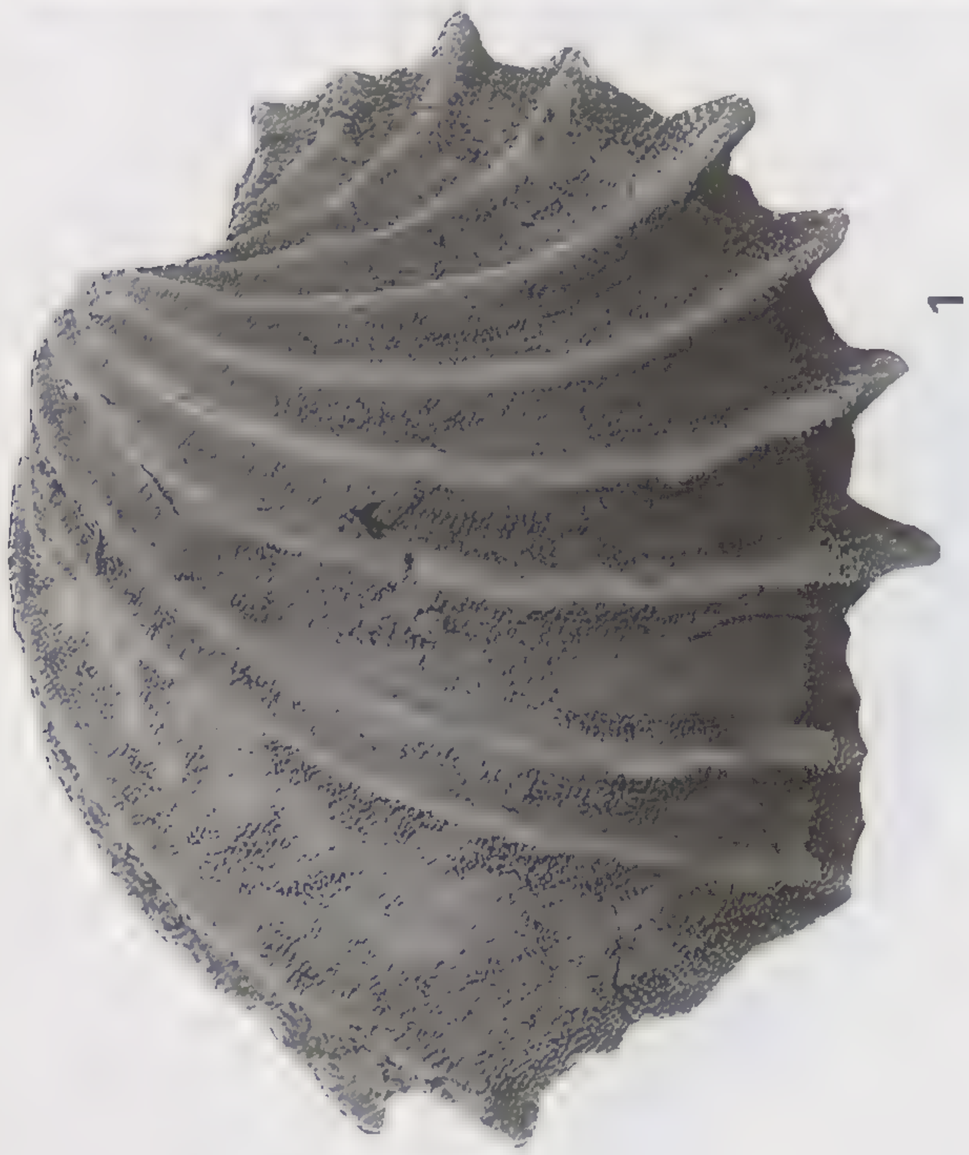

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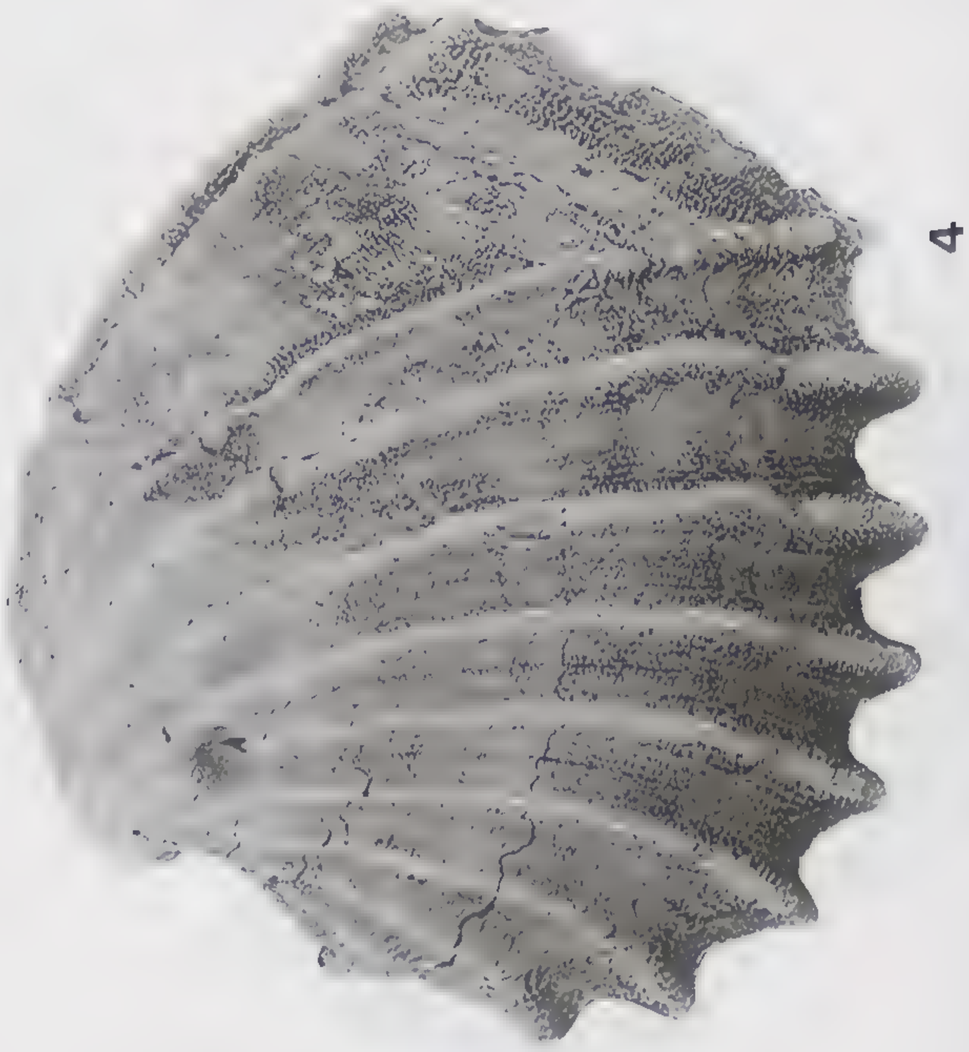


EXPLANATION OF PLATE 16

Figure

1–5. *Trigonulina bowdenensis* (Dall, 1903). . . . . Page 53

NMB locality 15846: Río Gurabo; Gurabo Formation (late Miocene).

1–3. NMB G 14150. Exterior of right valve. Length 3.8 mm; height 3.2 mm. 2. Enlargement of sculpture, ×75; 3. Further enlargement of sculpture, ×150.

4, 5. NMB G 14152. Exterior of left valve. Length 4.0 mm; height 3.3 mm. 5. Enlargement of sculpture, ×150.

EXPLANATION OF PLATE 17

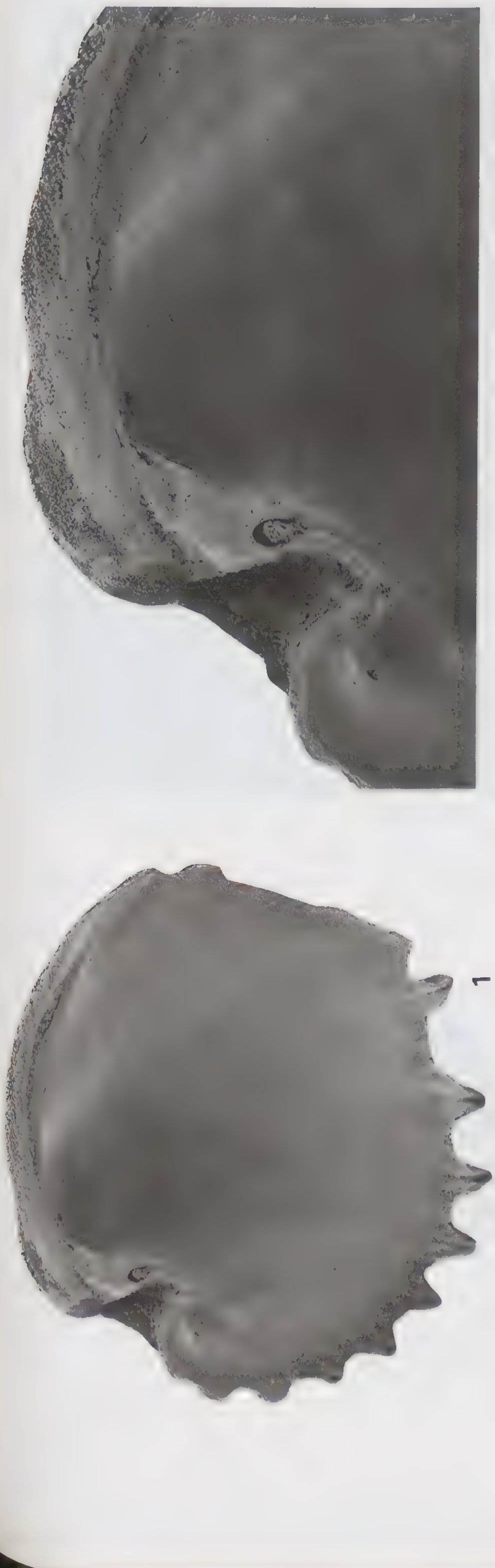
Figure — Page

1–4. *Trigonulina bowdenensis* (Dall, 1903). 53

NMB locality 10635: Bowden, Jamaica; Bowden Formation (early Pliocene).

1, 2. NMB G 14154. Interior of right valve. Length 2.8 mm; height 2.5 mm. 2. Enlargement of hinge, ×60.

3, 4. NMB G 14156. Interior of left valve. Length 2.1 mm; height 1.8 mm. 4. Enlargement of hinge, ×90.



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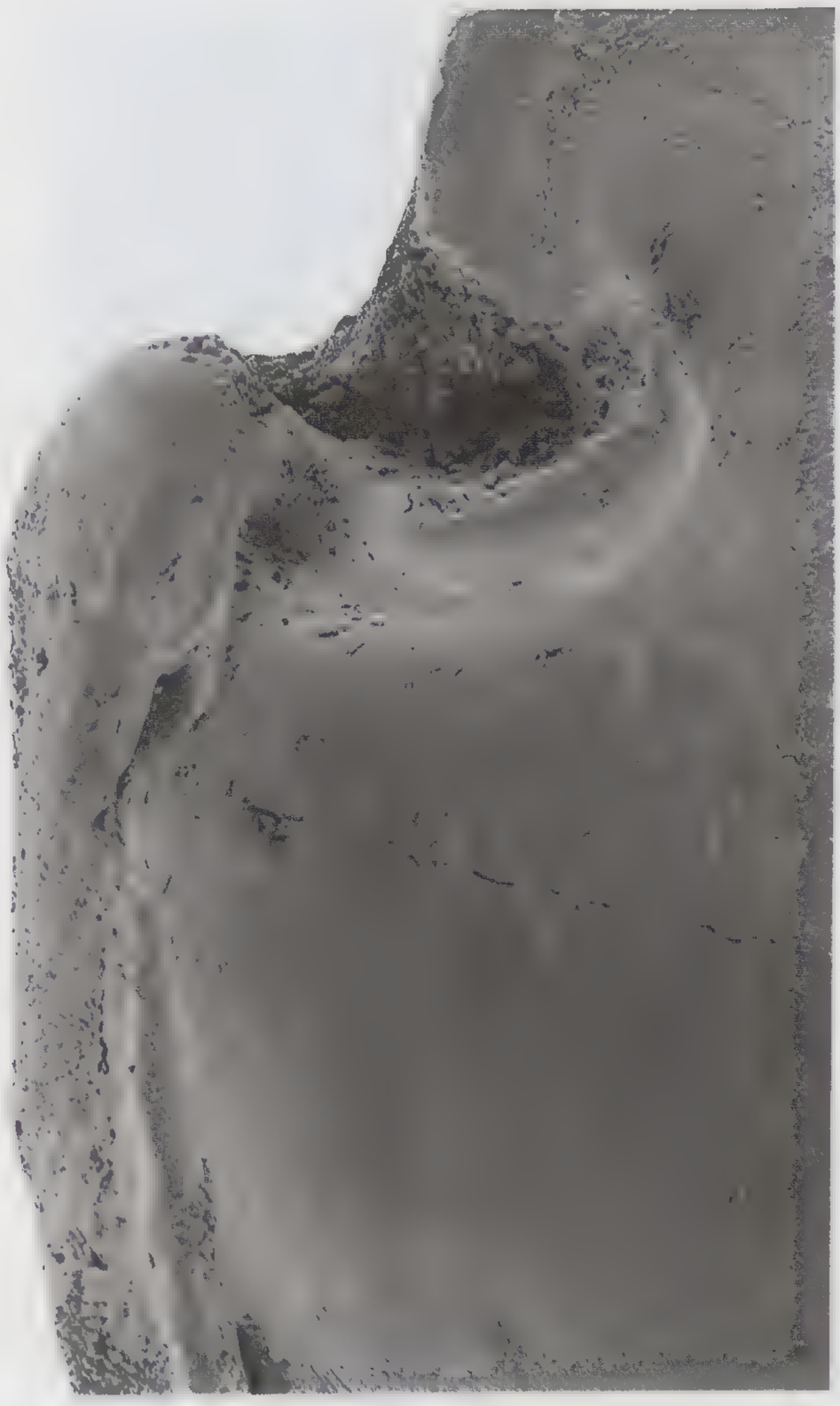

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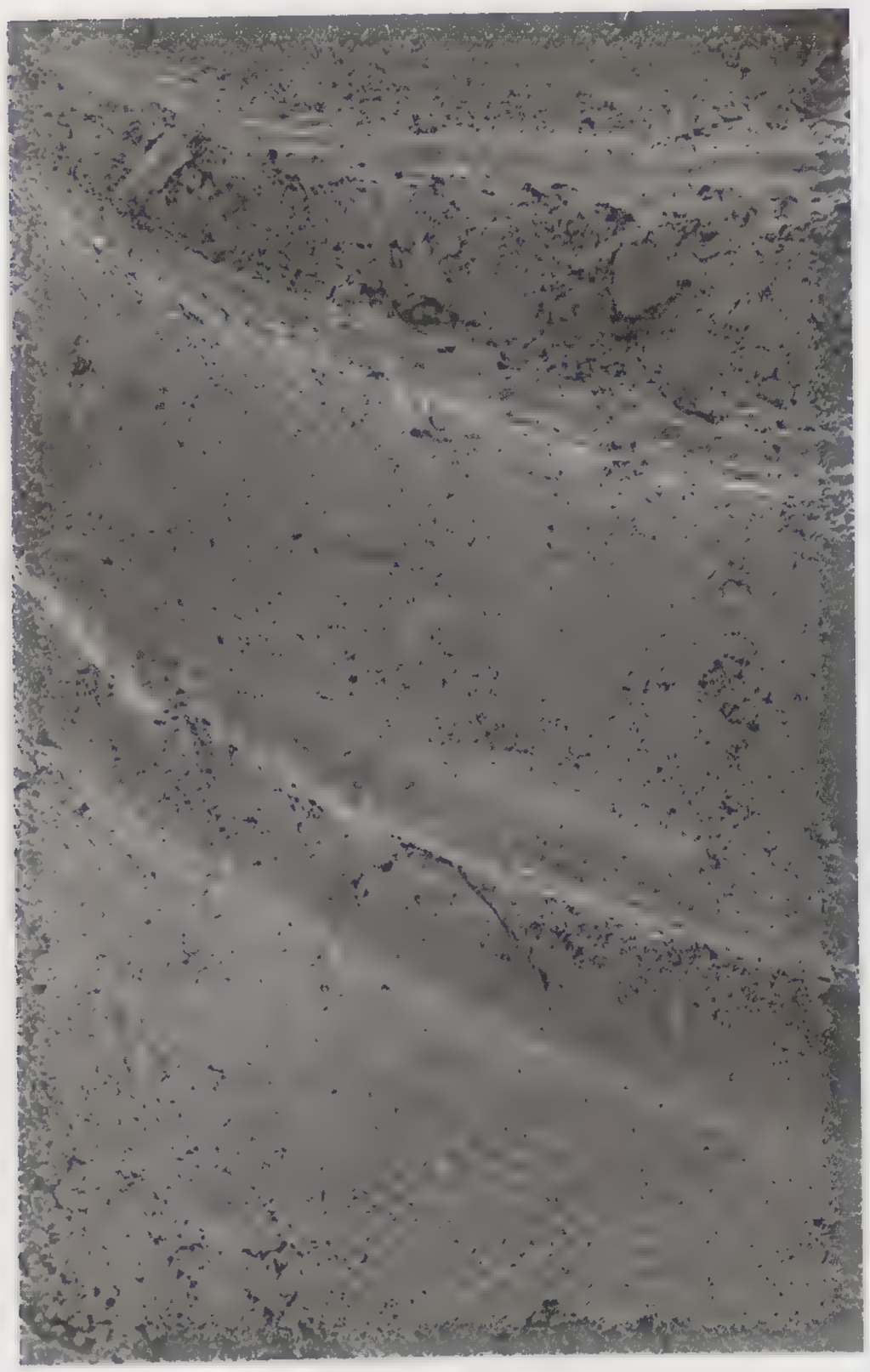

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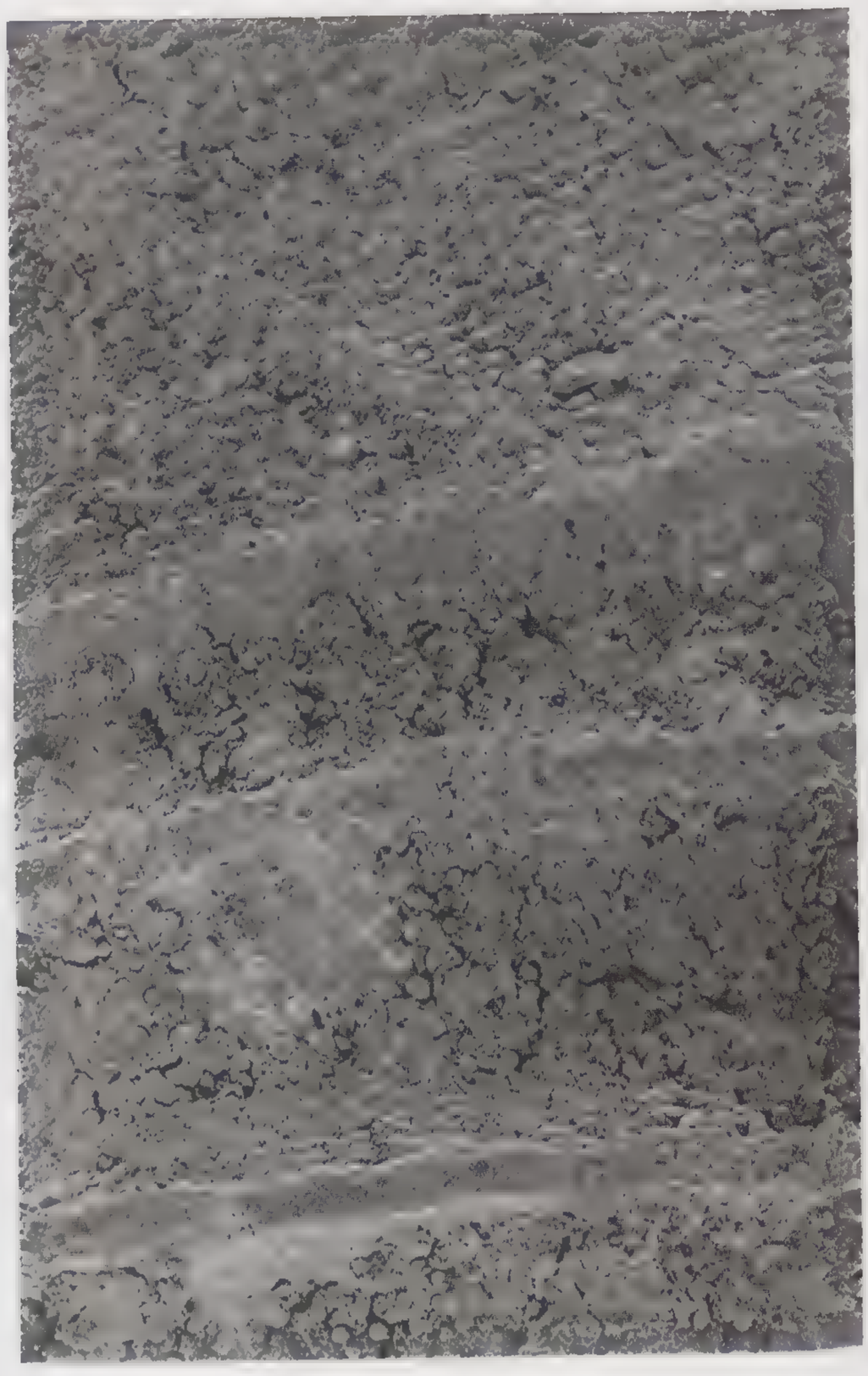

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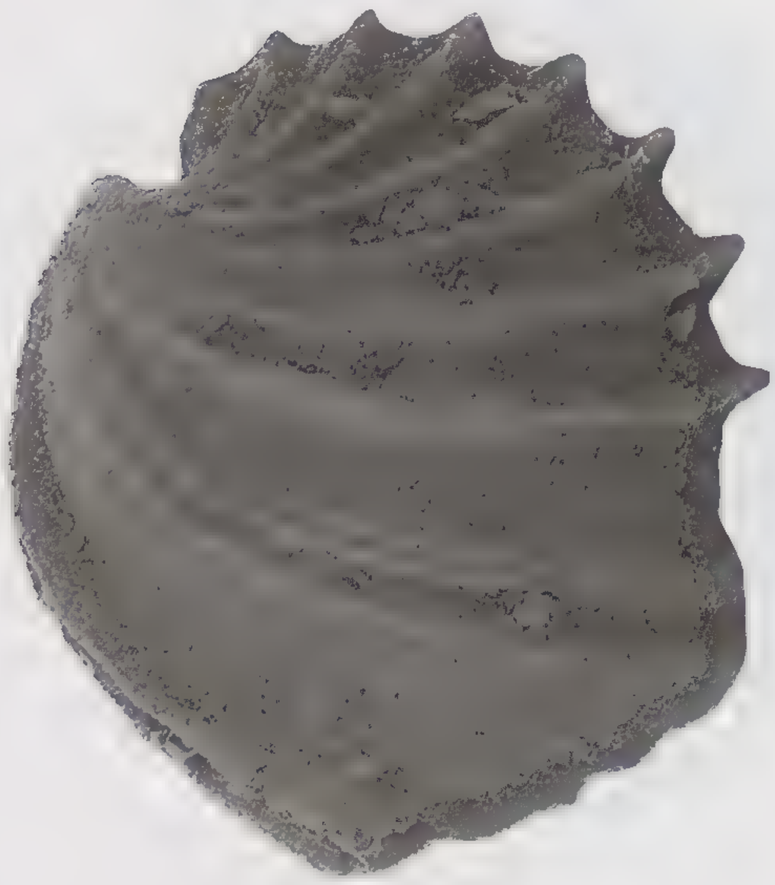

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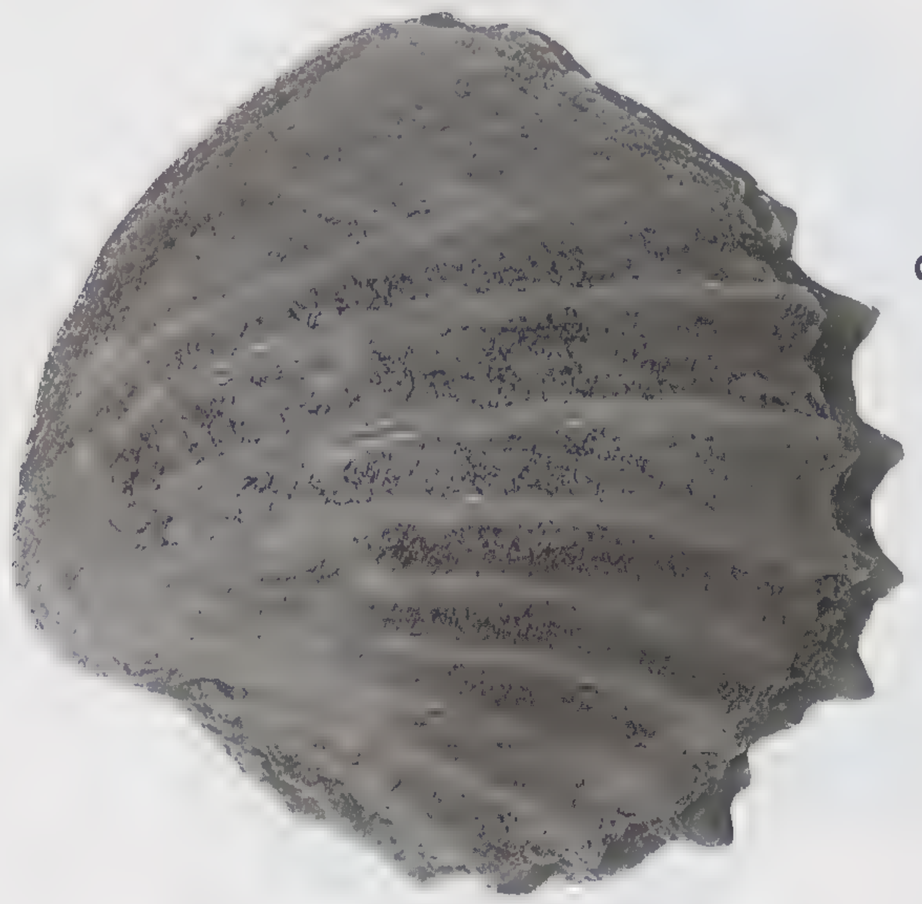

3

EXPLANATION OF PLATE 18

Figure

NMB locality 10635: Bowden, Jamaica; Bowden Formation (early Pliocene).

1, 2. NMB G 14155. Exterior of right valve. Length 2.3 mm; height 1.9 mm. 2. Enlargement of sculpture, ×100.

3, 4. NMB G 14157. Exterior of left valve. Length 2.8 mm; height 2.6 mm. 4. Enlargement of sculpture, ×100.

INDEX

Note: Page numbers are in light face; plate numbers are in **bold face**; page numbers on which principal discussions occur are in *italics*.

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