Geology and Paleontology Of Canal Zone and Adjoining Parts of Panama

GEOLOGY AND DESCRIPTION OF TERTIARY MOLLUSKS (GASTROPODS: TROCHIDAE TO TURRITELLIDAE)

By W. P. WOODRING

GEOLOGICAL SURVEY PROFESSIONAL PAPER 306-A

A contribution to the history of the Panamá land bridge

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C.

CONTENTS

	Page
Abstract	1
Introduction	2
Historical background	2
Purpose and scope of report	3
Orthography of geographic names	4
Acknowledgments	4
Annotated bibliography	5
Geology	10
Stratigraphy	10
Outline of stratigraphy	10
Cretaceous(?) system	13
Eocene series	13
Gatuncillo formation	13
Eocene or Oligocene series	22
Marine member of Bohio(?) formation	22
Oligocene series	24
Bohio formation	24
Caimito formation, exclusive of Madden basin and Pacific coastal area	28
Tuffaceous strata in Chorrera area	31
Bas Obispo formation and Las Cascadas agglomerate	31
Oligocene and Miocene series	32
Caimito formation of Madden basin and Pacific coastal area	32
Miocene series	34
Culebra formation, including Emperador limestone member	34
Cucaracha formation	39
Panamá formation, including La Boca marine member and Pedro Miguel agglomerate member	39
Gatun formation	42
Pliocene series	47
Chagres sandstone, including Toro limestone member	47
Pleistocene series	50
Correlation of Tertiary formations in different areas	50
Geology—Continued	
Igneous rocks	52
Cretaceous(?) volcanic and intrusive rocks	52
Tertiary volcanic and intrusive rocks	53
Granular intrusive rocks	53
Dike rocks	54
Volcanic rocks and tuff	54
Chemical composition	55
Age	56
Structure	57
Structural history	57
Structural features	58
Mineral resources	58
Metallic mineral deposits	58
Nonmetallic mineral deposits	59
Oil possibilities	60
Description of Tertiary mollusks	62
Gastropods	62
Family Trochidae	62
Family Turbinidae	64
Family Phasianellidae	65
Family Phasianellidae?	66
Family Neritidae	66
Family Thiaridae?	68
Family Littorinidae	68
Family Vitrinellidae	69
Family Rissoidae	76
Family Rissoinidae	77
Family Xenophoridae	77
Family Hipponicidae	78
Family Hipponicidae?	78
Family Crepidulidae	79
Family Calyptraeidae	79
Family Naticidae	84
Family Turritellidae	97
Localities at which fossils were collected	112
References cited	131
Index	137

ILLUSTRATIONS

[Plates 1, 2 in pocket, plates 3–23 follow p. 145]

PLATE 1. Geologic map of Canal Zone and adjoining parts of Panamá — In pocket
2. Geologic map of Gaillard Cut area, Canal Zone — In pocket
3. Foraminiferal limestone from Gatuncillo formation of Madden basin, Panamá.
4. Echinoid-bearing limestone from Gatuncillo formation of Madden basin, Panamá.
5. Boulder conglomerate of Bohio formation at Salud Point, Barro Colorado Island, Canal Zone.
6. Poorly sorted conglomerate of Bohio formation on Transisthmian Highway near Las Cumbres, just south of continental divide, Panamá.
7. Alhajuela sandstone member of Caimito formation at north abutment of Madden Dam, Canal Zone.

PLATE 8. Emperador limestone member of Culebra formation on west bank of Panama Canal at canal station 1619, Canal Zone.
9. Coralliferous limestone at base of La Boca marine member of Panamá formation on Río Masambí 200 meters upstream from east bank of Panama Canal, Canal Zone.
10. Strata in middle part of Gatun formation on east side of Gatun Third Locks excavation, Canal Zone.
11. Toro limestone member of Chagres sandstone resting on marly siltstone in middle part of Gatun formation in road cut 3 kilometers southwest of Gatun, Canal Zone.
12. Toro limestone member of Chagres sandstone in road cut 3 kilometers north-northwest of Gatun, Canal Zone.
13. Chagres sandstone in road cut 3 kilometers south of Lagarto, Panamá.
14. Middle and late Eocene mollusks from Gatuncillo formation.
15. Late Eocene or early Oligocene mollusks from marine member of Bohio(?) formation and late Oligocene mollusks from middle member of Caimito formation in Gatun Lake area.
16. Early Miocene mollusks from Culebra formation and La Boca marine member of Panamá formation.
17. Middle and late Miocene mollusks from Gatun formation.
18. Middle and late Miocene mollusks from Gatun formation and early Pliocene mollusk from Chagres sandstone.
19, 20. Middle Miocene mollusks from Gatun formation.
21, 22. Middle and late Miocene mollusks from Gatun formation.
23. Middle Miocene mollusks from Gatun formation.

Page

FIGURE 1. Map of Panamá showing principal areas of Tertiary marine sedimentary formations and area covered by plate 1 — 11
2. Ungulate metapodial from transition zone between Culebra and Cucaracha formations — 38
3. Reconnaissance geologic map of Caribbean coastal part of Panamá immediately west of Canal Zone — 45
4. Correlation of Tertiary formations in different areas — 51

GEOLOGY, AND DESCRIPTION OF TERTIARY MOLLUSKS (GASTROPODS: TROCHIDAE TO TURRITELLIDAE)

By W. P. Woodring

ABSTRACT

Most of the area covered by the present report lies in the central Panamá area of Tertiary marine sedimentary rocks, which extends obliquely across the trend of the isthmus. The central Panamá area contains a sequence of Tertiary deposits, for the most part marine, ranging in age from middle Eocene to early Pliocene. In the southwestern part of the Canal Zone and farther west a thick sequence of volcanic rocks borders the marine area. In the Gaillard Cut area, along the Panama Canal, the marine and volcanic rocks interfinger.

The oldest rocks, forming the basement on which the Tertiary formations rest, are more or less altered basaltic and andesitic lavas. Altered tuffs containing microscopic marine fossils are interbedded with the lavas. These basement rocks are of Cretaceous(?) age. Sometime during Late Cretaceous, Paleocene, or early Eocene time they were strongly deformed and perhaps at about the same time were intruded by dioritic and dacitic rocks. This is the strongest regional deformation in the known geologic history of this part of Panamá.

The middle and upper Eocene Gatuncillo formation rests with marked unconformity on the basement rocks. The Gatuncillo is widely transgressive and is essentially uniform lithologically, consisting principally of fine-grained detrital rocks. There is no indication of nearby volcanism during middle and late Eocene time.

Volcanism reached a climax during Oligocene and early Miocene time. The volcanic centers, which presumably are now concealed by later volcanic rocks, evidently were located in southern Panamá not far west of the Canal Zone. A tongue of Oligocene(?) volcanic rocks, interpreted to have accumulated at the periphery of a volcanic pile, extends eastward across the canal in the northern part of the Gaillard Cut area. These volcanic rocks, consisting of agglomerate, tuff, and thin andesitic flows and flow breccias, constitute the Bas Obispo formation and Las Cascadas agglomerate. They are considered of Oligocene(?) age because of their inferred relation to Oligocene deposits in the adjoining marine area.

The Oligocene deposits in the marine area are heterogenous and contain much volcanic debris. The earliest of these deposits are basaltic boulder conglomerate and basaltic graywacke forming the Bohio formation. This coarse debris, directly overlying the fine-grained rocks of the Gatuncillo formation, indicates movements in the source areas. As a result of these movements the Bohio formation overlaps the Gatuncillo formation in the Pacific coastal area east of the Canal Zone. The Bas Obispo formation is thought to grade northward into the Bohio. Though the Bohio represents for the most part an extension of nonmarine deposits into the marine area, it includes marine deposits. Marine upper Eocene or lower Oligocene strata in the western part of the Gatun Lake area are interpreted as a marine member in the lower part of the Bohio(?); the basal part of the Bohio in the Quebrancha syncline includes lower Oligocene marine siltstone; and the upper part of the formation on Barro Colorado Island and in the Pacific coastal area contains thin upper Oligocene marine deposits.

Late Oligocene time also witnessed the deposition in the marine area of heterogenous strata overlying the Bohio formation. These strata are almost entirely marine and are grouped as the Caimito formation. The Caimito overlaps the Bohio in the northern part of Madden basin and apparently also northeast of Gatun Lake, where it evidently rests directly on the basement. The overlap indicates continuation of the minor movements that affected the distribution of the Bohio formation. The Caimito formation is made up chiefly of tuffaceous sandstone, tuffaceous siltstone, conglomerate, tuff, agglomerate, and limestone. In the Quebrancha syncline it includes the economically important Quebrancha limestone member, which is quarried for the manufacture of cement. The lower member in the Gatun Lake area (or perhaps the entire formation) is thought to grade southward into the Las Cascadas agglomerate of the Gaillard Cut area.

Alternating marine and volcanic deposits were laid down in the Gaillard Cut area in early Miocene time. These deposits make up, in ascending order, the Culebra formation, including the Emperador limestone member, the Cucaracha formation, and the Panamá formation, including the La Boca marine member and the Pedro Miguel agglomerate member. Though the Culebra formation contains much tuffaceous material, it consists of dark thin-bedded shale, mudstone, and siltstone; calcareous sandstone, and limestone—all laid down during a minor marine transgression. The Cucaracha formation consists almost entirely of nonmarine tuff, altered to bentonitic clay. Tuff and relatively fine grained agglomerate are the chief constituents of the Panamá formation proper; silty mudstone, sandstone, limestone, and tuff make up the La Boca marine member; coarse-grained agglomerate the Pedro Miguel agglomerate member. The La Boca marine member represents a reinvasion of the sea that transgressed across the Cucaracha and Culebra formations onto the Bas Obispo formation. Two of these lower Miocene formations, the Culebra and Cucaracha, are readily eroded. They form topographic basins between hills of agglomerate and basalt, and these topographic basins determined the course of the canal. The Panamá formation is the youngest Tertiary formation in the Gaillard Cut area and in the Pacific coastal area east of the Canal Zone.

Tuffaceous sandstone and limestone deposited in Madden basin during early Miocene time are grouped with the underlying strata of late Oligocene age in that area as the Caimito formation. Though the lower Miocene part of the Caimito formation of Madden basin is thought to include the equivalent of the lower Miocene formations of the Gaillard Cut area, there is no satisfactory faunal or lithologic correlation from one area to the other. The lower Miocene formations of the Gaillard Cut area and the deposits in Madden basin considered to be their equivalent represent the early half of the early Miocene, which corresponds to the late Oligocene of some paleontologists. The youngest deposits in Madden basin (the Alhajuela sandstone member of the Caimito formation), however, are younger than the disputed Oligocene or Miocene. Madden basin is the only area where

late lower Miocene marine deposits have been found. They are almost exactly in the center of the present isthmus.

The Oligocene and lower Miocene volcanic rocks include widespread remnants of basalt flows in the Gaillard Cut and adjoining areas. The climax of volcanism during Oligocene and early Miocene time was accompanied by marked intrusive activity. Stocks of quartz diorite, diorite, and dacitic and andesitic rocks, dikes of andesite, and dikes and irregular bodies of basalt represent that interval of intrusive activity and are not known to be younger.

The Gatun formation was deposited during a middle and late Miocene marine transgression. The Gatun of the area covered by plate 1 is assigned to the middle Miocene. The upper part at the west end of the outcrop area is considered late Miocene. The relations between the Gatun formation and the Caimito formation—the next older formation in the Gatun Lake and Caribbean coastal areas—are unknown. The apparent absence of lower Miocene deposits in those areas indicates discontinuity, and transgressive overlap of the Caimito is shown by relations at the east end of the outcrop area of the Gatun, where it directly overlies the basement rocks. At least minor movements (and perhaps regional deformation) took place before the Gatun was deposited. How far inland beyond its present outcrop area the Gatun formation extended is not known. If it extended far inland, presumably it extended through Madden basin. The only tuff in the Gatun formation is very fine-grained and evidently was derived from a distant source.

The Chagres sandstone, including the Toro limestone member, represents a minor early Pliocene transgression. The Chagres crops out in a narrow belt along the Caribbean coast. The Toro limestone member consists of thin basal calcareous strata deposited in shallow water. These shallow-water deposits suggest that the formation did not extend much beyond its present inland border. The Chagres contains little tuffaceous material.

The moderately strong deformation of the pre-Gatun Tertiary formations is of regional extent, the results of the second regional deformation, but is not well dated. It may have taken place during early Miocene time or during Pliocene time after deposition of the Chagres sandstone. The Gatun formation and Chagres sandstone are only mildly deformed, but mild deformation in the Caribbean coastal area may have taken place at the same time as stronger deformation elsewhere.

Pleistocene deposits, characterized by much black organic material, are found in valleys that were cut in the Chagres standstone and older formations and later filled during submergence. Near the coast the Pleistocene strata include fossiliferous marine deposits.

Seventy-eight species and subspecies of Tertiary mollusks, representing 15 families of gastropods, are described and 13 others are recorded. Fifty of the 91 forms are from the Gatun formation. These 91 forms are estimated to represent about a seventh of the total available molluscan fauna in the marine Tertiary formations.

INTRODUCTION

HISTORICAL BACKGROUND

Marked advances in knowledge of the geology of the present Canal Zone coincide with three periods of active investigations bearing on construction of the canal or on proposed changes affecting it: French operations (1881–89 and 1895–99), American construction (1905–13), and Third Locks and Sea-level Conversion Route studies (1938–48).

With one exception, accounts of the geology that were published before French operations started are of historical interest only (Garella, 1845, 1849, pp. 519–524; Wagner, 1861; Maack, 1874, pp. 164–167; Wyse, Reclus, and Sosa, 1879, pp. 153–163; Boutan, 1880). The exception is Boutan's account. His scientifically and historically important paper, published in 1880, a few years after the earliest description of the microscopic petrology of American rocks, was based on a microscopic examination at the Ecole de Mines of rocks he collected along the Panama Railroad just before French operations got under way. He also had a better idea of the age of the sedimentary rock formations than his predecessors. Chaper's report (1890), written during liquidation of the first French company, does not add much to Boutan's.

During the operations of the first French company collections of fossils were sent to the French paleontologist Henri Douvillé. His age assignments (Douvillé, 1891), published after liquidation of the first company, placed the geology on a firmer footing.

The most important publication during the period of French operations was prepared by the French geologist Marcel Bertrand in collaboration with a Swiss engineer who had worked on the canal, Philippe Zürcher (Bertrand and Zürcher, 1899). It was based on the work done by the French companies and on a new set of age assignments by Douvillé (1898). The account by Bertrand and Zürcher emphasized the following major features of the geology along the canal: the pyroclastic rocks and associated lavas southeast of the big bend in Río Chagres at the present site of Gamboa are the oldest rocks; the strata overlying them are in general progressively younger toward both the Caribbean Sea and the Pacific Ocean; the fossiliferous strata are of Oligocene and Miocene age. The volcanic rocks are now thought to be of the same age as the oldest sedimentary formations along the shores of Gatun Lake. Otherwise Bertrand and Zürcher's conclusions have been confirmed by later investigations and are accepted at the present time.

In the meantime R. T. Hill visited Panamá in 1895, before the second French company resumed operations. He evidently did not have access to most of the subsurface records and there is no indication that he was aware of Douvillé's 1891 note. His report (1898) was supported by paleontologic work by Dall. Hill thought the oldest strata, probably pre-Tertiary, to be on the Pacific coast. Through some misfortune, one of his collections of fossils was mislabelled before it reached Dall's hands. As a result of the mislabelling, Dall referred part of the Gatun formation to the Eocene, an error that affected American geologic literature for many years.

Soon after American operations were started, Ernest Howe was employed by the Isthmian Canal Commission to study the geology. Though he was in the Canal Zone only five months during 1906 and 1907, his reports clearly set forth the essential features and went a long way toward systematizing the stratigraphic nomenclature (Howe, 1907, 1907a, 1908). Appointment of D. F. MacDonald, formerly of the U. S. Geological Survey, as resident geologist during the last two years of the construction period (1911–13) led to further advances and to the gathering of much information (MacDonald, 1913, 1913a, 1915, 1919). Only the first of the four publications by MacDonald just cited is generally cited on the following pages in the discussion of the stratigraphy. The others contain practically identical descriptions, aside from new names. Many of the fossils described in the present report were collected by MacDonald or by MacDonald and Vaughan, when Vaughan collaborated with him in the latter part of 1911. The stratigraphy, as worked out by MacDonald and Vaughan, was described in Bulletin 103 of the U. S. National Museum (Vaughan, 1919). Though Bulletin 103 was issued in 1919, many of its parts were published separately in 1918, and Jackson's part on the echinoids was issued separately in 1917 and again in 1918. In the preparation of Bulletin 103 Vaughan enlisted the services of a group of paleontologists, who described practically all the Canal Zone fossils then available in the National Museum collections, except the mollusks. Not all the fossils described in Bulletin 103 are mentioned in the summaries on the following pages. Calcareous algae (M. A. Howe, 1918), land plants (Berry, 1918), Bryozoa (Canu and Bassler, 1918), decapod crustaceans (Rathbun, 1918), and barnacles (Pilsbry, 1918) are omitted.

The third period of marked advances resulted from investigations, including the study of some 2,000 cores, of the Geological Section of the Special Engineering Division of the Panama Canal, carried out under the direction of T. F. Thompson. The surface and subsurface studies undertaken by this staff of geologists were for the most part directly related to the Third Locks and Sea-level Conversion Route projects. The published reports prepared by the Geological Section include summaries of the geology and more detailed descriptions of particular areas (Thompson, 1943, 1943a, 1944, 1947, 1947a). The oldest rocks, older than any along the canal, were found to consist of a basement of unknown age overlain by deposits of Eocene age. Agglomerate along the southeastern part of the canal, formerly correlated with agglomerate underlying the Culebra formation, overlies the Culebra. Marine deposits in the same region formerly identified as the Culebra formation, also are younger than that formation.

PURPOSE AND SCOPE OF REPORT

The National Museum's collection of fossil mollusks from the Canal Zone represent a collecting span of a century. Not many collections, however, were received prior to 1911, when the fossils collected by MacDonald began to arrive. It was expected that the mollusks would be studied by W. H. Dall, the dean of American Tertiary invertebrate paleontologists. For the most part he got no further than generic identification of MacDonald's early collections. Therefore the mollusks—the most abundant fossils then available—were omitted when Bulletin 103 was assembled. A considerable number of mollusks from the richly fossiliferous Gatun formation, collected while the canal was being constructed, were described by Toula (1909, 1911) and by Brown and Pilsbry (1911, 1913) before the publication of Bulletin 103. Other Gatun species have been recorded in scattered publications, and also a few from other formations (Culebra formation and its Emperador limestone member, Toro limestone member of Chagres sandstone). Nevertheless the National Museum collections represent much valuable information, which is not in useable form until the fossils are adequately studied. The present report is designed to meet that need.

The collections obtained before and during construction of the canal are especially valuable, for very few of them can be duplicated. Some of them, particularly in Gaillard Cut, represent excavated prisms of rock; many other localities are now submerged; still others are inaccessible through the rapid disintegration of rock and the rapid growth of a thick cover of vegetation.

To take advantage of the store of information gathered by the Geological Section of the Special Engineering Division, field work in the Canal Zone was undertaken during the dry season early in 1947. By that time it was evident that work in the fairly complete succession of lower and middle Tertiary marine formations in Panamá east of the Canal Zone was needed to interpret the less complete partly marine succession of the same age in the Zone. Further field work was carried out early in 1949 and early in 1954. The work in 1954 was limited to Barro Colorado Island and nearby parts of the Gatun Lake area. The geology of Barro Colorado is to be described in a separate publication.

The field work was designed as a stratigraphic and paleontologic project—not as a mapping project, which would have been very time-consuming. Some kind of map, however, was needed to show the localities at which fossils were collected. A decision was reached to compile a geologic map, based on the material in the publications and files of the Geological Section of the Special Engineering Division, supplemented by scattered personal observations. The resulting map on the scale of 1:75,000, issued as a separate publication in 1955, is reproduced with minor alterations as plate 1 of the present report. The quality of the map is very uneven. Parts of it show the geology in considerable detail; other parts are greatly generalized and represent rapid reconnaissance. Despite its defects, however, it shows the geologic setting of the Canal Zone and adjoining parts of Panamá. The only comparable map was published by MacDonald (1915, pl. 4; 1919, pl. 153) on a scale of about 1:260,000. The base used for the 1955 map does not show the recent suburban expansion of the city of Panamá.

At first the present report was planned to consist of a discussion of the stratigraphy, summaries of the occurrence of fossils other than mollusks, and description of the Tertiary mollusks. While the work was in progress, an incomplete carbon copy of a manuscript by MacDonald on the geology of Panamá was found among Dall's effects at the U. S. National Museum. This report, prepared soon after MacDonald's tour of duty as resident geologist in the Canal Zone, was mentioned by MacDonald (1913, p. 579) and Vaughan (1919, p. v). It was not finished because Dall's work on the fossils was not completed. One of MacDonald's duties as resident geologist was to recommend rock for use as concrete aggregate, as armoring for breakwaters and earth dams, and for other construction purposes. In carrying out this assignment he examined outcrops of igneous rocks, studied thin sections of them, and arranged for chemical analyses of some of the rocks to be made in the chemical laboratory of the U. S. Geological Survey. His description of the rocks, which is more complete than his published notes, and the chemical analyses are included in his manuscript. They have been incorporated in the present report, although the analyses have already been published.

Though the present report includes more than stratigraphy and paleontology, the title—chosen for brevity—is too comprehensive. Many aspects of the geology are omitted or are only briefly considered. This report is, in fact, a progress report so far as the geology is concerned. Much of the area covered by plate 1 has not yet been studied and it may be a long time before the entire region is adequately studied.

The systematic paleontology deals with the mollusks in about 260 collections from all the fossiliferous Tertiary formations, which range in age from middle and late Eocene to early Pliocene. In chapter A, 78 species and subspecies of gastropods are described and 13 others are recorded. These 91 forms are estimated to represent about a seventh of the total available molluscan fauna to be described. Fifty of the 91 are from the Gatun formation, an indication of the size of the Gatun fauna.

Fuller discussion of the age and correlation of the formations is planned for the final part of the report. That part also is to contain a discussion of the broader aspects of the succession of faunas, including their bearing on the history of the Panamá land bridge and the light they shed on paleoecology.

ORTHOGRAPHY OF GEOGRAPHIC NAMES

Spanish orthography, including accent marks, is used for geographic names in Panamá. In the Canal Zone, however, many names of Spanish origin are anglicized and for such names accent marks are omitted. The major streams cross the boundary, and therefore "río" or "quebrada" is used for all the streams that are named, regardless of location. The plan just outlined results in "Panamá" for the name of the country, the capital city, and a geologic formation, but "Panama Railroad" and "Panama Canal" for two features in the Canal Zone.

ACKNOWLEDGMENTS

Brig. General J. H. Stratton, (retired, then Col.), Supervising Engineer in charge of the Special Engineering Division, and T. F. Thompson, Chief of the Geological Section of the Division, placed every facility at my disposal during the field work in 1947, and Mr. Thompson again in 1949, when the Division had practically completed its work and its staff was greatly reduced. Mr. Thompson has a wide familiarity with the geology of the Canal Zone and Panamá, which he freely shared, and he guided me to many localities where fossils are available. Other geologists of the Geological Section were very helpful. Special acknowledgment should be made to S. K. Bartholomew, L. H. Henderson, S. M. Jones, J. M. Matthews, T. G. Moran, J. R. Schultz, R. H. Stewart, J. A. Tavelli, and L. C. Woolfe.

The general geologic map (pl. 1) is based for the most part on material gathered by geologists of the Geological Section: principally a published map of the Gatun Lake area by S. M. Jones (1950, pl. 2); a map of the Quebrancha syncline by T. F. Thompson, a small part of which was published (Thompson, 1944); a map of an area east of Gamboa, between Río Chagres and Madden Highway, by L. C. Woolfe; strip maps along the proposed sea-level canal (Thompson, 1947*a*, figs. 29–32); strip maps of the Chorerra route by J. R. Schultz. Mr. Thompson and Mr. Stewart offered valuable suggestions for filling in gaps. I, however, must assume responsibility for the map's shortcomings,

which will become apparent as additional work is done. G. E. Lewis, of the U. S. Geological Survey, and J. G. Marks, of Creole Petroleum Corporation, assisted in preparation of the Spanish explanation. The sea-level canal strip maps already mentioned were used for the more detailed map of the Gaillard Cut area (pl. 2). The field photographs, from the files of the Special Engineering Division, are available through the kindness of Mr. Thompson.

Large faunas of smaller Foraminifera from the Gatuncillo and Bohio formations, collected in 1947 and 1949, were identified by H. H. Renz and P. J. Bermúdez, both of Caracas, Venezuela. Larger Foraminifera collected at the same time were identified by W. S. Cole, of Cornell University and the U. S. Geological Survey (Cole, 1952 (1953)); corals by J. W. Wells, of Cornell University and the U. S. Geological Survey; echinoids by C. W. Cooke, of the U. S. Geological Survey (Cooke, 1948). M. N. Bramlette, of the Scripps Institution of Oceanography and the U. S. Geological Survey, furnished notes on smaller Foraminifera found in the Caimito and Culebra formations and in the La Boca marine member of the Panamá formation. R. A. Stirton, of the University of California, kindly furnished drawings of a mammal bone and comments concerning that interesting fossil. Samples of lava and tuff from the basement complex were examined by W. S. Burbank, of the U. S. Geological Survey, who also kindly read the part of the report dealing with the igneous rocks.

Extensive collections of mollusks from the Gatun formation, deposited at Stanford University by Mr. Thompson, were generously loaned by Miss A. Myra Keen. For permission to examine types and other specimens I am indebted to H. A. Pilsbry, A. A. Olsson, and Miss Anne Harbison, of the Academy of Natural Sciences of Philadelphia; W. S. Cole, of Cornell University; the late G. D. Harris, of the Paleontological Research Institution; J. W. Durham, of the University of California; and L. G. Hertlein, of the California Academy of Sciences. For much advice I am indebted to H. A. Rehder, of the U. S. National Museum, and R. T. Abbott, formerly of that institution, where this work was carried out.

ANNOTATED BIBLIOGRAPHY

The following briefly annotated bibliography lists publications on the geology and paleontology of the Canal Zone and adjoining parts of Panamá. It includes publications containing information on those subjects, though the publications are primarily devoted to other areas. With three exceptions, it does not include publications on engineering aspects of construction of the canal—notably on the canal slides—despite mention or discussion of geologic features. The three exceptions are MacDonald's U. S. Bureau of Mines Bulletin 86, issued in 1915, the National Academy of Sciences 1924 report on slides, and MacDonald's 1947 posthumous publication on the same subject. No attempt has been made to glean incidental geologic observations from early literature. A great number of travelers crossed the isthmus during the California gold rush, first by boat up Río Chagres to Las Cruces (a short distance above the present site of Gamboa) and thence by muleback, and later by the Panama Railroad, which was completed in 1855. Some of the travelers who wrote about their journey in books or nongeologic periodicals may have recorded observations on the geology.

1845. Garella, Napoléon, Projet d'un canal de jonction de l'Océan Pacifique et de l'Océan Atlantique à travers l'isthme de Panama, 233 p., maps, profiles, Paris.

Chapter 4 (p. 35–46), "Aperçu géologique sur la constitution des terrains de l'isthme", is generalized and of little interest. The 1:200,000 hachured topographic map, prepared in 1844, is an important historical document.

1849. Garella, Napoléon, Project of a canal to connect the Atlantic and Pacific oceans across the Isthmus of Panama: U. S. 30th Cong., 2nd sess., House Rept. 145, p. 506–590, maps, profiles.

Translation of preceding publication.

1853. Moore, J. C., Notes on the fossil Mollusca and fish from San Domingo: Geol. Soc. London Quart. Jour., v. 9, p. 129–132.

A note at the end of this paper (p. 132) is the first record in a scientific journal of the discovery of Miocene fossils in the present Canal Zone. The fossils were found "about 2½ miles from the shores of Navy Bay [Limon Bay] * * * in a cutting of the Panama Railway" [near Mindi].

1855. Deck, Isiah, Notes on the geological features of the Panama Railroad: Mining Mag., v. 4, p. 240–245, New York.

Fossils were observed at Monkey Hill [Mount Hope] but not at Gatun.

1855. Conrad, T. A., Report on the fossil shells collected in California by Wm. P. Blake, geologist of the expedition under the command of Lieutenant R. S. Williamson, United States Topographical Engineers; appendix to the preliminary geological report of William P. Blake: U. S. Pacific R. R. Expl., U. S. 33rd Cong., 1st sess., House Ex. Doc. 129, p. 5–20.

Includes three species of mollusks collected by Blake. The type of one species (*Gratelupia? mactropsis*) is in the National Museum.

1857. Blake, W. P., Geological report [Williamson's reconnaissance in California]: U. S. Pacific R. R. Expl., v. 5, pt. 2, 370 p., 11 pls., maps, sections.

Observations on trip across Panamá are recorded (p. 1–2). A few fossils were collected "at Gatun, or Monkey Hill?." The species indicate they were collected at Gatun.

1857. Conrad, T. A., Descriptions of the fossil shells [Williamson's reconnaissance in California]: Idem, app., art. 2, p. 317–329, pls. 2–9.

Conrad's 1855 descriptions are repeated and poor illustrations are added.

1857. Conrad, T. A., Description of the Tertiary fossils collected on the survey [Williamson's survey in California and Oregon]: Idem, v. 6, pt. 2, p. 69–73, pls. 2–5.

Includes five species of mollusks collected by Newberry at Gatun.

1861. Wagner, Moritz, Beiträge zu einer physisch-geographischen Skizze des Isthmus von Panama: Petermanns Mitt., Ergänzungsheft 5, 25 p., map.

Geologic observations are incidental and unimportant. Reddish conglomerate and fragmental rocks at city of Panamá are assigned to Permian.

1874. Maack, G. A., Report on the geology and natural history of the isthmuses of Choco, of Darien, and of Panama, in Selfridge, T. O., Reports of explorations and surveys to ascertain the practicability of a ship-canal between the Atlantic and Pacific Oceans by the way of the Isthmus of Darien, p. 155–175, Washington.

Geologic observations along Panama Railroad (p. 164–167) are inconsequential. Maack, like Wagner, suggested a Permian age for red conglomerate at Panamá.

1879. Wyse, L. N. B., Reclus, Armand, and Sosa, P., Rapports sur les études de la commission internationale d'exploration de l'isthme américain, 294 p., 2 maps, Paris.

Account of geology along route of proposed canal, like earlier accounts, is of historical interest only. List of rocks collected (p. 279–280) was prepared by Daubrée.

1880. Boutan, E., Note sur la constitution géologique de l'isthme de Panama: Annales de Mines, 7th ser., t. 18, p. 5–58, 2 pls. (map and profiles).

Interesting account of geology along route of proposed canal, based on microscopic examination, at Ecole des Mines, of rocks collected along Panama Railroad.

1881. Gabb, W. M., Descriptions of Caribbean Miocene fossils: Acad. Nat. Sci. Philadelphia Jour., 2d ser., v. 8, p. 337–348, pls. 44, 45.

Includes eight species of mollusks collected by Newberry at Gatun.

1886. Wyse, L. N. B., Le canal de Panama, 399 pp., maps, woodcuts, Paris.

Discussion of geology (pp. 12–20) is drawn from earlier accounts. Fossils at scattered localities are mentioned. Shaded relief map of canal route is on scale of 1:100,000.

1890. [Chaper, ———], Description géologique des terrains traversées par le canal: Commission d'études instituée par le liquidateur de la compagnie universelle, Rapport 6, 30 p., Paris.

According to Douvillé (1898, p. 589, footnote), Chaper, an engineer of the first French company, wrote this account. It does not add much to Boutan's. Black fossiliferous limestone at Vamos Vamos, however, is mentioned.

1890–1903. Dall, W. H., Contributions to the Tertiary fauna of Florida: Wagner Free Inst. Sci. Trans., v. 3, 6 pts., 1,654 p., 60 pls.

Includes mollusks from Vamos Vamos, Gatun, and Monkey Hill [Mount Hope].

1891. Douvillé, Henri, Sur l'âge des couches traversées par le canal de Panama: Acad. Sci. Paris Compte Rendu, t. 112, p. 497–499.

First modern age assignments. The fossiliferous strata are assigned to Oligocene and Miocene.

1896. Guppy, R. J. L., and Dall, W. H., Descriptions of Tertiary fossils from the Antillean region: U. S. Natl. Mus. Proc., v. 19, p. 303–331, pls. 27–30.

Includes two species of mollusks from Gatun and Monkey Hill [Mount Hope].

1898. Hill, R. T., The geological history of the Isthmus of Panama and portions of Costa Rica: Mus. Comp. Zool. Harvard College Bull., v. 28, p. 151–285, 19 pls., 24 figs.

Geology of Panama Railroad and French canal.

1898. Douvillé, Henri, Sur l'âge des couches traversées par le canal de Panama: Soc. Géol. France Bull., 3me ser., t. 26, p. 587–600.

Some of Douvillé's 1891 age assignments are changed; others are reinforced by additional data.

1899. Bertrand, Marcel, and Zürcher, Philippe, Etude géologique sur l'isthme de Panama: Compagnie Nouvelle du Canal de Panama, Rapport de la Commission, app. 1, p. 83–106, map, structure sections, Paris.

Most satisfactory of earlier accounts of geology of canal route. The map (scale 1:100,000), which has 10-meter (or several tens of meters) contours along route of canal and up Río Chagres to Alhajuela, is the last and the best of the French maps.

1899. Bouvier, E. L., *Calappa zurcheri*, crabe nouveau des terrains miocènes de Panama: Mus. Hist. Nat. Paris Bull., t. 5, p. 189–192, 1 fig.

Locality where this fossil was found is not specified.

1901. Hershey, O. H., The geology of the central portion of the Isthmus of Panama: Calif. Univ., Dept. Geol., Bull., v. 2, p. 231–267, map.

Panamá formation at and near Panamá is briefly mentioned (p. 245–246). Hershey's age assignments are much too old.

1904. Cushman, J. A., Pleistocene foraminifera from Panama: Am. Geologist, v. 33, p. 265–266.

List of 14 species from a locality near Mindi.

1904. Lemoine, P., and Douvillé, R., Sur le genre *Lepidocyclina* Gümbel: Soc. Géol. France Mém. 32 (t. 12), p. 1–42, pls. 1–3.

Includes *Lepidocyclina chaperi* and *L. canellei*, both named for engineers of first French company.

1907. Howe, Ernest, Report on the geology of the Canal Zone: Isthmian Canal Comm., Ann. Rept., 1907, app. E, p. 108–138, pl. 147.

Principal features of Canal Zone geology.

1907. Howe, Ernest, Isthmian geology and the Panama Canal: Econ. Geology, v. 2, p. 639–658, pl. 8.

Economic aspects of geology are emphasized.

1908. Howe, Ernest, The geology of the Isthmus of Panama: Am. Jour. Sci., 4th ser., v. 26, p. 212–237.

Stratigraphy and paleontology are emphasized.

1909. Toula, Franz, Eine jungtertiäre Fauna von Gatun am Panama-Kanal: K. k. Geol. Reichsanstalt Jahrb., Band 59, p. 673–760, pls. 25–28, 15 figs.

Mollusks, otoliths, and a few other fossils from Gatun formation, mostly from Gatun Locks site and spillway of Gatun Dam.

1911. Brown, A. P., and Pilsbry, H. A., Fauna of the Gatun formation, Isthmus of Panama: Acad. Nat. Sci. Phila. Proc., v. 63, p. 336–373, pls. 22–29.
Mollusks from Gatun Locks site, one of which also occurs at Monkey Hill [Mount Hope].

1911. Toula, Franz, Die jungtertiäre Fauna von Gatun am Panama-Kanal; 2. Teil: K. k. Geol. Reichsanstalt Jahrb., Band 61, p. 487–530, pls. 30, 31.
Mollusks and a few coral, echinoid, and crab remains.

1912. Dall, W. H., New species of fossil shells from Panama and Costa Rica: Smithsonian Misc. Coll., v. 59, no. 2, 10 p., March, 1912.
Includes 11 species of Pleistocene mollusks collected near Mount Hope and 1 species and variety collected at Toro Point [Toro limestone member of Chagres sandstone].

1912. de Boury, E., in Cossmann, M., Essais de paléoconchologie comparée t. 9, 215 p., 10 pls., August, 1912.
The fossil from Toro Point described by Dall five months earlier as *Epitonium* (*Sthenorytis*) *toroense* is described by de Boury as *Stenorhytis chaperi* (p. 177).

1913. de Boury, E., Catalogue raisonné de la collection de Scalaria vivants et fossiles du Muséum de Paris: Mus. Hist. Nat. Paris Nouv. Arch., 5me ser., t. 4, p. 209–266, pls. 12–16.
Includes another description of *Stenorhytis chaperi* (p. 252).

1913. Brown, A. P., and Pilsbry, H. A., Fauna of the Gatun formation, Isthmus of Panama; pt. 2: Acad. Nat. Sci. Phila. Proc., v. 64, p. 500–519, pls. 22–26, 5 figs., 1912 (1913).
Mollusks from Gatun formation, from "the *Pecten* bed at tower N, Las Cascadas" [Emperador limestone member of Cuelbra formation], and mollusks and a crab from "the lignitic layers near tower N, Las Cascadas" [Culebra formation proper].

1913. Brown, A. P., and Pilsbry, H. A., Two collections of Pleistocene fossils from the Isthmus of Panama: Idem, v. 65, p. 493–500, 3 figs.
Numerous Pleistocene mollusks and a barnacle collected near Mount Hope and at north end of Gatun Locks are listed, and 6 species and subspecies of mollusks are described.

1913. MacDonald, D. F., Geology of the Isthmus: Canal Record, v. 6, no. 27, p. 213–215, Feb. 26, 1913.
A preliminary account. Stratigraphic nomenclature is same as in next item, but it would be inappropriate to cite a weekly periodical of limited distribution for new stratigraphic names.

1913. MacDonald, D. F., Isthmian Geology: Isthmian Canal Comm., Ann. Rept., 1913, app. S, p. 564–582, pls. 65–77.
With exception of names published later, this publication is cited in present report for MacDonald's stratigraphic geolcgy. Published in latter part of 1913; transmittal of volume is dated Sept. 15.

1913. MacDonald, D. F., Geologic section of the Panama Canal Zone (abstract): Geol. Soc. America Bull., v. 24, p. 707–710.
Aside from omission of first two paragraphs, this is a republication of the earlier "Canal Record" account.

1913. Cossmann, M., Etude comparative de fossiles miocéniques recueillis à la Martinique et à l'isthme de Panama: Jour. Conchyliologie, t. 61, pp. 1–64, pls. 1–5.
Includes mollusks from Gatun formation at Mindi and Monkey Hill [Mount Hope].

1915. Douvillé, Henri, Les couches à orbitoïdes de l'isthme de Panama: Soc. Géol. France Compte Rendu Som., 1915, no. 16, p. 129–131.
Oligocene age of limestone on upper Chagres [Gatuncillo formation] is reiterated, despite presence of a discocyclinid. Strata at Peña Blanca [Caimito formation] and Pedro Miguel [probably Culebra formation] are considered to be of Aquitanian age.

1915. MacDonald, D. F., Some engineering problems of the Panama Canal in their relation to geology and topography: U. S. Bur. Mines Bull. 86, 88 p., 29 pls., 9 figs.
The name "Toro limestone" is proposed. Description of some formations is more detailed than in MacDonald's earlier publications.

1917. Sheldon, P. G., Atlantic slope Arcas: Palaeontographica Americana, v. 1, no. 1, p. 1–101, pls. 1–16.
A new name, *Arca balboai* (p. 69), is proposed for a species from Culebra formation.

1917. Jackson, R. T., Fossil echini of the Panama Canal Zone and Costa Rica: U. S. Natl. Mus. Proc., v. 53, p. 489–501, pls. 62–68, 4 figs.
Echinoids from Emperador limestone [member of Culebra formation] and Gatun formation.

1918. Howe, M. A., On some fossil and Recent Lithothamnieae of the Panama Canal Zone: U. S. Natl. Mus. Bull. 103, p. 1–13, pls. 1–11.
Calcareous algae from Caimito formation [misidentified as Culebra formation and Emperador limestone member] and Pleistocene deposits. Reissued in complete volume, 1919.

1918. Berry, E. W., The fossil higher plants from the Canal Zone: Idem, p. 15–44, pls. 12–18.
Plants from Bohio, Culebra, Cucaracha, and Gatun formations. Reissued in complete volume, 1919.

1918. Cushman, J. A., The smaller fossil Foraminifera of the Panama Canal Zone: Idem, p. 45–87, pls. 19–33.
Foraminifera from Caimito [misidentified as Culebra] and Culebra formations, Emperador limestone member of Culebra formation, La Boco marine member of Panamá formation [misidentified as Culebra formation], Gatun formation, and Pleistocene strata. Reissued in complete volume, 1919.

1918. Cushman, J. A., The larger fossil Foraminifera of the Panama Canal Zone: Idem, p. 89–102, pls. 34–45.
Foraminifera from Caimito formation [misidentified as Culebra formation and Emperador limestone member], Culebra formation and Emperador limestone member, and La Boca marine member of Panamá formation [misidentified as Culebra formation]. Reissued in complete volume, 1919.

1918. Jackson, R. T., Fossil echini of the Panama Canal Zone and Costa Rica: Idem, p. 103–116, pls. 46–52, figs. 1–3.
Reissue, with slight changes, of 1917 publication having same title. Reissued in complete volume, 1919.

1918. Canu, Ferdinand, and Bassler, R. S., Bryozoa of the Canal Zone and related areas: Idem, p. 117–122, pl. 53.

Two species from Emperador limestone [member of Culebra formation]. Reissued in complete volume, 1919.

1918. Rathbun, M. J., Decapod crustaceans from the Panama region: Idem, p. 123–184, pls. 54–66.

Species from Caimito [misidentified as Culebra], Culebra, and Gatun formations, and Pleistocene strata. Reissued in complete volume, 1919.

1918. Pilsbry, H. A., Cirripedia from the Panama Canal Zone: Idem, p. 185–188, pl. 67.

Five species from so-cllled Pliocene [Alhajuela sandstone member of Caimito formation], Gatun formation, and Pleistocene strata. Reissued in complete volume, 1919.

1919. Vaughan, T. W., Contributions to the geology and paleontology of the Canal Zone, Panama, and geologically related areas in Central America and the West Indies: U. S. Natl. Mus. Bull. 103, 612 p., 154 pls., 27 figs.

Separate parts of this volume are listed in present bibliography as 1918 or 1919 items.

1919. Vaughan, T. W., Fossil corals from Central America, Cuba, and Porto Rico, with an account of the American Tertiary, Pleistocene, and Recent coral reefs: Idem, p. 189–524, pls. 68–152, figs. 4–25.

Species from Caimito formation [misidentified as Culebra formation and Emperador limestone member], Culebra formation and Emperador limestone member, and La Boca marine member of Panamá formation [misidentified as Emperador limestone member of Culebra formation] are described, and species from Pleistocene strata are listed.

1919. MacDonald, D. F., The sedimentary formations of the Panama Canal Zone, with special reference to the stratigraphic relations of the fossiliferous beds: Idem, p. 525–545, pls. 153, 154, figs. 26, 27.

The name "Chagres sandstone" is proposed. Aside from that new name and slight changes in some age assignments, discussion of stratigraphy is essentially similar to that in MacDonald's 1915 account. Includes measured stratigraphic sections.

1919. Vaughan, T. W., The biologic character and geologic correlation of the sedimentary formations of Panama in their relation to the geologic history of Central America and the West Indies: Idem, p. 547–612.

Paleontology, age, and correlation of formations in Canal Zone.

1919. Sears, J. D., Deposits of manganese ore near Boqueron River, Panama: U. S. Geol. Survey Bull. 710, p. 85–91, figs. 1–3.

Manganese prospects near Río Boquerón. Southernmost prospect is shown on plate 1 of present report.

1921. Berry, E. W., A palm nut from the Miocene of the Canai Zone: U. S. Natl. Mus. Proc., v. 59, p. 21–22, 3 figs.

Found in Gatun formation.

1921. Cooke, C. W., *Orthaulax*, a Tertiary guide fossil: U. S. Geol. Survey Prof. Paper 129, p. 23–37, pls. 2–5.

Orthaulax gabbi is recorded from Caimito formation [not so specified] and Culebra formation.

1922. Olsson, A. A., The Miocene of northern Costa Rica: Bull. Am. Paleontology, v. 9, no. 39, 309 p., 32 pls.

Includes mollusks from Gatun formation of Canal Zone and one species from Toro limestone member of Chagres sandstone (*Pecten macdonaldi*).

1923. Vaughan, T. W., Studies of the larger Tertiary foraminifera from tropical and subtropical America: Natl. Acad. Sci. Proc., v. 9, p. 253–257.

Includes *Lepidocyclina miraflorensis* from a locality, apparently now submerged, evidently representing La Boca marine member of Panamá formation.

1924. Hanna, G. D., Rectifications of nomenclature: Calif. Acad. Sci. Proc., 4th ser., v. 13, p. 151–186.

Three new names are proposed for Canal Zone fossil mollusks.

1924. National Academy of Sciences, Report of the Committee of the National Academy of Sciences on Panama Canal Slides: Natl. Acad. Sci. Mem., v. 18, 84 p., 51 pls., 19 figs.

Appendix B on geology, by MacDonald, includes structure sections of part of Gaillard Cut. Appendix C is a discussion of chemical and physical properties of Cucaracha formation.

1924. Vaughan, T. W., American and European Tertiary larger Foraminifera: Geol. Soc. America Bull., v. 35, p. 785–822, pls. 30–36, 6 figs.

Includes *Miogypsina cushmani*, from Culebra formation, and *M. panamensis* from strata now referred to Caimito formation.

1924–1925. Douvillé, Henri, Revision des Lépidocyclines: Soc. Géol. France Mém., new ser., Mém. 2 (t. 2), 115 p., 7 pls., 83 figs.

Includes *Lepidocyclina canellei* and *L. chaperi*, and a new species from upper valley of Río Chagres, *L. decorata*, which has not been recognized in later collections (see Cole, 1952, [1953], p. 3).

1925. Dall, W. H., Illustrations of unfigured types of shells in the collections of the United States National Museum: U. S. Natl. Mus. Proc., v. 66, art. 17, 41 p., 36 pls.

Includes a Pliocene species (*Sthenorytis toroense*) and two Pleistocene species (*Corbula macdonaldi* and *Yoldia perprotracta*) described by Dall in 1912.

1925. Maury, C. J., A further contribution to the paleontology of Trinidad (Miocene horizons): Bull. Am. Paleontology, v. 10, no. 42, 250 p., 43 pls.

Includes a species from Culebra formation (*Scapharca balboai*) and two from Gatun formation (*Scapharca dariensis* and *Clementia dariena*).

1926. Hodson, Floyd, Venezuelan and Caribbean Turritellas: Idem, v. 11, no. 45, 50 p., 30 pls.

Turritella altilira is illustrated.

1926. Vaughan, T. W., The stratigraphic horizon of the beds containing *Lepidocyclina chaperi* on Haut Chagres, Panama: Natl. Acad. Sci. Proc., v. 12, p. 519–522.

At type locality, San Juan de Pequení in upper Chagres valley (locality 3 of present report), *Lepidocyclina chaperi* is associated with upper Eocene species.

1926. Woodring, W. P., American Tertiary mollusks of the genus *Clementia:* U. S. Geol. Survey Prof. Paper 147, p. 25–47, pls. 14–17, 1 fig.

Includes *Clementia dariena*, which occurs in Gatun formation and is doubtfully recorded from Culebra formation.

1927. Vaughan, T. W., Larger Foraminifera of the genus *Lepidocyclina* related to *Lepidocyclina mantelli:* U. S. Natl. Mus. Proc., v. 71, art. 8, 5 p., 4 pls.
Includes *Lepidocyclina miraflorensis.*

1927. Palmer, K. V. W., The Veneridae of eastern America, Cenozoic and Recent: Palaeontographica Americana, v. 1, no. 5, 428 p., 45 pls.
Includes described fossil species from the Canal Zone.

1927. Hodson, Floyd, Hodson, H. K., and Harris, G. D., Some Venezuelan and Caribbean mollusks: Bull. Am. Paleontology, v. 13, no. 49, 160 p., 40 pls.
Includes species from Gatun formation.

1929. Anderson, F. M., Marine Miocene and related deposits of north Colombia: Calif. Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 73–213, pls. 8–23.
Includes mollusks collected from Gatun formation at spillway of Gatun Dam.

1930. Li, Chih Chang, The Miocene and Recent Mollusca of Panama Bay: Geol. Soc. China Bull., v. 9, p. 249–279, 8 pls., map.
Includes species characteristic of Gatun formation, stated to have been dredged at Pacific entrance to canal.

1930. Rutsch, R., Einige interessante Gastropoden aus dem Tertiär der Staaten Falcón und Lara (Venezuela): Eclogae Geol. Helvetiae, Band 23, p. 604–614, pl. 17.
Type of *Distorsio gatunensis* is discussed and illustrated.

1930. Reeves, Frank, and Ross, C. P., A geologic study of the Madden Dam project, Alhajuela, Canal Zone: U. S. Geol. Survey Bull. 821, p. 11–49, pls. 4–13, figs. 1–5.
Geology of Madden Dam site and area to be flooded by Madden Lake.

1931. Pilsbry, H. A., The Miocene and Recent Mollusca of Panama Bay: Acad. Nat. Sci. Phila. Proc., v. 83, p. 427–440, pl. 41, 3 figs.
Eight of the species described by Li in 1930 are Miocene fossils. One (*Clementia dariena*) is labelled "Gatun Locks and Spillway" and all have matrix characteristic of Gatun formation at and near Gatun.

1931. Hodson, Floyd, and Hodson, H. K., Some Venezuelan mollusks: Bull. Am. Paleontology, v. 16, no. 59, 94 p., 24 pls.
Includes *Macoma gatunensis.*

1932. Vaughan, T. W., and Cole, W. S., A new species of *Lepidocyclina* from the Panama Canal Zone: Washington Acad. Sci. Jour., v. 22, p. 510–514, 9 figs.
Lepidocyclina pancanalis is described. The type locality, which is also the type locality of *Miogypsina panamensis* and *Nummulites panamensis*, represents Caimito formation, but is not so specified [locality 56 of present report].

1933. Vaughan, T. W., Studies of American species of Foraminifera of the genus *Lepidocyclina:* Smithsonian Misc. Coll., v. 89, no. 10, 53 p., 32 pls.
Includes *Lepidocyclina canellei* and *L. vaughani.*

1934. Collins, R. L., A monograph of the American Tertiary pteropod mollusks: Johns Hopkins Univ., Studies in Geology, no. 11, p. 137–234, pls. 7–14.
Includes a species from Gatun formation, *Vaginella caribbeana.*

1936. Tucker, H. I., The Atlantic and Gulf coast Tertiary Pectinidae of the United States: Am. Midland Naturalist, v. 17, p. 471–490, 4 pls.
Includes *Pecten macdonaldi*, from Toro limestone member of Chagres sandstone.

1937. Coryell, H. N., and Embich, J. R., The Tranquilla shale (upper Eocene) of Panama and its foraminiferal fauna: Jour. Paleontology, v. 11, p. 289–305, pls. 41–43, 1 fig.
Foraminifera from a locality on Río Chagres, now flooded by Madden Dam.

1937. Coryell, H. N., and Fields, Suzanne, A Gatun ostracode fauna from Cativa, Panama: Am. Mus. Novitates 956, 18 p., 47 figs.
Ostracodes from lower part of Gatun formation.

1941. Vaughan, T. W., and Cole, W. S., Preliminary report on the Cretaceous and Tertiary larger Foraminifera of Trinidad, British West Indies: Geol. Soc. America Special Paper 30, 137 p., 46 pls., 2 figs.
Includes *Operculinoides panamensis.*

1941. Merriam, C. W., Fossil Turritellas from the Pacific coast region of North America: Calif. Univ., Dept. Geol. Sci., Bull., v. 26, no. 1, p. 1–214, pls. 1–41, 19 figs.
Turritella altilira is illustrated.

1942. Olsson, A. A., Tertiary deposits of northwestern South America and Panamá: Eighth Am. Sci. Cong. Proc., v. 4, p. 231–287.
Tertiary formations of Panamá.

1943. [Thompson, T. F.], Geology: Panama Canal, Dept. Operation and Maintenance, Special Eng. Div., Third Locks Project, pt. 2, chap. 3, 33 p., 21 figs.
General discussion of geology of Canal Zone.

1943. [Thompson, T. F.], Foundations and slopes: Idem, pt. 2, chap. 5, 138 p., 6 pls., 136 figs.
Detailed geology of Third Locks sites.

1944. Thompson, T. F., Geological explorations in the vicinity of Rio Quebrancha for the Panama Cement Company: Panama Canal, Dept. Operation and Maintenance, Special Eng. Div., 34 p., 10 pls., 4 figs.
Geology of part of Quebrancha syncline, east of Canal Zone.

1945. Nicol, David, Restudy of some Miocene species of *Glycymeris* from Central America and Colombia: Jour. Paleontology, v. 19, p. 622–624, pl. 85.
Includes *Glycymeris canalis.*

1946. Vaughan, T. W., Initiation of geological investigations in the Panama Canal Zone: Science, v. 104, no. 2696, p. 209.
Geologic investigations during construction period after 1910 are attributed to a suggestion from Lord Bryce to President Taft.

1946. Keen, A. M., and Thompson, T. F., Notes on the Gatun formation (Miocene), Panama Canal Zone (abstract): Geol. Soc. America Bull., v. 57, p. 1,260.
Three faunal zones are recognized.

1947. Nicol, David, Tropical American species of *Glycymeris* from the Tertiary of Colombia, and a new species from Panama: Jour. Paleontology, v. 21, p. 346–350, pl. 50.
Includes *Glycymeris schencki* from Gatun formation.

1947. MacDonald, D. F., Panama Canal slides: Panama Canal, Dept. Operation and Maintenance, Special Eng. Div., Third Locks Project, 73 p., 52 pls., 5 figs.

A posthumous publication. Discussion of geology includes some modification of MacDonald's earlier views. Geology of slide area in Gaillard Cut is shown on detailed map (scale, 1 inch=465 feet).

1947. [Thompson, T. F.], Geology: Panama Canal, Rept. Governor under Public Law 280, 79th Cong., 1st Sess., Annex 3, 30 p., 8 figs.
Geology of proposed sea-level canal is summarized.

1947. [Thompson, T. F.], Geology: Idem, App. 8, 84 p., 38 figs.
Geology of proposed sea-level canal. Areal geology is shown on strip maps, scale 1:40,000 and 1:20,000.

1948. Cooke, C. W., Eocene echinoids from Panama: Jour. Paleontology, v. 22, p. 91–93, pl. 22.
Eocene echinoids collected in Madden basin during field work for present report.

1949. Woodring, W. P., and Thompson, T. F., Tertiary formations of Panama Canal Zone and adjoining parts of Panama: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 223–247, 2 figs.
Summary of stratigraphy and paleontology of Tertiary formations.

1949. Cole, W. S., Upper Eocene larger Foraminifera from the Panama Canal Zone: Jour. Paleontology, v. 23, p. 267–275, pls. 52–55.
First published record of Eocene deposits in Canal Zone. The fossils were collected at locality 29 of present report.

1949. Bermúdez, P. J., *Pavoninoides*, a new genus of the Miliolidae from Panama: Cushman Lab. Foram. Research Contr., v. 25, pt. 3, p. 58, 1 fig.
Pavoninoides panamensis, from "marly limestone of the Oligocene (probably middle), Madden Lake." Though the locality is indefinite, the limestone presumably is in Gatuncillo formation.

1949. Rubio, Angel, Notas sobre geología de Panamá: Panamá, Ministerio de Educación, Depto. de Cultura y Publicaciones, 183 p., 32 figs.
Compilation of data on geology of Panamá.

1950. Pilsbry, H. A., and Olsson, A. A., Review of *Anticlimax*, with new Tertiary species (Gastropoda, Vitrinellidae): Bull. Am. Paleontology, v. 33, no. 135, 22 p., 4 pls.
Includes *Anticlimax gatunensis* and *A. teleospira*, from lower part of Gatun formation.

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GEOLOGY

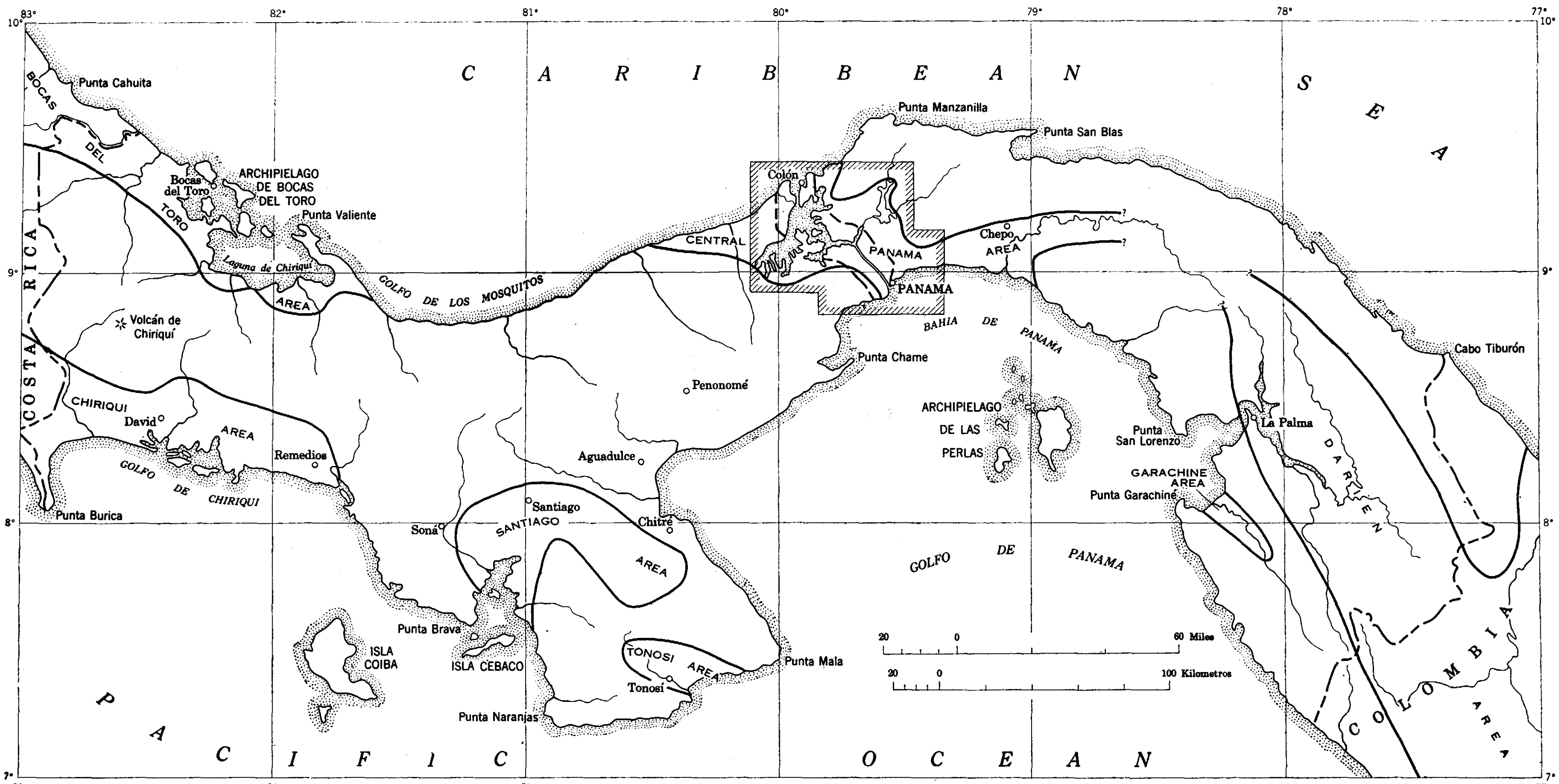
STRATIGRAPHY

OUTLINE OF STRATIGRAPHY

The region covered by plate 1 embraces all except the extreme western part of a Tertiary marine sedimentary area which may be designated the central Panamá area (fig. 1). The boundaries of the areas shown in figure 1 represent the approximate known extent of Tertiary marine formations, not the outlines of depositional basins. In the central Panamá area, Tertiary marine formations extend across the continental divide.

The stratigraphy in the region covered by plate 1 is notably different from place to place. For the purpose of description six main regions are recognized: Quebrancha syncline, Madden basin, Gatun Lake area, Caribbean coastal area, Gaillard Cut area, Pacific coastal region in Panamá east of the Canal Zone. Quebrancha syncline and Madden basin are structural features east of the Canal Zone. Gaillard Cut, designated Culebra Cut during the construction period, is the part of the canal excavation beginning opposite the south end of the Panama Railroad bridge across Río Chagres at Gamboa and extending southeastward, across the continental divide, to the north end of Pedro Miguel Locks. The correlation of the formations in different areas is shown in figure 4.

The basement on which the Tertiary formations rest consists principally of altered and strongly deformed volcanic rocks, including tuffs that contain marine



Base from American Geographical Society's 1:1,000,000 map of Hispanic America

Figure 1.—Map of Panamá showing principal areas of Tertiary marine sedimentary formations and area covered by plate 1. Base from American Geographical Society's 1:1,000,000 map of Hispanic America.

fossils. The volcanic rocks are intruded by dioritic rocks. This basal complex is probably of Cretaceous age, but so far all that is known about its age, in the region covered by plate 1, is that it is older than middle Eocene. It is much older than MacDonald's (1913, pl. 4) igneous complex—a map term he used for volcanic and intrusive rocks of Oligocene and early Miocene age.

The middle and upper Eocene Gatuncillo formation rests with marked unconformity on the basement rocks. It has been identified east of the Canal Zone and in the eastern part of the Zone. Lithologically it is more uniform than the Oligocene and lower Miocene formations.

Formations of known or inferred Oligocene age are of wide extent and very heterogeneous. They are marine and nonmarine, volcanic and nonvolcanic, at least nonvolcanic aside from tuffaceous debris. They represent all of Oligocene time and for the most part are conformable to each other and to the Gatuncillo formation. In the Pacific coastal area, however, the Bohio formation overlaps the Gatuncillo formation and in the northern part of Madden basin the Caimito formation overlaps the Bohio. Except in the Gaillard Cut area, the Oligocene formations are marine or partly marine: the Bohio and Caimito formations. Though the Bohio formation (the older of the two) appears to be for the most part nonmarine, marine strata are found in it at different horizons. Isolated outcrops in the Gatun Lake area, inferred to represent a tongue of marine strata in the lower part of the Bohio formation, contain mollusks considered of early Oligocene age and larger Foraminifera assigned to the late Eocene. Smaller Foraminifera of early Oligocene age are found in the basal part of the Bohio in the Quebrancha syncline. In both the Gatun Lake and Pacific coastal areas thin marine deposits in the upper part of the Bohio contain late Oligocene fossils. The Caimito formation overlies the Bohio and is for the most part marine. Late Oligocene fossils, particularly larger Foraminifera, are widespread in the Caimito. In Madden basin, however, the lower part of the formation is late Oligocene and the upper part is early Miocene.

In the Gaillard Cut area the place of the Bohio and Caimito formations apparently is taken by the wholly nonmarine and volcanic Bas Obispo formation and Las Cascadas agglomerate. They are considered Oligocene(?) on the basis of their inferred relations to the Bohio and Caimito formations. The Bas Obispo formation—the older of the two—seems to grade northwestward into the Bohio formation. The Las Cascadas agglomerate is thought to be the equivalent of the lower part, or perhaps all, of the Caimito formation of the Gatun Lake area.

The upper part of the Caimito formation of Madden basin, including the formally named Chilibrillo limestone and Alhajuela sandstone members, consists of marine deposits of early Miocene age. Nonmarine and marine lower Miocene deposits in the Gaillard Cut area are subdivided into relatively thin formations: in ascending order, the Culebra formation (including the Emperador limestone member), the Cucaracha formation, and the Panamá formation (including the La Boca marine member and Pedro Miguel agglomerate member). These three formations contain more volcanic material than supposedly equivalent deposits in Madden basin. The marine Culebra formation transgresses northward across the Las Cascadas agglomerate. According to present interpretations, the La Boca marine member of the Panamá formation interfingers with the upper part of the Cucaracha, or overlaps the Cucaracha and Culebra formations and rests on the Bas Obispo. All three formations and some of the lower Miocene of Madden basin are assigned to the upper Oligocene by some paleontologists.

The two Tertiary formations younger than those of early Miocene age are found only in the Gatun Lake and Caribbean coastal areas. These youngest formations are marine and, like the Eocene Gatuncillo formation, are more uniform lithologically than those of Oligocene and early Miocene age. The middle and upper Miocene Gatun formation is famous for its well-preserved fossils. Though the field relations between the Gatun and Caimito formations are unknown, the two formations evidently are separated by a discontinuity and perhaps by slight discordance. East of the Canal Zone the Gatun overlaps onto the Cretaceous(?) basement. The Gatun of the region covered by plate 1 is considered to be middle Miocene. The Gatun at the west end of the outcrop area, about 50 kilometers southwest of Colón, in the western part of the region shown in figure 3, is assigned to the late Miocene.

The lower Pliocene Chagres sandstone is the youngest of the Tertiary formations. It overlies and partly overlaps the Gatun formation. The thin Toro limestone member lies at the base of the Chagres in the eastern part of the outcrop area.

All the Tertiary formations are somewhat tuffaceous but the oldest and youngest contain the least tuffaceous debris, the Oligocene and lower Miocene the most. Moreover, the Oligocene and lower Miocene formations show a progressive southwestward increase in volcanic and intrusive rocks, until in the southwestern part of the region covered by plate 1 there is nothing but volcanic and intrusive rocks. The change is strikingly shown on plate 1; in fact, more so than would be the case if the map were equally detailed throughout. The volcanic rocks themselves and also the intrusive rocks are undifferentiated in the southwestern part of the map area. These undifferentiated rocks, however, adjoin a strip along the canal where greater detail is shown than elsewhere on the map.

CRETACEOUS(?) SYSTEM

The oldest rocks in the Canal Zone and nearby, much older than any seen along the canal, are chiefly altered lavas and dioritic rocks. These extrusive and intrusive rocks are briefly described or mentioned under the heading "Igneous rocks." Altered tuffs and other altered sedimentary rocks are associated with the lavas. None of these rocks, sedimentary or igneous, was studied during the field work and they were observed only casually. They crop out in the eastern part of the Zone and extensively in Panamá east of the Zone, making up the basement on which the Tertiary formations rest. This basement on the borders of Madden basin was designated the volcanic complex by Reeves and Ross (1930, p. 18).

Everywhere the basement forms high, rugged forested uplands and mountains. The composition, structure, and age of these rocks are important aspects of Panamanian geology that remain to be studied. Contrary to the expectation of geologists not familiar with the tropics, the high-gradient streams in the rugged terrain characteristic of the basement offer a wealth of rock outcrops. Moreover, the streams are so numerous that a closely spaced network of outcrops is available.

Strongly deformed altered tuffs were seen at a few localities. Three samples of different grain size, ranging from very fine-grained to very coarse and agglomeratic, were collected on the Transisthmian Highway 2 kilometers east-southeast of the bridge across Río Gatún. They were examined by W. S. Burbank, who found them to be moderately to strongly chloritized and carbonatized. The coarse-grained rock contains andesitic and latitic fragments and some devitrified glass. The two samples of finer grain contain angular fragments of feldspar, pyroxene, iron oxides, and quartz. These rocks of finer grain are sheared and fractured, and cut by veinlets of calcite and a colorless mineral, probably a zeolite.

Sedimentary and pyroclastic rocks of the basement complex at the Hyatt manganese prospects near Río Boquerón, the southernmost of which is shown at the north edge of the general geologic map (pl. 1), consist of siliceous limestone, quartzite, sheared agglomerate, and fine-grained tuff(?) altered to schist (Simons, *in* Roberts and Irving, 1957, p. 121, 124).

Though the age of the basement rocks is unkown—other than that they are older than the unconformably overlying middle and late Eocene deposits—they probably are Cretaceous, like widespread volcanic and associated rocks throughout the Caribbean region (Woodring, 1954, p. 722–725). Late Cretaceous Foraminifera (*Globotruncana* and *Gümbelina*) are reported to have been found in northwestern Panamá, near the Costa Rican border, in siliceous limestone that presumably represents the same major unit as the basement rocks of plate 1. The basement, however, may include rocks older and younger than Cretaceous. The altered tuffs sampled near Río Gatún are not the kinds of rocks that would be chosen as being likely to contain fossils. Yet thin sections of the three types sampled show indeterminable Foraminifera and Radiolaria. If further work on the basement rocks is undertaken, it doubtless is only a matter of time until identifiable fossils are found. The siliceous limestones are particularly promising for microscopic fossils.

EOCENE SERIES

GATUNCILLO FORMATION

Formations of Paleocene and early Eocene age are unknown in the central Panamá area. They may, however, be represented in the basement complex or by overlapped deposits in the structurally deeper parts of the area. The oldest known Tertiary formation is the Gatuncillo formation, which lies directly on the Cretaceous(?) basement.

The Gatuncillo formation was named by Thompson (1944, p. 12–13) as the Gatuncillo shale. The type region is in the valley of Río Gatuncillo on the east limb of the Quebrancha syncline. The name Tranquilla shale has priority, but that name was defined inadequately, principally on the basis of foraminiferal samples from a locality in Madden basin later flooded by Madden Dam (Coryell and Embich, 1937, p. 289; for location of Tranquilla see Reeves and Ross, 1930, pl. 5).

The Gatuncillo crops out in the eastern part of the Canal Zone and east of the Zone. It forms rolling lowlands, which stand in contrast to the rugged uplands characteristic of the basement complex. The thickness of the Gatuncillo is estimated to range from 150 to 800 meters. The formation unconformably overlies the Cretaceous(?) basement. In the type region and in other areas wherever the succession is complete, the Gatuncillo is conformably overlain by the Bohio formation. In Madden basin, however, the Bohio is overlapped by the Caimito formation. In the Pacific coastal area the Gatuncillo does not appear between the basement and the Bohio formation, being overlapped by the Bohio. Collections of larger Foraminifera sent to T. W. Vaughan many years ago by A. A. Olsson and R. A. Terry indicate that Eocene deposits reappear farther east in the Pacific coastal area in the valley of Río Bayano, 45 kilometers east-northeast of the eastern edge of the area shown on plate 1 (Terry, 1956, p. 32).

Though the Gatuncillo consists chiefly of mudstone and siltstone, it includes bentonitic mudstone, sandstone, and limestone, and at the base conglomerate of variable thickness.

STRATIGRAPHY AND LITHOLOGY

Río Agua Sucia area.—The Río Agua Sucia area lies west of the Quebrancha syncline, between the Azota Caballo and the Agua Sucia faults. Before it was realized that the deposits in the Río Agua Sucia area are of Eocene age, the name Río Duque shale was proposed for them (Thompson, 1944, p. 21–23). The area is crossed by the Transisthmian Highway. Cuts along the highway expose mudstone, siltstone, and sandstone of the Gatuncillo formation. Mudstone and siltstone are more prevalent in the southeastern part of the area, sandstone in the northwestern part. The mudstone is more silty than in the Quebrancha syncline; sandstone is more prevalent than in other areas; and northwestward, which also is stratigraphically upward, the sandstone is of coarser grain than in other areas. Sandstone at locality 27 [1] is medium-grained, poorly sorted, and contains much carbonaceous debris. The strata at locality 28 consist of poorly sorted gritty sandstone. The northwestward increase in grain size suggests that the depositional margin of the central Panamá area was not far to the north.

So far as observed, limestone is not common. Algal-foraminiferal limestone, about 15 meters thick, forms a little hill at locality 25, and foraminiferal limestone crops out at locality 23a.

Quebrancha syncline.—In the type region, on the east flank of the Quebrancha syncline, the maximum thickness of the Gatuncillo formation is estimated to be 800 meters, apparently greater than in other areas. An earlier estimate of 3,000 feet (900 meters) probably is excessive (Woodring and Thompson, 1949, p. 227). Fine-grained rocks—mudstone and siltstone—make up the bulk of the formation. Limestone, bentonic mudstone, sandstone, and conglomerate are minor constituents. Typical fine-grained rocks are readily accessible on Río Quebrancha about 100 meters upstream from the Transisthmian Highway bridge (locality 21). The limestones are algal and foraminiferal and most of them have a thickness of less than a meter, such as those off the north side of the Transisthmian Highway 50 meters east of the bridge across Río Gatuncillo (locality 20) and along the road leading southward from the Transisthmian Highway to Nuevo San Juan (localities 22, 23). On Quebrada Fea (the stream on the east side of Río Gatuncillo valley 4 kilometers northeast of the Transisthmian Highway bridge across Río Gatuncillo), however, algal-foraminiferal limestone has a thickness of at least 10 meters. Conglomerate and sandstone at the base of the formation are exposed on the Transisthmian Highway. The conglomerate, resting on Cretaceous(?) altered volcanic rocks, has a thickness of 30 to 90 centimeters and is made up of pebbles and cobbles of altered volcanic rock. It is overlain by soft medium- to fine-grained sandstone grading upward into soft silty fine-grained sandstone. The thickness of the sandstone is 6½ meters.

Madden basin.—The largest outcrop area of the Gatuncillo formation is in the northern and northeastern parts of Madden basin. Much of the outcrop area, however, is flooded by Madden Lake. The Eocene deposits of Madden basin were included in the Bohio formation by Reeves and Ross (1930, p. 17–18), although they are strikingly unlike those of the Bohio. The thickness of the formation is difficult to estimate, but probably is not more than 300 meters.

Limestones are more extensive and individual units of limestone are thicker than in other areas. As elsewhere, algal or algal-foraminiferal limestone is most common, but other kinds of limestone are represented. Algal and algal-foraminiferal limestone in the upper part of the Gatuncillo at locality 14 is fully 30 meters thick. It is separated by sandy strata from an overlying algal limestone that reaches a thickness of about 15 meters. Similar algal limestone, also about 15 meters thick, forms the natural bridge (puente natural) on Río Puente. A cliff on the north side of Río Puente, 800 meters in a direct line upstream from the natural bridge, exposes almost the same thickness of limestone. Silty somewhat fissile echinoid-bearing limestone (plate 4), soft yellowish marly limestone, moderately soft coralliferous limestone, and hard algal limestone, all representing a thickness of 10 meters, are exposed in a partly demolished hill at locality 11. There are numerous other exposures of limestone in Madden basin; in fact, all the fossils from that area were found in limestone. That limestone may occur at the base of the formation is shown by the following section measured on the south side of Río Pequení:

[1] The localities at which fossils were collected are listed on pages 112–130 and, unless otherwise specified in the list, are plotted on the general geologic map (pl. 1).

Section of basal part of Gatuncillo formation on south side of Río Pequení near head of Madden Lake (locality 1)

	Meters
Gatuncillo formation:	
Limestone, thin-bedded nodular-weathering; lowest 1 meter more granular and somewhat sandy. Scattered angular pieces and few pebbles of basement rocks (diameter of largest 8 centimeters) throughout lower half, more numerous in some layers. *Lepidocyclina* abundant; many *Yaberinella* in one layer. Collection (locality 1a) 3 to 4.5 meters above base	10. 6
Unexposed (possibly sandy or silty strata)	1. 5
Limestone, thin-bedded, in thicker beds than overlying limestone. Contains *Lepidocyclina* and *Yaberinella*. Collection (locality 1) 0.5 meter above base	1. 5
Unexposed (possibly sandy or silty strata)	1. 5
Limestone, few boulders of altered volcanics at base	. 5
Basement of altered volcanic rock.	
Thickness of section	15. 6

Fine-grained and sandy rocks presumably make up the bulk of the formation. Fine-grained rocks are not readily accessible, but they doubtless could be found by traversing streams. Sandy strata form a treeless area surrounding locality 11 and sandy strata in the upper part of the formation near locality 13 include practically pure quartz sand.

Río Agua Salud area.—The Río Agua Salud area is the long, narrow strip of the Gatuncillo formation on the upthrown side of the Chinilla fault, in the eastern part of the Canal Zone. Coring along the alinement for a diversion channel for Río Chagres—part of the Sea-level Canal project—showed the presence of the Gatuncillo formation in this area, the first record of Eocene deposits in the Canal Zone. R. H. Stewart and T. F. Thompson recognized larger Foraminifera of the Gatuncillo formation in cores from core hole SL84 (locality 29), drilled in 1947, and in float limestone at the core-hole locality. Their age identification was confirmed by W. S. Cole, who described the Foraminifera (Cole, 1949). The three localities in the Río Agua Salud area are core holes (localities 29–31), which started and bottomed in the Gatuncillo formation. The strata penetrated consist of mudstone, siltstone, silty sandstone, calcareous siltstone, silty limestone, and limestone. The depth of penetration ranged from 30.7 to 54.1 meters.

Río Fríjol area.—The Río Fríjol area includes the outcrop area of the Gatuncillo formation in the drainage basin of Río Fríjol and the smaller area farther east. The thickness of the formation along Río Fríjol is estimated to be between 300 and 400 meters. The lithologic types are similar to those elsewhere: mudstone, siltstone, sandstone, and thin beds of limestone. Some of the sandstone contains carbonaceous debris. For a discussion of the Gatuncillo formation in the Gatun Lake area seaward from the Río Fríjol area see page 61.

Gamboa area.—A narrow band of Gatuncillo rocks lies in the lowland north of the high ridge north of Gamboa. The strata dip northeastward and appear to be overlain in normal succession by the Bohio formation. If the high ridge is underlain by basement rocks, as shown on plate 1, and if the Gatuncillo is not bounded by faults to the south or north, the thickness of the Gatuncillo is not more than 150 meters. The only outcrop of the Gatuncillo seen in this area consists of calcareous mudstone containing a thin layer of limestone (locality 37).

Río Casaya area.—Outcrops of fossiliferous rocks of the Gatuncillo formation were found by R. H. Stewart along Quebrada de Oro, a northwestward-flowing tributary of Río Casaya about 4 kilometers southeast of Gamboa (locality 38). The stream may be recognized by mine-machinery debris and caved adits. Limestone, sandstone, and siltstone of the Gatuncillo formation are intruded by dacite porphyry. These sedimentary rocks are partly silicified. They probably are faulted against the Caimito formation, although no fault is shown on plate 1.

No outcrop areas of the Gatuncillo formation are known southwest of the Río Casaya area. Though the formation seems to be thinning southwestward, it may extend farther in that direction beneath the Oligocene and lower Miocene strata penetrated by the canal and the undifferentiated volcanic rocks farther southwest.

FOSSILS AND AGE

Smaller Foraminifera.—In most of the areas smaller Foraminifera are abundant in mudstone and siltstone. Coryell and Embich described species collected at Tranquilla, a village on Río Chagres flooded by Madden Lake, and assigned the fauna to the upper Eocene (Coryell and Embich, 1937). H. H. Renz and P. J. Bermúdez kindly identified the following species in five samples:

Smaller Foraminifera from Gatuncillo formation

[Identifications by H. H. Renz and P. J. Bermúdez]

	Localities				
	Quebrancha syncline		Río Agua Sucia area	Río Agua Salud area	Río Frijol area
	17	21	24	31	35
Alabamina sp	----	?	×	×	
Allomorphina trigona Reuss	----	----	×	----	----
Angulogerina sanjuanensis Coryell and Embich	×	----	×	×	×
sp	----	----	×	----	----
Anomalina pacoraensis Coryell and Embich	×	----	×	----	----
cf. *A. alazanensis* Nuttall	----	----	----	×	----
sp	----	×	----	×	----
Anomalinoides sp	----	×	----	----	----
Astacolus sp	----	×	----	----	----
Bathysiphon eocenica Cushman and Hanna	×	×	×	×	×
Bolivina alazanensis Cushman	----	×	----	----	----
byramensis Cushman	----	×	----	----	----
gracilis Cushman and Applin	----	----	----	----	×
cf. *B. gracilis* Cushman and Applin	×	----	----	×	----
jacksonensis Cushman and Applin	----	----	×	----	----
cf. *B. jacksonensis* Cushman and Applin	×	----	----	----	----
maculata Cushman and Stone	×	----	----	----	----
cf. *B. maculata* Cushman and Stone	----	----	×	----	----
malkinae Coryell and Embich	×	----	----	×	×
cf. *B. ventricosa* Galloway and Heminway	----	×	----	----	----
sp	×	----	----	----	----
Bulimina alazanensis Cushman	×	×	----	×	×
consanguinea Parker and Bermúdez	×	----	×	----	----
cf. *B. cooperensis* Cushman	----	----	----	×	----
guayabalensis Cole	----	×	----	----	----
cf. *B. impendens* Parker and Bermúdez	----	×	----	----	----
jacksonensis Cushman	×	----	----	×	×
cf. *B. jacksonensis* var. *cuneata* Cushman	----	×	----	----	----
palmerae Parker and Bermúdez	----	----	×	----	----
cf. *B. palmerae* Parker and Bermúdez	----	----	----	----	×
pupoides d'Orbigny	----	----	×	×	×
cf. *B. pyrula* d'Orbigny	----	----	----	×	----
tuxpamensis Cole	----	----	----	×	----
sp	----	----	×	----	×

Smaller Foraminifera from Gatuncillo formation—Continued

[Identifications by H. H. Renz and P. J. Bermúdez]

	Localities				
	Quebrancha syncline		Río Agua Sucia area	Río Agua Salud area	Río Frijol area
	17	21	24	31	35
Buliminella sp	×	----	----	----	----
Cassidulina crassa d'Orbigny	----	----	----	×	----
havanensis Cushman and Bermúdez	----	----	----	----	×
subglobosa Brady	----	×	----	×	----
sp	×	×	×	----	×
Cassidulinoides sp	----	×	----	----	----
Ceratobulimina alazanensis Cushman and Harris	----	×	×	×	----
Chilostomella mexicana Nuttall	----	×	×	----	----
cf. *C. ovoidea* Reuss	----	×	----	----	----
sp	----	----	×	----	×
Chilostomelloides oviformis (Sherborn and Chapman)	----	----	----	×	----
Chrysalogonium cf. *C. asperum* Cushman and Stainforth	----	×	----	×	----
elongatum Cushman and Jarvis	----	----	×	----	----
sp	×	----	----	----	?
Cibicides cocoaensis (Cushman)	×	----	×	×	----
cf. *C. concentricus* (Cushman)	×	----	----	----	×
cf. *C. cookei* Cushman and Garrett	×	----	----	----	----
leoni (Bermúdez)	×	×	----	----	----
mexicanus Nuttall	----	----	----	×	----
perlucidus Nuttall	----	----	----	×	----
cf. *C. perlucidus* Nuttall	----	----	×	----	----
cf. *C. pseudoungerianus* (Cushman)	×	----	×	----	----
sp	×	----	×	----	×
n. spp	----	×	----	×	----
Clavulinoides cubensis Cushman and Bermúdez	×	×	×	×	----
havanensis Cushman and Bermúdez	----	----	×	----	----
sp	----	----	----	×	×
Cornuspira olygogyra Hantken of Cushman	----	×	----	----	----
Cyclammina cf. *C. pacifica* Beck	----	×	×	×	----
sp	×	----	----	----	----
Dentalina cf. *D. communis* d'Orbigny	×	----	×	×	----
cf. *D. cooperensis* Cushman	----	----	----	×	----
cf. *D. mucronata* Neugeboren	×	----	----	----	----
semilaevis Hantken	×	----	----	----	----
sp	×	×	×	----	----
spp	----	----	----	×	----
Discorbis sp	----	----	×	----	----

Smaller Foraminifera from Gatuncillo formation—Continued

[Identifications by H. H. Renz and P. J. Bermúdez]

	Localities				
	Quebrancha syncline		Río Agua Sucia area	Río Agua Salud area	Río Frijol area
	17	21	24	31	35
Dorothia cylindrica (Nuttall)	×	--	--	--	×
cf. *D. nuttalli* Cushman	--	--	×	--	--
sp	--	×	×	×	×
Ellipsoglandulina labiata (Schwager)	--	--	×	--	--
multicostata (Galloway and Morrey)	--	--	×	--	--
Entosolenia cf. *E. laevigata* (Reuss)	--	×	--	--	--
cf. *E. marginata* (Walker and Boys)	--	×	--	×	--
orbignyana (Seguenza)	--	--	×	--	--
sp	×	--	--	×	--
Eponides jacksonensis Cushman	--	--	--	--	×
cf. *E. rutteni* Cushman and Bermúdez	--	--	×	--	--
umbonatus (Reuss)	×	×	×	×	--
var. *multisepta* Koch	--	×	--	--	--
Frondicularia tenuissima Hantken	×	--	--	--	--
Gaudryina (*Pseudogaudryina*) cf. *G. jacksonensis* Cushman	--	--	--	×	--
Glandulina sp.	×	×	--	×	--
Globigerina ciperoensis Bolli	--	×	--	--	×
ouachitaensis Howe and Wallace	--	×	×	×	--
sp	×	×	×	×	×
Globigerinoides mexicanus (Cushman)	--	--	--	×	×
sp	--	--	×	×	--
Globobulimina hannai Cushman and Ellisor	×	×	--	--	--
cf. *G. hannai* Cushman and Ellisor	--	--	--	×	×
sp	--	--	×	--	--
Globorotalia centralis Cushman and Bermúdez	×	--	×	×	×
Globulina cf. *G. gibba* d'Orbigny	--	×	--	--	--
rotundata (Bornemann)	×	--	--	--	--
sp	--	×	×	--	--
Gümbelina cubensis Palmer	--	×	--	--	×
martini (Pjipers)	--	--	×	×	--
Guttulina irregularis (d'Orbigny)	--	--	×	--	--
Gyroidinoides girardana (Reuss)	--	--	×	--	--
guayabalensis (Cole)	--	×	--	--	--
soldanii var. *octocamerata* (Cushman and Hanna)	×	×	×	×	--
sp	--	--	--	×	--
Hantkenina alabamensis Cushman	×	--	×	--	×
suprasuturalis Bronnimann	--	--	×	×	--
Haplophragmoides cf. *H. dibollensis* Cushman and Applin	--	--	×	--	--
Hastigerinella eocanica Nuttall	--	--	×	--	--
sp	--	--	×	--	--
Höglundina elegans (d'Orbigny)	--	×	×	×	×
Karreriella arenasensis Cushman and Bermúdez	--	×	--	--	--
chilostoma (Reuss)	×	×	--	--	--
mexicana (Nuttall)	--	×	--	--	--
cf. *K. mexicana* (Nuttall)	--	--	×	--	--
sp	×	--	--	×	--
Lagena acuticostata Reuss	--	--	×	--	×
cf. *L. hexagona* (Williamson)	×	--	--	--	--
sp	--	--	--	×	--
Lagenoglandulina subovata var. *chagresensis* Coryell and Embich	×	--	--	--	×
Lagenonodosaria cf. *L. sigmoidea* Coryell and Rivero	×	--	--	--	--
sp	--	--	×	--	--
Loxostoma dalli (Cushman)	×	--	--	×	--
Marginulina cf. *M. abbreviata* Neugeboren	--	--	×	--	--
cf. *M. attenuata* Neugeboren	×	--	--	--	--
cf. *M. eximia* Neugeboren	×	×	--	×	--
hantkeni (Bandy)	--	--	--	--	×
cf. *M. subcrassa* Schwager	--	×	--	--	--
cf. *M. triangularis* var. *panamensis* Coryell and Embich	--	--	×	--	--
sp	×	×	×	--	×
Marginulinopsis cocoaensis (Cushman)	--	--	--	--	×
sp	--	--	×	--	--
Matanzia? sp	--	--	--	--	×
Nodogenerina heterosculpta Bermúdez	--	×	--	--	--
sp	×	--	--	--	--
Nodosaria chirana Cushman and Stone	×	--	--	--	--
longiscata d'Orbigny	×	×	×	×	--
multilineata (Bornemann)	--	--	--	--	×
soluta (Reuss)	--	--	--	×	--
sp	×	×	×	×	×

Smaller Foraminifera from Gatuncillo formation—Continued

[Identifications by H. H. Renz and P. J. Bermúdez]

	Localities				
	Quebrancha syncline		Rio Agua Sucia area	Rio Agua Salud area	Rio Frijol area
	17	21	24	31	35
Nonion danvillense Howe and Wallace	×	----	×	×	×
pompilioides (Fichtel and Moll)	----	×	----	----	----
cf. *N. pompilioides* (Fichtel and Moll)	----	----	×	----	----
sp	×	×	----	×	----
Orthomorphina cf. *O. rohri* (Cushman and Stainforth)	----	----	×	----	----
Osangularia mexicana (Cole)	----	----	×	×	----
sp	×	×	----	----	----
Planularia sp	----	----	----	----	×
Planulina marialana Hadley	----	----	----	----	×
suturata Cushman and Bermúdez	×	----	×	----	----
Plectina nuttalli Cushman and Stainforth	----	----	----	×	----
Plectofrondicularia cookei Cushman	×	----	×	----	----
morreyae Cushman	----	×	----	----	----
vaughani Cushman	×	×	×	×	----
sp	----	----	×	----	----
Pleurostomella alternans Schwager	----	×	----	----	----
cf. *P. palmerae* Bermúdez	----	----	×	----	----
cf. *P. praegerontica* Cushman and Stainforth	----	×	----	----	----
sp	----	----	×	×	----
Pseudoglandulina laevigata (d'Orbigny)	----	----	----	----	×
cf. *P. laevigata* (d'Orbigny)	----	----	----	×	----
ovata (Cushman and Applin)	----	----	×	----	----
radicula (Linné)	×	----	----	----	----
cf. *P. radicula* (Linné)	----	×	----	----	----
sp	×	----	×	×	----
Pullenia cf. *P. bulloides* (d'Orbigny)	×	----	----	----	----
sp	×	----	×	×	----
Pyrgo pseudoinornata Cushman and Stainforth	----	×	----	----	----
sp	----	×	----	×	----
Quinqueloculina sp	----	×	----	×	----
Robulus cf. *R. dicampylus* (Franzenau)	----	----	----	×	----
terryi Coryell and Embich	----	×	----	----	----
spp	×	×	×	×	×
Rotaliatina mexicana Cushman	×	----	----	×	----
Saracenaria acutauricularis (Fichtel and Moll)	×	----	----	----	----
cf. *S. hantkeni* (Cushman	----	----	----	----	×
cf. *S. latifrons* (Brady)	----	×	×	----	----
cf. *S. schencki* Cushman and Hobson	----	----	×	----	----
Schenckiella cf. *S. petrosa* (Cushman and Bermúdez)	×	----	----	----	----
sp	----	----	×	----	----
Sigmoilina tenuis (Czjzek)	----	×	----	----	----
Sigmomorphina sp	×	----	----	×	----
Siphogenerina sp	----	×	----	×	----
Siphonina advena Cushman	----	----	×	----	×
tenuicarinata Cushman	----	----	----	×	----
Siphonodosaria cf. *S. annulifera* (Cushman and Bermúdez)	----	----	----	----	×
aff. *S. curvatura* (Cushman)	----	----	----	×	----
cf. *S. dentaliniformis* (Cushman and Jarvis)	----	----	×	----	----
cf. *S. nuttalli* (Cushman and Jarvis)	----	----	----	×	----
paucistriata (Galloway and Morrey)	----	×	×	----	----
puntensis Coryell and Embich	×	----	----	----	----
recta (Palmer and Bermúdez)	----	----	×	----	----
aff. *S. subspinosa* (Cushman)	×	----	----	----	----
verneuili (d'Orbigny)	----	----	----	×	×
var. *emaciata* (Palmer and Bermúdez)	----	----	----	----	×
sp	×	×	----	×	×
Siphotextularia sp	----	×	----	----	----
Spiroloculina cf. *S. texana* Cushman and Ellisor	----	×	----	----	----
sp	×	----	----	----	×
Spiroplectammina planulis (Coryell and Embich)	×	----	----	----	×
Textularia hockleyensis var. *malkinae* Coryell and Embich	----	×	----	----	----
cf. *T. recta* Cushman	×	----	----	----	----
Textularia? sp	×	----	----	----	----

Smaller Foraminifera from Gatuncillo formation—Continued

[Identifications by H. H. Renz and P. J. Bermúdez]

	Localities				
	Quebrancha syncline		Rio Agua Sucia area	Rio Agua Salud area	Rio Frijol area
	17	21	24	31	35
Textulariella sp.					×
Triloculina cf. *T. globosa* (Hanna and Hanna)		×			
cf. *T. subrotundata* (Montagu)			×		
sp.	×		×		
Uvigerina adelinensis Palmer and Bermúdez	×				
cf. *U. atwilli* Cushman and Simonson					×
cf. *U. chirana* Cushman and Stone	×			×	
curta Cushman and Jarvis				×	×
gardnerae var. *nuttalliana* Howe and Wallace		×			
spinicostata Cushman and Jarvis	×	×	×	×	
spinulosa Coryell and Embich		×			
cf. *U. spinulosa* Coryell and Embich				×	
sp.	×	×			×
Vaginulinopsis mexicanus (Nuttall)	×	×	×		
cf. *V. mexicanus* (Nuttall)				×	
sp.			×		
Valvulineria cushmani Coryell and Embich					×
gasparensis Bermúdez		×			
Virgulina cf. *V. danvillensis* Howe and Wallace			×		
cf. *V. dibollensis* Cushman and Applin		×			
cf. *V. advena* Cushman	×		×		
pachyheilus Hadley			×	×	
sp.	×	×		×	

Barring unknown structural complications and overlaps, localities 24 and 31 represent the lower third of the Gatuncillo formation, localities 17 and 35 the middle third, and locality 21 the upper third. The following comments concerning the five samples were prepared by Messrs. Renz and Bermúdez:

A considerable number of species and varieties are unidentified, either because they are undescribed or because comparative material was not available.

The smaller Foraminifera in the five samples represent various levels in the upper Eocene. The age determinations are based on a correlation of the faunas—with special emphasis on some of the pelagic species—with assemblages from other regions where the stratigraphic position and age are fairly well established. It should be mentioned, however, that the boundary between the lower part of the upper Eocene and the upper part of the middle Eocene, on the basis of smaller Foraminifera, is uncertain throughout the Caribbean region.

Two main upper Eocene faunal units are represented: an earlier (localities 24, 31, 17, and 35) and a later (locality 21). The earlier unit itself suggests two minor units: the older represented by localities 24 and 31, the younger by localities 17 and 35.

The faunas from localities 24, 31, 17, and 35 are characterized by the occurrence of *Bulimina jacksonensis* (or a related form), *Globorotalia centralis*, and *Hantkenina alabamensis* or *H. suprasuturalis*. They show distinct affinities with faunas of the Jackson group of southeastern United States, the Jicotea member of the Jabaco formation and the San Luis formation of Cuba (Bermúdez, 1950, p. 249–258), the Paují formation of Venezuela (Nuttall, 1935), and the lower part of the Mount Moriah formation and the Hospital Hill marl in the San Fernando group of Trinidad (Cushman and Renz, 1948).

The fauna from locality 21 has upper Eocene and lower Oligocene affinities. It lacks *Globorotalia centralis* and *Hantkenina*. The presence of a form related to *Bulimina jacksonensis*, however, indicates a late Eocene age. This fauna suggests relationship with that of the Consuelo formation of Cuba (Bermúdez, 1950, p. 258–262).

Larger Foraminifera.—The first Eocene fossils from Panamá were recorded in 1891, when Douvillé wrote that calcareous algae and heterostegine and orbitoid Foraminifera were found in limestone at San Juan in the upper Chagres valley (Douvillé, 1891, p. 498, 499). He thought the fossils to be of Oligocene age. By the time his second note on the age of the beds along and near the canal was published, he recognized that the orbitoid found at San Juan represents the genus *Lepidocyclina* (Douvillé, 1898, p. 598–599), later named *L. chaperi* as a tribute to the collector, an engineer of the first French canal company (Lemoine and R. Douvillé, 1904, p. 14). In a still later publication Douvillé reiterated the Oligocene age, as he was not then aware of the presence of *Lepidocyclina* in the Eocene (Douvillé, 1915, p. 129–130). At that time, however, he recorded the occurrence of a stellate discocyclinid ("*Asterodiscus*") in association with *Lepidocyclina* in another sample of limestone from the upper Chagres valley. Vaughan (1919b, p. 549, table opposite p. 595) left these strata in the Oligocene, despite Cushman's suggestion (in a footnote to Vaughan's table) that they should be referred to the upper Eocene. San Juan was located on Río Pequení and is submerged by Madden Lake. (For location see Reeves and Ross, 1930, pl. 5.) E. R. Lloyd collected at San Juan in 1919 before Madden Dam was built (locality 3 of present report). When this collection was sent to Vaughan in 1926, he found that at its type locality *Lepidocyclina chaperi* is associated with late Eocene species (Vaughan, 1926).

Larger Foraminifera are the most abundant and widespread fossils in limestone and calcareous mudstone of the Gatuncillo formation. Loose specimens weathered out of both kinds of rock are most suitable for identification, as oriented thin sections can be prepared. At many localities these fossils weather out of hard limestone because they are silicified or partly silicified, whereas the limestone is not silicified. Plate 3 shows slective silicification and iron staining in a slab of limestone collected at locality 14. At locality 13 specimens of a small *Lepidocyclina*, probably *L. pustulosa*, are completely silicified and covered with beekite excrescences, producing fantastic effects. Though no larger Foraminifera from the Río Casaya area appear in the table of identified species, they were found in the area. The partly silicified limestone that yielded mollusks under acid treatment also yielded many specimens which probably are *Lepidocyclina pustulosa*. They are hollow, however, and therefore indeterminable. Float limestone in the Río Casaya area contains somewhat silicified specimens of a saddle-shaped *Lepidocyclina*, probably *L. chaperi*.

Samples of larger Foraminifera were collected at 27 localities. Those from 15 localities were selected, on a basis of favorable preservation and geographic and stratigraphic range, for study by W. S. Cole, whose report was published in 1953 (Cole, 1952 [1953]). His identifications are as follows:

Larger Foraminifera from Gatuncillo formation

[Cole, 1952 (1953), p. 4]

	Localities[1]														
	Madden basin						Quebrancha syncline				Río Sucia	Agua area	Río Agua Salud area	Río Frijol area	Gamboa area
	1	1a	2	4	10	11	19	22	23	26	27a	28	29	33	37
Yaberinella jamaicensis Vaughan	×	×													
Operculinoides floridensis (Heilprin)					×								×		
jacksonensis (Gravell and Hanna)					×										
moodybranchensis (Gravell and Hanna)					×										
ocalanus (Cushman)		×	×						×			×	×		×
vaughani (Cushman)		×										×			
Nummulites[2] *striatoreticulatus* L. Rutten							×		×	×		×	×	×	
Heterostegina ocalana Cushman									×		×	×			
Fabiania cubensis (Cushman and Bermúdez)	×	×				×					×	×			×
Helicostegina soldadensis (Grimsdale)											×				
Lepidocyclina (Lepidocyclina) montgomeriensis Cole					×				×				×		
(Pliolepidina) gubernacula Cole										×	×				
macdonaldi Cushman	×	×	×	×		×	×	×	×			×	×		×
pustulosa H. Douvillé	×	×	×	×		×	×	×			×	×	×	×	×
pustulosa tobleri H. Douvillé		×	×		×		×	×					×		×
(Nephrolepidina) chaperi Lemoine and R Douvillé				×		×			×	×	×	×		×	×
Helicolepidina spiralis Tobler			×	×					×		×		×	×	
Asterocyclina georgiana (Cushman)			×				×	×	×		×		×		
mariannensis (Cushman)												×			
minima (Cushman)											×	×	×		
Pseudophragmina (Proporocyclina) flintensis (Cushman)									×			×	×		

[1] The locality numbers in Cole's publication are field numbers. For correlation with report numbers of present report see p. 112–116.
[2] Cited by Cole as *Camerina*.

Lepidocyclina pustulosa, *L. macdonaldi*, and *L. chaperi* are abundant and widespread. Discocyclinids (*Asterocyclina* and *Pseudophragmina*) were collected at 7 of the 15 localities, *Helicolepidina spiralis* at 6 localities, *Fabiania cubensis* at 6, *Helicostegina soldadensis* at only one. *Yaberinella jamaicensis* was found in the basal part of the formation (localities 1, 1a), associated with *Fabiania cubensis*. *Nummulites striatoreticulatus* is a relatively large nummulite for an American species. *Operculinoides* is extraordinarily abundant at locality 10.

According to Cole (1952 [1953], p. 4–5), the larger Foraminifera of the Gatuncillo formation are dominated by species characteristic of the upper Eocene rocks of Trinidad and Florida. He also pointed out that two of the species (*Yaberinella jamaicensis* and *Fabiania cubensis*) are recorded only from the middle Eocene, but that there are good grounds for considering that the former ranges upward into upper Eocene in Jamaica and the latter into upper Eocene in Cuba.

Corals.—Corals are fairly common in limestone, for the most part hard limestone that yields only random sections. Specimens that weathered out of softer marly limestone and calcareous mudstone were collected at five localities. Such fossils, which generally are poorly preserved, were found to be abundant only at locality 11, where slabs of limestone from a partly demolished hill are disintegrating. The collections were examined by J. W. Wells, who identified the following species:

Corals from Gatuncillo formation

[Identifications by J. W. Wells]

	Localities				
	Madden basin				Río Agua Sucia area
	8	11	12	16	26
Heliopora sp		×			
Astrocoenia incrustans Duncan				×	×
Astreopora n. sp		×			
Diploastrea n. sp. aff. *D. crassolamellata* (Duncan)		×			
Goniopora aff. *G. taberi* Wells		?	×		
Porites (*Synaraea*) n. sp		×			
Favia cf. *F. weisbordi* Wells		×			
Colpophyllia sp			×		
Antillia cf. *A. hadleyi* Wells	×		×		
Millepora aff. *M. alcicornis* Linné		×			

Wells reports that the new species of *Diploastrea* is closely allied to the widespread late Oligocene *D. crassolamellata* and that the fossils from locality 11 constitute the first record of a pre-Pleistocene *alcicornis*-like *Millepora* in America. He points out that most of the other species show close relationship to upper Eocene Cuban corals and a less marked relationship to middle Eocene corals from St. Bartholomew.

Mollusks from Gatuncillo formation (*Neritidae to Turritellidae*)

	Localities								
	Madden basin						Río Fríjol area		Río Casaya area
	6	7	9	11	12	16	32	34	38
Velates perversus (Gmelin), subsp.?	×	×	×	×					×
Hannatoma? cf. *H. emendorferi* Olsson									×
Xenophora sp			×		×				
Hipponix sp									×
Calyptraea cf. *C. aperta* (Solander)			×		×				
Polinices? sp					×				
Neverita? sp			×	×	×	×			
Sinum sp									×
Amaurellina? sp			×	×	×				
Pachycrommium? solenaeum Woodring, n. sp									×
Turritella cf. *T. carinata* Lea									×
cf. *T. samanensis* Olsson								×	
sp				×	×		×	×	

Mollusks.—A few microscopic mollusks were recovered from foraminiferal mudstone and siltstone. Molds of mollusks weather out of limestones in Madden basin. The largest number of species represented by such molds was found at localities 11 and 12. Somewhat calcareous sandstone in the Río Fríjol area contains a few species. The best preservation is shown by silicified fossils collected in the Río Casaya area (locality 38). These silicified fossils are casts composed of granular silica. They occur in partly silicified limestone and therefore can be extracted by treatment with acid.

The species listed on p. 21 are represented in the families covered by Chapter A of the present report.

The mollusks of the Gatuncillo formation include species of Tethyan affinities, an example of which is *Velates perversus*. *Hannatoma* is an American genus, found in the Eocene of Perú, Colombia, and Venezuela, and in the Oligocene of Perú. It is not certain, however, that *Hannatoma* occurs in the Gatuncillo formation, as the aperture and growth line of the species identified as *Hannatoma?* cf. *H. emendorferi* is unknown. *Turritella* cf. *T. carinata,* and other species from the Río Casaya area not included in the preceding list, indicate a middle Eocene age, but the bulk of the fauna suggests late Eocene.

Echinoids.—Echinoids collected at locality 11 were identified by C. W. Cooke (1948) as *Cubanaster*[1] *acuñai, Weisbordella dalli, W. cubae, Schizaster armiger,* and *Eupatagus clevei. Cubanaster acuñai* is very abundant in slabs of silty limestone that are strewn about at locality 11 (pl. 4). Incomplete remains of *Eupatagus* were seen at other places in the southern part of Madden basin. According to Cooke, four of the five species at locality 11 are found in the upper Eocene Ocala limestone of Florida, two in the upper Eocene of Cuba, and one in the middle Eocene of St. Bartholomew.

Age.—The Gatuncillo formation is considered to be of middle and late Eocene age. The faunal evidence consistently indicates that the greater part of the formation is late Eocene. Contrary to a former opinion (Woodring and Thompson, 1949, p. 228), the formation, perhaps only a small part of it, evidently includes middle Eocene, at least in Madden basin and the Río Casaya area. *Yaberinella jamaicensis* was found in two collections at the very base of the formation, but not in other collections. Though that species occurs in both middle and upper Eocene in Jamaica, its apparently more closely restricted range in Panamá suggests that the basal part of the Gatuncillo is middle Eocene. Unfortunately no other collections of larger Foraminifera from the basal part of the formation are now available. The collection of mollusks from the Río Casaya area includes species of middle Eocene affinities, such as *Turritella* cf. *T. carinata,* which are not represented in other collections. Stratigraphic control, however, is completely lacking in the Río Casaya area.

[1] The generic names for the first three species have been changed to agree with Durham's reclassification (Durham, J. W., A new family of clypeastroid echinoids: Jour. Paleontology, v. 28, p. 677–684, 3 figs., 1954).

EOCENE OR OLIGOCENE SERIES

MARINE MEMBER OF BOHIO(?) FORMATION

Marine strata of early Tertiary age in the Gatun Lake area are tentatively designated the marine member of the Bohio(?) formation, pending further data on their stratigraphic relations. They are thought to represent a marine tongue, or tongues, in the lower part of the essentially nonmarine Bohio formation, which is described on pages 24–28. That interpretation, however, is a matter of inference. It is adopted principally because in one of the outcrop areas the strata include rocks similar to those of the Bohio formation.

Whatever the stratigraphic relations of the unnamed strata may be, a separate formation name may eventually be preferred for them. As a matter of fact, a name was casually used for them many years ago—a name incorrect in orthography and no longer suitable: Vamos á Vamos beds or Vamos á Vamos formation (Hill, 1898, p. 179, 205).

Though the thickness and extent of this unit are unknown, the thickness probably is at least 100 meters.

STRATIGRAPHY AND LITHOLOGY

Vamos Vamos.—The unnamed marine strata were first observed near a now submerged village on Río Chagres that had the intriguing name Vamos Vamos. The approximate position of the fossiliferous strata is shown as locality 40 on plate 1. Though the name Vamos Vamos suggests American slang, my colleague G. E. Lewis informs me that "vamos" is a colloquial equivalent of the more elegant "vámonos" and that reiteration for emphasis is common in many languages. The name appears on Garella's 1:200,000 map, prepared in 1844 and published in 1845 (Garella, 1845). Hill had his own hybrid version of the name: Vamos á Vamos (Hill, 1898, p. 179), gallicized to Vamos à Vamos by MacDonald (1919, p. 542).

The strata described as those at Vamos Vamos actually were exposed in a cut on the southwest side of the French Canal, about 2 kilometers northwest of the place where the canal joined Río Chagres just upstream from the village of Vamos Vamos. (See map, pl. 1, accompanying publication cited under Bertrand and Zürcher, 1899.) These fossiliferous strata were first mentioned by Chaper (1890, p. 7) and were described by Hill (1898, p. 179–180), Howe (1907, p.

113; 1908, p. 219), and MacDonald (1919, p. 542). According to these descriptions, the strata dipped toward the northwest and consisted of dark tuffaceous silty sandstone, containing practically black calcareous concretions, and small-pebble conglomerate. Fossils were found in the calcareous concretions and also in the sandstone. MacDonald reported a thickness of 95 feet (29 meters) at locality 40.

Hill thought the strata at Vamos Vamos to be younger than the foraminiferal marl exposed farther east (Hill, 1898, p. 179), and so did Bertrand and Zürcher (1899, p. 88). (The foraminiferal marl, now submerged, is presumed to be part of the Caimito formation.) Howe concluded that the coarse conglomerate and volcanic breccia at Bohio, still farther east, and the strata of finer grain at Vamos Vamos represent different facies of the same formation: the Bohio formation (Howe, 1908, p. 221). MacDonald and Vaughan assigned the strata at Vamos Vamos to the Gatun formation (MacDonald, 1919, p. 542). Though little data on the structure and stratigraphy of the marine member of the Bohio(?) formation are now available, that unit seems to be exposed on an anticline, as suggested on plate 1.

Palenquilla Point.—When Mr. Thompson was reminded of the record of dark fossiliferous calcareous concretions at Vamos Vamos, he remembered that he had seen such concretions near Palenquilla Point, which is close to the submerged Vamos Vamos locality. Tuffaceous siltstone, tuffaceous medium- and coarse-grained sandstone, and lenses of conglomerate made up of basaltic pebbles, cobbles, and boulders are exposed at scattered localities on the east side of the peninsula ending at Palenquilla Point. The coarse basaltic fragments generally have a maximum diameter of 10 centimeters, exceptionally 30 centimeters. Loose dark fossiliferous calcareous concretions were found at the edge of Gatun Lake at locality 41 and in place in medium-grained sandstone halfway between that locality and Palenquilla Point. At other places medium-grained sandstone contains molds of mollusks. The basaltic conglomerate suggests the Bohio formation. Whether these marine strata will be found in an extensive area south and southwest of Palinquilla Point, as suggested on plate 1, remains to be determined.

Trinidad Island.—The same stratigraphic unit forms Trinidad Island. The following section is exposed on the north coast of the island:

Section of marine member of Bohio(?) formation on north coast of Trinidad Island

	Meters
Siltstone, sandy. Locality 42c, 4.5 meters above base	6
Sandstone, ledge-forming, silty, medium-grained, calcareous, containing few pebbles, few worn small heads of calcareous algae, and worn shell tips of *Turritella*. Locality 42b	1
Siltstone, sandy. Locality 42; locality 42a represents a thin calcareous layer	3
Thickness of section	10

FOSSILS AND AGE

Larger Foraminifera.—No Foraminifera of any kind are in the collections from Vamos Vamos and none were observed in the exposures near Palenquilla Point. The following larger Foraminifera were identified by Cole in two collections from Trinidad Island:

Larger Foraminifera from marine member of Bohio(?) formation, Trinidad Island

[Cole, 1952 (1953), p. 5]

	Localities 42	Localities 42b
Operculinoides jacksonensis (Gravell and Hanna)	×	×
kugleri Vaughan and Cole	×	×
trinitatensis (Nuttall)	×	×
Nummulites [1] *striatoreticulatus* (L. Rutten)	--	×
Fabiania cubensis (Cushman and Bermúdez)	--	×
Lepidocyclina (Pliolepidina) macdonaldi Cushman	×	×
(Pliolepidina) pustulosa H. Douvillé	×	×
pustulosa tobleri H. Douvillé	--	×

[1] Cited by Cole as *Camerina.*

Cole pointed out that all the larger Foraminifera collected at Trinidad Island are found elsewhere in deposits of late Eocene age; in fact, all except two (*Operculinoides kugleri* and *O. trinitatensis*) are found in the Gatuncillo formation. Moreover two (*Fabiana cubensis* and *Lepidocyclina pustulosa*) occur in the middle Eocene, but none in the early Oligocene.

Mollusks.—A collection of mollusks from Vamos Vamos was forwarded to the U. S. National Museum by Alexander Agassiz in 1891. Other collections were made by Hill and by Vaughan and MacDonald. All these collections presumably represent the same general locality. For some reason Hill sent in three lots that have different field numbers. Dall used specimens from the Agassiz and Hill collections to describe four species he named *Glyptostyla panamensis*, *Mactra (Mactrella?) dariensis*, *Cardium (Fragum) gatunense*, and *Pitaria (Lamelliconcha) hilli* in his monumental

Tertiary Fauna of Florida (Dall, 1890–1903, p. 233, 895, 1100, 1268). The collections from localities 41a and 41b were received too late to be included in the systematic descriptions of chapter A of the present report. Species in the families covered by chapter A of the present report are tabulated below.

Mollusks from marine member of Bohio(?) formation (Phasianellidae to Turritellidae)

	Localities									
	Vamos Vamos					Palenquilla Point			Trinidad Island	
	40	40a	40b	40d	40e	41	41a	41b	42	42c
Tricolia calypta Woodring, n. sp	----	×	----	×	----	----	----	----	----	----
Calyptraea sp	----	×	----	----	----	----	×	×	----	----
Natica (*Natica?*) sp	×	----	----	×	----	----	----	×	×	----
Tectonatica sp	----	----	----	----	----	----	----	----	×	----
Polinices? sp	----	×	----	×	----	×	----	×	----	----
Neverita? sp	----	----	----	----	----	×	----	----	----	----
Neverita (*Glossaulax*) *bolivarensis tapina* Woodring, n. subsp	×	×	----	×	----	×	----	×	----	----
Sinum sp	----	×	----	×	----	----	----	----	----	----
Globularia (*Ampulella*) sp	----	×	----	×	----	×	----	×	----	----
(*Ampulella?*) *nana* Woodring, n. sp	----	----	----	----	----	×	----	----	×	----
Pachycrommium? proinum Woodring, n. sp	----	×	×	×	----	×	----	×	----	----
Turritella adela Woodring, n. sp	×	×	----	×	?	×	----	×	----	----
cf. *T. caleta* Olsson	×	×	×	×	----	×	----	×	×	×

The mollusks of the marine member of the Bohio(?) formation are unlike those of the Gatuncillo formation. *Tricolia calypta* and the unnamed *Tectonatica* are the earliest known American species of genera that appear in the Paleocene and Eocene, respectively, of Europe. *Neverita bolivarensis tapina* is a subspecies of a late Eocene Colombian species. *Pachycrommium? proinum*, the other globularines, and *Turritella adela* also have Eocene affinities. *Turritella* cf. *T. caleta* appears to be allied to the Oligocene Peruvian *T. caleta*.

Age.—In view of their stratigraphic range elsewhere, the eight forms of larger Foraminifera point to a late Eocene age (Cole, 1952 [1953], p. 5–6). Had these fossils been found only in the sandstone that contains pebbles, worn small heads of calcareous algae, and worn shell tips of *Turritella* (locality 42b), the possibility of reworking might be considered, despite the lack of any other evidence for reworking. Five of them, however, were found also in siltstone (locality 42). So far no early Oligocene fauna of larger Foraminifera in the Caribbean region has been described, although larger Foraminifera of that age quite certainly are represented in the White Limestone of Jamaica, in similar limestones in Haiti and the Dominican Republic, and in Cuba.

Dall informed Hill that the Vamos Vamos mollusks are Eocene (Hill, 1898, p. 271, 273). Some of the species found there and at the other localities have Eocene affinities, but others have later affinities (Woodring and Thompson, 1949, p. 231). The latter affinities and, above all, the absence of typical Eocene genera are thought to outweigh the Eocene affinities and to indicate an early Oligocene age. That age, however, is not based on faunal similarity to the early Oligocene of western Europe or southeastern United States. The most marked faunal similarity is with the late Eocene of Colombia and the late Eocene and early Oligocene of Perú.

Pending resolution of the apparently conflicting testimony of the larger Foraminifera and mollusks, a late Eocene or early Oligocene age is assigned to the marine member of the Bohio(?) formation.

OLIGOCENE SERIES

BOHIO FORMATION

The Bohio formation proper, excluding the doubtful marine member just described, has fairly uniform lithologic features. It is characterized by the preponderance of poorly sorted debris, mostly basaltic: very coarse debris in the form of boulders and cobbles, and finer debris forming beds of sandstone, or more properly graywacke, and the matrix of conglomerate. The debris evidently came principally from the south and southwest. Boulder conglomerate is the dominant type of rock in the Gatun Lake area, the southern part of Madden basin, and the Pacific coastal area. In the Quebrancha syncline conglomerate is replaced by graywacke grit. In the Gatun Lake area the formation apparently grades southeastward into agglomerate of the Bas Obispo formation.

The poorly sorted conglomerate and the poorly sorted graywacke contain no marine fossils and seem to be nonmarine. Marine fossils are found in thin units in the upper part of the formation, in algal limestone and in both poorly sorted and fairly well sorted subgraywacke. If the tentatively designated marine member of the Bohio(?) formation is indeed the equivalent of the lower part of the Bohio, it represents a northwestward replacement of nonmarine conglomerate by marine sandstone, siltstone, and conglomerate.

Hill named the Bohio formation, but used the spelling Bujio (Hill, 1898, p. 183). The name was derived from Bohío or Bohío Soldado, a village on the Panama Railroad located on a bluff overlooking Río Chagres and now under the waters of Gatun Lake north of Barro Colorado Island. In Spanish orthography the name, anglicized in the Canal Zone, is Bohío. Though the little islands north of Barro Colorado Island are closer to the location of the village, the Bohio Peninsula may be considered the type region.

In his description of outcrops Hill casually used many names that have the form of formal stratigraphic names. His expression "Bujio formation" evidently was intended to mean no more than "the formation at "Bujio." Four of his names—Bujio (Bohio) formation, Culebra clays (altered to Culebra formation), Empire limestone (altered to Emperador limestone member of Culebra formation), and Panamá formation—have been preserved.

In complete sections the Bohio formation overlies the Gatuncillo formation. So far as known the two formations are conformable, except in the Pacific coastal area, where the Bohio overlaps the Gatuncillo and rests on basement rocks. The thickness of the Bohio ranges from about 75 meters to perhaps as much as 450 meters.

STRATIGRAPHY AND LITHOLOGY

Gatun Lake area.—Boulder conglomerate is the most characteristic rock type of the Bohio formation in the Gatun Lake area. As shown on plate 5, the conglomerate is a rude assortment of boulders, cobbles, and pebbles. Boulders predominate and reach a diameter of 2 meters. Basalt is by far the dominant rock in the coarse constituents. In general the coarse constituents are better rounded in the northwestern part of the outcrop area, including Barro Colorado Island, where the view reproduced as plate 5 was taken. Conglomerate like that shown on plate 5 borders the launch channel between the two small islands just northwest of the first peninsula on Barro Colorado Island west of Salud Point (Orchid Island and de Lesseps Island, not labelled on plate 1). This channel is the site of the excavation for the French locks near the village of Bohío, mentioned in early descriptions of the Bohio formation.

The poorly sorted coarse-grained matrix of the conglomerate and similar graywacke forming separate beds is made up chiefly of angular grains of basalt in a clay-like binder. On Barro Colorado Island carbonaceous debris is common in medium- to coarse-grained subgraywacke containing scattered pebbles, generally poorly rounded Marine fossils were found in such sandstone in the upper part of the formation on Barro Colorado Island at locality 42g and 42i. They also were found at locality 42d in medium-grained subgraywacke that is better sorted and has little carbonaceous debris. The fossiliferous sandstone at locality 42d contains somewhat calcareous irregular lumps.

Though conglomerate and sandstone predominate, the formation includes tuffaceous siltstone.

The Bohio formation and Bas Obispo formation appear to intertongue. Both Hill and Howe described agglomerate (volcanic breccia of their terminology) exposed in a quarry at Bohio (Hill, 1898, p. 183; Howe, 1907, p. 112; Howe, 1908, p. 216–217), and Howe described subsurface evidence indicating equivalence of agglomerate and conglomerate (1908, p. 217–218). According to Howe, between Darien and Gamboa a few patches of conglomerate could be seen overlying agglomerate before the flooding of Gatun Lake (1908, p. 215, "in the neighborhood of Mamei, Gorgona, and Matachin"). According to Jones, in the same region conglomerate and sandstone of the Bohio formation grade into agglomerate of the Bas Obispo (1950, p. 899–900).

MacDonald (1913, p. 568) estimated the thickness of the Bohio in the Gatun Lake area to be almost 1,000 feet (300 meters).

Quebrancha syncline.—The Bohio formation in the Quebrancha syncline consists of a graywacke grit member and an overlying volcanic member. Both members have been described by Thompson (1944, p. 13–17). The grit member is made up of poorly sorted coarse, angular grains and scattered pebbles of basalt and thin lenses of conglomerate, in which basalt predominates. The pebbles have an observed maximum diameter of 10 centimeters. In other words, the graywacke grit closely resembles conglomerate in the Gatun Lake area, but has a much finer texture. Like the conglomerate, the grit appears to be nonmarine. Thin marine siltstone, however, was found in the basal part of the member. The maximum thickness of the member is estimated to be 450 meters.

The volcanic member has a thickness of 30 meters. It consists, in ascending order, of porphyritic basalt (18 meters), agglomerate (9 meters), and greenish waxy bentonitic clay (3 meters). Spheroidal exfoliated masses, which weather out of the basalt and are very durable, were found by Thompson to be useful guides in mapping. This thin volcanic member evidently is a product of the eruptions that produced the Bas Obispo formation and the Las Cascades agglomerate. Study of the volcanic rocks may yield clues as to whether the volcanic member is the equivalent of part of the Bas Obispo or of part of the Las Cascadas.

Madden basin.—The Bohio formation has been recognized only in the southeastern part of Madden basin. The outcrop area in the basin extends southeastward across the continental divide and joins the Pacific coastal area. As in the Pacific coastal area, the formation consists chiefly of poorly sorted massive conglomerate. The estimated maximum thickness is 200 meters. The absence of the Bohio in the northern part of Madden basin is attributed to overlap by the Caimito formation.

Pacific coastal area.—In the Pacific coastal area the Bohio formation overlaps the Gatuncillo formation and lies directly on basement rocks. The Bohio thins abruptly eastward. On the west side of Río Cabra, where the formation rests on coarse-grained diorite, the thickness is not more than 75 meters. The outcrop in the western part of the area is very wide because the grade of the slope south of the continental divide is almost the same as the dip of the formation. Cuts along the Transisthmian Highway expose massive poorly sorted conglomerate (pl. 6) and poorly sorted graywacke. Basaltic debris predominates along the highway, but the proportion of basalt decreases eastward. Thin lenses of algal limestone are interbedded with conglomerate in the upper part of the formation at localities 43–45. At locality 44 the limestone has an exposed thickness of 60 centimeters, the greatest observed thickness.

FOSSILS AND AGE

The bulk of the Bohio formation evidently is nonmarine, as suggested by Howe (1907, p. 112–113) and MacDonald (1915, p. 20). Silicified wood is recorded from the formation in the Bohio Pennisula (Berry, 1918, p. 32). Marine fossils, however, establish the presence of marine strata in at least the basal and upper parts of the formation.

Smaller Foraminifera.—Sandy siltstone in the basal part of the graywacke grit member of the Bohio at locality 39, in the Quebrancha syncline, yielded the following smaller Foraminifera, identified by H. H. Renz and P. J. Bermúdez:

Smaller Foraminifera from basal part of graywacke grit member of Bohio formation at locality 39 in Quebrancha syncline

[Identifications by H. H. Renz and P. J. Bermúdez]

Alabamina cf. *A. scitula* Brady
Ammospirata mexicana (Cushman)
Angulogerina sp.
Astacolus nuttalli (Todd and Kniker)
  sp.
Bathysiphon eocenica Cushman and Hanna
Bolivina alazanensis Cushman
  byramensis Cushman
  cf. *B. gracilis* Cushman and Applin
  plicatella var. *mera* Cushman and Ponton
  rhomboidalis (Millett)
  tectiformis Cushman
  sp.
Bulimina alazanensis Cushman
Cassidulina subglobosa Brady
Chrysalogonium asperum Cushman and Stainforth
  sp.
Cibicides mexicanus Nuttall
  perlucidus Nuttall
  spp.
Clavulinoides cubensis Cushman and Bermúdez
Cyclammina cf. *C. deformis* Guppy
Dentalina alazanensis (Nuttall)
  cf. *D. mucronata* Neugeboren
  semilaevis Hantken
  sp.
Discorbis araucana (d'Orbigny) of Nuttall
Eponides umbonatus var. *multisepta* Koch
Gaudryina (*Pseudogaudryina*) *alazanensis* Chusman
Glandulina sp.
Globigerina ciperoensis Bolli
  ouachitaensis Howe and Wallace
  sp.
Gümbelina cubensis Palmer
Guttulina byramensis (Cushman)
  sp.
Gyroidinoides cf. *G. girardana* (Reuss)
Karreriella mexicana (Nuttall)
Lagena striata (d'Orbigny)
Marginulina pseudohirsuta Nuttall
  similis d'Orbigny
Nodogenerina cf. *N. havanensis* Cushman and Bermúdez
  sp.
Nodosaria longiscata d'Orbigny
  multilineata Bornemann
  obliqua (Linné)
  cf. *N. pyrula* d'Orbigny
  cf. *N. soluta* (Reuss)
  sp.
Nonion cf. *N. grateloupi* (d'Orbigny)
  pompilioides (Fichtel and Moll)
Osangularia mexicana (Cole)
Planularia sp.
Planulina marialana Hadley
  cf. *P. wuellerstorfi* (Schwager)
Plectina nuttalli Cushman and Stainforth
Plectofrondicularia alazanensis Cushman
  mexicana (Cushman)
  vaughani Cushman

Pleurostomella alterans Schwager
  bierigi Palmer and Bermúdez
  cf. *P. naranjoensis* Cushman and Bermúdez
Pseudoglandulina conica (Neugeboren)
  sp.
Pullenia cf. *P. quinqueloba* (Reuss)
Quinqueloculina cf. *Q. maculata* Galloway and Heminway
Robulus cf. *R. alazanensis* (Cushman)
  articulatus var. *texanus* (Cushman and Applin)
  iotus (Cushman)
  sp.
Schenckiella sp.
Sigmomorphina cf. *S. trinitatensis* Cushman and Ozawa
Siphonina tenuicarinata Cushman
Siphonodosaria nuttalli var. *gracillima* (Cushman and Jarvis)
  sp.
Spiroloculinc texana Cushman and Ellisor
Uvigerina cf. *U. adelinensis* Palmer and Bermúdez
  chirana Cushman and Stone
  gardnerae var. *nuttalliana* Howe and Wallace
  spinicostata Cushman and Jarvis
  sp.
Vaginulina sp.
Vaginulinopsis alazanensis (Nuttall)
Virgulina cf. *V. dibollensis* Cushman and Applin
Vulvulina pachyheilus Hadley

Messrs. Renz and Bermúdez prepared the following comments concerning these fossils:

The Foraminifera collected at locality 39 are of early Oligocene age. They have distinct affinities with the early Oligocene faunas of the Alazán formation (or Huasteca formation) of the Tampico region in Mexico (Nuttall, 1932), the Tinguaro formation (or Finca Adeline marl) of Cuba (Bermúdez, 1950, p. 264–270), and Zone I in the lower part of the Cipero formation of Trinidad (Cushman and Stainforth, 1945).

Larger Foraminifera.—The upper part of the Bohio on Barro Colorado Island yielded *Heterostegina antillea*, *Archaias compressus*, *Lepidocyclina canellei*, *L. giraudi*, *L. waylandvaughani*, *L. vaughani*, *Miogypsina antillea*, and *M. gunteri* (Cole, 1957). Cole identified the following species, which were collected at localities 43 and 45 in the upper part of the formation in the Pacific Coastal area:

Larger Foraminifera from upper part of Bohio formation in Pacific coastal area.

[Cole, 1952 (1953), p. 6]

	Localities 43	45
Heterostegina antillea Cushman	×	×
Lepidocyclina (*Lepidocyclina*) *parvula* Cushman	×	---
waylandvaughani Cole	--	×
yurnagunensis Cushman	×	---
yurnagunensis morganopsis Vaughan	×	×
(*Nephrolepidina*) *vaughani* Cushman	--	×
(*Eulepidina*) *favosa* Cushman	×	×
gigas Cushman	×	---

Mollusks.—The upper part of the Bohio formation in the Pacific coastal area yielded pectinids, but no other mollusks. On Barro Colorado Island the upper part of the formation yielded marine mollusks at two localities (42d, 42i) and a mixture of marine, brackish-water, and fresh-water mollusks at a third locality (locality 42f). Howe recorded the presence of marine mollusks in carbonaceous sandstone penetrated in a core hole at the French lock site near Barro Colorado Island (Howe, 1908, p. 220–221).

The fossils from Barro Colorado Islands, all of which occur in subgraywacke interbedded with conglomerate, were received too late to be included in the systematic descriptions of chapter A of the present report. The species in the families covered by chapter A are as follows:

Mollusks from upper part of Bohio formation on Barro Colorado Island (Trochidae to Turritellidae)

	Localities 42d	42f	42g
Solariella n. sp., cf. *S. depressa* Dall	×	--	---
Neritina sp	--	--	×
Hemisinus (*Longiverena*) n. sp., cf. *H. atriformis* Cooke	--	×	---
Crepidula? sp	--	--	×
Notica (*Naticarius*) sp	×	--	?
Polinices sp	×	--	?
Sinum sp	×	--	---
Glcbularia (*Globularia*) aff. *G. fischeri* (Dall)	×	--	?
Pachycrommium aff. *P. guppyi* (Gabb)	×	--	---
Turritella cf. *T. altilira* Conrad	×	--	---
n. sp., aff. *T. venezuelana* Hodson	×	--	?

In chapter B of the present report, it is proposed to describe the new species in the preceding list and to redescribe the species identified as *Globularia* aff. *G. fischeri*. The last species mentioned is abundant at locality 42d and is the same as that from the Caimito and Culebra formations described under the same name on page 94. The fossils found on Barro Colorado Island are of late Oligocene age.

Age.—The basal part of the Bohio in the Quebrancha syncline contains smaller Foraminifera of early Oligocene age and the upper part of the formation in the Pacific coastal and Gatun Lake areas, respectively, contains late Oligocene larger Foraminifera and mollusks. Whether the formation represents so great a time span in each of the areas where it crops out is not known at present. It represents, however, more than the early Oligocene age previously suggested (Woodring and Thompson, 1949, p. 228). That it does not include all of the Oligocene is shown by the late Oligocene age of the overlying Caimito formation.

The larger Foraminifera in the upper part of the Bohio formation of the Pacific coastal area represent the widespread Caribbean *Eulepidina* fauna. That fauna and the Antiguan coral fauna that accompanies it at many localities is traditionally assigned to the middle Oligocene, because Vaughan correlated the Caribbean deposits with the Rupelian of northeastern Italy on the basis of the corals and because he thought a middle

Oligocene assignment fitted the occurrence of these fossils in southeastern United States (Vaughan, 1919*a*, p. 199–203, 207). The *Eulepidina* fauna is found in the Chickasawhay limestone of Alabama, the Suwannee limestone of Florida, and the Flint River formation of Georgia usage, and the Antiguan coral fauna in the Flint River formation. These three formations are now assigned to the upper Oligocene (Cooke, Gardner, and Woodring, 1943, chart; MacNeil, 1944, fig. 1; Cole, 1952 (1953), p. 6). A middle Oligocene age is not unreasonable, if the American deposits that are essentially the equivalent of the European Aquitanian stage are assigned to the upper Oligocene. In the present report, however, they are referred to the lower Miocene. The age range of the *Eulepidina*-Antiguan coral fauna cannot be assumed to be narrowly restricted. It is a reef fauna and may eventually be found to have a considerable time range, like the Lower Cretaceous Urgovian reef fauna. In the Canal Zone and Panamá the *Eulepidina* fauna occurs in the upper part of the Bohio formation and at one locality in the Caimito formation (locality 51), and the closest approach to an Antiguan coral fauna is in the Caimito formation (localities 52 and 57). The time span between the deposition of the upper part of the Bohio in the Pacific coastal area and deposition of the Caimito at localities 51, 52, and 57 in the Gatun Lake area doubtless is not great, but it would be rash to correlate these deposits closely.

CAIMITO FORMATION EXCLUSIVE OF MADDEN BASIN AND PACIFIC COASTAL AREA

The Gatuncillo and Bohio formations are widespread, but are fairly uniform lithologically despite their widespread distribution. The Caimito formation is the youngest widely distributed formation. It is, however, lithologically heterogeneous. Deposits in too many areas have perhaps been included in the Caimito, but within the type region the formation is heterogeneous. In all the areas where the formation is identified it is marine, or at least mainly marine, and contains much volcanic debris.

The name for the Caimito formation was proposed by MacDonald (1913, p. 569). He did not properly define the name then or later, and he specified no type region. In the absence of evidence to the contrary, it may be assumed that the type region was intended to be the region that furnished the name. Caimito, or Caimito Junction, was located on the present alinement of the Panama Railroad near Darien in the Gatun Lake area (MacDonald, 1913, pl. 68). On the basis of accepting the Darien region as the type region, the Caimito formation consists of the strata, mostly tuffaceous, overlying the Bohio formation. MacDonald included in the Caimito formation strata now assigned to the La Boca marine member of the Panamá formation and his representation of the Caimito as overlying the Emperador limestone (now assigned member rank in the Culebra formation) was based on misidentification of both Emperador and Caimito (MacDonald, 1913, pl. 68).

In complete sections the Caimito formation overlies the Bohio formation or volcanic rocks that are thought to include the equivalent of the Bohio. Though the actual contact has not been observed, it evidently represents a discontinuity. In the northeastern part of the Gatun Lake area the Caimito seems to overlap the Bohio and Gatuncillo formations, directly overlying the basement complex, and in the northern part of Madden basin the Caimito overlaps the Bohio and rests on the Gatuncillo. In the southeastern part of the Gatun Lake area the lower part of the Caimito (or perhaps the entire formation), appears to grade into the Las Cascadas agglomerate. Wherever the Caimito formation is dated it is of late Oligocene age, except in Madden basin, where it includes both upper Oligocene and lower Miocene deposits. The Caimito of that area is described under the heading "Oligocene and Miocene series." The Caimito of the Pacific coastal area, which is entirely of Oligocene age, appears to be continuous with the Oligocene part in Madden basin and is discussed under the same heading.

According to estimates, the thickness of the Caimito ranges from 250 to 400 meters.

STRATIGRAPHY AND LITHOLOGY

Gatun Lake area.—Three members of the Caimito formation were recognized by Jones in the Gatun Lake area: lower, middle and upper (Jones, 1950, p. 900–901), which correspond, respectively, to the basal, lower, and upper members of his former usage (Woodring and Thompson, 1949, p. 232–233). According to Jones, the lower member is made up of conglomerate and tuffaceous sandstone. The conglomerate resembles conglomerate of the underlying Bohio formation, but includes pebbles of tuff. The sandstone and the matrix of the conglomerate contain acidic tuff. The lower member is correlated by Jones with the Las Cascadas agglomerate, but perhaps the entire formation is to be correlated with the Las Cascadas. The lower member of the Caimito is recognized only locally. Its absence elsewhere may indicate discontinuity or lateral gradation into deposits grouped with the middle member.

The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone, mostly algal limestone. Tuff, tuffaceous calcareous siltstone, and conglomerate are other constitutents. Agglomerate and poorly sorted, coarse-grained, tuffaceous, nonmarine sandstone in the northeastern part of Barro Colorado Island evidently are the equivalent of marine strata in the middle member. Foraminiferal soft limestone, such as that at locality

54f, doubtless corresponds to the foraminiferal marl of publications issued before the flooding of Gatun Lake. Foraminiferal marl was exposed at localities on Río Chagres, including Peña Blanca, the type of locality of *Lepidocyclina canellei.* The approximate location of Peña Blanca is shown as locality 55 on plate 1. Hill claimed that foraminiferal marl could be seen to rest unconformably on conglomerate (of the Bobio formation) near Bohio (Hill, 1898, p. 178–179), but Howe (1907, p. 113) was unable to recognize the locality Hill described. The rhyolitic tuff on Río Chagres at Barbacoas, where the original line of the Panama Railroad crossed the river about 9 kilometers west of Gamboa, presumably is to be included in the Caimito. The tuff was found to be so similar to tuff in the Panamá formation that Hill (1898, p. 201), Bertrand and Zürcher (1899, p. 91), and Howe (1907, p. 117) did not hesitate to correlate them. Though no data are available on the comparative volcanic constituents of the different formations, the correlation is not accepted (p. 41). Hill casually used the expression "Barbacoas formation" for the tuff and "San Pablo phase of the Barbacoas formation" or "San Pablo formation" for underlying rock he described as conglomerate of volcanic material (Hill, 1898, p. 184–185, 187).

Tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone are the principal constituents of the upper member, the thickest and most widespread part of the formation (Jones, 1950, p. 901).

The thickness of the Caimito in the Gatun Lake area is estimated to be at least 200 meters and may be considerably more.

Río Mandinga area.—Along a tributary of Río Mandinga, west of the canal and south of Gamboa, the Caimito formation is characterized by a unit of conglomerate and conglomeratic sandstone that has a thickness of between 75 and 100 meters. Conglomerate is not rare in the Caimito of other areas, but it consists of thin scattered beds. The unusual thickness of conglomerate prompted Jones to propose the name "Caraba facies of the Caimito formation" (Jones, 1950, p. 901). The conglomerate is overlain by fossiliferous silty calcareous sandstone (localities 59 and 60) and limestone. Locality 61 represents coralliferous limestone in this area.

The distribution of the conglomerate is unknown. The extensive area farther west along the south border of Gatun Lake, shown on plate 1 as doubtfully underlain by the Caimito formation, has not been examined.

Quebrancha syncline.—The Caimito formation of the Quebrancha syncline consists of two members: in ascending order, the Quebrancha limestone member and the calcareous siltstone member. They have been mapped and described by Thompson (1944, p. 17–21). The economically important Quebrancha limestone member, which is quarried for the manufacture of cement, was named by Thompson (1944, p. 17) as a separate formation. The type region is on the east limb of the syncline and includes the quarry of the Panama Cement Company. The Quebrancha member has a thickness of 110 to 135 meters. Subsurface explorations and outcrops reveal that it is made up, in ascending order, of three parts: calcareous siltstone and calcareous medium-grained sandstone, limestone and thin partings of calcareous siltstone, and somewhat marly foraminiferal limestone consisting for the most part of closely packed specimens of *Lepidocyclina.* The foraminiferal limestone is by far the thickest part.

The calcareous siltstone member, which gradationally overlies the Quebrancha limestone member, includes calcareous siltstone, tuffaceous pumice-bearing siltstone, and calcareous medium-grained sandstone. This member has an estimated thickness of 150 meters and is the youngest unit in the Quebrancha syncline.

Río Chagres area.—The lowland along Río Chagres north-northeast of Gamboa probably is underlain by the Caimito formation, but only a small part of it southwest of Nuevo San Juan was examined. Calcareous coarse-grained pebbly sandstone at locality 93 and limestone and siltstone farther west contain Foraminifera, including orbitoids identified in the field as *Lepidocyclina canellei* and *L. vaughani.* Limestone exposed at and near Las Cruces before the flooding of Gatun Lake yielded a few mollusks (localities 94, 94*a*).

FOSSILS AND AGE

Larger Foraminifera.—Larger Foraminifera are widespread and locally abundant in the Caimito formation of the areas just described, particularly in limestone and calcareous siltstone. No fossils of any kind, however, are known in the lower member in the Gatun Lake area and larger Foraminifera from one locality are the only fossils available for the upper member in that area. Douvillé recorded larger Foraminifera and calcareous algae in collections from localities near Peña Blanca and Bohío Soldado, and expressed the opinion that they are Oligocene (Douvillé, 1891, p. 498, 499). Later he identified the small orbitoid from Peña Blanca as *Lepidocyclina* and reaffirmed the Oligocene age (Douvillé, 1898, p. 598–599). This small species, one of the most common in the Caimito, was still later named *L. canellei* for the collector, an engineer of the first French company (Lemoine and R. Douvillé, 1904, p. 20). *L. vaughani,* another common species, is extraordinarily abundant in the Quebrancha limestone member. The type locality of *L. vaughani* is in the type region of the Caimito formation on the Panama Railroad near Darien: locality 49, which was referred to the Emperador limestone member of the Culebra formation by MacDonald and Vaughan (MacDonald, 1919, p. 539, locality 6021). Seven samples of larger Foraminifera were submitted to W. S. Cole, who identified the species in the following table. Recently Cole (1957, p. 314) also recorded 8 species from the Caimito of Barro Colorado Island, all except one of which occur in the Caimito elsewhere. The exception is *Archaias compressus*, which is still living.

Larger Foraminifera from Caimito formation of Gatun Lake area, Río Mandinga area, and Quebrancha syncline

[Cole, 1952 (1953), p. 7]

	Localities						
	Gatun Lake area					Río Mandinga area	Quebrancha syncline
	Middle member				Upper member	No members recognized	Quebrancha limestone member
	48	51	53	56a	58	59	62a
Operculinoides panamensis (Cushman)				×			
Heterostegina antillea Cushman	×	×					×
israelskyi Gravell and Hanna				×		×	
panamensis Gravell				×			×
Lepidocyclina (Lepidocyclina) asterodisca Nuttall						×	
(Lepidocyclina) canellei Lemoine and R. Douvillé	×		×	×			×
parvula Cushman		×		×			×
waylandvaughani Cole							×
yurnagunensis Cushman		×		×	×		
yurnagunensis morganopsis Vaughan		×	×				×
(Nephrolepidina) dartoni Vaughan							×
tournoueri Lemoine and R. Douvillé		×					
vaughani Cushman	×		×				×
(Eulepidina) undosa Cushman		×					
Miogypsina (Miogypsina) antillea (Cushman)			×				
(Miolepidocyclina) panamensis (Cushman)				×			

All the species in the preceding table occur elsewhere in deposits of late Oligocene age. Though the table does not include the calcareous siltstone member of the Quebrancha syncline, *Lepidocyclina canellei* has been recognized by R. H. Stewart in that member (Woodring and Thompson, 1949, p. 234).

Corals.—MacDonald and Vaughan found corals in the middle member of the Caimito formation of the Gatun Lake area at localities 52 (Geological Survey 6024b) and 57 (Geological Survey 6026). Locality 52 was assigned to the Emperador limestone [member of the Culebra formation] and locality 57 to the Culebra formation (MacDonald, 1919, p. 540, 541). Four of the seven species identified by Vaughan occur in the upper Oligocene Antigua formation of the island of Antigua and one in the lower Miocene Anguilla formation of the island of Anguilla (Vaughan, 1919a, p. 208, 209). Numerous specimens of a coral in limestone of the Caimito at locality 61 in the Río Mandinga area is identified by J. W. Wells as *Goniopora* cf. *G. cascadensis.*

Mollusks.—Mollusks have been found in the areas described in the preceding pages, but they are nowhere abundant. The species covered in chapter A of the present report are as follows:

Mollusks from Caimito formation of Gatun Lake area, Río Mandinga area, and Quebrancha syncline (Calyptraeidae to Turritellidae)

	Localities				
	Gatun Lake area			Río Mandinga area	Quebrancha syncline
	Middle member			No members recognized	Quebrancha limestone member
	56	57	57a	60	62
Trochita cf. *T. trochiformis* (Born)	----	?	×	----	----
Notica (*Naticarius?*) sp	×	----	----	----	----
Sinum sp	×	?	----	----	----
Globularia (*Globularia*) aff. *G. fischeri* (Dall)	×	×	×	----	----
Pachycrommium? cf. *P.? trinitotensis* (Mansfield)	----	----	----	×	----
Turritella meroensis Olsson	×	----	----	----	×
(*Torcula*) *altilira* Conrad, subsp	×	----	----	----	×

Collections of mollusks from Barro Colorado Island and Pato Horqueto Island are not included in the systematic descriptions of chapter A of the present report. (Pato Horqueto Island is one of the Brujas Islands northwest of Barro Colorado Island.) The Barro Colorado collections, which represent a moderate-depth facies, contain unidentified species of *Solariella?* (locality 54l), *Calyptraea?* (locality 54m), *Natica* (*Natica?*) (locality 54k), *Polinices* (locality 54h and probably localities 54j and 54k), and *Neverita?* (locality 54m). Conglomerate on Pato Horqueto Island yielded mollusks of shallow-water facies, including *Calyptraea* sp., *Sinum* sp., *Ampullinopsis spenceri*, and *Turritella* sp. *Ampullinopsis spenceri*, a representative of a genus mainly of Oligocene age not found heretofore in the Canal Zone, is to be described in chapter B.

Echinoids.—Fragmentary remains of *Clypeaster* are fairly common in some areas. C. W. Cooke identified a complete specimen from locality 60 as *C. concavus*.

Age.—A late Oligocene age for the fossiliferous parts of the Caimito in the areas described in the preceding pages is indicated by larger Foraminifera, corals, and mollusks. Most of the mollusks just listed would not be out of place in either upper Oligocene or lower Miocene deposits. *Ampullinopsis spenceri* [late Oligocene of Antigua, Puerto Rico(?), western Panamá(?), Ecuador(?), and Perú(?)] and *Turritella meroensis* (late Oligocene of western Panamá, Ecuador, and Perú) however, indicate late Oligocene. The lower member in the Gatun Lake area, the age of which is unknown, is tentatively grouped with the middle and upper members as late Oligocene.

TUFFACEOUS STRATA IN CHORRERA AREA

Tuffaceous strata in the Chorrera area, west of the Canal Zone and south of Gatun Lake, are shown by a separate pattern on the geologic map (pl. 1) in a region of undifferentiated volcanic rocks. Though the unnamed tuffaceous strata consist principally of tuffaceous siltstone, tuffaceous sandstone, and tuff, they include bentonitic clay, conglomerate, and agglomerate. Leaf imprints are the only fossils that have been found. The unnamed strata, which may be the equivalent of part of the Caimito formation of the Gatun Lake area, are doubtfully referred to the late Oligocene.

BAS OBISPO FORMATION AND LAS CASCADAS AGGLOMERATE

The Oligocene formations so far described contain more or less volcanic material, mostly in the form of tuffaceous debris. The Bas Obispo formation and Las Cascadas agglomerate are entirely volcanic. They are interpreted to represent pyroclastic rocks and minor flows that accumulated at the periphery of a volcanic pile. The center of the pile evidently was west of the Canal Zone south of the continental divide, but presumably is concealed by later flows. At all events that region is characterized by thick volcanic rocks. Still farther out from the center of the volcanic pile the Bas Obispo formation and Las Cascadas agglomerate are thought to grade, respectively, into the Bohio and Caimito formations.

The volcanic rocks now included in the Bas Obispo formation and Las Cascadas agglomerate were described as massive igneous rocks by Hill (1898, p. 189–191), and as "roche de Gamboa" by Bertrand and Zürcher (1899, p. 86). They were named the Obispo formation or Obispo breccia by Howe (1907, p. 110–111). The emendation to Bas Obispo formation and the splitting off of the younger part as the Las Cascadas agglomerate were proposed by MacDonald (1913, p. 568). The type region of both formations is in the northern part of Gaillard Cut, where they are the oldest exposed formations. Their thickness is unknown, but the combined thickness is presumably several hundred meters. According to plate 1, near Gamboa the Las Cascadas agglomerate rests on the Bohio formation, the Gatuncillo formation, or the basement complex. Confirmation of this overlap is needed.

STRATIGRAPHY AND LITHOLOGY

The Bas Obispo formation and Las Cascadas agglomerate probably would ordinarily be combined as one formation. They differ, however, in induration and therefore have different properties in excavations. Both crop out in the northern part of Gaillard Cut and in the Gamboa area northwest of the cut. The Las Cascadas agglomerate extends farther west along the canal than the Bas Obispo formation. To the southwest both merge into undifferentiated and unmapped volcanic rocks.

According to Howe and MacDonald (in the publications just cited) and to accounts published by geologists of the Geological Section of the Special Engineering Division, both formations consist principally of agglomerate and tuff. The matrix of agglomerate of the Bas Obispo is hard sandy tuff so firmly indurated that the rock breaks through the larger constituents. Crude bedding is apparent in local thin deposits of the Bas Obispo made up of imperfectly rounded pebbles and cobbles. Such rock is not as well indurated as the agglomerate. The matrix of agglomerate of the Las Cascadas consists of soft fine-grained altered tuff and bentonitic clay. Beds of tuff in the Las Cascadas also are softer than those of the Bas Obispo. Both formations include andesitic and dacitic flow breccias and both are cut by a few andesitic dikes and by numerous basaltic dikes.

AGE

Fossils have not been found in either the Bas Obispo or Las Cascadas. They are doubtfully referred to the Oligocene because of their inferred relations to the Bohio and Caimito formations (p. 25, 28). The Bas Obispo and Las Cascadas presumably represent most of the Oligocene, not only early Oligocene as previously suggested (Woodring and Thompson, 1949, p. 228).

OLIGOCENE AND MIOCENE SERIES

CAIMITO FORMATION OF MADDEN BASIN AND PACIFIC COASTAL AREA

The Caimito formation of Madden basin, unlike that of other areas, includes both upper Oligocene and lower Miocene deposits. As shown on plate 1, in the northern part of the basin the Bohio formation is overlapped by the Caimito. The thickness of the Caimito in the basin appears to be about 450 meters. The deposits now referred to the Caimito formation were designated the Culebra formation, Emperador limestone, Caimito(?) formation, and Gatun(?) formation by Reeves and Ross (1930, p. 14–17).

The strata in the Pacific coastal area assigned to the lower part of the Caimito appear to be a direct extension of that part in Madden basin. These strata in the Pacific coastal area have an estimated thickness of not more than 250 meters.

STRATIGRAPHY AND LITHOLOGY

Madden basin.—Five members are tentatively recognized in the Caimito formation of Madden basin. The only formal member names that are used are those that have already been proposed, for detailed work may show that some arrangement other than that adopted in the present report is preferable. Two members are grouped as the lower part of the formation and the upper three as the upper part. In the following paragraphs the members are described in upward stratigraphic sequence.

The calcareous sandstone-siltstone member overlies the Bohio formation or overlaps it and rests on the Gatuncillo formation. Sandstone of this member, ranging from very fine-grained to very coarse-grained and conglomeratic, is well exposed on Río Chilibrillo upstream and downstream from the bridge on the road from Buenos Aires to Casa Larga. The sandstone is variably tuffaceous, and at least on Río Chilibrillo the member includes massive coarse-grained tuff. The exposures on Río Chilibrillo indicate a thickness of at least 200 meters.

The pyroclastic-clay member includes agglomerate, tuff, bentonitic clay, conglomerate, and limestone. Agglomerate may be seen on the Transisthmian Highway near Río Chilibre on the east side of the basin. The strata on the east side of the basin also include three lenses of limestone, two of which are exposed on the Transisthmian Highway. The thickness of the member on the east side of the basin is about 110 meters. On the west side of the basin, where the member is represented by steeply dipping clay immediately north of Río Chagres and just west of the Transisthmian Highway, the thickness is probably not more than 50 meters.

The Chilibrillo limestone member—the lowest member in the upper part of the formation—consists of lenticular limestone that has a maximum thickness of about 30 meters. Detailed mapping may show that limestone of that thickness lies at more than one horizon. The name Chilibrillo was casually used by Olsson (1942, p. 234). The type region is on the east side of the basin near Río Chilibrillo. Entrances to caves in the limestone are located at locality 81, about 150 meters west of the Transisthmian Highway, and nearby.

The calcareous sandstone member overlies the Chilibrillo limestone member, or in its absence overlies the pyroclastic-clay member and in that event is at the base of the upper part of the formation. The most accessible exposures of the medium-grained calcareous and tuffaceous sandstone are on the east side of the basin along the Transisthmian Highway. Highly calcareous sandstone is exposed at the north abutment of the Transisthmian Highway bridge across Río Chagres. The thickness of this member is about 30 meters.

The Alhajuela sandstone member is confined to a small area in the central part of the basin at and near Madden Dam. Before the construction of the dam the village of Alhajuela was located on Río Chagres opposite locality 85. (For location of Alhajuala see Reeves and Ross, 1930, pl. 5.) The massive fine- to coarse-grained tuffaceous sandstone forms the foundation of Madden Dam and the gorge of Río Chagres below the dam. Plate 7 is a view at the dam site. Fossil shells are more conspicuous in this member than in any other part of the Caimito formation in Madden basin. The thickness of the Alhajuela is 85 meters. The name, in the form "Alajuela sandstones", was proposed by Olsson (1942, p. 234, 243). The restricted usage suggested by his chart (Olsson, 1942, p. 234) is adopted in the present report.

Pacific coastal area.—The lower part of the Caimito formation appears to extend continuously from Madden basin to the Pacific coastal area. Agglomerate, tuffaceous sandstone, tuffaceous conglomeratic sandstone, and conglomerate in the region between the basin and the coastal area are thought to represent the lower part of the Caimito. The geology of this intermediate region, however, is complicated by numerous intrusive stocks, and the succession of sedimentary strata and their relations to those in adjoining areas have not been worked out. Limestone at locality 97, just east of Madden Highway, contains a small *Lepidocyclina* suggesting *L. canellei* on the basis of field identification.

In the Pacific coastal area the lower part of the Caimito is made up mainly of tuffaceous siltstone, tuffaceous sandstone, and conglomerate. Algal limestone, like that at localities 95 and 96, is a minor constituent.

FOSSILS AND AGE

Smaller Foraminifera.—Smaller Foraminifera were found in the calcareous sandstone-siltstone member of Madden basin on Río Chilibrillo: in silty very fine-grained sandstone at locality 68 and in sandy siltstone at locality 70. These collections have not been identified.

Larger Foraminifera.—*Lepidocyclina vaughani* is widespread and abundant in the calcareous sandstone-siltstone member on the west side of Madden basin, ranges throughout that member in the exposures on Río Chilibrillo, and occurs in the lower part of the formation in the Pacific coastal area. Despite an apparently favorable depositional environment, no orbitoids were observed in limestone of the pyroclastic-clay member in Madden basin. In fact, an *Archaias*-like species is the only larger foraminifer noticed in limestone of that member. The species in the table that follows were identified by Cole.

Larger Foraminifera from lower part of Caimito formation of Madden basin and Pacific coastal area

[Cole, 1952 (1953), p. 7]

	Localities			
	Madden basin			Pacific coastal area
	64	67	69	95
Heterostegina antillea Cushman	----	----	----	×
Lepidocyclina (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé	×	----	----	----
parvula Cushman	----	----	----	×
yurnagunensis morganopsis Vaughan	----	----	----	×
(*Nephrolepidina*) *vaughani* Cushman	×	×	×	×
Miogypsina (*Miogypsina*) *antillea* Cushman	----	----	----	×

Mollusks.—Mollusks occur in the Caimito of Madden basin, but none was found in the Pacific coastal area. Limestone in the pyroclastic-clay member (localities 71-73) and submerged calcareous strata of the lower part of the Caimito (localities 65, 66) contain mollusks, but none of the families covered by chapter A of the present report is represented in the collections. The typical form of *Turritella altilira* occurs in the Alhajuela sandstone member at locality 89. Specimens of *T. altilira* from the Alhajuela at localities 88 and 92, and from the underlying calcareous sandstone member at localities 77 (*T.* cf. *T. altilira*) and 80, are not sufficiently well preserved to determine whether they represent the typical form. *Turritella gatunensis?* was found in the calcareous sandstone member (locality 82).

Echinoids.—According to identifications by C. W. Cooke, *Clypeaster lanceolatus* occurs in limestone of the pyroclastic-clay member (locality 71) and in submerged calcareous strata of the lower part of the Caimito (locality 66), and *Clypeaster* cf. *C. pinarensis* in the calcareous sandstone member (locality 84a).

Age.—The lower part of the Caimito formation in Madden basin, consisting of the calcareous sandstone-siltstone member and the pyroclastic-clay member, and the formation in the Pacific coastal area are considered of late Oligocene age, like the entire Caimito of other areas. The two species of larger Foraminifera from the calcareous sandstone-siltstone member in Madden basin and the five species from the Pacific coastal area are typical Caimito species and typical upper Oligocene species. The age of the pyroclastic-clay member of Madden basin is based principally on an early species of *Nodipecten* found also in the middle member of the Caimito in the Gatun Lake area.

The upper part of the Caimito in Madden basin, consisting of the Chilibrillo limestone member, the calcareous sandstone member, and the Alhajuela sandstone member, is assigned to the early Miocene on the basis of mollusks. The lower two members would be referred to the late Oligocene by those who claim that the Aquitanian and its essential American equivalents are of late Oligocene age. The Alhajuela sandstone member, however, is late early Miocene; that is, younger than the disputed Oligocene or Miocene. That it may include early middle Miocene, as suggested in a preliminary account (Woodring and Thompson, 1949, p. 236), appears to be unlikely.

Only the Oligocene part of the Caimito is recognized in the Pacific coastal area. It is overlain and perhaps partly overlapped by the Panamá formation, which is correlated with the lower part of the Miocene strata in the Caimito of Madden basin. No fossiliferous strata as young as the Alhajuela sandstone member have so far been found in the Pacific coastal or Gaillard Cut areas.

MIOCENE SERIES

CULEBRA FORMATION, INCLUDING EMPERADOR LIMESTONE MEMBER

The Culebra formation is recognized along and near the canal in the Gaillard Cut area and immediately to the southeast in the region straddling Pedro Miguel Locks. (For a large-scale map of the Gaillard Cut area see plate 2.) To the southwest presumably it merges into undifferentiated and unmapped volcanic rocks, like other formations in the Gaillard Cut area. The Culebra itself contains volcanic debris, but not nearly so much as the underlying and the overlying formations. The name for the formation, in the form "Culebra clays," was first used by Hill (1898, p. 192–195). The type region is in the central Gaillard Cut area, where the town of Culebra was located on the west side of the canal before and during the construction period. The Culebra formation unconformably overlies the Las Cascadas agglomerate. The maximum thickness of the formation is about 150 meters. The thickness decreases northward, evidently as a result of overlap of successively younger parts of the formation on the Las Cascadas agglomerate.

Coralliferous limestone exposed in a quarry near Empire attracted attention at an early date and was named the Empire limestone by Hill (1898, p. 195–196). MacDonald (1913, p. 569) changed the name to Emperador limestone, presumably because of the possibility of confusion with the Empire formation of Oregon. Empire was the American name for a town near Culebra, whereas the French used the Spanish name Emperador for the same town. The town was located on the pre-construction alinement of the Panama Railroad near Culebra, approximately at locality 117 as plotted on plate 2. The quarry near Empire (locality 118 of plate 2), which is to be regarded as the type locality of the Emperador limestone member, is overgrown and unrecognizable, and so is the similar limestone formerly exposed on a street in Empire. Limestone agreeing with descriptions of the Emperador is still exposed along the canal. These beds of relatively pure coralliferous limestone probably are at different horizons in the upper part of the Culebra formation and probably grade southeastward into calcareous sandstone (Woodring and Thompson, 1949, p. 237). Should it be demonstrated that the name is being used for limestone at different horizons, the name should be abandoned, except for the limestone at the type locality. In that event, however, a formal name would hardly be needed for a single locality, even if the locality were again found. In the meantime no serious errors should result from usage of the name. The coralliferous limestone has a maximum thickness of 15 meters. It therefore is a minor constituent and is given member rank in the Culebra formation.

The Emperador limestone member of the Culebra formation is known to occur only in the northern part of the outcrop area of the Culebra. MacDonald's representation of the Emperador as widespread and resting unconformably on formations of different age was based on misidentification of limestone in several formations (MacDonald, 1913, pl. 68). According to present interpretations, coralliferous limestone in the La Boca marine member of the Panamá formation on Río Masambí, in the Gaillard Cut area, was recently misidentified as Emperador (Woodring and Thompson, 1949, p 237).

STRATIGRAPHY AND LITHOLOGY

Stratigraphic sections of the Culebra formation in Gaillard Cut have been published by MacDonald (1919, p. 535–539) and he also published structure sections of part of the cut (Natl. Acad. Sci., 1924 figs. 4, 5, op. p. 52). He divided the Culebra into lower and upper parts. The lower part consists chiefly of dark-colored, thin-bedded or laminated, fine-grained rocks: carbonaceous or lignitic shale, carbonaceous silty mudstone, tuffaceous siltstone. It includes, however, minor beds of tuffaceous and calcareous sandstone and conglomerate. The upper part is characterized by calcareous and sandy strata ranging in thickness from 0.3 to 3.5

meters and in composition from tuffaceous and pebbly calcareous sandstone to sandy limestone. The calcareous and sandy strata are separated by dark calcareous or somewhat carbonaceous shale and mudstone. Carbonaceous strata in both parts of the formation contain land plant debris, including identifiable leaves (Berry, 1918).

Generally the Culebra formation is overlain directly by conglomerate at the base of the Cucaracha formation, marking a discontinuity, evidently a minor discontinuity. On both sides of Gaillard Cut, however, just northeast of the site of Culebra, somewhat calcareous silty sandstone and sandy siltstone interbedded with clay like that of the Cucaracha form a transition zone between the two formations. The transition zone is included in the Culebra formation. Sluicing operations carried on in 1947 on the west side of the canal, in the region where the transition zone is represented, exposed the section below. Unit 1 is at the level of the canal.

Section of upper part of Culebra formation, including transition zone between Culebra and Cucaracha formations, on west side of Gaillard Cut at canal station 1759 [2] *near site of Culebra*

	Meters
Transition zone between Culebra and Cucaracha formations:	
15. Clay, dark-gray, slickensided, and silty carbonaceous clay. Overlain by light-gray medium-grained locally conglomeratic sandstone taken as base of Cucaracha formation	4. 6
14. Siltstone, limonitic-weathering, dark-gray; few gypsiferous shell tips of *Turritella* weathered out	. 9
13. Siltstone, dark-gray, sandy; includes a 15-cm fossiliferous somewhat calcareous layer at base (locality 112) and fossiliferous calcareous concretions at and within 30 cm of top (locality 112a)	1. 0
12. Clay, greenish-brown, slickensided, silty	. 5
11. Sandstone, greenish-gray, silty, medium-grained; and siltstone	1. 6
10. Sandstone, brownish-gray, silty, medium-grained; and siltstone containing petrified wood	1. 1
9. Clay, limonitic-weathering, slickensided, dark-gray	1. 3
8. Clay, grayish-green, somewhat carbonaceous and somewhat fissile	2. 3
Culebra formation proper, upper part:	
7. Sandstone, light-gray, medium-grained, poorly sorted, silty, calcareous; siltstone partings	1. 5
6. Shale, dark-gray, silty, somewhat carbonaceous; includes thin layers of calcareous sandy siltstone	1. 3

[2] The canal stations are located at intervals of 100 feet (30½ meters) along the center alinement and are numbered from the Caribbean terminus to the Pacific terminus. Strictly speaking the rock exposures are opposite the stations, not at them.

Section of upper part of Culebra formation, including transition zone between Culebra and Cucaracha formations, on west side of Gaillard Cut at canal station 1759 near site of Culebra—Continued

	Meters
5. Sandstone, light-gray, medium- to coarse-grained, poorly sorted, calcareous; siltstone partings	3. 2
4. Shale, dark to black, calcareous, somewhat carbonaceous	1. 4
3. Sandstone, light-gray, medium- to coarse-grained, poorly sorted, calcareous, in beds 30 to 90 cm thick and interbedded with poorly exposed somewhat carbonaceous shale. Includes a 15-cm layer of conglomerate	8. 1
2. Sandstone, coarse-grained to conglomeratic, calcareous; contains a moderately large smooth species of oyster	. 5
1. Sandstone, light-gray fine- to medium-grained, poorly sorted, calcareous, in beds 30 cm thick and interbedded with dark to black calcareous and carbonaceous shale and mudstone. Locality 108, 1.5 m above edge of canal	4. 2
Thickness of section	33. 5

Part of the transition zone is exposed on the east side of the canal at canal station 1754. Fossiliferous strata corresponding to the fossiliferous parts of bed 13 of the preceding section are recognizable on the east side, but the best-preserved fossils are weathered out and were put in one collection (locality 110). Silicified wood is common at that locality, including segments of logs riddled with shipworm tubes (*Teredo*).

Limestone of Emperador type in the upper part of the Culebra crops out farther northwest on the west side of the canal on both limbs of a syncline near the site of Las Cascadas. At locality 120 (canal station 1600) the limestone is 6 meters thick and in a nearby core hole is 24.3 meters above the base of the Culebra. At locality 121 (canal station 1619, pl. 8) the thickness is 15.2 meters and the limestone is about 27.5 meters above the base of the Culebra. At both localities the underlying strata consist of dark carbonaceous clay and tuffaceous siltstone. The basal 30 to 60 centimeters of the limestone at locality 120 is silty and contains numerous pectinids. The limestone at locality 121 includes a basal calcareous siltstone bed that has a thickness of 15 to 30 centimeters and a middle calcareous siltstone bed 2.4 meters thick. The limestone at these two localities appears to represent the same zone and probably is the same as limestone near Tower N, a signal tower on the pre-construction line of the Panama Railroad near Las Cascadas. Fossils from "the *Pecten* bed" near Tower N were recorded by Brown and Pilsbry (1913, p. 502–503). The limestone in the Las Cascadas area is presumed to be the equivalent of calcareous sandstone in the measured section at canal station 1759. MacDonald (1919, p. 537) assigned to the Emperador "somewhat sandy limestone" at locality 99g (canal station 1606). The matrix of the numerous fossils MacDonald collected at that locality consists of sandy limestone that does not resemble the Emperador limestone.

FOSSILS AND AGE

Smaller Foraminifera.—A few species of smaller Foraminifera from the Culebra formation were recorded by Cushman (1918). Some of the localities referred to the Culebra in Cushman's publication represent other formations: Geological Survey localities 6009 and 6010 represent the La Boca marine member of the Panamá formation; localities 6024a, 6025, and 6026 the Caimito formation. Though the fauna of the Culebra is not extensive, more species than the few recorded by Cushman are represented in core collections obtained during the operations of the Geological Section of the Special Engineering Division. Meager collections can still be obtained at outcrop localities, such as localities 104 and 108. It has been claimed that *Siphogenerina transversa* is not found in the Culebra formation (Woodring and Thompson, 1949, p. 241). M. N. Bramlette, however, identified a small specimen of that species in core material from a depth of 88 feet (26.7 meters) in core hole SL108 and another small specimen from a depth of 133 feet (40.4 meters) in the same core hole. Core hole SL108 was located 1.1 kilometers west-southwest of locality 101 and evidently the Culebra formation was penetrated at the depths just specified.

Larger Foraminifera.—Cushman's identifications of the species of *Lepidocyclina* in the Culebra formation have not been confirmed (Cushman, 1918a, p. 90). H. G. Schenck identified *Lepidocyclina canellei* in core samples at horizons 30 to 45 meters below the top of the Culebra (Woodring and Thompson, 1949, p. 238). Cole recently described and illustrated *L. miraflorensis* (locality 99g) and *L. waylandvaughani* (locality 99a) from the Culebra formation proper, and *L. miraflorensis* (locality 119a) from the Emperador limestone member (Cole, 1953a). The type localities of *Miogypsina cushmani* (locality 107) and *"Orbitolites" americana* (locality 100) are in the Culebra formation. *Miogypsina intermedia* is recorded from the Culebra at locality 115 near Paraiso (Drooger, 1952, p. 36).

Corals.—Of the four species of corals recorded by Vaughan from the Culebra formation proper, one occurs in the Emperador limestone member, three in the Antigua formation, and all in the Anguilla formation (Vaughan, 1919a, p. 208; Geological Survey locality 6026 represents the Caimito formation). Vaughan listed 24 species of corals from the Emperador limestone member. Four of them occur in the Antigua formation and nine in the Anguilla formation (Vaughan, 1919a, p. 209; Geological Survey locality 6024b represents the Caimito formation and 6256 the La Boca marine member of the Panamá formation).

Mollusks.—MacDonald made numerous collections of mollusks from the Culebra formation during the excavation of Gaillard Cut. Much of the material, however, is poorly preserved. Except in the Paraiso area, the Culebra fauna includes species indicating brackish water, particularly in the transition zone between the Culebra and Cucaracha formations (localities 110 to 112a). The *Neritina*, for example, indicates brackish water and *Littorina angulifera* is a modern species that lives in mangrove swamps. Most of the species indicating brackish water are absent in the Paraiso area (localities 113 to 116). Plate 2 indicates that the fossiliferous strata in the Paraiso area are close to the top of the Culebra. It has been suggested that the uppermost part of the formation in the Paraiso area is the equivalent of the transition zone but represents an environment farther seaward (Woodring and Thompson, 1949, p. 239). According to the evolutionary scheme worked out by Drooger for miogypsinids, however, *Miogypsina intermedia*, which occurs in the Paraiso area, is less advanced than *M. cushmani*, found in the upper part of the Culebra farther northwest (locality 107), where the transition zone is not known to be present (Drooger, 1952, fig. 17, p. 72).

The following mollusks are in the families covered by chapter A of the present report:

Mollusks from Culebra formation, exclusive of Emperador limestone member (Neritidae to Turritellidae)

	98	99*a*	99*b*	99*c*	99*d*	99*f*	99*g*	99*h*	100	100*b*	104*b*	106	107	108*b*	108*c*	110	110*a*	111*a*	111*b*	112	112*a*	114	115*a*	115*b*	116
Neritina (*Vitta?*) sp															×										
Littorina aff. *L. angulifera* (Lamarck)																×									
Rissoina (*Zebinella?*) sp			×																						
Xenophora sp							×																		
Hipponix? sp															×										
Crepidula sp			×						×																
Calyptraea cf. *C. centralis* (Conrad)			×	×					×						×		×								
Trochita? cf. *T. trochiformis* (Born)																							×	×	×
Crucibulum sp			×	×								×										×			
Natica (*Naticarius?*) sp																×									
Polinices? sp					×				×			×											×	×	
Neverita? sp		×	×	×	×	×						×								×		×	×		
Sinum sp				×	×						×										×	×			
Globularia (*Globularia*) aff. *G. fischeri* (Dall)							?			×															
Pachycrommium? cf. *P.? trinitatensis* (Mansfield)								×																	
cf. *P. guppyi* (Gabb)																				×			×		
Turritella (*Torcula?*) *amaras* Woodring, n. sp	×		×										×	×	×	×	×	×	×	×	×				×
sp						×	×	×																	
cf. *T. subgrundifera* Dall					×																				
venezuelana Hodson			×										×			×		×		×	×	×			
cf. *T. berjadinensis cocoditana* Hodson																								×	

Collections from the type locality of the Emperador member contain only a few species of mollusks, none of which represents the families described in chapter A of the present report. Limestone in the Las Cascadas area assigned to the Emperador contains *Neverita?* sp. (localities 119a, 120) and *Turritella altilira* in the unrestricted sense (locality 120).

Echinoids.—*Clypeaster lanceolatus* and *Echinolampas semiorbis* were recorded from the Emperador limestone member by Jackson (1917, p. 490, 498).

Mammal.—In 1942 T. F. Thompson found an incomplete mammal bone in the transition zone between the Culebra and Cucaracha formations at locality 110 on the east side of the canal—the first Tertiary mammal to be found in Panamá. The following comments on this fossil and the drawings by O. J. Poe reproduced as figure 2 are available through the kindness of R. A. Stirton, of the University of California.

The bone found by Mr. Thompson is the distal part (length 78 millimeters) of a metapodial of an ungulate of medium size. It was examined by H. E. Wood, 2nd, who thought it represents a rhinoceros similar to *Diceratherium*. G. G. Simpson doubted that it is a South American ungulate, but had no material for close comparison with the leontiniids. The apparent rhinoceros affinities seemed to be conclusive until late Miocene leontiniid foot bones, collected by University of California expeditions in Colombia, were available for comparison. This material indicates that the metapodial from the Canal Zone may represent a South American leontiniid or a North American rhinocerotid.

Despite a search in 1947 and 1949, no additional mammal remains were found at or near locality 110

Age.—Douvillé (1891, p. 499) and Hill (1898, p. 195), relying entirely on lithologic similarity to lignitic strata in the Eocene of the Gulf states, suggested that the Culebra is Eocene. A review of other age assignments—Eocene, Oligocene, Miocene—would hardly be profitable. It may be pointed out, however, that Douvillé (1898, p. 591) and Bertrand and Zürcher (1899, p. 89, 90), evidently following his advice, thought that small orbitoids in strata that presumably represent the Culebra are reworked.

The fossils of the Culebra formation, including the Emperador member, have both Oligocene and Miocene affinities. The orbitoids (three lepidocycline species of *Lepidocyclina*) point to Oligocene. In fact, some paleontologists consider lepidocycline species to be decisive for an age not younger than late Oligocene. According to Vaughan's data, the corals favor correlation with the Anguilla formation of Anguilla, which contains no orbitoids. The mollusks also favor correlation with the Anguilla and other formations of the same age,

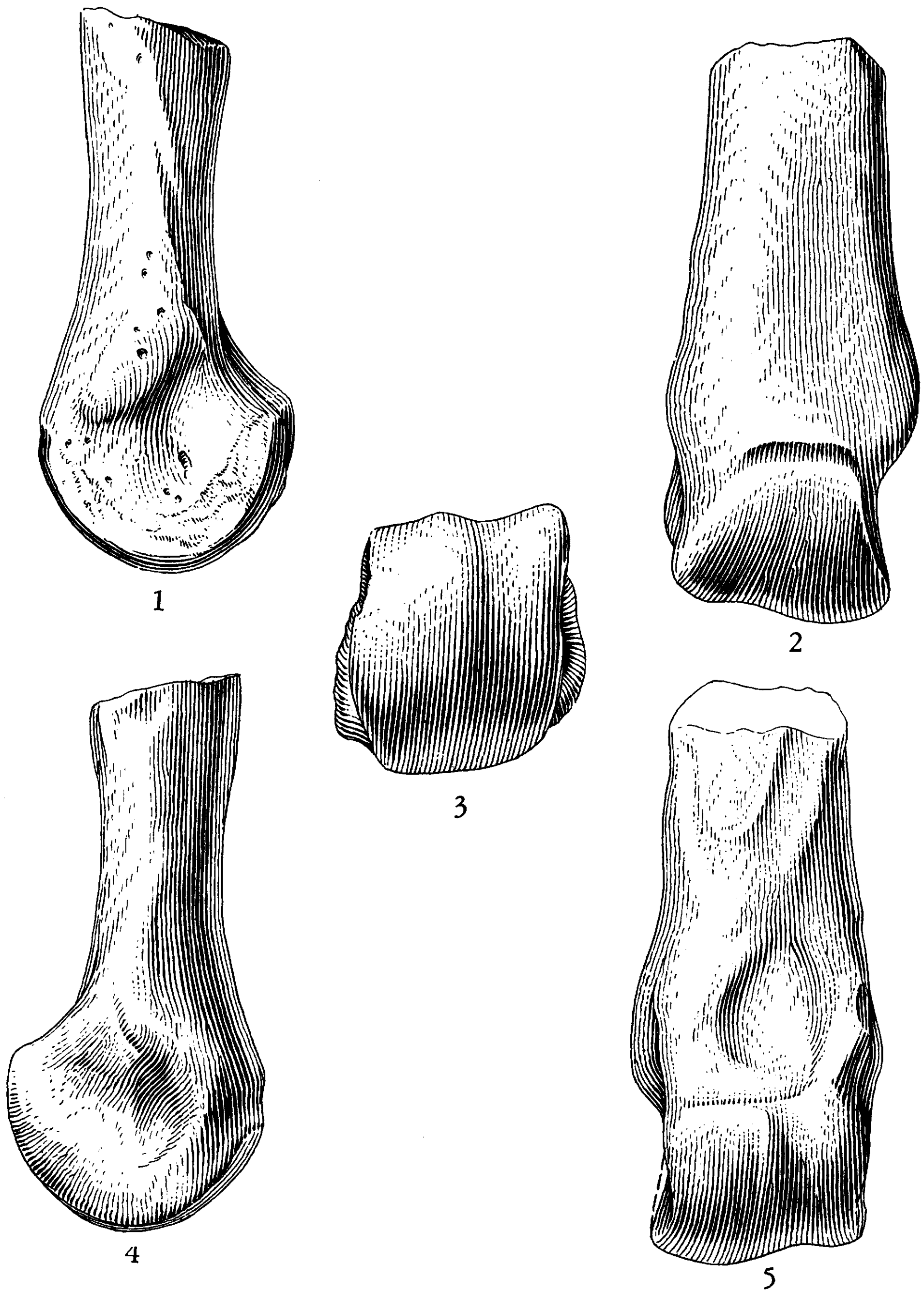


Figure 2.—Ungulate metapodial from transition zone between Culebra and Cucaracha formations. Univ. Calif. Mus. Paleontology 37363, natural size.
1, 4. Lateral views
2. Front view
3. Distal view
5. Posterior view

including the Tampa limestone of Florida, which also contains no orbitoids. None of the mollusks in the preceding list suggest species that are only of greater age than disputed Oligocene or Miocene, whereas *Littorina* aff. *L. angulifera*, *Pachycrommium?* cf. *P. guppyi*, and *Turritella* cf. *T. subgrundifera* suggest species that are only of younger age than disputed Oligocene or Miocene. Whether the Culebra formation is to be assigned to the late Oligocene or early Miocene is part of the larger question of whether the Aquitanian stage of western Europe is late Oligocene or early Miocene, for the Culebra and correlated formations are the essential equivalent of the Aquitanian. It has long been recognized that the marine type Aquitanian of the Aquitaine basin contains an early Miocene fauna. The argument concerning the age of the Aquitanian centers on the Oligocene aspect of the mammalian fauna in nonmarine strata that are thought to be the equivalent of the marine type Aquitanian. An early Miocene age for the Culebra formation agrees with the age assignment adopted by the Geological Survey for the Tampa limestone. That assignment for the Culebra, including the Emperador member, is adopted for the present report, instead of the late Oligocene(?) and early Miocene age assignment recently used (Woodring and Thompson, 1949, p. 239).

CUCARACHA FORMATION

The Cucaracha formation crops out along and near the canal in the Gaillard Cut area and southeastward to Miraflores Lake. Its distribution is much like that of the underlying Culebra formation, but it is recognized at a greater distance from the canal than the Culebra. The name was proposed by MacDonald (1913, p. 569). Up to that time the strata constituting the Cucaracha formation had been included in the Culebra. The type region is in the southern Gaillard Cut area. The site of the village of Cucaracha was on the east side of the canal between the continental divide and Paraiso. The maximum thickness of the formation is about 190 meters. The discontinuity at the base of the Cucaracha generally is sharp and marked by conglomerate, but in central Gaillard Cut a transition zone lies between the two formations. (See p. 35.)

STRATIGRAPHY AND LITHOLOGY

The Cucaracha formation is the most distinctive and the most uniform formation in the Canal Zone. It was involved in the extensive slides in Gaillard Cut during excavation of the cut and during a period of several years after the canal was opened. Its physical properties were exhaustively investigated during the studies of the Third Locks project, carried out by the Special Engineering Division.

The principal constituent of the formation is massive generally grayish yellow green waxy highly slickensided bentonitic clay. Carbonaceous and lignitic clay, clayey siltstone containing yellowish gray calcareous concretions, tuffaceous clayey sandstone, and small-pebble conglomerate that has a tuffaceous matrix are minor constituents (Thompson, 1947a, p. 16–17). A bed of dacitic welded tuff is a useful and exact datum plane. Its thickness ranges from 0.3 to 10 meters. In the type region of the Cucaracha it lies 85 meters above the base of the formation and 60 meters below the top (MacDonald, 1947, p. 9; Thompson, 1947a, p. 17). It is the only hard rock in the formation and looks much like a lava flow. In fact, it was described as a sill by Howe (1908, p. 231), as a flow by MacDonald (1913, p. 569), and was shown as a flow in MacDonald's structure sections (Natl. Acad. Sci., 1924, figs. 4, 5, op. p. 52). Later, however, it was found to be an agglomeratic tuff (MacDonald, 1947, p. 9–10; Thompson, 1947*a*, p. 16). Hand specimens show feldspar crystals, flattened little lentils of dark clay, and greenish angular rock fragments. During the investigations of the Geological Section of the Special Engineering Division this bed of tuff was known as the ash flow. Description of thin sections of the tuff and a chemical analysis are presented on pages 54, 55. Chemical analyses of six samples of clay from the Cucaracha were published in the National Academy of Sciences report on slides (Natl. Acad. Sci., 1924, p. 54) and were reproduced by MacDonald (1947, p. 10). Both reports just cited also include descriptions of microscopic and other features of the clay (Natl. Acad. Sci., 1924, p. 54–66; MacDonald, 1947, p. 12–19, 65–70). No mineralogical study of the clay by modern techniques has been undertaken.

FOSSILS AND AGE

The absence of marine fossils and the presence of plant debris in carbonaceous clay suggest that the bulk of the Cucaracha formation is nonmarine. The only plant remains recorded consist of wood (Berry, 1918). A few marine and brackish-water fossils have been found in the lower part of the formation: *Anadara* and *Crassostrea* in conglomerate and poorly preserved molds and impressions of *Anadara, Lucina?,* and *Tellina?* in carbonaceous clay (locality 122). The collection from locality 122 is the only collection now available.

In November, 1956, R. H. Stewart found the distal end of a femur in the Cucaracha formation, about 10 meters above the top of the welded tuff, at Contractors Hill, in the Gaillard Cut area at the continental divide. It was examined by R. A. Stirton, of the University of California, who reports (in a personal communication) that it may represent a North American rhinocerotid or a South American notoungulate. In other words, the uncertainty is the same as that for the metapodial from the transition zone between the Culebra and Cucaracha formations (p. 37).

The few fossils found thus far furnish no reliable evidence concerning the age of the Cucaracha. It is assigned to the early Miocene because both the underlying Culebra formation and the overlying Panamá formation are considered to be of that age.

PANAMÁ FORMATION, INCLUDING LA BOCA MARINE MEMBER AND PEDRO MIGUEL AGGLOMERATE MEMBER

The Panamá formation is the youngest Tertiary formation in the Gaillard Cut and Pacific coastal areas. It crops out in scattered areas in the central and southern Gaillard Cut area and more extensively farther southeast and east. It consists mostly of volcanic rocks, the youngest volcanic rocks in the Canal Zone. To the west it grades into undifferentiated volcanic rocks and west of the border of plate 1 volcanism continued much later.

The marine strata constituting the La Boca marine member and the agglomerate making up the Pedro Miguel agglomerate member interfinger with each other and with the lower part of the tuff and generally fine-grained agglomerate forming the Panamá formation proper. All three were formerly given formation rank (Thompson, 1947a, p. 18–19, 20; Woodring and Thompson, 1949, p. 241–242). For the time being, however, member rank appears to be preferable for the La Boca and the Pedro Miguel.

The Panamá formation was named by Hill (1898, p. 200–202). That the name was casual is indicated by the expression "so-called Panama formation" on page 206 in his publication. The formation was named for exposures along the water front in the city of Panamá, which is considered the type area. The names La Boca formation and Pedro Miguel agglomerate were proposed by Thompson (1943, p. 16–18). The Miraflores Locks area has been designated the type region of the La Boca marine member (Woodring and Thompson, 1949, p. 241) and the Pedro Miguel area is the type region of the Pedro Miguel agglomerate member. The thickness of the formation is estimated to be at least 300 meters.

STRATIGRAPHY AND LITHOLOGY

The La Boca marine member extends farther inland than any other part of the Panamá formation. It overlies the Cucaracha formation or interfingers with the upper part of that formation. Nevertheless, if the La Boca is correctly identified, it also overlaps the Cucaracha and Culebra formations and rests directly on the Bas Obispo formation. The member consists principally of silty or sandy tuffaceous mudstone, flaggy tuffaceous sandstone, calcareous tuffaceous sandstone, conglomerate, and coralliferous limestone. Agglomerate and tuff, presumed to represent tongues from the Pedro Miguel agglomerate member and the main part of the formation, respectively, are other constituents. The stratigraphic relations of these strata, most of which contain marine fossils, were not understood until the subsurface explorations of the Geological Section of the Special Engineering Division revealed evidence that they overlie the Cucaracha formation. The fine-grained strata formerly were assigned to the Culebra formation, sandstone to the Caimito formation, and limestone to the Emperador limestone member of the Culebra formation. No satisfactory outcrop section showing both a considerable part of the member and its stratigraphic relations is known. For that reason the Miraflores Locks area has been designated the type region. In that area there are outcrops, and relations to the Cucaracha formation are shown by subsurface sections. The town of La Boca, which furnished the name, was located near the entrance to Balboa Harbor, but was abandoned in 1954. Though the La Boca member overlies the Cucaracha formation, the lower part of the La Boca evidently is the southward marine equivalent of the upper part of the Cucaracha formation in the area of maximum thickness of that formation. The maximum thickness of the La Boca member is about 185 meters.

Along and near the canal the La Boca member is represented principally by mudstone in both outcrop and subsurface sections. The mudstone is similar to that in the Culebra formation, but may be distinguished by the lower content of carbonaceous matter and the richer foraminiferal fauna of the La Boca. Locality 124, on the east side of the canal at canal station 1702, is the northernmost locality where such mudstone is now known to crop out along the canal. Core drilling, however, penetrated the La Boca farther north in a syncline on the west side of the canal.

Mudstone of the La Boca exposed in the canal excavation between Paraiso and Pedro Miguel Locks (locality 130), at the north end of Mariflores Locks, and south of those locks (Geological Survey locality 6009) was described by MacDonald as part of the Culebra formation (MacDonald, 1919, p. 533–534).

Fossiliferous calcareous tuffaceous massive sandstone of the La Boca is exposed in an abandoned quarry off old Gaillard Highway near Summit (locality 128). When the cuts along the present alinement of the Panama Railroad were fresh, MacDonald found fossils in similar but less massive sandstone in cuts north and south of Summit (localities 126 to 127b.) At locality 127b the sandstone is overlain by tuff that MacDonald identified as representing the Panamá formation. (See his data in description of locality 127b, p. 124.) Fine-grained fossiliferous tuff and tuffaceous siltstone crop out at locality 132 near Red Tank, a village that has been abandoned since plate 1 was drafted. Flaggy tuffaceous strata, ranging in grain size from sandy siltstone to poorly sorted gritty sandstone, are exposed in a cliff at the mouth of Río Masambí on the east side of the canal. These strata are considered part of the La Boca member. They are unlike any strata in the Culebra formation and, like the La Boca member elsewhere, contain molds of *Acila* cf. *A. isthmica.*

Cream-colored and gray coralliferous limestone of Emperador type at the base of the La Boca member overlies, and partly interfingers with, the Cucaracha formation on Gaillard Highway 400 meters northwest of the junction with Madden Highway (locality 129). Similar limestone on Río Masambí, on the east side of the canal (locality 123), lies directly on the Bas Obispo formation and has a thickness of 35 meters, the greatest known thickness for limestone of Emperador type. A view of this limestone is shown in plate 9. It was recently identified as the Emperador limestone member of the Culebra formation (Woodring and Thompson, 1949, p. 237), but is now thought to represent the La Boca member. It is in an area where the La Boca is known to be present, although no continuity with other La Boca rocks has been established. If the limestone is now correctly identified, the La Boca member overlaps onto the Bas Obispo formation. The strata in Gaillard Cut between canal stations 1720 and 1730, described by MacDonald as "light-colored tuff bed locally overlapping Culebra beds" may possibly represent overlapping La Boca (Natl. Acad. Sci., 1924, p. 52, fig. 4). Limestone of the La Boca near Red Tank (locality 131) was referred by MacDonald to the Emperador member of the Culebra formation, and sandstone and agglomerate overlying the limestone to the Caimito formation (MacDonald, 1919, p. 534, "section at Bald Hill near Miraflores Locks"; for other locality data see p. 124). In fact, MacDonald used the section near Red Tank to define the Caimito formation and its stratigraphic relations to the Emperador limestone member of the Culebra formation (MacDonald, 1913, p. 569).

The Pedro Miguel agglomerate member is a lens of essentially coarse-grained pyroclastic rocks. In the Pedro Miguel area, the type region, these rocks overlie the Cucaracha formation. The lower part of the pyroclastic rocks, like the lower part of the La Boca marine member, apparently is the equivalent of the upper part of thick Cucaracha sections. Farther south the pyroclastics appear as a tongue in the lower part of the La Boca marine member. The pyroclastic rocks of the Pedro Miguel member, as described by Thompson (1947a, p. 18–19), consist chiefly of fine- to very coarse-grained agglomerate. Bedding and sorting are poor to moderately well developed. Fine-grained tuff is interbedded with the agglomerate. The thickness of the Pedro Miguel member is variable, but the maximum averages about 100 meters. Agglomerate of the Pedro Miguel in the Miraflores area was formerly considered part of the Las Cascadas agglomerate or was doubtfully referred to that formation (MacDonald, 1919, p. 533). Howe, however, realized that agglomerate near the continental divide rests on the Culebra formation (1908, p. 222–223). (The Cucaracha formation had not yet been differentiated.) Like MacDonald, he thought that agglomerate farther south near Corozal is of pre-Culebra age (Howe, 1908, p. 223).

Much agglomerate is known to be present in an unmapped area between Madden Highway and Curundu. It is not known, however, whether all this agglomerate represents the Pedro Miguel member, as shown on plate 1, or what rocks other than agglomerate crop out in the area.

The Panamá formation proper is made up of tuff, tuffaceous siltstone, tuffaceous sandstone, and agglomerate. They evidently represent nonmarine essentially fine-grained tuff and tuffaceous strata that interfinger with and overlie the La Boca marine member and the Pedro Miguel agglomerate member. The geologic map (pl. 1) suggests that in the Pacific coastal area the Panamá formation proper overlaps part of the Caimito formation, but that relation needs confirmation. Tuff characteristic of the Panamá formation is light gray, rhyolitic, and contains much pumice and minute fragments of glass (Hill, 1898, p. 200–201; Howe, 1907, p. 116–117). Such tuff is exposed along the water front in Panamá and in street cuts in Diablo Heights. Similar tuff near Miraflores, now included in the La Boca marine member, was informally designated the Miraflores pumice by Hill (1898, p. 198–199), a name he suppressed on a later page (Hill, 1898, p. 206). Comparison of the volcanic constituents of the Panamá and Caimito formations may afford a basis for confirming or rejecting earlier correlations of tuff in the Panamá formation with rhyolitic tuff along the canal north of the continental divide (Hill, 1898, p. 201; Bertrand and Zürcher, 1899, p. 91; Howe, 1907, p. 117). The apparent overlap of the La Boca marine member of the Panamá formation across the Cucaracha and Culebra formations indicates that their correlation deserves further consideration. In the meantime, however, it is not accepted.

FOSSILS AND AGE

The only available fossils were found in the La Boca marine member.

Smaller Foraminifera.—Smaller Foraminifera are fairly abundant in fine-grained strata. They represent a more open-sea marine environment than the meager fauna of the Culebra formation. M. N. Bramlette, who examined the outcrop sample from locality 124 and some subsurface samples, points out the abundance of *Siphogenerina transversa*. The type locality of that species (Geological Survey locality 6010, 130 of present report) is in strata of the La Boca member penetrated in the canal excavation between Paraiso and Pedro Miguel. *Siphogenerina* also is found in calcareous sandstone at locality 128. Both the type locality of *Siphogenerina transversa* and Geological Survey locality 6009 were assigned to the Culebra formation in Cushman's account of Canal Zone smaller Foraminifera (Cushman, 1918).

Larger Foraminifera.—The type locality of *Lepidocyclina miraflorensis* (locality 132a), a lepidocycline species, represents the La Boca marine member. It has been suggested that that locality is near the railroad tunnel north of Miraflores Locks (Woodring and Thompson, 1949, p. 241), but it probably is submerged by Miraflores Lake. Cole has recently described thin sections of specimens from the type lot (Cole, 1953a). He also identified and described *Lepidocyclina parvula*, also a lepidocycline species, and *Miogypsina panamensis* from locality 131a, MacDonald's locality near Red Tank.

Corals.—MacDonald found two species of corals in limestone at his locality near Red Tank (locality 131). Both were recorded by Vaughan from the Emperador limestone member of the Culebra formation and one from the Anguilla formation (Vaughan, 1919a, p. 209; Geological Survey locality 6256). The following corals, found in limestone at the base of the La Boca member at localities 123 and 129, were identified by J. W. Wells:

Corals from limestone at base of La Boca marine member of Panamá formation

[Identification by J. W. Wells]

	Localities 123	129
Stylophora imperatoris Vaughan	×	---
Stylophora macdonaldi Vaughan	--	×
Acropora saludensis Vaughan	--	×
Porites cf. *P. douvillei* Vaughan	×	×
Montastrea imperatoris Vaughan	--	×
Montastrea costata (Duncan)	×	×

According to Wells, all except one of the above species (or comparable species) occur in the Emperador limestone member of the Culebra formation and that species (*Montastrea costata*) occurs in the Culebra formation proper. Two are found in the Antigua formation and three in the Anguilla formation of the Leeward Islands.

Mollusks.—Though mollusks are widespread in the La Boca member, they are nowhere abundant and most of them are not well preserved. *Crepidula* sp. (locality 125), *Neverita?* sp. (locality 130), and *Turritella* cf. *T. collazica* (locality 123) are the only species in the families covered by chapter A of the present report.

Echinoids.—Limestone at the base of the La Boca member at locality 123 yielded an echinoid identified by C. W. Cooke as *Clypeaster concavus?*. That species occurs in the Caimito formation of the Río Mandinga area and in both the Antigua and Anguilla formations of the Leeward Islands. According to Jackson, *Clypeaster gatuni*, a Gatun species, was found in limestone in a swamp north of Ancon Hill (Jackson, 1917, p. 491). The swamp is now filled, but limestone occuring in that region presumably is in the La Boca marine member.

Age.—The Panamá formation was the first formation in or near the Canal Zone to be given an age assignment. Wagner thought that reddish conglomerate and fragmental rocks at Panamá are Permian (Wagner, 1861, p. 6, 16). Though that opinion, of course, has not been taken seriously, Hill was inclined to consider the formation pre-Tertiary (Hill, 1898, p. 202). Bertrand and Zürcher (1899, p. 90–91), however, pointed out that the tuff on the Pacific slope of the district to be traversed by the canal is younger than strata ("grès ligniteux") now referred to the Culebra formation, and Howe (1907, p. 117) came to the same conclusion.

Though the La Boca fossils and the Culebra fossils for the most part indicate somewhat different facies, they have essentially the same age significance: both have Oligocene and Miocene affinities. The La Boca member—and presumably the entire Panamá formation—is not much younger than the Culebra formation. Like the Culebra formation, it is considered early Miocene. The entire succession above the Las Cascadas agglomerate (Culebra, Cucaracha, and Panamá formations) is thought to represent the early half of early Miocene time; that is, the disputed Oligocene or Miocene. If the Panamá formation east of the Canal Zone does not include the equivalent of the Culebra formation, presumably there is a slight discontinuity between the Caimito and Panamá formations east of the Zone.

GATUN FORMATION

The two remaining Tertiary formations to be described are found in the Gatun Lake and Caribbean coastal districts. The older of the two is the Gatun formation, well-known for its rich fauna. In fact, the fossils of the Gatun formation attracted attention at an early date. When Blake traveled across Panamá in 1853 on his way to California to join one of the transcontinental railroad surveying parties, he collected a few Gatun fossils (Blake, 1857, p. 1). Two years later Newberry crossed Panamá on the same mission and also collected some Gatun fossils, but left no account of his observations. At about the same time another traveler briefly commented on fossils at Monkey Hill (now known as Mount Hope) but saw none at Gatun (Deck, 1855, p. 241). A search of books and magazine articles written by California-bound travelers during and after the gold rush doubtless would reveal other accounts.

The Gatun formation was named by Howe (1907, p. 113–114). In Spanish orthography the name is Gatún. That name, however, was not the earliest for the formation. Hill had already used the names Monkey Hill formation and Mindi Hill beds (1898, p. 176, 180). Howe, indeed, used both Gatun formation and Monkey Hill formation in a structure section in the publication in which he proposed his name (1907, pl. 147), and in a later publication used only Monkey Hill formation (1908, p. 228). MacDonald's usage apparently established preference for Howe's name (MacDonald, 1913, p. 530). The type area is the one described by Howe: from Gatun to Mount Hope (Monkey Hill of Howe's time). As a result of faulty paleontological information, Howe excluded the oldest strata near Gatun from the Gatun formation and grouped them with the Bohio formation (1907, p. 113). It is now known that the oldest outcropping part of the formation is not represented in the type region.

The outcrop area of the Gatun extends from María Chiquita, 20 kilometers northeast of Colón (pl. 1), to Río Miguel, 50 kilometers southwest of Colón (fig. 11), but much of that area has not yet been examined. The relations of the Gatun to the next older formation in the Gatun Lake and Caribbean coastal districts—the Caimito formation—are unknown. In the Canal Zone the contact between the two formations is covered by the waters of Gatun Lake and even before the flooding of the lake perhaps all of the contact was concealed by swamps. East and west of the Canal Zone, however, the Gatun presumably rests on the Caimito formation at outcrop localities, as shown on plate 1. So far as now known, no deposits of early Miocene age are included in the Caimito formation of the Gatun Lake area. The boundary between the two formations therefore is presumed to represent a discontinuity representing early Miocene time. Still farther east the Gatun formation overlaps the Caimito and directly overlies the Cretaceous(?) basement. At the west end of the outcrop area the upper part of the formation is interpreted as overlapping on the Caimito formation, not on the basement complex as previously surmised (Woodring and Thompson, 1949, p. 243).

The dip of the Gatun is low, between 5° and 10°, and flattens out northwestward toward the coast. Nevertheless a water well at Mount Hope penetrated a thickness of 425 meters of Gatun strata without reaching the base of formation (Thompson, 1947a, p. 20). The total thickness is estimated to be at least 500 meters and perhaps a considerable thickness is concealed by overlap.

STRATIGRAPHY AND LITHOLOGY

Massive medium- to very fine-grained sandstone and siltstone are the chief constituents of the Gatun formation. They are somewhat calcareous, or marly, somewhat tuffaceous, and have a clay-like matrix. The sandstone contains numerous grains of black and greenish volcanic rocks and is practically a subgraywacke, as indicated by Boutan's (1880, p. 13) early account, the only description of the microscopic petrology so far published. Conglomerate and hard brittle very fine-grained tuff make up a small part of the formation. Basalt intrudes older formations in the Gatun Lake area, but is not known to penetrate the Gatun.

The Gatun formation has been subdivided in various ways on faunal grounds (Woodring, 1928, p. 76–77; Olsson, 1942, p. 244–247; Thompson and Keen, 1946). The subdivisions adopted for the present report correspond to the three faunal zones proposed by Thompson and Keen. Though the subdivisions are based on faunal grounds, they are simply designated lower, middle, and upper parts, at least until the study of the fossils is completed. Both fossil collections and observations on the lithology, however, are scattered and eventually some other nomenclature may be found to be more satisfactory.

The lower part consists principally of medium- to very fine-grained sandstone. This part of the formation was unknown before the explorations of the Geological Section of the Special Engineering Division. In some exposures along the Transisthmian Highway and the road from the highway to María Chiquita, a basal conglomerate of variable thickness is present. It is most conspicuous along the Transisthmian Highway immediately south of Sabanita and is thin or absent along the road to María Chiquita. At locality 135 molds and impressions of marine mollusks were found in sandstone partings in the conglomerate: in the sandstone itself and in ferruginous concretions. At some localities along the road to María Chiquita, sandstone is at the base of the formation and at others, where the base itself is not exposed, carbonaceous siltstone or mudstone, containing molds of marine mollusks, is close to the base. Fine-grained sandstone is exposed in cuts on the Transisthmian Highway between Sabanita and Cativa. Much of the sandstone, as at localities 136–138, contains numerous well-preserved fossils.

The middle part includes the best known strata: those at and near Gatun, including the strata excavated for the Gatun Locks and the uncompleted Gatun Third Locks. The three members recognized by MacDonald (1913, p. 570) and the strata he described later (1919, p. 542–543) are in the middle part. Though sandstone is the chief constituent, the middle part includes conglomerate, siltstone, and tuff. When dry the tuff is almost white and forms conspicuous outcrops in excavations. It was designated fullers earth by MacDonald.

The following section, described in a report by the Geological Section of the Special Engineering Division (Thompson, 1943a, p. 10–19, figs. 5–13 to 5–22) and by Jones (1950, p. 916–917, table 3), is exposed in the Gatun Third Locks excavation east of Gatun. The numbering of the units is that used by Thompson and Jones.

Section of strata in middle part of Gatun formation as exposed in Gatun Third Locks excavation

[After Thompson and Jones]

	Meters
12. Sandstone and siltstone	
d. Massive very fine-grained silty sandstone; thin lenses of conglomerate (thickness a few cm) made up of pebbles of volcanic rocks. Contains leached shells and few carbonized plant remains	7. 9
c. Marly siltstone	3. 3
b. Clayey marly siltstone. Contains abundant well-preserved shells and some plant remains. Locality 155c	8. 4
a. Lens of medium- to very fine-grained silty and marly sandstone	0–1. 5
11. Massive medium- to very fine-grained, silty and marly sandstone. Contains abundant shells and fragments of carbonized wood. Shells arranged in layers and concentrated in pockets. Locality 155 represents units 11 and 12	7. 5–9. 1
10. Poorly sorted conglomerate, increasingly calcareous upward. Consists of pebbles of dense volcanic rocks (maximum length 10 cm) in matrix of medium-grained sandstone. Contains shells and bits of carbonized wood. Locality 154	3. 6
9. Coarse-grained tuffaceous sandstone, consisting principally of grains of dark-colored volcanic rocks, quartz, and pumice. Uppermost 60 cm conglomeratic; thin lenses of conglomerate throughout. Contains a few shells, mostly leached	7. 2
8. Sandy and silty tuff. Grain size decreasing downward and pumice more abundant downward. Contains a few leached shells	9. 1
7. Hard, brittle, massive, very fine-grained tuff, consisting chiefly of minute glass shards. Contains rounded pieces of pumice (maximum diameter generally 5 cm)	3. 6–6
6. Coarse-grained sandstone, upper part conglomeratic	1. 2
5. Massive medium- to fine-grained, poorly sorted, somewhat tuffaceous sandstone. Contains scattered basalt pebbles, leached shells, and bits of carbonized wood	11. 5
4. Medium- to very fine-grained tuffaceous sandstone, sandy tuff, and very fine-grained tuff in beds 15 to 90 cm thick. Increasingly fine-grained, tuffaceous, and pumiceous downward	33. 5
3. Massive, medium- to very fine-grained somewhat marly sandstone. Glass shards and pumice fairly common in lowest 3 meters, decreasing upward. Contains scattered shells, echinoid fragments, and fragmentary carbonized and calcified plant remains. Locality 153*a*	21. 3
2. Hard, brittle, massive, very fine-grained tuff	1. 8
1. Massive medium- to very fine-grained, silty to somewhat marly sandstone. Contains numerous shells, for most part more or less leached. Locality 153	31. 1
Thickness of section	151–156. 5

Units 1 to 4, inclusive, of the preceding section are shown in plate 10. The conglomerate forming unit 10 probably is the same bed as the conglomerate near Gatun described by Howe (1907, pp. 113–114; 1908, pp. 228–229). In his 1908 account Howe was tempted to select the conglomerate as the base of the Gatun formation (his Monkey Hill formation of that account), but his view was influenced by faulty paleontologic information. Unit 10 is stratigraphically not far from the base of the Gatun at Gatun Dam spillway as selected by Olsson (1942, p. 244–245). At all events his unconformity between the Gatun and Caimito formations, as he now realizes (personal communication), is a minor discontinuity in the middle part of the Gatun formation.

Sandy and marly siltstone seem to be the principal constituents of the upper part of the formation, at least in the Mindi (localities 171–173) and Mount Hope (localities 174–178) areas.

Both upper and middle parts are represented west of the canal. Farther south—that is, west of Gatun Lake—the upper part evidently is overlapped by the Chagres sandstone and its Toro limestone member. Collections of fossils west of the canal and west of Gatun Lake were made by A. A. Olsson during explorations for the Sinclair Central American Oil Corporation in 1918, but his map and report are no longer available. Some of the localities at which fossils were collected cannot be plotted on plate 1 and those that are plotted are located only approximately. Olsson's *Anomia* zone west of Gatun Lake is considered part of the Toro limestone member of the Chagres sandstone, not part of the Gatun formation (Olsson, 1942, p. 246–247).

No information is available concerning the Gatun formation between locality 170, west of Gatun Lake near Escobal, and the western end of the outcrop area, where the formation emerges on the coast, as shown in figure 3. Collections of fossils made by geologists of the Sinclair Central American Oil Corporation in 1918 indicate that only the upper part of the Gatun is represented in the far western coastal area. That

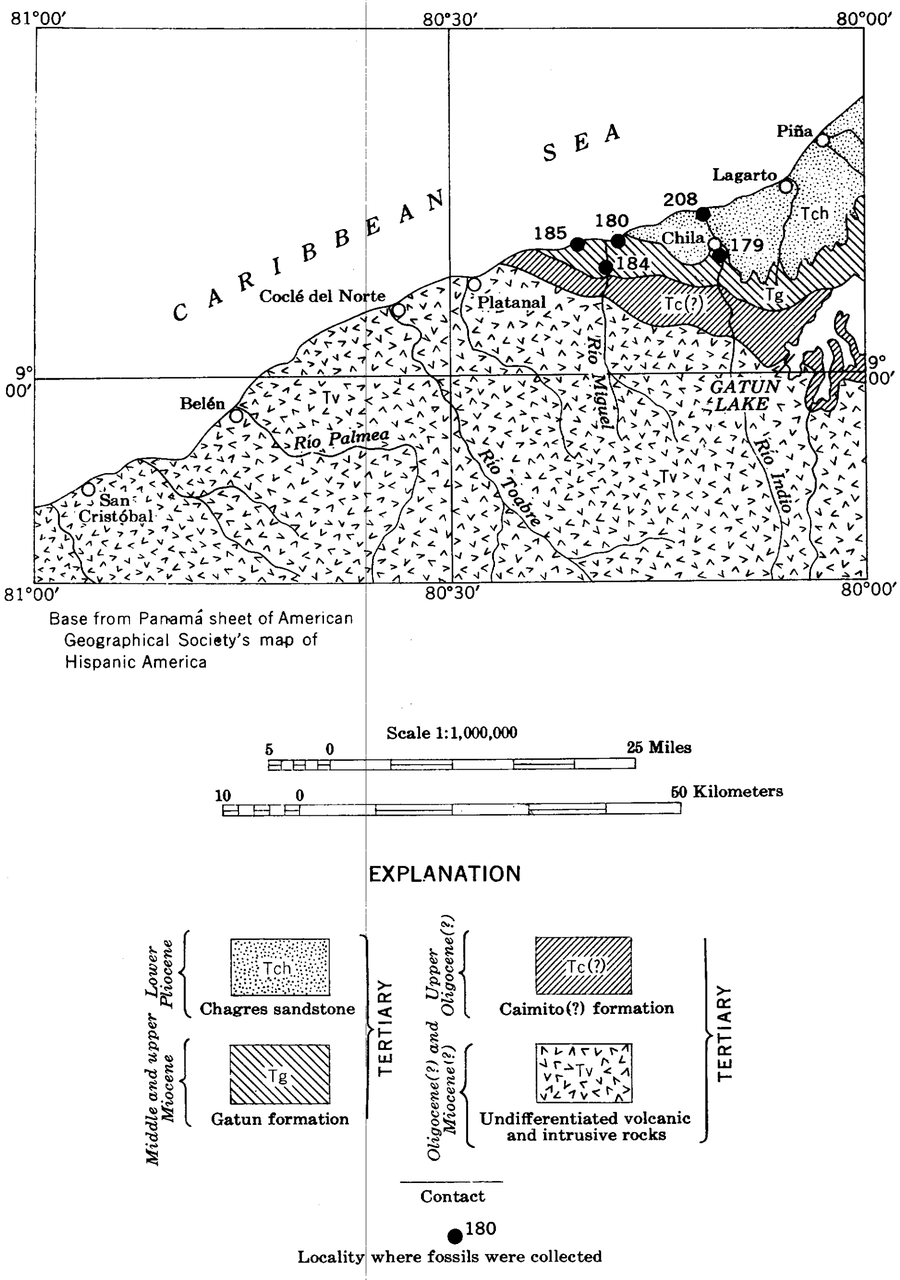


Figure 3.—Reconnaissance geologic map of Caribbean coastal part of Panamá immediately west of Canal Zone. Base from Panamá sheet of American Geographical Society's map of Hispanic America.

interpretation, however, and the areal geology shown on figure 3 need confirmation. The matrix of the fossils consists of silty very fine-grained sandstone and sandy siltstone.

FOSSILS AND AGE

Smaller Foraminifera.—Smaller Foraminifera from the Gatun formation were recorded by Cushman (1918). Marly siltstone in the upper part of the formation in the Canal Zone contains more species than those of Cushman's report.

Mollusks.—Mollusks are by far the most abundant and widespread fossils in the Gatun formation. The collections at the U. S. National Museum represent a collecting span of a century. In 1853 Blake collected three species described two years later by Conrad (1855, p. 18; 1857, p. 328, pl. 6, figs. 53–55). Only one of the fossils found by Blake is known to have survived: the type of *"Gratelupia?" mactropsis* [*Lirophora mactropsis*], a double-valve mold to which some inner shell material clings. Blake's form of locality citation is equivocal:

"At Gatun, or Monkey Hill?, where we stopped for a few moments, I obtained several fossil shells from the embankment at the side of the road" (Blake, 1857, p. 1). He evidently meant he was not certain whether the place where the train stopped was Gatun or Monkey Hill, although that uncertainty seems strange. Two of the three species he collected (*Lirophora mactropsis* and *Clementia dariena*) are not known to occur at Monkey Hill [Mount Hope], whereas they do occur at Gatun. The preservation and matrix of the type of *Lirophora mactropsis* strongly suggests unit 1 of the section on page 44. There is no reasonable doubt that Blake picked up his fossils at Gatun. According to the locality data in Conrad's description of Newberry's fossils, Newberry on his trip two years after Blake's also collected at Gatun (Conrad, 1857a, p. 72). Conrad recorded five species, but Gabb added eight others, including the only cephalopod to be found in the Gatun formation (Gabb, 1881). Some of Newberry's fossils have been found recently at the Academy of Natural Sciences of Philadelphia.

Other Gatun fossils of the same vintage were collected at Monkey Hill (Mount Hope of present terminology) in 1857 by J. Rowell. Some of Rowell's specimens have early Smithsonian Institution catalog numbers (6391–6395), which were entered in 1880 under the locality "Monkey Hill, near Gatun." Most of them, however, have National Museum catalog numbers entered in 1893 under the locality "near Gatun." One of the latter series of numbers has the notation "collected in 1857." It is assumed that "near Gatun" should read "Monkey Hill, near Gatun." According to Dall, Rev. J. Rowell was an old collaborator of the Smithsonian Institution and a pioneer of 1849 in California (Guppy and Dall, 1896, p. 307). Rowell also collected fossils in the Dominican Republic. Unfortunately some of his specimens, including the types of *Phos metuloides*, *Terebra bipartita spirifera*, and *Pecten scissuratus*, are alleged to be from the Dominican Republic, but evidently were collected at Mount Hope. On the contrary, a few labeled "near Gatun" apparently were collected in the Dominican Republic.

The bulk of the collections at the National Museum was gathered during the period 1911–13 by MacDonald and Vaughan. Notable later accessions resulted from the field work of Olsson and other geologists of the Sinclair Central American Oil Corporation in 1918. The most recent collections studied for the present report are Thompson's made in 1942–43 and my own resulting from the 1947 field work for the present report.

A total of 90 collections is being studied for the present report: 9 from the lower part of the formation, 58 from the middle part, and 23 from the upper part. On the basis of slight faunal differentiation, the collections from the middle part are divided into those from an eastern area (east of the canal, 43 collections) and those from a western area (west of the canal and west of Gatun Lake, 15 collections). On the basis of both faunal and age differentiation, an eastern area in the Canal Zone (15 collections) and a western area, comprising the western coastal district (8 collections), are recognized in the outcrop area of the upper part. As shown by the data in the description of localities (p. 125–129), many collections, particularly from the middle part of the formation in the eastern area, are duplicates or virtual duplicates. Three collections contain more than 100 species: those from localities 138a and 155 (both about 125 species), and locality 147b (about 110 species). The first two are among Thompson's collections from the lower and middle parts of the formation, respectively. The third, one of MacDonald and Vaughan's from the middle part, is especially rich in minute specimens, including 300 or more of *Teinostoma spermatia* and about 200 microscopic shell tips of *Turritella altilira*.

The scattered publications describing mollusks of the Gatun formation are listed on pages 5–10. The most important are those by Toula (1909, 1911), Brown and Pilsbry (1911, 1913), and Olsson (1922). Almost all the large species that occur in the middle part of the formation have been described, but most of the minute species in that part, and many of both large and minute species in the lower and upper parts are described for the first time in the present report.

The available molluscan fauna is estimated to total about 350 species. In chapter A of the present report 46 species and subspecies are described and 4 others, not represented in the collections at hand, are recorded. The species included in chapter A are tabulated on page 48. In that table "cf." in the locality columns indicates the presence of incomplete or poorly preserved material that may or may not represent the form listed opposite in the species column. Likewise the designation "sp." in the locality columns means an unidentified incomplete or poorly preserved species that may or may not be the same as that in the species column. The designation "?sp." in the locality columns indicates that the genus is questioned. The columns labeled "Other collections" list species or occurrences not represented in the collections at hand.

The table on page 48 includes two of the most characteristic species of the Gatun formation: *Turritella altilira* and *T. gatunensis*. It also includes species that have living relatives in the Pacific Ocean but not in the Caribbean Sea, and species that survived in the Pacific but not in the Caribbean Sea (*Trochita trochiformis*, *Neverita reclusiana*, and *N. helicoides*).

Echinoids.—*Clypeaster gatuni*, *Encope annectens*, *E. platytata*, *E. megatrema*, and *Schizaster panamensis* were described by Jackson (1917).

Ostracodes.—Strata in the lower part of the Gatun formation at Cativa, for which the name Cativa marl was casually used, yielded 18 species and varieties of ostracodes (Coryell and Fields, 1937).

Age.—Age assignment of the Gatun formation was off to a good start when Douvillé (1891, p. 497–498) wrote that strata at Monkey Hill, Mindi, and Gatun are Miocene, and a few years later ventured the opinion that the strata at Monkey Hill are perhaps of Helvetian age, whereas those on the upper Chagres [Alhajuela sandstone member of Caimito formation] seem to be of Burdigalian age (Douvillé, 1898, p. 592). Both age assignments are practically the same as those of the present time. Between publication of Douvillé's two reports, Dall beclouded the issue by maintaining that the strata at Gatun and Mindi are Eocene, and those at Monkey Hill Oligocene (Hill, 1898, p. 176, 180–181, 271–272, 273–274). As already outlined (Woodring and Thompson, 1949, p. 231), Dall was a victim of unfortunate circumstances so far as the Eocene part is concerned. One of Hill's collections was labelled Vamos Vamos, though there is no doubt it was collected from the Gatun formation near Gatun (locality 158), apparently from strata near the base of the middle part; that is, it was labelled as though it represents the late Eocene or early Oligocene marine member of the Bohio(?) formation. (See notations under localities 40 and 158 on p. 115, 127.) Nevertheless Dall certainly would have been suspicious had he arranged the collections according to Hill's field numbers, instead of arranging the real and alleged collections from Vamos Vamos biologically in one lot. The same mistake was made much later when an ill-advised early Miocene age was proposed for Hill's mixed fossils (Woodring, 1928, p. 76). All except a few of the alleged fossils from Vamos Vamos have Hill's field number 17 on the specimens, in the vials, or on the labels written by Dall. Two lots bear the field number 18 (a Vamos Vamos collection, locality 40a), but 17 is written on the labels. One lot of *Turritella altilira praecellens* (USNM 135160) has 18 on the label and nothing but the catalog number in the vial. Regardless of numbering, the fossils from the Gatun formation may readily be sorted out, not only because the rock matrix on microscopic examination is seen to be characteristic, but also because none of the species occurs at Vamos Vamos.

Dall's assignment of part of the Gatun formation to the Oligocene was the result of his conviction, first published in 1896 (Guppy and Dall, 1896, p. 303–304), that the Miocene of the Caribbean region (and all except the very latest of the Miocene in southeastern United States) really is upper Oligocene. Toula justly protested against an early Tertiary age for the Gatun formation, but went too far in the opposite direction in claiming that the Gatun (that is, the middle part of the formation) is of late Miocene or even Pliocene age (Toula, 1909, p. 737). For many years the Gatun formation has been considered middle Miocene. A discussion of the age would be premature until the numerous mollusks are identified. Preliminary examination suggests that in the Canal Zone the formation represents the entire span of middle Miocene time—essentially the equivalent of the Cercado and Gurabo formations of the Dominican Republic—and that the upper part in the western area, west of the Canal Zone, is late Miocene.

PLIOCENE SERIES

CHAGRES SANDSTONE, INCLUDING TORO LIMESTONE MEMBER

The youngest Tertiary marine formation, the Chagres sandstone, overlies and partly overlaps the Gatun formation. The outcrop area lies entirely west of the canal, extending from the Canal Zone southwestward along the Caribbean coast to a locality between Río Indio and Río Miguel, about 45 kilometers southwest of Colón (fig. 3). Much of the outcrop area, except in the Canal Zone and along the coast, still remains to be examined. Calcareous strata at the base of the formation throughout most of the outcrop area in the Canal Zone constitute the Toro limestone member.

The name Chagres sandstone was proposed by MacDonald for the sandstone forming the hills that overlook the coast from Toro Point to the mouth of Río Chagres (MacDonald, 1919, p. 532). The sandstone is so massive that estimates of thickness are uncertain. MacDonald's estimate of 1,000 feet (300 meters) or more may be excessive.

The Toro limestone member also was named by MacDonald, who designated it a separate formation (MacDonald, 1915, p. 26). Toro Point was specified as the type locality. Earlier MacDonald (1913, p. 570) used the informal name Caribbean limestone for this unit. The average thickness of the Toro is about 40 meters (Thompson, 1947a, p. 21).

STRATIGRAPHY AND LITHOLOGY

The Toro limestone member is a local basal calcareous deposit of variable thickness. It consists princi-

Mollusks from Gatun formation

[For explanation of symbols see p. 46]

	Localities																																
	Lower part									Middle part																							
										Eastern area																							
	135	136	136*a*	137	137*a*	138	138*a*	139	Other collections	140	141	142	144	144*a*	144*b*	146	147	147*a*	147*b*	147*c*	147*d*	147*e*	147*f*	147*g*	147*h*	147*i*	147*j*	150	150*a*	151	152	153	153*a*
"Margarites" sp																																	
Calliostoma (*Leiotrochus*) *eremum* Woodring, n. sp																						?sp											
Turbo (*Marmarostoma*) aff. *T. castaneus* Gmelin																																	
Tricolia? *syntoma* Woodring, n. sp																																	
Neritina (*Vitta?*) cf. *N. virginea* (Linné)																																	
Teinostoma (*Idioraphe*) *spermatia* Woodring, n. sp																×			×				×	×	×	?							×
angulatum trochalum Woodring, n. subsp			×	×			×																										
(*Aepystoma*) *andrium* Woodring, n. sp				×																						×							
(*Pseudorotella*) *pycnum* (Woodring)						×													×														
stemonium Woodring, n. sp							×																										
(*Diaerecallus*) *sychnum* Woodring, n. sp																			×														
Anticlimax (*Anticlimax*) *gatunensis* Pilsbry and Olsson						×	×																										
(*Subclimax*) *teleospira teleospira* Pilsbry and Olsson									×																								
hystata Woodring, n. subsp																																	
Cyclostremiscus (*Ponocyclus*) *pentagonus* (Gabb)						×	×									×			×				×	×	×								×
Solariorbis (*Solariorbis*) *strongylus* Woodring, n. sp						×	×																										
(*Hapalorbis*) *hyptius hyptius* Woodring, n. sp. and n. subsp							×									×			×				×										
anebus Woodring, n. subsp																																	
Episcynia megalia Woodring, n. sp						×																											
"Alvania" aff. *"A." epulata* (Pilsbry and Johnson)			×																														
Rissoina (*Phosinella*) *oncera* Woodring, n. sp																																	
Xenophora delecta (Guppy)																																	
Crepidula cf. *C. maculosa* Conrad				×		×													×														
plana Say					×	×	×																										
Calyptraea centralis (Conrad)				×		×	×																				cf.						
Trochita trochiformis (Born)		×	×																														
Crucibulum (*Crucibulum*) *chipolanum* Dall																																	
(*Dispotaea*) *springvaleense* Rutsch				×	×	×	×	×								×			×			×	?	×	×					×	×		
Cheilea princetonia Brown and Pilsbry																																	
Natica (*Natica?*) *bolus* Brown and Pilsbry						×						×	?						×					×									
(*Naticarius*) *canrena* (Linné)																																	
stenopa Woodring, n. sp		×		×	×	×	×									×			×					×	?					×			
Stigmaulax guppiana (Toula)				×	×	×	×					×				×	?		×				×	×	×				×	×		×	×
Tectonatica agna Woodring, n. sp																×			×				×	×	×					×			×
Polinices canalizonalis (Brown and Pilsbry)			×																														
brunneus subclausus (Sowerby)																																	
stanislas-meunieri Maury		×	×	×		×	×			×						?			?					?	?								
Neverita (*Glossaulax*) *reclusiana xena* Woodring n. subsp			×	×	×										?sp.																		
(*Hypterita*) *helicoides* (Gray)			×																														
Sinum gatunense (Toula)																																	
euryhedra Woodring, n. sp					×																												
gabbi (Brown and Pilsbry)																			×														
Turritella (*Torcula*) *altilira* Conrad, s. l								×												cf.		×									×		
altilira altilira Conrad					×		×				×	×				×			×				×	×	×				×	×		×	×
altilira praecellens Pilsbry and Brown			×	×		×	×						cf.																				
abrupta Spieker														×																			
matarucana Hodson	?	×	×	×	×		×							?																			
gatunensis gatunensis Conrad			×	×	×	×	×	sp.		×	×		×	?				×			×	×				×			×			×	
rhytodes Woodring, n. subsp																																	
mimetes Brown and Pilsbry											?																	×					
bifastigata Nelson				×	×																												

(Trochidae to Turritellidae)

[For explanation of symbols see p. 46]

Localities																																													
Middle part																										Upper part																			
Eastern area													Western area													Eastern area															Western area				
154	155	155a	155b	155c	156	157	158	159	159a	159b	160	Other collections	161	161a	161b	161c	161d	162	162a	165	166	168	169	170	170a	163	171	172	173	173a	174	175	176	176a	177	177a	177b	177c	177d	178	182	182a	183	184	185
				X																																									
	X			X																																									
			X																																										
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pally of lime-cemented coquina made up of small fragments of barnacles, shells, echinoid spines, and corals (pls. 11, 12). Barnacle fragments predominate at many localities and cross-bedding is common. Lenses of medium- to coarse-grained sandstone occur in the coquina. Descriptions of outcrops of the Toro have been published by MacDonald (1919, p. 544–545) and Olsson (1942, p. 246).

The Chagres sandstone proper is made up of massive generally fine-grained sandstone and some siltstone (pl. 13). Unlike the Gatun formation, the Chagres is not known to include conglomerate or tuff, and the sandstone itself contains less volcanic material than sandstone of the Gatun.

FOSSILS AND AGE

Mollusks.—A few molds of mollusks from Olsson's *Anomia* zone are included in the families covered by chapter A of the present report: *Calliostoma?* sp. and *Turritella gatunensis?* from locality 194; *Turritella altilira* s. l. from locality 195; *Turbo* aff. *T. castaneus*, *Turritella gatunensis?*, and *Turritella mimetes?* from locality 195. Olsson's *Anomia* zone (Olsson, 1942, p. 246–247) appears to be part of the shallow-water calcareous deposits forming the overlapping Toro limestone member of the Chagres sandstone rather than part of the Gatun formation.

A new species of *Calliostoma*, *C. metalium* (localities 206, 206a), an unidentified mold of *Crucibulum* (locality 201), and *Stigmaulax guppiana* (locality 208) occur in the Chagres sandstone proper. The mollusks of the Chagres sandstone proper, unlike those of the Toro limestone member, indicate deposition in water of moderate depth.

Echinoid.—A large species of *Clypeaster*, found in the Toro limestone member at locality 196 (Olsson's *Anomia* zone), is identified by C. W. Cooke as *C.* aff. *C. bowersi*. *C. bowersi* occurs in the Imperial formation of the Colorado Desert, of disputed Miocene or Pliocene age (probably late Miocene).

Age.—The Chagres sandstone is close to the border between Miocene and Pliocene; it has been assigned to both series. Preliminary examination of the mollusks suggests early Pliocene, despite the presence of a few Gatun species, such as *Stigmaulax guppiana*, and of other species that have Gatun affinities.

PLEISTOCENE SERIES

STRATIGRAPHY AND LITHOLOGY

Pleistocene marine deposits occur at altitudes of a few feet above sea level and in the seaward part of buried valleys are interbedded with swamp and stream deposits. Swamp and stream deposits filling buried valleys extend as far inland as Gamboa on the Caribbean side of the Canal Zone and as far as Miraflores Locks on the Pacific side (Thompson, 1947a, p. 22). Black organic muck is the most widely distributed type of deposit. In fact, the geologists of the Geological Section of the Special Engineering Division used the informal designations Atlantic muck and Pacific muck for the Pleistocene deposits (Thompson, 1947a, p. 22). According to Thompson's description, much of the black muck represents swamp deposits and is a mixture of silt, very fine-grained organic debris, and partly carbonized wood, stems, and leaves. Layers of marine fossils are found in black organic silt and calcareous mud containing plant matter. They were encountered at the north end of the excavation for the Gatun Locks and in ditches in swamps north and east of Mount Hope (Brown and Pilsbry, 1913, p. 493–494; MacDonald, 1919, p. 544). Brown and Pilsbry casually used the name Mount Hope formation, which they attributed to W. B. Scott, for Pleistocene strata near Mount Hope (Brown and Pilsbry, 1913a, p. 493).

FOSSILS AND AGE

Corals.—Corals in collections from localities near Mt. Hope have been listed by Brown and Pilsbry (1913a, p. 497) and Vaughan (1919b, p. 563). They evidently represent reef-flat species.

Mollusks.—A few new species of mollusks were described by Dall (1912, p. 1–6) and Brown and Pilsbry (1913a). Brown and Pilsbry listed the species in the two collections they studied. The few species in their collection from the north end of the Gatun Locks excavation indicate brackish water and the deposits themselves point to deposition in a swamp. The depositional environment of the large number of marine species in their collection from a locality near Mount Hope, and in MacDonald's collections from the same region, is uncertain on the basis of published data.

Contrary to Dall's statement (1912, p. 1), MacDonald's collections from the Caribbean side do not contain any species now living along the Pacific side.

The Pleistocene mollusks are not described in the systematic part of the present report.

Age.—With the exception of the new species of mollusks, the identified fossils from the Pleistocene marine deposits on the Caribbean side of the Canal Zone are known to be living in the Caribbean Sea. Dall, and Brown and Pilsbry realized that their new species may be found to be living when the fauna along the Caribbean coast of Panamá is better known. The Pleistocene deposits—at least the marine deposits—probably are of late Pleistocene age, but may be too old for radiocarbon dating.

CORRELATION OF TERTIARY FORMATIONS IN DIFFERENT AREAS

Correlation of the Tertiary formations in different areas and age assignments, as adopted in the present

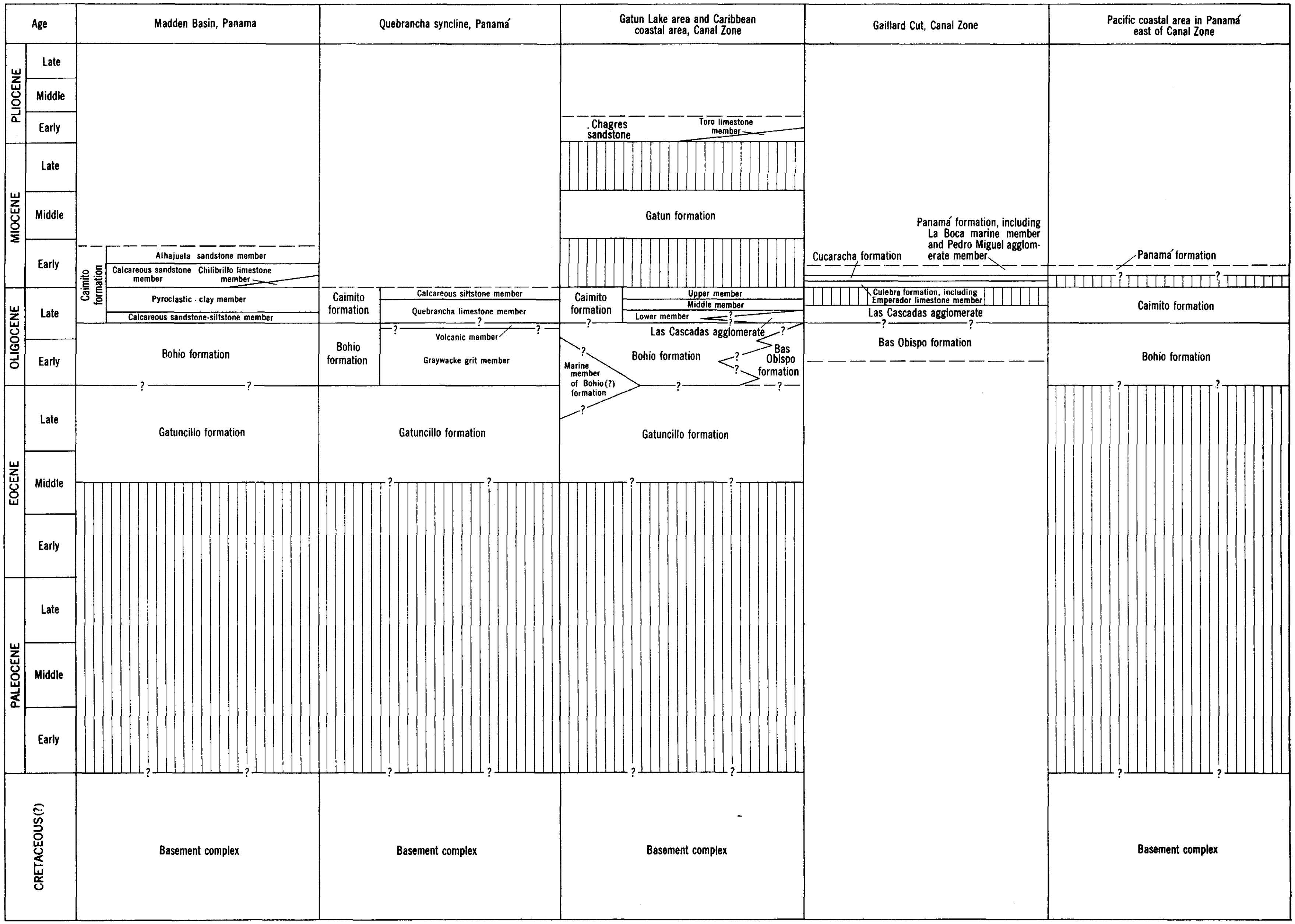

FIGURE 4.—Correlation of Tertiary formations in different areas.

Broken horizontal line indicates top or base of formation is not represented. Vertical ruling indicates hiatus.

report, are shown in figure 4. Some features cannot be shown properly in figure 4: the age assignment for the Bas Obispo formation and Las Cascadas agglomerate is Oligocene(?), despite the seemingly definite position on the chart; the age assignment for the marine member of the Bohio(?) formation of the Gatun Lake area is late Eocene or early Oligocene, not late Eocene and early Oligocene as the chart suggests.

The correlations differ only in some minor details from those of Woodring and Thompson in 1949 (fig. 2). The following changes have been made in age assignments: Gatuncillo formation, middle and late Eocene instead of late Eocene; Bohio formation of all five areas, early and late Oligocene instead of only early Oligocene (except in Pacific coastal area, which was not shown in the 1949 chart); Culebra formation, including Emperador limestone member, early Miocene instead of late Oligocene(?) and early Miocene; upper part of Gatun formation in western area (not shown in figure 4), late Miocene, instead of middle or late Miocene; Chagres sandstone, early Pliocene instead of late Miocene or early Pliocene. Though the Bas Obispo and Las Cascadas formations are still considered Oligocene(?), they are given a greater probable time range in the Oligocene.

Some of the proposed correlations are unsatisfactory. There is no satisfactory faunal or lithologic correlation between Madden basin and the Gaillard Cut area. On the contrary, at least parts of the Caimito formation of the Quebrancha syncline, the Gatun Lake area and the Pacific coastal area can be correlated with the lower part of the Caimito of Madden basin on fairly satisfactory faunal grounds. Plate 1 shows at a glance that Gaillard Cut and the Pacific part of the canal are close to the eastern border of a pile of volcanic rocks. Madden basin, the Quebrancha syncline, and the Gatun Lake area are farther seaward in the marine basin. The coarse pyroclastic rocks and flows of the Bas Obispo formation and Las Cascadas agglomerate, and the coarse pyroclastic rocks in the Panamá formation represent seaward extensions of volcanic rocks from the volcanic pile. In Madden basin and the Quebrancha syncline such rocks are much thinner and are found only in the volcanic member of the Bohio formation and the pyroclastic-clay member of the Caimito formation. Pyroclastic deposits in the Gatun Lake area are of much finer grain than in Gaillard Cut. Tuffaceous debris is present in the Tertiary formations of all the area, but is more dominant in the Gaillard Cut area and the Pacific part of the canal than in Madden basin, the Quebrancha syncline, or the Gatun Lake area. The Cucaracha formation, for example, consists almost entirely of altered volcanic ash.

The lack of studies of the pyroclastic rocks and the tuffaceous constituents of other rocks is the most serious deficiency in present knowledge of the geology of the Canal Zone and adjoining parts of Panamá. Such studies are likely to yield clues to correlations of the formations that may be more convincing than the faunal correlations.

IGNEOUS ROCKS

The following brief account of the igneous rocks is based principally on MacDonald's manuscript on the geology of Panamá mentioned on page 4. Much of the original manuscript, including some pages of the part dealing with the igneous rocks, is not preserved and his rock specimens and thin sections are no longer available. MacDonald's 1915 publication (p. 27–30) contains more data on the igneous rocks than his other publications.

The igneous rocks may be divided into two age groups: Cretaceous(?) and Tertiary. That classification embodies the chief addition to MacDonald's treatment.

CRETACEOUS(?) VOLCANIC AND INTRUSIVE ROCKS

Altered basaltic and andesitic lavas are the most common rocks in the basement complex, at least along the Transisthmian Highway and the pipe-line road in the eastern part of the Canal Zone. Two samples from the eastern part of the Canal Zone were examined by W. S. Burbank, who reports that the rocks are similar in texture and composition to the basalt-andesite rocks of the Southern Peninsula of Haiti (Woodring, Brown, and Burbank, 1924, p. 320–330). Chlorite, calcite, and a little epidote are the principal alteration products in the two samples.

Basalt containing unaltered olivine is exposed on Quebrada López (between Sabanita and Río Agua Clara) at the Transisthmian Highway bridge. According to R. H. Stewart, similar olivine-rich basalt crops out in an extensive area northeast of the highway.

Andesite at Porto Bello—the colonial settlement 35 kilometers northeast of Colón—is presumed to be part of the basement complex. As described by MacDonald, the rock is dark. Under the microscope it is markedly porphyritic and the phenocrysts are andesine, labradorite, bronzite, and some augite. The groundmass is largely glassy, but contains some minute crystals of plagioclase. This rock was used for concrete in the construction of Gatun Locks and great slabs were quarried for armoring the Limon Bay breakwaters.

The Cretaceous(?) lavas are intruded by dioritic rocks and dacitic porphyry. Though no debris from these intrusive rocks was noticed at the few localities where conglomerate of the Gatuncillo formation was observed, they probably antedate the Gatuncillo formation and probably are of late Cretaceous, Paleocene, or early Eocene age. Cobbles of granodiorite, found by MacDonald in the gravels of Río Chagres and in conglomerate of the Bohio formation, presumably represent a group related to the Cretaceous(?) dioritic rocks.

TERTIARY VOLCANIC AND INTRUSIVE ROCKS

Though Tertiary lavas are found east of the canal and are widespread west of the canal, most of the Tertiary igneous rocks described by MacDonald and selected by him for chemical analysis were obtained from intrusive bodies.

GRANULAR INTRUSIVE ROCKS

Quartz diorite.—Cocovi Island, a small island in Panamá Bay west of the entrance to the canal, was found by MacDonald to be made up of quartz diorite porphyry. The rock is light gray but weathers almost white. It is markedly porphyritic, the phenocrysts, up to 6 millimeters in diameter, consisting of andesine, andesine-labradorite, some quartz, and a little orthoclase. Some of the feldspars are partly saussuritized. The ferromagnesian minerals are highly altered and for the most part unidentifiable; a few outlines of hornblende crystals were recognized. Though the finely crystalline groundmass is somewhat cloudy and altered, it seems to consist of plagioclase and shreds of ferromagnesian minerals. Magnetite, apatite, and chlorite are found in the rock. A chemical analysis of the porphyry is included in the table on page 55 (analysis 1).

Augite quartz diorite forms Point Farfan, on the west side of the Pacific approach to the canal at the ferry terminus opposite La Boca. At Point Farfan, like on Cocovi Island, MacDonald obtained, by blasting, rock that proved to be considerably altered, although of fresh appearance. The quartz diorite at Point Farfan is gray and weathers light gray. In hand specimens it is slightly porphyritic and the groundmass is granular and almost medium grained. In thin sections andesine and somewhat altered augite are conspicuous. Quartz is present in small irregular masses, some of which appear to be secondary. Many small shreds of highly altered indeterminable ferromagnesian minerals were observed. Magnetite and apatite are accessory minerals and chlorite is the chief secondary mineral. The rock was analyzed and the results of the analysis are presented in the table on page 55 (analysis 2).

Dacite.—The rock forming the Ancon Hill stock (between Ancon and Balboa), as well as Naos Island and Culebra Island in Panamá Bay, was described as rhyolite by Howe (1908, p. 230–231) and MacDonald (1915, p. 28–29). In his manuscript MacDonald points out that although the rock has the appearance of rhyolite and some thin sections show as much quartz as shown by many rhyolites, the chemical analysis and additional microscopic examination show that it is dacite.

The dacite at Ancon Hill is light gray and weathers to a light creamy color. As described by MacDonald, it has a fine-grained texture and some lathlike phenocrysts of plagioclase, the largest of which have faces measuring about 1 by 5 millimeters. In thin section the rock shows flow structure, particularly around the phenocrysts, which consist principally of andesine and some albite. Quartz in irregular grains, some augite, and a few small greatly altered needles of hornblende are present. The phenocrysts are widely scattered and grade in size into the coarser particles of the groundmass. Though the groundmass is somewhat cloudy and altered, it consists principally of perthitic aggregates of orthoclase and plagioclase and some quartz and feldspar intergrowths. Accessory minerals, in order of decreasing abundance, are magnetite, ilmenite, and apatite. A considerable amount of chlorite is present and scattered patches of an unidentified light yellowish secondary mineral show in the groundmass. (See analysis 3, p. 55.) W. S. Burbank suggests that MacDonald's description and the chemical analysis indicate that the rock is considerably altered, principally by processes allied to albitization. During the construction of the canal a quarry on the west face of Ancon Hill, at a locality now known as Quarry Heights, furnished great quantities of this dacite for use in concrete in the construction of Miraflores and Pedro Miguel Locks.

The stocks of porphyry between the canal and Madden basin, northeast of Gaillard Cut, include dacite porphyry, according to geologists of the Geological Section of the Special Engineering Division. The porphyry intruding the Gatuncillo formation in the Río Casaya area (locality 38), for example, is dacite porphyry. The borders of this stock and the intruded rocks are slightly mineralized and some mining operations were carried on many years ago, as described on p. 59. MacDonald thought some of the rock in this area probably is granodiorite, but he found nothing suitable for microscopic examination.

Diorite.—A minor facies of the quartz diorite at Point Farfan is described by MacDonald as quartz-bearing gabbro. W. S. Burbank, however, points out that MacDonald's description of the mineralogical composition and the chemical analysis indicate a classification near diorite. The rock is dark gray, medium-grained, and equigranular. The principal minerals, arranged in approximate order of relative abundance, are andesine, augite, and oligoclase. Quartz in small irregular patches is a minor constituent, which W. S. Burbank suggests may be secondary. Accessory magnetite, apatite, and ilmenite are present. Chlorite is found in the rock and some of the feldspars show slight saussuritization. W. S. Burbank points out that the soda content of the analysis of this rock on page 55 (analysis 4) is slightly high for normal diorite and suggests that the alteration recorded by MacDonald may indicate weak albitization.

Andesite.—Andesite porphyry forms some of the stocks in the area between the canal and Madden basin. A small stock of hornblende andesite, characterized by conspicuous needles of hornblende, is being quarried along the road between Miraflores Lake and the Transisthmian Highway.

DIKE ROCKS

Andesite.—Andesitic dike rocks that cut the Las Cascadas agglomerate are mentioned by MacDonald.

Basalt.—Dikes and small irregular intrusive bodies of almost black rocks, all grouped as basalt, are widely distributed southwestward from the southeastern part of the Gatun Lake area and the southern part of Madden basin. The irregular intrusive bodies form hills; in fact, most of the high hills in the southeastern part of the Canal Zone are formed by intrusive or extrusive basalt.

Basalt obtained from dikes at 10 localities, for the most part in Gaillard Cut, was examined by MacDonald. These rocks are very dark and fine-grained. Labradorite, andesine, and augite are the principal constituents among the larger crystals. Some of the rocks also contain enstatite and a little biotite. The groundmass is made up of laths of plagioclase and grains of augite, but generally includes a little glassy material. Magnetite and ilmenite are the chief accessory minerals. Some chlorite and a few patches of serpentine—possibly an alteration product of olivine—are present.

Basalt from a dike on the Panama Railroad 3 kilometers northwest of Monte Lirio was selected for chemical analysis. (See table, p. 55, analysis 5.) As described by MacDonald, the rock is of coarser texture than the usual basalt in the Canal Zone and its feldspars are more calcic. Hand specimens show crystal faces of pyroxene that shine with a resinous luster and have a maximum diameter of 4 millimeters. Under the microscope the largest phenocrysts are seen to be augite. The feldspar crystals, slightly in excess of the ferromagnesian minerals, are for the most part labradorite and some of them are zoned. A little andesine is present. Augite occurs in granular aggregates as well as in phenocrysts. Magnetite, apatite, some ilmenite, and a few small grains of zircon are present. Secondary minerals consist of numerous patches of iron oxide(?), some serpentine that may be an alteration product of olivine, and a few small patches of chlorite. Some of the feldspar crystals are partly saussuritized and in zoned crystals the alteration is zonally selective. This rock was quarried for use in facing the water-level part of Gatun Dam.

VOLCANIC ROCKS AND TUFF

Dacite.—Dacitic glassy lava from the Las Cascadas agglomerate is included in the rocks selected for chemical analysis (see analysis 6, p. 55). According to MacDonald's description, the glassy lava forms the matrix of thin flow breccia. The brecciated fragments enclosed in the glassy matrix consist chiefly of pyroclastic rocks of the Las Cascadas. Some of the glassy lava contains elongated gas cavities drawn out in the direction of flow.

The hard dacitic tuff in the Cucaracha formation, mentioned in the description of that formation, was also analyzed (analysis 7, p. 55). Thin sections of the tuff were examined by W. S. Burbank and R. L. Smith, who found it to be a welded tuff. The glassy base consists of compressed glass shards, for the most part partly or entirely altered to clay. Some of the plagioclase (andesine-labradorite) crystals are euhedral; others are fragmental. Decomposition products of a few unidentifiable ferromagnesian minerals are recognizable and the rock has a few veinlets of calcite. Fragments of finely crystalline lavas of varying composition are scattered through the tuff. The dark little lentils, conspicuous in hand specimens, consist of saponite (a clay mineral of the montmorillonite group), evidently an alteration product of compressed pumice lapillae.

Andesite.—MacDonald mentioned andesitic flow breccias and dark coarse-grained andesitic flows in the Las Cascadas agglomerate.

Basalt.—Some of the basalt in the southern part of the Canal Zone consists of remnants of flows and the undifferentiated volcanic rocks in the southwestern part of the map area include much basaltic lava.

A flow remnant capping Gold Hill, which forms the continental divide on the east side of Gaillard Cut, is described by MacDonald as dark fine-grained basalt. The larger crystals consist of feldspar, mostly labradorite, and augite. Augite also occurs as grains and irregular aggregates. The groundmass is distinctly crystalline, though very fine-grained. It has about the same composition as the larger crystals. Small grains and irregular aggregates of magnetite, some apatite, and a little ilmenite are scattered through the rock. Epidote in light and dark yellow irregular patches fills cracks in broken feldspars and occurs as cloudy masses in the interior of some feldspar crystals. The thin sections show no olivine, but a light yellow secondary mineral may represent altered remnants of olivine. A chemical analysis (No. 8) of this rock is included in the table on page 55.

CHEMICAL COMPOSITION

The chemical analyses of some of the rocks described in the preceding paragraphs are included in MacDonald's manuscript. As noted in the explanatory matter following the table of analyses, they have already been published in the Geological Survey's Bulletin 591. Missing pages of the manuscript may contain descriptions of the "andesitic rock near Empire" and the "lava near Las Cascadas", analyses of which were published in Bulletin 591. The norms of the analyzed rocks were calculated by MacDonald.

Some abnormalities in mineralogical composition resulting from various degrees of albitization probably account for the high soda and low lime content of some of the rocks, particularly the dacites (analyses 3, 6). The low potash content is typical of many similar rocks in the Caribbean region.

Analyses of igneous rocks and tuff from Canal Zone

[Analysts: 1, 2, 6, 7, R. C. Wells; 3, 8, George Steiger; 4, 5, W. C. Wheeler]

	Granular intrusive rocks				Dike rock	Volcanic rocks and tuff		
	[1]1	[2]2	3	4	5	6	7	8
SiO_2	63. 51	57. 39	69. 20	51. 72	48. 23	62. 23	65. 17	51. 04
Al_2O_3	18. 07	15. 84	15. 00	15. 38	14. 69	14. 95	15. 22	17. 34
Fe_2O_3	2. 01	2. 38	1. 57	3. 35	4. 49	2. 04	2. 08	2. 88
FeO	2. 18	5. 96	1. 83	7. 91	5. 85	1. 52	3. 98	7. 33
MgO	2. 19	2. 41	. 69	4. 38	6. 73	. 75	1. 19	5. 50
CaO	5. 14	5. 24	1. 88	7. 84	12. 12	3. 10	3. 79	9. 79
Na_2O	4. 08	5. 23	5. 87	4. 37	2. 55	5. 08	3. 71	2. 88
K_2O	. 88	. 84	1. 81	. 47	1. 49	1. 26	1. 52	. 53
H_2O-	1. 07	1. 09	. 90	. 56	1. 50	8. 94	2. 57	. 96
H_2O+	. 60	1. 74	. 67	2. 00	. 98			. 72
TiO_2	. 33	1. 35	. 52	1. 67	1. 00	. 59	. 96	1. 32
CO_2	None	Trace	None	None	Trace	Trace	. 32	None
P_2O_5	. 19	. 68	. 10	. 49	. 46	. 04		. 25
SO_3				. 03	. 05			
Cl	. 01	. 05		. 12	. 09			
S	. 01	. 01						
Cr_2O_3				None	. 06			
MnO	. 06	. 18	. 15	. 16	. 17		. 06	. 13
BaO	. 03	. 02						
Total	100. 36	100. 41	100. 19	100. 45	100. 46	100. 50	100. 57	100. 67

[1] Shows a trace of V_2O_3. [2] Shows traces of ZrO_2, F, and V_2O_3.

1. Quartz diorite porphyry, Cocoví Island, Panamá Bay. Clarke, F. W., Analyses of rocks and minerals from the laboratory of the U. S. Geol. Survey: U. S. Geol. Survey Bull. 591, p. 214, 1915, analysis O.
2. Augite quartz diorite, Point Farfan. Bull. 591, p. 214, analysis N.
3. Dacatie, Ancon Hill. Bull. 591, p. 213, analysis A.
4. Diorite, Point Farfan. Bull. 591, p. 214, analysis P.
5. Basalt, Panama Railroad, 3 km northwest of Monte Lirio. Bull. 591, p. 214, analysis Q.
6. Dacitic glassy lava in Las Cascadas agglomerate, Gaillard Cut. Bull. 591, p. 213, analysis E.
7. Dacitic tuff in Cucaracha formation, Gaillard Cut. Bull. 591, p. 213, analysis B.
8. Basalt capping Gold Hill, Gaillard Cut. Bull. 591, p. 213, analysis G.

Norms

[Cross—Iddings—Pirsson—Washington classification]

	1	2	3	4	5	6	8
Quartz	22.26	8.22	22.74	2.40		20.16	3.06
Orthoclase	5.00	5.00	10.56	2.78	8.34	7.78	2.78
Albite	34.58	44.01	49.25	35.63	20.96	42.97	24.10
Anorthite	24.74	20.01	9.45	21.68	24.74	14.18	33.08
Corundum	1.22						
Diopside		.81		11.19	26.26	.99	11.12
Hypersthene	6.06	12.63	3.15	14.63	3.09	1.63	17.40
Olivine					4.75		
Magnetite	2.78	3.48	2.32	4.87	6.50	3.02	4.17
Ilmenite	.60	2.58	.91	3.19	1.82	1.22	2.43
Apatite	.31	1.55	1.57	1.24	.93		.62

Symbols: (1) I.4.3.5, amadorose; (2) II.5.3.5, beerbachose; (3) I.4.2.4, lassenose; (4) II.5.3.5, beerbachose; (5) III.5.3.4, camptonose; (6) I.4.3.4, yellowstonose; (8) II.5.4.4–5, hessose.

AGE

The Bobio formation of the Quebrancha syncline, which is of Oligocene age, includes a thin flow of basalt. Flow breccias and minor flows are found in the Oligocene(?) Bas Obispo formation and Las Cascadas agglomerate. Coarse-grained fragmental volcanic rocks, in the form of agglomerates, make up the bulk of the Bas Obispo formation and Las Cascadas agglomerate and occur in other formations of Oligocene and early Miocene age, particularly the Caimito formation of the Gatun Lake area (Oligocene), the Oligocene part of the Caimito formation of Madden basin, and the Panamá formation (early Miocene). Altered tuff is the chief constituent of the early Miocene Cucaracha formation, which underlies the Panamá formation. The Gatuncillo formation (middle and late Eocene) and Chagres sandstone (early Pliocene) contain very little tuffaceous material, and tuff in the middle Miocene Gatun formation is very fine-grained.

The distribution outlined in the preceding paragraph indicates that the well-dated Tertiary volcanic rocks, including the fragmental volcanics derived from a nearby source, are of Oligocene and early Miocene age. The volcanic centers presumably were in the area of undifferentiated volcanic rocks in the southwestern part of the area covered by plate 1 or farther west. Many remnants of basaltic flows in the southeastern part of the Canal Zone which are not dated, except insofar as they lie on rocks of Oligocene or early Miocene age, probably are of the same age as the better dated volcanic rocks. The fine-grained tuffaceous material in formations of earlier and younger age than Oligocene and early Miocene evidently was erupted at distant localities, probably west of the map area, where a thick succession of volcanic rocks is known to be present. The thick succession of that area doubtless includes flows and intrusives younger than those of the map area.

The intrusive Tertiary rocks are intruded into formations ranging in age from middle and late Eocene to early Miocene. In the Gatun Lake area the Oligocene Caimito formation is intruded by basalt, but no intrusive rocks have been found in the next younger formation—the middle Miocene Gatun formation—or in the still younger Chagres sandstone. In the Gaillard Cut area and still farther southeast, the formations of early Miocene age (Culebra, Cucaracha, and Panamá formations) are widely intruded by dikes, sills, and stocks. In that area, however, no Tertiary deposits younger than those just mentioned are recognized and they represent the early half of the early Miocene. If the upper limit of intrusive activity in the Gatun Lake area is applicable in the Gaillard Cut area and farther southeast, none of the intrusive rocks is younger than early Miocene. Some of them, however, may be older. The intrusive rocks, like the volcanic rocks, probably represent the period of time from Oligocene to early Miocene.

The youngest intrusive rocks include the basalt forming dikes that extend around small hills of agglomerate in the Gaillard Cut area (Thompson, 1947a, p. 27; 1952). The agglomerate, which represents part of the Pedro Miguel agglomerate member of the Panamá formation, is faulted into the underlying Cucaracha formation along a more or less circular minor fault dipping steeply toward the agglomerate. Movement along the fault may have resulted principally from plastic deformation of the bentonitic clay of the Cucaracha formation. The basalt dike is intruded along the fault. Drilling through the agglomerate, however, shows that some of the dikes are cup-shaped rather than ring-shaped (Thompson, 1952).

STRUCTURE

STRUCTURAL HISTORY

Late Cretaceous or early Tertiary deformation.—The strongest deformation in the known geologic history of the Canal Zone and adjoining parts of Panamá took place after eruption of the Cretaceous(?) lavas and deposition of the interbedded sedimentary rocks and before the laying down of the basal part of the Gatuncillo formation in middle Eocene time. At the present time this deformation is poorly dated and the structural pattern it produced will not be known until the basement rocks are studied and mapped. Almost vertical altered tuffs on the Transisthmian Highway between Río Gatun and Río Agua Sucia strike northward. The basement rocks elsewhere in the eastern part of the Canal Zone and nearby show a north-south grain (Jones, 1950, pl. 2). The intrusion of the dioritic and dacitic rocks that metamorphosed the lavas and tuffs probably accompanied the deformation.

Movements during late Eocene(?) to early Miocene time.—Minor and local movements during middle Tertiary time are indicated by coarse detritus and overlaps. The earliest of these movements, late Eocene or early Oligocene, is suggested by the coarse detritus of the Bohio formation and the overlap of the Bohio on the basement complex in the Pacific coastal area east of the Canal Zone. The source of the coarse detritus may have been beyond the limits of the region covered by plate 1, both to the southwest and northeast.

Minor movement during the middle or late Oligocene is indicated by overlap of the Caimito formation on the Gatuncillo formation in the northern part of Madden basin and by the presumed overlap of the Caimito on the basement northeast of Gatun Lake. Overlap of the Culebra formation on the Las Cascadas agglomerate points to late Oligocene movement.

The overlap of the La Boca marine member of the Panamá formation on the Bas Obispo formation suggests comparable minor movement during early Miocene time.

Miocene or Pliocene deformation.—Regional deformation, the second period of regional deformation now recognized, took place during Miocene or Pliocene time. The present structural features of the central Panamá area were then formed. The dating is uncertain not only because basic data are still incomplete, but also because the Gatun formation and the Chagres sandstone do not have an extensive distribution. The Gatun formation, which is of middle Miocene age in the region covered by plate 1, is not known to overlie early Miocene deposits at outcrop localities anywhere in the central Panamá area. The structural relations between the Gatun formation and the Caimito formation—the next older formation in the Gatun Lake and Caribbean coastal areas—are at present unknown. The overlap of the Gatun on the basement, however, indicates at least minor movement presumably at the end of early Miocene time and the regional deformation probably took place at that time. The Gatun formation and also the early Pliocene Chagres sandstone dip gently seaward in the relatively narrow coastal strip where those formations are preserved. The distribution of the Caimito formation and the marine member of the Bohio(?) formation in the western part of the Gatun Lake area indicates a pronounced unconformity between the Gatun and those older formations or that the Gatun is separated from them by a fault. A fault is suggested on plate 1. Minor movement, evidently of late Miocene age, is indicated by the partial overlap of the Chagres sandstone on the Gatun formation. The regional deformation may have taken place in middle or late Pliocene time after deposition of the Chagres sandstone, but that appears to be unlikely.

How far southward the Chagres sandstone and Gatun formation extended is not known. The Chagres sandstone, however, apparently did not extend far. The Toro limestone member, at the base of the Chagres in the northeastern part of its outcrop area, and the *Anomia*-bearing strata at the base farther southwest are shallow-water deposits. The conglomerate and other deposits at the base of the Gatun formation between Sabanitas and María Chiquita also represent a shallow-water facies. That area, however, is at the east end of the basin. To the southwest, in the Gatun Lake area, the Gatun may have extended considerably beyond its present inland border. The base of the formation east of Zorra Island, however, has not yet been examined and farther southwest the inland border of the formation is under Gatun Lake, and was concealed by extensive swamps before the flooding of the lake. In the area where the inland border of the Gatun is concealed, the middle part of the formation may overlap the lower part, just as farther west, in the region covered by figure 3, the upper part seems to overlap both lower and middle parts. If the formation extended far beyond its present inland border, the submerged area probably passed through Madden basin. Fossils characteristic of the Gatun formation are supposed to have been dredged in Panamá Bay off La Boca during the construction of the canal (Li, 1930). Pilsbry, (1931, p. 427–428), who examined the types and figured specimens described by Li, found that the few Miocene fossils, among the Recent species actually dredged in Panamá Bay, are indeed characteristic of the Gatun.

One of them, however, is labeled "Gatun Locks and Spillway" and all have a matrix typical of the Gatun formation at and near Gatun. The record of Gatun fossils in Panamá Bay is spurious.

STRUCTURAL FEATURES

During the period when geological work was practically limited to a narrow strip along the canal, the canal appeared to cross a major anticlinal crest which is located immediately southeast of Gamboa, about halfway across the isthmus, and is essentially parallel to the trend of the isthmus. When two sets of volcanic rocks (Cretaceous(?) and Oligocene to early Miocene) were differentiated, however, it was evident that the anticlinal crest along the canal is a minor feature in a belt of Tertiary rocks extending obliquely across the isthmus.

Plate 1 shows a marked contrast between the Gaillard Cut area and the region to the north and east. Though the numerous minor faults and folds of the Gaillard Cut area reflect the detailed work that has been carried out there, its location with reference to the trough of the Tertiary marine basin may have a bearing on its structural features. The Gaillard Cut area is in the transition zone between a volcanic sequence and a marine sequence, and the cover of sedimentary strata in the transition zone is thin.

The largest well-defined folds—Madden basin and Quebrancha syncline—lie east of the Canal Zone in the trough of the Tertiary marine basin. Madden basin has the greater structural relief. It is the only area where late early Miocene marine deposits have been found and they are almost exactly at the middle of the isthmus. Madden basin is a broad gentle fold trending north-northeastward. Toward the south it flares out in an area where the geology is not well known. As shown by Reeves and Ross (1930, pl. 6), a narrow belt of relatively steeply dipping rocks (20° to 45°) extends northward from Río Chagres on the west side of the basin. The floor of the basin may be irregular through overlap of the Bohio formation by the Caimito formation.

Quebrancha syncline also trends north-northeastward, but is more sharply folded than Madden basin. The southward-plunging anticline between Quebrancha syncline and Madden basin is greatly modified by the Limón fault.

The northeastward trending anticline in Bohio Peninsula, in the Canal Zone, appears to be well defined. The interpretation that it extends farther southwestward, and there reaches its greatest structural relief, is adopted to account for the upper Eocene or lower Oligocene strata of the marine member of the Bohio(?) formation in the northern part of the peninsula ending in Palenquilla Point and on Trinidad Island. Evidence for a major eastward-trending fault, just north of Trinidad Island and just south of the Brujas Islands, is presented on page 61.

So far as known the faults are steeply dipping normal faults and many of them probably have strike-slip displacement (Jones, 1950, p. 906). Most of the major faults have a general northward trend, but the trend of that group of faults ranges from about N. 30° W. to about N. 30° E. A few major faults, such as the Río Gatún fault and a fault along the lower course of Río Fríjol northwest of Gamboa, trend more to the east, about N. 70° E. The Chinilla fault, one of the group of major faults having a general northward trend, lies close to the Panama Railroad south of the embayment of Gatun Lake formed by Río Agua Salud and Río Frijolito. When MacDonald and Vaughan examined the fresh cuts and collected fossils from the Caimito formation along the railroad in 1911, they had no way of knowing that strata older than any along the canal or railroad (strata of the Gatuncillo formation) crop out only 200 meters east of the railroad.

Jones' geologic map of the Gatun Lake area (1950, pl. 2) shows many faults and fractures not shown on plate 1 of the present report.

The structure of the volcanic rocks west of Gaillard Cut is practically unknown. Detailed field work east of the Gaillard Cut area should show whether there is any correlation between the thin sedimentary cover and the structure of the Gaillard Cut area. Two characteristic formations of the thin sedimentary cover do not extend far east; the Culebra and Cucaracha formations. The distribution of those two formations in the complexly faulted Gaillard Cut area determined the course of the canal. Both are readily eroded and form topographic basins between irregularly arranged hills of basalt and agglomerate.

MINERAL RESOURCES

METALLIC MINERAL DEPOSITS

Gold.—Gold ore has been mined in two districts: in the basement rocks southeast of Sabanita and at a stock of dacite porphyry southeast of Gamboa.

I am indebted to R. H. Stewart for guiding me to the area southeast of Sabanita. Evidence of three periods of mining activity may be seen along streams immediately north and northeast of Cerro Santa Rita (at the summit of which is located the 268-meter triangulation station plotted on plate 1): remnants of large stone mortars pointing to aboriginal operations; caved and also almost imperceptible adits associated with a French boiler still standing upright; and modern adits. The aboriginal operations suggest the origin of the name for Bahía de las Minas, the bay into which the streams drain. When Mr. Stewart first visited this region in 1947, the boiler fire-box door (now missing) bore the name of a French manufacturer and the date 1883. The country rock is olivine-rich basalt, a typical exposure of which is readily accessible at the Transisthmian Highway bridge across Quebrada López, a small stream 1¼ kilometers in a direct line northwest of the junction with the road to Nueva Providencia. The ore occurs in sulphide-bearing small quartz veins. No data are available on the mineralogy and tenor of the ore or on the tonnage that has been mined.

Gold-mining operations at a stock of dacite porphyry southeast of Gamboa were carried on near the head of Quebrada de Oro, a small northwestward-flowing tributary of Río Casaya. Locality 38 is located on Quebrada de Oro downstream from the adits (pl. 1). Remnants of mine and mill machinery and stretches of tram track are strewn along the stream. Mr. Adrian Bouche, of Pedro Miguel, the present owner of the property, orally reported that an English Company installed the mine and mill in the late 1870's or early 1880's, but that there is no evidence any gold was produced. The adits are located in a narrow aureole of mildly contact-metamorphosed sedimentary rocks of the Gatuncillo formation at the border of the porphyry stock. No attempt was made to enter the caved adits.

Other adits and pits are located in the same stock of dacite porphyry, across the divide and 700 meters south of locality 38, near the head of a tributary of Río Sardanilla, which flows southward and westward toward the Panama Canal. Boutan (1880, p. 31–32) mentioned a road built to haul machinery to a gold mine on Río Sardanilla. The last French map, in the report of a Commission of the second French canal company that includes an account of the geology by Bertrand and Zürcher (1899), shows near Río Sardanilla a "mine de quartz aurifère en exploitation."

In his unpublished manuscript, written about 1918 and mentioned on page 4 of the introduction of the present report, MacDonald reported that none of some 40 samples from the most promising veinlets, "about 2½ miles east of the canal opposite Las Cascadas," showed gold values of more than $1.00 to the ton. That statement evidently refers to the Quebrada de Oro area. He also reported on samples collected "a mile more or less in a southeasterly direction from these [those of preceding two sentences] old workings"; that is, in the Río Sardanilla area. The gold value of his samples is as follows:

Gold value (as of about 1912) of samples collected in Río Sardanilla area

[Extracted from manuscript by D. F. MacDonald]

Sample	*Value of gold per ton*
Float from quartz vein	$6.80
End of open cut	1.04
Open cut	.41
Outcrop, top of ridge	.20
Lower part of cut	Trace

Manganese.—Plate 1 was extended far enough to the north to show the location of the southern of two manganese prospects near Río Boquerón. An abandoned tram line extends from the prospects to the coast near Nombre de Diós. The country rock consists of strongly deformed, low-grade metamorphic rocks—quartzite, siliceous limestone, micaceous schist (probably metamorphosed tuff), and greenstone (highly altered alglomerate)—all representing the Cretaceous(?) basement complex. The ore deposits are manganese oxides associated with red jasper. Boulder-like masses of ore form great trains down the slopes and streams. These deposits were described briefly by Sears (1919) and are described in greater detail by Simons in a recent publication (Roberts, R. J., and Irving, E. M., 1957, p. 119–128), from which the preceding sentences were abstracted.

In the publication just cited Simons mentions a minor manganese prospect in Madden basin, south of Río Chilibrillo and about 2 kilometers south of Casa Larga. According to a written communication from T. F. Thompson, shallow pits and trenches scattered over an area of about a hectare show aggregations of manganiferous concretions and lenses in the Bohio formation.

NONMETALLIC MINERAL DEPOSITS

Limestone for cement.—Limestone in the Quebrancha limestone member of the Caimito formation is at present the most important nonmetallic mineral deposit. The limestone is quarried by the Cía. Cemento Panamá, S.A., immediately east of the Transisthmian Highway on the east limb of the Quebrancha syncline (locality 62, pl. 1) and is processed as an ingredient for cement in the company's adjoining plant. The thickness and properties of three grades of limestone and one of calcareous siltstone are described in Thompson's (1944) detailed report. The reserves are enormous.

Other limestones in the Caimito formation of Madden basin and the Gatun Lake area, the Emperador limestone member of the Culebra formation, and at the base of the La Boca marine member of the Panamá formation may be suitable for cement. According to an oral communication from Thompson, the widespread limestones of the Gatuncillo formation are too high in magnesia.

Rock for construction.—MacDonald (1915, p. 35–38) adequately covered construction material used in the building of the canal. The great quarry in dacite on the west face of Ancon Hill, the quarry in basalt at Sosa Hill adjoining the Balboa docks, and the quarry in basalt on the west side of the Panama Railroad 3 kilometers northwest of Monte Lirio, are reminders of the construction period.

Since MacDonald wrote his account, a quarry has been opened in hornblende andesite on the Chiva Chiva Road 6⅓ kilometers northeast of Pedro Miguel.

OIL POSSIBILITIES

Though the central Panamá area of Tertiary marine sedimentary formations is small and the total thickness of marine strata is moderate, the oil possibilities deserve consideration, especially since the discovery in 1956 of oil in the Costa Rican part of the Bocas del Toro area. The southeastern end of the Costa Rican part of the Bocas del Toro area is shown in figure 1. At the time of writing (Sept., 1956) the discovery well, Union Oil Co. No. 2 Cocoles, located 1½ kilometers north of the international boundary, had just been completed and stratigraphic data had not been released.

In many respects the stratigraphic succession in the southeastern part of the Bocas del Toro area is similar to that in the central Panamá area, which includes the Canal Zone. On the islands of Bocas del Toro Archipelago a thin section of carbonate and other rocks of Pliocene age crops out. They are underlain in the archipelago and on the mainland by Miocene strata, designated by Olsson the Gatun stage or formation (Olsson, 1922, p. 10–16). The upper part of Olsson's Gatun consists of carbonate and fine-grained, calcareous detrital rocks of late Miocene age, correlated with the upper part of the Gatun formation in the western area of the present report. The lower part of Olsson's Gatun corresponds to the late middle Miocene middle part of the Gatun in the Canal Zone and also to the late middle Miocene upper part in the eastern area, although the depth-facies in the Bocas del Toro basin is shallower than that of the upper part in the Canal Zone. The equivalent of the early middle Miocene lower part of the Gatun in the Canal Zone is missing at the outcrop in the Bocas del Toro area or is partly represented by nonmarine conglomerate, rocks of finer grain containing land plants, and lignite. Olsson's Gatun rests unconformably on the Uscari formation (or better Uscari shale), which consists almost entirely of moderately deep-water fine-grained rocks (Olsson, 1922, p. 10). Light oil issues from fractures in strongly deformed strata of the Uscari in the type region along Uscari Creek. The Uscari is of late Oligocene and early Miocene age and corresponds in age to the Caimito formation of Madden basin. The oldest outcropping Tertiary strata in the southeastern part of the Bocas del Toro area are limestones, probably of both Oligocene and Eocene age. The presence of subsurface marine strata of Eocene age is a reasonable expectation. There are two important differences between the two areas. No oil seeps have been found in the central Panamá area and nothing in the Oligocene and lower Miocene outcrop section closely resembles the almost uniformly fine-grained rocks of the Uscari shale.

Three districts in the part of the central Panamá area covered by plate 1 are promising for testing oil possibilities: the Gatun Lake district, Madden basin, and the Pacific coastal district east of Panamá City.

Gatun Lake district.—Estimates of outcrop and probable maximum subsurface thickness in the Gatun Lake district are as follows.

Estimated outcrop and probable maximum subsurface thickness of sedimentary rock formations in Gatun Lake district

Formation	*Outcrop thickness in meters*	*Maximum subsurface thickness in meters*
Chagres sandstone	250	250
Deposits of late Miocene age	Overlapped	100
Gatun formation	250	500
Deposits of early Miocene age	Overlapped	300
Caimito formation	300	400
Bohio formation	300	300
Marine member of Bohio(?) formation	100	250
Gatuncillo formation	25+	300
Total	1, 225+	2, 400

The outcropping formations in the Gatun Lake district are marine, with the exception of the Bohio formation, which is nonmarine throughout most of the area. On Barro Colorado Island, however, the upper part of the Bohio includes thin marine tongues of somewhat calcareous, medium-grained subgraywacke, suggesting that the nonmarine coarse-grained rocks are replaced seaward by marine rocks of finer grain.

The upper part of the Gatun formation consists of more or less calcareous, sandy and silty rocks containing a clay-like matrix. The fauna, which includes pelagic Foraminifera, a few pteropods, and a rich assortment of benthonic foraminifera and mollusks, indicates a moderate-depth environment (50 to 100 fathoms; outer neritic zone of forthcoming "Treatise on paleoecology" to be published by the Geological Society of America). The late Miocene upper part of the Gatun in the western area, west of the Canal Zone (fig. 3), is overlapped by the Chagres sandstone, but is presumed to be present in the subsurface section.

Deposits of early Miocene age are unknown in the Gatun Lake district. That they were deposited there is indicated by the Caribbean faunal affinities of the early Miocene part of the Caimito formation in Madden basin. As it is unlikely that they were removed before deposition of the Gatun formation, it is concluded that they are overlapped by the Gatun, which, along the northeast border of the central Panamá area, overlaps the Caimito formation and rests on the Cretaceous(?) basement.

Except on Barro Colorado Island, the Caimito formation consists of moderately coarse, shallow-water, highly tuffaceous rocks and thin algal-foraminiferal limestone. Though the lower part of the Caimito on Barro Colorado includes thin algal-foraminiferal limestone, it is made up chiefly of medium- to very fine-grained, somewhat tuffaceous sandstone. These fine-grained rocks contain a moderate-depth fauna. At one locality (54n) silty, very fine-grained sandstone contains numerous discoasters and other pelagic coccolithophores and numerous pelagic Foraminifera. The outcrop section of the Caimito on Barro Colorado, like that of the Bohio formation, points to progressively deeper water and finer grain size in a seaward direction.

By the same line of reasoning outlined for deposits of early Miocene age, the Gatuncillo formation is expectable in the subsurface section of the Gatun Lake district. That expectation recently was realized, when the Gatuncillo was indentified at a depth much shallower than expected. In 1955 R. H. Stewart, of the Panama Canal Company's Meteorological and Hydrographic Branch, examined the cores obtained in Core Hole CH–5, drilled in 1946 at a locality in Gatun Lake 325 meters south of Guava Island, a small island of the Brujas Islands group. (The core-hole locality is 1.3 kilometers east of locality 55a of plate 1.) The cores include a considerable thickness of fossiliferous limestone, logged as part the Caimito(?) formation when the core hole was drilled. Mr. Stewart, however, thought it probably is a limestone of the Gatuncillo formation and his suspicion was confirmed when W. S. Cole identified *Heterostegina ocalana*, *Lepidocyclina macdonaldi*, *L. chaperi*, and *Asterocyclina georgiana* in a sample of readily disintegrated limestone from the core. A synopsis of the core is as follows:

Log of Core Hole CH–5, drilled in Gatun Lake

	Thickness (meters)
Lake sediments	0. 9
Caimito(?) formation:	
Bentonitic tuff grading downward into sandy siltstone in basal 3 m	11. 2
Gatuncillo formation:	
Hard fossiliferous limestone grading downward into soft marly limestone in lower 1.9 m	11. 5
Sandy siltstone and thin beds of tuff and limestone	14. 4
Total thickness	38. 0

The presence of the Gatuncillo formation 11.2 meters below the bottom of the lake sediments can hardly be accounted for without an assumption of a major fault trending a little north of east and lying just north of Trinidad Island and just south of the Brujas Islands group. The Caimito formation is not known to overlap the Bohio formation anywhere in the central part of the Gatun Lake area, although in the northeastern part of the area, north of Nueva Providencia, it evidently overlaps both Bohio and Gatuncillo. The strata in the core hole overlying the Gatuncillo formation do not suggest overlapping deposits. Nevertheless the siltstone strongly suggests the tuffaceous siltstone of the Caimito exposed on the south coast of Pato Horqueto Island (locality 55a, pl. 1), the island in the Brujas group west of the core-hole site. If these suggestions are correct, the core hole passed through a fault at a depth of 29.7 meters below the surface of the lake—a fault having a stratigraphic displacement of about 300 meters. No evidence indicating a fault, however, was recorded by the geologist who prepared the log. As a matter of fact, a fault of that character and of the trend just specified accounts for the marine member of the Bohio(?) formation on Trinidad Island much more satisfactorily than plate 1. The Gatuncillo formation, consisting chiefly of moderate-depth siltstone and mudstone, is a likely source for oil throughout the central Panamá area and its limestones are suitable reservoirs.

Madden basin.—The following table shows estimates of outcrop and probable maximum subsurface thickness in Madden basin.

Estimated outcrop and probable maximum subsurface thickness of sedimentary rock formations in Madden basin

Formation	Outcrop thickness (meters)	Maximum subsurface thickness (meters)
Caimito formation	450	450
Bohio formation	0–200	300
Gatuncillo formation	300	500
Total	750–950	1, 250

As in the Gatun Lake district, the bulk of the Bohio formation consists of nonmarine boulder conglomerate. At the continental divide the upper part of the formation includes thin lenses of algal-foraminiferal limestone. In the Quebrancha syncline, northwest of Madden basin, the Bohio is made up of graywacke grit, the basal part of which includes marine siltstone. In the northern part of Madden basin the Caimito formation overlaps the Bohio.

The Gatuncillo formation evidently rests on an uneven surface of the basement complex. Reeves and Ross (1930, p. 18, pl. 5) mentioned and mapped a small outcrop of dioritic rock near the head of Río Azote Caballo, just south of the present south shore of Madden Lake. This outcrop evidently is the top of a basement hill or ridge, on the sides of which the Gatuncillo is overlapped by the Caimito. Practically pure quartz sandstone in the upper part of the Gatuncillo is exposed along the road from Casa Larga to Laguna, near locality 13—the only locality where such sandstone was observed in the area covered by plate 1.

Pacific coastal district east of Panamá City.—In the Pacific coastal district east of Panamá City, the Gatuncillo formation is overlapped by the Bohio formation. The Gatuncillo reappears farther east in the valley of Río Bayano, 45 kilometers east-northeast of the eastern border of plate 1 (Terry, 1956, p. 32).

DESCRIPTION OF TERTIARY MOLLUSKS

The formal description of species is held to a minimum. Lengthy descriptions almost invariably include matter at the generic level which is of no value in the discrimination of species.

The following terms are used for type material of species:

Type: A specimen selected by the describer as the name-bearer of a species. Also known as holotype.

Paratype: A specimen showing a feature, or features, not shown by type. Also used by others for any specimen, other than type, on which the description of a species is based.

Syntype: A specimen in a lot of two or more on which a species is based, but none of which was selected by the describer as the name-bearer. Also known as cotype.

Lectotype: A syntype subsequently selected as the name-bearer.

Neotype: A specimen, from the same locality and horizon, selected as the name-bearer to take the place of destroyed or lost type material.

Topotype: A specimen from the same locality and horizon as the name-bearer.

Terms used for types of genera are as follows:

Orthotype: Type by original designation.
Monotype: Type by monotypy. Also known as haplotype.
Tautotype: Type by tautonymy.
Logotype: Type by subsequent designation.

Adoption of the preceding terms for the types of genera, which have the advantage of brevity, was prompted by Iredale's (1939, p. 223) usage in his Great Barrier Reef report. Monotype, however, has been substituted for haplotype. Iredale's usage was based on Jordan's, who in turn picked up terms from Cooke, but also added one of his own. Those interested in the origin and varying usage of the terms in the preceding two lists will find definitions and citations in Frizzell's useful "Terminology of types" (1933). It is entirely appropriate to use the term "type" for a species and a genus. There can be no confusion: the type of a species is a specimen, whereas the type of a genus is a species.

The following new subgeneric names are proposed:

Aepystoma, subgenus of *Teinostoma*, Vitrinellidae.
Type: *Teinostoma* (*Aepystoma*) *andrium* Woodring, n. sp., Gatun formation, Miocene, p. 70. Gender neuter.

Diaerecallus, subgenus of *Teinostoma*, Vitrinellidae.
Type: *Teinostoma* (*Diaerecallus*) *sychnum* Woodring, n. sp., Gatun formation, Miocene, p. 71. Gender masculine.

Hapalorbis, subgenus of *Solariorbis*, Vitrinellidae.
Type: *Circulus liriope* Bartsch, Recent, Gulf of California, p. 75. Gender masculine.

Hypterita, subgenus of *Neverita*, Naticidae, Polinicinae.
Type: *Natica helicoides* Gray, Recent, Baja California to Perú, p. 92. Gender feminine.

GASTROPODS

Family TROCHIDAE

Trochids are rare in the Tertiary formations of the Canal Zone and adjoining parts of Panamá. Each of the two species of *Calliostoma* herewith described is represented by two specimens. In addition three other trochids are recognized: a minute "*Margarites*" from the middle part of the Gatun formation; an exfoliated apical fragment sculptured with nodose spirals, evidently a calliostome, also found in the middle part of the Gatun formation; and an incomplete impression, probably a calliostome sculptured with weakly noded spirals, from the Toro limestone member of the Chagres sandstone. Each of these three trochids is represented by only one specimen.

Subfamily MARGARITINAE

Genus?

"Margarites" species

Minute, very thin-shelled, outline naticid, whorls rapidly enlarging. Protoconch consisting of a smooth naticoid whorl. End of protoconch marked by fine closely spaced axial and spiral threads. Both sets of threads gradually become more widely spaced and on later part of penult they disappear, the early part of the penult bearing a sutural thread, a thread on the shoulder, and widely spaced retractive axial threads between them. Body whorl smooth. Outer lip broken far back. Columellar lip incomplete. Umbilicus evidently very narrow, umbilical border broadly rounded.

Height 2.4 mm, diameter 2.2 mm.

This curiously sculptured species represents an unknown genus of the Margaritinae. The outline and thin shell suggest "*Solariella*" *iridea* Dall (1889, p. 382), dredged by the *Blake* off Cape Florida at a depth of 193 fathoms. "*Solariella*" *iridea*, however, has more inflated whorls, no axial sculpture, a faintly undulated spiral near the suture, a wider umblicus, and elongate nodes on the umbilical border. Though "*Solariella*" *iridea* was described as a variety of "*Solariella*" *lubrica* Dall, it is not closely related to that species, which is the type of the genus *Suavotrochus* (Dall, 1924, p. 90), described as a section of *Solariella*.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, locality 155c.

Subfamily CALLIOSTOMATINAE

Genus Calliostoma Swainson

Swainson, A treatise on malacology, p. 351, 1840.

Type (logotype, Herrmannsen, Indicis generum malacozoorum, v. 1, p. 154, 1846): *Trochus conulus* Linné (cited by Swainson as "*conula* Mart."), Recent, Mediterranean Sea.

Subgenus Calliostoma s. s.

Calliostoma (Calliostoma) metalium Woodring, n. sp.

Plate 18, figures 12–14

An imperforate very weakly sculptured, nonnoded, carinate callistome of medium size. Whorls rapidly enlarging, outline of spire concave. Whorls, except body whorl of mature shells near outer lip, very strongly carinated by a peripheral spiral, which is visible on spire whorls adjoining anterior suture. Three weak spirals visible on earliest preserved whorl, which is somewhat exfoliated. A few very faint spirals visible on anterior part of other spire whorls. Body whorl between suture and periphery bearing weak spirals. Base bearing faint spirals adjoining periphery and wider faint spirals adjoining columellar lip. Columellar lip everted, molded against base of shell except near base of lip.

Height (almost complete, but crushed) 19.5 mm, diameter (incomplete) 24 mm (type).

Type: USNM 561430.

Type locality: 206a (Stanford Univ. locality 2699, Caribbean coast near mouth of Río Piña, road cut on west side of river about 90 m. west of road fork, Panamá; same locality as USGS 16937), Chagres sandstone.

Though the type is somewhat crushed and evidently is immature, the characters of this weakly sculptured, nonnoded, carinate species are well defined. Much of the type is more or less exfoliated, but even unexfoliated patches are very weakly sculptured, aside from the strong peripheral spiral. That the type is not mature and that the peripheral spiral is reduced near the outer lip of mature shells are shown by an exfoliated body whorl fragment from the type locality—the only specimen other than that illustrated. This fragment indicates a body-whorl diameter of at least 30 millimeters.

In outline of spire, strongly carinate periphery, and almost smooth base, *Calliostoma metalium* is allied to *C. aurora* Dall (1889, p. 366, pl. 37, fig. 2), dredged at a depth of 140 fathoms off Barbados. (Dall also recorded a fragment from a depth of 576 fathoms.) *C. metalium*, however, lacks the noded spirals of *C. aurora* and the basal spirals of the fossil are even weaker.

Occurrence: Chagres sandstone (early Pliocene), localities 206, 206a.

Subgenus Leiotrochus Conrad

Conrad, Acad. Nat. Sci. Philadelphia Proc., p. 288, 1862.

Type (monotype): *Leiotrochus distans* Conrad, Miocene, Maryland.

Assignment of *Calliostoma eremum* to *Leiotrochus* has the advantage of indicating that this species has an umbilicus. It is doubtful, however, whether the strongly sculptured *C. eremum* and its allies are closely related to the faintly sculptured *C. distans*. For the characters of *C. distans*, reliance is placed on specimens in the U. S. National Museum from Yorktown, Virginia, labelled *C. briani* Conrad. According to Dall (1890–1903, pt. 2, p. 402, 1892), who handled specimens identified by Conrad, *C. briani* is *C. distans*. The *C. distans* of the Maryland Geological Survey Miocene volume (Martin, 1904, p. 258, pl. 61, fig. 6) is imperforate and has moderately strong sculpture. Evidently it is not *C. distans*, as it does not agree with Conrad's description.

As suggested by Gardner (1926–47, p. 619–620, 1947), a more natural grouping of perforate and imperforate species of *Calliostoma* may possibly be gained through a study of the development of the sculpture.

Calliostoma (Leiotrochus) eremum Woodring, n. sp.

Plate 22, figures 3,5

A perforate calliostome of medium size. Whorls of spire slightly inflated, body whorl strongly inflated. Sculpture of spire whorls and of body whorl between periphery and suture consisting of strongly noded primary spirals (3 on earliest preserved whorl, 5 to 6 on penult, and 9 to 12 on body whorl). A weakly noded secondary spiral in some interspaces. On late whorls some secondary spirals are transformed into primaries by becoming wider and more strongly noded. Base sculptured with 10 or 11 primary spirals. A secondary spiral present or absent in interspaces on base. Nodes on basal spirals long, low, and not well defined. Edge of umbilicus not sharply angulated and therefore junction of basal and columellar lips not angulated. Interspaces on base and umbilical wall adjoining innermost basal spiral roughened by axial wrinkles. Remainder of umbilical wall smooth, aside from subdued growth lines.

Height (incomplete) 17.5 mm, diameter 19 mm (type). Height (almost complete) 18.7 mm, diameter 19 mm (paratype).

Type: USNM 561311; paratype, Stanford Univ.

Type locality: 155c (USGS 16915, Gatun Third Locks excavation, east side of excavation, 1 mile (1.6 km) north of Gatun Lake, Canal Zone), middle part of Gatun formation.

This species is represented by two specimens, both collected at the Gatun Third Locks. It has a less angulated umbilical border than *Calliostoma grabaui* Maury (1917, p. 155, pl. 24, fig. 19), from the middle Miocene Gurabo formation of the Dominican Republic, and also has weaker nodes on the spirals of the body whorl, particularly on the base. *C. mancinella* Olsson (1922, p. 164, pl. 15, figs. 9, 10), from the middle Miocene of Costa Rica, has a lower spire, less inflated spire whorls, and more widely spaced basal nodes. The more inflated spire whorls and less angulated umbilical border of *C. eremum* differentiate it from the living *C. sayanum* Dall (1889, p. 370, pl. 33, figs. 10, 11), which furthermore is twice as large. The two specimens of *C. sayanum* mentioned by Dall in 1889 still are the only representatives of that species in the collections of the U. S. National Museum: the type dredged at a depth of 120 fathoms 20 miles southeast of Cape Hatteras and a body-whorl fragment from a depth of 107 fathoms 36 miles south of Cape Hatteras.

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

Family TURBINIDAE

Genus Turbo Linné

Linné, Systema naturae, ed. 10, p. 761, 1758.

Type (logotype, Montfort, Conchologie systématique, v. 2, p. 203, 1810): *Turbo petholatus* (*Turbo petholatus* Linné), Recent, tropical western Pacific and Indian Oceans.

Subgenus Marmarostoma Swainson

Swainson, Zoological illustrations, 2d ser., v. 1, text accompanying pl. 14 (unnumbered), 1829.

Type (orthotype): *Turbo chrysostomus* Linné, Recent, tropical western Pacific.

When Swainson proposed the generic name *Marmarostoma*, he designated *Turbo chrysostomus* as the type. The only species of *Marmarostoma*, however, described by him at that time, *M. undulata* (correctly *M. undulatum*), evidently is the Panamic species named *Turbo saxosus* by Wood (1828, p. 20, pl. 6, fig. 45) a year earlier; that is, it is a species of the subgenus *Callopoma* Gray (Gray, M. E., 1850, p. 87; type (logotype, Cossmann, 1895–1924, pt. 11, p. 116, 1918): *Turbo fluctuosus* Wood, cited by Cossmann as *Turbo fluctuatus* Gray), Recent, tropical eastern Pacific), characterized by a deep central pit and granular ribs on the operculum.

Many years ago Iredale (1915, p. 444) discussed Swainson's type designation, but, apparently on the tacit assumption that *Turbo marmoratus* Linné is the type of *Turbo*, he considered *Marmarostoma* to be a synonym of *Turbo*. Thiele in his Handbuch der systematischen Weichtierkunde and Wenz in his treatise on fossil gastropods have called attention to the availability of *Marmarostoma* in place of the better known *Senectus* Swainson (1840, p. 348; type (logotype), Herrmannsen, 1846–52, v. 2, p. 438, 1848: *Turbo chrysostomus* Linné, (cited by Swainson as "*chrysostomus* Mart."), which is an objective synonym.

Caribbean fossil and Recent species that are referred to *Marmarostoma* are not typical of that subgenus. The operculum of *Turbo chrysostomus* and its close allies has marginal oblique narrow grooves separating minutely granular bands, whereas the operculum of the Caribbean species has a more or less distinct shallow marginal ledge and is faintly granular or smooth.

Turbo (Marmarostoma) aff. T. castaneus Gmelin

Plate 20, figure 10

Of medium size, sculpture nonlamellar. Early whorls bearing a conspicuous practically smooth basal spiral. Later whorls weakly shouldered, sculptured with noded spirals. Somewhat worn operculum assumed to represent this species is smooth, bearing a poorly defined shallow marginal ledge.

Height (not quite complete) 20.5 mm, diameter (incomplete) 18 mm (figured specimen).

An incomplete apparently immature shell and associated operculum from the middle part of the Gatun formation and a mold of a few whorls from the Toro limestone member of the Chagres sandstone are identified as *Turbo* aff. *T. castaneus*. They may, in fact, represent the Recent Caribbean *T. castaneus*. The operculum fitted into a shell considerably larger than the only shell collected at the same locality.

The typical form of *T. castaneus*, as long accepted, is sculptured with nonlamellar noded spirals. Recent Caribbean shells that have noded spirals but also have thin lamellae forming vaulted scales on the primary spiral at the shoulder, or on that spiral and others, have been referred to *T. crenulatus*, also named by Gmelin. *T. crenulatus* has the same geographic range as *T. castaneus* (North Carolina to the West Indies), but is said to be more common at slightly shallower depths (Dall, 1890–1903, pt. 2, p. 382, 1892). It has been considered a synonym of *T. castaneus,* a variety of *castaneus,* or a valid species. The collections of the U. S. National Museum indicate that the two forms intergrade. They are considered forms of a variable species, at least until more is known about their habitat and habits.

The fossils from Panamá are nonlamellar. They are not as strongly shouldered as most Recent shells—that is, the spiral at the shoulder is not as strong—and the nodes on the sutural spiral, particularly on the specimen from the Gatun formation, are not as coarse as those of most Recent shells. In both features, however, a few Recent shells closely approach the fossils.

Other fossils suggest that *Turbo castaneus* was living in the Miocene Caribbean Sea. A small incomplete strongly shouldered lamellar specimen from the middle Miocene Bowden formation of Jamaica is recorded as *Turbo* (*Senectus*) species (Woodring, 1928, p. 411). A strongly shouldered nonlamellar form, *Turbo* (*Senectus*) cf. *castaneus* (Rutsch, 1934, p. 40, pl. 1, figs. 1, 2) occurs in the late Miocene Punta Gavilán formation of Venezuela. *Turbo crenulatoides* Maury (1917, p. 153, pl. 24, fig. 14), from the middle Miocene Cercado and Gurabo formations of the Dominican Republic, is sculptured with strong lamellae that extend from suture to base on the body whorl. It is doubtful, however, whether it can be differentiated from strongly lamellar Recent shells.

Late Miocene deposits in western Florida yielded a strongly shouldered *Turbo* bearing a few lamellae on spirals below the shoulder on the later part of the body whorl. It was recorded as *Turbo castaneus* var. *crenulatus* (Mansfield, 1930, p. 127, pl. 19, fig. 5). *T. castaneus* and *T. castaneus* var. *crenulatus* are recorded from the Pliocene Caloosahatchie formation of Florida.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, locality 155b. Toro limestone member of Chagres sandstone, (early Pliocene), locality 196.

Family PHASIANELLIDAE

When the family name Tricoliidae was used in 1928 (Woodring, 1928, p. 418), it was not intended as a new name. It was used under the impression that the name had been proposed or suggested: evidently the result of an erroneous interpretation, perhaps of Iredlae's (1924, p. 232) statement. At all events the name is to be suppressed, for *Tricolia* appears to be properly referred to the family Phasianellidae.

Genus Tricolia Risso

Risso, Histoire naturelle des principales productions de l'Europe méridionale, v. 4, p. 122, 1826.

Type (logotype, Gray, Zool. Soc. London Proc., p. 144, 1847): *Turbo pullus* (*Turbo pullus* Linné), Recent, Mediterranean. (Gray cited the generic name as *Tricolea.)*

Before the generic name *Tricolia* can be used it is necessary to dispose of Lamarck's name *Phasianella* (1804, p. 295). Though that name appeared in a publication on fossils from the vicinity of Paris and two Eocene species are the only ones that were described, Lamarck stated that he was naming the genus for a Recent shell, "*faisan* (*phasianus*)". Despite Lamarck's clear intention and although there is no doubt about the identification of the shell he mentioned and partly described, he cited no references that could be used in fixing its Latin name. Therefore the view that *faisan* (=*Buccinum australis* Gmelin) is the type by original designation (Woodring, 1928, p. 418, 419, footnote) is hardly admissible. I am indebted to H. A. Rehder for pointing out that the deficiency in Lamarck's treatment was rectified within the next year by Roissy (1805 or 1806, p. 330), when he wrote "Le type de ce nouveau genre, que l'on doit encore à M. de Lamarck, est une jolie coquille appelée *faisan,* * *." He stated that this species is from New Holland and on the next page described it as *Phasianella variegata,* citing *Buccinum tritonis* Chemnitz in synonymy. This is an unequivocal type designation and it is irrelevant that Lamarck used only a vernacular name for the type species. The type of *Phasianella* therefore is *P. variegata* Roissy (=*Buccinum australis* Gmelin). Roissy's action fortunately saves the traditional usage of *Phasianella.*

Tricolia calypta Woodring, n. sp.

Plate 15, figures 1, 2

Of medium size, moderately inflated, spire high. Columellar lip and parietal callus thin. Umbilical groove narrow. Type showing curved strongly retractive bands on later part of body whorl, bands standing out in slight relief on the somewhat altered and corroded shell, but may originally have been color bands. Operculum unknown.

Height 4.8 mm, diameter 3.1 mm (type).

Type: USNM 561327.

Type locality: 40a (USGS 2683, Vamos Vamos, off Palenquilla Point, Canal Zone, now submerged), marine member of Bohio(?) formation.

The type and an additional specimen are in one of Hill's collections from Vamos Vamos, and two others are in MacDonald and Vaughan's collection from the same locality. The type is the only specimen that shows the retractive bands.

The whorls of *Tricolia calypta* are less constricted at the suture than those of *T. precursor* (Dall) (1915, p. 94, pl. 12, fig. 5), and the species from Panamá has a narrower umbilical groove. *T. precursor* occurs in the early Miocene Tampa limestone of Florida.

In Europe *Tricolia* is recognized in strata as old as Paleocene, but *T. calypta* is the earliest American species so far described.

Occurrence: Marine member of Bohio(?) formation (late Eocene or early Oligocene), Gatun Lake area, localities 40a, 40d.

Family PHASIANELLIDAE?

Tricolia? syntoma Woodring, n. sp.

Plate 17, figure 47

Small, strongly inflated, spire low, outline like that of a minute naticid. Columellar lip wide, its outer edge bearing a faint low narrow rim. Parietal callus thick, continuous with the columellar lip, its edge sharply defined. Umbilical groove very narrow, almost closed. Operculum unknown.

Height 2.2 mm, diameter 2.2 mm (type).

Type: USNM 561328.

Type locality: 170a (USGS 8411, headwaters of Quebrada Caña (Río Caño Quebrado), Panamá, middle part of Gatun formation.

The family and generic assignment of this minute species, represented by one specimen from the middle part of the Gatun formation, are doubtful. Some features suggest a low-spired *Tricolia,* but no species of *Tricolia* examined has a wide-rimmed columellar lip. The type and only specimen of *"Eucosmia" lurida* Dall (1897, p. 15, pl. 1, fig. 11) in the collection of the U. S. National Museum (a Recent shell from British Columbia) has a wide distinctly rimmed columellar lip, which is not shown on the poorly drawn aperture of Dall's illustration. This species, however, is probably a *Homalopoma* related to *H. subobsoletum* (Willett) (1937, p. 63, pl. 25). Most species of *Tricolia* have a thin parietal callus that fades out on the parietal wall. Nevertheless some species have a moderately thick callus that joins the columellar lip. Despite its relatively narrow aperture, *Tricolia? syntoma* may represent an undescribed turbinid genus remotely related to *Homalopoma.*

In outline *Tricolia? syntoma* suggests the Miocene Jamaican species *Tricolia* (*Eulithidium*) *hadra* Woodring (1928, p. 420, pl. 34, figs. 10, 11) and a minute Recent Cuban *Tricolia* described by Dall (1889, p. 351, pl. 19, fig. 10b) as *"Phasianella (Eucosmia)" brevis* d'Orbigny. Both species, however, have *Tricolia*-like apertural features.

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

Family NERITIDAE

Subfamily NERITINAE

Genus Velates Montfort

Montfort, Conchyliologie systématique, v. 2, p. 355, 1810.

Type (orthotype): *Velates conoideus* (*Nerita conoidea* Lamarck = *Nerita perversa* Gmelin), Eocene, Paris Basin.

Velates perversus (Gmelin), subspecies?

Plate 14, figures 5–8

Reaching a large size, ovid in ventral plan, apex moderately eccentric. Columellar lip bearing seven or eight teeth. Callus deeply indented adjoining lower end of columellar lip and extending along inner border of outer lip, forming a wide rim.

Approximate height 60 mm, restored diameter 100 mm (largest specimen). Height 22.5 mm, diameter 43.7 mm (larger figured specimen).

Though *Velates* was found in limestone of the Gatuncillo formation at five localities, the only specimens showing the aperture are from locality 38 in the Río Casaya area. The shell of medium size shown on plate 14, figures 5, 7 is the largest of 18 collected at that locality. Twelve of the 18 have complete columellar lips, and on 9 the outer lip is preserved. The shells from locality 38, and the incomplete specimens from the other localities so far as they are preserved, closely resemble Lutetian Paris Basin specimens of *Velates perversus* (for citations and synonymy see Eames, 1952, p. 12). The fossils from Panamá that show the outer lip, however, have a wide rim along the inner border of the lip, whereas the rim is absent on 10 Paris Basin shells ranging in diameter from three to 70 millimeters.

Katherine V. W. Palmer has kindly called my attention to the illustrations of *V. balkanicus* Bontscheff (1896 [1897], p. 380, pl. 6, figs. 1–5), based on specimens from the Eocene of Bulgaria. The illustrations show a rim on the outer lip like that on the specimens from Panama. Bontscheff (1896 [1897], p. 380, pl. 6, fig. 6) also described a variety (*V. balkanicus marginatus*) for specimens on which the thin edge of the outer lip extends around the entire aperture, bordering the callus. The teeth of the Bulgarian fossils are heavier than those of specimens from Panamá. It is doubtful whether the rim on the outer lip is an indication of close relationship.

Velates has a range of Late Cretaceous to late Eocene. *V. perversus* is widely distributed in Eocene deposits from India to the Mediterranean region and the Paris Basin, reaching its acme in the middle Eocene. The genus is relatively rare in the American Eocene. Under the name *V. schmideliana, V. perversus* is recorded from the Yellow Limestone of Jamaica (Trechmann, 1923, p. 347, pl. 15, figs. 1–3). A similar, if not identical, form (Trechmann, 1929, p. 490, pl. 18, figs. 19a, b) and an unidentified species (Trechmann, 1924, p. 10, pl. 1, fig. 7) have been found in other Eocene strata of that island. Fossils from California have been referred to *V. perversus* (Vokes, 1935, p. 382, pl. 25, figs. 1, 3, 5, pl. 26, fig. 1) and to a species of doubtful validity, *V. californicus* Vokes (1935, p. 384, pl. 26, figs. 3–8. A Florida locality yielded a large *Velates*, possibly a large form of *V. perversus*, described as *V. floridanus* Richards (1946; Richards and Palmer, 1953, p. 13, pl. 1, figs. 6–9). *V. vokesi* Cooke (1946; 1919, p. 126, pl. 5, figs. 7, 8), from the middle Eocene of the island of St. Bartholomew, is represented by poorly preserved specimens, none of which shows the aperture. The apex of *V. vokesi* is almost marginal, like that of *V. noetlingi* Cossmann and Pissarro (Cox, 1931, p. 37). The groove on the large specimen of *V. vokesi* figured by Cooke and also on the small figured specimen, which is the type, evidently marks the boundary between the area where growth takes place by addition to the outer lip and the area where growth is the result of resorption of the callus. The boundary between these two areas on the opposite side of the shell is not apparent. A species of *Velates*, similar in outline to *V. vokesi*, is found in limestone of middle(?) Eocene age in the Sierra de Bahoruco of the Dominican Republic, and in deposits of probable middle Eocene age in Chiriquí Province, Panamá and Baja California.

The remarkable architecture of *Velates* was described many years ago by Woodward (1892).

Occurrence: Gatuncillo formation (middle and late Eocene), Madden basin, localities 6, 7, 9, 15; Río Casaya area, locality 38.

Genus Neritina Lamarck

Lamarck, Encyclopédie méthodique, Histoire naturelle des vers, v. 3, pl. 455; Liste, p. 11, 1816.

Type (logotype, Children, Lamarck's Genera of shells, p. 111, 1823): *Neritina pulligera* (*Nerita pulligera* Linné), Recent, rivers of India and Melanesia.

Opinion 119 of the International Commission on Zoological Nomenclature, issued in 1931, placed *Neritina* Lamarck, with *N. pulligera* as the type, in the Official List of Generic Names.

Subgenus Vitta Mörch

Mörch, Catalogus conchyliorum * * * Comes de Yoldi, pt. 1, p. 166, 1852.

Type (logotype, Baker, Acad. Nat. Sci. Phila. Proc., v. 75, p. 137, 1923): *Nerita virginea* Linné, Recent, southern Florida to northern South America, mainly estuarine.

The convex callus and color pattern suggest that the following two species may be allied to *Neritina virginea*. They therefore are doubtfully assigned to the subgenus *Vitta*. According to Baker, in the publication just cited, *Vitta* is estuarine to fresh-water and is found in eastern America and western Africa.

Neritina (Vitta?) species

Small, spire worn. Callus thick, moderately convex. Columellar lip finely and weakly denticulate. Color pattern poorly preserved, consisting of dark wavy axial lines.

Height (practically complete) 7 mm, diameter (incomplete) 6 mm. Height (practically complete) 5 mm, diameter (practically complete) 5 mm.

This unidentified *Neritina* is represented by four incomplete specimens from the Culebra formation at locality 108c. The columellar lip is exposed on only one of them. The smallest has traces of dark axial lines and another shows such lines on a remnant of the outer calcite shell layer adjoining the edge of the callus. This Culebra species, like the following Gatun species, may be allied to the Recent Caribbean *Neritina virginea* (Linné). It has a thicker callus than small specimens of that Recent species.

Occurrence: Culebra formation (early Miocene). Gaillard Cut, locality 108c.

Neritina (Vitta?) cf. N. virginea (Linné)

Plate 21, figures 1, 2

Small, spire corroded. Callus moderately thick, strongly convex. Columellar lip finely and weakly denticulate. Color pattern consisting of closely spaced minutely zigzag dark axial lines, wider at forward apex of V's (apex toward outer lip). Near outer lip and also near callus the widened apices disintegrate into isolated triangles. On later half of body whorl a solid relatively wide dark spiral band adjoins suture.

Height (incomplete, spire corroded) 3.6 mm, diameter 3.6 mm (figured specimen).

Two small shells, collected from the middle part of the Gatun formation at two localities in the western area, are referred to *Neritina* cf. *N. virginea* (Linné). The color pattern is well preserved on the figured specimen. On the other, slightly larger, specimen only small patches of the outer calcite layer, and therefore of the color lines, remain. The lines evidently are not as closely spaced as on the figured specimen.

The convex callus and color pattern suggest relationship to the Caribbean Recent *N. virginea*, which reaches a much larger size. The most common color pattern of *N. virginea* consists of wavy dark lines interrupted by dark-bordered ovoid or triangular light-colored eyes. The eyes are absent on some specimens and in some subspecies, but on Recent shells that lack eyes the lines are not as strongly zigzagged as on the figured fossil from Panamá. A specimen collected at the type locality of *Neritina* (*Puperita*) *figulopicta* Maury (1917, p. 152, pl. 24, fig. 10; Cercado formation, Dominican Republic), presumably conspecific with *N. figulopicta*, has the callus and the prevailing color pattern of *N. virginea* and evidently belongs to that species.

The fossils from the Gatun formation, and also those from the Culebra formation referred to *Neritina* sp., may be immature shells of species as large as *N. virginea*, or may be mature shells of small species. As shown by numerous specimens, *N. chipolana* Dall (1890–1903, pt. 2, p. 422, pl. 23, fig. 19, 1892), from the Chipola formation of Florida, is a small species (height 5 millimeters) comparable in size to the fossils from Panamá. It has a color pattern of widely spaced, irregularly curved or zigzag, axial lines, or widely spaced groups of two to five such lines. The callus is thinner than that of the fossils from Panamá and is indented by a ledge adjoining the base of the columellar lip.

Occurrence: Middle part of Gatun formation (middle Miocene), western area, localities 161c, 170a.

Family THIARIDAE?

Genus Hannatoma Olsson?

Olsson, Bull. Am. Paleontology, v. 17, no. 63, p. 80, 1931.

Type (orthotype): *Melanatria? gesteri* Hanna and Israelsky, Oligocene, Perú.

Hannatoma? cf. H. emendorferi Olsson

Plate 14, figure 3

Of small size for genus *Hannatoma*, *Mesalia*-like in outline. Preserved spire whorls preceding penult sculptured with two strong flangelike spirals, the posterior spiral adjoining the suture, the anterior spiral lying a little in front of middle of whorl. Penult bearing also a narrower spiral emerging from anterior suture. Body whorl broken; aperture and growth line unknown.

Height (incomplete) 35.5 mm, diameter (incomplete) 15 mm (figured specimen).

An incomplete silicified fossil from the Gatuncillo formation in the Río Casaya area is doubtfully identified as a species of *Hannatoma* comparable to *H. emendorferi*, which occurs in the Eocene of Perú, in strata that were thought to be of Oligocene age when the species was described (Olsson, 1931, p. 82, pl. 15, figs. 3, 8). Unfortunately the aperture is not preserved and the growth line is not discernable. The spirals are more flangelike than those of *H. emendorferi* and of a closely allied, or identical, form found in strata of late Eocene age in eastern Colombia and western Venezuela.

Some species of *Mesalia*, including forms of the widely distributed Eocene *M. fasciata* (Lamarck) (Cox, 1930, p. 157, pl. 18, figs. 2, 3) have two flangelike spirals on spire whorls. The spirals, however, are narrow and the posterior one does not adjoin the suture.

Occurrence: Gatuncillo formation (middle Eocene), Río Casaya area, locality 38.

Family LITTORINIDAE

Genus Littorina Férussac

Férussac, Tableaux systématiques des animaux mollusques, p. XI (vernacular name "littorine" for "paludines marines", five species of which are listed on p. ix–x with the designation "*Paludina*, marine"), p. XXXIV ["Littorine, *Littorina*" as subgenus of "Paludine, *Paludina*, Féruss. (fluv. et marin)", no species mentioned], 1822.

Type (logotype, de Blainville, Dictionnaire des sciences naturelles, v. 56, p. 98 ("le genre Littorine, ayant pour type le *T. littoreus*"), 1828: *Turbo littoreus* Linné, Recent, western Europe.

Férussac gave no definition of the name *Littorina* and cited no species under it. On other pages, however, he listed five species as marine species of *Paludina* and on still another page he stated that he was forming a subgenus under the name littorine for marine paludines, which constituted the genus *Trochus* of Adanson. These vernacular names are the same as those used on page XXXIV with the corresponding formal names. This is a roundabout method, involving vernacular names, of determining what species Férussac included under *Littorina*.

Littorina aff. L. angulifera (Lamarck)

Plate 16, figures 1, 2

Of medium size, high-spired. Periphery of body whorl sharply angulated at beginning of whorl, obtusely angulated toward outer lip. Narrow spiral grooves visible on preserved parts of outer shell. Columellar lip excavated.

Height (practically complete) 12 mm, diameter 8.5 mm (figured specimen).

An imperfect specimen of the genus *Littorina* was found in the uppermost part of the Culebra formation in an association of brackish-water and marine species. Much of the shell is not preserved, including the edge of the basal and outer lips. The sculpture, however, remains on two patches of outer shell. It shows to best advantage on the base of the body whorl adjoining the thin wash of parietal callus.

Imperfect as this fossil is, it is of exceptional interest, as it is the first Tertiary *Littorina* to be recorded from the Caribbean region and it extends back to the early Miocene the lineage of a living Caribbean species, *L. angulifera* (Lamarck) (Bequaert, 1943, p. 23, pl. 7). The fossil so closely resembles small angulated specimens of *L. angulifera* that unequivocal assignment to that species may be justified. The columellar lip is wider than on most small shells of *L. angulifera* examined, but on some small shells of the Recent species it is as wide or wider.

According to Bequaert (1943, p. 24), in his recent monograph of the western Atlantic species of the genus, *L. angulifera* is found, generally on mangroves in brackish inlets, from Florida to Brazil, on the west coast of Africa, and has reached the Pacific coast of Panamá by transportation through the Panamá Canal. This species is recorded from Pleistocene deposits on the Caribbean side of the Canal Zone near Mount Hope (Brown and Pilsbry 1913a, p. 495). It is represented in three of MacDonald's Pleistocene collections from that area (USGS 5849, 5850, 5868) and also in two lots of Pleistocene fossils he collected at and near the north end of Gatun Locks (USGS 5867, 6038).

After this report was in proof a small imperfect specimen that seems to be *L. angulifera* was found in a collection from strata of middle Miocene age on Río Banana in southeastern Costa Rica (USGS 5882f) and a large specimen, unequivocally identified as that species, was found in a collection of late Miocene fossils from Swan Cay, in the Bocas del Toro Archipelago, northwestern Panamá (USGS 8305).

Bequaert (1943, p. 3) assigned *L. angulifera* to the subgenus *Littoraria.*

Occurrence: Uppermost part of Culebra formation (early Miocene), Gaillard Cut, locality 110.

Family VITRINELLIDAE

Studies of Recent vitrinellids have not yet progressed far enough to sort the genera of probably diverse affinities that are currently placed in this family. The Gatun formation yielded all the vitrinellids described in the present report.

Genus Teinostoma H. and A. Adams

H. and A. Adams, Genera of Recent Mollusca, v. 1, p. 122, August, 1853.

Type (virtual monotype and logotype, A. Adams, Thesaurus conchyliorum, pt. 22, p. 259, 1863): *Teinostoma politum* A. Adams, Recent, Santa Elena (presumably Ecuador).

Pilsbry and McGinty (1945–50, pt. 1, p. 1, 1945) have pointed out that *Teinostoma* was virtually monotypic, as *T. anomalum* C. B. Adams, the only species mentioned other than *T. politum*, was a nude name.

No known Caribbean fossil species has the characters of the subgenus *Teinostoma* s.s.: greatly depressed shell and spoutlike extension of the peristome.

Subgenus Idioraphe Pilsbry

Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 73, p. 398, 1922.

Type (orthotype): *Teinostoma angulatum* (Gabb) (*Cyclops angulatus* Gabb), Miocene, Dominican Republic.

It has been claimed that the spire of *Teinostoma* s.s. is concealed by overlap of the body whorl (Woodring, 1928, p. 444) and that it is not concealed (Pilsbry and Olsson, 1941, p. 47). As a matter of fact, it has become evident that both statements are justified (Pilsbry and Olsson, 1945–52, p. 38, 1952). The typical form of the type species, known only from Arthur Adams' descriptions and illustrations, reproduced by Pilsbry and Olsson (1945–52, p. 251, pl. 22, fig. 6, 1945; p. 38, pl. 2, figs. 1, 1a, 1b, 1952), has an exposed spire. A form from the Gulf of California, so similar in essential features to *T. politum* that it was described as *T. politum ultimum* (Pilsbry and Olsson, 1945–52, p. 252, pl. 22, figs. 1, 1a, 1b, 1945), has a concealed spire. In other words, the subgenus *Idioraphe*, which has a concealed spire, is not as sharply set off as it was once thought to be. *Idioraphe* also resembles *Teinostoma* s.s. in having a thick shell, thick callus, and thick enamel. Nevertheless *Idioraphe* is a useful name for small teinostomes that have a concealed spire, are not strongly depressed, and lack the spoutlike extension of the peristome characteristic of *T. politum.*

Teinostoma (Idioraphe) spermatia Woodring, n. sp.

Plate 17, figures 19–24, 31–33, 37–39

?*Teinostoma* cf. *carinatum* d'Orb., Toula, K. k. Geol. Reichsanstalt Jahrb., Band 61, p. 497, pl. 31, fig. 10, 1911 (Miocene, Canal Zone).

Small, thick-shelled, depressed but somewhat dome-shaped. Periphery bluntly angular on early part of body whorl, narrowly rounded on later part. Tip of spire exposed, remainder concealed by overlap of body whorl. Entire spire concealed by enamel on very large specimens. Umbilical and parietal callus thick and completely coalesced.

Height 0.7 mm, diameter 1.8 mm (type); height 1.1 mm, diameter 2.6 mm (large form, figured).

Type: USNM 561312; paratypes, Stanford Univ.

Type locality: 147b (USGS 6033c, Panama Railroad, about 3,500 feet (1,065 m) southeast of Gatun railroad station, Canal Zone), middle part of Gatun formation.

Teinostoma spermatia is the most widespread teinostome in the middle part of the Gatun formation and is particularly abundant at the type locality, where several hundred specimens were collected. It is represented, however, by only one specimen from the upper part of the formation, and none was found in the lower part.

Immature shells (pl. 17, figs. 22–24) are more nearly circular than mature shells. Furthermore the outer lip of immature shells ascends almost to the tip of the spire and therefore has a different outline from that of mature shells. Three specimens from the type locality, one of which is illustrated (pl. 17, figs. 19–21), show faint to fairly strong microscopically punctate spiral striae. This sculpture is doubtless a normal character, but is ordinarily concealed by enamel. The three specimens that show it have thin enamel, except on the later part of the body whorl, where the sculpture gradually disappears under the thicker coat of enamel. Fourteen specimens from the type locality that are assigned to *T. spermatia* are exceptionally large as compared with scores of apparently mature specimens, like the type. As shown on plate 17, figure 31, the tip of the spire of this relatively large form is covered with a thin glaze of enamel. These 14 large specimens, which do not intergrade with the much more abundant smaller apparently also mature form, may represent a different species. If so, however, immature shells of the large and the small species have not been distinguished and apparently are indistinguishable.

Species more or less closely resembling *Teinostoma spermatia* have been living in American waters since Eocene time. The very similar *T. tectispira* (Pilsbry, in Olsson and Harbison, 1953, p. 417, pl. 50, figs. 6–6c), a Pliocene species from Florida, has no trace of spiral sculpture. *T. spermatia* is more depressed and more elongate in dorsal outline than *T. angulatum* (Gabb) (Pilsbry, 1922, p. 398, pl. 37, figs. 1, 1a, 1b), and even the large form of *T. spermatia* is a little smaller. *T. angulatum*, which is found in the Cercado formation of the Dominican Republic, has very faint closely spaced spiral striae. Species similar to *T. spermatia* are living in both western Atlantic and eastern Pacific waters. *T. cryptospira* (Verrill) (Bush, 1897, p. 118, figs. 1, 2) ranging from Cape Hatteras to Florida, is more circular in dorsal outline. *T. cecinella* Dall (1919, p. 369), a species from Lower California, is more elongate in dorsal outline, larger, and has a thicker shell.

Toula's *Teinostoma* cf. *T. carinatum* may be *T. spermatia*, though his illustrations show an exposed spire and a peripheral carina. Pilsbry (in Olsson and Harbison, 1953, p. 415), however, thought it is very similar to the Recent *T. carinatum* (d'Orbigny).

Occurrence: Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, localities 146, 147b, 147f, 147g, 147h, 147i (identification doubtful), 153a. Upper part, eastern area, locality 177.

Teinostoma (Idioraphe) angulatum trochalum Woodring, n. subsp.

Plate 17, figures 4–6

Small, moderately depressed, dome-shaped. Periphery moderately angular on early part of body whorl, rounded on later part. Spire partly concealed by overlap of body whorl and glaze of enamel. Umbilical and parietal callus thick and coalescing.

Height 1 mm, diameter (incomplete) 1.7 mm (type).

Type: USNM 561431; paratypes, Stanford Univ.

Type locality: 137 (USGS 16911, Transisthmian Highway, 1.7 km northwest of Sabanita, Panamá), lower part of Gatun formation.

This teinostome, found in the lower part of the Gatun formation, is considered a small race of *T. angulatum* (Gabb), the type of *Idioraphe*, from the Miocene of the Dominican Republic (Pilsbry, 1922, p. 398, pl. 37, figs. 1, 1a, 1b). Gabb's specimens were collected at an unknown locality in the Dominican Republic. Specimens from the Cercado formation—Maury's *T. sandomingense* (Maury, 1917, p. 156, pl. 24, fig. 24)—evidently are conspecific, although the early part of the body whorl of the type has a more sharply angulated periphery. *T. angulatum trochalum* is smaller and lacks spiral sculpture. *T. umbilicatum* (Lea) (Mansfield, 1930, p. 134, pl. 20, figs. 1–3) and other Tertiary species from southeastern United States, as well as the Recent *T. cryptospira* (Verrill), have a less angular periphery.

Occurrence: Lower part of Gatun formation (middle Miocene), localities 136a, 137, 138a.

Subgenus Aepystoma Woodring, n. subgen.

Type: *Teinostoma (Aepystoma) andrium* Woodring, n. sp., Miocene, Gatun formation, Panamá and Canal Zone.

Of medium size, thick-shelled, spire moderately depressed, exposed. Smooth or sculptured with punctate fine spiral striae. Umbilical and parietal callus thick, more or less coalesced. Callus filling umbilicus on mature shells.

The subgeneric name *Aepystoma* is proposed for a group of thick-shelled teinostomes that have an exposed spire and callus-filled umbilicus. Fossil and Recent Panamic species allied to *Teinostoma andrium* have been assigned to the subgenus *Pseudorotella* by Pilsbry and Olsson. *Pseudorotella*, however, has a smaller and thinner shell and less depressed spire.

Teinostoma (Aepystoma) andrium Woodring, n. sp.

Plate 17, figures 40–42; plate 18, figures 9–11

Of medium size, thick-shelled, dorsal surface slightly domed. Periphery rounded on later part of body whorl, faintly and bluntly angular on early part. Sculpture of microscopically punctate faint spiral striae, for most part concealed on body whorl of mature specimens by glaze of enamel. Umbilical and parietal callus thick and coalescing.

Height 2 mm, diameter 4.7 mm (type).

Type: USNM 561315; paratype, Stanford, Univ.

Type locality: 137 (USGS 16911, Transisthmian Highway, 1.7 km northwest of Sabanita, Panamá), lower part of Gatun formation.

Teinostoma andrium is by far the largest of the Gatun teinostomes. The sculpture is distinct only on early whorls. The umbilicus of immature shells is not completely filled with callus (pl. 17, fig. 41).

T. andrium is closely related to *T. caroniense* Maury (1925, p. 249, pl. 43, figs. 3, 4), a late Miocene species from Trinidad, but has a flatter columellar lip and flatter umbilical callus. The recent Ecuadorean *T. millepunctatum* Pilsbry and Olsson (1945–52, p. 253, pl. 23, figs. 1, 1a, 1b, 1945) has more coarsely punctate spirals, and is smaller and thinner. The Recent western Panamic *T. imperfectum* Pilsbry and Olsson (1945–52, p. 254, pl. 22, figs. 2, 2a, 2b, 1945) also is smaller and thinner, and has a thin, narrow umbilical callus.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, locality 137. Middle part, eastern area, locality 147i.

Subgenus Pseudorotella Fischer

Fischer, Jour. Conchyliologie, t. 6, p. 52, 1857.
Type (monotype): *Pseudorotella semistriata* (d'Orbigny) (*Rotella semistriata* d'Orbigny), Recent, Cuba.

Pseudorotella is used in the present report for small, smooth or spirally sculptured teinostomes that have a moderately thick shell, exposed relatively high spire, wide umbilical callus filling—or not quite filling—the umbilicus, and narrow parietal callus. This usage may be found to be inappropriate when specimens of the type species are available. The type species has fine spiral striae above the periphery, according to d'Orbigny's illustrations.

As suggested by Pilsbry and McGinty (1945–50, pt. 1, p. 2, 1945), subgeneric rank is preferable to the generic rank that has been assigned to *Pseudorotella* (Woodring, 1928, p. 445). The Miocene Jamaican "*Pseudorotella*" *homala* Woodring (1928, p. 447, pl. 38, figs. 13–15) represents a minor group of teinostomes, more closely related to *Aepystoma* than to *Pseudorotella*, characterized by a bicarinate truncated periphery and relatively strong spiral sculpture.

Teinostoma (Pseudorotella) pycnum (Woodring)

Plate 17, figures 25–27

Pseudorotella pycna Woodring, Carnegie Inst. Washington Pub. 385, p. 446, pl. 38, figs. 10–12, 1928 (Miocene, Jamaica).

Small, moderately thick-shelled, periphery rounded. Body whorl pinched against suture, producing a suggestion of a sutural collar, corresponding to faint gutter between outer lip and parietal callus. Umbilical callus thick, filling umbilicus. Parietal callus narrow, its edge sharply defined.

Height 0.8 mm, diameter 1.3 mm (figured specimen).

Type: USNM 135502.

Type locality: Bowden, Jamaica, Bowden formation (middle Miocene).

The faint sutural collar and narrow parietal callus are characteristic features of *Teinostoma pycnum*. The few specimens from the Gatun formation are slightly smaller than the type. *T. vitreum* (Gabb) (Pilsbry, 1922, p. 399, pl. 37, figs. 3, 3a, 3b), from the Cercado formation of the Dominican Republic, lacks the faint sutural collar. *T. parvicallum* Pilsbry and McGinty (1945–50, pt. 1, p. 4, pl. 2, fig. 2, 1945), a Recent teinostome from Florida, is slightly larger and has a higher spire.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, locality 138. Middle part, eastern area, locality 147b. Bowden formation (middle Miocene), Jamaica.

Teinostoma (Pseudorotella) stemonium Woodring, n. sp.

Plate 17, figures 1–3

Small, moderately thick-shelled, periphery rounded, but marked by a spiral thread. Body whorl somewhat pinched against suture. Whorls smooth between suture and periphery. Periphery and base near periphery sculptured with four or five relatively heavy spiral threads (three or four on immature shells). Umbilical callus completely, or not quite completely, filling umbilicus. Parietal callus narrow, overlapping umbilical callus. Junction of outer lip and parietal callus forming a faint gutter.

Height 1 mm, diamter 1.5 mm (type).

Type: USNM 561432. Paratype, USNM 561433. Paratypes, Stanford Univ.

Type locality: 138a (Stanford Univ. locality 2656, Transisthmian Highway 1.6 km northeast of Canal Zone boundary, Panamá; same as USGS 16909), lower part of Gatun formation.

This sculptured *Pseudorotella* is represented by nine specimens collected by T. F. Thompson from the lower part of the Gatun formation. It seems to have no known close allies.

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

Subgenus Diaerecallus Woodring, n. subgen.

Type: *Teinostoma* (*Diaerecallus*) *sychnum* Woodring, n. sp. Miocene, Gatun formation, Canal Zone.

Small, thick-shelled, smooth or practically smooth. Suture strongly impressed. Umbilicus filled with callus. Edge of umbilical callus forming well defined ridge. Extension of parietal callus overlapping umbilical callus, deeply grooved adjoining columellar lip.

Diaerecallus is characterized by the strongly impressed suture and the abrupt overlap of a grooved extension of the parietal callus. It may represent a modification of *Aepystoma*, or possibly of a teinostome more or less similar to the subgenus *Annulicallus* Pilsbry and McGinty (1945–50, pt. 4, p. 17, 1946; type (orthotype): *Teinostoma carinicallus* Pilsbry and McGinty, Recent, Florida). *Annulicallus* has a sharp ridge at the edge of the umbilical callus, which is concave.

Teinostoma (Diaerecallus) sychnum Woodring, n. sp.

Plate 17, figures 28–30

Small, thick-shelled, periphery rounded. Apical whorl large for size of shell. Very faint microscopic spiral striae visible on penult or earlier whorls of some specimens. Umbilical callus bounded by ridge, which is overlapped by extension of parietal callus. Extension of parietal callus deeply grooved adjoining outer lip.

Height 1.1 mm, diameter 1.7 mm (type). Height 1.6 mm, diameter 2.2 mm (largest specimen).

Type: USNM 561316.

Type locality: 147b (USGS 6033c, Panama Railroad, about 3,500 ft (1,065 m) southeast of Gatun railroad station, Canal Zone), middle part of Gatun formation.

The curious callus, shown by four specimens from the type locality, at first glance suggests abnormality. The extension of the parietal callus is formed at a late growth stage. It is missing on three immature shells from the type locality and also on an immature shell from locality 155a, the only specimen from that locality. These immature shells resemble the subgenus *Aepystoma*, but have a low ridge at the edge of the umbilical callus. The large apical whorl and strongly impressed suture of this species are noteworthy features. No close fossil or living allies are known.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, localities 147b, 155a.

Genus Anticlimax Pilsbry and McGinty

Subgenus Anticlimax s.s.

Pilsbry and McGinty, Nautilus, v. 60, p. 12, 1946.

Type (logotype (Pilsbry and McGinty, Nautilus, v. 59, p. 77, 1946) of *Climacia* Dall, 1903 (not M'Lachlan, 1869), renamed *Climacina* Aguayo and Borro, 1946 (not Gemmellaro, 1878), renamed *Anticlimax*): *Teinostoma* (*Climacia*) *calliglyptum* Dall, Pliocene, Florida.

Perhaps *Anticlimax*, the second name proposed in rapid succession as replacement of the homonym *Climacia*, was not intended to be as derisive as it sounds. It recalls some of Jousseaume's names.

Teinostoma (*Climacia*) *calliglyptum* was virtually the monotype of *Climacia*. Dall used that combination in a list of fossils and in the explanation of a plate (Dall, 1890–1903, pt. 6, p. 1,610, 1,633, 1903). He also used the combination *Teinostoma* (*Climacia*) *radiata* Dall in the same list of fossils. There is, however, no indication that he intended that name for his *Collonia radiata*, no matter how unequivocal his intention proves to be.

The species of *Anticlimax* have recently been reviewed by Pilsbry and Olsson. The genus is strongly dome-shaped and has axial folds or undulations of varying strength on the base of the shell. The subgenus *Anticlimax* s. s. is characterized by a narrow callus on the columellar lip, from which a ridge spirals up the widely open umbilicus. The earliest species occurs in the early Miocene Thomonde formation of Haiti. A Recent species is found in the Caribbean Sea and another possibly off Florida, but none so far in the Panamic region.

Anticlimax (Anticlimax) gatunensis Pilsbry and Olsson

Plate 18, figures 5–7

Anticlimax gatunensis Pilsbry and Olsson, Bull. Am. Paleontology, v. 33, No. 135, p. 7, pl. 2, figs. 5, 5a, 5b, 1950 (Miocene, Panamá).

Dome-shaped, base flattened. Peripheral carina a relatively wide thin ledge. Upper surface sculptured with weak spiral striae, which disappear near periphery and on upper surface of peripheral ledge are replaced by microscopic axial threads. Base bearing 13 heavy axial folds. Outer half of base, including base of peripheral ledge, sculptured with spiral striae. Ridge bordering umbilicus moderately narrow.

Height 1.7 mm, diameter (incomplete) 3 mm (figured specimen).

Type: Acad. Nat. Sci. Phila. 18401.

Type locality: Cut on Boyd-Roosevelt (Trans-isthmian) Highway, just below bridge over Río Cativa and about 3¾ miles from road junction at Margarita, Panamá (same as USGS 16909) lower part of Gatun formation.

The figured specimen, a topotype, has a damaged peristome and carina. It is the only specimen in the U. S. National Museum collections; two smaller specimens are in the Stanford University collection from the same locality. The flattened base and wide peripheral carina are the most characteristic features of this species. These features distinguish it from the most closely related species, *A. schumoi* (Vanatta) (1913, p. 24, pl. 2, figs. 2, 7), a Recent species from British Honduras. *A. derbyi* (Maury) (1917, p. 156, pl. 24, fig. 20), the only other described Miocene species of *Anticlimax* s.s., occurs in the Cercado formation of the Dominican Republic and in the Thomonde formation of Haiti. It has a more swollen base, narrower peripheral ledge, fewer and heavier folds on the base, and no spiral striae on the base.

Occurrence: Lower part of Gatun formation (middle Miocene), localities 138, 138a.

Subgenus Subclimax Pilsbry and Olsson

Pilsbry and Olsson, Bull. Am. Paleontology, v. 33, No. 135, p. 5, 1950.

Type (orthotype): *Anticlimax hispaniolensis* Pilsbry and Olsson, Miocene, Dominican Republic.

Subclimax, which is somewhat intermediate between *Anticlimax* s.s. and dome-shaped species of *Teinostoma*, has the umbilicus partly or completely closed by a wide umbilical callus. It has, however, axial undulations or folds of varying strength on the base, like those of *Anticlimax* s. s. The earliest species, occurring in the early Miocene Baitoa formation of the Dominican Republic, is of the same age as the earliest species of *Anticlimax* s. s. *Subclimax* is living in the western Atlantic and the eastern Pacific.

Anticlimax (Subclimax) teleospira hystata Woodring, n. subsp.

Plate 18, figures 1–3

Dome-shaped, base slightly inflated. Periphery bluntly angular, except near outer lip, where it is drawn out into a ledge. Upper surface sculptured with faintly punctate spiral striae, which are indistinct or absent on middle third of body whorl and near outer lip. Base sculptured with faintly punctate spiral striae that disappear near umbilical margin and toward aperture, except on peripheral ledge. Base also bearing faint crude axial undulations. Umbilical callus filling umbilicus, except a narrow niche adjoining parietal callus. Junction of outer and basal lips drawn out in an angular thickened spoutlike projection, broken on type.

Height 1.5 mm, diameter (incomplete) 2.7 mm (type).

Type: USNM 561319.

Type locality: 185 (USGS 8383, Caribbean coast, west of Río Miguel, station 26 plus 100 feet (30 m) Panamá), upper part of Gatun formation.

Anticlimax teleospira hystata is represented by two specimens from the upper part of the Gatun formation in the coastal area west of the Canal Zone. The spoutlike projection of the peristome is like the projection of the type of *Teinostoma*. It is broken on the type but preserved on the other specimen, which is otherwise less complete. *A. teleospira* proper (Pilsbry and Olsson, 1950, p. 10, pl. 2, figs. 7, 7a), which occurs in the lower part of the Gatun formation but is not represented in the U. S. National Museum collections, has a carinate periphery and stronger basal undulations.

The closely related *A. tholus* (Pilsbry and McGinty) (1945–50, pt. 3, p. 79, pl. 8, figs. 1, 1a, 1b, 2, 2a, 1946), a Recent species from Florida, has stronger spiral sculpture and lacks the extended peristome. An undescribed species, dredged at a depth of 6 to 9 fathoms off Beaufort, N. C., has a more angular periphery, narrower umbilical callus, and lacks the extended peristome. *A. willetti* Hertlein and Strong (1940–51, pt. 10, p. 112, pl. 9, figs. 13–15, 1951), from the Pacific coast of Costa Rica, is larger and has stronger basal undulations. The only other recorded Miocene species of *Subclimax*, *A. hispaniolensis* Pilsbry and Olsson, has a sunken apex and axial undulations on the upper surface of the body whorl. Both Gatun species of *Anticlimax* are more similar to Recent species than to contemporaneous or slightly older Miocene species in the Caribbean region so far described.

Occurrence: Upper part of Gatun formation, western area (late Miocene), locality 185.

Genus Cyclostremiscus Pilsbry and Olsson

Pilsbry and Olsson, Acad. Nat. Sci. Phila. Proc., v. 97, p. 266, 1945.

Type (orthotype): *Vitrinella panamensis* C. B. Adams, Recent, Pacific coast of Panamá.

Subgenus Ponocyclus Pilsbry

Pilsbry, Acad. Nat. Sci. Phila. Mon. 8, p. 426, 1953.

Type (orthotype): *Adeorbis beauii* Fischer, Recent, Florida and West Indies.

Ponocyclus lacks the axial sculpture of the subgenus *Cyclostremiscus* s. s. Some species, however, are more or less intermediate and Pilsbry realized that the name *Ponocyclus* may eventually be found to be superfluous.

Cyclostremiscus (Ponocyclus) pentagonus (Gabb)

Plate 17, figures 7–15

Cyclostrema pentagona Gabb, Am. Philos. Soc. Trans., n. ser., v. 15, p. 243, 1873 (Miocene, Dominican Republic).

Vitrinella pentagona (Gabb), Gabb, Acad. Nat. Sci. Phila. Jour., 2d ser., v. 8, p. 368, pl. 47, fig. 68, 1881 (Miocene, Dominican Republic).

Cyclostrema quadrilineatum Toula, K. k. Geol. Reichsanstalt Jahrb., Band 61, p. 497, pl. 31, figs. 11a–c, 1911 (Miocene, Canal Zone).

Circulus pentagona (Gabb), Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 73, p. 397, 1922 (Miocene, Dominican Republic).

"*Circulus*" *pentagonus* (Gabb), Woodring, Carnegie Inst. Washington Pub. 385, p. 441, pl. 37, figs. 16–18, 1928 (Miocene, Jamaica).

Small, depressed, whorls 4½, the first 2½ very slowly enlarging. Protoconch relatively large, rising abruptly. Body whorl bicarinate or, less commonly, tricarinate. Early whorls rounded between sutures. A carina appears on later half of penult about midway between sutures and forms upper carina on body whorl. Basal carina generally weaker than upper. Periphery rounded, bluntly angular (the usual condition), or sharply angular, forming a third carina. A few specimens have one or more faint spiral threads on penult above carina, and a few have a low spiral thread on body whorl below and near upper carina or above and near lower carina. Umbilical wall bearing crude generally faint spiral cords more or less roughened by growth threads. Upper part of peristome gently arched forward.

Height 1 mm, diameter 1.6 mm (figured bicarinate specimen). Height 1.1 mm, diameter 2.3 mm (figured large specimen).

Type: Acad. Nat. Sci. Phila. 2831.

Type locality: Dominican Republic, Miocene.

This small *Cyclostremiscus* occurs throughout the Gatun formation. It is rare in the lower part, rare to abundant in the middle part, and rare in the upper part. Several hundred specimens were collected from the middle part at locality 147b.

These fossils show a considerable range of variation in the outline of the body whorl, in the presence or absence of spiral threads near the upper and lower carinae, and in the strength and coarseness of the spiral cords facing the umbilicus. The usual form is bicarinate (pl. 17, figs. 7–9). Though tricarinate shells (pl. 17, figs. 10–12) are not common in the middle part of the Gatun formation, the few specimens from the lower and upper parts (one and two, respectively) are tricarinate. Spiral threads, generally faint, near the upper and lower carinae are exceptional. The umbilical spirals generally are weak. They are, however, exceptionally strong on the large specimen shown on plate 17, figures 13–15. This large specimen, collected from the middle part of the Gatun foımation, shows a further modification in the rounded outline of the body whorl. At the beginning of the body whorl of this specimen the upper carina is moderately strong, the basal carina is weak, and the peripheral angulation is faint. These carinae and angulation rapidly disappear. This specimen is larger than the bicarinate and tricarinate forms. Inasmuch as mature bicarinate and tricarinate forms are rounded near the peristome, the exceptional features of the rounded specimen aıe presumably correlated with its size. Toula's illustrations, however, show a shell of moderate size, the body whorl of which is rounded at an early stage.

Cyclostremiscus pentagonus occurs in the Cercado formation of the Dominican Republic and in the Bowden formation of Jamaica. The few available specimens from the Dominican Republic and Jamaica are tricarinate. It was formerly thought that the Gatun form could be differentiated by the weak sculpture on the umbilical wall (Woodrıng, 1928, p. 441). That sculpture, however, is too variable for consistent differentiation.

Closely related forms are living in the western Atlantic and the eastern Pacific. "*Circulus*" *trilix* (Bush) (1897, p. 127, pl. 22, figs. 6, 10, 10a, 12, pl. 23, figs. 10, 15), ranging from Cape Hatteras to Cuba, is consistently tricarinate and enlarges more rapidly, so that with the same number of whorls (about 4½) Recent shells are almost twice as large. Recent shells and those from the Gatun formation have the same kind of protoconch and aperture. Inasmuch as the degree of enlargement is the only character now apparent to differentiate Recent shells and tricarinate fossils, treatment of "*C.*" *trilix* as a subspecies of *C. pentagonus* appears to be preferable. Fossils from the early Miocene Chipola formation and the middle Miocene Shoal River formation of Florida have been referred to "*Circulus*" *trilix* (Gardner, 1926–47, p. 600, 1947). These Florida fossils are tricarinate and are larger than those from the Gatun formation.

"*Circulus*" *cerrosensis* Bartsch (1907, p. 173, figs. 9a, b, c), which ranges from Santa Catalina Island, California, to Baja California and the Gulf of California, and probably to Panamá, is the eastern Pacific analog of "*Circulus*" *trilix*. It has not been determined whether Pacific and Atlantic shells can consistently be distinguished. Relatively strong spiral cords facing the umbilicus are more common in the few lots of Pacific shells. Shells from both oceans that are still lustrous show under strong light very faint microscopic spiral lineation. It is doubtful whether *Cyclostremiscus glyptomphalus* Pilsbry and Olsson (1945–52, p. 67, pl. 7, fig. 3, 1952), a Pleistocene form from the Pacific coasts of western Panamá, can be distinguished from "*Circulus*" *cerrosensis*. Pilsbry and Olsson suggested the probability of local races of a widely spread species. *Cyclostremiscus glyptobasis* Pilsbry and Olsson (1945–52, p. 66, pl. 7, figs. 4, 4*a*, 1952), also from the Pleistocene of western Panama, probably is a variety, or subspecies, of "*C.*" *cerrosensis* with a sculptured base. The Ecuadorean form "*Circulus*" *cosmius* Bartsch (1907, p. 173, figs. 8a, b, c) also is closely allied to "*Circulus*" *cerrosensis*, but is characterized by a slight downward bending of the upper margin of the peristome where it extends forward. Though the peristome of the type of "*Circulus*" *cosmius* is damaged, four specimens in the type (and only) lot have a perfect peristome. The seven specimens in the type lot have very weak umbilical sculpture. "*Circulus*" *occidentalis* Pilsbry and Olsson (1941, p. 48, pl. 9, fig. 3), from the Pliocene of Ecuador, shows downward bending of the peristome and should be compared with "*Circulus*" *cosmius*.

Cyclostremiscus tricarinatus (C. B. Adams) (Pilsbry and Olsson, 1945, p. 271, pl. 28, figs. 3, 3a, 3b), living on the Pacific coast of Panamá, is similar to the tricarinate species so far mentioned. It has, however, faint axial riblets between the periphery and suture, and therefore is intermediate between *Ponocyclus* and *Cyclostremiscus* s.s.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle and late Miocene). Lower part, localities 138, 138a. Middle part, eastern area, localities 146, 147b, 147f, 147g, 147h, 153a, 155c; western area, locality 161. Upper part, eastern area, locality 173; western area, locality 185. Cercado and Gurabo formations (middle Miocene), Dominican Republic. Bowden formation (middle Miocene), Jamaica.

Genus Solariorbis Conrad

Conrad, American Jour. Conch., v. 1, p. 30, 1865.
Type (logotype, Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 2, p. 414, 1892): *Delphinula depressa* Lea, Eocene, Alabama.

Subgenus Solariorbis s.s.

The subgenus *Soliariorbis* s. s. is characterized by relatively large size, faint spiral sculpture (microscopically punctate in the type species), and a wide umbilical wall on the body whorl adjoining the aperture.

Solariorbis (Solariorbis) strongylus Woodring, n. sp.

Plate 17, figures 43–45

Of medium size, thick-shelled, moderately depressed. Periphery faintly and bluntly angulated, except at and near peristome where it is rounded. Penult and part of preceding whorl sculptured with closely spaced spiral threads. Spirals become faint and even disappear on body whorl, but most persistent near suture and just above periphery. Under strong light base shows barely discernible microscopic spiral striation. Umbilicus moderately narrow, asymmetrical, bounded by a crude spiral ridge, which is slightly roughened by growth wrinkles. Parietal callus thin.

Height 1.3 mm, diameter 2.4 mm (type). Height 1.5 mm, diameter 3 mm (largest specimen).

Type: USNM 561322; paratypes, Stanford Univ.

Type locality: 138 (USGS 16909, Transisthmian Highway, 1.6 kilometers northeast of Canal Zone boundary, Panamá), lower part of Gatun formation.

The weak sculpture and moderately narrow asymmetrical umbilicus are characteristic features of this species. It is represented by 13 specimens, all from the type locality.

Occurrence: Lower part of Gatun formation (middle Miocene), localities 138, 138a.

Subgenus Hapalorbis Woodring, n. subgen.

Type: *Circulus liriope* Bartsch, Recent, Gulf of California.

The name *Hapalorbis* is proposed for a minor group of *Solariorbis* consisting of small carinate species that have a narrow umbilical wall on the body whorl adjoining the aperture. The type species has a spiral thread above and below the peripheral carina-forming thread. Others have one to three threads below the periphery and one or two above. Still others have none below or above the periphery.

The subgenus *Systellomphalus* (Pilsbry and Olsson, 1941, p. 48; type (orthotype): *Systellomphalus perornatus* Pilsbry and Olsson, Pliocene, Ecuador), with which Pilsbry and Olsson associated species closely allied to "*Circulus*" *liriope*, may be defined as embracing species that have axial riblets on spire whorls and axial wrinkles on the base of the body whorl adjoining the umbilicus.

Hapalorbis is not known to have survived the Miocene in Caribbean waters.

Solariorbis (Hapalorbis) hyptius hyptius Woodring, n. sp. and n. subsp.

Plate 17, figures 16–18

Small, thick-shelled, depressed, body whorl increasing rapidly in diameter. Periphery sharply or moderately carinate, except at and near peristome. Umbilicus very narrow, asymmetrical. Umbilical wall very narrow, the angulated umbilical border being inserted almost flush with base of body whorl where it emerges from umbilicus. Parietal callus moderately thick.

Height 0.7 mm, diameter 1.4 mm (type).

Type: USNM 561323; paratypes Stanford Univ.

Type locality: 147b (USGS 6033c, Panama Railroad, about 3,500 feet (1,065 meters) southeast of Gatun railroad station, Canal Zone), middle part of Gatun formation.

The very narrow and asymmetrical umbilicus, and very narrow umbilical wall are conspicuous and characteristic features of this species. It is closely related to the type of *Hapalorbis*: "*Circulus*" *liriope* Bartsch (1911, p. 231, pl. 40, figs. 7–9), which is represented by the type and an imperfect specimen, both dredged at a depth of 21 fathoms off La Paz, Lower California. The fossils are smaller, more depressed, have a smaller more asymmetrical umbilicus and narrower umbilical wall, and lack a spiral thread above and below the peripheral carina.

Solariorbis hyptius proper was found in the lower and middle parts of the Gatun formation, but is rare except at the type locality. The 68 specimens collected at the type locality and the 2 additional specimens from the middle part of the Gatun have remarkably uniform characters. The five specimens from the lower part, however, are not so sharply carinate and reach a slightly larger size.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, locality 138a. Middle part, localities 146, 147b, 147f.

Solariorbis (Hapalorbis) hyptius anebus Woodring, n. subsp.

Plate 17, figures 34–36

Resembling *S. hyptius* proper, but larger and umbilicus correspondingly larger. Peripheral carina flanked above and below by a narrow low spiral thread.

Height 0.9 mm, diameter 1.5 mm (type).

Type: USNM 561324.

Type locality: 185 (USGS 8383, Caribbean coast, west of Río Miguel, Panamá), upper part of Gatun formation.

This subspecies is based on two specimens from the upper part of the Gatun formation. Though the spirals flanking the periphery are narrower and lower than those of "*Circulus*" *liriope*, the sculptural pattern is the same, suggesting close relationship. As indicated by the name, however, alliance with the smaller *Hapalorbis* from the middle part of the Gatun formation is thought to be closer. Both *Solariorbis hyptius* proper and *S. hyptius anebus* have a depressed outline and very narrow umbilical wall, whereas "*Circulus*" *liriope* is less depressed and has a wider umbilical wall.

A Pliocene species from Ecuador, "*Pseudorotella*" *lens* Plisbry and Olsson (1941, p. 47, pl. 9, fig. 2; 1945–52, p. 51, 1952) has the same sculptural pattern as *Solariorbis hyptius anebus* and "*Circulus*" *liriope*, but has a heavy callus facet almost closing the umbilicus and is sculptured with two spiral threads above the periphery, The Recent Panamic "*Vitrinella*" *seminuda* C. B. Adams (Pilsbry and Olsson, 1945–52, p. 278, pl. 27, figs. 3, 3a, 3b, 1945; p. 51, 1952) lacks spirals above the periphery.

Occurrence: Upper part of Gatun formation (middle and late Miocene), eastern area, locality 173, western area, locality 185.

Genus Episcynia Mörch

Mörch, Malakozool. Blätter, Band 22, p. 155, 1875.
Type (monotype): *Architectonica* (*Episcynia*) *inornata* (d'Orbigny) (*Solarium inornatum* d'Orbigny), Recent, West Indies.

In the western Atlantic *Episcynia* ranges from North Carolina to Brazil, and in the eastern Pacific from Santa Cruz Island, Calif., to Perú. Miocene species from Florida and the Caribbean region are the earliest known.

Episcynia megalia Woodring, n. sp.

Plate 18, figures 4, 8

Large, thin-shelled, whorls 5. Suture shallow, located on peripheral carina of preceding whorl, even at peristome. Peripheral carina minutely and irregularly roughened by exaggerated growth wrinkles. Similar growth wrinkles adjoin suture on later part of body whorl. Umbilical half of base and umbilical wall sculptured with more strongly emphasized growth wrinkles. Upper half of umbilical wall also sculptured with two narrow spiral threads that disappear near peristome. Umbilical border sharply angular.

Height 2.7 mm, diameter 5.3 mm (type).

Type: USNM 561325.

Type locality: 138 (USGS 16909, Transisthmian Highway, 1.6 kilometers northeast of Canal Zone boundary, Panamá), lower part of Gatun formation.

Episcynia megalia, which is based on one specimen from the lower part of the Gatun formation, is the largest *Episcynia* so far described. It is most closely related to two species living in the eastern Pacific: *E. nicholsoni* (Strong and Hertlein) (1939, p. 241, pl. 22, figs. 2–4; Panamá) and the closely allied *E. bolivari* Pilsbry and Olsson (1946, p. 11, pl. 1, figs. 6–8; Colombia and Perú; Pleistocene, western Panamá). On both Recent forms the carina is exposed on the later whorls of the spire. *E. nicholsoni* evidently is more depressed than *E. megalia*, and *E. bolivari* has a slight angulation on the body whorl above the periphery.

E. naso (Pilsbry and Johnson) (Pilsbry, 1922, p. 379, pl. 37, figs. 5, 5a), the only other described fossil species from the Caribbean region (Miocene, Dominican Republic and Jamaica), has strong regularly spaced serrations on the peripheral carina.

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

Family RISSOIDAE

Subfamily RISSOINAE

Genus?

"Alvania" aff. "A." epulata (Pilsbry and Johnson)

Minute, rapidly enlarging. Protoconch very large for size of shell, consisting of 2½ rapidly enlarging smooth whorls. Remaining 2¼ whorls sculptured with closely spaced axial ribs (17 on body whorl), between which are closely spaced spiral threads. Base sculptured with three wider and more widely spaced spirals. Outer lip varicose, its interior inaccessible.

Height 1.2 mm, diameter 0.7 mm.

Two minute specimens, both found by T. F. Thompson in the Gatun formation, are the only rissoids. They evidently are conspecific and are closely allied to "*Rissoa*" *epulata* Pilsbry and Johnson (Pilsbry, 1922, p. 384, pl. 34, fig. 5), a Miocene species from an unknown locality in the Dominican Republic. That species is narrowly umbilicate. The specimen from the lower part of the Gatun formation is immature and has a narrow umbilical groove, but the mature specimen from the upper part of the formation, of approximately the same dimensions as the type of "*Rissoa*" *epulata*, is completely nonumbilicate.

Rissoids more or less similar to the Gatun species are generally referred to the genus *Alvania* (Risso, 1826, p. 140; logotype, Nevill, 1884 [1885], p. 105, *Alvania europea* Risso=*Turbo cimex* Linné, Recent, Mediterranean). The type of *Alvania* is four times as large, and has a relatively much smaller protoconch, coarser sculpture, and lirations on the interior of the outer lip.

One or more of the numerous generic and subgeneric names proposed for European, Australian, and Neozelanic rissoids may possibly be suitable for "*Alvania*" aff. "*A.*" *epulata*.

Nevill's designation for the type of *Alvania*—"type *A. cimex* Lin. [as *Alv. europaea* Risso]"—appears to be the earliest valid designation. It has the same effect as numerous designations of *Turbo cimex* Linné and the much later designation of *Alvania freminvillea* Risso, also a synonym of *Turbo cimex* (Gordon, 1939, p. 29).

Occurrence: Lower and upper parts of Gatun formation (middle Miocene). Lower part, locality 136a (1 immature). Upper part, eastern area locality 173 (1 mature, protoconch crushed during examination).

Family RISSOINIDAE

Genus Rissoina d'Orbigny

d'Orbigny, Voyage dans l'Amérique Méridionale, t. 5 (Mollusques), p. 395, 1840.
Type (monotype): *Rissoina inca* d'Orbigny, Recent, Perú and Chile.

Subgenus Zebinella Mörch

Mörch, Malakozool. Blätter, Band 23, p. 47, 1876.
Type (logotype, von Martens, Zool. Record, 1876, p. 30, 1877): *Rissoina decussata* (Montagu) (*Helix decussata* Montagu), Recent, West Indies and Florida (described as a British species).

Rissoina (Zebinella?) species

A poorly preserved altered shell from the Culebra formation is assigned to *Rissoina* on the basis of outline and sculpture. The outer lip and aperture are not preserved. The sculpture, consisting of narrow axial ribs and fine spiral threads between the ribs, suggests the subgenus *Zebinella*.

Occurrence: Culebra formation (early Miocene), Gaillard Cut, locality 99b.

Subgenus Phosinella Mörch

Mörch, Malakozool. Blätter, Band 23, p. 51, 1876.
Type (logotype, Nevill, Hand list of Mollusca in the Indian Museum, pt. 2, p. 73, 83, 1885): *Rissoina pulchra* (C. B. Adams) (*Rissoa pulchra* C. B. Adams), Recent, West Indies.

Rissoina (Phosinella) oncera Woodring, n. sp.

Plate 23, Figure 3

Small, slender. Protoconch of 3½ smooth rapidly enlarging whorls, the last half whorl obscurely angulated. Sculpture reticulate; axial ribs slightly wider than spiral threads. Four spirals at beginning of penult, five on later half. Outer lip strongly varicose. Fasciolelike swelling on base strongly inflated.

Height 4.3 mm, diameter 1.7 mm (type).

Type: USNM 561332.

Type locality: 177c (USGS 5855, west side of Panama Railroad, opposite Mount Hope cemetery, Canal Zone), upper part of Gatun formation.

The type (and only) specimen of this species was collected from the upper part of the Gatun formation at Mount Hope. It is closely allied to *R. guppyi* Cossmann (Woodring, 1928, p. 366, pl. 28, fig. 10), which occurs in the Bowden formation of Jamaica and in the Cercado and Gurabo formations of the Dominican Republic, but has a more widely expanding protoconch, slightly narrower spirals on the early whorls, more inflated fasciolelike swelling, and wider space between the swelling and the lowest spiral. The Recent West Indian and Florida species identified by Dall (1890–1903, pt. 2, p. 343, 1892) as *R. cancellata* Philippi has a smaller protoconch, coarser sculpture, and less inflated fasciolelike swelling.

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

Family XENOPHORIDAE

Genus Xenophora Fischer von Waldheim

Fischer [von Waldheim], Muséum-Demidoff, t. 3, p. 213, 1807.
Type (logotype, Harris, Catalogue of Tertiary Mollusca in the British Museum; pt. 1, Australasian, p. 253, 1897): *Xenophora laevigata* Fischer [von Waldheim] ("*Trochus conchyliophorus* Gmel., Bosc, Born") = *Trochus conchyliophorus* Born, Recent, West Indies.

Unidentified species of *Xenophora* are represented by two molds from the Gatuncillo formation and an incomplete mold from the Culebra formation.

Xenophora delecta (Guppy)

Plate 22, figures 1, 2,4

Phorus agglutinans (Lamarck), Gabb, Am. Philos. Soc. Trans., n. ser., v. 15, p. 241, 1873 (Miocene, Dominican Republic).
Phorus delecta Guppy, Geol. Soc. London Quart. Jour., v. 32, p. 529, pl. 28, fig. 10, 1876 (Miocene, Dominican Republic).
Xenophora delecta (Guppy), Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 134, pl. 23, figs. 8, 9, 1917 (Miocene, Dominican Republic). Pilsbry, 1922, Acad. Nat. Sci. Phila. Proc., v. 73, p. 385, pl. 32, figs. 7, 8, 1922 ("*dilecta*" by error; Miocene, Dominican Republic). Woodring, Carnegie Inst. Washington Pub. 385, p. 376, pl. 30, figs. 3, 4, 1928 (Miocene, Jamaica).
Xenophora conchyliophora (Born), Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 133, pl. 23, fig. 7, 1917 (Miocene, Dominican Republic).
Xenophora aff. *trochiformis* (Born), Rutsch, Schweizer. Palaeont. Gesell. Abh., Band 54, no. 3, p. 48, pl. 2, figs. 2, 3, 1934 (Miocene, Venezuela).

Moderately large, widely umbilicate. Spire low, periphery somewhat extended. Sculpture above periphery, between agglutinated shells and shell fragments, consisting of strongly protractive irregularly rippled threads. Base sculptured with more uniform rippled arcuate threads parallel to columeller lip, which is broken back.

Height 25 mm, diameter (incomplete) 46 mm (figured specimen).

Type: British Mus. (Nat. Hist.), Geol. Dept., Geol. Soc. London 12842.

Type locality: Dominican Republic, Miocene.

An incomplete *Xenophora*, found by T. F. Thompson in the upper part of the Gatun formation at Stanford University locality 2654 near Fort Davis, is referred to *X. delecta*. The attached shells and shell fragments with one exception (a fragment of the body whorl of a *Phos*-like gastropod, attached by the exterior surface) consist of pelecypods, *Aequipecten* being most abundant. These pelecypods and pelecypod fragments are concave side upward, also with one exception: a fragment of a mature *Aequipecten scissuratus*.

The generally open umbilicus and relatively strong sculpture differentiate *X. delecta* from the only Recent species in the Caribbean region, *X. conchyliophora* (Born). The Gatun fossil is widely umbilicate. On specimens of comparable size from the Dominican Republic the umbilicus is narrower and even reduced to a narrow groove. Rutsch's illustration of a specimen from the late Miocene Punta Gavilán formation of Venezuela also shows only a narrow groove.

The type of *X. delecta* is a small specimen, like specimens from the Gurabo formation in the collections of the U. S. National Museum (maximum diameter 24 mm). Two imperfect shells from the Cercado formation are even smaller. The Bowden formation of Jamaica also has yielded only small specimens (maximum diameter 19 mm). The ripples on the base of these small specimens, from both the Dominican Republic and Jamaica, are so strong that they form nodes. Pilsbry figured two large specimens (diameter 51 and 56 mm) that are in Gabb's collection of fossils from the Dominican Republic, and Maury illustrated, under the name *X. conchyliophora*, a large specimen from the Gurabo formation.

X. textilina Dall (Gardner, 1926–47, p. 561, pl. 58, figs. 31, 32, 1947), of the Chipola formation of Florida, evidently is an early form of *X. delecta*. It is umbilicate, but its sculpture is not as strong as that of *X. delecta*. The larger of the two syntypes figured by Gardner is herewith designated the lectotype. The widely umbilicate strongly sculptured fragment from the Shoal River formation, doubtfully recorded as *X. textilina*, is indistinguishable from *X. delecta*. It might, however, be the high-spired subspecies of *X. delecta*, *X. delecta floridana* Mansfield (1930, p. 121, pl. 18, figs. 5, 6), which occurs in upper Miocene deposits in western Florida.

X. delecta left no descendents in the Caribbean or Panamic regions. It is closely related, however, to *X. senegalensis* Fischer, a Recent west African species, and its close Recent Mediterranean ally, *X. crispa* "König" Bronn, which occurs in rocks of late Miocene and Pliocene age in Italy. *X. delecta* has somewhat coarser sculpture than those species.

The Recent Caribbean *X. conchyliophora* has a long history in the southeastern states and is one of the few Recent species recognized in the Eocene of that region. The Recent Panamic *X. robusta* Verrill, characterized by the deep orange-brown parietal callus and adjoining inner half of the interior of the body whorl, is better treated as a subspecies of *conchyliophora*.

Occurrence: Upper part of Gatun formation (middle Miocene), eastern area, locality 173. Cercado and Gurabo formations (middle Miocene), Dominican Republic. Bowden formation (middle Miocene), Jamaica. Punta Gavilán formation (late Miocene), Falcón, Venezuela.

Family HIPPONICIDAE

Genus Hipponix Defrance

Defrance, Jour. Phys. Chim. Hist. Nat. Arts, t. 88, p. 217, 1819.

Type (logotype, Gray, Zool. Soc. London Proc., p. 157, 1847): *Patella cornucopia* (*Patella cornucopia* Lamarck), Eocene, Paris Basin.

Hipponix species

The Gatuncillo fossils from the Río Casaya area include a small presumably immature *Hipponix*, shaped like a wide cornucopia. Some growth lamellae are exaggerated and there is a faint suggestion of fine radial sculpture. The muscle scar is not discernible.

Length (not quite complete) 9 mm, width 7.5 mm, approximate height 6.5 mm.

So far as this small specimen goes, it suggests a miniature replica of the type species of the genus.

Occurrence: Gatuncillo formation (middle Eocene), Río Casaya area, locality 38.

Family HIPPONICIDAE?

Hipponix? species

A poorly preserved limpet-shaped fossil from the Culebra formation is doubtfully referred to *Hipponix*. It is moderately large and elongate, and the apex is near the posterior end. The apex is worn and practically smooth. Preserved parts of the outer shell are sculptured with crude radial ribs overriden by crude concentric threads. The interior is inaccessible.

Approximate dimensions: length 21 mm, width 17 mm, height 9 mm.

If this fossil is an *Hipponix*, it is more similar to the Pacific *H. pilosus* (Deshayes) (an earlier name for *H. barbatus* Sowerby) than to Caribbean Recent species. *H. pilosus* ranges from California to Ecuador and the Galapagos, and is found in the western Pacific. It is recorded from the Miocene of the Dominican Republic (Pilsbry, 1922, p. 384).

Occurrence: Culebra formation (early Miocene), Gaillard Cut, locality 108c.

Family CREPIDULIDAE

Genus Crepidula Lamarck

Lamarck, Soc. Hist. Nat. Paris Mém., p. 78, 1799.
Type (monotype): *Patella fornicata* Linné, Recent, eastern United States.

Molds from the Culebra formation are identified as *Crepidula* sp.

Crepidula cf. C. maculosa Conrad

Plate 19, figures 4, 5

Crepidula gatunensis Toula, K. k. Geol. Reichsanstalt Jahrb., Band 61, p. 498, pl. 31, figs. 12a, b, 1911 (Miocene, Canal Zone).

Of medium size, moderately narrow, moderately vaulted. Protoconch of small specimens consisting of about 1¼ whorls of neritoid outline. Deck of small specimens moderately deep seated, bearing a wide shallow median indentation.

Length 28.5 mm, width 17.5 mm, approximate height 10.5 mm (figured specimen).

A species of *Crepidula* from the Gatun formation is comparable to the Recent *C. maculosa*, to which attention has recently been called (Stingley, 1952). As pointed out by Stingley, *C. maculosa* has a pedal muscle scar adjoining the adapical insertion of the deck and the edge of the deck has a very slight median indentation, whereas the better known and more northern *C. fornicata* (with which *C. maculosa* has been confused) lacks the muscle scar and has a pronounced median indentation.

The only fairly large shell from Gatun (pl. 19, figs. 4, 5) is attached to a crab carapace and the interior is inaccessible. Owing presumably to inequalities on the carapace, this shell has two faint depressions and correspondingly modified growth lines. The other shells (all of which are small, ranging in length from 1.5 to 12 millimeters) evidently represent the same species as the fairly large specimen. Two that are moderately small show the muscle scar of *C. maculosa*.

According to Toula's description and illustration, *C. gatunensis* was based on a small shell (length 2.8 millimeters) like those in the collections at hand. That name is available, should the name *C. maculosa* be found to be inappropriate for the fossils.

Though *C. fornicata* is recorded from the Miocene of Trinidad (Maury, 1925, p. 244), it is unlikely that that species lived in the Caribbean Sea at any time.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, localities 137, 138. Middle part, eastern area, localities 147b, 155c, 157. Upper part, eastern area, locality 178.

Crepidula plana Say

Plate 19, figures 1–3

Crepidula plana Say, Acad. Nat. Sci. Phila. Jour., 1st ser., v. 2, p. 226, 1822 (Recent, Maryland to Florida). Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 2, p. 358, 1892 (Miocene to Recent, eastern United States). Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 63, p. 360, 1911 (Miocene, Canal Zone). Brown and Pilsbry, idem, v. 65, p. 495, 1913 (Pleistocene, Canal Zone). Pilsbry, idem, v. 73, p. 385, 1922 (Miocene, Dominican Republic). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 159, 1922 (Miocene, northwestern Panamá). Gardner, U. S. Geol. Survey Prof. Paper 142, p. 565, 1947 (Miocene, Florida); see this publication for other citations.

Crypta fornicata (Linné), Gabb, Am. Philos. Soc. Trans., v. 15, p. 242, 1873 (Miocene, Dominican Republic).

Of medium size, narrow, compressed, flat or concave. Protoconch of immature shells consisting of 1¼ to 1½ rapidly enlarging whorls of neritoid outline, destroyed at later stage by encroachment of aperture. Deck bearing a moderately deep narrow abapical marginal indentation and a moderately deep very wide median indentation.

Length 15 mm, width 10.5 mm, height 2 mm (larger figured specimen).

Slipper limpets recovered from the apertures of Gatun coiled gastropods agree closely with the Recent *Crepidula plana*. All the fossils were found in the lower part of the formation. *C. plana* is already recorded from the Gatun formation of the Canal Zone and from late Miocene strata in northwestern Panamá.

A species of *Crepidula* that has a similar outline and similar deck characters is living in the eastern Pacific Panamic region. It presumably is *C. nivea* C. B. Adams, but is generally known as *C. nummaria* Gould. The few specimens of this species from Panamá in the collection of the U. S. National Museum have slightly deeper deck indentations than *C. plana*.

Occurrence: Lower part of Gatun formation (middle Miocene), localities 137a, 138, 138a. Middle part of Gatun formation (middle Miocene), eastern area (Brown and Pilsbry). Late Miocene, Water Cay, Panamá. Miocene, Dominican Republic. Early to late Miocene, Maryland to Florida. Pliocene, North Carolina to Florida. Pleistocene, Massachusetts to Florida, Canal Zone. Recent, Prince Edward Island, Canada, to Texas and the West Indies.

Family Calyptraeidae

The genus *Cheilea* is not represented in the collections at hand. *Cheilea princetonia* Brown and Pilsbry (1911, p. 360, fig. 2), based on an internal and external mold from the Gatun formation, may be conspecific with the *Cheilea* from the Bowden formation of Jamaica identified as the Recent Caribbean form designated *C. equestris* (Linné) (Woodring, 1928, p. 375, pl. 30, figs. 1, 2).

Genus Calyptraea Lamarck

Lamarck, Soc. Hist. Nat. Paris Mém., p. 78, 1799.
Type (monotype): *Patella chinensis* Linné, Recent, western Europe.

An unidentified small *Calyptraea* that has an eccentric apex is represented by poorly preserved specimens from the marine member of the Bohio(?) formation at Vamos Vamos.

Calyptraea cf. C. aperta (Solander)

Molds of a relatively large, relatively high-spired *Calyptraea* from the Gatuncillo formation of Madden basin are comparable to *C. aperta*, which is widely distributed in the Eocene and Oligocene of western Europe and southeastern United States. (For citation and synonomy see Palmer, 1937, p. 145.) In tropical America *C. aperta*, or a comparable form, is recorded from the Paleocene of Trinidad and the Eocene of Colombia and Perú.

Occurrence: Gatuncillo formation (late Eocene), localities 9, 12.

Calyptraea centralis (Conrad)

Infundibulum centralis Conrad, Am. Jour. Sci., 1st ser., v. 41, p. 348, 1841 (Miocene, North Carolina, p. 343). Conrad, Fossils of the Medial Tertiary of the United States, No. 3 (Fossils of the Miocene formation of the United States), p. 80, pl. 45, fig. 5, 1845 (Miocene, North Carolina).

Trochita sp. indet., Gabb, Am. Philos. Soc. Trans., v. 15, p. 242, 1873 (Miocene, Dominican Republic).

?*Trochita collinsii* Gabb, Acad. Nat. Sci. Phila. Jour., 2d ser., v. 8, p. 342, pl. 44, figs. 11, 11a, 1881 (Miocene, Costa Rica).

Calyptraea centralis (Conrad), Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 2, p. 353, 1892 (Miocene to Recent). Maury, Acad. Nat. Sci. Phila. Jour., 2d ser., v. 15, p. 100, pl. 13, fig. 6, 1912 (Miocene, Trinidad). Maury, New York Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 1, p. 48, 1920 (Miocene, Puerto Rico). Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 73, p. 385, 1922 (Miocene, Dominican Republic). Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 243, pl. 43, fig. 2, 1925 (Miocene and Pliocene, Trinidad). Gardner, U. S. Geol. Survey Prof. Paper 142, p. 562, pl. 56, figs. 3–5, 1947 (Miocene, Florida); see this publication for other citations.

?*Calyptraea* cf. *centralis* (Conrad), Hubbard, N. Y. Acad. Sci., Scientific Survey of Porto Rico and Virgin Islands, v. 3, pt. 2, p. 133, 1920 (Miocene, Puerto Rico). Maury, 1925, Brasil Serv. Geol. Min. Mon. 4, p. 65, pl. 1, figs. 5, 10, 1925 (Miocene Brazil).

Of medium size, circular in ventral plan, apex central. Protoconch of about 1½ strongly inflated, rapidly enlarging whorls. Free edge of platform convex forward; reflected columellar edge not closely appressed, forming a relatively high umbilicuslike opening.

Maximum diameter 16 mm, height 6 mm (largest specimen).

Type: Apparently lost.

Type locality: Natural Well, N. Car., Duplin formation (late Miocene).

Specimens from the Culebra formation, identified as *Calyptraea* cf. *C. centralis*, are comparable in size and outline to *C. centralis*, but none shows the interior. All are molds, with the exception of one, which was collected at locality 108c and has much of the shell preserved.

The description is based on specimens from the lower part of the Gatun formation. The only large specimen, from locality 138, is imperfect. The interior of the only specimen from the middle part of the Gatun formation is inacessible. It is listed as *Calyptraea* cf. *C. centralis*.

The Gatun fossils that show the interior agree closely with topotypes of *C. centralis* collected at Natural Well, N. Car. As pointed out by Dall and Gardner, Recent specimens are smaller than those from the Miocene. Recent specimens in the collection of the U. S. National Museum, representing localities from Cape Hatteras to the West Indies, are not more than a third the size of large Miocene fossils. Two large Recent shells, however, are exceptions. One, which has a maximum diameter of 11.5 millimeters, was cataloged at an early date and is labelled "West Indies." The other (maximum diameter 15.5 millimeters) was in the Henderson collection and is labelled "Marco, Florida." The reflected edge of the platform of both is closely appressed, like that of the western European *C. chinensis*, the type of the genus. They probably are specimens of that species with erroneous locality data. Should a name be desirable for the small Recent race, it may be designated *Calyptraea centralis candeana* (d'Orbigny), as indicated by Dall's synonymy. Pliocene fossils from the Caloosahatchee marl of Florida have a maximum diameter of 10 millimeters and therefore are intermediate in size.

The Recent Panamic *C. mamillaris* Broderip is larger than *C. centralis*, and has a thicker shell and mottled brown color pattern.

Occurrence: Culebra formation (early Miocene; *Calyptraea* cf. *C. centralis*), Gaillard Cut, localities 99b, 99c, 100, 108c, 110a. Lower and middle parts of Gatun formation (middle Miocene); lower part, localities 137, 138, 138a; middle part, eastern area, locality 147j, (*Calyptraea* cf. *C. centralis*). Early Miocene, Puerto Rico, ?Costa Rica, ?Brazil. Late Miocene(?), Trinidad. Miocene, Dominican Republic. Early to late Miocene, Maryland to Florida. Pliocene, Trinidad, Florida. Recent (small race) Cape Hatteras to West Indies.

Genus Trochita Schumacher

Schumacher, Essai d'un nouveau système des habitations des vers testacés, p. 57, 184, 1817.

Type (logotype, Rehder, Biol. Soc. Washington Proc., v. 56, p. 41, 1943): *Trochita spiralis* Schumacher (= *Trochus radians* Lamarck = *Turbo trochiformis* Born), Recent, Ecuador to Chile.

Trochita has a thick shell, distinct suture, and moderately strong to strong radial sculpture. The free edge of the platform is convex forward, except at the distal margin, where it bears a narrow identation. The columellar edge of the platform is reflected only at its insertion. On adult shells this short reflected border is molded on the platform, like callus. The genus and its species were discussed by Rehder (1943) in the publication cited for the type designation.

Trochita heretofore has not been recorded from the Caribbean region. It is now extinct there, and in the western Atlantic is limited to the Falkland Islands and the coast of Argentina. Though it occurs in the Miocene and Pliocene of California, in the eastern Pacific it is now found only south of the equator. The survival of the genus in west African waters—a genus otherwise confined to the Peruvian, Magellanic, and South African provinces—is more readily understood in view of its occurrence in the Miocene of the Caribbean region and in the Pliocene and Pleistocene of west Africa. The West African species is considered conspecific with the Miocene Caribbean fossil and the Recent eastern Pacific species. It is an expectable fossil in the West African Miocene.

Trochita trochiformis (Born)

Plate 19, figures 11–14

Turbo trochiformis Born, Index Musei Caesarei Vindobonensis, p. 355, 1778 (sole citation: Knorr, pt. 3, pl. 29, figs. 1, 2, 1768, "Antillean Islands").

Trochus radians Lamarck, Encyclopédie méthodique, Histoire naturelle des vers, t. 3, pl. 445, figs. 3a, b; Liste, p. 10, 1816. Lamarck, Histoire naturelle des animaux sans vertèbres, t. 7, p. 11, 1822 (Recent, "mer des Antilles").

Calyptraea (*Trochatella*) *trochiformis* (Gmelin), d'Orbigny, Voyage dans l'Amérique Méridionale, t. 5, pt. 3, p. 461, pl. 59, fig. 3, 1841 (Recent, Chile, Perú; *Calyptraea radians* in explanation of plate). Nicklès, Manuels Ouest-Africains, t. 2, p. 73, fig. 99, 1950 (Recent, Angola). Lecointre, Morocco Service Géologique, Notes et Mém. 99, t. 2, p. 108, pl. 25, figs. 1–4, 1952 (Pleistocene, Morocco).

Infundibulum trochiforme (Gmelin), d'Orbigny, Voyage dans l'Amérique Méridionale, t. 3, pt. 4 (Paléontologie), p. 158, 1842 (Pleistocene, Chile).

Trochita radians (Lamarck), Reeve, Conchologia Iconica, v. 11, *Trochita*, pl. 1, species 3, 1859 (Recent, Chile). Sowerby, Thesaurus Conchyliorum, v. 5, p. 64, pl. 451, figs. 95, 96, 99, 1883 (Recent, Chile). Rehder, Biol. Soc. Washington Proc. v. 56, p. 42, 1943 (Recent, Ecuador to Chile); see this publication for other citations and synonymy.

Calyptraea (*Trochita*) *trochiformis* (Gmelin), Grant and Gale, San Diego Soc. Natural History Mem., v. 1, p. 795, pl. 31, fig. 11, 1931 (Miocene and Pliocene, California; Recent-Panamá to Perú).

Trochatella trochiformis (Gmelin), Lecointre, Jour. Conchyliologie, t. 90, p. 240, unnumbered pl., fig. 2, 1950 (Pliocene, Pleistocene, Morocco).

Of medium size, moderately low spired or moderately high spired, apex broken. Sculpture consisting of heavy crude axial ribs. Platform broken back to insertion.

Maximum diameter 28.8 mm, height (incomplete) 10.7 mm (smaller figured specimen). Maximum diameter 43.5 mm, height (almost complete) 27 mm (larger figured specimen).

This calyptraeid is represented by two specimens from the lower part of the Gatun formation, both collected by T. F. Thompson. Though the interior of the larger specimen is inaccessible and the platform of the smaller is broken far back, they are identified with considerable confidence as *Trochita trochiformis*. The middle part of the Gatun formation in the western area at locality 151 yielded a worn thick-shelled apical fragment listed as *Trochita?* sp. Incomplete and poorly preserved fossils from the middle member of the Caimito formation in the Gatun Lake area and the Culebra formation suggest that the lineage of *T. trochiformis* can be traced back to the late Oligocene. None of these Caimito and Culebra fossils, however, is unequivocally identified.

Trochita trochiformis now ranges from Manta, Ecuador, to Valparaiso, Chile. It is low spired to high spired. On low-spired shells the platform is almost flush with the base of the shell; on high-spired shells it is a considerable distance above the base. The heavy crude axial ribs are characteristic. The largest Recent specimen in the collection of the U. S. National Museum has a maximum diameter of 65 millimeters.

A small form of *Trochita trochiformis* (recorded as *T. radians*) occurs in formations of Pliocene age in California as far north as the Santa Maria district (Arnold and Anderson, 1907, p. 60, pl. 21, fig. 1; Woodring and Bramlette, 1950 [1951], p. 72, pl. 13, fig. 19), in Santa Barbara County. Early and middle Miocene forms from California have been identified as *Trochita costellata* Conrad (Eldridge and Arnold, 1907, p. 148, pl. 32, fig. 3; Loel and Corey, 1932, p. 268, pl. 63, fig. 11), and late Miocene forms have been named "*Calyptraea*" *diabloensis* Clark (1915, p. 485, pl. 70, fig. 9) and "*Calyptraea*" *martini* Clark (1915, p. 486, pl. 70, fig. 8). As suggested by Grant and Gale, these heavily ribbed Miocene forms, ranging in age from early to late Miocene, are probably to be referred to *Trochita trochiformis*. The inadequate type material of *Trochita costellata* Conrad (1857b, p. 195, pl. 7, fig. 3) consists of two molds showing traces of relatively fine ribs. Additional specimens from the type locality (Gaviota Pass in the western Santa Ynez Mountains, Santa Barbara

County, Calif.) have not been described and the age is still unknown.

I am indebted to R. T. Abbott for pointing out that Born's *Turbo trochiformis* is an earlier name for Lamarck's *Trochus radians*.

Occurrence: Middle member of Caimito formation (late Oligocene), Gatun Lake area, localities 57 (*Trochita?* sp.), 57a (*Trochita* cf. *T. trochiformis*). Culebra formation (early Miocene), Gaillard Cut, localities 115a (*Trochita?* cf. *T. trochiformis*), 115b (*Trochita* cf. *T. trochiformis*, 116 (*Trochita* cf. *T. trochiformis*). Lower part of Gatun formation (middle Miocene), locality 136, 136a. Middle part of Gatun formation (middle Miocene), western area, locality 161c (*Trochita?* sp.). Miocene, California (identification doubtful). Pliocene, California, Morocco. Pleistocene, Chile, Cape Verde Islands, Morocco. Recent, Manta, Ecuador, to Valparaiso, Chile; Cape Verde Islands, Angola.

Genus Crucibulum Schumacher

Schumacher, Essai d'un nouveau système des habitations des vers testacés, p. 56, 182, 1817.

Type (logotype, Burch, Conchological Club Southern Calif. Proc., no. 56, p. 19, 1946): *Crucibulum planum* Schumacher (=*Patella auricula* Gmelin), Recent, Florida and West Indies.

J. E. Gray's (1847, p. 157) designation of *Patella auriculata* as the type of *Crucibulum* is not valid in the strict sense, as *Patella auriculata* was not mentioned by Schumacher. Schumacher, however, based *Crucibulum planum* on Chemnitz's *Patella auriculata* without mentioning it by name. Both *Crucibulum planum* and *Patella auriculata*, given binomial standing by Dillwyn in the year when Schumacher published the generic name *Crucibulum*, are synonyms of *Patella auricula* Gmelin.

The recent type designation by Burch, on the advice of Keen, appears to be the first valid designation. The question of possible virtual monotypy, raised by Keen, need not be considered. Whatever the status of *Crucibulum rugoso-costatum*, the only other species mentioned by Schumacher, may be, *Crucibulum* was not monotypic.

Unidentified molds from the Culebra formation, the Alhajuela sandstone member of the Caimito formation, and the Chagres sandstone are listed as *Crucibulum* sp.

Subgenus Crucibulum s. s.

Crucibulum (Crucibulum) chipolanum Dall

Plate 19, figures 6, 7

Crucibulum auricula var. *chipolanum* Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 2, p. 349, 1892 (Miocene, Florida).

Crucibulum chipolanum Dall, Gardner, U. S. Geol. Survey Prof. Paper 142, p. 567, pl. 56, figs. 10, 11, 1947 (Miocene, Florida).

Of medium size, elliptical in ventral plan. Protoconch of about 1½ rapidly enlarging whorls. Shell smooth to diameter of 1½ to 3 mm. At that stage the shell is elliptical and the apex lies far to the rear. Sculpture consisting of closely spaced crudely roughened radial ribs, some of which bifurcate and a few of which unite as they extend outward. Right anterior border of cup sharply angulated, joined to side of shell at level far above ventral margin of cup.

Maximum diameter 27 mm, height 16.5 mm (figured specimen).

Type (lectotype, the specimen figured by Gardner): USNM 112783.

Type locality: USGS 2212, Tenmile Creek, Fla., Chipola formation (early Miocene).

Specimens from the middle part of the Gatun formation at the Gatun Third Locks excavation closely resemble *Crucibulum chipolanum* in characters of protoconch, sculputre, and cup. The right side of the cup of the figured specimen was uncovered, but the shell is too fragile to uncover the entire cup. Locality 155c yielded a worn incomplete specimen. It shows the same kind of cup and traces of radial ribs, but is only tentatively identified as *C. chipolanum*.

C. chipolanum was described as a variety of the Recent Caribbean *C. auricula* (Gmelin). Undoubtedly it is closely related to that species and to the Recent Panamic *C. spinosum* (Sowerby). The cups of all three are similar. The sculpture of *C. auricula* is weaker and more varied than that of *C. chipolanum*. As pointed out by Gardner, the protoconch whorls of *C. auricula* are wider and emerge more obtusely. Both *C. auricula* and *C. spinosum* are recorded from the Miocene of the Dominican Republic (Pilsbry, 1922, p. 385).

A species of *Crucibulum* from the Shoal River formation of Florida and its Oak Grove sand member, *C. chipolanum dodoneum* Gardner (1926–47, p. 567, pl. 56, figs. 18–20, 1947), has coarser sculpture than *C. chipolanum*. It presumably is not closely related, however, to *C. chipolanum*, as its cup is attached to the side of the shell at the level of the ventral margin of the cup.

Dall designated no type material for *C. chipolanum*. In his description he mentioned only one locality: the Chipola River, a mile below Baileys Ferry. He also examined and identified, however, specimens from the nearby Tenmile Creek locality, a mile west of Baileys Ferry. The specimen from the Tenmile Creek locality figured by Gardner is herewith designated the lectotype.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, localities 155, 155b, 155c (including a doubtfully identified worn specimen). Chipola formation (early Miocene), Florida.

Subgenus Dispotaea Say

Say, Acad. Nat. Sci. Phila. Jour., 1st ser., v. 4, p. 131, 1824.
Type (logotype, Olsson and Harbison, Acad. Nat. Sci. Phila. Mon. 8, p. 276, 1953): *Calyptraea costata* Say, Miocene, Maryland.

After describing *Calyptraea grandis*, Say remarked that it does not properly belong in the genus *Calyptraea* and therefore proposed to place it in a new genus *Dispotaea*. He then assigned two other species to *Dispotaea: Dispotaea tubifera*, a new Recent species from South America, and his previously described *Calyptraea costata* (Say, 1820, p. 40; see p. 38 for locality data), a fossil species from Upper Marlborough, Maryland, associated with others now known to be Miocene. The types of these three species evidently are lost. So far as known *Dispotaea tubifera* has not been recognized. *Calyptraea costata* has been interpreted in different ways by Dall (1890–1903, pt. 2, p. 349, 1892) and Martin (1904, p. 244, pl. 58, figs. 7a, b). Dall thought it is the strongly costate *Crucibulum* that occurs in the St. Marys formation of Maryland and assigned it varietal rank under *Crucibulum auricula*, the type of *Crucibulum*. According to Martin, it is the weakly costate *Crucibulum* found in the Calvert formation of Maryland. Martin's interpretation is reasonable in view of the locality cited by Say and in view of Say's statement that the cup is attached by one side to the wall of the shell. At all events Martin's identification is accepted.

Olsson and Harbison, apparently not realizing that Say assigned the unequivocally identifiable *Calyptraea grandis* to *Dispotaea*, recently designated *Calyptraea costata* as the type of *Dispotaea*.

The cup of *Dispotaea* is attached by the right side, or part of the right side, to the interior of the shell. The type species has a wide attachment area; *Crucibulum grande* has an attachment area of varied width. The Recent *Crucibulum striatum* (Say) (Nova Scotia to Florida), which has been cited as the type of *Dispotaea* by several authors, has a consistently wide attachment area.

Crucibulum (Dispotaea) springvaleense Rutsch

Plate 19, figures 8–10

?*Capulus? gatunensis* Toula, K. k. Geol. Reichsanstalt Jahrb., Band 58, p. 692, pl. 25, fig. 1, 1909 (Miocene, Canal Zone). Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 63, p. 360, 1911 (Toula's record).
Capulus? sp., Toula, K. k. Geol. Reichsanstalt Jahrb., Band 58, p. 692, pl. 25, fig. 2, 1909 (Miocene, Canal Zone).
Crucibulum (*Dispotaea*) *gatunense* (Toula), Anderson, Calif. Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 121, pl. 13, figs. 4–6, 1929 (Miocene, Canal Zone, Colombia).
Crucibulum? springvaleense Rutsch, Naturf. Gesell. Basel Verhandl., Band 54, p. 138, pl. 4, fig. 8, 1942 (Miocene, Trinidad).

Of medium size, circular to elliptical in ventral plan. Protoconch of 1¼ to 1½ rapidly enlarging whorls. Shell smooth to a diameter of 3 to 6 mm. Shell at that stage circular and apex central or subcentral. Sculpture consisting of heavy widely spaced radial ribs, the interspaces bearing crude concentric lamellae, or consisting of closely spaced, generally narrower, roughened and pitted irregular ribs. Right side of cup widely attached to interior of shell.

Maximum diameter 19.2 mm, height 11 mm (figured specimen). Maximum diameter 24.5 mm, height 14 mm (largest specimen).

Type: 518/190 Basel Natural History Museum.

Type locality: Springvale quarry, Trinidad, Springvale formation (late Miocene).

Crucibulum springvaleense is widely distributed in the Gatun formation. Though the interior of the Trinidad specimens, on which this species was based, is unknown, the *Crucibulum* from Panamá is unequivocally identified. Coarsely sculptured specimens have the external characters of a topotype of *C. springvaleense* kindly forwarded by Dr. Rutsch. Some fossils from Panamá have only regular coarse sculpture, others only irregular generally finer sculpture, and still others, like the specimen figured, a combination of both.

This species has left no descendants in the Caribbean region. It appears to be allied, however, to the Recent Panamic *Crucibulum pectinatum* Carpenter, which has fewer ribs than the coarsely sculptured typical form of *C. springvaleense*. *C. pectinatum* ranges from the southern part of the Gulf of California to Panamá, possibly to Perú.

It is unlikely that *Crucibulum springvaleense* is the species Toula described as *Capulus? gatunensis*. At a diameter of 11.5 millimeters, the greatest diameter of the type of *Capulus? gatunensis*, it should show traces of strong sculpture, if it were the *Crucibulum*. According to a communication from Dr. Rutsch, who examined the types of Toula's Gatun gastropods, the type of *Capulus? gatunensis* is an unidentifiable mold retaining parts of the inner shell layer. In the text Toula cited figures 1 and 2 of plate 25 for *Capulus? gatunensis*. According to the explanation of the plate and the dimensions, however, figure 2 is his *Capulus?* sp. Figure 2 quite certainly represents a mold of the coarsely sculptured *Crucibulum* that occurs in the Gatun formation. Perhaps through this error in citation Anderson was led to use the name *Crucibulum gatunense* for that species.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle and late Miocene). Lower part, localities 137, 137a, 138, 138a, 139. Middle part, eastern area, localities 146, 147b, 147e, 147f (identification doubtful, immature specimens only), 147g, 147h, 151, 152, 155, 155a, 155b, 155c, 159, 160 (*Crucibulum* cf. *C. springvaleense*); western area, locality 162a. Upper part, western area, locality 185. Springvale formation (late Miocene), Trinidad. Miocene, Bolívar, Colombia.

Family NATICIDAE

Subfamily NATICINAE

Genus Natica Scopoli

Scopoli, Introductio ad historiam naturalem, p. 392, 1777.
Type (logotype, Harris, Catalogue of Tertiary Mollusca in the British Museum; pt. 1, Australasian, p. 255, 1897); *Nerita vitellus* Linné, Recent, tropical western Pacific.

Anton (1839, p. 31) also designated *Nerita vitellus* as the type of *Natica* at a much earlier date than Harris. Anton's designation, however, is of doubtful validity, as it is a designation for *Natica* Lamarck.

Subgenus Natica s. s.?

Natica (Natica?) species

The collections from the marine member of the Bohio(?) formation at Vamos Vamos include two naticid opercula that have a narrow marginal rib, separated by a shallow groove from a wider second rib. They represent *Natica* s. s. or possibly some other subgenus that has a similar operculum. The larger specimen has a restored length of about 12 millimeters and a width of 7.5 millimeters. Small poorly preserved shells from locality 42 may represent this species.

Occurrence: Marine member of Bohio(?) formation (late Eocene or early Oligocene), localities 40, 40d, 42 (identification doubtful).

Natica (Natica?) bolus Brown and Pilsbry

Plate 20, figures 1–3

Natica bolus Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 64, p. 508, pl. 22, fig. 9, 1913 (Miocene, Canal Zone).
Natica youngi Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 135, pl. 23, figs. 11, 12, 1917 (Miocene, Dominican Republic). Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 73, p. 386, pl. 34, fig. 21, 1922 (Miocene, Dominican Republic). Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 239, pl. 40, fig. 4, 1925 (Miocene, Trinidad). Mansfield, U. S. Natl. Mus. Proc., v. 66, art. 22, p. 57, 1925 (Miocene, Trinidad).
Natica finitima Pilsbry and Johnson, Acad. Nat. Sci. Phila. Proc., v. 69, p. 173, 1917 (Miocene, Dominican Republic).
Not *Natica youngi* Maury, Li, Geol. Soc. China Bull., v. 3, p. 266, pl. 6, figs. 47, 47a, 1930 (Miocene, Panama Bay; = *Natica unifasciata* Lamarck, fide Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 83, p. 432, 1931, Recent, Panamá Bay).
Not *Natica* (*Polinices*) cf. *youngi* Maury, Trechmann, Geol. Mag., v. 72, p. 550, pl. 20, figs. 3–5, 1935 (Miocene, Carriacou); = *Polinices* sp.

Of medium size, thick-shelled, spire very low or moderately low, shoulder strongly or slightly inflated. Protoconch not clearly differentiated from remainder of shell, apical whorl large. Umbilicus wide, umbilical rib narrow, ending in a small callus lobe bearing a shallow anterior depression. A narrow deep groove lies in front of umbilical rib and callus pad, separating them from umbilical border. Parietal callus thick, especially in front of junction with outer lip, where it forms a ridge. On immature shells anterior part of parietal callus relatively wider than on mature shells and roofing over posterior end of umbilicus as it extends forward to join umbilical lobe. Operculum assumed to represent this species bearing a narrow marginal rib, separated by a narrow groove from a second rib that is as narrow as the marginal rib or slightly wider.

Height 14.5 mm, diameter 15.2 mm (figured mature specimen). Height 9.7 mm, diameter 10.2 mm (figured immature specimen).

Type: Acad. Nat. Sci. Phila. 3846.

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

The type, the largest of 6 in the type lot, is a small immature shell (height 9 millimeters). On the type and other immature shells, such as that shown on plate 20, figure 3, the anterior part of the parietal callus is wide and roofs over the posterior end of the umbilicus. On mature shells more of the umbilicus is uncovered. The largest shell, which is incomplete, has a height of 19.5 millimeters. Very low-spired shells have an inflated shoulder, whereas shells that have a higher spire have a less inflated shoulder. Two small opercula assumed to represent *N. bolus* were found in association with shells at locality 155c and another of medium size at locality 172.

Though *Natica bolus* is fairly widespread in the Gatun formation, only a few specimens were collected at any locality, except locality 177b. *N. youngi*, from the Miocene of the Dominican Republic, reaches a somewhat larger size (height 24 millimeters), but has the umbilical and callus features, as well as the outline, of *N. bolus*. *N. youngi* from the Miocene of Trinidad has a narrower umbilicus and less conspicuous umbilical rib than *N. bolus*, but is considered conspecific. *N. youngi cocleana* Olsson (1922, p. 155, pl. 13, fig. 8; Miocene, Costa Rica), however, has a narrow umbilicus, weak umbilical rib, and narrower umbilical callus lobe, and evidently is not closely related. An early Miocene species from Costa Rica, *N. milleri* Gabb (1881, p. 338, pl. 44, fig. 3) has a higher spire and weaker umbilical rib. *N. castrenoides* Woodring (1928, p. 377, pl. 30, fig. 5; Miocene, Jamaica) and its Recent Caribbean analog, *N. castrensis* Dall (1889, p. 293), have a wider and weaker umbilical rib and thinner parietal callus. *N. bolus* appears to have no close living allies in either Caribbean or Panamic waters.

The strong, though narrow, umbilical rib indicates that *N. bolus* is not closely related to *N. vitellus;* it probably is to be assigned to an unnamed subgenus. As pointed out by Powell (1933, p. 165), undue emphasis on opercular characters in effecting a classification of naticids may lead to artificial alliances.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, locality 138. Middle part, eastern area, localities 142, 144 (incomplete, identification doubtful), 147b, 147g, 155, 155a, 155b, 155c, 157, 159; western area, localities 161a, 161c, 161d. Upper part, eastern area, localities 172, 173, 175, 176a, 177, 177a (incomplete, identification doubtful), 177b, 178. Cercado and Gurabo formations (middle Miocene), Dominican Republic. Springvale formation (late Miocene), Trinidad.

Subgenus Naticarius Duméril

Duméril, Zoologie analytique, p. 164, 1806; genus without species.
Type (monotype, Froriep, C. Duméril's analytische Zoologie, p. 165, 1806; quoted from Iredale, Malacol. Soc. London Proc., v. 12, p. 83, 1916): *Nerita canrena* Linné, Recent, West Indies.

The status of Duméril's names, all of which end in "*arius*", will not be settled without a specific ruling, for they may be interpreted in various ways. According to Opinion 148 of the International Commission on Zoological Nomenclature, issued in 1943

> A generic name published as an emendation of an earlier name of the same origin and meaning is to be rejected as a synonym of the earlier name, and the type of the genus bearing the emended name is automatically the same species as the type of the genus bearing the earlier name so proposed to be emended.

Duméril's names doubtless are emendations of earlier names of the same origin and meaning. All of them can be matched with earlier names that lack the "*arius*" termination. He probably emended the earlier names with the Latin suffix "arius" (pertaining to) as the name of the animal; *Naticarius*, for example, being the name of the animal "pertaining to" the shell *Natica*. His statement that "notre objet étoit de faire connoître les animaux et non les couquilles que les revêtent" supports that interpretation. In that event it could be argued that the names are to be rejected on the grounds that Duméril adopted a system that results in two names for shell-bearing mollusks. If the names are to be accepted and are emendations, and therefore synonyms, is *Naticarius* a synonym of *Natica* Scopoli or of *Natica* Lamarck? If it is a synonym of *Natica* Lamarck, it is available in place of that name, which is a homonym of *Natica* Scopoli. Duméril's names, however, were not admitted to be emendations when they were proposed. They therefore may be interpreted as entirely new names dating from his or Froriep's usage, depending on whether Duméril's usage is considered nude. For the time being the view that they are new names is arbitrarily adopted. In 1928 *Naticarius* was regarded as a substitute name for *Natica* Lamarck not Scopoli (Woodring, 1928, p. 378). That view, which followed Iredale's (1916, p. 82) interpretation, is far fetched, but has the same nomenclatorial effect as the view adopted in the present report.

Natica s s., or naticids having similar opercula, occur in the Eocene (Harris and Palmer, 1946–47, p. 247, pl. 29, figs. 1, 2, 1947; Wrigley, 1949, p. 11, 13, figs. 1, 2, 8–12). *Naticarius*, however, evidently does not antedate the late Oligocene. The late Eocene (Jackson) *Natica permunda* Conrad, which has been referred to *Naticarius* (Harris and Palmer, 1946–47, p. 246, 1947), lacks the axial grooves of that subgenus, and has a less rapidly enlarging umbilical rib and correspondingly narrower umbilical callus lobe. *Naticarius* is now found in western Atlantic and eastern Pacific tropical and subtropical waters. The Mediterranean *N. millepunctata* Lamarck has a multiribbed operculum, suggesting alliance with *Naticarius*, but the ribs are very narrow and the shell has a narrow umbilical rib. This species has been erroneously assigned to *Nacca* Risso.

An unidentified species of *Naticarius* occurs in the upper part of the Bohio formation and poorly preserved fossils from the middle member of the Caimito formation in the Gatun Lake area and the Culebra formation are identified as *Natica* (*Naticarius?*) sp. They have a relatively high spire and short axial grooves adjoining the suture. Their umbilical features and opercula are unknown.

Natica (Naticarius) stenopa Woodring, n. sp.

Plate 20, figures 4–6

Of medium size, thin shelled, moderately inflated, whorls enlarging at moderate rate, spire high. Protoconch of 2½ to 3 whorls, apical whorl small. End of protoconch marked by slight change in texture of shell and beginning of sculpture. Sculpture consisting of short closely spaced retractive axial grooves, parallel to growth lines, extending from suture and ending on shoulder on later whorls. Umbilicus moderately wide, umbilical rib rapidly enlarging, ending in a wide callus lobe, the anterior part of which is concave. A very narrow deep groove in front of umbilical rib and umbilical callus lobe. Parietal callus moderately thick. Operculum bearing a marginal rib and 4 or 5 wider flat ribs, all separated by deep grooves.

Height 15.2 mm, diameter 14.8 mm (type). Height 21.5 mm, diameter 19.5 mm (largest specimen).

Type: USNM 561340; paratype, USNM 561341; paratypes Stanford Univ.

Type locality: 177b (USGS 5854, Mount Hope, west side of Panama Railroad near oil tanks, Canal Zone), upper part of Gatun formation.

Natica stenopa is widespread and locally common in the Gatun formation, especially abundant in the upper part of the formation in the eastern area. Eighteen of the 21 lots, however, consist only of immature specimens, up to a maximum of 115 immature shells in one lot. The largest shells are imperfect. A shell of medium size from locality 177c has an operculum in place (pl. 20, fig. 6). An incomplete operculum of medium size, not associated with shells, was found at locality 161. A small incomplete operculum, collected at locality 162, has three ribs, an indeterminate number of other lower ribs being covered with a glaze of enamel. The identification of this operculum is uncertain. The axial grooves disappear on the body whorl of an incomplete doubtfully identified shell from locality 147h.

Though Brown and Pilsbry (1913, p. 508) recorded *N. canrena* from the Gatun formation and though Olsson (1922, p. 155, pl. 13, fig. 9) figured a specimen of that Recent Caribbean species from the Gatun formation near Gatun, that species is not represented in the Gatun collections of the U. S. National Museum or Stanford University. *N. stenopa* is of meduim size and has a high spire, small apical whorl, closely spaced axial grooves, and 5 or 6 ribs on the operculum. *N. canrena*, on the contrary, is much larger and has more inflated and more rapidly enlarging whorls, low spire, large apical whorl, more widely spaced axial grooves, more rapidly enlarging umbilical rib and correspondingly larger umbilical callus lobe, and 8 or 9 ribs on the operculum.

On the basis of shell characters *N. stenopa* is closely related to a Recent Panamic species identified by Dall as *N. limacina* Jousseaume (1874, p. 14, pl. 2, figs. 7, 8). Jousseaume's description and illustrations suggest that the identification is erroneous. The operculum of *N. limacina* is unknown and the type locality is indefinite: "West Indies(?)". Dall's *N. limacina* is represented in the collections of the U. S. National Museum by one shell dredged in Panamá Bay at a depth of 33 fathoms. *N. stenopa* has a somewhat thinner shell, narrower groove in front of the umbilical rib and umbilical callus lobe, and wider umbilical opening back of the umbilical rib. *Naticarius* opercula, having 7 to 9 ribs, are represented by 2 lots from Panamá Bay, and also by lots dredged in the Gulf of California off Guaymas and La Paz, but it is not known that the opercula are to be associated with Dall's *N. limacina*. They agree with the operculum of *N. colima* Strong and Hertlein (1937, p. 174, pl. 35, figs. 12, 13, 16), dredged near Manzanillo, Mexico. *N. colima*, however, is thin shelled and has a very narrow umbilical rib and small umbilical callus lobe.

Natica canrena or allied forms are widespread in the Caribbean region in formations of Miocene and Pliocene age. *N. precanrena* F. Hodson (Hodson, Hodson, and Harris, 1927, p. 68, pl. 36, figs. 2, 6, 9), a small Venezuelan early Miocene species (height 6.8 millimeters), has a high spire, small initial whorl, and closely spaced axial grooves. It has, however, a higher spire and a wider umbilicus than small specimens of *N. stenopa*.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle and late Miocene). Lower part, localities 136, 137, 137a, 138, 138a. Middle part, eastern area, localities 146, 147b, 147g, 147h (incomplete, identification doubtful), 151, 155, 155c, 157; western area, localities 161, 161a, 161c, 161d, 170, 170a. Upper part, eastern area, localities 175, 176a, 177b, 177c; western area, localities 183, 185.

Genus Stigmaulax Mörch

Mörch, Catalogus conchyliorium * * * Comes de Yoldi, pt. 1, p. 133, 1852.

Type (logotype, Harris, Catalogue of Tertiary Mollusca in the British Museum; pt. 1, Australasian, p. 262, 1897): *Natica sulcata* Born (*Nerita sulcata* Born), Recent, West Indies.

Stigmaulax, like *Naticarius*, lives in American tropical and subtropical waters on both sides of Central America. It is found in the late Tertiary of the same region, the earliest species being of early Miocene age.

Stigmaulax guppiana (Toula)

Plate 20, figures 11–16

Natica guppiana Toula, K. k. Geol. Reichsanstalt Jahrb., Band 58, p. 696, pl. 25, fig. 6, 1909 (Miocene, Canal Zone). Hodson, Hodson, and Harris, Bull. Am. Paleontology, v. 13, no. 49, p. 67, pl. 36, figs. 1, 4, 1927 (Miocene, Venezuela).

Natica guppyana Toula, Engerrand and Urbina, Soc. Geol. Mexicana Bol., v. 6, p. 130, pl. 60, figs .53, 54, 55 (reproduction of Toula's illustration), 1910 (Miocene, Mexico). Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 63, p. 360, 1911 (Miocene, Canal Zone). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 156, pl. 13, figs. 13–15, 1922 (Miocene, Panamá, Costa Rica). Anderson, California Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 123, 1929 (Miocene, Colombia). Tucker and Wilson, Bull. Am. Paleontology, v. 18, no. 65, p. 13, pl. 2, figs. 3, 4, 1932 (Miocene, Florida). Mansfield, Florida Dept. Conservation, Geol. Bull. 12, p. 10, 13 (lists), 1935 (Miocene, Florida).

Natica (Stigmaulax) sulcata guppiana Toula, Rutsch, Schweizer. Palaeont. Gessel. Abh., Band 54, no. 3, p. 51, pl. 1, fig. 15 (type), 1934 (Miocene, Canal Zone).

Natica (Naticarius) guppyana Toula, Oinomikado, Geol. Soc. Japan Jour., v. 46, p. 621, pl. 29, fig. 18, 1939 (Miocene, Colombia).

Natica (Stigmaulax) guppiana Toula, Gardiner, U. S. Geol. Survey Prof. Paper 142, p. 546, pl. 59, fig. 9 (reproduction of Toula's illustration), 1947 (Miocene, Florida).

Natica (Stigmaulax) guppiana toulana Gardner, idem, p. 547, pl. 59, figs. 7, 8, 1947 (Miocene, Florida).

Natica (Stigmaulax) guppyana Toula, Marks, Bull. Am. Paleontology, v. 33, no. 139, p. 98, 1951 (Miocene, Ecuador).

Operculum (sp.?), Toula, K. k. Geol. Reichsanstalt Jahrb., Band 61, p. 511, pl. 31, fig. 26, 1911 (Miocene, Canal Zone).

Not *Natica guppyana* Toula, Li, Geol. Soc. China Bull., v. 3, p. 266, pl. 6, fig. 46, 1930 (Miocene, Panama Bay; =*Natica elenae* Récluz, fide Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 83, p. 432, 1931, Recent, Panama Bay).

Large, thick shelled, spire low, whorls strongly inflated and rapidly enlarging. Protoconch of 2¼ to 2½ whorls, apical whorl small. Sculpture of relatively widely spaced retractive axial grooves, parallel to growth lines, extending away from suture and generally ending at or above periphery. On some shells they extend to umbilical region, but not on last half of body whorl of large shells. Umbilicus very wide, umbilical rib rapidly enlarging, ending in a moderately wide callus lobe, the anterior part of which is concave on large shells and strongly excavated on shells of small and medium size. On shells of large and medium size a more or less distinct supplementary rib lies on umbilical rib at its posterior border and may modify outline of callus lobe. Groove in front of umbilical rib and umbilical callus lobe moderately wide on large shells, narrow on others. Parietal callus very thick. Operculum dominated by very wide thick warty central rib. Marginal rib very narrow, denticulate. Several minor ribs, two of which generally are undercut along their inner margin, lie between marginal and central ribs. Outermost minor rib irregularly roughened.

Height 33.5 mm, diameter 30.5 mm (figured large specimen with short axial grooves). Height 30.5 mm, diameter 29 mm (figured large specimen with axial grooves extending from suture to umbilical region on first half of body whorl).

Type: Tech. Hochschule, Vienna (temporarily at Geol. Inst., Univ. of Berne, Switzerland).

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

Stigmaulax guppiana is the most widespread and most abundant of the Gatun naticids and was found in the Chagres sandstone at the mouth of Río Indio. All of the numerous large shells and many of medium size have one or more healed breaks on the body whorl. The more widely spaced axial grooves and the excavated umbilical callus lobe differentiate very young shells from very young shells of *Natica stenopa*. The sculpture is variable. Shells of large and medium size on which the axial grooves extend to the umbilical region are common only in the upper part of the Gatun formation in the eastern area. Locality 155c is the only locality in the middle part of that formation where all the specimens collected have grooves extending to the umbilical region. No large shell has grooves extending to the umbilical region on the later half of the body whorl. Though the body whorl of some large shells shows indistinct microscopic spiral lineation, like that on some specimens of *Natica canrena*, there is no gross spiral sculpture. The supplementary umbilical rib is of variable strength, but is visible on shells of large and medium size.

Opercula are not rare. They were collected at 11 localities, as many as 10 at a locality. A large shell having the operculum in place (pl. 20, fig. 18) was collected by T. F. Thompson. The only other in place is in a minute shell, which has a height of 1.5 millimeters (locality 147b). Details of opercular sculpture are variable, especially the number of minor ribs. The fine denticles on the very narrow marginal rib are obscure on some large opercula. That the thick callus of the warty central rib conceals flat minor ribs, like those adjoining the central rib on some opercula, is shown by the mergence of such ribs on 2 large opercula, (pl. 20, figs. 13, 18). Toula described a small operculum without realizing that it belongs to a species he had named.

Forms of *Stigmaulax* closely related to the Recent Caribbean *S. sulcata* (Born) are found in Miocene formations in Jamaica, Haiti, the Dominican Republic, Puerto Rico, and Brazil. *S. guppiana*, however, is not one of them. It lacks gross spiral sculpture and is more closely allied to the Recent Panamic *S. broderipiana* (Récluz), as pointed out by Olsson (1932, p. 207). *S. broderipiana* is smaller and has a less depressed suture. The opercula of the two species are similar, but the central rib of *S. broderipiana* has a narrow crest. *S. elenae* (Récluz), also a Recent Panamic species, is another close ally. It also has a less depressed suture and its axial grooves are in general more closely spaced. The single available operculum has a narrower central rib. The color pattern, however, is the most distinctive feature of *S. elenae*.

S. guppiana is found in the Gurabo formation of the Dominican Republic. A close ally of *S. sulcata* also occurs in the Gurabo formation, but not at the same localities. This close ally of *S. sulcata* was recorded as *S. vererugosum* (Cossmann) (Woodring, 1928, p. 383) and has been named *Natica sulcata gurabensis* by Rutsch (1934, p. 52, pl. 2, fig. 10). *S. guppiana* also occurs in deposits of middle and late Miocene age in Florida. The collection from Shell Bluff on Shoal River (USGS 3742) consists of numerous specimens, all smaller than large shells from the Canal Zone. The collection also includes 3 opercula which agree with opercula of *S. guppiana*. Two specimens from locality 3742 that have short axial grooves were named *Natica guppiana toulana* by Gardner. This is the common form in the lower and middle parts of the Gatun formation, and the numerous Gatun collections show gradation in the length of the grooves. The single specimen (height 22 millimeters) from Vaughan Creek (USGS 12046) agrees closely with Gatun shells of medium size that have grooves extending to the umbilical region. According to Tucker and Wilson, *S. guppiana* occurs in upper Miocene deposits at Acline, Florida.

A large *Stigmaulax* from the late Miocene Punta Gavilán formation of Venezuela has been described as *Natica* (*Stigmaulax*) *sulcata beaumonti* Rutsch (1934, p. 50, pl. 2, figs. 6–8, pl. 3, fig. 5). I am indebted to Dr. Rutsch for two topotypes of this form. It is allied to *S. guppiana* and may be considered a subspecies of *S. guppiana*. It is considerably larger than *S. guppiana* proper (height 42 millimeters), but even on these large shells the axial grooves continue to the umbilical region almost to the outer lip. This large form, *S. guppiana beaumonti*, and the typical form of *S. guppiana* in the Chagres sandstone are the last Caribbean allies of *S. broderipiana*.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle and late Miocene). Lower part localities 137, 137a, 138, 138a. Middle part, eastern area, localities 142, 146, 147 (identification doubtful), 147b, 147f, 147g, 147h, 150a, 151, 153, 153a, 155, 155b, 155c, 156, 157, 158 (identification doubtful); western area, localities 161, 161c, 161d. Upper part, eastern area, localities 172, 175, 176, 176a, 177a, 177b, 177c, 178; western area, localities 182, 182a, 183, 185. Chagres sandstone (early Pliocene), locality 208. Miocene, Falcón, Venezuela. Middle Miocene, Bolívar and Chocó, Colombia. Daule formation (middle Miocene), Ecuador. Middle Miocene, northeastern Panamá and Costa Rica. Miocene, Chiapas, Mexico. Shoal River formation (middle Miocene), Florida. Late Miocene deposits at Acline, Florida.

Genus Tectonatica Sacco

Sacco, Mus. Zoologia Anatomia Comparata R. Univ. Torino Bol., v. 5, no. 86, p. 33, 1890.

Type (monotype): *Tectonatica tectula* Bors. (error for Bon.) (*Natica tectula* Bonelli), Miocene and Pliocene, Italy.

Though the name *Tectonatica* has been used for small tropical American species (Woodring, 1928, p. 384), that usage was not entirely satisfactory, because no specimens of the type species were examined. Through the kindness of John Q. Burch, of Los Angeles, a specimen of *Natica tectula* identified by Sacco is now available. It is larger than the small tropical American species (height 7 millimeters; maximum height 12 millimeters, according to Sacco) and the umbilical callus lobe does not completely fill the umbilicus, leaving a narrow unfilled space, comparable to the narrower space of varying width on the small American "*Natica*" *pusilla* Say. In his later description of *Tectonatica*. Sacco (1891, p. 81) described the operculum as calcareous. He evidently was relying on allied Recent species, as in his description of *Natica tectula* the operculum is not mentioned. Though the operculum of that species evidently is still unknown, there is no reasonable doubt that *Tectonatica* is an appropriate name for the small American species. The type of *Cryptonatica* (Dall, 1890–1903, p. 362, 1892; type (logotype, Dall, 1909, p. 85): *Natica clausa* Broderip and Sowerby) is a large arctic and boreal species, on which the umbilical callus lobe completely fills the umbilicus. Like the small species, it has a smooth calcareous operculum. When the anatomy of the large arctic and small tropical species is known, both names (*Tectonatica* and *Cryptonatica*) may be found to be useful.

Tectonatica has been recognized in the Eocene of England (Wrigley, 1949, p. 14).

Tectonatica species

Two imperfect specimens record the occurrence of a small inflated species of *Tectonatica* in the late Eocene or early Oligocene strata of Trinidad Island. The unbilical callus lobe is preserved on the smaller specimen, but is absent (presumably dissolved) on the larger. The larger specimen has a more strongly bulging body whorl than *T. agna* of the Gatun formation. *T. floridana* (Dall) (1890–1903, pt. 2, p. 366, pl. 17, fig. 5, 1892), of the early Miocene Tampa limestone of Florida, is more than three times as large and is more elongate. Heretofore *T. floridana* was the earliest recorded east American species.

The larger specimen has the following dimensions: height 2.4 mm, diameter 2.6 mm.

Occurrence: Marine member of Bohio(?) formation (late Eocene or early Oligocene), Gatun Lake area, locality 42.

Tectonatica agna Woodring, n. sp.

Plate 17, figure 46

Very small, strongly inflated, spire low or moderately low. Protoconch not clearly differentiated from remainder of shell, apical whorl small. Umbilical callus lobe thick, completely filling umbilicus, bearing a shallow central depression. Edge of umbilical callus lobe raised above level of umbilical border. Parietal callus thick. Operculum unknown.

Height 2.8 mm, diameter 2.4 mm (type).

Type: USNM 561348; paratypes, Stanford Univ.

Type locality: 147b (USGS 6033c, Panama Railroad, about 3,500 feet (1,065 meters) southeast of Gatun railroad station, Canal Zone), middle part of Gatun formation.

This minute *Tectonatica*, like many other small species from the Gatun formation, is abundant at locality 147b, the type locality. The shallow, but distinct, depression on the umbilical callus lobe is its most distinctive feature. On a few shells the suture on the last half of the body whorl descends more sharply than on the common form, producing a correspondingly higher spire.

The more distinct depression on the umbilical callus lobe and the narrower groove at the outer edge of the lobe differentiate *Tectonatica agna* from *T. pusilla* (Say), which moreover is slightly larger. *T. pusilla* is the only fossil *Tectonatica* recorded from the Caribbean region (Woodring, 1928, p. 384, pl. 30, fig. 12). It now ranges from Massachusetts to Florida. A Recent West Indian species, possibly *T. sagraiana* (d'Orbigny) also lacks the callus depression. No Recent Panamic species is represented in the U. S. National Museum collection.

Occurrence: Middle and upper parts of Gatun formation (middle and late Miocene). Middle part, eastern area, localities 146, 147b, 147f, 147g, 147h, 151, 153a. Upper part, eastern area, locality 177c; western area, locality 185 (identification doubtful).

Subfamily POLINICINAE

Genus Polinices Montfort

Montfort, Conchyliologie systématique, v. 2, p. 223, 1810.
Type (orthotype): *Polinices albus* Montfort (=*Natica mamillaris* Lamarck=*Natica brunnea* Link), Recent, West Indies.

Incomplete and poorly preserved naticids from the Gatuncillo formation, the marine member of the Bohio(?) formation, and the Culebra formation are doubtfully referred to *Polinices*. The umbilical features of these fossils, most of which are molds, are not known.

Polinices canalizonalis (Brown and Pilsbry)

Plate 20, figures 7, 8

Natica canalizonalis Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 64, p. 508, pl. 22, fig. 10, 1913 (Miocene, Canal Zone).

Of medium size, thick-shelled. Body whorl appressed at suture, strongly inflated below appressed area. Aperture small for size of shell. Apical whorl small. Faint microscopic spiral lineation visible on unworn parts of shell. Umbilicus wide. Umbilical rib strong on immature shells, somewhat flattened on mature shells, ending in a wide callus lobe. Parietal callus very thick, bearing a shallow transverse groove.

Height 21 mm, diameter 18.7 mm (figured mature specimen). Height 11 mm, diameter 10 mm (figured immature specimen).

Type: Acad. Nat. Sci. Phila. 3844.

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

Polinices canalizonalis is the least abundant of the three Gatun species of *Polinices*. It also is the only one of the three that has a conspicuous umbilical rib. The type is an immature shell (height 8.2 millimeters). The well-defined umbilical rib indicates alliance with a Recent Caribbean species labelled *P. porcellanus* (d'Orbigny) in the U. S. National Museum collection. The Recent species has a stronger rib and is less appressed at the suture. *P. carolinianus* (Conrad) (Mansfield, 1930, p. 127, pl. 19, fig. 1), which occurs in the Duplin formation of North Carolina and in deposits of late Miocene age in western Florida, is larger, less appressed at the suture, and has a stronger rib. A late Miocene species from Trinidad, *P. boutakoffi* Rutsch (1942, p. 139, pl. 6, figs. 7a, 7b), belongs in this group of species characterized by a strong umbilical rib. According to Rutsch's illustrations, it is more inflated, less appressed at the suture, and has a deeper groove on the parietal callus.

Occurrence: Lower middle, and upper parts of Gatun formation (middle Miocene). Lower part, locality 136a. Middle part, eastern area, Gatun Locks excavation (Brown and Pilsbry); western area, locality 161a. Upper part, eastern area, localities 177b, 177c.

Polinices brunneus subclausus (Sowerby)

Plate 20, figure 9

Natica subclausa Sowerby, Geol. Soc. London Quart. Jour., v. 6, p. 51, 1850 (Miocene, Dominican Republic).
Polinices subclausa (Sowerby), Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 63, p. 360, 1911 (Miocene, Canal Zone). Maury, Bull. Am. Paleontology, v. 5, no. 29. p. 136, pl. 23, fig. 14, 1917 (Miocene, Dominican Republic). Olsson, idem, v. 9, no. 39, p. 157, pl. 13, figs. 16–17, 1922 (Miocene, Costa Rica, Canal Zone). Hodson, Hodson, and Harris, idem, v. 13, no. 49, p. 69, pl. 36, fig. 5, 1927 (Miocene, Jamaica). Anderson, Calif. Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 124, 1929 (Miocene, Colombia, Canal Zone).
Polinices brunnea subclausa (Sowerby), Woodring, Carnegie Inst. Washington Pub. 385, p. 385, pl. 30, fig. 13, 1928 (Miocene, Jamaica); see this publication for other citations.
?*Polinices* (*Mammilla*) cf. *brunnea* Link, Weisbord, Bull. Am. Paleontology, v. 14, no. 54, p. 29, pl. 9, fig. 12, 1929 (Miocene, Colombia).

Of medium size, thick shelled. Whorls strongly and smoothly appressed at suture. Apical whorl small. Umbilicus moderately narrow; umbilical rib almost flat. Umbilical callus lobe narrow, slightly widened by umbilical rib. Parietal callus very thick, bearing a shallow transverse groove.

Height 20.3 mm, diameter 16.7 mm (figured specimen).

Type material: British Mus., Natural History, Geol. Depart., Geol. Soc. London 12826 (6 syntypes).

Type locality: Dominican Republic, Miocene.

This *Polinices* is fairly common in the middle part of the Gatun formation at locality 161c, west of Gatun Dam, and occurs at other localities, all in the middle part of the Gatun formation. The groove on the parietal callus is relatively deep on some small specimens. The largest Gatun shells are half as large as the largest from the Miocene of the Dominican Republic and Bowden, Jamaica (height 40 millimeters), and are much smaller than large specimens of the Recent Caribbean *P. brunneus* proper (height 50 millimeters). Like the Miocene fossils from the Dominican Republic and Jamaica, the Gatun fossils have a slightly narrower umbilicus than Recent shells of the same size. The fairly wide umbilicus of Weisbord's *Polinices* cf. *P. brunnea* indicates, however, that the Miocene form cannot consistently be distinguished by the width of the umbilicus. Recent shells that are not worn show a faint microscopic spiral lineation, which has not been observed on the fossils from the Canal Zone, the Dominican Republic, and Jamaica. The apparent absence of lineation on the fossils, however, may be due to slight wear. A small form of *P. brunneus subclausus* from the Miocene of Banana River, Costa Rica, has faint spiral lineation and also has a deep groove on the parietal callus, as shown by Olsson's illustrations.

A form of *P. brunneus subclausus* that has a notch between the parietal callus and the umbilical callus lobe has been recognized in the Miocene of Venezuela and Jamaica, and has been named *P. subclausa lavelana* F. Hodson (Hodson, Hodson, and Harris, 1927, p. 69, pl. 36, fig. 8, pl. 37, figs. 12, 14).

Polinices nelsoni Olsson (1932, p. 208, pl. 24, figs. 8, 10), which is more slender than *P. brunneus* and has a narrower umbilicus, is a late Miocene Peruvian relative of *P. brunneus*, but no close allies are known to be living in the Panamic region.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, localities 155b, 155c; western area, localities 161 (immature, identification doubtful), 161c, 161d, 170 (immature, identification doubtful). Cercado and Gurabo formations (middle Miocene), Dominican Republic. Bowden formation (middle Miocene), Jamaica. Middle Miocene, Costa Rica. Miocene, Bolívar, Colombia.

Polinices stanislas-meunieri Maury

Plate 21, figures 11–14

Polinices stanislas-meunieri Maury, Bull. Am. Paleontology, v. 5, no. 29, p. 136, pl. 23, figs. 15–16, 1917 (Miocene, Dominican Republic). Olsson, idem, v. 9, no. 39, p. 157, pl. 13, fig. 7, 1922 (Miocene, Costa Rica). Maury, idem, v. 10, no. 42, p. 240, pl. 40, fig. 7, 1925 (Miocene, Trinidad). Anderson, Calif. Acad. Sci. Proc. 4th ser., v. 18, no. 4, p. 124, 1929 (Miocene, Colombia).

Polinices stanislas-meunieri venezuelana F. Hodson, Bull. Am. Paleontology, v. 13, no. 49, p. 70, pl. 37, figs. 10, 15, 1927 (Miocene, Venezuela).

Not *Polinices stanislas-meunieri* Maury, Li, Geol. Soc. China Bull., v. 9, p. 267, pl. 6, fig. 48, 1930 (Miocene, Panama Bay; =*P. uber* (Valenciennes) and *P. rapulum limi* Pilsbry, fide Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 83, p. 432, 1931, Recent, Panama Bay).

Polinices springvalensis Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 241, pl. 40, fig. 6, 1925 (Miocene, Trinidad).

Moderately large, moderately thick-shelled, moderately slender to strongly inflated. Whorls not appressed at suture, except near outer lip or on most of body whorl of large specimens. Apical whorl small. Microscopic spiral lineation distinct on unworn shells. Umbilicus and umbilical callus lobe narrow. Parietal callus moderately thick, much wider than umbilical lobe, bearing a faint to distinct transverse groove on immature shells.

Height 43.5 mm, diameter 33 mm (figured large slender specimen). Height 32.5 mm., diameter 28 mm (figured inflated specimen).

Type: Cornell University 36931.

Type locality: Río Cana, Dominican Republic, Gurabo(?) formation (middle Miocene).

Polinices stanislas-meunieri is the most widespread of the Gatun species of *Polinices*. It is locally common in the lower part of the formation, but many of the specimens are relatively slender, like that shown on plate 21, figure 14. The large figured specimen (pl. 21, fig. 13) was collected by T. F. Thompson. The umbilical rib is so flat that it is virtually absent. Therefore the narrow umbilical callus lobe widens very slightly. The umbilicus is of varying width on immature shells, and is practically closed on one from locality 136 (height 6 millimeters). The transverse groove on the parietal callus is absent on shells of large and medium size, and generally is faint on small shells.

Differentiation of *P. stanislas-meunieri venezuelanus* appears to be unwarranted. *P. springvalensis* is a shouldered form of *P. stanislas-meunieri*, but is not much more strongly shouldered than the Gatun specimen shown on plate 21, fig. 12. The early Miocene Costa Rican *P. eminuloides* (Gabb) (1881, p. 339, pl. 44, fig. 4) probably is related to *P. stanislas-meunieri*. The type, and only specimen, is high spired; the umbilical area is not completely exposed; and the parietal callus is damaged.

P. stanislas-meunieri is widely distributed in the Miocene of the Caribbean region, but has no living allies there. It is closely related, however, to the Recent Panamic *P. uber* (Valenciennes). *P. stanislas-meunieri* is not much more than half as large, but its parietal callus is thicker than that of specimens of *P. uber* of the same size, indicating maturity. The outline of *P. stanislas-meunieri* ranges from strongly and smoothly inflated to moderately slender, whereas that of *P. uber* is more uniformly strongly and smoothly inflated.

P. coensis (Dall) (Mansfield, 1930, p. 124, pl. 17, fig. 8), which occurs in deposits of late Miocene age in western Florida, and *P. robustus* Gardner (1926–47, p. 550, pl. 59, figs. 5, 14, 1947), a middle Miocene form, are the representatives of *P. stanislas-meunieri* in the Miocene of Florida. *P. coensis* is smaller than the Caribbean species. It has a more distinct notch between the umbilical callus lobe and parietal callus, thicker parietal callus, and the transverse groove on the parietal callus persists to a later stage than on Gatun fossils. *P. robustus*, which perhaps is to be considered a large high-spired subspecies of *P. coensis*, closely resembles high-spired Gatun shells, but has a thicker parietal callus.

P. coensis is the type of the subgenus *Dallitesta* Mansfield (1930, pp. 124, 125), which was proposed without any discussion of differentiating characters. Perhaps it was proposed because of the distinct spiral lineation. Should the genus *Polinices* be subdivided into subgenera, *Dallitesta* would be available for species that have a narrow umbilicus, virtually no umbilical rib, narrow umbilical callus lobe, and distinct spiral lineation. There are, however, gradations from a strong umbilical rib, like that *P. canalizonalis*, to virtually none; and many species, including *P. brunneus*, the type of the genus, have more or less distinct spiral lineation.

Occurrence: Lower, middle, and upper parts of Gatun formation (middle and late Miocene). Lower part, localities 136, 136a, 137, 138, 138a. Middle part, eastern area, localities 140, 146 (immature, identification doubtful), 147b (immature, identification doubtful), 147g (immature, identification doubtful), 147h (immature, identification doubtful), 155, 155c (incomplete, immature, identification doubtful), 157, 159a; western area, localities 161, 161c. Upper part, eastern area, localities 171, 173 (incomplete, identification doubtful), 177b; western area, localities 182, 182a, 183, 185 (immature, identification doubtful). Middle Miocene, Costa Rica. Gurabo(?) formation (middle Miocene), Dominican Republic. Miocene, Bolívar, Colombia. Miocene, Falcón, Venezuela. Springvale formation (late Miocene), Trinidad.

Genus Neverita Risso

Risso, Histoire naturelle des principales productions de l'Europe méridionale, v. 4, p. 149, 1826.

Type (monotype): *Neverita josephinia* Risso, Recent, Mediterranean Sea.

The Gatuncillo and Culebra formations, Emperador limestone member of the Culebra formation, and the La Boca marine member of the Panamá formation yielded molds of low-spired naticids identified as *Neverita?* sp. A large low-spired naticid from the marine member of the Bohio(?) formation near Palenquilla Point (diameter 39 millimeters), the umbilicus of which is not exposed, also is identified as *Neverita?* sp.

Subgenus Glossaulax Pilsbry

Pilsbry, Nautilus, v. 42, p. 113, 1929.

Type (orthotype): *Neverita reclusiana* (Deshayes) (*Natica reclusiana* Deshayes), Recent, southern California to Gulf of California.

The subgenus *Glossaulax* embraces neverites that have a groove on the umbilical callus, dividing it into anterior and posterior lobes. The groove of the type species is located on the anterior part of the callus.

Glossaulax is widely distributed on both sides of the northern Pacific and is represented in the Eocene of western North America by a typical species, *N. secta* Gabb, which Stewart (1927, p. 325) suggested may be treated better as a subspecies of *N. reclusiana*. This subgenus formerly had a more extensive distribution. It is represented in the Eocene of southeastern United States by *N. limula* (Conrad) (Palmer, 1937, p. 125, pl. 13, figs. 13, 14, 16, 19–22, pl. 80, figs. 13, 16), in the Eocene of the Caribbean region by *N. bolivarensis* Clark, and in the Eocene or Oligocene of Peru by *N. subreclusiana* (Olsson). These early Tertiary species are hardly typical, as the umbilical callus groove is not consistently present. Typical species, however, mentioned under *N. reclusiana xena*, are found in the Miocene of Florida and the Caribbean region.

Neverita (Glossaulax) bolivarensis tapina Woodring, n. subsp.

Plate 15, figures 7, 8, 11

Of medium size, depressed, conical. Umbilical callus partly filling umbilicus, the wide unfilled space decreasing in width toward parietal callus, but extending to junction of umbilical and parietal callus. Parietal callus set off from umbilical callus by a faint groove. Posterior part of umbilical callus bearing a faint groove. Umbilical wall faintly striate.

Height 14.5 mm, diameter 19 mm (type). Height 16.5 mm, diameter 26.5 mm (largest specimen).

Type: USNM 561354. Paratype, USNM 561442.

Type locality: 40d (USGS 6028a, Gatun Lake area, lower bed at Vamos Vamos, off Palenquilla Point, Canal Zone, now submerged), marine member of Bohio(?) formation.

Though *Neverita bolivarensis tapina* is represented by 12 specimens from the marine member of the Bohio(?) formation, only a few show the callus features. The callus is completely exposed on the type and paratype, both of which have a relatively wide unfilled umbilical space, a faint groove between the umbilical and parietal callus, and a faint groove on the posterior part of the umbilical callus. The groove on the umbilical callus of the type probably is modified by an artificial crack. The paratype has a shallow groove that disappears before reaching the umbilical border. Enough of the umbilical callus is exposed on two other specimens to show that a considerable part of the umbilicus is not filled.

This neverite is considered a subspecies of *N. bolivarensis* Clark (Clark and Durham, 1946, p. 16, pl. 15, figs. 10, 11, 14, 15, 18–20, 22, 26)—a subspecies characterized by its depressed outline and wide umbilical space gradually tapering toward the parietal callus. The specimen of *N. bolivarensis* proper shown by Clark on plate 15, figure 11, is depressed and has a wide umbilical space. The umbilical space, however, separates the callus from the entire umbilical wall. *N. bolivarensis* proper occurs in the late Eocene of Colombia. It and the subspecies from Panamá are related to *N. subreclusiana* (Olsson) (1931, p. 68, pl. 10, figs. 1, 4), of the late Eocene or early Oligocene Chira shale of Perú. That species has a high spire and practically filled umbilicus.

Occurrence: Marine member of Bohio(?) formation (late Eocene or early Oligocene), Gatun Lake area, localities 40, 40a, 40d, 41 (immature).

Neverita (Glossaulax) reclusiana xena Woodring, n. subsp.

Plate 21, figures 5, 8, 9

Of medium size, generally low spired. Spiral lineation visible on umbilical wall, but not elsewhere, presumably due to slight wear. Posterior lobe of umbilical callus longer than anterior lobe, reaching umbilical wall. Space between umbilical wall and anterior lobe of umbilical callus narrow or very narrow.

Height 25 mm, diameter 27 mm (type). Height 34 mm, diameter (incomplete) 35 mm (figured large high-spired specimen).

Type: USNM 561355; paratypes, Stanford Univ.

Type locality: 137 (USGS 16911, Transisthmian Highway, 1.7 kilometers northwest of Sabanita, Panamá), lower part of Gatun formation.

Neverita reclusiana zena is based on 12 specimens from the lower part of the Gatun formation and one from the middle part. It is remarkably similar to a small form of *N. reclusiana* (Deshayes) found along the outer coast of Baja California and along the Gulf of California. The Gatun neverite in general has a narrower space between the umbilical wall and the anterior callus lobe. Some small Recent shells, however, are practically indistinguishable from the fossils. This Mexican form has been listed as a variety of *N. reclusiana* (Pilsbry and Lowe, 1932, p. 126), but its status is not yet satisfactorily determined.

Typical species of *Glossaulax* are found in the Miocene of Florida and the Caribbean region: *N. chipolana* (Dall) (Gardner, 1926–47, p. 551, pl. 59, fig. 22, 1947; Chipola formation, Florida), *N. subporcana* (F. Hodson) (Hodson, Hodson, and Harris, 1927, p. 70, pl. 36, fig. 3, pl. 37, figs. 5, 9, 16; Miocene, Venezuela), and *N. cuspidata* (Guppy) (Maury, 1925, p. 239, pl. 40, figs. 9, 10; Rutsch, 1942, p. 140; Springvale formation, Trinidad). *N. chipolana* has a short anterior callus lobe; *N. subporcana* has a narrow anterior lobe and the posterior lobe leaves part of the umbilicus unfilled; *N. cuspidata* is very large (height 60 mm) and has short subequal lobes. There are no living species of *Glossaulax* in the Caribbean Sea or elsewhere in the western Atlantic. The late Miocene *N. cuspidata* is the last Caribbean species.

Inasmuch as *N. reclusiana* has a long history in the eastern Pacific going back to the Miocene, if not earlier, *N. reclusiana xena* evidently is a migrant from the Pacific. The present distribution of *N. reclusiana* and its allies, which are not found south of the Gulf of California, shows a marked reduction since Miocene time.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, localities 136a, 137, 137a. Middle part, eastern area, locality 155.

Subgenus Hypterita Woodring, n. subgen.

Type: *Natica helicoides* Gray, Recent, Baja California to Perú.

Hypterita is proposed for neverites that are greatly depressed, and have a very wide umbilicus with gently sloping wall, a thin umbilical callus lobe perched on a narrow or moderately wide umbilical rib, and a very thin wash of parietal callus. This well defined group of neverites includes only two known species: the type species and the Miocene Caribbean *Neverita nereidis*. The type species is generally known as *Neverita glauca* (Lesson).

Neverita (Hypterita) helicoides (Gray)

Plate 18, figures 15, 16

Natica patula G. B. Sowerby, Zool. Jour., vol. 1, p. 60, pl. 5, fig. 4, 1824 (Recent, locality unknown, but another specimen cited as South American). Barnes, Lyceum Natural History New York Annals, vol. 1, p. 136, 1824 (Recent, Perú). Not *Natica patula* J. Sowerby, 1822.

Natica helicoides Gray, Zool. Jour., vol. 1, p. 511, footnote, 1825 (cited as manuscript name of Barnes).

Natica glauca "Humboldt", Lesson, Voyage autour du monde * * la Coquille * *, Zoologie, vol. 2, pt. 1, p. 369, pl. 11, figs. 1, 1′, 1830 (Recent, Perú).

Natica bonplandi Valenciennes, in Humboldt and Bonpland, Voyage aux régions equinoxiales du nouveau continent, pt. 2, Recueil d'observations de zoologie, vol. 2, p. 264, pl. 57, figs. 3*a*, 3*b*, 1832 (Recent, Acapulco, Mexico; not seen).

?*Neverita nereidis* Maury, Olsson, Bull. Am. Paleontology, vol. 9, no. 39, p. 158, 1922 (Miocene, Costa Rica).

Polinices (*Neverita*) *glauca* Humboldt, Olsson, idem, vol. 27, no. 106, p. 20 (list), 1942 (Pliocene, Costa Rica).

Polinices helicoides (Gray), Hertlein and Strong, Am. Mus. Natural History Bull., vol. 107, art. 2, p. 287, 1955 (Recent, Baja California to Perú; see this publication for other citations).

Of medium size. Microscopic spiral lineation of fresh Recent shells not apparent, presumably due to slight wear. Umbilical rib narrow, slowly enlarging; unfilled umbilical space wide.

Height (incomplete) 16 mm, diameter (incomplete) 34 mm (figured specimen).

The Gatun formation yielded three incomplete fossils that closely resemble Recent shells of *Neverita helicoides* of medium size. The largest fossil, if it were complete, would have a diameter of about 45 millimeters. The largest Recent shells of *N. helicoides* in the U. S. National Museum collections have a diameter of between 55 and 60 millimeters. Slightly worn Recent shells do not show the very fine slightly wavy microscopic lineation of fresh shells.

Neverita nereidis Maury (1917, p. 137, pl. 23, figs. 17, 18), which occurs in the Cercado formation of the Dominican Republic, is closely allied to *N. helicoides*. Like the Gatun fossils, it is smaller than *N. helicoides* (diameter 35 mm). Moreover it has a wider umbilical rib than the Recent species. However remarkable it may be to recognize two very closely related species of *Hypterita* in the Miocene of the Caribbean region, the Gatun fossils are identified as *N. helicoides* on the basis of their narrow umbilical rib.

The fragment from the Miocene of Banana River, Costa Rica, identified by Olsson as *N. nereidis*, is not accessible at the present time. A fragment from that area, however, in the collections of the U. S. National Museum has a narrow umbilical rib and is doubtfully identified as *N. helicoides*.

Gray's name is far from satisfactory. He cited it as Barnes' manuscript name, a name that was still-born so far as Barnes' mention of it is concerned. Unfortunately the name, as Gray's name, is nomenclaturally available and therefore, as pointed out by Hertlein and Strong, replaces the well known name *Neverita glauca*.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, locality 136a. Middle part, eastern area, locality 155b; western area, locality 161c. Middle Miocene, eastern Costa Rica (identification doubtful). Pliocene, western Costa Rica. Recent, Magdalena Bay, Baja California, and Gulf of California to Perú.

Subfamily SININAE

Genus Sinum Röding

Röding, Museum Boltenianum, pt. 2, p. 14, 1798.
Type (logotype, Dall, U. S. Natl. Mus. Bull. 90, p. 109, 1915): *Helix haliotoidea* Linné (cited by Röding as *Helix haliotoidea* Gmelin), Recent, western Pacific(?).

The collections from the Gatuncillo formation, the marine member of the Bohio(?) formation, and the Caimito and Culebra formations include unidentified species of *Sinum*, represented by poorly preserved specimens. The Culebra *Sinum* may be the species from the Anguilla formation, of the island of Anguilla, recorded as *Sinum chipolanum* (Dall) (Cooke, 1919, p. 124, pl. 5, figs. 6a, 6b), but the species so identified is smaller and more depressed than *S. chipolanum*.

A species from the Gatun formation, *Sinum gatunense* (Toula) (1909, p. 697, pl. 28, figs. 3a, 3b, 3c) is not represented in the collections examined. It was compared by Toula with the Recent West Indian *S. perspectivum* (Say) and, according to his illustrations, is closely related to that species and the Recent Panamic *S. noyesi* Dall. Toula's species is greatly depressed and has a very narrow base. *S. gatunense* has been recognized in the Cercado formation of the Dominican Republic (Maury, 1917, p. 138, pl. 24, fig. 2) and in the Bowden formation of Jamaica (Woodring, 1928, p. 390, pl. 31, figs. 3, 4). *S. dodonum* Gardner (1926–47, p. 554, pl. 59, figs. 37, 39, 1947), of the Oak Grove sand member of the Shoal River formation of Florida, probably is a large form of *S. gatunense*. Though Toula's illustration shows no faint spirals on the base, some specimens of the species from the Dominican Republic and Jamaica identified as *S. gatunense* have faint basal spirals like those on the type of *S. dodonum*.

Sinum euryhedra Woodring, n. sp.

Plate 21, figures 4, 7, 10

Sinum species, Woodring, Carnegie Inst. Washington Pub. 385, p. 390, 1928 (Miocene, Jamaica).

Of medium size, moderately depressed, base relatively very wide. Protoconch consisting of about 1½ smooth whorls. Spire whorls and body whorl between periphery and suture sculptured with spiral bands, separated by grooves that, for the most part, are of about same width as the bands, but near suture are twice as wide as the bands. Base smooth except for exaggerated growth lines. A narrow groove lies behind posterior part of everted columellar lip.

Height (incomplete, spire crushed) 11 mm, diameter (incomplete) 27 mm (type).

Type: USNM 561441.

Type locality: 137a (Stanford University locality 2655, Transisthmian Highway, 1.7 kilometers northwest of Sabanita, Panamá; same as USGS 16911), lower part of Gatun formation.

The type, an incomplete and somewhat crushed specimen collected from the lower part of the Gatun formation by T. F. Thompson, is the only representative of this species. It is characterized by moderate depression, wide base, and strong sculpture. Owing to crushing, the spire is too low in apertural aspect (pl. 21, fig. 4).

There are no known close allies of this species in Caribbean and Panamic waters. *S. maculatum* (Say), a Recent Floridian and West Indian species, has a narrower base, thinner columellar lip and parietal callus, and weaker sculpture.

The small incomplete *Sinum* from the Miocene of Jamaica, so far as it goes, has the characters of *S. euryhedra*.

Occurrence: Lower part of Gatun formation (middle Miocene), locality 137a. Bowden formation (middle Miocene), Jamaica.

Sinum gabbi (Brown and Pilsbry)

Plate 21, figures 3, 6

Sigaretus (*Eunaticina*) *gabbi* Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 64, p. 509, pl. 22, fig. 13, 1913 (Miocene, Canal Zone).

?*Sinum quirosanum* F. Hodson, Bull. Am. Paleontology, v. 13, no. 49, p. 67, pl. 36, figs. 10, 12, 1927 [Miocene (Oligocene-Miocene of Hodson), Zulia, Venezuela].

Reaching a large size, not depressed, body whorl strongly inflated. Spire low or relatively high. Protoconch of 2½ smooth slowly enlarging whorls. Sculpture of narrow closely spaced spiral threads of two or three orders. Spirals of early whorls variably crinkled by growth lines. A very narrow umbilical groove lies behind posterior part of everted columellar lip of adult shells. Immature shells umbilicate.

Height 23 mm, diameter 23 mm (figured specimen). Height 27 mm, diameter 24 mm (largest complete specimen). Estimated diameter 35 mm (largest specimen, incomplete).

Type: Acad. Nat. Sci. Phila. 3845.

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

The type is a very small shell 6.5 millimeters high. The largest complete specimen (height 27 mm), collected at locality 175, has a higher spire than the others, but is associated with a smaller low-spired shell. That this species reaches a considerably larger size is shown by half of a body whorl (locality 176), which indicates a diameter of about 35 millimeters. The Venezuelan *S. quirosanum* is small, agreeing with *S. gabbi* in outline and sculpture, and may represent a small early Miocene race of *S. gabbi*. *S. nolani* Maury (1917, p. 139, pl. 24, fig. 1), a species that occurs in the Gurabo formation of the Dominican Republic, is more inflated than *S. gabbi*.

S. gabbi is a nondepressed species related to the Recent Peruvian *S. concavum* (Lamarck), the largest species of the genus (height 48 mm). The fossils, except the high-spired specimen, have a similar outline, but have spirals of less uniform width. No similar species is living in the western Atlantic.

Occurrence: Middle and upper parts of Gatun formation (middle Miocene). Middle part, eastern area, localities 147*b*, 155, 155a, 155b, 155c (very small), 157. Upper part, eastern area, localities 175, 176, 177c.

Subfamily GLOBULARIINAE

Data concerning the anatomy of *Cernina fluctuata* (Sowerby), the only surviving globularine, are desirable as a basis for consideration of the subfamily or family status of that species and its numerous fossil allies.

Wrigley (1946, p. 88) has proposed a useful terminology for features in the umbilical region and on the columellar lip of globularines. The sheath (the limbe of French authors and the callus or fasciole of American authors) is the shell layer emerging from the umbilicus of umbilicated species. Its outer edge is designated the rim. The downward extension of the parietal callus, overlapping the sheath, is designated the lobe of the columellar border, or simply the lobe. The outer edge of the lobe, where it overlaps the sheath below the umbilicus, is either fairly sharp or indefinite. The sheath of some nonumbilicated species, such as *Globularia sigaretina* (Lamarck), is as well defined as that of umbilicated species, but the umbilicus is represented only by a slight depression at the posterior end of the sheath, formed by the outer edge of the lobe. On other nonumbilicated or narrowly umbilicated species a sheath is not recognizable. If present, it is concealed by the lobe, which forms an everted columellar lip that has an outer edge as sharp as a rim.

Genus Globularia Swainson

Swainson, A treatise on malacology, p. 345, 1840.

Type (logotype, Herrmannsen, Indicis generum malacozoorum, v. 1, p. 480, 1847): *Natica sigaretina* Lamarck, Eocene, Paris basin.

Subgenus Globularia s.s.

Globularia (Globularia) aff. G. fischeri (Dall)

Plate 15, figures 9, 17, 18

Moderately large, weakly shouldered, greatly inflated. Spire low, turreted. A narrow sloping shelf lies between suture and shoulder. Aperture greatly expanded. Sheath moderately wide on immature specimens. Posterior part of lobe well defined on immature specimens. Umbilicus closed.

Height (almost complete) 35.5 mm, diameter 31 mm (large figured specimen). Height 18.5 mm, diameter (incomplete) 15.5 mm (small figured specimen).

This greatly inflated *Globularia*, represented by more or less incomplete and poorly preserved specimens from the middle member of the Caimito formation of the Gatun Lake area and the Culebra formation, is closely related to *Globularia fischeri* (Gardner, 1926–47, p. 556, pl. 59, fig. 28, 1947). *G. fischeri* occurs in the Chipola formation of Florida. Young shells of *G. fischeri*, up to a height of 13 millimeters, are narrowly umbilicated. With further growth the umbilicus is closed and the outer edge of the lobe is less well defined. A large incomplete specimen (diameter 60 mm) of *G. fischeri* has a very wide sheath, apparently almost completely covered by the thin lobe. Characters distinguishing the moderately large *G. anguillana* (Cooke) (1919, p. 123, pl. 4, figs. 9a, b; Anguilla formation, Anguilla) from *G. fischeri* are not evident. The type of *G. anguillana* has a very wide sheath; the umbilicus apparently is closed. *G. streptostoma* (Heilprin) (Dall, 1915, p. 107, pl. 12, fig. 27), from the Tampa limestone of Florida, like young shells of *G. fischeri*, is narrowly umbilicated. The umbilicus persists, however, on the largest available specimen (height 30 millimeters).

G. fischeri is the youngest *Globularia* in southeastern United States. In the Caribbean region the last representatives of the genus are found in slightly older strata: the Anguilla formation and its equivalents, which are correlated with the Tampa limestone.

Occurrence: Middle member of Caimito formation (late Oligocene), Gatun Lake area, localities 56, 57, 57a. Culebra formation (early Miocene) Gaillard Cut, localities 99g (*Globularia?* cf. *G. fischeri*), 100b.

Subgenus Ampulella Cox

Cox, Royal Soc. Edinburgh Trans., v. 57, p. 38, 1931.
Type (orthotype): *Ampullaria depressa* Lamarck, Eocene, Paris basin.

Ampulella, typical *Ampullina* of former usage, lacks the greatly expanded aperture and body whorl of *Globularia* s.s.

Globularia (Ampulella) species

Plate 15, figure 13

Small, weakly shouldered, strongly inflated. Spire low, turreted. A narrow sloping to slightly concave shelf lies between suture and shoulder. Faint microscopic lineation visible on some specimens. Aperture moderately expanded. Umbilicus narrow. Sheath moderately wide. Lobe narrow, its outer edge indefinite below umbilicus.

Height (incomplete) 21 mm, diameter (modified by dorso-ventral crushing) 19.3 mm (figured specimen).

This small *Globularia*, evidently a new species, is represented by poorly preserved fossils from the marine member of the Bohio(?) formation of the Gatun Lake area. The umbilicus is not exposed on the figured specimen and the upper part of the sheath is missing. The outline suggests the Eocene Paris basin species *Globularia parisiensis* (d'Orbigny), which occurs also in the late Eocene and early Oligocene of England (Wrigley, 1946, p. 92, figs. 6, 9). *G. parisiensis*, however, has a wider sheath and axially arranged microscopic punctae.

Occurrence: Marine member of Bohio(?) formation (late Eocene or early Oligocene) Gatun Lake area, localities 40a, 40d, 41.

Globularia (Ampulella?) nana Woodring, n. sp.

Plate 15, figures 3, 4

Very small, strongly inflated. Spire high, faintly turreted. Upper part of body whorl sculptured with faint microscopic spirals, lower part with widely spaced spiral grooves. Umbilicus practically closed. Sheath not recognizable. Lobe forming a very wide everted columellar lip.

Height (not quite complete) 7 mm, diameter 5 mm (type).

Type: USNM 561361.

Type locality: 42 (USGS 17692, northeast coast of Trinidad Island, Canal Zone), marine member of Bohio(?) formation.

This minute globularine is fairly common in the Bohio(?) formation of Trinidad Island and occurs in the same formation near Palenquilla Point. The very wide everted columellar lip—that is, very wide for the size of the shell—widely spaced spiral grooves on the lower part of the body whorl, and minute size indicate that it represents an unnamed minor subdivision of *Globularia* or *Ampulella*.

Amaurellina garzaensis Vokes (1939, p. 173, pl. 22, figs. 9, 12, 16), a middle Eocene species from California, is of comparable size, but has a narrower columellar lip and relatively strong, evenly spaced spiral grooves.

Occurrence: Marine member of Bohio(?) formation (late Eocene or early Oligocene), Gatun Lake area, localities 41, 42.

Genus Amaurellina Fischer?

Fischer, Manuel de conchyliologie, p. 766, 1885.
Type (monotype): *Ampullina spirata* (Lamarck) (*Ampullaria spirata* Lamarck), Eocene, Paris Basin.

Amaurellina? species

Plate 14, figure 4

Molds from limestone of the Gatuncillo formation are doubtfully referred to *Amaurellina*. They are large, strongly inflated, shouldered, and have a moderately high turreted spire. The wide space between the shoulder and the preceding whorl indicates a wide shelf or channel adjoining the suture.

Height (incomplete) 53 mm, diameter 52 mm (largest specimen). Height (incomplete) 46 mm, diameter 38 mm (figured specimen).

If these molds represent an *Amaurellina*, it is an exceptionally large species.

Occurrence: Gatuncillo formation (late Eocene), Madden basin, localities 9, 12, 15.

Genus Pachycrommium Woodring?

Woodring, Carnegie Inst. Washington Pub. 385, p. 391, 1928.
Type (orthotype): *Amaura guppyi* Gabb, Miocene, Dominican Republic.

Pachycrommium? solenaeum Woodring, n. sp.

Plate 14, figure 1

Of medium size, shouldered, moderately inflated. Spire high, turreted. A narrow channel adjoins suture. Aperture short. Sheath narrow, rim low. Posterior part of sheath overlapped by narrow lobe, which becomes low and unrecognizable anteriorly. Umbilicus closed.

Height (not quite complete) 32.5 mm, diameter (somewhat crushed) 22 mm (type).

Type: USNM 561364.

Type locality: 38 (USGS 17166, Río Casaya area, Quebrada de Oro, a northwestward-flowing tributary of Río Casaya, 3.3 kilometers southeast of east end of Gamboa bridge, Canal Zone), Gatuncillo formation.

The type (and only specimen) of this species is a silicified fossil from the Gatuncillo formation. The outline of body whorl and aperture is somewhat distorted by lateral crushing. The replacing silica is granular.

The generic assignment of this species is doubtful. The type of *Pachycrommium* has a gently sloping shelf between the suture and the shoulder, and a more elongate aperture. Moreover, sheath and lobe can be distinguished only on immature specimens, the lobe of mature shells forming a wider and more strongly edged everted columellar lip than that of *Pachycrommium? solenaeum.* Nevertheless a species that appears to be properly referred to *Pachycrommium* has a channel adjoining the suture and separation of sheath and lobe evidently depends on growth stage. *"Amauropsis" burnsii meridionalis* Pilsbry (1922, p. 387, pl. 34, figs. 23, 24; Miocene, Dominican Republic), which is discussed under *Pachycrommium?* cf. *P. trinitatensis* (p. 97), has a channel adjoining the suture. Lobe and sheath are well defined on the posterior part of the sheath on the only specimen in the U. S. National Museum, but not on the type, according to Pilsbry's illustration.

Eocene high-spired globularines from America and other regions have been referred to *Pachycrommium.* It is doubtful, however, how many of them—including species mentioned when the generic name was proposed, as noted by Palmer (1937, p. 136–137)—are closely related to *Pachycrommium guppyi.*

Occurrence: Gatuncillo formation (middle Eocene), Río Casaya area, locality 38.

Pachycrommium? proinum Woodring, n. sp.

Plate 15, figure 12

Lupia perovata (Conrad), Dall *in* Hill, Mus. Comp. Zool. Harvard College Bull., v. 28, p. 273, 1898 (list; Eocene, Canal Zone). Brown and Pilsbry, Acad. Nat. Sci. Philadelphia Proc., v. 63, p. 360, 1911 (Dall's record).

Of medium size, shouldered, strongly inflated. Spire high, turreted. Whorls sloping from suture to shoulder. Aperture elongate. Sheath narrow, for most part not preserved. Lobe narrow, imperfect. Umbilicus closed. Very faint microscopic spiral lineation visible on some specimens on and near shoulder. Type and two other specimens show narrow retractive dark axial bands.

Height (incomplete) 26 mm, diameter 19 mm (type). Height (not quite complete) 35 mm, diameter 22 mm.

Type: USNM 135200.

Type locality: 40a (USGS 2683, Vamos Vamos, off Palenquilla Point, Canal Zone, now submerged), marine member of Bohio(?) formation.

Though this globularine is represented by 15 specimens collected at Vamos Vamos and at locality 41 near Plaenquilla Point, none completely shows the columellar lip. The lobe is shown on five specimens, on all of which it is narrow, and an imperfect narrow sheath is visible on the type. Dark axial bands are well shown on the body whorl of three specimens. They may possibly indicate axial bands differing in shell texture rather than color bands.

Incomplete as these fossils are, they suggest a *Pachycrommium* that is less inflated than *P. guppyi* and has whorls characterized by a steeper slope between the suture and the shoulder.

Dall identified this globularine as the Claiborne (middle Eocene) species *"Lupia" perovata* (Conrad), an identification that doubtless had much influence on his conclusion that the strata at Vamos Vamos, and by inference at Gatun, are Eocene. *"Lupia" perovata* has a higher less turreted spire. In outline of whorls *Pachycrommium? proinum* is more similar to the Jackson (late Eocene) species *"Amauropsis" jacksonensis* Harris, which, like *"Lupia" perovata,* has a higher spire. Mansfield's (1940, p. 222, pl. 27, fig. 44) late Oligocene *Pachycrommium* sp., from the lower part of the Chickasawhay marl of Alabama, is less inflated than the species from Panamá and has a higher spire.

Pachycrommium? proinum is closely related to *Pseudocrommium gabrielensis* Clark (Clark and Durham, 1946, p. 19, pl. 16, figs. 14, 15), from the late Eocene of Colombia, but is smaller and has a more turreted spire. The paratype of *Pseudocrommium gabrielensis* has indistinct alternating dark and light axial bands. *Pseudocrommium carmenensis* Clark (Clark and Durham, 1946, p. 19, pl. 16, fig. 7) evidently is conspecific with *P. gabrielensis.*

Both "*Lupia*" *perovata* and "*Amauropsis*" *jacksonensis* have been considered high-spired species of *Crommium* (Palmer, 1937, p. 136, pl. 14, figs. 5, 9; Harris and Palmer, 1946–47, p. 256, pl. 30, fig. 5, 1947). Should the names *Euspirocrommium* or *Pachycrommium* prove to be inappropriate for these high-spired species that evidently are related to *Crommium*, *Pseudocrommium* (Clark, in Clark and Durham, 1946, p. 18; type (orthotype): *Pseudocrommium carmenensis* Clark), based on a late Eocene species from Colombia, is available for them and has recently been used for them (Richards and Palmer, 1953, p. 27).

Occurrence: Marine member of Bohio(?) formation (late Eocene or early Oligocene), Gatun Lake area, localities 40a, 40b, 40d, 41.

Pachycrommium? cf. P.? trinitatensis (Mansfield)

Plate 16, figure 11

Large, shouldered, strongly inflated. Spire high, turreted. Aperture moderately elongate. Other apertural features unknown.

Height (incomplete) 50 mm, diameter (exaggerated by crushing) 39 mm (figured specimen).

Molds of a large high-spired globularine, which occur in the middle member of the Caimito formation in the Gatun Lake area and in the Culebra formation, resemble the type of "*Amauropsis*" *trinitatensis* (Mansfield, 1925, p. 58, pl. 10, figs. 4, 5). The type of that species is a mold from early Miocene strata in Trinidad. Mansfield's (1937, p. 177, pl. 9, fig. 7) "*Amauropsis*" aff. "*A.*" *burnsii meridionalis* Pilsbry, a late Oligocene form represented by molds from Georgia and Florida, also resembles the type of "*Amauropsis*" *trinitatensis*. "*Amauropsis*" *burnsii meridionalis* (Pilsbry, 1922, p. 387, pl. 34, figs. 23, 24) occurs in the Miocene of the Dominican Republic. Despite its wide deep channel adjoining the suture, it appears to be a *Pachycrommium*. Mansfield's (1940, p. 223, pl. 27, fig. 8) late Oligocene *Pachycrommium?* sp., a mold from the lower part of Chickasawhay marl, has a similar sutural channel, but is larger and has a higher spire. Though "*Amauropsis*" *burnsii meridionalis* has a sutural channel like that of the Chipola species "*Polinices* (*Amauropsis*)" *burnsii* Dall (Gardner, 1926–47, p. 557, pl. 59, fig. 12, 1947), a close relationship between the two forms is doubtful. The Chipola species has a wide expanded aperture and thickened outer lip. It is a remarkable globularine.

If the unknown apertural features of both "*Amauropsis*" *trinitatensis* and the fossils from Panamá could be ignored, the fossils from Panamá would be unequivocally identified as the Trinidad species. The outline of the figured mold is distorted by dorso-ventral crushing. Should "*Amauropsis*" *trinitatensis* prove to be a *Pachycrommium*, it would be the largest species of the genus. "*Natica*" *phasianelloides* d'Orbigny [1852(?), p. 9, pl. 1, fig. 7] may be an earlier name for it.

Occurrence: Middle member of Caimito formation (late Oligocene), Gatun Lake area, locality 60. Culebra formation (early Miocene), Gaillard Cut, locality 108c.

Pachycrommium? cf. P. guppyi (Gabb)

Plate 16, figure 12

Of medium size, strongly inflated, strongly shouldered. Spire high, strongly turreted. Gently sloping shelf extends from suture to shoulder. Apertural features unknown.

Height (not quite complete) 27 mm, diameter 21.5 mm (figured specimen).

The Culebra formation yielded three incomplete high-spired globularines. The most nearly complete specimen, which is figured (and probably also the other two) is comparable in outline to the strongly shouldered form of *Pachycrommium guppyi* (Pilsbry, 1922, p. 386, pl. 34, figs. 25–27). *P. guppyi* occurs in the early Miocene Baitoa formation of the Dominican Republic and also in the middle Miocene Cercado and Gurabo formations. Mansfield (1937, p. 174) considered "*Amauropsis*" *floridana* Dall (1915, p. 108, pl. 5, fig. 11), a small *Pachycrommium* from the early Miocene Tampa limestone of Florida, to be indistinguishable from *P. guppyi*. *P. floridanum*, however, has a more expanded aperture and correspondingly more inflated body whorl. The middle Miocene Oak Grove form, *P. dodonum* Gardner (1926–47, p. 557, pl. 59, figs. 4, 13, 1947), agrees with the strongly shouldered form of *P. guppyi*.

Though *Pachycrommium guppyi* occurs in formation correlated with the Gatun formation, the genus has not been found in the Gatun formation. *Pachycrommium?* cf. *P. guppyi* is the youngest of the high-spired globularines in the Canal Zone.

Occurrence: Culebra formation (early Miocene). Gaillard Cut, localities 112, 115a.

Family TURRITELLIDAE

Genus Turritella Lamarck

Lamarck, Soc. Histoire Nat. Paris Mém., p. 74, 1799.

Type (monotype): *Turbo terebra* Linné, Recent, tropical western Pacific.

Turritella occurs in all marine formations of the Canal Zone and adjoining parts of Panamá, except the Chagres sandstone proper. The number of forms therefore is large: 17 species and 3 subspecies. The Gatun formation, which contains 6 species and 2 named minor forms, has the largest number of species. Not more than 4 species, however, were found in the Gatun formation at any one locality.

The importance of the sculpture of the early whorls and the growth line in a study of the affinities of turritellas was emphasized by Merriam in his monograph of fossil turritellas from the Pacific coast of North America. His term "growth-line angle" (Merriam, 1941, p. 59) is adopted for the angle between the axis of the shell and a line extending from the posterior end of the growth line to the anterior end on spire whorls, or to the apex of the forward bend, if such a bend is present near the anterior suture.

Merriam pointed out that among the several hundred described species of *Turritella*, groups of closely allied species are as distinctive as groups of species in other families—groups that are given generic and subgeneric rank in other families. Nevertheless he was reluctant to assign superspecific names to the groups of species he recognized, as suitable material for consideration of many of the superspecific names proposed for turritellids was not available to him. He therefore grouped his species into stocks named for a typical species (Merriam, 1941, p. 33–55). At an earlier date Guillaume (1924) classified European Tertiary species in groups, also named for a typical species. Merriam's stocks, however, are more restricted than Guillaume's groups and afford a much better basis for a satisfactory classification. Guillaume relied on the growth line, ignoring the development of the sculpture and other features.

Though no exhaustive study has been attempted, only one subgenus of turritellas from the Canal Zone and adjoining parts of Panamá appears to have a suitable name: *Torcula;* in fact, two names (*Torcula* and *Bactrospira*) are available for that subgenus, which corresponds to Merriam's *T. altilira* stock.

Subgenus? (?Guillaume's T. hybrida group, in part)

Turritella cf. T. carinata Lea

Plate 14, figure 2

Moderately large, moderately slender. Whorls slightly concave, the profile modified by a spiral forming a basal carina immediately adjoining anterior suture. Remainder of late whorls apparently smooth; remainder of intermediate whorls apparently smooth or sculptured with a low spiral at anterior third. Poorly preserved early whorls show a spiral at about anterior third, but no other sculpture apparent. Growth line not known.

Height (incomplete, 7+ whorls) 41.5 mm, diameter 16 mm (figured specimen).

The figured specimen and fragments consisting of several intermediate and late whorls are silicified fossils from the Gatuncillo formation in the Río Casaya area. The basal carina suggests affinity with the Claiborne (middle Eocene) species *Turritella carinata* (Palmer, 1937, p. 189, pl. 24, figs. 5, 6, 8, 9, 12). The last few whorls of some large specimens of *T. carinata* have no macroscopic spirals other than the basal carina, like the figured fossil from Panamá. On other large specimens of *T. carinata*, however, the last few whorls have one to several additional spirals. Though the figured specimen reaches a greater diameter than *T. carinata*, even the last whorl tightly clasps the preceding whorl, whereas the last few whorls of large shells of *T. carinata* gradually withdraw from the carina. *T. carinata* has microscopic spiral lineation, but such sculpture would not be reproduced by the granular silica of the fossils from Panamá. The early whorls of *T. carinata* are sculptured with three spirals; the growth-line sinus is very deep and the growth-line angle very narrow.

The middle Eocene Peruvian *T. bosworthi* Woods (Woods and others, *in* Bosworth, 1922, p. 80, pl. 8, figs. 8–10) is more strongly carinate.

T. carinata evidently represents, in part, Guillaume's *T. hybrida* group (Guillaume, 1924, pp. 286–290).

Occurrence: Gatuncillo formation (middle Eocene), Río Casaya area, locality 38.

Subgenus?

Turritella cf. T. collazica Maury

Plate 16, figure 13

Large, late whorls rapidly enlarging. Whorls slightly concave, the profile dominated by a wide swollen basal carina occupying anterior third, or a little more, of whorl. Other sculpture obscure or absent. Sculpture of early whorls and growth line unknown.

Height (incomplete, 4+ whorls) 56 mm, diameter (exaggerated by crushing) 25 mm (figured specimen).

The basal limestone of the La Boca marine member of the Panamá formation on Río Masambí yielded a poorly preserved crushed *Turritella* characterized by a wide swollen basal carina. The Oligocene Puerto Rican *T. collazica* has a similar basal carina (Maury, 1920, p. 51, pl. 8, fig. 5). According to Maury's illustration, the basal carina bears a groove and the remainder of the whorl is sculptured with six low spiral threads.

A fragment from the Culebra formation at locality 5857, listed as *Turritella* sp., resembles the La Boca species, but its preservation is too poor to permit identification.

Occurrence: Limestone at base of La Boca marine members of Panamá formation (early Miocene) Río Masambí, locality 123.

Subgenus? (?Merriam's T. buwaldana stock)

Turritella cf. T. samanensis Olsson

Moderately large, slender. Whorls slightly convex or flat, sculptured with about 10 subequal low spirals. On at least some intermediate and late whorls the basal spiral and another near middle of whorl are slightly stronger than others. Sculpture of early whorls and growth line unknown.

Height (incomplete, 3+ whorls) 25 mm, diameter 15 mm.

This species is represented by poorly preserved fragments from calcareous sandstone in the Gatuncillo formation of the Río Fríjol area. The slightly convex or flat whorls and the subequal spirals resemble features of the late Eocene Peruvian *Turritella samanensis* (Olsson, 1928, p. 65, pl. 14, figs. 3, 4, 6–8; 1931, p. 74), which is recorded from the late Eocene of Colombia (Clark, *in* Clark and Durham, 1946, p. 26, pl. 23, figs. 1, 4). *T. masinguiensis* Clark (*in* Clark and Durham, 1946, p. 24, pl. 23, figs. 3, 5–7, 9, 10), also from the late Eocene of Colombia, appears to be *T. samanensis.*

According to Olsson, the early whorls of *T. samanensis* have three spirals. Therefore it is unlikely that it is related to *T. uvasana* Conrad, of the Eocene of California, the early whorls of which have two spirals (Merriam, 1941, p. 89.) Probably it is a representative of Merriam's *T. buwaldana* stock (Merriam, 1941, p. 42).

Occurrence: Gatuncillo formation (late Eocene), Río Fríjol area, locality 34.

Subgenus?

Turritella species

Large, slender. Late whorls slightly concave, a narrow carina lying near anterior suture and a wider carina near posterior suture. Intermediate whorls sculptured with a spiral at anterior third, one or two spirals at posterior third, and microscopic minor spirals. Sculpture of early and late whorls and growth line unknown.

Height (incomplete, 3 whorls) 43 mm, diameter 24 mm.

The affinities of this species, which occurs in the Gatuncillo formation, are undetermined. Late whorls are represented only by molds.

Occurrence: Gatuncillo formation (late Eocene), Madden basin, localities 12, 15; Río Fríjol area, localities 32, 34.

Subgenus? (Merriam's T. uvasana stock)

Turritella adela Woodring, n. sp.

Plate 15, figures 5, 6

Turitella gatunensis Conrad, Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 2, p. 310 (part, not pl. 17, fig. 10=*T. atacta* Dall), 1892 (Miocene, Vamos Vamos, Panamá). Dall, in Hill, Mus. Comp. Zool. Harvard College Bull., v. 28, p. 273 (part), 1898 (list; Eocene, Vamos Vamos, Panamá).

Of medium size, slender. Whorls moderately convex. Sculpture of late whorls consisting of 9 or 10 primary spirals, the 3 or 4 on anterior half of whorls slightly stronger than those on posterior half. Minor spirals of unequal strength lie between primaries. Earliest preserved whorls sculptured with two spirals: One at middle of whorl, the other midway between it and anterior suture. Spirals persist as the posteriormost and third (numbered anteriorly from middle of whorl), respectively, of the strong spirals on anterior half of late whorls. Base sculptured with numerous minor spirals of unequal strength and two stronger spirals adjoining periphery. Growth-line sinus moderately deep, the apex at middle of whorl; growth-line angle narrow.

Height (incomplete) 25 mm, diameter 7.5 mm (type). Height (incomplete, 3 whorls) 22.5 mm, diameter 12 mm (paratype).

Type: USNM 561370; paratype, USNM 561371.

Type locality: 41 (USGS 17716, east side of promontory 375 meters southeast of Palenquilla Point, Canal Zone), marine member of Bohio(?) formation.

Turritella adela is abundant in the marine member of the Bohio(?) formation near Palenquilla Point and at the nearby submerged Vamos Vamos locality. All the specimens, however, are incomplete. In general features it resembles *T. galvesia* Olsson (1931, p. 78, pl. 14, figs. 2–7), of the Oligocene of Perú, but has more inflated whorls and a deeper growth-line sinus. The lower limb of the sinus of *T. galvesia* is practically vertical. The sculptural pattern and growth line of the Oligocene Venezuelan *T. andreasi* Hodson (1926, p. 37, pl. 24, figs. 7–9, 12, pl. 25, fig. 2) suggest relationship. Though the early sculpture of *T. andreasi* is unknown, intermediate whorls do not have the two strong spirals characteristic of *T. adela* at the same diameter.

The early sculpture, the subsequent sculptural pattern, and the growth line indicate that *T. adela* is a medium-sized late Eocene or early Oligocene species of Merriam's *T. uvasana* stock, which reached its acme in the Eocene of the Pacific coast of North America and continued through the Oligocene (Merriam, 1941, p. 42–44). Dall identified *T. adela* as *T. gatunensis* Conrad. If he had specimens from Vamos Vamos in mind, he was justified in claiming that his *T. gatunensis* is closely related to *T. uvasana.*

Occurrence: Marine member of Bohio(?) formation (late Eocene or early Oligocene), Gatun Lake area, localities 40, 40a, 40d, 41.

Turritella meroensis Olsson

Plate 15, figure 19

Turritella gatunensis Conrad, Joukowsky, Soc. Phys. Histoire Nat. Geneva Mém., v. 35, p. 163 (list), pl. 6, figs. 26, 27, 1906 (Oligocene, Panamá).

Turritella meroensis Olsson, Bull. Am. Paleontology, v. 17, no 63, p. 76, pl. 13, figs. 1–4, 1931 (Oligocene, Perú, Ecuador).

Moderately large, slender. Whorls strongly inflated, sculptured with strong subequal spirals, 5 on intermediate whorls, 5 or 6 on late whorls. Late whorls bearing a gradually enlarging secondary spiral between anteriormost primary and suture, and between posteriormost and suture. Well-preserved whorls showing microscopic spirals between primaries. Sculpture of early whorls and growth line not known.

Height (incomplete, 3+ whorls) 39 mm, diameter 21 mm (figured specimen).

Type: Paleontological Research Institution, Ithaca, N. Y., 2051.

Type locality: Caleto Mero, Perú, Heath formation (late Oligocene).

Turritella meroensis occurs in the middle member of the Caimito formation in the Gatun Lake area and in the Quebrancha limestone member of the same formation in the Quebrancha syncline. Preservation of the specimens from the Quebrancha limestone member is poor. This species has already been recorded by Olsson (1942, p. 239) from strata in the Canal Zone now assigned to the Caimito formation, and he thought also that Joukowsky's *T. gatunensis* is *T. tristis* or *T. meroensis* (Olsson, 1942, p. 241). Wherever *T. meroensis* has been found, in Perú, Ecuador, and Panamá, it occurs in formations of late Oligocene age.

The later whorls of this *Turritella* are *Mesalia*-like, as pointed out by Olsson. The specimens from the Caimito formation closely agree with the form from the type locality shown in Olsson's figure 1 and with Joukowsky's illustrations of his *T. gatunensis* from late Oligocene strata in the Santiago area, Panamá, and also with specimens from that region. The growth line is not shown on specimens from the Caimito formation. On specimens from the type locality the sinus is of moderate depth and its apex is near the middle of the whorl; the growth-line angle is narrow. Also on specimens from the type locality the growth lines form threads on unworn primary spirals.

T. vientoensis Clark (in Clark and Durham, 1946, p. 27, pl. 23, figs. 2, 11–13, 17, 18), a late Eocene species from Colombia, is closely allied to *T. meroensis*, but the later whorls of *T. vientoensis* have more numerous spirals. *T. saltoensis* Clark (in Clark and Durham, 1946, p. 26, pl. 23, fig. 28) evidently is a form of *T. vientoensis* differing in details of sculpture.

There are no known descendents of *T. meroensis*. Though this well-defined species was identified by Joukowsky as *T. gatunensis*, it needs no comparison with that species. According to the growth line and the early sculpture of two spirals (Olsson, 1931, p. 76), *T. meroensis* is a representative of Merriam's *T. uvasana* stock, which is not known to have survived the Oligocene. The heavy spirals and strongly inflated whorls suggest affinity with *T. variata lorenzana* Wagner and Schilling (Merriam, 1941, p. 99, pl. 18, fig. 3, pl. 19, figs. 9, 12–14), of the Oligocene of California.

Gabb's illustrations of his *T. gatunensis* (Gabb, 1881, p. 342, pl. 44, fig. 10, 10a), which does not even remotely resemble *T. gatunensis* and was named *T. tristis* by Brown and Pilsbry (1911, p. 358, footnote), suggest a species resembling *T. meroensis*, but more slender. Three incomplete specimens are in the type (and only) lot (Acad. Nat. Sci. Philadelphia 3532). The largest, which has a height of 28 millimeters and a diameter of 8 millimeters, evidently is the original of Gabb's freely drawn figure 10 and is herewith designated the lectotype. The whorls enlarge very slowly. The earliest whorls are bicarinate, but also have a weak posterior spiral; at the same stage *T. meroensis* has similar sculpture. A fragment of late whorls has five primary spirals, the third from the base being carinate. The third specimen, also a fragment of late whorls, is sculptured with five primary spirals and very fine secondaries; that is, the sculpture is much like that of late whorls of *T. meroensis*. On the basis of this inadequate material *T. tristis* may be a very slender ally of *T. meroensis*. The stratigraphic relations of the black shale on Oronli Creek, in southern Costa Rica—the type locality of *T. tristis*—are unknown, but, according to the fossils Gabb found there, its age probably is Oligocene. Apparently no geologist has seen it since Gabb's visit.

Occurrence: Middle member of Caimito formation (late Oligocene), Gatun Lake area, locality 56. Quebrancha limestone member of Caimito formation (late Oligocene), Quebrancha syncline, locality 62. Late Oligocene, Santiago area, Panamá. Late Oligocene, Posorja, Ecuador. Heath formation (late Oligocene), Perú.

Subgenus?

Turritella cf. T. caleta Olsson

Plate 15, figures 14–16

Small, slender, more or less bicarinate. Early whorls sculptured with three equally spaced spirals. Anterior and posterior spirals emphasized on intermediate whorls, producing a bicarinate outline, and generally emphasized on late whorls. Intermediate and late whorls also sculptured with unequal minor spirals, including original middle spiral. Primary and some minor spirals of well-preserved specimens slightly noded by growth lines. Growth-line sinus deep, apex slightly back of middle of whorl; growth-line angle very narrow.

Height (incomplete, 2+ whorls) 13.5 mm, diameter 9.5 mm (figured fragment of large specimen). Height (incomplete, 4 whorls) 13 mm, diameter 6.5 mm (figured fragment of specimen of intermediate size).

Variation affects the strength of the spirals and therefore the whorl profile. Though late whorls are typically bicarinate, the bicarinate outline is somewhat obscured on some specimens by weakening of one or both primaries, or by development of posterior minor spirals that are almost as strong as the posterior primary (pl. 15, fig. 16).

Turritella cf. *T. caleta* occurs in the marine member of the Bohio(?) formation. It is represented by numerous fragments and immature specimens, or shell tips, in collections from Vamos Vamos and Trinidad Island, and was found near Palenquilla Point. Apparently it is related to the Oligocene Peruvian *T. caleta* Olsson (1931, p. 79, pl. 12, figs. 9, 11, 12, 15), but the early sculpture of that species is unknown. The late whorls of *T. caleta* have a weak posterior primary spiral.

The bicarinate outline and growth line suggest relationship to *T. altilira* Conrad. That suggestion, however, is not supported by the sculpture of the early whorls. The bicarinate outline and growth line also suggest relationship to *T. olssoni* Clark (Clark and Durham, 1946, p. 25, pl. 23, figs. 14–16, 22), a late Eocene Colombian species, which has less strongly beaded late whorls. *T. olssoni* was claimed to be an early member of the *T. altilira* group. Specimens that show the early sculpture, available through the kindness of J. Wyatt Durham, substantiate that claim, the earliest sculptured whorls bearing an anterior spiral, a weaker posterior spiral appearing later. *T.* cf. *T. caleta* therefore is not related to *T. olssoni.*

Occurrence: Marine member of Bohio(?) formation (late Eocene or Oligocene), Gatun Lake area, localities 40, 40a, 40b, 40d, 41, 42, 42c.

Subgenus Torcula Gray

Gray, Proc. Zool. Soc. London, p. 155, 1847.
Type (orthotype): *Turbo exoletus* Linné, Recent, Florida and West Indies.

The subgenus *Torcula* is characterized by an anterior spiral on the earliest sculptured whorls, an intermediate sculpture of two widely spaced spirals, typically a similar mature sculpture of two primary carina-forming spirals, and also a deep growth-line sinus and a narrow growth-line angle. The intermediate sculpture of the type species is weak, five or six whorls sculptured with two weak spirals following the first two whorls sculptured with a stronger anterior spiral. The intermediate sculpture of *T. altilira* and its close allies is much stronger.

Most of the lots of *T. exoleta* in the U. S. National Museum collections are from depths of 35 to 85 fathoms. A few lots, however, were dredged at shallower depths; one lot from Conch Key, Fla., at a depth of 1 to 5 feet. As orally pointed out by R. T. Abbott, it is remarkable that a species almost unobtainable except by dredging was available to Linné.

Bactrospira Cossmann (1895–1924, pt. 9, p. 129, 1912; type [orthotype], *Turritella perattenuata* Heilprin, Pliocene, Florida) is available as a name for a minor group under *Torcula*, including *T. altilira* and its close allies. *T. altilira* has more rapidly enlarging early whorls than *T. perattenuata. Eurytorus* Gardner (1926–47, p. 596, 1947; type [orthotype], *Turritella mixta* Dall, Miocene, Florida), proposed as a section of *Torcula*, has the growth line and early and intermediate sculpture of *Torcula.* The whorls enlarge so rapidly, however, and on mature whorls two or three original secondary spirals are so strong that subgeneric rank may be justified.

T. amaras is by no means a typical species of *Torcula* in plan of mature sculpture. It is somewhat comparable to *Eurytorus* in divergence from the basic pattern of *Torcula,* but diverges in a different direction.

Turritella (Torcula?) amaras Woodring, n. sp.

Plate 16, figures 4–7, 10

Large, rapidly enlarging. Whorls typically flat; suture typically obscured by overhanging anterior spiral. Intermediate and late whorls of some specimens carinate at the anterior spiral, the suture being exposed. Sculpture consisting of three strong subequal primary spirals. Earliest preserved whorls sculptured with two spirals, anterior one at about anterior third of whorl, posterior one at about posterior third; anterior spiral slightly stronger. These spirals are middle and posterior spirals of subsequent whorls. Anterior spiral, adjoining suture, appearing at early stage and gradually increasing in size. Middle and posterior spirals farther apart than middle and anterior, the middle spiral lying in front of middle of whorl. One to three weak secondary spirals generally present between middle and posterior primaries, and between posterior primary and suture. Well-preserved shell surfaces show microscopic spiral striae. Primary and secondary spirals of some whorls obscurely noded by growth lines. Growth-line sinus deep, the apex at about middle of whorl between middle and posterior spirals; growth-line angle narrow.

Height (incomplete) 47 mm, diameter 14.5 mm (type, a specimen of intermediate size). Height (incomplete, 3+ whorls) 43 mm, diameter 24.5 mm (figured fragment of large specimen).

Type: USNM 561373.

Type locality: 116 (USGS 5853, west side of Gaillard Cut, Canal station 1863, Canal Zone, Culebra formation.

The only important variation affects the whorl profile. Carinate whorls owe their profile to loose clasping, which completely exposes the anterior spiral and the part of the whorl lying immediately in front of it (pl. 16, fig. 6). This is not a late-growth feature, for some specimens of intermediate size have carinate whorls and many large specimens have tightly clasped whorls. On the typical flat-whorled form the suture is obscured by the overhanging anterior spiral. However obscure the suture may be, the base of a whorl may be identified by the narrow space between the anterior and middle spirals. Apparent variation affecting minor sculptural features may be due principally to differences in preservation rather than to original variation.

This well-defined species is widespread and abundant in the Culebra formation. It occurs in sandstone, principally in the upper part of the Culebra and in the transition zone between the Culebra and Cucaracha formations. Like other Culebra fossils, most of the specimens have some calcareous sandstone adhering to them or are otherwise poorly preserved. The type, of intermediate size, was collected from pebbly sandstone in the Paraiso region. Its earliest preserved whorls are strongly worn and the others are somewhat worn.

Turritella caparonis Maury (1925, p. 234, pl. 42, figs. 1, 2), from strata of late early Miocene age in Trinidad, is a related species. It has four equally spaced spirals, the anteriormost (adjoining and obscuring the suture) not quite as strong as the others. The more distinct nodes on the spirals, as compared with *T. amaras*, are probably the result of better preservation. The two species are similar in growth line. *T. amaras* may be more closely related to the Oligocene Puerto Rican *T. mitchelli* Hubbard (1920, p. 137, pl. 22, fig. 3), which has three similarly spaced primary spirals and appears to have a similar growth line. According to the illustration of the imperfect type (and only specimen), it has two strong secondary spirals between the middle and posterior primaries, minor spirals superimposed on the primaries, and fairly strong nodes, particularly on the secondary spirals. Merriam's (1941, pl. 24, fig. 2) *Turritella* aff. *T. altilira*, from the Miocene of Colombia, needs comparison with *T. amaras*.

T. amaras and its allies represent a minor offshoot from the stock of *T. altilira* that failed to survive the Miocene.

Occurrence: Culebra formation (early Miocene), Gaillard Cut, localities 98, 99b, 107, 108b, 108c, 110, 110a, 111a, 111b, 112, 112a, 116.

Turritella (Torcula) altilira altilira Conrad

Plate 23, figures 1, 7, 12, 13

Turritella altilira Conrad, Pacific R. R. Expl., v. 6, Geol. Rept., p. 72, pl. 5, fig. 19, 1857 (Miocene, Gatun, Panamá). (Reprinted U. S. Geol. Survey Prof. Paper 59, p. 178, 1909.) Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 63, p. 358, pl. 27, figs. 2, 3, 1911 (Miocene, Canal Zone). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 150, pl. 14, figs. 6, 7, 1922 (Miocene, Canal Zone). Hodson, idem, v. 11, no. 45, p. 45, pl. 26, fig. 1, pl. 28, fig. 3, pl. 29, fig. 1, 1926 (Miocene, Canal Zone). Oinomikado, Geol. Soc. Japan Jour., v. 46, p. 620, pl. 29, fig. 2, 1939 (Miocene, Colombia). Merriam, Calif. Univ. Dept. Geol. Sci. Bull., v. 26, p. 44, pl. 24, figs. 3, 4, 1941 (Miocene, Canal Zone).

Turritella gabbi Toula, K. k. Geol. Reichsanstalt Jahrb., Band 58, p. 695, pl. 25, fig. 5, 1909 (Miocene, Canal Zone).

Turritella altilira urumacoensis Hodson, Bull. Am. Paleontology, v. 11, no. 45, p. 44, pl. 26, figs. 4, 7, pl. 27, figs. 3–7, 10, 1926 (Miocene, Venezuela).

Not *Turritella altilirata* Conrad (error for *T. altilira*), Gabb, Acad. Nat. Sci. Phila. Jour., 2d ser., v. 8, p. 341, pl. 44, figs. 9, 9*a*, 1881 (Miocene, Costa Rica; = *T. sapotensis* Brown and Pilsbry). Grzybowski, Neues Jahrb., Beilage-Band 12, p. 645, pl. 20, fig. 7, 1899 (Miocene, Perú; subsp. of *T. altilira*).

Not *Turritella altilira* Conrad, Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 64, p. 503 (list), 1913 (Miocene, Culebra Cut, Canal Zone; subsp. of *T. altilira*). Spieker, Johns Hopkins Univ. Studies in Geology, no. 3, p. 59, pl. 2, fig. 12, 1922 (Miocene, Perú; subsp. of *T. altilira*). Anderson, Calif. Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 118, pl. 17, figs. 4, 5, 1929 (Miocene, Colombia; subsp. of *T. altilira*). Marks, Bull. Am. Paleontology, v. 33, no. 139, p. 99, 1951 (Miocene, Ecuador; subsp. of *T. altilira*).

Large, slender, strongly bicarinate. Protoconch small, bulbous, consisting of about 1¼ whorls. End of protoconch marked by gradual appearance of anterior primary spiral, which rapidly enlarges on first sculptured whorl. Posterior primary spiral appearing on latter part of third or on fourth sculptured whorl, slowly enlarging until on sixth to tenth sculptured whorl it generally is as stong as anterior spiral Even, however, on intermediate whorls of some specimens anterior primary is larger. Unequal minor spirals appearing between primaries on sixth to eighth sculputured whorl. Almost as soon as they appear they are noded (at first microscopically), and a few whorls later nodes appear on primaries. Primary spirals of late whorls flangelike and strongly noded. Posterior primary wider than anterior, generally unequally doubled by partial coalescene of an original strong minor spiral lying in front of it. Minor spirals between primaries conspicuously noded; one minor spiral generally stronger than others. A wide, but low and moderately noded, minor spiral adjoins anterior suture. Minor spirals absent between posterior primary and suture. Well-preserved specimens show microscopic spirals over entire whorl, including primaries. On last whorl, or a little more, of mature shells, nodes subdued, widely and irregularly spaced, and growth line emphasized at irregular intervals. Minor spiral adjoining anterior suture of spire whorls emerging on base of body whorl as a stong spiral. Remainder of base sculptured with very weak minor or microscopic spirals fading out toward columellar lip. Growth-line sinus deep, its apex a little behind middle of whorl; growth-line angle narrow.

Height (incomplete, 6 whorls) 43.5 mm, diameter 17.5 mm (topotype). Height (incomplete 7+whorls), 63 mm, diameter 19 mm (figured fragment of large specimen). Height (incomplete) 73 mm, diameter 13 mm (figured almost complete large specimen).

Type material: Lectotype, Acad. Nat. Sci. Phila. 3513.

Type locality: Gatun, Canal Zone. Locality of topotype: 150a (USGS 10997, Panama Railroad, high cut about 0.4 mile (650 meters) southeast of Gatun railroad station, Canal Zone), middle part of Gatun formation.

In February, 1957, Ellen James Trumbull, of the Geological Survey, found at the Academy of Natural Sciences of Philadelphia a poorly preserved 4-whorled specimen of *Turritella altilira* that was collected by Newberry. It is all that is left of the type lot and is an obligatory lectotype, if not the remains of the 7-whorled type illustrated by Conrad. The specimen shown on plate 23, figure 7, was collected close to, if not at, the type locality. In 1855, when Newberry gathered a few fossils on his way to California, Gatun was located on the banks of the Chagres at the west end of the bluffs formed by the Quebrancha Hills. Presumably he found his fossils, including *T. altilira*, in a railroad cut. In the French literature on the geology of the present Canal Zone, *T. altilira* is designated *T. tornata* (*T. tornata* Guppy=*T. guppyi* Cossmann, a subspecies of *T. altilira*).

The typical form, which has flangelike strongly noded primary spirals, is rare in the lower part of the Gatun formation, but is widespread and abundant in the middle and upper parts in the Canal Zone. The posterior primary is almost invariably wider than the anterior on late whorls and, with few exceptions, is unequally doubled. Details of sculpture and the degree of whorl constriction between the posterior primary and the suture are variable. No specimens of the typical form are in the U. S. National Museum collections from the lower part of the Gatun formation, but T. F. Thompson collected from the lower part three specimens identified as *T. altilira altilira*. Only one specimen (from locality 138a), however, is really typical. One of the other two—a large specimen from locality 137a—has anterior and posterior primary spirals of equal width. The other (from locality 138a) has a nonflanged posterior primary; that is, it combines characters of the typical form and *T. altilira praecellens*, with which it is associated. On specimens from about the lower half of the middle part of the Gatun, including strata in the type region, one of the minor spirals in the concave area between the primaries is stronger and more coarsely noded than the others, and the suture is deeply impressed, as the result of strong whorl constriction (pl. 23, fig. 7). On specimens from about the upper half of the middle part, no minor spiral dominates the others and the suture is not so deeply impressed (pl. 23, fig. 12). On specimens from still higher strata in the upper part of the formation, however, a minor spiral is dominant on about half of the specimens, and most of them have a deeply impressed suture. Shells from a U. S. Geological Survey locality representing the upper part of the formation near Mount Hope (locality 175) have been illustrated by Merriam (1941, pl. 24, figs. 3, 4). Plate 23, figure 13 shows one of the few shells that have a simple posterior primary. On this specimen the posterior face of the posterior primary is not deeply concave. The shell was damaged and repaired while the second preserved whorl was being formed and after the repair the posterior primary is farther from the suture. This specimen therefore is abnormal, but the posterior primary is not doubled preceding the repair.

Maturity, as indicated by suppression of the nodes, is reached at a diameter of 15 to 20 millimeters. Healed breaks are conspicuous on the body whorl of mature shells and are not unusual on spire whorls. About 200 perfectly preserved shell tips from locality 147b and a considerable number from several other localities show the protoconch and early sculptured whorls (pl. 23, fig. 1).

In the Canal Zone and adjoining parts of Panamá the earliest forms of *Turritella altilira* appear in the upper Oligocene part of the Caimito formation and in the lower Miocene Emperador limestone member of the Culebra formation; the last in the Toro limestone member of the Chagres sandstone. The Caimito and Emperador fossils are discussed under the next heading. The earliest occurrence of the typical form is in the lower Miocene part of the Caimito formation in Madden basin. A poorly preserved small specimen from Madden basin, probably from the calcareous sandstone member of the Caimito formation, and molds (including one of a large specimen) from the overlying Alhajuela sandstone member are referred to the typical form. Though some details of the sculpture are partly or completely lacking, the identification is made with considerable confidence, for the primaries are flangelike, and the posterior primary is wider than the anterior and is unequally doubled. Other specimens from the Miocene part of the Caimito formation are too small or too imperfect for identification, other than in the unrestricted sense. A subspecies (or variety), discussed under a separate heading, is represented in the lower part of the Gatun formation and apparently occurs in the middle part. The acme of the typical form is reached in the middle and upper parts of the Gatun. The typical form is less abundant in the middle part west of the canal than east of the canal, and no form was found in the upper part in the coastal area west of the Canal Zone. Most of the lots collected in the middle part west of the canal are small specimens identifiable only in the unrestricted sense. A mold of a small specimen records the presence of the species in the Toro limestone member of the Chagres sandstone. According to current age assignments, *Turritella altilira*, in the unrestricted sense, therefore ranges from late Oligocene to early Pliocene; the typical form from late early Miocene to middle Miocene.

T. altilira and its immediate close allies are widely distributed in the upper Oligocene deposits of Puerto Rico, Antigua, Trinidad, Venezuela, and Panamá; the lower Miocene of Haiti, Dominican Republic, Puerto Rico, Anguilla, Brazil, Trinidad, Venezuela, Colombia, Panamá, and Costa Rica; the middle Miocene of Jamaica, Dominican Republic, Trinidad, Venezuela, Colombia, Panamá, Costa Rica, southeastern Mexico, Florida, Ecuador, and Perú; the upper Miocene of Trinidad, Venezuela, Colombia, Panamá, Costa Rica, the Colorado Desert of southern California; and the lower Pliocene of Panamá. Nineteen names have been proposed for forms of the *T. altilira* group. Some doubtless are superfluous, but many are to be regarded as subspecies of *T. altilira;* indeed six were described as subspecies or varieties. A study of the stratigraphic and geographic grades would be certain to yield valuable results, but would be a lengthy diversion. Only a few of the described forms combine flange-like, strongly noded primary spirals and a posterior primary wider than the anterior. Nevertheless middle Miocene fossils from southwestern and northern Colombia and Venezuela have flange-like, strongly noded primary spirals, and some have a posterior primary wider than the anterior. They so closely approach the typical form that they are referred to it. That is, the typical form occurs in the central Panamá area, along the south border of the Caribbean Sea, and at the south end of the Miocene Atrato Valley strait.

The *T. altilira* group reached southeastern United States in middle Miocene time. Gardner's (1926–47, p. 595, pl. 57, fig. 17, 1947) *Turritella* cf. *T. altilira*, found in the Shoal River formation of Florida, represents a form of *T. altilira,* but like many Caribbean forms it lacks flangelike primaries. Merriam's (1941, p. 44–47) Pacific coast *T. altilira* stock consists of *T. inezana* Conrad and *T. imperialis* Hanna. *T. inezana* appears in the early Miocene of California as a migrant. Though the immediate predecessor of *T. inezana* has not been recognized, the presence of a subspecies of the closely related *T. altilira* in the late Oligocene of Panamá shows that tropical America was a potential reservoir for the lineage leading to *T. inezana,* as had been inferred. Merriam has pointed out that *T. imperialis,* of disputed Miocene or Pliocene age (preferably late Miocene) is practically indistinguishable from some forms of *T. altilira* that lack flangelike primaries. It presumably is to be treated as a subspecies of *T. altilira.*

T. altilira has living allies in the Caribbean Sea and in the Panamic region: *T. exoleta* (Linné) and *T. mariana* Dall, respectively. Neither closely resembles the typical form of *T. altilira. T. exoleta* is the type of *Torcula.*

Occurrence: Calcareous sandstone(?) member of Caimito formation (early Miocene), Madden basin, localities 77 (*T.* cf. *T. altilira*), 80. Alhajuela sandstone member of Caimito formation (early Miocene), Madden basin, localities 88 (*T. altilira* s. l.), 89, 92 (*T. altilira* s. l.). Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, localities 137a, 138a, 139 (*T. altilira* s. l.). Middle part, eastern area, localities 141, 142, 143 (*T.* cf. *T. altilira*), 146, 147b, 147c, (*T.* cf. *T. altilira*), 147e (*T. altilira* s. l.), 147f, 147g, 147h, 150a, 151, 152 (*T. altilira* s. l.), 153, 153a, 154, 155, 155a, 155b, 155c, 157, 158, 159, 159a, 160 (*T. altilira* s. l.); western area, localities 161c, 161d (*T. altilira* s. l.), 162 (*T. altilira* s. l.). 162a (*T. altilira* s. l.) 165 (*T. altilira* s. l.), 166 (*T. altilira* s. l.), 168 (*T. altilira* s.l.), 170a. Upper part, eastern areas, localities 171, 173a, 174, 175, 176, 177, 177c, 177d (*T. altilira* s. l.), 178. Toro limestone member of Chagres sandstone (early Pliocene) locality 195 (*T. altilira* s. l.). Middle Miocene, Chocó, southwestern Colombia; northern Colombia. Middle Miocene, Falcón, Venezuela.

Turritella (Torcula) altilira Conrad, subspecies

Plate 15, figure 10

?*Turritella* aff. *T. perattenuata praecellens* Pilsbry and Brown, Mansfield, U. S. Natl. Mus. Proc., v. 66, art. 22, p. 55, pl. 9, figs. 7, 8, 1925 (Miocene, Trinidad).

Moderately large, moderately slender. Primary spirals relatively low, strongly noded. Posterior face of posterior primary slightly concave. Posterior primary wider than anterior, doubled or tripled. Minor spirals between primaries of unequal strength. Sculpture of early whorls unknown. Growth line like that of typical *T. altilira.*

Height (incomplete, 5+ whorls) 29.5 mm, diameter 13.3 mm (figured specimen). Height (incomplete, 7 whorls) 41.5 mm, diameter 17 mm.

The shell tapers more gently than that of the typical form of *Turritella altilira.* The most conspicuous difference, however, lies in the features of the primary spirals, which are not flangelike. The difference is particularly marked on the wide posterior primary, the posterior face of which is only slightly concave. On most of the specimens the posterior primary is doubled—on a few it is tripled. Though the primaries are strongly noded, the nodes are not as conspicuous as on the typical form, possibly owing to slight wear.

Mansfield's *Turritella* aff. *T. perattenuata praecellens* Pilsbry and Brown, of the early Miocene at Machapure (or Machapoorie) Quarry, Trinidad, has similar heavy strongly noded primaries.

This unnamed subspecies of *T. altilira* is found in the middle member of the Caimito formation in the Gatun Lake area and in the Quebrancha limestone member of the Caimito in the Quebrancha syncline. The Quebrancha limestone fossils are poorly preserved. A mold of a small specimen from the Emperador limestone member of the Culebra formation evidently is more similar to the typical form, as intermediate whorls have high primaries.

Occurrence: Middle member of Caimito formation (late Oligocene), Gatun Lake area, locality 56. Quebrancha limestone member of Caimito formation (late Oligocene), Quebrancha syncline, locality 62. Emperador limestone member of Culebra formation (early Miocene), Gaillard Cut, locality 120 (*T. altilira* s. l.).

Turritella (Torcula) altilira praecellens Pilsbry and Brown

Plate 23, figures 2, 8

Turritella perattenuata praecellens Pilsbry and Brown, Acad. Nat. Sci. Phila. Proc., v. 69, p. 36, footnote, pl. 5, fig. 12, 1917 (Miocene, Dominican Republic).

Of medium size, slender. Primary spirals relatively low, moderately or weakly noded. Posterior face of posterior primary slightly concave. Posterior primary wider than anterior, generally doubled. Minor spirals between primaries of subequal strength. Sculpture of early whorls like that of typical *T. altilira*, but minor spirals appearing several whorls later. Growth line like that of typical *T. altilira*.

Height (incomplete, 8 whorls) 42 mm, diameter 12.5 mm (larger figured specimen). Height (incomplete, 4+ whorls) 30.5 mm, diameter 13 mm (smaller figured specimen).

Type: Acad. Nat. Sci. Phila. 2608.

Type locality: Dominican Republic, Miocene (presumably Baitoa formation, late early Miocene).

This form of *Turritella altilira*, like the subspecies in the Caimito formation, lacks flangelike primary spirals. It is more slender than the Caimito subspecies and its primaries are not as strongly noded. Suppression of the nodes at a diameter of 12 millimeters suggests that it does not reach a large size.

The fossils from Panamá may represent a local race of *T. altilira* not of the same genetic stock as *T. altilira praecellens*. Nevertheless the identification emphasizes the direction of differentiation from the typical form. Collections of *T. altilira praecellens* from the Baitoa formation of the Dominican Republic include larger specimens than those from Panamá and some that have more strongly noded primaries. Though *T. altilira praecellens* was described as a subspecies of *T. perattenuata* Heilprin, of the Pliocene of Florida, it apparently lacks the greatly attenuated whorls of that species and evidently is more closely related to *T. altilira*. *T. perattenuata*, however, also is a nonflanged member of the *T. altilira* group.

T. montserratensis (Mansfield, 1925, p. 53, pl. 9, figs. 5, 6), which occurs in the Telemaque sand member of the Springvale formation (late Miocene) of Trinidad and should be assigned subspecific rank under *T. altilira*, is very similar, but its posterior spiral is not doubled.

The form of *T. altilira* identified as *T. altilira praecellens* occurs in the lower part of the Gatun formation. It is, indeed, the only *altilira*-like *Turritella* in the U. S. National Museum collections from that part of the formation. A form comparable to *T. altilira praecellens*, but very weakly noded and less slender, is found in the middle part of the Gatun at locality 144. The lower Gatun subspecies (or variety) and the typical *T. altilira* are represented in Hill's Gatun collection labelled Vamos Vamos (locality 158).

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, localities 136a, 137, 138, 138a. Middle part, eastern area, localities 144 (*T. altilira* subsp., cf. *T. altilira praecellens*), 158. Baitoa formation (late early Miocene), Dominican Republic.

Subgenus? (Merriam's T. ocoyana stock)

Turritella cf. T. subgrundifera Dall

Plate 16, figure 3

Small, slender, strongly carinate at about anterior fourth of whorl. Sculpture consisting of 6 or 7 widely spaced spirals. Spiral immediately in front of and behind carina-forming spiral and 1 or 2 near posterior suture weaker than others. Sculpture of early whorls and growth line not known.

Height (incomplete, 3 whorls) 18 mm, diameter 5 mm (figured specimen). Height (incomplete, 3 whorls) 25 mm, diameter 15 mm (increased by crushing).

The whorl profile, slender outline, and widely spaced spirals of this species, represented by two poorly preserved fragments from the Culebra formation, strongly suggest *Turritella subgrundifera*, of the Chipola formation of Florida (Gardner, 1926–47, p. 590, pl. 57, fig. 1, 1947). Though the early whorls and growth line of the species from Panama are not known, it is without much doubt a close ally of *T. subgrundifera*, if not that species. The protoconch of *T. subgrundifera* is cylindrical, consisting of 1¾ strongly inflated whorls. Three spirals appear gradually and practically simultaneously on the first sculptured whorl: a strong middle spiral, a moderately strong anterior spiral (the carina-forming spiral of later whorls), and a weak posterior spiral. The growth-line sinus is very shallow and wide, and the growth-line angle very wide.

T. subgrundifera is recorded from the Miocene of Colombia (Pilsbry and Brown, 1917, p. 35).

Occurrence: Culebra formation (early Miocene), Gaillard Cut, locality 99d.

Turritella venezuelana Hodson

Plate 16, figures 8, 9

Turritella venezuelana Hodson, Bull. Am. Paleontology, v. 11, no. 45, p. 32, pl. 21, figs. 4, 8, pl. 22, figs. 1, 6, 1926 [Miocene (Oligocene-Miocene of Hodson), Venezuela].

Turritella venezuelana quirosana Hodson, idem, p. 34, pl. 22, figs. 9, 10, pl. 24, fig. 1, 1926 [Miocene (Oligocene-Miocene of Hodson), Venezuela].

Turritella venezuelana watkinsi Hodson, idem, p. 34, pl. 22, fig. 8, 1926. [Miocene (Oligocene-Miocene of Hodson), Venezuela].

Small, early whorls rapidly enlarging. Whorls moderately carinate at about anterior fourth or rounded. Sculpture consisting of 6 or 7 primary spirals. On some specimens a minor spiral is present in some interspaces. Earliest preserved whorls sculptured with three spirals, the posteriormost weak and the anteriormost forming the carina on later carinate whorls. Base sculptured with weak closely spaced minor spirals. Growth-line sinus very shallow and wide; growth-line angle very wide.

Height (incomplete, 6 whorls) 15.3 mm, diameter 5.4 mm (larger figured specimen). Height (incomplete, 4 whorls) 23.5 mm, diameter 9.5 mm.

Type: Paleontological Research Institution, Ithaca, N. Y.

Type locality: Locality 6, Oil seep at Mene de Saladillo, 1½ kilometers southwest of Quirós, District of Miranda, Zulia, Venezuela (Hodson and Hodson, 1931, p. 5), La Rosa formation (Sutton, 1946, p. 1694), early Miocene.

This small species occurs in the Culebra formation. It shows considerable variation in whorl profile, in width of primary spirals, and in presence or absence of minor spirals. According to Hodson, it is variable in Venezuela also. The types of the three forms named by him were found at the same locality.

Turritella venezuelana is closely related to *T. subgrundifera*, but evidently is not a small form of that species. *T. subgrundifera* is carinate (except the late whorls of a few specimens), its early whorls enlarge less rapidly, and the posteriormost of the three spirals of early whorls appear at an earlier stage. Both species are representatives of Merriam's *T. ocoyana* stock (Merriam, 1941, p. 47).

Occurrence: Culebra formation (early Miocene), Gaillard Cut, localities 99b, 107, 110, 111a, 112, 112a, 114. La Rosa formation (early Miocene), Zulia, Venezuela.

Turritella abrupta Spieker

Plate 23, figures 6, 15, 16

Turritella (*Haustator*) *robusta* Grzybowski, Neues Jahrb., Beilage-Band 12, p. 646, pl. 20, fig. 3, 1899 (Miocene, Perú). Not *T. robusta* Gabb, 1864.

Turritella robusta Grzybowski, Woods, *in* Bosworth, Geology of the Tertiary and Quaternary periods in the north-west part of Peru, p. 110, pl. 18, fig. 4, pl. 19, fig. 1, 1922 (Miocene, Perú). Spieker, Johns Hopkins Univ. Studies in Geology, no. 3, p. 84, pl. 4, fig. 5, 1922 (Miocene, Perú).

Turritella robusta var. *abrupta* Spieker, idem, p. 85, pl. 4, fig. 6, 1922 (Miocene, Perú).

Turritella charana Spieker, idem, p. 86, pl. 4, fig. 7, 1922 (Miocene, Perú).

Turritella supraconcava Hanna and Israelsky, Calif. Acad. Sci. Proc., 4th ser., v. 14, no. 2, p. 59, 1925 (new name for *T. robusta* Grzybowski).

Turritella robusta fredeai Hodson, Bull. Am. Paleontology, v. 11, no. 45, p. 13, pl. 5, figs. 1, 3, pl. 6, figs. 2, 5, pl. 7, figs. 1, 6, 7, pl. 9, fig. 7, pl. 29, fig. 6, 1926 (Miocene, Venezuela).

Turritella supraconcava var. *fredeai* Hodson, Weisbord, idem, v. 14, no. 54, p. 30, pl. 9, figs. 3, 4, 1929 (Miocene, Colombia).

Turritella fredeai Hodson, Anderson, Calif. Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 119, pl. 17, fig. 1, 1929 (Miocene, Colombia).

Turritella abrupta Spieker, Olsson, Bull. Am. Paleontology, v. 19, no. 68, p. 200, 1932 (Miocene, Perú). Merriam, Calif. Univ. Dept. Geol. Sci. Bull., v. 26, p. 48, pl. 29, fig. 4 ("cf."), pl. 30, fig. 6, pl. 31, figs. 2–4, 1941 (Miocene, Colombia, Venezuela). Marks, Bull. Am. Paleontology, v. 33, no. 139, p. 99, 1951 (Miocene, Ecuador).

Moderately large, rapidly enlarging. Whorls very strongly and sharply carinate at about anterior fourth. Sculpture consisting of 8 or 9 widely spaced spirals. Protoconch of about 1¾ inflated whorls. Two strong spirals appear on first sculptured whorl: one at middle of whorl, the other halfway between it and anterior suture. A low narrow spiral adjoining anterior suture also appears on first sculptured whorl. Anterior of the two strong spirals gradually increasing in size until on about sixth sculptured whorl it is stronger than middle spiral and forms the carina. At about same stage weak spirals appear between middle spiral and posterior suture, and elsewhere. On late whorls a spiral adjoins anterior suture and a weaker spiral lies between it and carina. Anterior sutural spiral emerging on base as a strong spiral. Base between this spiral and columellar lip sculptured with weak spirals. Growth-line sinus very shallow and wide, the apex just above carina; growth-line angle very wide.

Height (incomplete, 4 whorls) 39 mm, diameter 23 mm (largest figured specimen).

Type: Johns Hopkins University.

Type locality: Zorritos, Perú, Zorritos formation (early Miocene).

Turritella abrupta occurs in the middle part of the Gatun formation, but is rare. It is represented by the figured specimen of moderate size, collected in the eastern area, and by very small specimens from the western area. Adhering calcareous sandstone somewhat masks the strength and sharpness of the carina on the largest figured specimen.

This overnamed *Turritella*, which reaches a relatively gigantic size (height about 200 mm), is found in Perú, Ecuador, the Darién basin of Panamá, the Chiriquí area of Panamá, Colombia, and Venezuela, generally in formations of middle Miocene age. In Perú, however, it occurs both in the upper Zorritos and Cardalitos formations, dated as late early and middle Miocene, respectively, by Olsson (1932, fig. 2, p. 42). The occurrence of *T. abrupta* in the Miocene of the Isthmus of Tehuantepec (Woodring, 1928, pp. 66, 98) cannot be confirmed at the present time. The fossils on which that record was based have been mislaid or were misidentified.

On the basis of the characters of intermediate and late whorls, *T. abrupta* may be considered a large very strongly and sharply carinate subspecies of *T. ocoyana* Conrad, of the middle Miocene of California. Nevertheless these two forms show a considerable difference in development of sculpture. According to Merriam's (1941, pl. 31, fig. 1) illustration of the early whorls of *T. ocoyana*, fairly strong spirals, other than the middle and anterior spiral, appear at an early stage. On the early whorls of the Gatun specimens of *T. abrupta* such spirals are weaker and appear at a later stage. Until additional data on the sculpture of the early whorls are available, specific rank is retained for *T. abrupta*.

T. trinitaria Maury (1925, p. 230, pl. 42, fig. 10; Vokes, 1938, p. 26, fig. 29; Rutsch, 1942, p. 129), from the late Miocene Springvale formation of Trinidad, presumably is a less strongly carinate subspecies of *T. abrupta*. *T. abrupta trinitaria* and *T. matarucana*, representing different lineages, are the last survivors of the *T. ocoyana* group in the Caribbean and nearby areas.

T. ocoyana is widespread in the middle Miocene of California, but has no predecessors there. The inference that it is a migrant from tropical America is justified, for there are earlier closely related species in that region.

Occurrence: Middle part of Gatun formation (middle Miocene), eastern area, locality 144a; western area, localities 161c, 161d, 170a. Upper part of Zorritos formation (early Miocene) and Cardalitos formation (middle Miocene), Perú. Progreso formation (middle Miocene), Ecuador. Middle Miocene, Darién area, Panamá. Middle Miocene, Chiriquí area, Panamá. Middle Miocene, Bolívar, Colombia. Miocene, Falcón, Venezuela.

Turritella matarucana Hodson

Plate 22, figures 11, 12

Turritella matarucana Hodson, Bull. Am. Paleontology, v. 11, no. 45, p. 31, pl. 20, fig. 4, pl. 21, figs. 1, 9, 1926 (Miocene, Venezuela).

Turritella plebeia A-L-Owensi Hodson, idem, p. 31, pl. 20, figs. 1, 2, 5, 6, pl. 23, fig. 2, pl. 28, fig. 1, 1926 (Miocene, Venezuela).

Moderately large, early whorls rapidly enlarging, late whorls slowly enlarging. Intermediate whorls moderately convex, late whorls slightly convex. Late whorls narrowly beveled at posterior suture. Sculpture consisting of numerous closely spaced spirals some of which are narrower and more closely spaced than others. Earliest preserved whorls sculptured with two spirals: one at middle of whorl, the other halfway between it and anterior suture. Base sculptured with very weak spirals disappearing toward columellar lip. Growth-line sinus very wide and shallow; growth-line angle very wide.

Height (incomplete, 5 whorls) 44.5 mm, diameter 16 mm (larger figured specimen).

Type: Paleontological Research Institution, Ithaca, N. Y.

Type locality: Locality 197, Río Mataruca, Buena Vista anticline, near La Vela, District of Colina, Falcón, Venezuela, La Vela formation (late Miocene).

Turritella plebeia alowensi,[3] also from the Miocene of Falcón, Venezuela, was based on specimens that have moderately inflated whorls. They are similar to *T. matarucana* in sculptural pattern and growth line, and evidently represent a form of that species having moderately inflated whorls even at a late stage.

Despite the absence of a carina and the presence of numerous closely spaced spirals, *T. matarucana* is allied to *T. abrupta* and other species of the *T. ocoyana* group, according to the sculpture of the early whorls and the growth line. In whorl profile and sculpture it more closely resembles the larger, more rapidly enlarging, and more convex-whorled Miocene European species *T. terebralis* Lamarck, which has similar early sculpture and growth line. The whorl profile and

[3] Though "the original orthography of a name is to be preserved unless an error of transcription, a lapsus calami, or a typographical error is evident" (International Rules of Zoological Nomenclature, Article 19), a name like "*A-L-Owensi*" is so objectionable that alteration to "*alowensi*" appears to be justified.

sculpture suggest *T. plebeia* Say, of the Miocene of Maryland. *T. plebeia* has similar early sculpture, but its growth-line sinus is narrower and deeper, and its growth-line angle is narrower.

T. matarucana occurs in the Gatun formation. It is locally abundant in the lower part of the formation and rare in the middle part.

Occurrence: Lower and middle parts of Gatun formation (middle Miocene). Lower part, localities 135 (identification doubtful), 136, 136a, 137, 137a, 138a. Middle part, eastern area, locality 144a (identification doubtful); western area, locality 161c. Uramaco (middle Miocene) and La Vela (late Miocene) formations, Falcón, Venezuela.

Subgenus?

Turritella gatunensis gatunensis Conrad

Plate 23, figures 4, 5, 9, 14

Turritella gatunensis Conrad, Pacific R. R. Expl., v. 6, Geol. Rept., p. 72, pl. 5, fig. 20, 1857 (Miocene, Gatun, Panamá). (Reprinted, U. S. Geol. Survey Prof. Paper 59, p. 178, 1909.) Dall, Wagner Free Inst. Sci. Trans., v. 3, pt. 2, p. 310 (part, not pl. 17, fig. 10=*T. atacta* Dall), 1892 (Miocene, Gatun, Panamá). Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 63, p. 358, pl. 27, figs. 4, 5. 9, 1911 (Miocene, Canal Zone). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 148, pl. 14, figs. 12, 13, 1922 (Miocene, northwestern Panamá, Costa Rica). Anderson, Calif. Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 120, 1929 (Miocene, Colombia). Li, Geol. Soc. China Bull., v. 9, p. 267, pl. 6, fig. 49, 1930 (Miocene, Panamá Bay; Miocene, Gatun, fide Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 83, p. 432, 1931). Marks, Bull. Am. Paleontology, v. 33, no. 139, p. 100, 1951 (Miocene, Ecuador).

Turritella cf. *T. gatunensis* Conrad, Weisbord, Bull. Am. Paleontology, v. 14, no. 54, p. 33, pl. 9, fig. 7, 1929 (Miocene, Colombia).

Turritella gatunensis lavelana Hodson, idem, v. 11, no. 45, p. 23, pl. 18, fig. 6, pl. 19, fig. 7, 1926 (Miocene, Venezuela).

Turritella conradi Toula, K. k. Geol. Reichsanstalt Jahrb., Band 58, p. 694, pl. 25, fig. 4, 1909 (Miocene, Canal Zone).

Not *Turritella gatunensis* Conrad, Gabb, Acad. Nat. Sci. Phila. Jour., 2d ser., v. 8, p. 342, pl. 44, figs. 10, 10a, 1881 (Oligocene(?), Costa Rica;=*T. tristis* Brown and Pilsbry). Joukowsky, Soc. Phys. Histoire Nat. Geneva Mém., t. 35, p. 163 (list), pl. 6, figs. 26, 27, 1906 (Oligocene, Panamá;=*T. meroensis* Olsson). Maury, Bull. Am. Paleontology, v. 10, no. 42, p. 229, pl. 42, fig. 12, 1925 (Miocene, Trinidad;=*T. caronensis* Mansfield, described as a subspecies of *T. gatunensis*). Mansfield, Washington Acad. Sci. Jour., v. 28, p. 102, figs. 1–3, 6, 1938 (Oligocene, Florida).

Moderately large, slender. Posterior part of whorls constricted, anterior part concave between primary spirals. Sculpture consisting of a primary spiral near, but generally behind, middle of whorl, a second primary at anterior third to fourth, and numerous minor spirals. Microscopic spirals generally visible on late whorls. A minor spiral lying behind, and close to, middle primary is almost, or quite, as strong as primaries on some specimens. On a few specimens a minor spiral in front of anterior primary or between primaries is accentuated. Primaries decreasing in strength on last whorl or two of some specimens. As they decrease, anterior part of whorl becomes more inflated. Spirals slightly undulated by axial waves on a few specimens. Protoconch cylindrical, of two inflated whorls. Early sculptured whorls attenuated. A very strong middle spiral, forming a strong median carina, a very weak spiral adjoining anterior suture, and a very weak spiral half-way between them appear on first sculptured whorl. The strong middle spiral is the middle primary of later whorls. The weak spiral adjoining the anterior suture gradually enlarges and becomes the anterior primary. Other weak spirals appear on third or fourth sculptured whorl. Base sculptured with numerous low minor spirals. Growth-line sinus wide and shallow, the apex between primaries; growth-line angle wide. Interior of late whorls smooth or bearing narrow spiral ridges of varying strength.

Height (almost complete) 58.5 mm, diameter 15 mm (largest figured specimen).

Type: Lost.

Type locality: Gatun, Canal Zone.

Turritella gatunensis, like *T. altilira*, was based on fossils collected by Newberry at Gatun. The type of *T. gatunensis* is lost. As Conrad's illustration is even cruder than his representation of *T. altilira*, the identification rests primarily on the brief and unsatisfactory description. The collection that furnished a topotype of *T. altilira* (locality 150a) includes the traditional *T. gatunensis*, but the preservation is not good enough for designation of a neotype. The specimens shown on plate 23, figures 4, 9, collected at the Gatun Locks site, 250 meters west of Gatun, are considered representative of the typical form.

The typical form of *T. gatunensis* probably is represented in the calcareous sandstone member of the Caimito formation in Madden basin. It is locally abundant in the lower part of the Gatun formation, widespread and locally abundant in the middle part, rare in the upper part in the eastern area, and probably occurs in the Toro limestone member of the Chagres sandstone.

Intermediate whorls are characterized by the two primary spirals and the concave space between them. Early sculptured whorls are attenuated and are very strongly carinate at the middle of the whorl. Late whorls, however, are variable in sculpture and whorl profile. Nevertheless the basic pattern of a middle and anterior primary is more or less discernible. This basic pattern, the constriction of the posterior part of whorls, and the growth line are the most reliable features for identification of late whorls. Most of the shells from the lower part of the Gatun formation are relatively flat-whorled and have strong primaries (pl. 23, fig. 14). Strong minor spirals are less common in the lower part of the formation than in the middle part. Specimens that have axial waves were not found in the lower part and are not common in the middle part, except at localities where the subspecies (or variety), described under the next heading was collected. Some specimens in the collection from locality 150a, which is close to, if not at, the type locality, have weak axial waves.

The profile, sculpture, and growth line of late whorls indicate that the typical form, or closely related forms, occur in the Miocene of northwestern Panamá, Costa Rica, Colombia, Ecuador, and Venezuela. Confirmation, based on the sculpture of the early whorls, is desirable. Weisbord's *T.* cf. *T. gatunensis*, from the Miocene of Colombia, may be referred to the typical form, despite its wide primaries. The early sculptured whorls of *T. gatunensis caronensis* Mansfield (1925, p. 51, pl. 8, figs. 12–14), of the Miocene of Trinidad, are not attenuated; the first few sculptured whorls are weakly carinate; and later early whorls are not as strongly carinate as those of *T. gatunensis*. This Trinidad species of *Turritella* is closely related to *T. gatunensis*, but presumably is to be given specific rank.

There seem to be no close relatives of *T. gatunensis* in the Miocene of southeastern United States. Though intermediate and late whorls of *T. gatunensis blountensis* Mansfield (1935, p. 41, pl. 4, figs. 1, 2), from deposits of middle Miocene age in western Florida, are practically indistinguishable in sculpture and growth line from specimens of *T. gatunensis* that have a strong posterior minor spiral, they enlarge less rapidly. The earliest preserved whorls (not quite the earliest sculptured whorls) are not carinate and are sculptured with 6 or 7 spirals. *T. blountensis* therefore is not a subspecies of *T. gatunensis*. The small specimens from the Shoal River formation of Florida doubtfully recorded as *T. gatunensis blountensis* (Gardner, 1926–47, p. 592, pl. 57, figs. 11, 12, 1947) are less like *T. gatunensis* in whorl profile. The earliest preserved whorls are not carinate and are sculptured with three strong spirals.

Mansfield's *T. gatunensis*, from the late Oligocene of Florida, has the sculptural pattern of that species, but late whorls are more or less uniformly convex. The earliest preserved whorls have two spirals. One specimen shows a suggestion of a moderately deep growth-line sinus, with the apex a little behind the middle of the whorl, and a narrow growth-line angle. This species of *Turritella* is without much doubt related to the species from Vamos Vamos, *T. adela:* the species mentioned by Mansfield as *T. gatunensis*, following Dall's identification. According to Mansfield, a form of *T. gatunensis* from the "lower faunal zone" of the Gatun formation has early whorls like those of the species of *Turritella* from Vamos Vamos. That observation, however, evidently was based on some misunderstanding, for no specimen of *T. gatunensis* from the Gatun formation that shows the early whorls has such sculpture. The affinities of Mansfield's (1940, p. 218, pl. 27, figs. 56, 57) *Turritella* cf. *T. gatunensis*, from the late Oligocene Chickasawhay marl, are uncertain. The growth line is unknown and the early whorls of the only specimen that shows them are too poorly preserved to reveal the sculpture.

Occurrence: Calcareous sandstone member of Caimito formation (early Miocene), Madden basin, locality 82 (mold, identification doubtful). Lower, middle, and upper parts of Gatun formation (middle Miocene). Lower part, localities 136a, 137, 137a, 138, 138a. Middle part, eastern area, localities 140, 141, 144, 144a (identification doubtful), 147a, 147d, 147e, 147i, 150a, 153, 155, 155b, 155c, 156, 157, 158, 159, 159a, 159b, 160; western area, localities 161, 161a, 169. Upper part, eastern area, localities 163, 172. Toro limestone member of Chagres sandstone (early Pliocene; molds, identification doubtful), localities 194, 196. Late Miocene, Water Cay, Panamá. Middle Miocene, Costa Rica. Middle Miocene, Bolívar, Colombia. Miocene, Falcón, Venezuela. Subibaja formation (early Miocene) and Progreso formation (middle Miocene), Ecuador.

Turritella gatunensis rhytodes Woodring, n. subsp.

Plate 23, figures 10, 11, 17

Moderately large, slender. Protoconch and early whorls like those of typical form. Posterior part of intermediate and late whorls strongly constricted. On intermediate whorls minor spirals, particularly one or more between primaries, increase in strength until on late intermediate and late whorls they are as strong as primaries, the whorls losing the typical *T. gatunensis* profile. Spirals of intermediate whorls more or less undulated by axial waves on most specimens. Growth line like that of typical form.

Height (incomplete) 66 mm, diameter 16.5 mm (type).

Type: USNM 561395; paratypes, Stanford Univ.

Type locality: 162a (USGS 8359, lower trail on west side of Río Chagres northwest of Gatun Dam, Canal Zone), middle part of Gatun formation.

Turritella gatunensis rhytodes is abundant in the middle part of the Gatun formation at localities 162 and 162a on the west side of Río Chagres northwest of Gatun Dam. Presumably it is a local subspecies or variety. The typical form occurs in the middle part of the Gatun at nearby localities, but is not represented in the collections from localities 162 and 162a. As shown by the illustrations, the sculpture is variable. On some specimens the axial waves are so strong that the sculpture has a cerithid appearance; on a few they are absent or practically absent. The strong constriction of the posterior part of the whorls and the strong minor spirals are characteristic features. In whorl profile *T. gatunensis rhytodes* closely resembles *T. gatunensis willistoni* Hodson (1926, p. 25, pl. 18, figs. 2–4), which, however, has strongly differentiated primary and secondary spirals on late whorls. Axial waves were cited as the characteristic feature of *T. gatunensis taratarana* Hodson (1926, p. 25, pl. 18, figs. 5, 7). The posterior part of the whorls of that form are not strongly constricted. The presence or absence of axial waves evidently is a variable character in different forms of *T. gatunensis*, including the typical form. *T. gatunensis willistoni* and *T. gatunensis taratarana* appear to be varieties of *T. gatunensis*. They are found together at some localities in Miocene strata in Falcón, Venezuela, and at a few localities are recorded in association with *T. gatunensis lavelana*, which, as indicated by the synonomy citation under *T. gatunensis*, is considered the typical form.

The typical form of *Turritella subannulata* Heilprin (1887, p. 89, pl. 8, fig. 17), a Pliocene species from Florida, has cerithid axial sculpture, two primary spirals on intermediate and late whorls, and a growth line similar to that of *T. gatunensis*. The development of the sculpture, however, indicates that it is not closely allied to *T. gatunensis*.

"*Turritella gatunensis*" *tarataranoides* Haas (1942, p. 315, figs. 3, 4), and also "*Crepitacella*" *altispira* Haas (idem, p. 315, figs. 5, 6) and "*Crepitacella*" n. sp. indet. aff. "*C.*" *altispira* Haas (idem, p. 316), are fresh-water snails, as the editor of the Journal of Paleontology was informed when Haas' manuscript and illustrations were received. The type material of these species is so poorly preserved that their affinities are uncertain, but the "*Turritella*" seems to be a *Pachychilus*. Not only is the type material poorly preserved, these species also were collected at an unknown Costa Rican locality (Idem, p. 310). Despite these deficiencies, they were given an unqualified middle Miocene age. Specimens of these fresh-water snails, collected in 1910 in a tunnel at Brasil (in the Meseta Central west of San José), are in the collections of the U. S. National Museum. They were presented to W. H. Dall by Don Anastasio Alfaro, Director of the Museo Nacional at San José, during a visit to Washington.

Occurrence: Middle part of Gatun formation (middle Miocene), localities 162, 162a.

Subgenus?

Turritella cf. T. berjadinensis cocoditana Hodson

A whorl fragment from the Culebra formation has a strong carina-forming spiral at the anterior fourth, two primary spirals near the middle, two weaker spirals between the carina and the anterior suture, and closely spaced fine minor spirals over the entire whorl.

Though its middle spirals are of subequal strength, this fragment is comparable to the Miocene Venezuelan *Turritella berjadinensis cocoditana* (Hodson, 1926, p. 29, pl. 19, fig. 5, pl. 20, figs. 3, 7, 10).

Occurrence: Culebra formation (early Miocene), Gaillard Cut, locality 115b.

Subgenus? (Merriam's T. broderipiana stock)

Turritella mimetes Brown and Pilsbry

Plate 22, figures 6–9

Turritella mimetes Brown and Pilsbry, Acad. Nat. Sci. Phila. Proc., v. 63, p. 357, pl. 27, fig. 1, 1911 (Miocene, Canal Zone). Olsson, Bull. Am. Paleontology, v. 9, no. 39, p. 149, pl. 14, fig. 5, 1922 (Miocene, Canal Zone).

Turritella (*Haustator*) aff. *T. hanleyana* Reeve, Toula, K. k. Geol. Reichsanstalt Jahrb., Band 61, p. 498, pl. 30, fig. 6, 1911 (Miocene, Canal Zone).

?*Turritella mimetes* Brown and Pilsbry, Anderson, Calif. Acad. Sci. Proc., 4th ser., v. 18, no. 4, p. 120, 1929 (Miocene, Colombia; not described, possibly *T. lloydsmithi* Pilsbry and Brown).

Not *Turritella* cf. *T. mimetes* Brown and Pilsbry, Merriam, Calif. Univ. Dept. Geol. Sci. Bull., v. 26, no. 1, pl. 38, fig. 7, 1941 (Miocene, Colombia; = *T. lloydsmithi* Pilsbry and Brown).

Moderately large, slender. Whorl profile flat or slightly concave. Late intermediate and late whorls generally loosely clasping, producing a weak basal carina. Protoconch cylindrical, of 1¾ inflated whorls. Early sculptured whorls attenuated, strongly inflated. A middle spiral, forming a weak carina, and minor spirals appear on first sculptured whorl. Middle spiral decreasing in strength on next whorl and lost among minor spirals covering entire whorl. Second and succeeding sculptured whorls therefore not medially carinate. On some specimens a median spiral again attains slight prominence on sixth or seventh sculptured whorl. Late whorls sculptured with spirals roughly representing three ranks, the third rank being microscopic. Base sculptured with numerous spirals. Growth-line sinus wide and shallow; growth-line angle wide. Interior of late whorls smooth or bearing narrow spiral ridges.

Height (incomplete) 73 mm. diameter 17.5 mm (largest figured specimen).

Type: Acad. Nat. Sci. Phila. 1734.

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

Turritella mimetes is widespread in the middle part of the Gatun formation, fairly common in the upper part in the western area, and probably occurs in the Toro limestone member of the Chagres sandstone. The whorl profile, determined by clasping of the succeeding whorl, and the sculpture are variable. The shells from the upper part of the Gatun, all collected in the western area, are relatively small. Their early whorls are not preserved, but their early intermediate whorls are like those of specimens from the middle part of the formation.

T. mimetes is related to the Recent Caribbean *T. variegata* (Linné). In fact, the marked similarity of late whorls in profile, sculpture, and growth line suggests that it is a subspecies of *T. variegata.* The early and early intermediate whorls of *T. variegata,* however, are medially carinate and rapidly enlarging. Allies of *T. variegata* are widespread in the Miocene of the Caribbean region. It is not known whether any of them are closely related to *T. mimetes. T. lloydsmithi* Pilsbry and Brown (1917, p. 35, pl. 5, fig. 11), a middle and late(?) Miocene Colombian species, has more crowded spirals separated by very narrow grooves. Its early intermediate whorls are medially carinate and rapidly enlarging. It therefore is a close ally of *T. variegata,* possibly a subspecies. *T. planigyrata* Guppy (Mansfield, 1925, p. 55, pl. 9, figs. 1, 9; Rutsch, 1942, p. 131, pl. 8, fig. 5), the first of these Miocene Caribbean allies of *T. variegata* to be named, was based on fossils from the late Miocene Springvale formation of Trinidad. Its medially carinate and rapidly enlarging early intermediate whorls link it closely with *T. variegata.* Its sculpture is uniformly fine like that of some specimens of *T. variegata.*

T. mimetes is also related to the Recent Panamic *T. leucostoma* Valenciennes, as identified by Kiener. The Recent species has attenuated early whorls, which, however, are medially carinate and have fewer spirals.

Occurrence: Middle and upper parts of Gatun formation (middle and late Miocene). Middle part, eastern area, localities 141 (identification doubtful), 150, 154 (identification doubtful), 155, 155a, 155b, 157, 159; western area, localities 161, 161b, 161c, 162, 165 (identification doubtful), 170. Upper part, western area, localities 182, 182a, 183, 184, 185. Toro limestone member of Chagres sandstone (early Pliocene), locality 196 (identification doubtful).

Turritella bifastigata Nelson

Plate 22, figure 10

Turritella bifastigata Nelson, Conn. Acad. Arts Sci. Trans., v. 2, p. 189, 1870 (Miocene, Perú). Spieker, Johns Hopkins Univ. Studies in Geology no. 3, p. 63, pl. 3, fig. 1, 1922 (Miocene, Perú). Hodson, Bull. Am. Paleontology, v. 11, no. 45, p. 48, pl. 30, fig. 1, 1926 (Miocene, Perú). Olsson, idem, v. 19, no. 68, p. 198, 1932 (Miocene, Perú).

Turritella gothica Grzybowski, Neues Jahrb., Beilage-Band 12, p. 645, pl. 20, fig. 10, 1899 (Miocene, Perú). Woods, *in* Bosworth, Geology of the Tertiary and Quaternary periods in the north-west part of Peru, p. 110, 1922 (Miocene, Perú).

Moderately large. Intermediate whorls rapidly enlarging; late whorls slowly enlarging. Last whorl or two loosely clasping. Early intermediate whorls medially carinate; late intermediate whorls slightly convex; late whorls slightly concave between a faint collar adjoining posterior suture and a more distinct, but narrower, collar adjoining anterior suture. Anterior collar forming a carina on whorls preceded by a loosely clasping whorl and on body whorl. Sculpture of early whorls not known. Early intermediate whorls sculptured with three subequal primary spirals (a median spiral forming a carina, a spiral adjoining anterior suture, and another halfway between them) and minor spirals. Anterior spiral developing into anterior collar, the other two gradually weaken. Late whorls sculptured with faint minor and microscopic spirals, the strongest of which corresponds to the second (from anterior suture) primary of intermediate whorls. Base sculptured with low wide spirals, between which and on which are fine minor spirals. Growth-line sinus moderately deep, the apex at middle of whorl; growth-line angle wide.

Height (not quite complete) 66 mm, diameter 18.5 mm (figured specimen).

Lectotype: Peabody Museum, Yale Univ. 534.

Type locality: Zorritos, Perú, Zorritos formation, late early Miocene.

Late whorls are characterized by the sutural collars, producing a slightly concave profile, and faint spiral sculpture between the collars.

Several names have been proposed for Miocene Caribbean allies of *Turritella bifastigata,* all of which probably are to be assigned subspecific rank under that species or the Recent *T. broderipiana.* The Colombian *T. cartagenensis* Pilsbry and Brown (1917, p. 34, pl. 5, fig. 13; Weisbord, 1929, p. 30, pl. 9, figs. 1, 2) has stronger spirals. The Costa Rican *T. oreodoxa* Olsson (1922, p. 152, pl. 14, fig. 1) has a wide posterior collar, no anterior collar, and stronger spirals. Hodson (1926, pp. 48–50, pl. 29, fig. 3, pl. 30, figs. 2–6) described fossils from the Miocene of Falcón, Venezuela, as *T. bifastigata maracaibensis* and *T. bifastigata democraciana.* They are recorded together at numerous localities and evidently represent a variable form that probably is to be identified as *T. bifastigata cartagenensis* which also is recorded from the Miocene of Trinidad (Maury, 1925, p. 233, pl. 42, fig. 13).

T. bifastigata was found only in the lower part of the Gatun formation. Though it has no living allies in the Caribbean Sea, it is closely related to *T. broderipiana* d'Orbigny, a living Panamic species that lacks sutural collars or has greatly subdued collars. The early intermediate whorls of *T. broderipiana* are like those of *T. bifastigata*, but the middle spiral and the spiral adjoining the anterior suture are stronger, and the spiral midway between them is weaker. The early whorls of *T. broderipiana* enlarge rapidly. A middle spiral and one on both sides of it appear on the first sculptured whorl, and an anterior sutural spiral on the next whorl. With further growth the middle and anterior sutural spirals increase in strength, the others diminish. The middle spiral strongly carinates the early whorls, except the first. The first three whorls bear slightly arcuate exaggerated growth lines above the carina.

T. bifastigata and *T. mimetes* represent Merriam's *T. broderipiana* stock (Merriam, 1941, pp. 50–51).

Occurrence: Lower part of Gatun formation (middle Miocene), localities 137, 137a. Upper part of Zorritos formation (late early Miocene), Perú.

LOCALITIES AT WHICH FOSSILS WERE COLLECTED

The localities at which fossils were collected are described in the following list and the numbers used for them in the present report are correlated with the permanent numbers recorded in the Geological Survey's Cenozoic invertebrate register. The list includes not only localities that yielded fossil mollusks, but also some important localities where only other kinds of fossils were collected. Unless otherwise specified, the report locality numbers are plotted on the general geologic map (pl. 1). As noted in the list, localities in the Gaillard Cut area are plotted on the large-scale geologic map of that area (pl. 2). Some early collections have such inadequate data that they cannot be plotted, and other localities are not plotted to avoid congestion of the map. Early localities that are now submerged are shown on plate 1 and plate 2 by a special symbol, even though the plotted location may be only approximate. Some submerged localities, however, cannot be plotted even approximately.

Before the construction of the canal, Río Chagres flowed southwestward to the present site of Gamboa and there turned northwestward to the Caribbean Sea. It was first dammed near Gatun to form Gatun Lake and later was dammed upstream from Gamboa to form Madden Lake. The course of the river and the location of the Panama Railroad before the canal was built are shown on the map accompanying the publication cited under Bertrand and Zürcher (1899). The relocated line of the Panama Railroad, cited in the following list, is the present line constructed in 1911–13.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			GATUNCILLO FORMATION
1	--------	131	Madden basin, Panamá. South side of Río Pequení near head of Madden Lake, 120 meters west of former Canal Zone Pequení Police Substation. Thin-bedded limestone, 2.5 meters above base of Gatuncillo formation. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
1a	--------	131a	Same locality. Thin-bedded nodular-weathering limestone, 5.5 to 7 meters higher stratigraphically. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]). Not plotted.
2	--------	132	Madden basin, Panamá. West shore of Madden Lake at abandoned Salamanca Gaging station. Fairly soft limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
3	8400	------	Madden basin, Panamá. San Juan de Pequení, on Río Pequení about 1 kilometer upstream from junction with Río Chagres. Fragmental limestone. E. R. Lloyd, 1919. Now submerged. Topotypes of *Lepidocyclina chaperi* and other larger Foraminifera (Vaughan, 1926). For location of San Juan de Pequení see Reeves and Ross, 1930, pl. 5.
4	--------	150	Madden basin, Panamá. Trail west of Madden Lake, 4.8 kilometers north of Madden Dam. Limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
5	--------	118	Madden basin, Panamá. Trail north of Río Puente, 2 kilometers northeast of Natural Bridge (Puente Natural). Thin-bedded limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera.
6	17433	114	Madden basin, Panamá. Lumber road north of Río Puente, 1.7 kilometers east-southeast of Natural Bridge. Limestone. T. F. Thompson and W. P. Woodring, 1949.
7	17432	115	Madden basin, Panamá. Lumber road north of Río Puente, 1.6 kilometers east-southeast of Natural Bridge. Limestone. T. F. Thompson and W. P. Woodring, 1949.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			GATUNCILLO FORMATION—continued
8	--------	116	Madden basin, Panamá. Trail south of Río Puente, 800 meters southeast of Natural Bridge. Limestone. T. F. Thompson and W. P. Woodring, 1949. Corals.
9	17161	113	Madden basin, Panamá. Lumber road south of Río Puente, 1.5 kilometers southeast of Natural Bridge. Marly limestone. T. F. Thompson, 1948. Also a collection by T. F. Thompson and W. P. Woodring, 1949.
10	--------	108	Madden basin, Panamá. Road to Madden Airfield, 650 meters northeast of Casa Larga. Marly limestone. T. F. Thompson, 1948. Also a collection by T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
11	16889	15	Madden basin, Panamá. Madden Airfield, about 300 meters north of north end of paved runway, 1.7 kilometers east of Casa Larga. Limestone. J. R. Schultz, T. F. Thompson, and W. P. Woodring, 1947. Also larger Foraminifera (Cole, 1952 [1953]), corals, and echinoids (Cooke, 1948).
12	1762	107	Madden basin, Panamá. Lumber road south of Río Puente, 4 kilometers east of Casa Larga. Marly limestone. T. F. Thompson, 1948. Also a collection by T. F. Thompson and W. P. Woodring, 1949. Also corals.
13	--------	106	Madden basin, Panamá. Road from Casa Larga to Laguna, 1 kilometer south-southeast of Río Chilibrillo bridge. Marly limestone. T. F. Thompson, 1948. Also a collection by T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera.
14	--------	105	Madden basin, Panamá. 325 meters east of road from Casa Larga to Laguna, 1.1 kilometers southeast of Río Chilibrillo bridge. Limestone. T. F. Thompson, 1948. Also a collection by T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera.
15	--------	129	Madden basin, Panamá. Road from Casa Larga to Laguna, 1 kilometer west of Laguna. Limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera.
16	17434	128	Madden basin, Panamá. Road from Casa Larga to Laguna, south side of Río Limón immediately south of Laguna. Limestone. T. F. Thompson and W. P. Woodring, 1949. Also corals.
17	--------	147	Quebrancha syncline, Panamá. Stream about 50 meters west of trail on east side of Río Gatuncillo, 4.5 kilometers northeast of Transisthmian Highway bridge across Río Gatuncillo. Mudstone and siltstone. W. P. Woodring, 1949. Smaller Foraminifera.
18	--------	146	Quebrancha syncline, Panamá. Trail on east side of Río Gatuncillo, 3.3 kilometers northeast of Transisthmian Highway bridge across Río Gatuncillo. Limestone. W. P. Woodring, 1949. Larger Foraminifera.
19	--------	145	Quebrancha syncline, Panamá. Trail on east side of Río Gatuncillo, 2 kilometers northeast of Transisthmian Highway bridge across Río Gatuncillo. Soft limestone. W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
20	--------	19	Quebrancha syncline, Panamá. North side of Transisthmian Highway, 50 meters east of bridge across Río Gatuncillo. Limestone. J. R. Schultz and W. P. Woodring, 1947. Larger Foraminifera.
21	--------	20	Quebrancha syncline, Panamá. East bank of Río Quebrancha about 100 meters northeast of Transisthmian Highway bridge. Mudstone. J. R. Schultz and W. P. Woodring, 1947. Smaller Foraminifera.
22	--------	124	Quebrancha syncline, Panamá. Road to Nuevo San Juan, 0.5 kilometer southwest of junction with Transisthmian Highway. Fairly soft limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
23	--------	125	Quebrancha syncline, Panamá. Road to Nuevo San Juan, 2 kilometers southwest of junction with Transisthmian Highway. Fairly soft limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			GATUNCILLO FORMATION—continued
23a	--------	------	Río Agua Sucia area, Panamá. About 30 meters southeast of trail, 2 kilometers southwest of Nuevo San Juan. Limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera, not collected.
24	--------	21	Río Agua Sucia area, Panamá. Transisthmian Highway, 3.5 kilometers northwest of Río Gatuncillo bridge. Silty mudstone. J. R. Schultz and W. P. Woodring, 1947. Smaller Foraminifera.
25	--------	139	Río Agua Sucia area, Panamá. Half a kilometer northeast of Transisthmian Highway and 5.5 kilometers northwest of Transisthmian Highway bridge across Río Gatuncillo. Limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera.
26	--------	23	Río Agua Sucia area, Panamá. Transisthmian Highway, 5.7 kilometers northwest of Río Gatuncillo bridge. Calcareous mudstone. J. R. Schultz and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]) and corals.
27	16931	22	Río Agua Sucia area, Panamá. Transisthmian Highway, 6.5 kilometers northwest of Río Gatuncillo bridge. Siltstone. J. R. Schultz and W. P. Woodring, 1947.
27a	--------	22a	Same locality, calcareous sandstone 0.5 to 1 centimeter thick, about 6 meters lower stratigraphically. J. R. Schultz and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]). Not plotted.
28	--------	140	Río Agua Sucia area, Panamá. Transisthmian Highway, 7.3 kilometers northwest of Río Gatuncillo bridge. Poorly sorted gritty sandstone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
29	--------	------	Río Agua Salud area, Canal Zone. Core hole SL–84, 5.7 kilometers north-northwest of Frijoles station on Panama Railroad and 300 meters south of head of Quebrada La Chinilla arm of Gatun Lake. Depth 22.5 meters, silty limestone. Drilled in 1947. Also outcrop float limestone at same locality. Larger Foraminifera (Cole, 1949).
30	--------	------	Río Agua Salud area, Canal Zone. Core hole SL–99, 2.2 kilometers southeast of Frijoles station on Panama Railroad. Mostly siltstone. Drilled in 1947. Foraminifera.
31	--------	------	Río Agua Salud area, Canal Zone. Core hole SL–100, 3.3 kilometers southeast of Frijoles station on Panama Railroad. Depth 40.5 to 40.8 meters, siltstone. Drilled in 1947. Foraminifera.
32	17163	136	Río Fríjol area, Canal Zone. Río Fríjol 6 kilometers northwest of west end of Gamboa bridge. Sandstone. T. F. Thompson, 1948. Also a collection by W. P. Woodring, 1949.
33	--------	137	Río Fríjol area, Canal Zone. Pipe-line road, 6.5 kilometers northwest of west end of Gamboa bridge. Fairly soft limestone. W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
34	17165	------	Río Fríjol area, Canal Zone. Río Fríjol, 6.5 kilometers northwest of west end of Gamboa bridge. Sandstone. T. F. Thompson, 1948.
35	17700	135	Río Fríjol area, Canal Zone. Pipe-line road, 5 kilometers northwest of west end of Gamboa bridge. Silty mudstone. W. P. Woodring, 1949. Also smaller Foraminifera.
36	--------	134	Río Fríjol area, Canal Zone. Pipe-line road, 3.3 kilometers northwest of west end of Gamboa bridge. Limestone. W. P. Woodring, 1949. Larger Foraminifera.
37	--------	138a	Gamboa area, Canal Zone. 1.9 kilometers north-northwest of west end of Gamboa bridge, on road to core holes SL–94 and SL–96, 15 meters south of bridge across drainage ditch. Fairly soft limestone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
38	17166	119	Río Casaya area, Canal Zone. Quebrada de Oro, a northwestward-flowing tributary of Río Casaya, 3.3 kilometers southeast of east end of Gamboa bridge. Partly silicified sandy limestone. R. H. Stewart, 1948. Also collections by T. F. Thompson, 1948, and W. P. Woodring, 1949.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			GRAYWACKE GRIT MEMBER OF BOHIO FORMATION QUEBRANCHA SYNCLINE, PANAMÁ
39	--------	127	South bank of eastward-flowing tributary of Río Quebrancha, 375 meters west-northwest of Transisthmian Highway bridge across Río Quebrancha. Sandy siltstone in basal part of graywacke grit member of Bohio formation. T. F. Thompson and W. P. Woodring, 1949. Smaller Foraminifera.
			MARINE MEMBER OF BOHIO(?) FORMATION GATUN LAKE AREA, CANAL ZONE
40	--------	------	Vamos Vamos station, Panama Canal, in a cut about 2 meters above level of canal. Collected by F. Sensa, received from Alexander Agassiz, 1891. [A submerged locality off Palenquilla Point west of Barro Colorado Island, originally on south bank of French Canal.] Location approximate.
40a	2683	18	Vamos Vamos, lot 1. R. T. Hill, 1895. [The six collections from Vamos Vamos are presumably from the same locality.] Not plotted.
40b	2685	19	Panama Canal at Vamos Vamos and 10.5 kilometers from Colón. R. T. Hill, 1895. [The designation "and 10.5 kilometers from Colon" should be deleted. Vamos Vamos was about 20 kilometers from Colón.] Not plotted.
40c	2687	26	Vamos Vamos, lot 2. R. T. Hill, 1895. Not plotted.
40d	6028a	------	Vamos Vamos, lower bed. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 542, pl. 154). Not plotted.
40e	6028b	------	Vamos Vamos, upper sandstone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 542). Poorly preserved molds in weathered sandstone. Not plotted.
41	17716	148	East side of promontory 375 meters southeast of Palenquilla Point, west of Barro Colorado Island. Loose calcareous concretions at water's edge. T. F. Thompson and W. P. Woodring, 1949.
41a	18838	208	East side of Palenquilla Point, wide cove east of triangulation station. Approximately same as locality 41a, but from soft weathered medium-grained sandstone. W. P. Woodring, 1954. Not plotted.
			MARINE MEMBER OF BOHIO(?) FORMATION GATUN LAKE AREA, CANAL ZONE—continued
41b	18839	209	East side of Palenquilla Point, head of cove north of triangulation station and southwest of Corozo Island. Calcareous concretion in soft sandstone. W. P. Woodring, 1954. Not plotted.
42	17692	149	Northeast coast of Trinidad Island. Sandy siltstone, basal 3 meters of exposed section. T. F. Thompson and W. P. Woodring, 1949. Also larger Foraminifera (Cole, 1952 [1953]).
42a	17693	149a	Same locality and same part of section, but from thin calcareous layer. T. F. Thompson and W. P. Woodring, 1949. Not plotted.
42b	--------	149b	Same locality, about 3 meters higher stratigraphically. One-meter ledge-forming silty medium-grained calcareous sandstone containing few small pebbles, few worn small heads of calcareous algae, and worn shell tips of *Turritella*. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]). Not plotted.
42c	17965	149c	Same locality, sandy siltstone about 4.5 meters stratigraphically above locality 42b. T. F. Thompson and W. P. Woodring, 1949. Not plotted.
			BOHIO FORMATION, GATUN LAKE AREA, CANAL ZONE
42d	18837	207	Barro Colorado Island, northern part of island, stream heading west of Miller Trail near Miller 17,[4] about 100 meters above mouth. Somewhat calcareous medium-grained subgraywacke. W. P. Woodring, 1954.
42e	18835	205	Barro Colorado Island, northern part of island, stream southeast of Fuertes House, about 275 meters above mouth. Conglomerate. W. P. Woodring, 1954. Not plotted.
42f	18836	206	Barro Colorado Island, same stream as that for locality 42e, but about 60 meters upstream and from slide on west side of stream. Poorly sorted subgraywacke. W. P. Woodring, 1954. Not plotted.

[4] The trails on Barro Colorado Island have consecutively numbered signs at intervals of 1 hectometer, starting from the laboratory at the launch landing or at the end of the trail heading toward the laboratory.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			BOHIO FORMATION, GATUN LAKE AREA, CANAL ZONE—continued
42g	18832	203	Barro Colorado Island, northern part of island, stream crossing Pearson Trail at Pearson 6, about 365 meters above mouth. Poorly sorted subgraywacke. W. P. Woodring, 1954.
42h	--------	215	Barro Colorado Island, eastern part of island, stream east of Shannon Trail, about 365 meters southeast of Shannon 1. Somewhat calcareous coarse-grained gritty subgraywacke. W. P. Woodring, 1954. Larger Foraminifera.
42i	18845	215a	Barro Colorado Island, same stream as that for locality 54b, but 30 meters downstream. Soft muddy subgraywacke. W. P. Woodring, 1954. Not plotted.
			BOHIO FORMATION, PACIFIC COASTAL, AREA, PANAMÁ
43	--------	39	Transisthmian Highway, 9 kilometers north-northwest of junction with Panamá National Highway, about 100 meters north of Continental divide. Lens of algal limestone. J. A. Tavelli and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]).
44	17435	109	375 meters north-northwest of locality 43. Lens of algal limestone. W. P. Woodring, 1949.
45	18375	38	Transisthmian Highway, 1 kilometer north-northwest of junction with Panamá National Highway. Lens of algal limestone. J. A. Tavelli and W. P. Woodring, 1947. Also larger Foraminifera (Cole, 1952 [1953]).
			MIDDLE MEMBER OF CAIMITO FORMATION, GATUN LAKE AREA, CANAL ZONE
46	--------	41	Peninsula 2 kilometers east-southeast of Darien. Limestone. S. M. Jones and W. P. Woodring, 1947. Larger Foraminifera.
47	--------	42	East side of peninsula 1.3 kilometers east-southeast of Darien. Limestone. S. M. Jones and W. P. Woodring, 1947. Larger Foraminifera.
48	--------	43	About 45 meters eastward up path from west landing at Darien. Algal limestone. S. M. Jones and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]).
			MIDDLE MEMBER OF CAIMITO FORMATION, GATUN LAKE AREA, CANAL ZONE—continued
49	6021	------	Limestone on relocated line of Panama Railroad opposite San Pablo. First limestone outcrop north of Caimito station, about 4 miles (6.5 kilometers) north [west] of Gamboa bridge. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 539, pl. 154). [Type locality of *Lepidocyclina vaughani*. First cut northwest of Darien, now covered with soil and vegetation. A later collection from same locality was given the permanent number 6673.]
50	--------	44	Trail 1.2 kilometers north of Darien. Calcareous tuffaceous sandstone. S. M. Jones and W. P. Woodring, 1947. Larger Foraminifera.
51	--------	45	Field in peninsula 3 kilometers south-southeast of Frijoles. Pebbly calcareous tuffaceous sandstone. S. M. Jones and W. P. Woodring, 1947. Larger Foraminifera (Cole 1952 [1953]).
52	6024b	------	Limestone above foraminiferal marl at Río Agua Salud bridge, about 0.3 mile (475 meters) north of Frijoles, relocated Panama Railroad. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 540, pl. 154). Also corals (Vaughan, 1919a, p. 209). [A submerged locality, originally downstream from Río Agua Salud culvert.] Location approximate.
52a	5908	------	Limestone 1 mile or less (0.5 kilometers) north of Frijoles on relocated Panama Railroad. D. F. MacDonald, 1911. Presumably same as locality 52. Not plotted.
53	--------	53	Low islet 400 meters northeast of landing at Barro Colorado Island. Soft sandy calcareous siltstone. S. M. Jones and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]).
54	--------	46	Barro Colorado Island, northeastern part of island, stream immediately east of laboratory clearing, 150 meters upstream from mouth at launch landing. Calcareous tuffaceous sandstone. W. P. Woodring, 1947. Larger Foraminifera.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			MIDDLE MEMBER OF CAIMITO FORMATION, GATUN LAKE AREA, CANAL ZONE—continued
54a	--------	214	Barro Colorado Island, northeastern part of island, second stream east of laboratory clearing, 150 meters above mouth. Soft sandstone. W. P. Woodring, 1954. Larger Foraminifera. Not plotted.
54d	--------	202	Barro Colorado Island, northwestern part of island, stream heading north of Zetek Trail at Zetek 9, about 550 meters in direct line north-northwest of Zetek 9. Calcareous tuffaceous sandstone. W. P. Woodring, 1954. Larger Foraminifera. Not plotted.
54e	--------	202a	Barro Colorado Island, same stream as that for locality 54d, but about 200 meters downstream. Soft limestone. W. P. Woodring, 1954. Larger Foraminifera. Not plotted.
54f	--------	201	Barro Colorado Island, northwestern part of island, stream crossing Standley Trail at 60 meters northwest of Standley 11, about 30 meters downstream from trail. Soft limestone. W. P. Woodring, 1954. Larger Foraminifera.
54g	18840	210	Barro Colorado Island, western part of island, first stream north of Zetek House, about 300 meters above mouth. Soft medium-grained sandstone. W. P. Woodring, 1954.
54h	18841	210a	Barro Colorado Island, same stream as that for locality 54g, but at mouth. Soft sandstone containing calcareous lumps. W. P. Woodring, 1954. Not plotted.
54i	--------	211	Barro Colorado Island, western part of island, mouth of small stream 450 meters in direct line south-southeast of Zetek House. Soft sandstone. W. P. Woodring, 1954. Larger Foraminifera.
54j	18833	204	Barro Colorado Island, southwestern part of island, stream crossing Conrad Trail at Conrad 2, about 365 meters upstream from mouth. Soft sandstone. W. P. Woodring, 1954.
54k	18834	204a	Barro Colorado Island, same stream as that for locality 54j, but about 60 meters upstream above mouth. Soft sandstone. W. P. Woodring, 1954. Not plotted.
			MIDDLE MEMBER OF CAIMITO FORMATION, GATUN LAKE AREA, CANAL ZONE—continued
54l	18842	212	Barro Colorado Island, southwestern part of island, second stream northwest of end of Armour Trail, 60 meters above mouth. Gritty sandstone containing larger Foraminifera and mollusks, and somewhat calcareous sandstone containing mollusks. W. P. Woodring, 1954.
54m	18843	213	Barro Colorado Island, southwestern part of island, small stream 400 meters northeast of end of Armour Trail, 15 meters above mouth. Medium-grained sandstone containing somewhat calcareous lumps. W. P. Woodring, 1954.
54n	18844	213a	Barro Colorado Island, same stream as that for locality 54m, but 100 meters above mouth. Fine-grained silty sandstone containing small Foraminifera and mollusks. W. P. Woodring, 1954. Not plotted.
55	--------	------	Peña Blanca. Type locality of *Lepidocyclina canellei*. A submerged locality, originally on west bank of Río Chagres. Location approximate.
55a	18846	216	Pato Horqueto Island, south coast about 200 meters west of southeast end of island. Tuffaceous siltstone containing small Foraminifera and mollusks. W. P. Woodring, 1954.
55b	18847	216a	Pato Horqueto Island, south coast about 75 meters west of southeast end of island. Conglomerate. W. P. Woodring, 1954. Not plotted.
56	6025	------	Foraminiferal marl and coarse sandstone about 200 yards (200 meters) south of southern end of switch at Bohio Ridge station, relocated Panama Railroad. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 540, pl. 154). [Type locality of *Lepidocyclina pancanalis*, *Operculinoides panamensis*, and *Miogypsina panamensis*.]
56a	--------	55	Panama Railroad, east side of second cut southeast of Bohio Peninsula. Soft calcareous tuffaceous sandstone. S. M. Jones and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]). Same as locality 56. Not plotted.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			MIDDLE MEMBER OF CAIMITO FORMATION, GATUN LAKE AREA, CANAL ZONE—continued
57	6026	------	Foraminiferal coarse sandy marl about halfway between Monte Lirio and Bohio Ridge, relocated Panama Railroad. D. F. MacDonald and T. W. Vaughan, 1911. (MacDonald, 1919, p. 541, pl. 154). Also corals (Vaughan, 1919a, p. 208).
57a	5901	------	Relocated Panama Railroad about 2 miles (3 kilometers) south of Mitchelville [Monte Lirio]. D. F. MacDonald, 1911. Same as locality 57 Not plotted.
			UPPER MEMBER OF CAIMITO FORMATION, GATUN LAKE AREA, CANAL ZONE
58	--------	54	Puma Island, in front of shed near crest of island. Hard calcareous sandstone. S. M. Jones and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]).
			UNDIFFERENTIATED CAIMITO FORMATION, RÍO MANDINGA AREA, CANAL ZONE
59	--------	110	Northward-flowing tributary of Río Mandinga, 3.3 kilometers southwest of west end of Gamboa bridge. Medium-grained poorly sorted silty tuffaceous sandstone. R. H. Stewart, 1948. Also collection by W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
60	17685	111	300 meters upstream from locality 59. Pebbly calcareous tuffaceous sandstone. W. P. Woodring, 1949.
61	--------	112	About 45 meters west of pipe-line road and 3.5 kilometers west-southwest of west end of Gamboa bridge. Limestone. W. P. Woodring, 1949. Corals.
			QUEBRANCHA LIMESTONE MEMBER OF CAIMITO FORMATION, QUEBRANCHA SYNCLINE, PANAMÁ
62	16939	11	North side of Transisthmian Highway at entrance to plant of Cía. Cemento Panamá, S. A., 125 meters northwest of Transisthmian Highway bridge across Río Gatuncillo. Lower part of limestone. T. F. Thompson and W. P. Woodring, 1947.
			QUEBRANCHA LIMESTONE MEMBER OF CAIMITO FORMATION, QUEBRANCHA SYNCLINE, PANAMÁ—continued
62a	--------	11a	Quarry of Cía. Cemento Panamá, S. A., 150 meters northwest of locality 11. Middle part of limestone. J. R. Schultz and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]). Not plotted.
			LOWER PART OF CAIMITO FORMATION, MADDEN BASIN, PANAMÁ
63	--------	29	Transisthmian Highway, 4 kilometers north-northwest of Río Chagres bridge. Sandy limestone in calcareous sandstone-siltstone member. W. P. Woodring, 1947. Larger Foraminifera.
64	--------	30	Transisthmian Highway, 3.3 kilometers north-northwest of Río Chagres bridge. Medium-grained calcareous tuffaceous sandstone in calcareous sandstone-siltstone member. W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]).
65	5907	------	Río Chagres at locality where trail from Alhajuela reaches river, about 6 miles (10 kilometers) by river above Alhajuela. D. F. MacDonald, 1911. [A submerged locality.]
66	8386	------	Río Chagres about a mile (1.5 kilometers) below mouth of Río Pequení, limestone at Marcelito, just below Bajilla Rain Gage Station. A. A. Olsson, 1919. [A submerged locality.] Location approximate.
67	--------	121	Río Chilibrillo, 650 meters above bridge on road to Casa Larga. Coarse-grained poorly sorted calcareous somewhat tuffaceous sandstone in calcareous sandstone-siltstone member, about 15 meters above base of Caimito formation. W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
68	--------	120	Río Chilibrillo, 325 meters above bridge on road to Casa Larga. Very fine-grained silty sandstone in calcareous sandstone-siltstone member. W. P. Woodring, 1949. Smaller Foraminifera.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			LOWER PART OF CAIMITO FORMATION, MADDEN BASIN PANAMÁ—continued
69	--------	123	Río Chilibrillo, 1 kilometer below bridge on road to Casa Larga. Medium-grained somewhat calcareous and somewhat tuffaceous sandstone in calcareous sandstone-siltstone member, about 300 meters above base of Caimito formation. W. P. Woodring, 1949. Larger Foraminifera (Cole, 1952 [1953]).
70	--------	130	Río Chilibrillo, 1.5 kilometers below bridge on road to Casa Larga. Sandy siltstone in calcareous sandstone-siltstone member. W. P. Woodring, 1949. Smaller Foraminifera.
71	16945	6	Transisthmian Highway, 1 kilometer northwest of Madden Highway overpass. Limestone in pyroclastic-clay member. J. R. Schultz and W. P. Woodring, 1947.
72	16957	40	Madden Highway, 1.7 kilometers northwest of Transisthmian Highway underpass. Limestone in pyroclastic-clay member. J. A. Tavelli and W. P. Woodring, 1947.
73	16944	7	Transisthmian Highway, 2 kilometers northwest of Madden Highway overpass. Limestone in pyroclastic-clay member. J. R. Schultz and W. P. Woodring, 1947.
74	17439	142	Transisthmian Highway, 1.5 kilometers south of Río Chilibrillo bridge. Conglomerate near top of pyroclastic-clay member. W. P. Woodring, 1949.
74a	17493	142a	Same locality. Coarse-grained sandstone overlying conglomerate. W. P. Woodring, 1949. Not plotted.
75	17437	133	Transisthmian Highway, 0.5 kilometer north of Río Chagres bridge. Clay at top of pyroclastic-clay member. T. F. Thompson and W. P. Woodring, 1949. Also smaller Foraminifera.
			UPPER PART OF CAIMITO FORMATION, MADDEN BASIN, PANAMÁ
76	5906a	------	Río Chagres about 1.5 miles (2.5 kilometers) above Alhajuela, about 50 to 75 feet (15 to 23 meters) stratigraphically below 17c (5905), in lighter colored limestone. D. F. MacDonald, 1911. [A submerged locality.] Location approximate.
			UPPER PART OF CAIMITO FORMATION, MADDEN BASIN, PANAMÁ—continued
76a	5906b	------	Same locality, 10 to 25 feet (3 to 7 meters) lower stratigraphically, in hard limestone. D. F. MacDonald, 1911. [A submerged locality.] Not plotted.
77	5905	------	Río Chagres about 1.25 miles (2 kilometers) above Alhajuela, about 50 to 75 feet (15 to 23 meters) stratigraphically below 17b (5904). D. F. MacDonald, 1911. [A submerged locality, about 375 meters southwest of locality 76.] Not plotted.
78	8399	------	Río Chagres, pebbly limy sandstone at Purgatorio, about 2 miles (3.2 kilometers) below mouth of Río Pequiní. E. R. Lloyd, 1919. [A submerged locality, probably about 750 meters northeast of locality 76.] Not plotted.
79	8398	------	Río Chilibrillo. A. A. Olsson, 1919. [Location indefinite.] Not plotted.
80	7289	------	Cave near Chilibre River, about 6 miles (10 kilometers) from Alhajuela. August Busck, 1911. [Matrix consists of sandstone. Presumably near locality 81.] Not plotted.
81	16932	24	Transisthmian Highway, 1.2 kilometers south-southwest of Río Chilibrillo bridge, about 150 meters west of highway. Chilibrillo limestone member. J. R. Schultz and W. P. Woodring, 1947.
82	16929	8	Transisthmian Highway, 650 meters south-southeast of Río Chilibrillo bridge. Calcareous sandstone member. J. R. Schultz and W. P. Woodring, 1947.
82a	17494	8a	Transisthmian Highway, 75 meters south of locality 82. Calcareous sandstone member. W. P. Woodring, 1949. Not plotted.
83	16930	10	Transisthmian Highway, 400 meters north of Río Chagres bridge. Calcareous sandstone member. J. R. Schultz and W. P. Woodring, 1947.
84	17941	10a	Transisthmian Highway, west end of north abutment of Río Chagres bridge. Calcareous sandstone member. T. F. Thompson and W. P. Woodring, 1949.
84a	17942	10b	Same locality, but at east end of abutment. Calcareous sandstone member. W. P. Woodring, 1949. Not plotted.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			UPPER PART OF CAIMITO FORMATION, MADDEN BASIN, PANAMÁ—continued
85	5903	------	Río Chagres, top of hill opposite Alhajuela. [Alhajuela sandstone member.] D. F. MacDonald, 1911. [For location of Alhajuela see Reeves and Ross, 1930, pl. 5.]
85a	8385	------	Río Chagres, top of hill opposite Alhajuela. [Alhajuela sandstone member.] A. A. Olsson, 1919. Same as locality 85. Not plotted.
86	5904	------	Río Chagres, ⅛ to ¼ mile (200 to 400 meters) above Alhajuela. [Alhajuela sandstone member.] D. F. MacDonald, 1911. [A submerged locality, about 400 meters north of locality 85.] Not plotted.
87	5874	------	Río Chagres between Alhajuela and El Vigia. [Presumably Alhajuela sandstone member.] H. Pittier, 1911. [For location of El Vigia see Reeves and Ross, 1930, pl. 5. [A submerged locality, too indefinite to plot.]
88	17682	143	1.6 kilometers northwest of Madden Dam, on abandoned Public Roads Administration road to powder magazine. Alhajuela sandstone member. W. P. Woodring, 1949.
89	16956	17	Madden Highway, 1 kilometer northwest of Madden Dam. Alhajuela sandstone member. J. R. Schultz, T. F. Thompson, and W. P. Woodring, 1947.
90	17683	144	1.2 kilometers south-southwest of Madden Dam, on road between Madden Highway and Transisthmian Highway. Alhajuela sandstone member. W. P. Woodring, 1949.
90a	17684	144a	30 meters southwest of locality 90. Alhajuela sandstone member. W. P. Woodring, 1949. Not plotted.
91	16952	9	Transisthmian Highway, 1.3 kilometers southeast of Río Chagres bridge. Alhajuela sandstone member. J. R. Schultz and W. P. Woodring, 1947.
92	16940	16	Madden Highway, 2 kilometers south-southeast of Madden Dam. Alhajuela sandstone member. J. R. Schultz, T. F. Thompson, and W. P. Woodring, 1947.
			UNDIFFERENTIATED CAIMITO FORMATION, RÍO CHAGRES AREA, CANAL ZONE
93	--------	126	Trail 750 meters southwest of Nuevo San Juan. Coarse-grained conglomeratic pebbly sandstone. T. F. Thompson and W. P. Woodring, 1949. Larger Foraminifera.
94	6509	------	Río Chagres, limestone at and a little above Las Cruces. D. F. MacDonald, 1913. [A submerged locality.] Location approximate.
94a	6510	------	Río Chagres, limestone a little below Las Cruces, on north bank of river. D. F. MacDonald, 1913. [A submerged locality a short distance south of locality 94.] Not plotted.
			LOWER PART OF CAIMITO FORMATION, PACIFIC COASTAL AREA, PANAMA
95	--------	37	Transisthmian Highway, 325 meters north of junction with Panamá National Highway. Thin lens of algal limestone in tuff and tuffaceous sandstone. J. A. Tavelli and W. P. Woodring, 1947. Larger Foraminifera (Cole, 1952 [1953]).
96	--------	104	Panamá National Highway, about 175 meters northeast of junction with Transisthmian Highway. Lens of algal limestone in tuff and tuffaceous sandstone. T. F. Thompson and W. P. Woodring, 1947. Larger Foraminifera.
96a	--------	------	Borrow pit on north side of road to housing development, about 3.2 kilometers northeast of Tocúmen. Fine-grained tuff. T. F. Thompson and W. P. Woodring, 1947. Larger Foraminifera.
			LOWER PART OF CAIMITO FORMATION, MADDEN HIGHWAY AREA, CANAL ZONE
97	--------	18	Stream about 100 meters west of Madden Highway and 1.6 kilometers northeast of junction with Gaillard Highway. Limestone T. F. Thompson and W. P. Woodring, 1947. Larger Foraminifera

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			CULEBRA FORMATION, GAILLARD CUT, CANAL ZONE
98	16942	35a	West side of Gaillard Cut, canal station 1600.[5] Float from Culebra formation. T. G. Moran and W. P. Woodring, 1947. Not plotted, same as locality 120.
99	6019	------	Lower half of section near Las Cascades, exact horizon not known. D. F. MacDonald and T. W. Vaughan, 1911. [Presumably float near canal station 1610.] Not plotted.
99a	6019a	------	Near canal station 1611. D. F. MacDonald and T. W. Vaughan, 1911. Also larger Foraminifera (Cole 1953a). Plotted on plate 2. [Localities 6019a to 6019g, inclusive, are located between canal stations 1606 and 1611 and are arranged in upward sequence in that order. For stratigraphic section see MacDonald, 1919, p. 537–538 and for general location see MacDonald, 1919, pl. 154. Location with reference to the canal stations are taken from manuscript structure sections prepared by MacDonald. The construction-period localities in Gaillard Cut presumably represent the excavated prism of rock. Those plotted are shown by the symbol for submerged localities, though many may be above the level of the canal.]
99b	6019b	------	Near canal station 1611. D. F. MacDonald and T. W. Vaughan, 1911. Not plotted.
99c	6019c	------	Canal station 1610. D. F. MacDonald and T. W. Vaughan, 1911. Not plotted.
99d	6019d	------	Canal station 1609. D. F. MacDonald and T. W. Vaughan, 1911. Not plotted.
99e	6019e	------	Near canal station 1608. D. F. MacDonald and T. W. Vaughan, 1911. Not plotted.
99f	6019f	------	Near canal station 1607. D. F. MacDonald and T. W. Vaughan, 1911. Also larger Foraminifera (Cole, 1953a). Not plotted.
99g	6019g	------	Canal station 1606. D. F. MacDonald and T. W. Vaughan, 1911. Also larger Foraminifera (Cole, 1953a). Plotted on plate 2. [Assigned by MacDonald to Emperador limestone member, but apparently represents a sandy limestone referable to the Culebra formation proper.]
			CULEBRA FORMATION, GAILLARD CUT, CANAL ZONE—continued
99h	5857	------	Near canal station 1610. D. F. MacDonald, 1911. Not plotted, practically same as locality 99c.
100	6020a	------	Near canal station 1614. D. F. MacDonald and T. W. Vaughan, 1911. Plotted on plate 2. [Localities 6020a to 6020c, inclusive, underlie 6019a (MacDonald, 1919, p. 538). Type locality of *"Orbitolites" americana*.]
100a	6020b	------	Near canal station 1614. D. F. Mac. Donald and T. W. Vaughan, 1911. Not plotted.
100b	6020c	------	Near canal station 1613. D. F. MacDonald and T. W. Vaughan, 1911. Also corals (Vaughan, 1919a, p. 208). Not plotted.
101	16943	34	West side of Gaillard Cut, canal station 1619. Black clay 60 centimeters below base of limestone. T. G. Moran and W. P. Woodring, 1947. Plotted on plate 2.
102	6012a	------	Near canal station 1723. D. F. MacDonald and T. W. Vaughan, 1911. Plotted on plate 2. [For stratigraphic section including localities 6012a and 6012b see MacDonald, 1919, p. 537 and for general location see pl. 154.]
102a	6507	------	Lower part of Culebra formation about 0.25 mile (300 meters) south of Empire bridge, altitude 55 feet (17 meters). D. F. MacDonald, 1911. (Probably near canal station 1720.) Not plotted.
103	6012b	------	Near canal station 1717. D. F. MacDonald and T. W. Vaughan, 1911. Plotted on plate 2.
104	16933	31	West side of Gaillard Cut, canal station 1730. Sandy pebble bed in almost black mudstone. T. G. Moran and W. P. Woodring, 1947. Plotted on plate 2.
104a	6976	------	Culebra (Gaillard) Cut, about midway between Empire and Culebra, about 50 feet (15 meters) below original surface. Received from George Gaillard, 1909. [Presumably near canal station 1730.] Not plotted.
104b	5863	------	Conglomerate near canal station 1731, about 0.3 mile (0.5 kilometer) below Empire bridge. D. F. MacDonald, 1911. Not plotted.
105	6517	------	East side of canal opposite Culebra railroad station. D. F. MacDonald, 1913. [Between canal stations 1750 and 1760.] Not plotted.

[5] The canal stations are located along the center alinement of the canal at intervals of 100 feet (30.5 meters) and are numbered from the Caribbean terminus to the Pacific terminus.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			CULEBRA FORMATION, GAILLARD CUT, CANAL ZONE—continued
106	6012c	------	Near canal station 1759. D. F. MacDonald and T. W. Vaughan, 1911. Plotted on place 2. [For stratigraphic sections including localities 6012a to 6012e inclusive, see MacDonald, 1919, p. 536–537 and for general locations see plate 154.]
107	6012d	------	Near canal station 1768. Calcareous sandstone. D. F. MacDonald and T. W. Vaughan, 1911. Also larger Foraminifera. [Type locality of *Miogypsina cushmani*.] Plotted on plate 2.
108	--------	1	West side of Gaillard Cut, canal station 1759. Dark gray calcareous mudstone 1.5 meters above water level. See stratigraphic section, page 35 J. R. Schultz and W. P. Woodring, 1947. Smaller Foraminifera. Not plotted.
108a	16951	1a	Same locality, float 7.5 meters below uppermost calcareous sandstone of Culebra formation. J. R. Schultz and W. P. Woodring, 1947. Not plotted.
108b	4897	------	East side of Culebra [Gaillard] Cut, about three-fourths mile (1.2 kilometers) northwest of Gold Hill. Sidney Paige, 1908. [Presumably near canal station 1760.] Not plotted.
108c	5859	-----	West side of canal, canal station 1760 D. F. MacDonald, 1911. Not plotted.
109	6013	------	East side of Culebra [Gaillard] Cut, opposite Culebra. Pebbly calcareous sandstone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 536, plate 154). [Canal station 1762.] Plotted on plate 2.
110	16886	5	East side of Gaillard Cut, canal station 1754, about 60 meters northeast of edge of canal and about 100 meters northwest of northwest edge of Culebra Extension slide. Tuffaceous sandstone and calcareous concretions in transition zone between Culebra and Cucaracha formations. J. R. Schultz and W. P. Woodring, 1947. Plotted on plate 2.
110a	6508	------	East side of Culebra [Gaillard] Cut, canal station 1755, upper part of Culebra formation. D. F. MacDonald, 1913. Not plotted; approximately same as locality 110.
111	--------	------	Stanford University locality 2701, west side of Gaillard Cut, canal station 1754, altitude 140 feet (42.5 meters). T. F. Thompson, 1943. Plotted on plate 2.
111a	16887	25	West side of Gaillard Cut, canal station 1755 and 30 meters northwestward along strike, about 45 meters southwest of edge of canal. Calcareous concretions in sandy siltstone corresponding to top of bed 13 of section on page 35. J. R. Schultz and W. P. Woodring, 1947. Not plotted; same as locality 111.
111b	16888	25a	West side of Gaillard Cut, canal station 1754, from dirty sandstone brought to surface by test explosion, evidently from base of bed 13 of section on page 35. J. R. Schultz and W. P. Woodring, 1947. Not plotted; same as locality 111a.
112	16910	2	West side of Gaillard Cut, canal station 1759, about 30 meters southwest of edge of canal. Basal part of bed 13 of section on page 35. J. R. Schultz and W. P. Woodring, 1947. Plotted on plate 2.
112a	16927	3	Same locality, top of bed 13 of section on page 35. J. R. Schultz and W. P. Woodring, 1947. Not plotted.
113	6011	------	East side of Culebra [Gaillard] Cut, near canal station 1845, between Paraiso and Gold Hill. Foraminiferal limy sandstone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 535, pl. 154). Plotted on plate 2.
114	5860	------	West side of Culebra [Gaillard] Cut, canal station 1847 plus 25 feet (6.2 meters). D. F. MacDonald, 1913. Plotted on plate 2.
115	6505	------	West side of Culebra [Gaillard] Cut, near canal station 1860. Lower part of limy sandstone. D. F. MacDonald, 1913. Also larger Foraminifera: *Miogypsina intermedia* (Drooger, 1952, p. 36). Plotted on plate 2.
115a	6515	------	West side of Culebra [Gaillard] Cut, about one-third mile (500 meters) north [northwest] of Paraiso. D. F. MacDonald, 1913. Not plotted; apparently close to locality 115.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			CULEBRA FORMATION, GAILLARD CUT, CANAL ZONE—continued
115b	6443	------	A mile (1.6 kilometers) south of Culebra Cut. Ralph Arnold and D. F. MacDonald, 1913. [The locality data are indefinite, but this presumably is the collection to which MacDonald referred in a notation on his label for 6515: "Arnold took fossils from here."] Not plotted; evidently same as locality 115a.
116	5853	------	West side of Culebra [Gaillard] Cut, canal station 1863. Pebbly tuffaceous sandstone about 2.5 feet (75 centimeters) thick. D. F. MacDonald, 1911. Also coral (Vaughan, 1919*a*, p. 208, cited as locality 5863). Plotted on plate 2.
			EMPERADOR LIMESTONE MEMBER OF CULEBRA FORMATION, CANAL ZONE
117	6014	------	Limestone on street near railroad at Empire, 0.25 or 0.3 mile (400 or 500 meters) north-northwest of railroad station. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, pl. 154). Plotted on plate 2; location approximate, based on MacDonald's plotted location.
118	6016	------	Old quarry 0.3 mile (500 meters) west-northwest of Empire. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, pl. 154). Also corals (Vaughan, 1919a, p. 208–209). Plotted on plate 2, location approximate, based on MacDonald's plotted location.
118a	6444	------	Quarry at Empire. Ralph Arnold, 1913. Not plotted; presumably same as locality 118 or nearby.
119	5858	------	Lower part of upper limestone near tower N. Thought to be equivalent of fossil lot 6a [5856], but bed is not directly traceable. D. F. MacDonald, 1911. [Tower N was a signal tower on the original line of the Panama Railroad near Las Cascades. The right-of-way, still recognizable at some places as a low artificial ridge, immediately adjoins the left bank of the canal in the Las Cascades area. Locality 119 presumably is near locality 120.] Not plotted.
119a	5866	------	Upper limestone bed near tower N. Same as fossil lot 6c [5858]. D. F. MacDonald, 1911. Also larger Foraminifera (Cole, 1953a). Not plotted; same as locality 119.
			EMPERADOR LIMESTONE MEMBER OF CULEBRA FORMATION, CANAL ZONE—continued
119b	6669	------	Upper bed of limestone near tower N. D. F. MacDonald, 1913. Not plotted; same as locality 119.
119c	5856	------	Highest limestone near tower N, between towers M and N. D. F. MacDonald, 1911. Not plotted; near locality 119.
120	16958	35	West side of Gaillard Cut, canal station 1600. Calcareous siltstone and limestone. T. G. Moran and W. P. Woodring, 1947. Plotted on plate 2.
120a	8043	------	Las Cascades [west side of Gaillard Cut, canal station 1600]. Limestone. W. P. Woodring, 1917. Not plotted; same as locality 120.
121	16941	34a	West side of Gaillard Cut, canal station 1619. Limestone overlying clay and siltstone. T. G. Moran and W. P. Woodring, 1947. Not plotted; same as locality 101.
			CUCARACHA FORMATION, CANAL ZONE
122	6012e	------	East side of Gaillard Cut, one-eighth mile (200 meters) north of Gold Hill [near canal station 1775]. Black carbonaceous shale. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 535–536). Plotted on plate 2.
			LA BOÇA MARINE MEMBER OF PANAMÁ FORMATION, CANAL ZONE
123	16955	33	East of Gaillard Cut, 200 meters up Río Masambí from east bank of canal. Río Masambí enters the canal at canal station 1696. Coralliferous limestone at base of La Boca member. T. G. Moran and W. P. Woodring, 1947. Plotted on plate 2.
124	--------	32	East side of Gaillard Cut, canal station 1702. Dark, almost black mudstone. T. G. Moran and W. P. Woodring, 1947. Smaller Foraminifera. Plotted on plate 2.
125	5852	------	East side of Gaillard Cut near Empire bridge. [The Empire bridge was located approximately at canal station 1709.] D. F. MacDonald, 1911. Plotted on plate 2; location approximate.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			LA BOCA MARINE MEMBER OF PANAMÁ FORMATION, CANAL ZONE—continued
126	6267	------	Relocated line of Panama Railroad, a little south of station at New Culebra, about opposite Catholic church at Culebra, half a mile (750 meters) northwest of 6268. Same formation as 6268 and 6018. Yellowish spherically weathering limy sandstone. D. F. MacDonald, 1912. [Possibly the unnumbered fossil locality west of 6018 on MacDonald's map (MacDonald, 1919, pl. 154)]. Plotted on plate 2; location approximate.
127	6018	------	Cut on relocated line of Panama Railroad opposite Empire, near road from Empire to Las Cascades Plantation. Tuffaceous calcareous(?) sandstone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, pl. 154). Plotted on plate 2; location approximate.
127a	6268	------	Relocated line of Panama Railroad, junction with track leading down to Canal between Gold Hill and Empire bridge. Yellowish spherically weathering limy sandstone. D. F. MacDonald, 1912, 1913. Not plotted; presumably near locality 127.
127b	6336	------	Relocated line of Panama Railroad, junction with track leading down to Canal between Gold Hill and Empire bridge. Light-colored tuff and kaolinitic beds overlying light gray and buff spherically weathering sandstone. Hill's Panamá formation. D. F. MacDonald, 1913. Not plotted; same as locality 127a, but from overlying tuff.
128	16947	4	Abandoned quarry on north side of Old Gaillard Highway, 230 meters southwest of New Gaillard Highway entrance to Summit Experimental Gardens. Massive calcareous sandstone. J. R. Schultz and W. P. Woodring, 1947. Plotted on plate 2.
129	16954	14a	South side of New Gaillard Highway at milepost 11, about 400 meters northwest of Madden Highway turnoff. Relatively soft yellowish coralliferous limestone with marly partings at base of La Boca marine member of Panamá formation. J. R. Schultz, T. F. Thompson, and W. P. Woodring, 1947. Also corals.
129a	16953	14	South side of New Gaillard Highway, 100 meters southeast of locality 129. Hard grayish limestone overlying limestone at locality 129, but part of same unit. J. R. Schultz, T. F. Thompson and W. P. Woodring, 1947. Not plotted.
130	6010	------	Near Canal station 1910, northwest of Pedro Miguel Locks. [About 600 meters northwest of north end of Pedro Miguel Locks.] Mudstone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 534, pl. 154). Also smaller Foraminifera; type locality of *Siphogenerina transversa*. Plotted on plate 2.
131	6256	------	One-eighth mile (200 meters) east of wagon road at Bald Hill, 1.5 miles (2.4 kilometers) south of Miraflores. Limestone. D. F. MacDonald, 1912. Corals (Vaughan, 1919a, p. 209). Presumably near locality 132. [Bald Hill is identified as the currently unnamed hill immediately northeast of Red Tank. For a section at Bald Hill see MacDonald (1919, p. 534). His manuscript on the geology of Panamá includes a sketch of the strata at this locality labeled, in his writing, "Section at Bald Hill, a mile (1.6 kilometers) south [southeast] of Pedro Miguel and 100 yards (100 meters) east of the main road." The locality data just quoted approximately fit the specified identification of Bald Hill. The data in the Cenozoic register evidently are erroneous.] Not plotted.
131a	6257	------	Practically same limestone bed as 6256, but about 10 feet (3 meters) higher stratigraphically. D. F. MacDonald, 1912. Also larger Foraminifera (Cole, 1953a). Not plotted.
132	16939	57	1.6 kilometers north-northwest of north end of Miraflores Locks, on incinerator road leading off Gaillard Highway on west side of middle arm of Miraflores Lake. Fine-grained tuff and tuffaceous siltstone. T. F. Thompson and W. P. Woodring, 1947.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			LA BOCA MARINE MEMBER OF PANAMÁ FORMATION, CANAL ZONE—continued
132a	6255	------	Fossiliferous limy sandstone ½ mile (750 meters) south of Miraflores station, on wagon road to Panamá. D. F. MacDonald, 1912. Larger Foraminifera (Cole, 1953a). Type locality of *Lepidocyclina miraflorensis*. Apparently submerged. Not plotted.
133	6237	------	Limestone in swamp north of Ancon Hill, about ¼ mile (400 meters) south of Diablo Ridge. D. F. MacDonald, 1912. [The swamp and any outcrops in it are now covered with fill.] Not plotted.
			LOWER PART OF GATUN FORMATION
134	17691	102	Road from Sabanita to María Chiquita, cut on south side of ridge, 1.3 kilometers south-southwest of María Chiquita, Panamá. Silty sandstone. W. P. Woodring, 1949.
135	17690	101	Cut on west side of Transisthmian Highway at south edge of Sabanita, Panamá. Ferrugineous concretions in sandstone interbedded with conglomerate. W. P. Woodring, 1949.
136	16912	12	North side of Transisthmian Highway, knoll about 30 meters north of highway, 1.2 kilometers northwest of Sabanita, Panamá. Silty fine-grained sandstone. T. F. Thompson and W. P. Woodring, 1947.
136a	--------	------	Same locality. Stanford University locality 2611. Latitude 9°21′ N., plus 1,100 feet (335 meters), longitude 79°49′ W. T. F. Thompson, 1942. Not plotted.
137	16911	26	South side of Transisthmian Highway, 1.7 kilometers northwest of Sabanita, Panamá. Soft silty fine-grained sandstone. W. P. Woodring, 1947.
137a	--------	------	Same locality. Stanford University locality 2655. Latitude 9°21′ N., plus 3,000 feet (915 meters), longitude 79°49′ W., plus 1,100 feet (335 meters). T. F. Thompson, 1942. Not plotted.
138	16909	27	North and south sides of Transisthmian Highway, 1.6 kilometers northeast of Canal Zone boundary, Panamá. Soft silty fine-grained sandstone. W. P. Woodring, 1947.
			LOWER PART OF GATUN FORMATION—continued
138a	--------	------	Same locality. Stanford University locality 2656. Latitude 9°21′ N., plus 5,000 feet (1,525 meters), longitude 79°50′ W., plus 1,000 feet (300 meters). T. F. Thompson, 1942. Not plotted.
139	6667	------	Steep ridge about 2.5 miles (4 kilometers) northeast [north] of Monte Lirio, overlooking and about 250 feet above Gatun Lake, Canal Zone. D. F. MacDonald, 1913. [Southern part of Zorra Island.] Location approximate.
			MIDDLE PART OF GATUN FORMATION, EASTERN AREA
140	--------	------	Stanford University locality 2708. Latitude 9°21′ N., plus 4,200 feet (1,280 meters), longitude 79°51′ W., plus 800 feet (245 meters). T. F. Thompson, 1943. [500 meters northwest of intersection of Transisthmian Highway and Canal Zone boundary, Canal Zone.]
141	16948	28	About 100 meters northwest of Transisthmian Highway, on secondary road entering Highway 600 meters west of Canal Zone boundary, Canal Zone. Medium-grained sandstone. W. P. Woodring, 1947.
142	--------	------	Stanford University locality 2698. Northeast of Fort Gulick, latitude 9°20′ N., longitude 79°52′ W., plus 1,010 feet (310 meters). T. F. Thompson, 1943. [1.1 kilometers southeast of junction of Transisthmian Highway and road to Fort Gulick, Canal Zone.]
143	6030	------	Relocated Panama Railroad, 85-foot (25 meter) cut 1.5 to 2 miles (2.4 to 3.2 kilometers) east of Camp Cotton, Canal Zone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 542, pl. 154).
144	6029a	------	Relocated Panama Railroad, big cut ¼ to ½ mile (0.6 to 0.8 kilometers) northeast of Camp Cotton, Canal Zone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 542, pl. 154).

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			MIDDLE PART OF GATUN FORMATION, EASTERN AREA—continued
144a	6029b	------	Same locality, from overlying 32 to 42 feet (10 to 13 meters). D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 542). Not plotted.
144b	6335	------	Relocated Panama Railroad, lowest bed in big cut about ½ mile (0.8 kilometer) east of Camp Cotton, Canal Zone. Same locality as lot 17 of 1911 [6029a]. D. F. MacDonald, 1913. Same as locality 144. Not plotted.
144c	6235	------	Relocated Panama Railroad, 3.5 miles (5.6 kilometers) out from Gatun, Canal Zone. Above fuller's earth beds. D. F. MacDonald, 1912. [Apparently same as locality 144a.] Not plotted.
144d	6334	------	Relocated Panama Railroad, big curved cut about 1 mile (1.6 kilometers) east of Camp Cotton, Canal Zone. Above fuller's earth beds. D. F. MacDonald, 1913. [Probably close to locality 144a.] Not plotted.
145	6031	------	Relocated Panama Railroad, ½ mile (0.8 kilometer) west of Camp Cotton, Canal Zone. Basal part of section; conglomerate and 1 foot above conglomerate. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 543, pl. 154).
146	5845	------	Quebrancha Hills overlooking Gatun Lake, 1.5 miles (2.4 kilometers) northeast [east-southeast] of Gatun, Canal Zone. D. F. MacDonald, 1911. [Presumably in railroad cut.] Location approximate.
147	6033a	------	Panama Railroad, about 3,500 feet (1,065 meters) southeast of Gatun railroad station, Canal Zone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 543, pl. 154).
147a	6033b	------	Same locality, from overlying 4 feet (1.2 meters). D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 543). Not plotted.
147b	6033c	------	Same locality, from overlying 15 to 20 feet (4.5 to 6 meters). D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 543). Not plotted.
147c	6003	------	Same locality and bed as locality 147. D. F. MacDonald, 1911 (MacDonald, 1919, p. 543). Not plotted.
147d	6004	------	Same locality, but higher stratigraphically. D. F. MacDonald, 1911. Not plotted.
147e	6005	------	Same locality, but higher stratigraphically. D. F. MacDonald, 1911. Not plotted.
147f	6006	------	Same locality, but higher stratigraphically. D. F. MacDonald, 1911. Not plotted.
147g	5899	-----	Highest fossil-bearing beds, Quebrancha Hills, ¾ mile (1.2 kilometers) out from Gatun, Canal Zone. D. F. MacDonald, 1911. Probably same as locality 147b. Not plotted.
147h	6442	------	Half a mile (750 meters) south [southeast] of Gatun, Canal Zone. Ralph Arnold and D. F. MacDonald, 1913. [Probably at or near locality 147.] Not plotted.
147i	8376	------	Panama Railroad, southeast of Gatun, station 6 plus 20, Canal Zone. A. A. Olsson, 1918. [Probably near locality 147.] Not plotted.
147j	8379	------	Panama Railroad, southeast of Gatun, station 4A, Canal Zone. A. A. Olsson, 1918. [Probably near locality 147.] Not plotted.
148	8380	------	Lower Gatun along Panama Railroad between Monte Lirio and Gatun, station 4, Canal Zone. A. A. Olsson, 1918. Echinoid. Location indefinite; not plotted.
149	8381	------	Panama Railroad, southeast of Gatun, station C, Canal Zone. A. A. Olsson, 1918. Locality indefinite; not plotted.
150	8377	------	Panama Railroad, first cut south of Gatun, Canal Zone. A. A. Olsson, 1918.
150a	10997	------	Panama Railroad, high cut about 0.4 mile (650 meters) southeast of Gatun railroad station, Canal Zone. W. P. Woodring, 1923. [Same as locality 150.] Not plotted.
151	8388	------	Gatun, station B, Canal Zone. Lower Gatun, lower *Turritella altilira* zone. A. A. Olsson, 1918. [In Gatun area, but location indefinite.] Not plotted.
152	8483	------	Gatun area, station B, Canal Zone. A. A. Olsson, 1918. Location indefinite; not plotted.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			MIDDLE PART OF GATUN FORMATION, EASTERN AREA—continued
153	16950	47	Gatun Third Locks excavation, plug at south end of excavation, Canal Zone. Unit 1 of section on p. 44; silty to marly sandstone. T. F. Thompson and W. P. Woodring, 1947.
153a	--------	------	Stanford University locality 2657. Gatun Third Locks excavation, south end of excavation, Canal Zone. Latitude 9°15′ N., plus 5,600 feet (1,705 meters), longitude 79°54′ W., plus 5,150 feet (1,570 meters). Unit 3 of section on p. 44; medium-grained to very fine-grained sandstone. T. F. Thompson, 1942. 425 feet (130 meters) north of locality 153. Not plotted.
154	16935	------	Gatun Third Locks excavation, west side of excavation 0.6 mile (1 kilometer) north of Gatun Lake, Canal Zone. Unit 10 of section on p. 44; conglomerate. T. F. Thompson and W. P. Woodring, 1947.
155	--------	------	Stanford University locality 2653. Gatun Third Locks excavation, Canal Zone. Latitude 9°16′ N., plus 4,700 feet (1,430 meters), longitude 79°54′ W., plus 5,800 feet (1,770 meters). Units 11 and 12 of section on p. 44; fine-grained sandstone and marly siltstone. T. F. Thompson, 1942.
155a	16970	------	Spoil dump of Gatun Third Locks excavation, Canal Zone. T. F. Thompson, 1945. [Essentially same stratigraphic range as locality 155.] Not plotted.
155b	16949	49	Spoil dump of Gatun Third Locks excavation, Canal Zone. T. F. Thompson and W. P. Woodring, 1947. Essentially same stratigraphic range as locality 155. Not plotted.
155c	16915	50	Gatun Third Locks excavation, east side of excavation 1 mile (1.6 kilometers) north of Gatun Lake, Canal Zone. *Turritella*-bearing marly siltstone in lower part of unit 12b of section on p. 44. T. F. Thompson and W. P. Woodring, 1947. Included in stratigraphic range of locality 155. Not plotted.
156	16928	13	Jadwin Road at crossing of Panama Railroad, northern part of Gatun, Canal Zone. *Turritella*-bearing marly siltstone. T. F. Thompson and W. P. Woodring, 1947.
157	16926	56	Westernmost cut on Panama Railroad cutoff south of Fort Davis, 1.2 miles (1.9 kilometers) northeast of Gatun railroad station, Canal Zone. Siltstone and silty sandstone. W. P. Woodring, 1947.
158	2682	17	Vamos á Vamos, Canal Zone. R. T. Hill, 1895. [Locality erroneous; it apparently should be "French Canal, 10.5 kilometers from Colón"; that is, near Gatun. See remarks under locality 173a.] Not plotted.
159	5211	------	Lock site at Gatun, Canal Zone. W. S. Standifer, 1909. Not plotted.
159a	5414	------	Upper lock site at Gatun, Canal Zone. W. J. Ergenzinger, 1910(?). Not plotted.
159b	6273	------	Lock site [at Gatun], Canal Zone, 10 to 50 feet (3 to 15 meters) below surface. Dan St. Clair, 1912(?). Not plotted.
159c	5662	------	Near Gatun Dam site, Canal Zone. D. F. MacDonald, 1911. Not plotted.
160	5846	------	Near spillway at Gatun Dam site, Canal Zone. D. F. MacDonald, 1911.
160a	8369	------	Chagres Dam spillway, station 5, Canal Zone. Just above contact with Caimito sandstone. A. A. Olsson, 1918. [At or near locality 160.] Not plotted.
			MIDDLE PART OF GATUN FORMATION, WESTERN AREA
161	8365	------	Railroad cuts west of Gatun Dam, station C, Canal Zone. A. A. Olsson, 1918. Location approximate.
161a	8395	------	Railroad cuts west of Gatun Dam, station D, Canal Zone. A. A. Olsson, 1918. [Near locality 161.] Not plotted.
161b	8375	------	Cuts west of Gatun Dam, station 4 plus 5, Canal Zone. A. A. Olsson, 1918. [Near locality 161.] Not plotted.
161c	8382	------	Railroad cuts west of Gatun Dam, station B, Canal Zone. A. A. Olsson, 1918. [Near locality 161.] Not plotted.
161d	8366	------	Cuts west of Gatun Dam, station 3a, Canal Zone. A. A. Olsson, 1918. [Near locality 161.] Not plotted.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			MIDDLE PART OF GATUN FORMATION, WESTERN AREA—continued
162	8396	------	Lower trail on west side of Río Chagres, a mile (1.6 kilometers) north [west-northwest] of Gatun Dam, Canal Zone. A. A. Olsson, 1918. Location approximate.
162a	8359	------	Lower trail on west side of Río Chagres northwest of Gatun Dam, Canal Zone. D. D. Condit and A. A. Olsson, 1918. [Probably near locality 162.] Not plotted.
163	8394	------	Trail on east side of Río Chagres, halfway between Gatun Dam and mouth of river, station 2, Canal Zone. A. A. Olsson, 1918. Location approximate. Represents upper part of formation.
164	8391	------	Bluff on west side of Gatun Lake, Canal Zone. D. D. Condit, 1918. Location indefinite; not plotted.
165	8372	------	Headwaters of Río Piña, station 14b, Canal Zone. Middle Gatun. A. A. Olsson, 1918. Location approximate.
166	8357	------	Piña triangulation station region, station 6c, Canal Zone. Base of upper Gatun. D. F. MacDonald and A. A. Olsson, 1918. Location approximate.
167	8374	------	Tick Creek, station 56B, Canal Zone. Top of middle Gatun, oyster bed. A. A. Olsson, 1918. Location approximate.
168	8361	------	Tick Creek, station 27, Canal Zone. Base of upper Gatun. A. A. Olsson, 1918. [Downstream from locality 167.] Not plotted.
169	8360	------	West of Gatun Lake, Tick Camp sheet, station 6c, Canal Zone. A. A. Olsson, 1918. [Probably near locality 167.] Location indefinite; not plotted.
170	8368	------	Headwaters of Quebrada Caña [Río Caño Quebrado], station 4a, Panamá. Base of upper Gatun. A. A. Olsson, 1918. Location approximate.
170a	8411	------	Headquarters of Quebrada Caña [Río Caño Quebrado], station 2 plus 50, Panamá. A. A. Olsson, 1918. Near locality 170. Not plotted.
			UPPER PART OF GATUN FORMATION, EASTERN AREA
171	--------	------	Stanford University locality 2707. Drainage ditch 500 feet (150 meters) west of French Canal, Canal Zone. Latitude 9°17′ N., plus 3,500 feet (1,065 meters), longitude 79°55′ W., plus 4,000 feet (1,220 meters). T. F. Thompson, 1943.
172	6035	------	Mindi Hill cut, near bottom of canal, Canal Zone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 544, pl. 154). A submerged locality.
173	--------	------	Stanford University locality 2654. Panama Railroad realignment [Third Locks realignment] cut about ¾ mile (1 kilometer) north of north end of Gatun Third Locks excavation, Canal Zone. Latitude 9°18′ N., longitude 79°55′ W., plus 200 feet (60 meters). T. F. Thompson, 1942.
173a	--------	48	[French Canal] 10.5 kilometers from Colón, Canal Zone. R. T. Hill, 1895. [According to Dall (Hill, 1898, p. 271), Hill's no. 48 represents Hill's Monkey Hill beds. The locality record probably should read 6 kilometers from Colón. See remarks under locality 158.] Not plotted.
174	2688 2690	29 49	Deviation [Diversion] cut south of Monkey Hill [Mount Hope], Canal Zone. R. T. Hill, 1895. Location approximate.
175	8410	------	Cuts on north [west] side of French Canal [East Diversion], Mount Hope, Canal Zone. A. A. Olsson, 1918. Location approximate.
176	8358	------	Road bordering French Canal [East Diversion], near Mount Hope, Canal Zone. A. A. Olsson, 1918. Location approximate.
176a	8409	------	Road on south [east] side of French Canal [East Diversion], Canal Zone. A. A. Olsson, 1918. [Probably near locality 176.] Not plotted.
177	--------	------	Monkey Hill [Mount Hope], near Gatun, Canal Zone. J. Rowell, 1857 and possibly later. [Some specimens have early Smithsonian Institution catalog numbers, but most have later U. S. National Museum numbers.]

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			UPPER PART OF GATUN FORMATION, EASTERN AREA—continued
177a	4895	------	Mount Hope, west side of Panama Railroad, Canal Zone. Ernest Howe, 1908. [Essentially same as locality 177.] Not plotted.
177b	5854	------	Mount Hope, west side of Panama Railroad near oil tanks, Canal Zone. D. F. MacDonald, 1911. [Essentially same as locality 177.] Not plotted.
177c	5855	------	[West side of Panama Railroad] opposite Mount Hope Cemetery, Canal Zone. D. F. MacDonald, 1911. [Essentially same as locality 177.] Not plotted.
177d	6036	------	Mount Hope, about ⅙ mile (270 meters) south of railroad station, Canal Zone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 544, pl. 154). [Essentially same as locality 177.] Not plotted.
178	--------	------	Stanford University locality 2672. Old quarry ¾ mile (1 kilometer) west-southwest of junction of Transisthmian Highway and Coco Solo road, Canal Zone. Latitude 9°20′ N., plus 2,000 feet (600 meters), longitude 79°53′ W., plus 4,000 feet (1,200 meters). T. F. Thompson, 1943.
			UPPER PART OF GATUN FORMATION, WESTERN AREA
179	8413	------	Upper edge of Chilas [Chila] village, Río Indios [Indio], Panamá. D. D. Condit and Strohm, 1918. Plotted on figure 3.
180	8362	------	Caribbean coast 8 miles (13 kilometers) west of Río Indios [Indio], Panamá. Strohm, 1918. Plotted on figure 3.
181	8364	------	Caribbean coast 10 miles (16 kilometers) west of Río Indios [Indio], Panamá. Strohm, 1918. Between locality 180 and Río Miguel. Not plotted.
182	8408	------	Caribbean coast east of San Miguel [Río Miguel], station 25 plus 600 feet (150 meters), Panamá. E. R. Smith, 1918. [Between locality 180 and Río Miguel.] Not plotted.
182a	8488	------	Caribbean coast east of San Miguel [Río Miguel], station 25 plus 400 feet (120 meters), Panamá. E. R. Smith, 1918. [Between locality 180 and Río Miguel.] Not plotted.
			UPPER PART OF GATUN FORMATION, WESTERN AREA—continued
183	8487	------	Caribbean coast east of Río San Miguel [Río Miguel], station 4 plus 40 feet (12 meters), Panamá. E. R. Smith, 1918. [Between locality 180 and Río Miguel.] Not plotted.
184	8363	------	Río San Miguel [Río Miguel] 4 miles (6.5 kilometers) above mouth, Panamá. Strohm, 1918. Plotted on figure 3.
185	8383	------	Caribbean coast, west of Río San Miguel [Río Miguel], station 26 plus 100 (30 meters), Panamá. E. R. Smith, 1918. Location approximate. Plotted on figure 3.
			TORO LIMESTONE MEMBER OF CHAGRES SANDSTONE
186	6037	------	Coquina limestone at Toro Point, Canal Zone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 545).
186a	6675	------	Coquina rock at Toro Point, Canal Zone. D. F. MacDonald, 1913. [Same as locality 186.] Not plotted.
186b	8440	------	Toro Point, Canal Zone. D. F. MacDonald and A. A. Olsson, 1918. [Same as locality 186.] Not plotted.
187	--------	------	Stanford University locality 2700. Between Limon Bay and Río Chagres, Canal Zone. Latitude 9°18′ N., plus 1,000 feet (300 meters), longitude 79°56′ W. T. F. Thompson, 1943.
188	16946	51	Río Piña road, 0.9 mile (1.4 kilometers) southwest of Gatun Dam spillway bridge, Canal Zone. Coquina limestone. T. F. Thompson and W. P. Woodring, 1947.
188a	5909	------	Limestone overlying Gatun formation west of Gatun Dam, Canal Zone. D. F. MacDonald, 1911. [Approximately same as locality 188.] Not plotted.
188b	6034	------	Top of ridge at west end of Gatun Dam, Canal Zone. D. F. MacDonald and T. W. Vaughan, 1911 (MacDonald, 1919, p. 543). [Approximately same as locality 188.] Not plotted.
188c	6668	------	Coquina limestone on crest of ridge west of Gatun Dam, Canal Zone. D. F. MacDonald, 1913. [Approximately same as locality 188.] Not plotted.

No. used in this report	USGS Cenozoic No.	Field No.	Description of locality
			TORO LIMESTONE MEMBER OF CHAGRES SANDSTONE—continued
188d	6236	------	Borrow pit west of Gatun Dam, Canal Zone. Limestone overlying Gatun formation. D. F. MacDonald, 1912. [Approximately same as locality 188.] Not plotted.
188e	8442	------	Hill southwest of Gatun locks, Canal Zone. A. A. Olsson, 1918. [Approximately same as locality 188.] Not plotted.
189	8392	------	Río Indio trail from Gatun to Chagres, Canal Zone. A. A. Olsson, 1918. Location approximate.
190	8402	------	Tick Creek, station 4H, Panamá(?). *Anomia* zone. A. A. Olsson, 1918. [Probably downstream from locality 167.] Not plotted.
191	8371	------	Headwaters of Río Piña, station 46, Canal Zone. *Anomia* zone. E. R. Lloyd and G. M. Bevier, 1918. Location approximate.
192	8404	------	Piña triangulation station region, station O, Canal Zone. *Anomia* zone. D. F. MacDonald and A. A. Olsson, 1918. Location approximate.
193	8401	------	200 feet (60 meters) below and 500 feet (150 meters) southeast of Ramos triangulation station, Canal Zone. *Anomia* zone. A. A. Olsson, 1918. Location approximate.
194	8373	------	Trail from Gatun Dam to Escobal, station 28, Canal Zone. *Anomia* zone limestone. G. M. Bevier and A. A. Olsson, 1918. Location indefinite; not plotted.
195	8403	------	Trail from Escobal to Lagarto, station 1, Panamá. *Anomia* zone. A. A. Olsson, 1918. [Possibly along Río Arriero.] Not plotted.
196	8405	------	Trail from Escobal to Lagarto, station 6, Panamá. *Anomia* zone limestone. A. A. Olsson, 1918. [Possibly along Río Arriero.] Not plotted.
			CHAGRES SANDSTONE PROPER
197	8482	------	Río Indio area, station 4, Canal Zone. A. A. Olsson, 1918. [This Río Indio is the minor tributary of Río Chagres west and northwest of Gatun Dam; unnamed on plate 1.] Location approximate.
198	8484	------	Piña region, station 33, Canal Zone. A. A. Olsson and G. M. Bevier, 1918. [Probably along Río Piña.] Not plotted.
			CHAGRES SANDSTONE PROPER—continued
199	8443	------	Piña region, station 34, Canal Zone. A. A. Olsson and G. M. Bevier, 1918. [Probably along Río Piña.] Not plotted.
200	8406	------	Headwaters of Quebrada Caña [Río Caño Quebrado], station 32 plus 100 feet (30 meters), Panamá. A. A. Olsson, 1918. Location approximate.
201	8439	------	Quebrada Caña [Río Caño Quebrado] region, station 2 plus 200 feet (60 meters), Panamá. A. A. Olsson, 1918. [Probably along Río Caño Quebrado or Río Arriero.] Not plotted.
202	8389	------	Trail from Escobal to Lagarto, station 2 plus 100 feet (30 meters). A. A. Olsson, 1918. [Probably along Río Caño Quebrado or Río Arriero.] Not plotted.
203	8436	------	Río Pavolina, a tributary of Río Lagarto, station 4, Panamá. A. A. Olsson, 1918. Location indefinite; not plotted.
204	8441	------	1.5 miles (2. 4 kilometers) east [northeast] of mouth of Río Chagres, 1,000 feet (300 meters) from ocean, Canal Zone. A. A. Olsson, 1918.
205	8387	------	Caribbean coast between Río Chagres and Piña, near Piña, Canal Zone. A. A. Olsson, 1918. Not plotted.
206	16937	52	Caribbean coast near mouth of Río Piña; road cut on west side of river about 90 meters west of road fork, Panamá. Massive fine-grained sandstone. T. F. Thompson and W. P. Woodring, 1947.
206a	--------	------	Stanford University locality 2699. Same locality. Latitude 9°16′ N., plus 4,200 feet (1,280 meters), longitude 80°3′ W. T. F. Thompson, 1943. Not plotted.
206b	16938	52a	Caribbean coast near mouth of Río Piña; road cut about 90 meters west of locality 206, Panamá. Massive fine-grained sandstone. T. F. Thompson and W. P. Woodring, 1947. Not plotted.
207	16969	------	Caribbean coast; road cut on south side of Río Lagarto about 230 meters south of Lagarto, Panamá. S. M. Jones, 1947.
208	8437	------	Caribbean coast at mouth of Río Indios [Indio], station 5, Panamá. A. A. Olsson, 1918. Plotted on figure 3.

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INDEX

[Italic numbers indicate descriptions]

A

Page

abbreviata, Marginulina cf. 17
abrupta, Turritella 48, *106–107*, pl. 23
robusta 106
trinitaria, Turritella 107
Acila cf. *A. isthmica* 40
Acknowledgments 4–5
Acropora saludensis 42
acuñai, Cubanaster 22
acutauricularis, Saracenaria 18
acuticostata, Lagena 17
adela, Turritella 24, *99*, 109, pl. 15
adelinensis, Uvigerina 19
Uvigerina cf. 27
advena, Siphonina 18
Virgulina cf. 19
Aepystoma *70*, 71
agglutinans, Phorus 77
agna, Tectonatica 48, *88–89*, pl. 17
alabamensis, Hantkenina 17, 19
Alabamina cf. *A. scitula* 26
Alabamina sp. 16
alazanensis, Anomalina cf. 16
Bolivina 16, 26
Bulimina 16, 26
Ceratobulimina 16
Dentalina 26
Gaudryina (Pseudogaudryina) 26
Plectofrondicularia 26
Robulus cf. 27
Vaginulinopsis 27
alcicornis, Millepora aff. 21
Allomorphina trigona 16
A-L-Owensi, Turritella plebeia 107
alowensi, Turritella plebeia 107
alternans, Pleurostomella 18, 27
altilira, Turritella 33, 37, 46, 47, 50, 101, 102–104, 105, 108
Turritella aff. 102
Turritella cf. 27, 33, 104
Turritella altilira 103
(Torcula) 31, 48, pl. 15
altilira 48, *102–104*, pl. 23
altilira, Turritella 103
(Torcula) 48, *102–104*, pl. 23
praecellens, Turritella 47, 103, 105
(Torcula) 48, *105*, pl. 23
urumacoensis, Turritella 102
altilira subsp., *Turritella* 102, 105
Turritella cf. *T. altilira praecellens* 105
(Torcula) *104–105*
altilirata, Turritella 102
altispira, "Crepitacella" 110
"Crepitacella" n. sp. indet. aff. 110
Alvania 76
"Alvania" aff. *"A." epulata* 48, *76*, 77
amaras, Turritella 101
(Torcula?) 37, *101–102*, pl. 16
Amaurellina? 95
Amaurellina garzaensis 95
Amaurellina? sp. 21, *95–96*, pl. 14
"Amauropsis" burnsii meridionalis 96, 97
aff. *"A." burnsii meridionalis* 97
floridana 97
jacksonensis 96, 97
trinitatensis 97
americana, "Orbitolites" 36, 121
Ammospirata mexicana 26
Ampulella *95*
Ampullina 95
Ampullinopsis spenceri 31
Anadara 39
Andesite 54
andreasi, Turritella 99
andrium, Teinostoma (Aepystoma) 48, *70–71*, pls. 17, 18
anebus, Solariorbis (Hapalorbis) hyptius 48, *75–76*, pl. 17
anguillana, Globularia 95
angulatum, Teinostoma 70
trochalum, Teinostoma (Idioraphe) 48, *70*, pl. 17
angulifera, Littorina 36, 70, 71
Littorina aff. 37, 38, *68*, pl. 16
Angulogerina sanjuanensis 16
Angulogerina sp. 16, 26
annectens, Encope 47
Annulicallus 72
annulifera, Siphonodosaria cf. 18
Anomalina cf. *A. alazanensis* 16
pacoraensis 16
Anomalina sp. 16
Anomalinoides sp. 16
anomalum, Teinostoma 69
Anticlimax *72*
Anticlimax s. s. *72*, 73
derbyi 72
hispaniolensis 73
schumoi 72
teleospira 73
tholus 73
willetti 73
(Anticlimax) gatunensis 48, *72*, pl. 18
(Subclimax) teleospira hystata 48, *73*, pl. 18
teleospira 48
Antiguan coral fauna 27–28
antillea, Heterostegina 27, 30, 33
Miogypsina 27
(Miogypsina) 30, 33
Antillia cf. *A. hadleyi* 21
aperta, Calyptraea 80
Calyptraea cf. 21, *80*
Aquitanian, age 38–39
araucana, Discorbis 26
Archaias compressus 27, 30
arenasensis, Karreriella 17
armiger, Schizaster 22
articulatus texanus, Robulus 27
asperum, Chrysalogonium 26
Chrysalogonium cf. 16
Astacolus nuttalli 26
Astacolus sp. 16, 26
Asterocyclina georgiana 20, 61
mariannensis 20
minima 20
asterodisca, Lepidocyclina (Lepidocyclina) 30
Astreopora n. sp. 21
Astrocoenia incrustans 21
atacta, Turritella 99, 108
atriformis, Hemisinus (Longiverena) n. sp., cf. 27
attenuata, Marginulina cf. 17
atwilli, Uvigerina 19
auricula, Crucibulum 82
aurora, Calliostoma 63
australis, Buccinum 65

B

Background, historical 2–3
Bactospira 98, 101
balkanicus, Velates 66
barbatus, Hipponix 78
Bas Obispo formation, age 32
stratigraphy and lithology 31–32
Basalt 54
Bathysiphon eocenica 16, 26
beaumonti, Natica (Stigmaulax) sulcata 88
Stigmaulax guppiana 88
berjadinensis cocoditana, Turritella 110
Turritella cf. 37, *110*
Bermúdez, P. J., quoted 19, 26–27
Bibliography, annotated 5–10
bierigi, Pleurostomella 27
bifastigata, Turritella 48, *111–112*, pl. 22
cartagenensis, Turritella 111
democraciana, Turritella 111
maracaibensis, Turritella 111
bipartita spirifera, Terebra 46
blountensis, Turritella 109
gatunensis 109
Bohio formation, description 24–25
fossiliferous localities 115–116
fossils and age 23–24, 26–28
marine member 22–24
stratigraphy and lithology 22–23, 25–26
structural history 57
bolivarensis, Neverita 91, 92
tapina, Neverita (Glossaulax) 24, *91–92*, pl. 15
bolivari, Episcynia 76
Bolivina alazanensis 16, 26
byramensis 16, 26
gracilis 16
cf. *B. gracilis* 16, 26
jacksonensis 16
cf. *B. jacksonensis* 16
maculata 16
cf. *B. maculata* 16
malkinae 16
plicatella mera 26
rhomboidalis 26
tectiformis 26
cf. *B. ventricosa* 16
Bolivina sp. 16, 26
bolus, Natica 84
(Natica?) 48, *84–85*, pl. 20
bondplandi, Natica 92
bosworthi, Turritella 98
boutakoffi, Polinices 89
bowersi, Clypeaster 50
Clypeaster aff. 50
brevis, "Phasianella (Eucosmia)" 66
briani, Calliostoma 63
broderipiana, Stigmaulax 87, 88
Turritella 110, 111, 112
brunnea, Polinices cf. 90
(Mammila) cf. 89
brunneus, Polinices 90, 91
subclausus, Polinices 48, *89–90*, pl. 20
Buccinum australis 65
tritonis 65
Bulimina alazanensis 16, 26
consanguinea 16
cf. *B. cooperensis* 16
guayabalensis 16
cf. *B. impendens* 16
jacksonensis 16, 19
cf. *B. jacksonensis cuneata* 16
palmerae 16
cf. *B. palmerae* 16
pupoides 16
cf. *B. pyrula* 16
tuxpamensis 16
Bulimina sp. 16
Buliminella sp. 16
bulloides, Pullenia cf. 18
burnsii, "Polinices (Amauropsis)" 97
buwaldana, Turritella 98, 99

Page

byramensis, Bolivina 16, 26
Guttulina 26

C

Caimito formation, exclusive of Madden basin and Pacific coastal area 28–31
fossiliferous localities 116–120
fossils and age 29–31
Madden Basin and Pacific coastal area 12, 32–34
stratigraphy and lithology 28–29, 32–33
structural history 57
caleta, Turritella 101
Turritella cf 24, 100–101, pl. 15
californicus, Velates 67
calliglyptum, Teinostoma (Climacia) 72
Calliostoma 62, 63
Calliostoma s. s 63
Calliostoma aurora 63
briani 63
distans 63
grabaui 64
mancinella 64
metalium 50
sayanum 64
Calliostoma? sp 50
Calliostoma (Calliostoma) metalium 63, pl. 18
(Leiotrochus) eremum 48, 63–64, pl. 22
Calliostomatinae 63
Callopoma 64
calypta, Tricolia 24, 65–66, pl. 15
Calyptraea 80
aperta 80
cf. C. aperta 21, 80
centralis 48, 80
cf. C. centralis 37, 80
centralis candeana 80
chinensis 80
"Calyptraea" diabloensis 81
Calyptraea mamillaris 80
"Calyptraea" martini 81
Calyptraea sp 24, 31, 80
Calyptraea? sp 31
Calyptraea (Trochatella) trochiformis 81
(Trochita) trochiformis 81
Calyptraeidae 79
canalizonalis, Natica 89
Polinices 48, 89, 91, pl. 20
cancellata, Rissoina 77
candeana, Calyptraea centralis 80
canellei, Lepidocyclina 27, 29, 30, 33, 36, 117
(Lepidocyclina) 30, 33
canrena, Natica 86, 87
(Naticarius) 48
caparonis, Turritella 102
Capulus? gatunensis 83
Capulus? sp 83
Cardium (Fragum) gatunense 23
carinata, Turritella 98
Turritella cf 21, 22, 98, pl. 14
carinatum, Teinostoma 70
Teinostoma cf 69, 70
carinicallus, Teinostoma 72
carmenensis, Pseudocrommium 96, 97
carolinianus, Polinices 89
caronensis, Turritella 108
gatunensis 109
caroniense, Teinostoma 71
cartagenensis, Turritella 111
bifastigata 111
cascadensis, Goniopora cf 30
Cassidulina crassa 16
havanensis 16
subglobosa 16, 26
Cassidulina sp 16
Cassidulinoides sp 16
castaneus, Turbo 64
Turbo aff 50
Turbo (Marmarostoma) aff 48, 64–65, pl. 20
(Senectus) cf 65
castrenoides, Natica 84
castrensis, Natica 84
cecinella, Teinostoma 70
centralis, Calyptraea 48, 80
Calyptraea cf 37, 80
Globorotalia 17, 19
Infundibulum 80
Ceratobulimina alazanensis 16
Cernina fluctuata 94
cerrosensis, "Circulus" 74
Chagres sandstone, description 12, 47
fossiliferous localities 129–130
fossils and age 50
stratigraphy and lithology 47, 50
structural history 57
chagresensis, Lagenoglandulina subovata 17
chilostoma, Karreriella 17
chaperi, Lepidocyclina 19, 20, 21, 61, 112
(Nephrolepidina) 20
charana, Turritella 106
Cheilea 79
equestris 80
princetonia 48, 79
Chilibrillo limestone 32
Chilostomella mexicana 16
cf. C. ovoidea 16
Chilostomella sp 16
Chilostomelloides oviformis 16
chinensis, Calyptraea 80
chipolana, Neritina 68
Neverita 92
chipolanum, Crucibulum 82
auricula 82
(Crucibulum) 82, pl. 19
chipolanum, Sinum 93
chirana, Nodosaria 17
Uvigerina 27
Uvigerina cf 19
Chrysalogonium asperum 26
cf. C. asperum 16
elongatum 16
Chrysalogonium sp 16, 26
chrysostomus, Turbo 64
Cibicides cocoanesis 16
cf. C. concentricus 16
cf. C. cookei 16
leoni 16
mexicanus 16, 26
perlucidus 16, 26
cf. C. perlucidus 16
cf. C. pseudoungerianus 16
Cibicides n. spp 16
Cibicides sp 16
Cibicides spp 26
ciperoensis, Globigerina 17, 26
"Circulus" cerrosensis 74
cosmius 74
liriope 75, 76
occidentalis 74
Circulus pentagona 73
"Circulus" pentagonus 73
trilix 74
clausa, Natica 88
Clavulinoides cubensis 16, 26
havanensis 16
Clavulinoides sp 16
Clementia dariena 46
clevei, Eupatagus 22
Climacia 72
Clypeaster bowersi 50
aff. C. bowersi 50
concavus 31
concavus? 42
gatuni 42, 47
lanceolatus 33, 37
cf. C. pinarensis 33
cocleana, Natica youngi 84
cocoaensis, Cibicides 16
Marginulinopsis 17
cocoditana, Turritella berjadinensis 110
Turritella cf. T. berjadinensis 37, 110
coensis, Polinices 91
Cole, W. S., quoted 20, 30, 33
colima, Natica 86
collazica, Turritella 98
Turritella cf 42, 98, pl. 16
collinsii, Trochita 80
Collonia radiata 72
Colpophyllia sp 21
communis, Dentalina cf 16
compressus, Archaias 27, 30
concavum, Sinum 94
concavus, Clypeaster 31
concavus?, Clypeaster 42
concentricus, Cibicides cf 16
conchyliophora, Xenophora 77, 78
conica, Pseudoglandulina 27
conradi, Turritella 108
consanguinea, Bulimina 16
cookei, Cibicides cf 16
Plectofrondicularia 18
cooperensis, Bulimina cf 16
Dentalina cf 16
Corals, from Caimito formation 30
from Culebra formation 36
from Gatuncillo formation 21
from Panamá formation 42
from Pleistocene series 50
Cornuspira olygogyra 16
cosmius, "Circulus" 74
costata, Montastrea 42
costellata, Trochita 81
crassa, Cassidulina 16
crassolamellata, Diploastrea n. sp., aff 21
Crassostrea 39
crenulatoides, Turbo 65
crenulatus, Turbo 64
castaneus 65
Crepidula 79
fornicata 79
gatunensis 79
maculosa 79
cf. C. maculosa 48, 79, pl. 19
nivea 79
nummaria 79
plana 48, 79, pl. 19
Crepidula sp 37, 42, 79
Crepidula? sp 27
Crepidulidae 79
"Crepitacella" altispira 110
n. sp. indet. aff. "C." altispira 110
Cretaceous rocks 52
Cretaceous system, stratigraphy 13
crispa, Xenophora 78
Crommium 97
Crucibulum 82, 83
Crucibulum s. s 82
Crucibulum auricula 82, 83
chipolanum 82
Crucibulum chipolanum 82
dodoneum 82
pectinatum 83
spinosum 82
Crucibulum? springvaleense 83
Crucibulum cf. C. springvaleense 84
Crucibulum sp 37, 50, 82
(Crucibulum) chipolanum 48, 82, pl. 19
(Dispotaea) gatunense 83
springvaleense 48, 83–84, pl. 19
Crypta fornicata 79
Cryptonatica 88
cryptospira, Teinostoma 70
cubae, Weisbordella 22
Cubanaster acuñai 22
cubensis, Clavulinoides 16, 26
Fabiania 20, 21, 23
Gümbelina 17, 26
Cucaracha formation, description 39
fossiliferous localities 123
fossils and age 39
mammal 39

Page

Cucaracha formation—Continued
stratigraphy and lithology 39
Culebra formation, description 34
fossiliferous localities 121–123
fossils and age 36–39
mammal 37–38
stratigraphy and lithology 34–36
cuneata, Bulimina jacksonensis cf 16
curta, Uvigerina 19
curvatura, Siphonodosaria aff 18
cushmani, Miogypsina 36, 122
Valvulineria 19
cuspidata, Neverita 92
Cyclammina cf. *C. deformis* 26
cf. *C. pacifica* 16
Cyclammina sp 16
Cyclostrema pentagona 73
quadrilineatum 73
Cyclostremiscus 73, 74
Cyclostremiscus s. s 73, 74
Cyclostremiscus glyptobasis 74
glyptomphalus 74
tricarinatus 74
(*Ponocyclus*) *pentagonus* 48, *73–75*, pl. 17
cylindrica, Dorothia 17

D

Dacite 53, 54
dalli, Loxostoma 17
Weisbordella 22
Dallitesta 91
danvillense, Nonion 18
danvillensis, Virgulina cf 19
dariena, Clementia 46
dariensis, Mactra (*Mactrella?*) 23
dartoni, Lepidocyclina (*Nephrolepidina*) 30
deformis, Cyclammina cf 26
delecta, Phorus 77
Xenophora 48, *77–78*, pl. 22
democraciana, Turritella bifastigata 111
Dentalina alazanensis 26
cf. *D. communis* 16
cf. *D. cooperensis* 16
cf. *D. mucronata* 16, 26
semilaevis 16, 26
Dentalina sp 16, 26
Dentalina spp 16
dentaliniformis, Siphonodosaria cf 18
depressa, Solariella n. sp., cf 27
derbyi, Anticlimax 72
diabloensis, "Calyptraea" 81
Diaerecallus *71–72*
dibollensis, Haplophragmoides cf 17
Virgulina cf 19, 27
dicampylus, Robulus cf 18
Dike rocks 54
Diorite 53–54
Diploastrea n. sp. aff. *D. crassolamellata* 21
Discorbis araucana 26
Discorbis sp 16
Dispotaea 83
distans, Calliostoma 63
dodoneum, Crucibulum chipolanum 82
dodonum, Pachycrommium 97
Sinum 93
Dorothia cylindrica 17
cf. *D. nuttalli* 17
Dorothia sp 17
douvillei, Porites cf 42

E

Echinoids, from Caimito formation 31
from Chagres sandstone 50
from Culebra formation 37
from Gatun formation 47
from Gatuncillo formation 22
from Panamá formation 42
Echinolampas semiorbis 37
elegans, Höglundina 17
elenae, Stigmaulax 87
Ellipsoglandulina labiata 17
multicostata 17
elongatum, Chrysalogonium 16
emaciata, Siphonodosaria verneuili 18
emendorferi, Hannatoma 68
Hannatoma? cf 21, 22, *68*, pl. 14
eminuloides, Polinices 90
Emperador limestone 34, 36, 59
Encope annectens 47
megatrema 47
platytata 47
Entosolenia cf. *E. laevigata* 17
cf. *E. marginata* 17
orbignyana 17
Entosolenia sp 17
eocanica, Hastigerinella 17
Eocene or Oligocene series 22–24
Eocene series 13–22
eocenica, Bathysiphon 16, 26
Episcynia *76*
bolivari 76
megalia 48, *76*, pl. 18
naso 76
nicholsoni 76
Eponides jacksonensis 17
cf. *E. rutteni* 17
umbonatus 17
multisepta 17, 26
epulata, "Alvania" aff 48, *76–77*
"Rissoa" 76
equestris, Cheilea 80
eremum, Calliostoma (*Leiotrochus*) 48, *63–64*
"Eucosmia" lurida 66
Eulepidina fauna 27–28
Eupatagus clevei 22
euryhedra, Sinum 48, *93–94*, pl. 21
Eurytorus 101
Euspirocrommium 97
eximia, Marginulina cf 17
exoleta, Turritella 101, 104

F

Fabiania cubensis 20, 21, 23
fasciata, Mesalia 68
Favia cf. *F. weisbordi* 21
favosa, Lepidocyclina (*Eulepidina*) 27
figulopicta, Neritina (*Puperita*) 68
finitima, Natica 84
fischeri, Globularia 94, 95
Globularia? cf 95
Globularia (*Globularia*) aff 27, 31, 37, *94–95*, pl. 15
flintensis, Pseudophragmina (*Proporocyclina*) 20
floridana, "Amauropsis" 97
Tectonatica 88
Xenophora delecta 78
floridanus, Velates 67
floridensis, Operculinoides 20
fluctuata, Cernina 94
fluctuatus, Turbo 64
fluctuosus, Turbo 64
Foraminifera, from Bohio formation 23, 26–27
from Caimito formation 29–30, 33
from Culebra formation 36
from Gatun formation 45
from Gatuncillo formation 15–21
from Panamá formation 41–42
fornicata, Crepidula 79
Crypta 79
Fossiliferous localities 45, 112–130
Fossils, descriptions 62–112
from Bohio formation 23–24, 26–28
from Caimito formation 29–31
from Culebra formation 36–39
from Gatun formation 45–47
from Gatuncillo formation 15–22
from Panamá formation 41–42
fredeai, Turritella 106
robusta 106
supraconcava 106
Frondicularia tenuissima 17

G

gabbi, Sigaretus (*Eunaticina*) 94
Sinum 48, *94*, pl. 21
Turritella 102
gabrielensis, Pseudocrommium 96
galvesia, Turritella 99
Gamboa area, Gatuncillo formation 15, 20
gardnerae nuttalliana, Uvigerina 19, 27
garzaensis, Amaurellina 95
gasparensis, Valvulineria 19
Gastropods 62
Gatun formation, description 42–47
fossiliferous localities 125–129
fossils and age 45–47
stratigraphy and lithology 43–45
structural history 57
Gatun Lake area, Bohio formation 25
Caimito formation 28
Gatun Lake district, oil possibilities 60–61
Gatuncillo formation, description 13–14
fossiliferous localities 112–114
fossils and age 15–22
stratigraphy and lithology 14–15
structural history 57
gatunense, Cardium (*Fragum*) 23
Crucibulum (*Dispotaea*) 83
Sinum 48, 93
gatunensis, Anticlimax (*Anticlimax*) 48, *72*, pl. 18
Capulus? 83
Crepidula 79
Turritella 47, 99, 100, 108–109, 110
gatunensis?, Turritella 33, 50
gatunensis, Turritella cf 108, 109
Turritella gatunensis 48, *108–109*, pl. 23
blountensis, Turritella 109
caronensis, Turritella 109
gatunensis, Turritella 48, *108–109*, pl. 23
lavelana, Turritella 108, 110
rhytodes, Turritella 48, *109–110*, pl. 23
taratarana, Turritella 110
"gatunensis" tarataranoides, "Turritella" 110
gatunensis willistoni, Turritella 110
gatuni, Clypeaster 42, 47
Gaudryina (*Pseudogaudryina*) *alazanensis* 26
cf. *G. jacksonensis* 17
Geographic names, orthography 4
georgiana, Asterocyclina 20, 61
gibba, Globulina cf 17
gigas, Lepidocyclina 27
girardana, Gyroidinoides 17
Gyroidinoides cf 26
giraudi, Lepidocyclina 27
Glandulina sp 17, 26
glauca, Natica 92
Neverita 92, 93
Polinices (*Neverita*) 92
Globigerina ciperoensis 17, 26
ouachitaensis 17, 26
Globigerina sp 17, 26
Globigerinoides mexicanus 17
Globigerinoides sp 17
Globobulimina hannai 17
cf. *G. hannai* 17
Globobulimina sp 17
Globorotalia centralis 17, 19
globosa, Triloculina cf 19
Globotruncana 13
Globularia 94, 95
Globularia s. s 94, 95
Globularia anguillana 95
fischeri 94, 95
Globularia? cf. *G. fischeri* 95
Globularia parisiensis 95
sigaretina 94
streptostoma 95
(*Ampulella?*) *nana* 24, *95*, pl. 15
(*Ampulella*) sp 24, *95*, pl. 15
(*Globularia*) aff. *G. fischeri* 27, 31, 37, *94–95*, pl. 15

Page

Globulariinae ... 94
Globulina cf. *G. gibba* ... 17
rotundata ... 17
Globulina sp ... 17
Glossaulax ... 91, 92
glyptobasis, Cyclostremiscus ... 74
glyptomphalus, Cyclostremiscus ... 74
Glyptostyla panamensis ... 23
Gold ... 58–59
Goniopora cf. *G. cascadensis* ... 30
aff. *G. taberi* ... 21
gothica, Turritella ... 111
grabaui, Calliostoma ... 64
gracilis, Bolivina ... 16
Bolivina cf ... 16, 26
gracillima, Siphonodosaria nuttalli ... 27
grateloupi, Nonion cf ... 26
"*Gratelupia?*" *mactropsis* ... 45
guayabalensis, Bulimina ... 16
Gyroidinoides ... 17
gubernacula, Lepidocyclina (*Pliolepidina*) ... 20
Gümbelina ... 13
cubensis ... 17, 26
martini ... 17
gunteri, Miogypsina ... 27
guppiana, Natica ... 86, 87
(*Stigmaulax*) ... 86
sulcata ... 86
Stigmaulax ... 47, 50, 86–88, pl. 20
guppyana, Natica ... 86
(*Naticarius*) ... 86
(*Stigmaulax*) ... 86
guppyi, Pachycrommium ... 96, 97
Pachycrommium aff ... 27
Pachycrommium? cf ... 37, 38, 97, pl. 16
Rissoina ... 77
Turritella ... 103
gurabensis, Natica sulcata ... 87
Guttulina byramensis ... 26
irregularis ... 17
Guttulina sp ... 26
Gyroidinoides girardana ... 17
cf. *G. girardana* ... 26
guayabalensis ... 17
soldanii octocamerata ... 17
Gyroidinoides sp ... 17

H

hadleyi, Antillia cf ... 21
hadra, Tricolia (*Eulithidium*) ... 66
hanleyana, Turritella (*Haustator*) aff ... 110
hannai, Globobulimina ... 17
Globobulimina cf ... 17
Hannatoma ... 68
Hannatoma? ... 68
Hannatoma emendorferi ... 68
Hannatoma? cf. *H. emendorferi* ... 21, 22, 68, pl. 14
hantkeni, Marginulina ... 17
Saracenaria cf ... 18
Hantkenina alabamensis ... 17, 19
suprasuturalis ... 17, 19
Hapalorbis ... 75, 76
Haplophragmoides cf. *H. dibollensis* ... 17
Hastigerinella eocanica ... 17
Hastigerinella sp ... 17
havanensis, Cassidulina ... 16
Clavulinoides ... 16
Nodogenerina cf ... 26
helicoides, Natica ... 92
Neverita ... 47, 93
(*Hypterita*) ... 48, 92–93, pl. 18
Polinices ... 92
Helicolepidina spiralis ... 20, 21
Helicostegina soldadensis ... 20, 21
Heliopora sp ... 21
Hemisinus (*Longiverena*) n. sp., cf. *H. atriformis* ... 27
heterosculpta, Nodogenerina ... 17
Heterostegina antillea ... 27, 30, 33
israelskyi ... 30
ocalana ... 20, 61
Heterostegina antillea—Continued
panamensis ... 30
hexagona, Lagena cf ... 17
hilli, Pitaria (*Lamelliconcha*) ... 23
Hipponicidae ... 78
Hipponicidae? ... 78
Hipponix ... 78
barbatus ... 78
pilosus ... 78
Hipponix sp ... 21, 78
Hipponix? sp ... 37, 78
hispaniolensis, Anticlimax ... 73
hockleyensis malkinae, Textularia ... 18
Höglundina elegans ... 17
homala, "*Pseudorotella*" ... 71
Homalopoma ... 66
subobsoletum ... 66
hybrida, Turritella ... 98
Hypterita ... 92, 93
hyptius, Solariorbis (*Hapalorbis*) *hyptius* ... 48, 75, pl. 17
anebus, Solariorbis (*Hapalorbis*) ... 48, 75–76, pl. 17
hyptius, Solariorbis (*Hapalorbis*) ... 48, 75, pl. 17
hystata, Anticlimax (*Subclimax*) *teleospira* ... 48, 73, pl. 18

I

Idioraphe ... 69, 70
Igneous rocks ... 52–57
impendens, Bulimina cf ... 16
imperatoris, Montastrea ... 42
Stylophora ... 42
imperfectum, Teinostoma ... 71
imperialis, Turritella ... 104
incrustans, Astrocoenia ... 21
inezana, Turritella ... 104
Infundibulum centralis ... 80
trochiforme ... 81
intermedia, Miogypsina ... 36, 122
Introduction ... 2–10
iotus, Robulus ... 27
iridea, "*Solariella*" ... 63
irregularis, Guttulina ... 17
israelskyi, Heterostegina ... 30
isthmica, Acila cf ... 40

J

jacksonensis, "*Amauropsis*" ... 96, 97
Bolivina ... 16
Bolivina cf ... 16
Bulimina ... 16, 19
cuneata, Bulimina cf ... 16
Eponides ... 17
Gaudryina (*Pseudogaudryina*) cf ... 17
Operculinoides ... 20, 23
jamaicensis, Yaberinella ... 20, 21, 22

K

Karreriella arenasensis ... 17
chilostoma ... 17
mexicana ... 17, 26
cf. *K. mexicana* ... 17
Karreriella sp ... 17
kugleri, Operculinoides ... 23

L

La Boca marine member, Panamá formation ... 40–41
labiata, Ellipsoglandulina ... 17
laevigata, Entosolenia cf ... 17
Pseudoglandulina ... 18
Pseudoglandulina cf ... 18
Lagena acuticostata ... 17
cf. *L. hexagona* ... 17
striata ... 26
Lagena sp ... 17
Lagenoglandulina subovata chagresensis ... 17
Lagenonodosaria cf. *L. sigmoidea* ... 17
Lagenonodosaria sp ... 17
lanceolatus, Clypeaster ... 33, 37
Las Cascadas agglomerate, age ... 32
stratigraphy and lithology ... 21–32
latifrons, Saracenaria cf ... 18
lavelana, Polinices subclausa ... 90
Turritella gatunensis ... 108, 110
Leiotrochus ... 63
lens, "*Pseudorotella*" ... 76
leoni, Cibicides ... 16
Lepidocyclina canellei ... 27, 29, 30, 33, 36, 117
chaperi ... 19, 20, 21, 61, 112
gigas ... 27
giraudi ... 27
macdonaldi ... 21, 61
miraflorensis ... 36, 41, 125
pancanalis ... 117
parvula ... 42
pustulosa ... 20, 21, 23
vaughani ... 27, 29, 30, 33, 116
waylandvaughani ... 27, 36
(*Eulepidina*) *favosa* ... 27
undosa ... 30
(*Lepidocyclina*) *asterodisca* ... 30
canellei ... 30, 33
montgomeriensis ... 20
parvula ... 27, 30, 33
waylandvaughani ... 27, 30
yurnagunensis ... 27, 30
morganopsis ... 27, 30
(*Nephrolepidina*) *chaperi* ... 20
dartoni ... 30
tournoueri ... 30
vaughani ... 27, 30, 33
(*Pliolepidina*) *gubernacula* ... 20
macdonaldi ... 20, 23
pustulosa ... 20, 23
pustulosa tobleri ... 20, 23
leucostoma, Turritella ... 111
limacina, Natica ... 86
Limestone, cement ... 59–60
limi, Polinices rapulum ... 90
limula, Neverita ... 91
liriope, "*Circulus*" ... 75, 76
Lirophora mactropsis ... 45, 46
Littoraria ... 69
Littorina ... 68
angulifera ... 36, 68, 69
aff. *L. angulifera* ... 37, 38, 68–69, pl. 16
Littorinidae ... 68
lloydsmithi, Turritella ... 110, 111
longiscata, Nodosaria ... 17, 26
lorenzana, Turritella variata ... 100
Loxostoma dalli ... 17
lubrica, "*Solariella*" ... 63
Lucina? ... 39
Lupia perovata ... 96
"*Lupia*" *perovata* ... 96, 97
lurida, "*Eucosmia*" ... 66

M

macdonaldi, Lepidocyclina ... 21, 61
(*Pliolepidina*) ... 20, 23
Stylophora ... 42
Mactra (*Mactrella?*) *dariensis* ... 23
mactropsis, "*Gratelupia?*" ... 45
Lirophora ... 45, 46
maculata, Bolivina ... 16
Bolivina cf ... 16
Quinqueloculina cf ... 27
maculatum, Sinum ... 94
maculosa, Crepidula ... 79
Crepidula cf ... 48, 80, pl. 19
Madden basin, Bohio formation ... 26
Caimito formation ... 32
Gatuncillo formation ... 14–15, 20
oil possibilities ... 61–62
structural description ... 58
malkinae, Bolivina ... 16
Textularia hockleyensis ... 18
mamillaris, Calyptraea ... 80

Page

Mammal, fossil 37–38, 39
mancinella, Calliostoma 64
Manganese 59
maracaibensis, Turritella bifastigata 111
'*Margarites*" 62
"*Margarites*" sp 48, *62–63*
Margaritinae 62
marginata, Entosolenia cf 17
marginatus, Velates balkanicus 66
Marginulina cf. *M. abbreviata* 17
cf. *M. attenuata* 17
cf. *M. eximia* 17
hantkeni 17
pseudohirsuta 26
similis 26
cf. *M. subcrassa* 17
cf. *M. triangularis panamensis* 17
Marginulina sp 17
Marginulinopsis cocoaensis 17
Marginulinopsis sp 17
marialana, Planulina 18, 26
mariana, Turritella 104
mariannensis, Asterocyclina 20
Marmarostoma *64*
undulata 64
undulatum 64
marmoratus, Turbo 64
martini, "*Calyptraea*" 81
Gümbelina 17
masinguiensis, Turritella 99
Matanzia? sp 17
matarucana, Turritella 48, *107–108*, pl. 22
megalia, Episcynia 48, *76*, pl. 18
megatrema, Encope 47
mera, Bolivina plicatella 26
meridionalis, "*Amauropsis*" *burnsii* 96, 97
aff. "*Amauropsis*" *burnsii* 97
meroensis, Turritella 31, *99–100*, 108, pl. 15
Mesalia fasciata 68
metalium, Calliostoma 50
(*Calliostoma*) *63*, pl. 18
metuloides, Phos 46
mexicana, Ammospirata 26
Chilostomella 16
Karreriella 17, 26
Karreriella cf 17
Osangularia 18, 26
Plectofrondicularia 26
Rotaliatina 18
mexicanus, Cibicides 16, 26
Globigerinoides 17
Vaginulinopsis 19
Vaginulinopsis cf 19
Millepora aff. *M. alcicornis* 21
millepunctata, Naticarius 85
millepunctatum, Teinostoma 71
milleri, Natica 84
mimetes, Turritella 48, *110–111*, 112, pl. 22
Turritella cf 110
mimetes?, Turritella 50
Mineral resources, metallic 58–59
nonmetallic 59–60
minima, Asterocyclina 20
Miocene series 34–47
Miogypsina antillea 27
cushmani 36, 122
gunteri 27
intermedia 36, 122
panamensis 42, 117
(*Miogypsina*) *antillea* 30, 33
(*Miolepidocyclina*) *panamensis* 30
miraflorensis, Lepidocyclina 36, 41, 125
mitchelli, Turritella 102
mixta, Turritella 101
Mollusks, from Bohio formation 23–24, 27–28
from Caimito formation 30–31, 33
from Chagres sandstone 50
from Culebra formation 36–37
from Gatun formation 45–47, 48–49
from Gatuncillo formation 21–22

413788—57——10

Page

Mollusks—Continued
from Panamá formation 42
from Pleistocene series 50
Tertiary, description 62–112
Montastrea costata 42
imperatoris 42
montgomeriensis, Lepidocyclina (*Lepidocyclina*) 20
montserratensis, Turritella 105
moodybranchensis, Operculinoides 20
morganopsis, Lepidocyclina (*Lepidocyclina*) *yurnagunensis* 27, 30, 33
morreyae, Plectofrondicularia 18
mucronata, Dentalina cf 16, 26
multicostata, Ellipsoglandulina 17
multilineata, Nodosaria 17, 26
multisepta, Eponides umbonatus 17, 26

N

Nacca 85
nana, Globularia (*Ampulella?*) 24, *95*, pl. 15
naranjoensis, Pleurostomella cf 27
naso, Episcynia 76
Natica *84*, 85
Natica s. s 84, 85
Natica s. s.? 84
Natica bolus 84
bonplandi 92
canalizonalis 89
canrena 86, 87
castrenoides 84
castrensis 84
clausa 88
colima 86
finitima 84
glauca 92
guppiana 86, 87
guppyana 86
helicoides 92
limacina 86
milleri 84
patula 92
permunda 85
"*Natica*" *phasianelloides* 97
Natica precanrena 86
"*Natica*" *pusilla* 88
Natica subclausa 89
sulcata gurabensis 87
tectula 88
unifasciata 84
vitellus 84
youngi 84
youngi cocleana 84
(*Natica?*) *bolus* 48, *84–85*, pl. 20
(*Natica?*) sp 24, 31, *84*
(*Naticarius*) *canrena* 48
guppyana 86
stenopa 48, *85–86*, 87, pl. 20
(*Naticarius*) sp 27
(*Naticarius?*) sp 31, 37, 85
(*Polinices*) cf. *youngi* 84
(*Stigmaulax*) *guppiana* 86
toulana 86, 87
guppyana 86
sulcata beaumonti 88
guppiana 86
Naticarius *85*, 86
millepunctata 85
Naticidae 84
Naticinae 84
nelsoni, Polinices 90
nereidis, Neverita 92, 93
Neritidae 66
Neritina 67
chipolana 68
virginea 67, 68
Neritina sp 27
Neritina (*Puperita*) *figulopicta* 68
(*Vitta?*) cf. *N. virginea* 48, *67–68*, pl. 21
(*Vitta?*) sp 37, *67*, 68

Page

Neritinae 66
Neverita *91*
bolivarensis 91, 92
tapina 91
chipolana 92
cuspidata 92
glauca 92, 93
helicoides 47, 93
limula 91
nereidis 92, 93
reclusiana 47, 91, 92
xena 91
secta 91
subporcana 92
subreclusiana 91, 92
Neverita? sp 21, 24, 31, 37, 42, 91
Neverita (*Glossaulax*) *bolivarensis tapina* 24, *91–92*, pl. 15
reclusiana xena 48, *92*, pl. 21
(*Hypterita*) *helicoides* 48, *92–93*, pl. 18
nicholsoni, Episcynia 76
nivea, Crepidula 79
Nodipecten 34
Nodogenerina cf. *N. havanensis* 26
heterosculpta 17
Nodogenerina sp 17, 26
Nodosaria chirana 17
longiscata 17, 26
multilineata 17, 26
obliqua 26
cf. *N. pyrula* 26
soluta 17
cf. *N. soluta* 26
Nodosaria sp 17, 26
noetlingi, Velates 67
nolani, Sinum 94
Nonion danvillense 18
cf. *N. grateloupi* 26
pompilioides 18, 26
cf. *N. pompilioides* 18
Nonion sp 18
noyesi, Sinum 93
nummaria, Crepidula 79
Nummulites striatoreticulatus 20, 21, 23
nuttalli, Astacolus 26
Dorothia cf 17
Plectina 18, 26
Siphonodosaria cf 18
gracillima, Siphonodosaria 27
nuttalliana, Uvigerina gardnerae 19, 27

O

obliqua, Nodosaria 26
ocalana, Heterostegina 20, 61
ocalanus, Operculinoides 20
occidentalis, "*Circulus*" 74
ocoyana, Turritella 105, 106, 107
octocamerata, Gyroidinoides soldanii 17
Oil possibilities, Gatun Lake district 60–61
Madden basin 61–62
Oligocene and Miocene series 32–34
Oligocene series 12, 24–32
olssoni, Turritella 101
olygogyra, Cornuspira 16
oncera, Rissoina (*Phosinella*) 48, *77*, pl. 23
Operculinoides floridensis 20
jacksonensis 20, 23
kugleri 23
moodybranchensis 20
ocalanus 20
panamensis 30, 117
trinitatensis 23
vaughani 20
orbignyana, Entosolenia 17
"*Orbitolites*" *americana* 36, 121
oreodoxa, Turritella 111
Orthomorphina cf. *O. rohri* 18
Osangularia mexicana 18, 26
Osangularia sp 18
Ostracodes from Gatun formation 47

Page

ouachitaensis, Globigerina 17, 26
ovata, Pseudoglandulina 18
oviformis, Chilostomelloides 16
ovoidea, Chilostomella cf. 16

P

Pachychilus 110
Pachycrommium 96, 97
Pachycrommium? 96, 97
Pachycrommium dodonum 97
guppyi 96, 97
aff. *P. guppyi* 27
Pachycrommium? cf. *P. guppyi* 37, 38, *97*, pl. 16
proinum 24, *96–97*, pl. 15
solenaeum 21, *96*, pl. 14
cf. *P. trinitatensis* 96, *97*
cf. *P.? trinitatensis* 31, 37, 96, *97*, pl. 16
Pachycrommium sp 96
Pachycrommium? sp 97
pachyheilus, Virgulina 19
Vulvulina 27
Pacific coastal area, Bohio formation 26
Caimito formation 33
pacifica, Cyclammina cf 16
pacoraensis, Anomalina 16
Palenquilla Point, marine member of Bohio formation 23
palmerae, Bulimina 16
palmerae, Bulimina cf 16
Pleurostomella cf 18
Panamá formation, description 39–40
fossiliferous localities 123–125
fossils and age 41–42
stratigraphy and lithology 40–41
panamensis, Glyptostyla 23
Heterostegina 30
Marginulina triangularis cf 17
Miogypsina 42, 117
(Miolepidocyclina) 30
Operculinoides 30, 117
Schizaster 47
pancanalis, Lepidocyclina 117
parisiensis, Globularia 95
parvicallum, Teinostoma 71
parvula, Lepidocyclina 42
(Lepidocyclina) 27, 30, 33
patula, Natica 92
paucistriata, Siphonodosaria 18
Pecten scissuratus 46
pectinatum, Crucibulum 83
Pedro Miguel agglomerate member, Panamá formation 40–41
pentagona, Circulus 73
Cyclostrema 73
Vitrinella 73
pentagonus, "Circulus" 73
Cyclostremiscus (Ponocyclus) 48, *73–75*, pl. 17
perattenuata, Turritella 101, 105
praecellens, Turritella 105
Turritella aff 104, 105
perlucidus, Cibicides 16, 26
Cibicides cf 16
permunda, Natica 85
perornatus, Systellomphalus 75
perovata, Lupia 96
"Lupia" 96, 97
perspectivum, Sinum 93
perversus, Velates 22, 66, 67
perversus subsp.?, *Velates* 21, *66–67*, pl. 14
petrosa, Schenckiella cf 18
Phasianella 65
variegata 65
'Phasianella (Eucosmia)" brevis 66
Phasianellidae *65*
Phasianellidae? 66
phasianelloides, "Natica" 97
Phorus agglutinans 77
delecta 77
Phos metuloides 46
Phosinella 77
pilosus, Hipponix 78
pinarensis, Clypeaster cf 33
Pitaria (Lamelliconcha) hilli 23
plana, Crepidula 48, *79*, pl. 19
planigyrata, Turritella 111
Planularia sp 18, 26
Planulina marialana 18, 26
suturata 18
cf. *P. wuellerstorfi* 26
planulis, Spiroplectammina 18
platytata, Encope 47
plebeia, Turritella 108
A-L-Owensi, Turritella 107
alowensi, Turritella 107
Plectina nuttalli 18, 26
Plectofrondicularia alazanensis 26
cookei 18
mexicana 26
morreyae 18
vaughani 18, 26
Plectofrondicularia sp 18
Pleistocene series, fossils and age 50
stratigraphy and lithology 50
Pleurostomella alternans 18, 27
bierigi 27
cf. *P. naranioensis* 27
cf. *P. palmerae* 18
cf. *P. praegerontica* 18
Pleurostomella sp 18
plicatella mera, Bolivina 26
Pliocene series 47, 50
Polinices 89, 91
boutakoffi 89
cf. *P. brunnea* 90
brunnea subclausa 89
brunneus 90, 91
subclausus 48, *89–90*, pl. 20
canalizonalis 48, *89*, 91, pl. 20
carolinianus 89
coensis 91
eminuloides 90
helicoides 92
nelsoni 90
porcellanus 89
rapulum limi 90
robustus 91
springvalensis 90
stanislas-meunieri 48, *90–91*, pl. 21
venezuelana 90
subclausa 89
subclausa lavelana 90
uber 90
Polinices sp 27, 31
Polinices? sp 21, 24, 37, 89
"Polinices (Amauropsis)" burnsii 97
Polinices (Mammilla) cf. *brunnea* 89
(Neverita) glauca 92
Polinicinae 89
politum, Teinostoma 69
pompilioides, Nonion 18, 26
Nonion cf 18
Ponocyclus *73*, 74
porcellanus, Polinices 89
Porites cf. *P. douvillei* 42
(Synaraea) n. sp 21
praecellens, Turritella altilira 47, 103, 105
altilira subsp. cf 105
perattenuata 105
perattenuata aff 104, 105
(Torcula) altilira 48, *105*, pl. 23
praegerontica, Pleurostomella cf 18
precanrena, Natica 86
precursor, Tricolia 65–66
princetonia, Cheilea 48, 79
proinum, Pachycrommium? 24, *96–97*, pl. 15
Pseudocrommium 97
carmenensis 96, 97
grabrielensis 96
Pseudoglandulina conica 27
laevigata 18
cf. *P. laevigata* 18
ovata 18
radicula 18
cf. *P. radicula* 18
Pseudoglandulina sp 18, 27
pseudohirsuta, Marginulina 26
pseudoinornata, Pyrgo 18
Pseudophragmina (Proporocyclina) flintensis 20
Pseudodorotella 70, *71*
"Pseudorotella" homala 71
lens 76
Pseudorotella pycna 71
pseudoungerianus, Cibicides cf 16
Pullenia cf. *P. bulloides* 18
cf. *P. quinqueloba* 27
Pullenia sp 18
puntensis, Siphonodosaria 18
pupoides, Bulimina 16
Purpose of report 3–4
pusilla, "Natica" 88
Tectonatica 89
pustulosa, Lepidocyclina 20, 21, 23
(Pliolepidina) 20, 23
tobleri, Lepidocyclina (Pliolepidina) 20, 23
pycna, Pseudorotella 71
pycnum, Teinostoma (Pseudorotella) 48, *71*, pl. 17
Pyrgo pseudoinornata 18
Pyrgo sp 18
pyrula, Bulimina cf 16
Nodosaria cf 26

Q

quadrilineatum, Cyclostrema 73
Quartz diorite 53
Quebrancha syncline, Bohio formation 25
Caimito formation 29
description 58
Gatuncillo formation 14, 20
quinqueloba, Pullenia cf 27
Quinqueloculina cf. *Q. maculata* 27
Quinqueloculina sp 18
quirosana, Turritella venezuelana 106
quirosanum, Sinum 94

R

radians, Trochita 81
Trochus 81, 82
radiata, Collonia 72
Teinostoma (Climacia) 72
radicula, Pseudoglandulina 18
Pseudoglandulina cf 18
reclusiana, Neverita 47, 91, 92
xena, Neverita (Glossaulax) 48, *92*, pl. 21
recta, Siphonodosaria 18
Textularia cf 18
References cited 131–135
Renz, H. H., quoted 19, 26–27
rhomboidalis, Bolivina 26
rhytodes, Turritella gatunensis 48, *109–110*, pl. 23
Río Aqua Salud area, Gatuncillo formation 14, 20
Río Agua Sucia area, Gatuncillo formation 14, 20
Río Casaya area, Gatuncillo formation 15
Río Chagres area, Caimito formation 29
Río Frijol area, Gatuncillo formation 15, 20
Río Mandinga area, Caimito formation 29
"Rissoa" epulata 76
Rissoidae 76
Rissoina 77
cancellata 77
guppyi 77
(Phosinella) oncera 48, 77, pl. 23
(Zebinella?) sp 37, 77
Rissoinae 76
Rissoinidae 77
Robulus cf. *R. alazanensis* 27
articulatus texanus 27
cf. *R. dicampylus* 18

Page

Robulus cf. *R. alazanensis*—Continued
iotus 27
terryi 18
Robulus sp 27
Robulus spp 18
robusta, Turritella 106
(Haustator) 106
Xenophora 78
abrupta, Turritella 106
fredeai, Turritella 106
robustus, Polinices 91
rohri, Orthomorphina cf 18
Rotaliatina mexicana 18
rotundata, Globulina 17
rutteni, Eponides cf 17

S

sagraiana, Tectonatica 89
saltoensis, Turritella 100
saludensis, Acropora 42
samanensis, Turritella 99
Turritella cf 21, 98
sandomingense, Teinostoma 70
sanjuanensis, Angulogerina 16
sapotensis, Turritella 102
Saracenaria acutauricularis 18
cf. *S. hantkeni* 18
cf. *S. latifrons* 18
cf. *S. schencki* 18
saxosus, Turbo 64
sayanum, Calliostoma 64
schencki, Saracenaria cf 18
Schenckiella cf. *S. petrosa* 18
Schenckiella sp 18, 27
Schizaster armiger 22
panamensis 47
schmideliana, Velates 66
schumoi, Anticlimax 72
scissuratus, Pecten 46
scitula, Alabamina cf 26
Scope of report 2–3
secta, Neverita 91
semilaevis, Dentalina 16, 26
seminuda, "Vitrinella" 76
semiorbis, Echinolampas 37
Senectus 64
senegalensis, Xenophora 78
sigaretina, Globularia 94
Sigaretus (Eunaticina) gabbi 94
sigmoidea, Lagenonodosaria cf 17
Sigmoilina tenuis 18
Sigmomorphina cf. *S. trinitatensis* 27
Sigmomorphia sp 18
similis, Marginulina 26
Sininae 93
Sinum *93*
chipolanum 93
concavum 94
dodonum 93
euryhedra 48, *93–94*, pl. 21
gabbi 48, *94*, pl. 21
gatunense 48, 93
maculatum 94
nolani 94
noyesi 93
perspectivum 93
quirosanum 94
Sinum sp 21, 24, 27, 31, 37, 93, 94
Siphogenerina transversa 36, 41, 124
Siphogenerina sp 18
Siphonina advena 18
tenuicarinata 18, 27
Siphonodosaria cf. *S. annulifera* 18
aff. *S. curvatura* 18
cf. *S. dentaliniformis* 18
cf. *S. nuttalli* 18
nuttalli gracillima 27
paucistriata 18
puntensis 18
recta 18

Siphonodosaria cf. *S. annulifera*—Continued
aff. *S. subspinosa* 18
verneuili 18
emaciata 18
Siphonodosaria sp 18, 27
Siphotextularia sp 18
Solariella 63
Solariella n. sp., cf. *S. depressa* 27
"Solariella" iridea 63
lubrica 63
Solariella? sp 31
Solariorbis 75
Solariorbis s. s *75*
Solariorbis (Hapalorbis) hyptius anebus 48, *75–76*, pl. 17
hyptius 48, *75*, 76, pl. 17
(Solariorbis) strongylus 48, *75*, pl. 17
soldadensis, Helicostegina 20, 21
soldanii octocamerata, Gyroidinoides 17
solenaeum, Pachycrommium? 21, *96*, pl. 14
soluta, Nodosaria 17
Nodosaria cf 26
spenceri, Ampullinopsis 31
spermatia, Teinostoma 46
(Idioraphe) 48, *69–70*, pl. 17
spinicostata, Uvigerina 19, 27
spinosum, Crucibulum 82
spinulosa, Uvigerina 19
Uvigerina cf 19
spiralis, Helicolepidina 20, 21
spirifera, Terebra bipartita 46
Spiroloculina texana 27
cf. *S. texana* 18
Spiroloculina sp 18
Spiroplectammina planulis 18
springvaleense, Crucibulum? 83
Crucibulum cf 84
Crucibulum (Dispotaea) 48, *83–84*, pl. 19
springvalensis, Polinices 90
stanislas-meunieri, Polinices 48, *90–91*, pl. 21
stemonium, Teinostoma (Pseudorotella) 48, *71*, pl. 17
stenopa, Natica (Naticarius) 48, *85–86*, 87, pl. 20
Stigmaulax *86*, 87, 88
broderipiana 87, 88
guppiana 47, 51, *86–88*, pl. 20
beaumonti 88
elenae 87
sulcata 87
vererugosum 87
Stirton, R. A., quoted 37
Stratigraphic section, basal part of Gatuncillo formation 15
marine member of Bohio formation 23
middle part of Gatun formation 44
upper part of Culebra formation 35
Stratigraphy, outline 10–13
streptostoma, Globularia 95
striata, Lagena 26
striatoreticulatus, Nummulites 20, 21, 23
strongylus, Solariorbis (Solariorbis) 48, *75*, pl. 17
Structural features 58
Structural history 57–58
Stylophora imperatoris 42
macdonaldi 42
Suavotrochus 63
subannulata, Turritella 110
subclausa, Natica 89
Polinices 89
brunnea 89
brunneus 48, *89–90*, pl. 20
Subclimax *73*
subcrassa, Marginulina cf 17
subglobosa, Cassidulina 16, 26
subgrundifera, Turritella 105–106
Turritella cf 37, 38, *105–106*, pl. 16
subobsoletum, Homalopoma 67
subovata chagresensis, Lagenoglandulina 17
subporcana, Neverita 92
subreclusiana, Neverita 91, 92
subrotundata, Triloculina cf 19

subspinosa, Siphonodosaria aff 18
sulcata, Stigmaulax 87
supraconcava, Turritella 106
fredei, Turritella 106
suprasuturalis, Hantkenina 17, 19
suturata, Planulina 18
sychnum, Teinostoma (Diaerecallus) 48, *72*, pl. 17
syntoma, Tricolia? 48, *66*, pl. 17
Systellomphalus 75
peronatus 75

T

taberi, Goniopora aff 21
tapina, Neverita bolivarensis 91
(Glossaulax) bolivarensis 24, *91–92*, pl. 15
taratarana, Turritella gatunensis 110
tarataranoides, "Turritella gatunensis" 110
tectiformis, Bolivina 26
tectispira, Teinostoma 70
Tectonatica *88*, 89
agna 48, *88–89*, pl. 17
floridana 88
pusilla 89
sagraiana 89
Tectonatica sp 24, *88*
tectula, Natica 88
Teinostoma *69*, 73
Teinostoma s. s 69
Teinostoma angulatum 70
anomalum 69
carinatum 70
cf. *carinatum* 69, 70
carinicallus 72
caroniense 71
cecinella 70
cryptospira 70
imperfectum 71
millepunctatum 71
parvicallum 71
politum 69
ultimum 69
sandomingense 70
spermatia 46
tectispira 70
umbilicatum 70
vitreum 71
(Aepystoma) andrium 48, *70–71*, pls. 17, 18
(Climacia) calliglyptum 72
radiata 72
(Diaerecallus) sychnum 48, *72*, pl. 17
(Idioraphe) angulatum trochalum 48, *70*, pl. 17
spermatia 48, *69–70*, pl. 17
(Pseudorotella) pycnum 48, *71*, pl. 17
stemonium 48, *71*, pl. 17
teleospira, Anticlimax 73
(Subclimax) teleospira 48
hystata, Anticlimax (Subclimax) 48, *73*, pl. 18
teleospira, Anticlimax (Subclimax) 48
Tellina? 39
tenuicarinata, Siphonina 18, 27
tenuis, Sigmoilina 18
tenuissima, Frondicularia 17
Terebra bipartita spirifera 46
terebralis, Turritella 107
Teredo 35
terryi, Robulus 18
Tertiary formations, correlation 50–52
locations 11, 12
texana, Spiroloculina 27
Spiroloculina cf 18
texanus, Robulus articulatus 27
textilina, Xenophora 78
Textularia hockleyensis malkinae 18
cf. *T. recta* 18
Textularia? sp 18
Textulariella sp 19
Thiaridae? 68
tholus, Anticlimax 73
tobleri, Lepidocyclina (Pliolepidina) pustulosa 20, 23

Page

Torcula 99, *101*
tornata, Turritella 103
Toro limestone member of Chagres sandstone 47, 50
toulana, Natica (Stigmaulax) guppiana 86, 87
tourouëri, Lepidocyclina (Nephrolepidina) 30
transversa, Siphogenerina 36, 41, 124
triangularis panamensis, Marginulina cf 17
tricarinatus, Cyclostremiscus 74
Tricolia *65*, 66
calypta 24, *65–66*, pl. 15
precursor 65–66
Tricolia? syntoma 48, *66*, pl. 17
Tricolia (Eulithidium) hadra 66
Tricoliidae 65
trigona, Allomorphina 16
trilix, "Circulus" 74
Triloculina cf. *T. globosa* 19
cf. *T. subrotundata* 19
Triloculina sp 19
Trinidad Island, marine member of Bohio formation 23
trinitaria, Turritella 107
abrupta 107
trinitatensis, "Amauropsis" 97
Operculinoides 23
Pachycrommium? cf 31, 37, 96, *97*, pl. 16
Sigmomorphina cf 27
tristis, Turritella 100, 108
tritonis, Buccinum 65
trochalum, Teinostoma (Idioraphe) angulatum 48, *70*
Trochatella trochiformis 81
Trochidae *62*
trochiforme, Infundibulum 81
trochiformis, Calyptraea (Trochatella) 81
(Trochita) 81
Trochatella 81
Trochita 47, 48, *81–82*, pl. 19
Trochita cf 31, 82
Trochita? cf 37, 82
Turbo 81, 82
Xenophora aff 77
Trochita *80–81*
collinsii 80
costellata 81
radians 81
trochiformis 47, 48, *81–82*, pl. 19
cf. *T. trochiformis* 31, 82
Trochita? cf. *T. trochiformis* 37, 82
Trochita sp. indet 80
Trochita? sp 81, 82
Trochus radians 81, 82
Turbinidae 64
Turbo 64, 65
castaneus 64
aff. *T. castaneus* 51
castaneus crenulatus 65
chrysostomus 64
crenulatoides 65
crenulatus 64
fluctuatus 64
fluctuosus 64
marmoratus 64
saxosus 64
trochiformis 81, 82
(Marmarostoma) aff. *T. castaneus* 48, *64–65*, pl. 20
(Senectus) cf. *castaneus* 65
Turbo (Senectus) sp 65
Turritella *97–98*
abrupta 48, *106–107*, pl. 23
trinitaria 107
adela 24, *99*, 109, pl. 15
altilira 33, 37, 46, 47, 50, 101, 102–104, 105, 108
aff. *T. altilira* 102
cf. *T. altilira* 27, 33, 104
altilira altilira 103
praecellens 47, 103, 105
urumacoensis 102
altilira subsp 102, 105
Turritella—Continued
altilira subsp., cf. *T. altilira praecellens* 105
altilirata 102
amaras 101
andreasi 99
atacta 99, 108
berjadinensis cocoditana 110
cf. *T. berjadinensis cocoditana* 37, *110*
bifastigata 48, *111–112*, pl. 22
cartagenensis 111
democraciana 111
maracaibensis 111
blountensis 109
bosworthi 98
broderipiana 110, 111, 112
buwaldana 98, 99
caleta 101
cf. *T. caleta* 24, *100–101*, pl. 15
caparonis 102
carinata 98
cf. *T. carinata* 21, 22, *98*, pl. 14
caronensis 108
cartagenensis 111
charana 106
collazica 98
cf. *T. collazica* 42, *98*, pl. 16
conradi 108
exoleta 101, 104
fredeai 106
gabbi 102
galvesia 99
gatunensis 47, 99, 100, 108–109, 110
gatunensis? 33, 50
cf. *T. gatunensis* 108, 109
gatunensis blountensis 109
caronensis 109
gatunensis 48, *108–109*, pl. 23
lavelana 108, 110
rhytodes 48, *109–110*, pl. 23
tatarana 110
"Turritella gatunensis" tataranoides 110
Turritella gatunensis willistoni 110
gothica 111
guppyi 103
hybrida 98
imperialis 104
inezana 104
leucostoma 111
lloydsmithi 110, 111
mariana 104
masinguiensis 99
matarucana 48, *107–108*, pl. 22
meroensis 31, *99–100*, 108, pl. 15
mimetes 48, *110–111*, 112, pl. 22
mimetes? 51
cf. *T. mimetes* 110
mitchelli 102
mixta 101
montserratensis 105
ocoyana 105, 106, 107
olssoni 101
oreodoxa 111
perattenuata 101, 105
praecellens 105
aff. *T. perattenuata praecellens* 104, 105
planigyrata 111
plebeia 108
A-L-Owensi 107
alowensi 107
robusta 106
abrupta 106
fredeai 106
saltoensis 100
samanensis 99
cf. *T. samanensis* 21, 98
sapotensis 102
subannulata 110
subgrundifera 105–106
cf. *T. subgrundifera* 37, 38, *105–106*, pl. 16
Turritella—Continued
supraconcava 106
fredeai 106
terebralis 107
tornata 103
trinitaria 107
tristis 100, 108
uvasana 99, 100
variata lorenzana 100
variegata 111
venezuelana 37, *106*, pl. 16
n. sp., aff. *T. venezuelana* 27
venezuelana quirosana 106
watkinsi 106
vientoensis 100
Turritella sp 21, 31, 37, 98, *99*
(Haustator) aff. *T. hanleyana* 110
robusta 106
(Torcula) altilira 31, 48, pl. 15
altilira 48, *102–104*, pl. 23
praecellens 48, *105*, pl. 23
altilira subsp *104–105*
(Torcula?) amaras 37, *101–102*, pl. 16
Turritellidae 97
tuxpamensis, Bulimina 16

U

uber, Polinices 90
ultimum, Teinostoma politum 69
umbilicatum, Teinostoma 70
umbonatus, Eponides 17
multisepta, Eponides 17, 26
undosa, Lepidocyclina (Eulepidina) 30
undulata, Marmarostoma 64
undulatum, Marmarostoma 64
unifasciata, Natica 84
urumacoensis, Turritella altilira 102
uvasana, Turritella 99, 100
Uvigerina adelinensis 19
cf. *U. adelinensis* 27
cf. *U. atwilli* 19
chirana 27
cf. *U. chirana* 19
curta 19
gardnerae nuttalliana 19, 27
spinicostata 19, 27
spinulosa 19
cf. *U. spinulosa* 19
Uvigerina sp 19, 27

V

Vaginulina sp 27
Vaginulinopsis alazanensis 27
mexicanus 19
cf. *V. mexicanus* 19
Vaginulinopsis sp 19
Valvulineria cushmani 19
gasparensis 19
Vamos Vamos, marine member of Bohio formation 22
variegata, Phasianella 65
Turritella 111
vaughani, Lepidocyclina 27, 29, 30, 33, 116
(Nephrolepidina) 27, 30, 33
Operculinoides 20
Plectofrondicularia 18, 26
Velates 66, 67
balkanicus 66
marginatus 66
californicus 67
floridanus 67
noetlingi 67
perversus 22, 66, 67
perversus subsp.? 21, *66–67*, pl. 14
schmideliana 66
vokesi 67
venezuelana, Polinices stanislas-meunieri 90
Turritella 37, *106*, pl. 16
Turritella n. sp., aff 27

Page

venezuelana—Continued
quirosana, Turritella ---- 106
watkinsi, Turritella ---- 106
ventricosa, Bolivina cf ---- 16
vererugosum, Stigmaulax ---- 87
verneuili, Siphonodosaria ---- 18
verneuili emaciata, Siphonodosaria ---- 18
vientoensis, Turritella ---- 100
virginea, Neritina ---- 67, 68
(*Vitta?*) cf ---- 48, *67–68*, pl. 21
Virgulina cf. *V. advena* ---- 19
cf. *V. danvillensis* ---- 19
cf. *V. dibollensis* ---- 19, 27
pachyheilus ---- 19
Virgulina sp ---- 19
vitellus, Natica ---- 84
vitreum, Teinostoma ---- 71
Vitrinella pentagona ---- 73
"*Vitrinella*" *seminuda* ---- 76
Vitrinellidae ---- 69
Vitta ---- *67*
vokesi, Velates ---- 67

Page

Volcanic and intrusive rocks, Cretaceous ---- 52–53
Tertiary, age ---- 56–57
chemical composition ---- 55
dike rocks ---- 54
granular intrusive rocks ---- 53–54
tuff ---- 13, 54
Vulvulina pachyheilus ---- 27

W

watkinsi, Turritella venezuelana ---- 106
waylandvaughani, Lepidocyclina ---- 27, 36
(*Lepidocyclina*) ---- 27, 30
Weisbordella cubae ---- 22
dalli ---- 22
weisbordi, Favia cf ---- 21
Wells, J. W., quoted ---- 21, 42
willetti, Anticlimax ---- 73
willistoni, Turritella gatunensis ---- 110
wuellerstorfi, Planulina cf ---- 26

X

xena, Neverita reclusiana ---- 91
(*Glossaulax*) *reclusiana* ---- 48, *92*, pl. 21

Page

Xenophora ---- 77, 78
conchyliophora ---- 77, 78
crispa ---- 78
delecta ---- 48, *77–78*, pl. 22
floridana ---- 78
robusta ---- 78
senegalensis ---- 78
textilina ---- 78
aff. *trochiformis* ---- 77
Xenophora sp ---- 21, 37
Xenophoridae ---- 77

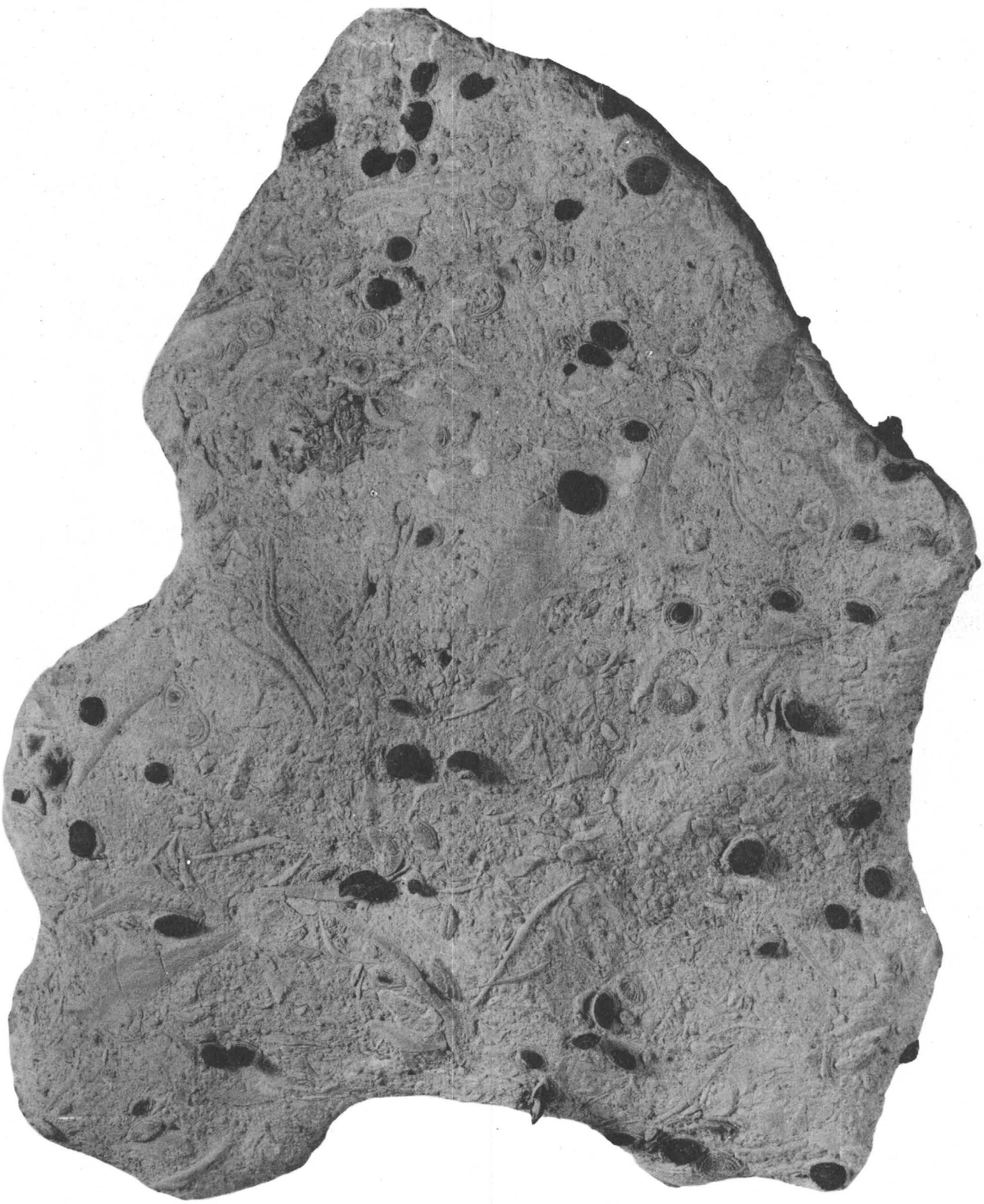
Y

Yaberinella jamaicensis ---- 20, 21, 22
youngi, Natica ---- 84
youngi, Natica (*Polinices*) cf ---- 84
yurnagunensis, Lepidocyclina (*Lepidocyclina*) ---- 27, 30
morganopsis, Lepidocyclina (*Lepidocyclina*) 27, 30, 33

Z

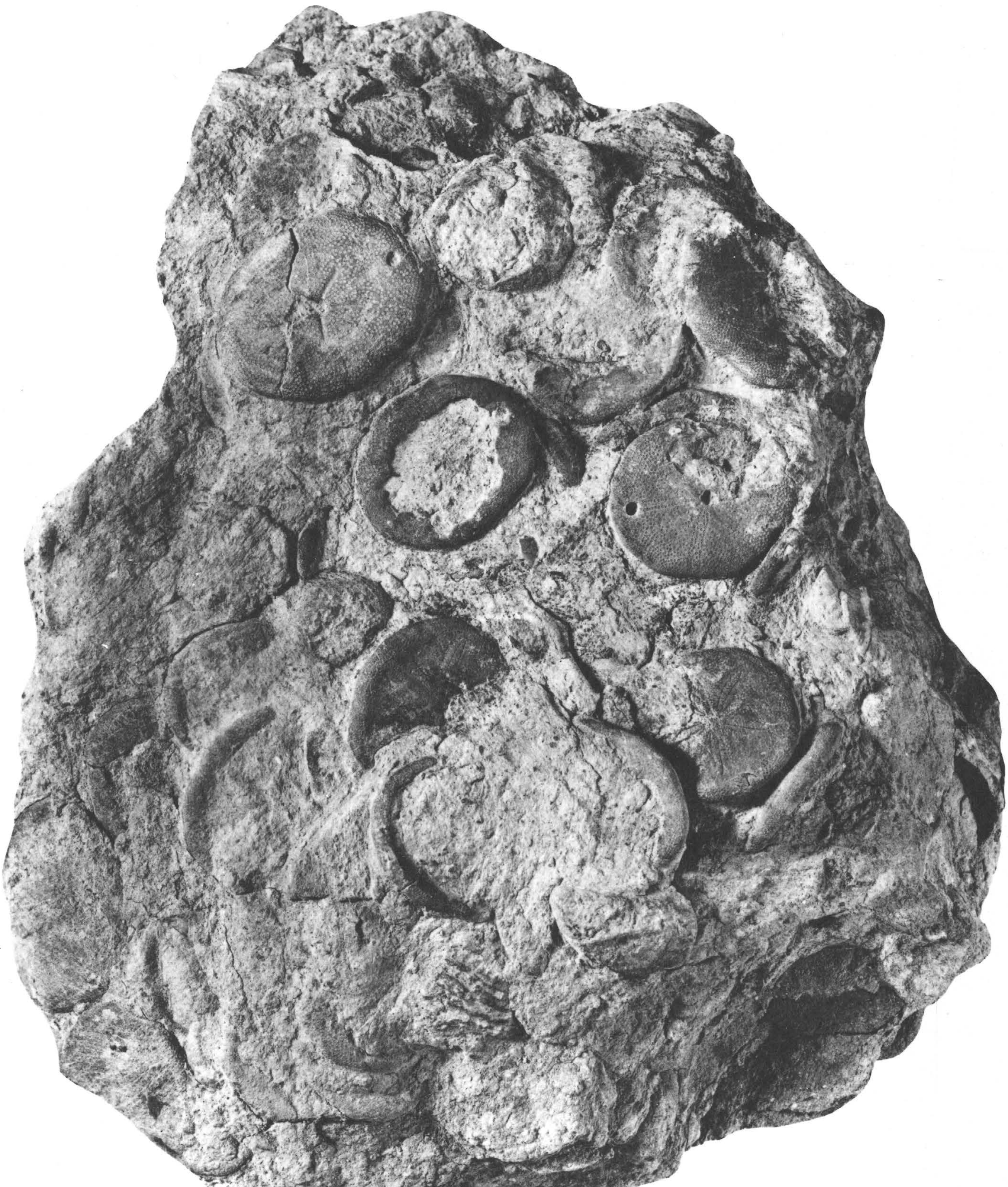
Zebinella ---- 77

PLATES 3–23



FORAMINIFERAL LIMESTONE FROM GATUNCILLO FORMATION OF MADDEN BASIN, PANAMA

Nummulites striatoreticulatus represented by dark silicified specimens standing out in relief and partly silicified sections. The large partly silicified orbitoid presumably is *Lepidocyclina chaperi*. Natural size.



ECHINOID-BEARING LIMESTONE FROM GATUNCILLO FORMATION OF MADDEN BASIN, PANAMA

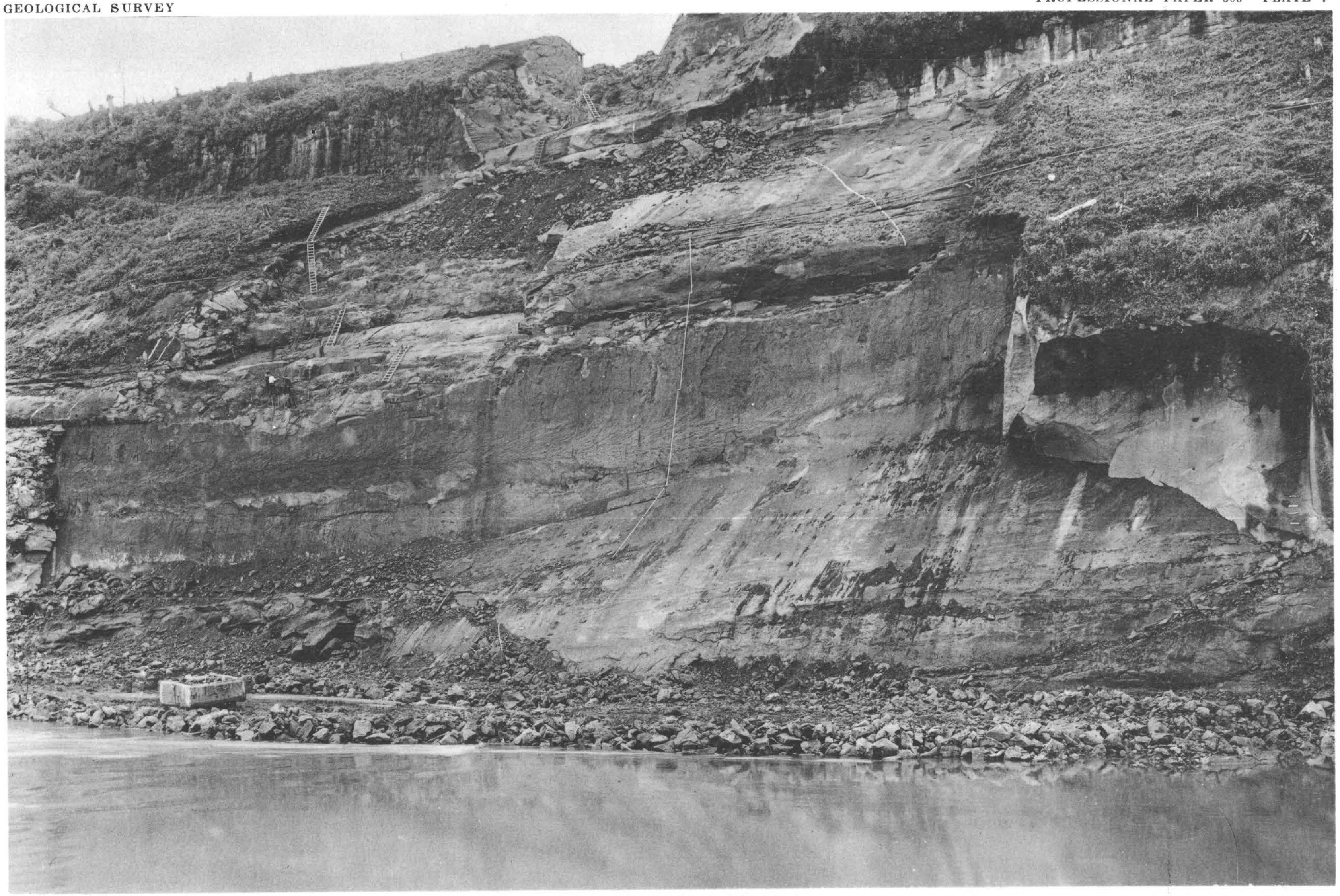
Cubanaster acuñai. Natural size.

BOULDER CONGLOMERATE OF BOHIO FORMATION AT SALUD POINT, BARRO COLORADO ISLAND, CANAL ZONE

Photograph by Geological Section, Special Engineering Division, Panama Canal Company.

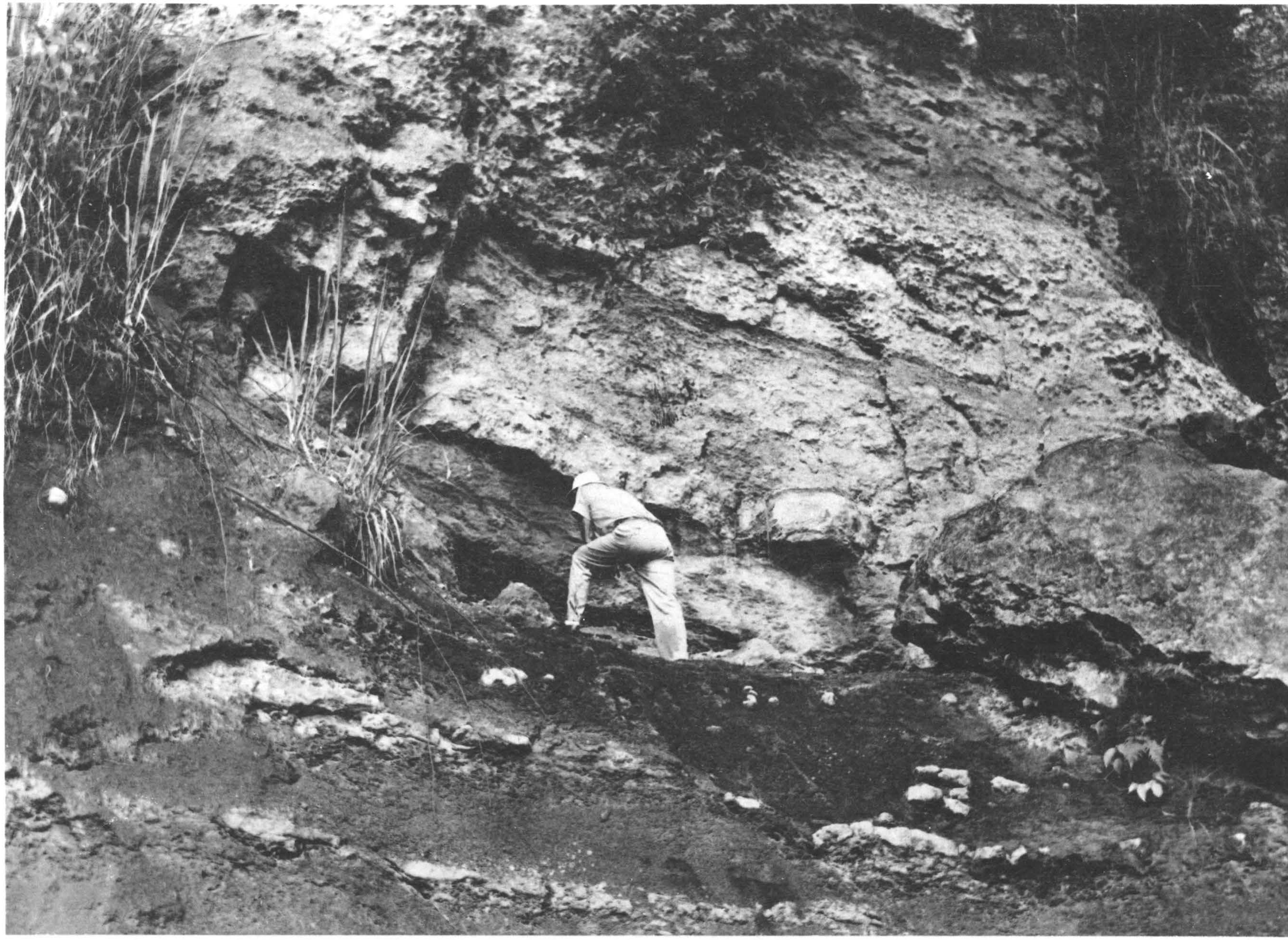
POORLY SORTED CONGLOMERATE OF BOHIO FORMATION ON TRANSISTHMIAN HIGHWAY NEAR LAS CUMBRES, JUST SOUTH OF CONTINENTAL DIVIDE, PANAMA

Photograph by Geological Section, Special Engineering Division, Panama Canal Company.



ALHAJUELA SANDSTONE MEMBER OF CAIMITO FORMATION AT NORTH ABUTMENT OF MADDEN DAM, CANAL ZONE

Photograph by Engineering and Construction Bureau, Panama Canal Company, 1932.

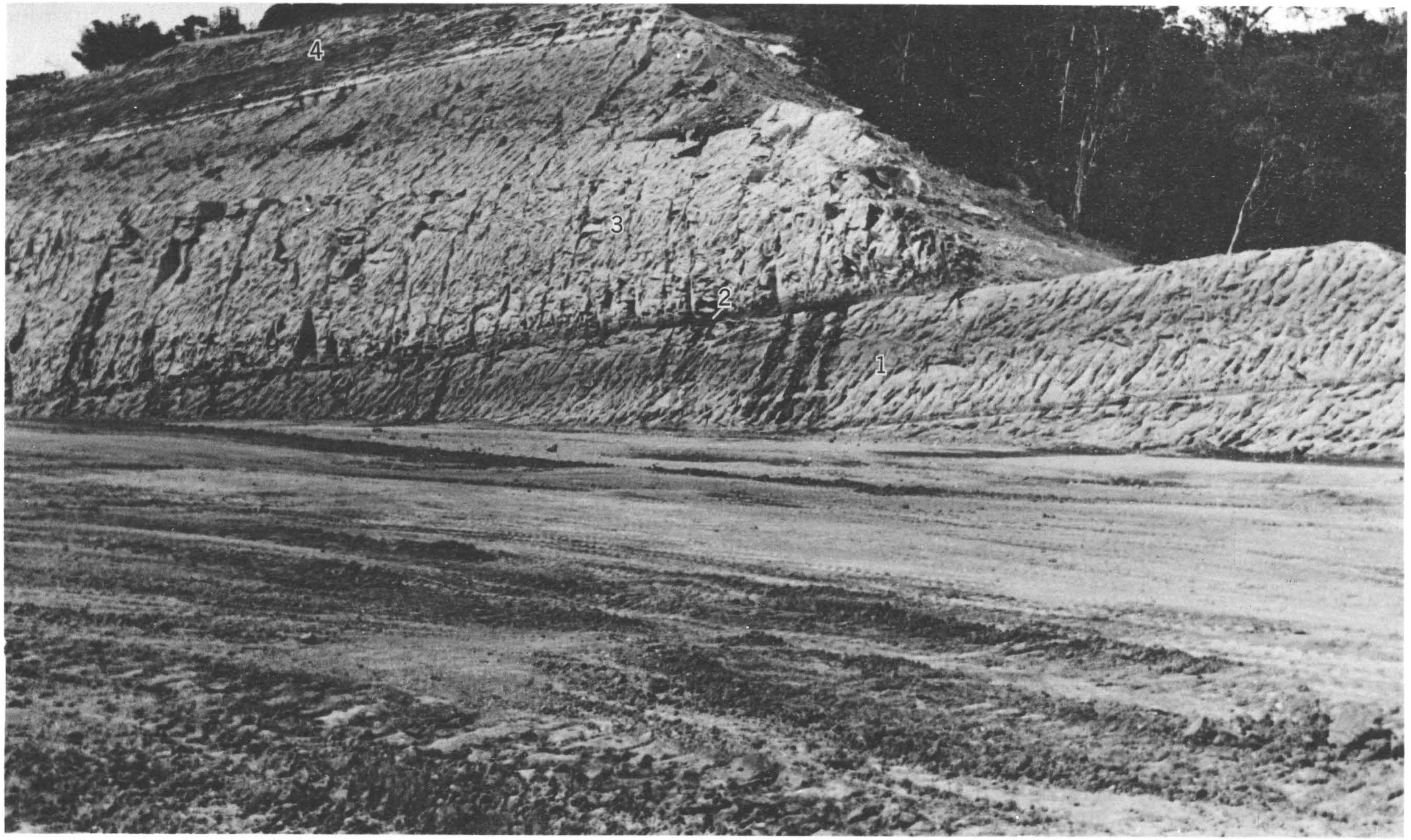


EMPERADOR LIMESTONE MEMBER OF CULEBRA FORMATION ON WEST BANK OF PANAMA CANAL AT CANAL STATION 1619, CANAL ZONE

Photograph by Geological Section, Special Engineering Division, Panama Canal Company.

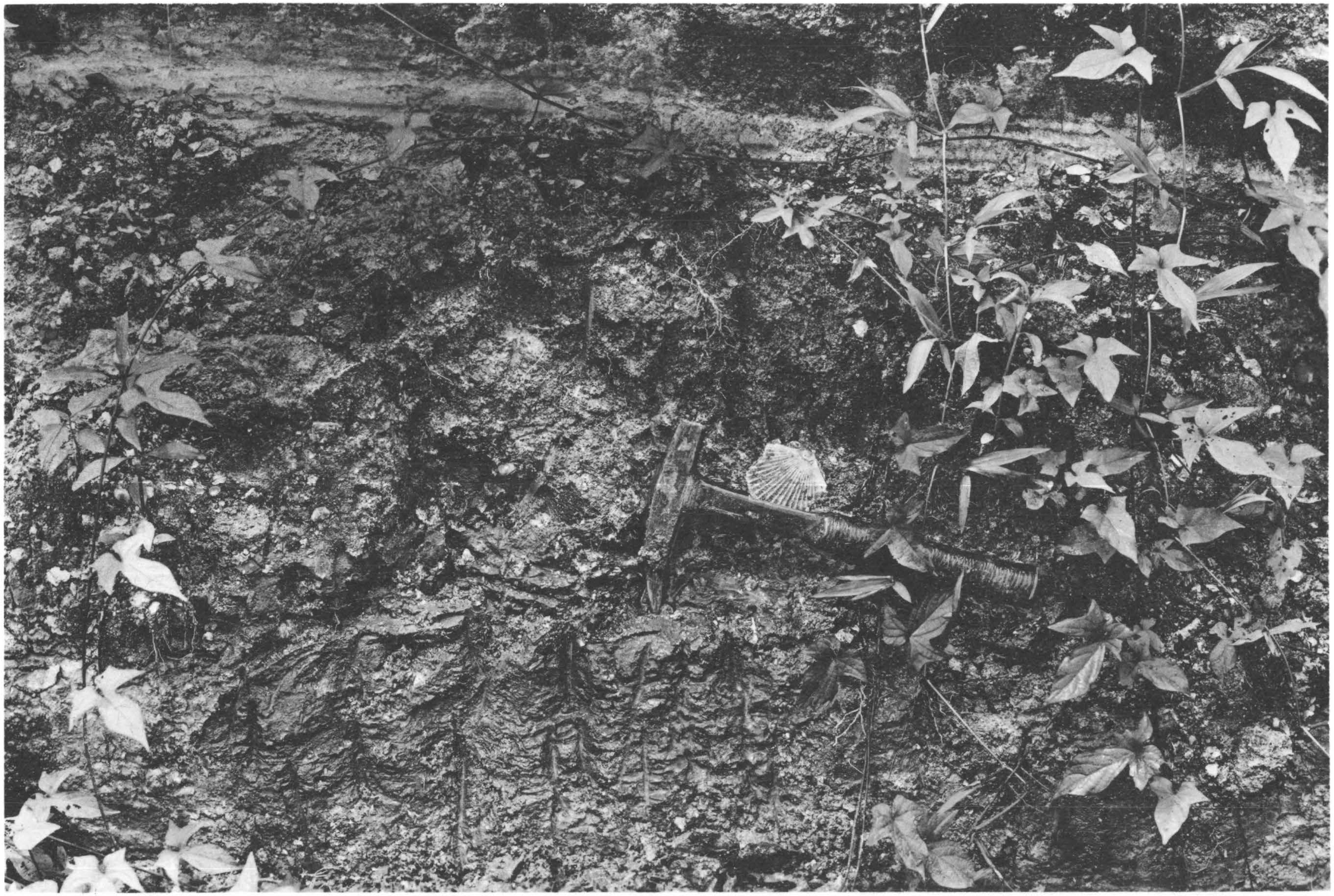
CORALLIFEROUS LIMESTONE AT BASE OF LA BOCA MARINE MEMBER OF PANAMA FORMATION ON RIO MASAMBI 200 METERS UPSTREAM FROM EAST BANK OF PANAMA CANAL, CANAL ZONE

Photograph by Geological Section, Special Engineering Division, Panama Canal Company.



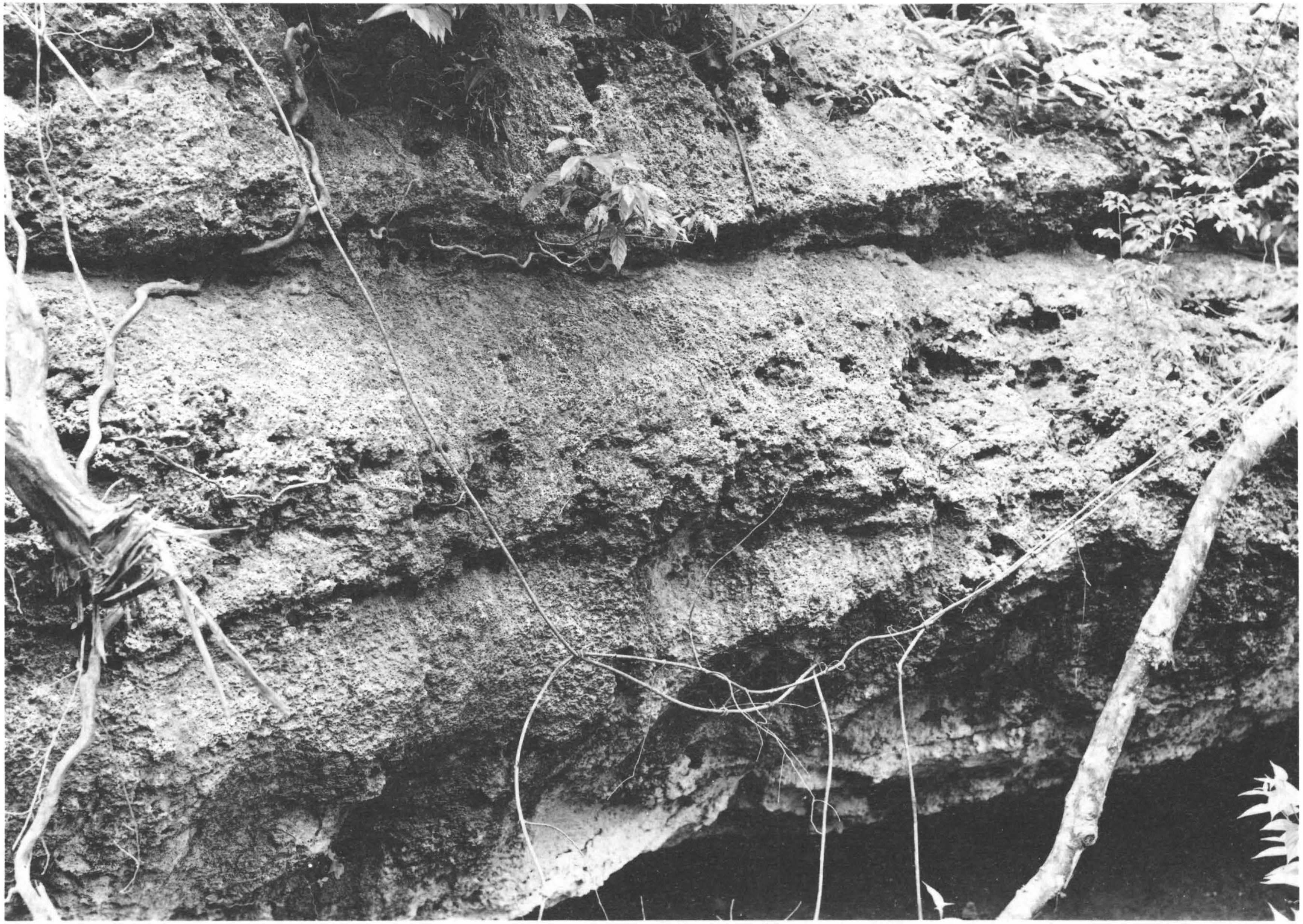
STRATA IN MIDDLE PART OF GATUN FORMATION ON EAST SIDE OF GATUN THIRD LOCKS EXCAVATION, CANAL ZONE

The numbered units correspond to those of the stratigraphic section. Photograph by Geological Section, Special Engineering Division, Panama Canal Company.



TORO LIMESTONE MEMBER OF CHAGRES SANDSTONE RESTING ON MARLY SILTSTONE IN MIDDLE PART OF GATUN FORMATION IN ROAD CUT 3 KILOMETERS SOUTHWEST OF GATUN, CANAL ZONE

The contact between the formations is at the pick point of the hammer. Photograph by Geological Section, Special Engineering Division, Panama Canal Company.



TORO LIMESTONE MEMBER OF CHAGRES SANDSTONE IN ROAD CUT 3 KILOMETERS NORTH-NORTHWEST OF GATUN, CANAL ZONE

Photograph by Geological Section, Special Engineering Division, Panama Canal Company.

CHAGRES SANDSTONE IN ROAD CUT 3 KILOMETERS SOUTH OF LAGARTO, PANAMA
Photograph by Geological Section, Special Engineering Division, Panama Canal Company.

PLATE 14

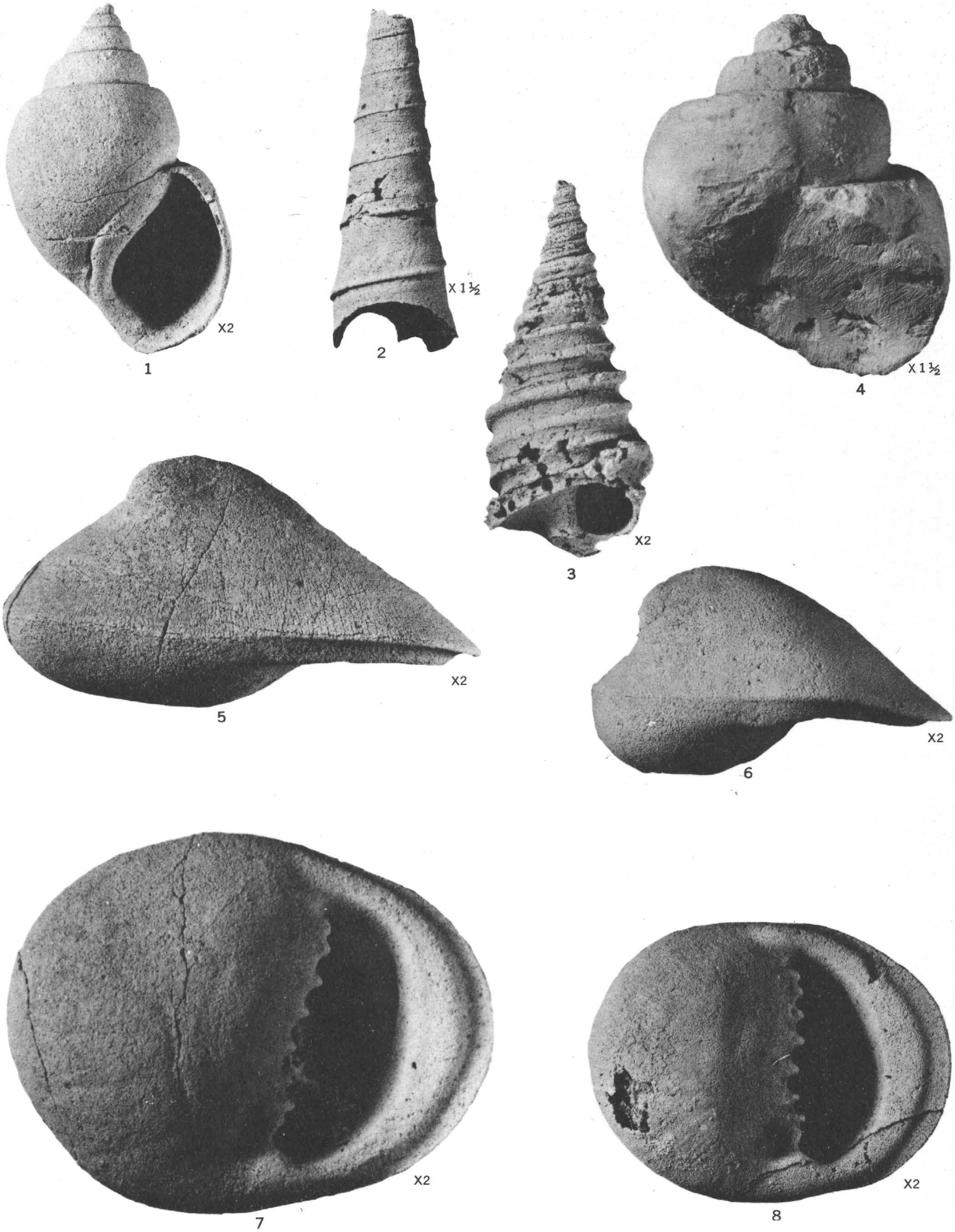
FIGURE 1. *Pachycrommium? solenaeum* Woodring, n. sp. (p. 96).
Type. Height (not quite complete) 32.5 mm, diameter (somewhat crushed), 22 mm. Locality 38. Gatuncillo formation, middle Eocene. USNM 561364.

2. *Turritella* cf. *T. carinata* Lea (p. 98).
Height (incomplete, 7+ whorls) 41.5 mm, diameter 16 mm. Locality 38. Gatuncillo formation, middle Eocene. USNM 561367.

3. *Hannatoma?* cf. *H. emendorferi* Olsson (p. 68).
Height (incomplete) 35.5 mm, diameter (incomplete) 15 mm. Locality 38. Gatuncillo formation, middle Eocene. USNM 561446.

4. *Amaurellina?* sp. (p. 95).
Height (incomplete) 46 mm, diameter 38 mm. Locality 9. Gatuncillo formation, late Eocene. USNM 561363.

5–8. *Velates perversus* (Gmelin), subsp.? (p. 66).
Locality 38. Gatuncillo formation, middle Eocene. USNM 561329.
5, 7. Height 22.5 mm, diameter 43.7 mm.
6, 8. Height 19 mm, diameter 31.7 mm.



MIDDLE AND LATE EOCENE MOLLUSKS FROM GATUNCILLO FORMATION

PLATE 15

FIGURE 1, 2. *Tricolia calypta* Woodring, n. sp. (p. 65).
Type. Height 4.8 mm, diameter 3.1 mm. Locality 40*a*. Marine member of Bohio(?) formation; USNM 561327.

3, 4. *Globularia* (*Ampulella?*) *nana* Woodring, n. sp. (p. 95).
Marine member of Bohio(?) formation.
3. Type. Height (not quite complete) 7 mm, diameter 5 mm. Locality 42. USNM 561361.
4. Height (incomplete) 7.1 mm, diameter (incomplete) 5.5 mm. Locality 41. USNM 561362.

5, 6. *Turritella adela* Woodring, n. sp. (p. 99).
Locality 41. Marine member of Bohio(?) formation.
5. Paratype. Height (incomplete, 3 whorls) 22.5 mm, diameter 12 mm. USNM 561371.
6. Type. Height (incomplete) 25 mm, dlameter 7.5 mm, USNM 561370.

7, 8, 11. *Neverita* (*Glossaulax*) *bolivarensis tapina* Woodring, n. subsp. (p. 91).
Locality 40*d*. Marine member of Bohio(?) formation.
7, 11. Type. Height 14.5 mm, diameter 19 mm. USNM 561354.
8. Paratype. Diameter 18.5 mm. USNM 561442.

9, 17, 18. *Globularia* (*Globularia*) aff. *G. fischeri* (Dall) (p. 94).
Locality 56. Middle member of Caimito formation.
9. Height 18.5 mm, diameter (incomplete) 15.5 mm. USNM 561359.
17, 18. Height (almost complete) 35.5 mm, diameter 31 mm. USNM 561358.

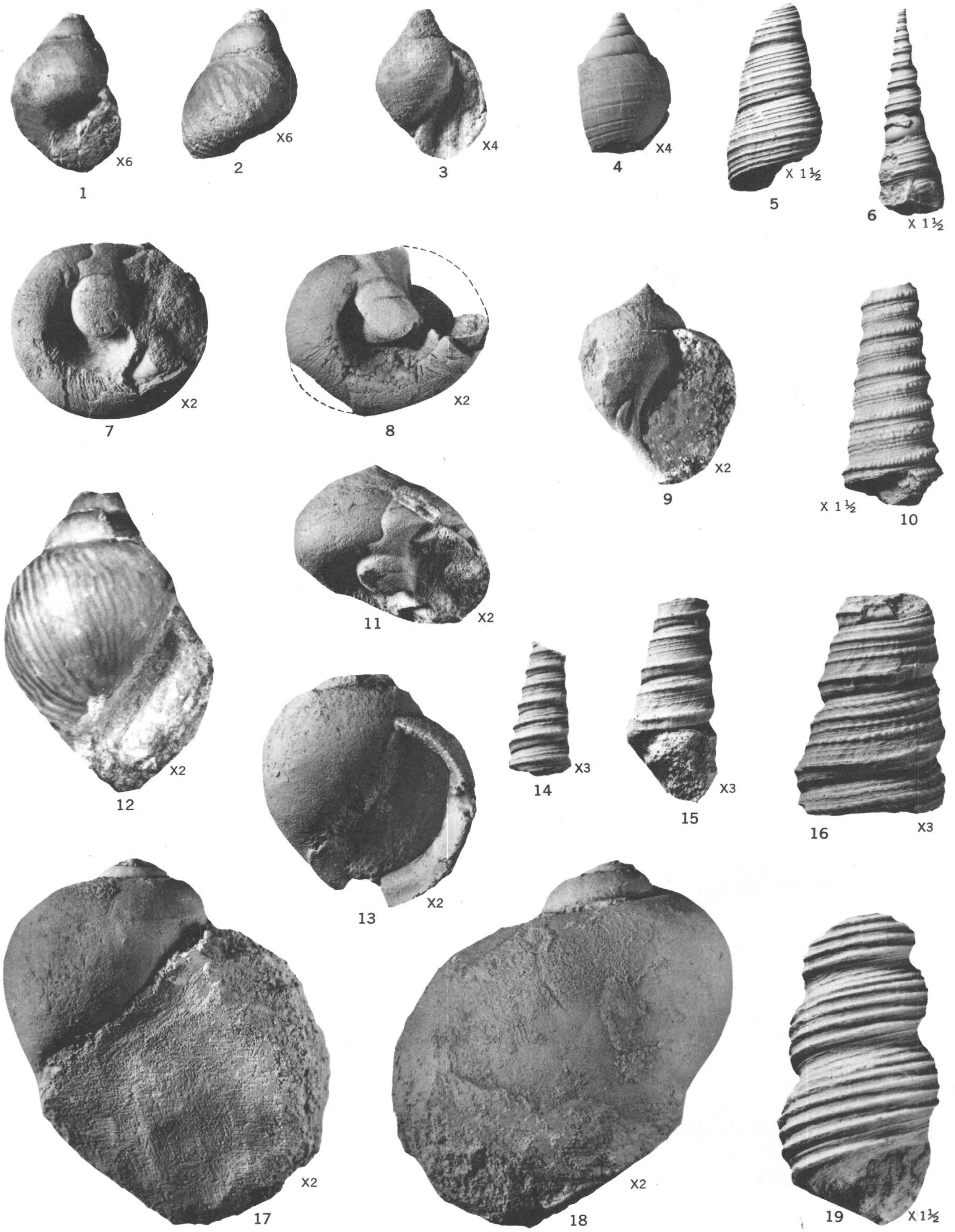
10. *Turritella* (*Torcula*) *altilira* Conrad, subsp. (p. 104).
Height (incomplete, 5+ whorls) 29.5 mm, diameter 13.3 mm. Locality 56. Middle member of Caimito formation. USNM 561382.

12. *Pachycrommium? proinum* Woodring, n. sp. (p. 96).
Type. Height (incomplete) 26 mm, diameter 19 mm. Locality 40*a*. Marine member of Bohio(?) formation. USNM 135200.

13. *Globularia* (*Ampuella*) sp. (p. 95).
Height (incomplete) 21 mm, diameter (modified by dorso-ventral crushing) 19.3 mm. Locality 40*d*. Marine member of Bohio(?) formation. USNM 561360.

14–16. *Turritella* cf. *T. caleta* Olsson (p. 100).
Marine member of Bohio(?) formation.
14. Height (incomplete, 3+ whorls) 7.9 mm, diameter 6.5 mm. Locality 40*b*. USNM 135166.
15. Height (incomplete, 4 whorls) 13 mm, diameter 6.5 mm. Locality 42*c*. USNM 561369.
16. Height (incomplete, 2+ whorls) 13.5 mm, diameter 9.5 mm. Locality 42*c*. USNM 561369.

19. *Turritella meroensis* Olsson (p. 99).
Height (incomplete, 3+ whorls) 39 mm, diameter 21 mm. Locality 56. Middle member of Caimito formation. USNM 561372.



LATE EOCENE OR EARLY OLIGOCENE MOLLUSKS FROM MARINE MEMBER OF BOHIO(?) FORMATION AND LATE OLIGOCENE MOLLUSKS FROM MIDDLE MEMBER OF CAIMITO FORMATION IN GATUN LAKE AREA

PLATE 16

FIGURE 1, 2. *Littorina* aff. *L. angulifera* (Lamarck) (p. 68).
Height (practically complete) 12 mm, diameter 8.5 mm. Locality 110. Uppermost part of Culebra formation. USNM 561331.

3. *Turritella* cf. *T. subgrundifera* Dall (p. 105).
Height (incomplete, 3 whorls) 18 mm, diameter 5 mm. Locality 99*d*. Culebra formation. USNM 561384.

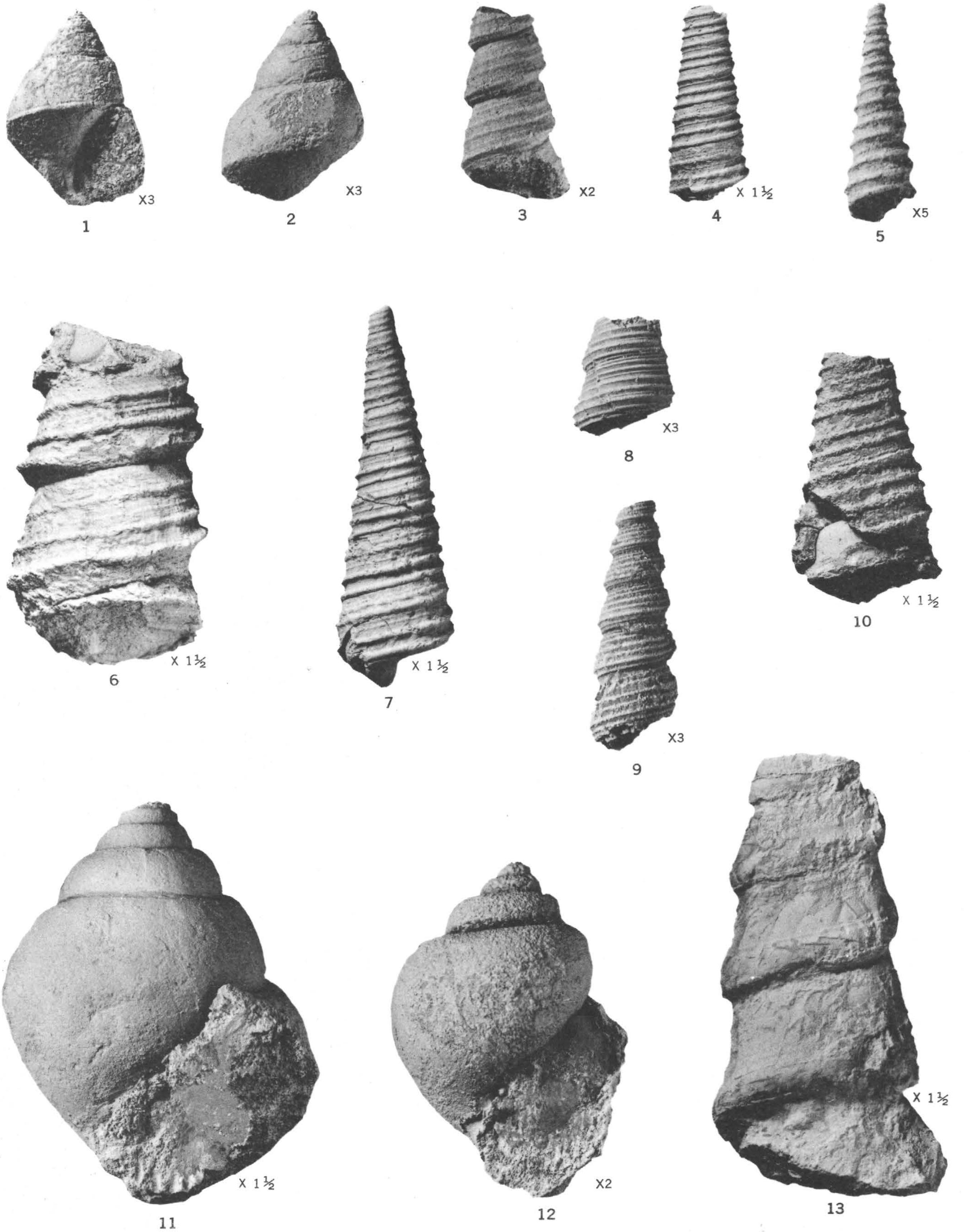
4–7, 10. *Turritella* (*Torcula*?) *amaras* Woodring, n. sp. (p. 101).
Culebra formation.
4. Height (incomplete, 5 whorls), 23.5 mm, diameter 10 mm. Locality 107. USNM 561374.
5. Height (incomplete, 7 whorls) 8 mm, diameter 2.7 mm. Locality 99*b*. USNM 561377.
6. Height (incomplete, 3+ whorls) 43 mm, diameter 24.5 mm. Locality 98. USNM 561376.
7. Type. Height (incomplete) 47 mm, diameter 14.5 mm. Locality 116. USNM 561373.
10. Height (incomplete, 4+ whorls) 30 mm, diameter 18 mm. Locality 112. USNM 561375.

8, 9. *Turritella venezuelana* Hodson (p. 106).
Culebra formation.
8. Height (incomplete, 2 whorls) 6.8 mm, diameter 6 mm. Locality 110. USNM 561386.
9. Height (incomplete, 6 whorls) 15.3 mm, diameter 5.4 mm. Locality 112*a*. USNM 561385.

11. *Pachycrommium*? cf. *P.*? *trinitatensis* (Mansfield) (p. 97).
Height (incomplete) 50 mm, diameter (exaggerated by crushing) 39 mm. Locality 99*h*. Culebra formation. USNM 561365.

12. *Pachycrommium*? cf. *P. guppyi* (Gabb) (p. 97).
Height (not quite complete) 27 mm, diameter 21.5 mm. Locality 115*a*. Culebra formation. USNM 561366.

13. *Turritella* cf. *T. collazica* Maury (p. 98).
Height (incomplete, 4+ whorls) 56 mm, diameter (exaggerated by crushing) 25 mm. Locality 123. La Boca marine member of Panamá formation. USNM 561368.



EARLY MIOCENE MOLLUSKS FROM CULEBRA FORMATION AND LA BOCA MARINE MEMBER OF PANAMA FORMATION

PLATE 17

FIGURE 1–3. *Teinostoma* (*Pseudorotella*) *stemonium* Woodring, n. sp. (p. 71).
Type. Height 1 mm, diameter 1.5 mm. Locality 138*a*. Lower part of Gatun formation, middle Miocene. USNM 561432.

4–6. *Teinostoma* (*Idioraphe*) *angulatum trochalum* Woodring, n. subsp. (p. 70).
Type. Height 1 mm, diameter (incomplete) 1.7 mm. Locality 137. Lower part of Gatun formation, middle Miocene. USNM 561431.

7–15. *Cyclostremiscus* (*Ponocyclus*) *pentagonus* (Gabb) (p. 73).
Middle part of Gatun formation, middle Miocene.
7–9. Bicarinate specimen. Height 1 mm, diameter 1.6 mm. Locality 147*b*. USNM 561320.
10–12. Tricarinate specimen. Height 1 mm, diameter 1.8 mm. Locality 147*b*. USNM 561320.
13–15. Exceptionally large specimen. Height 1.1 mm, diameter 2.3 mm. Locality 155*c*. USNM 561321.

16–18. *Solariorbis* (*Hapalorbis*) *hyptius hyptius* Woodring, n. sp. and n. subsp. (p. 75).
Type. Height 0.7 mm, diameter 1.4 mm. Locality 147*b*. Middle part of Gatun formation, middle Miocene. USNM 561323.

19–24, 31–33, 37–39. *Teinostoma* (*Idioraphe*) *spermatia* Woodring, n. sp. (p. 69).
Locality 147*b*. Middle part of Gatun formation, middle Miocene.
19–21. Sculptured specimen. Height 0.8 mm, diameter 1.6 mm. USNM 561313.
22–24. Small specimen. Height 0.6 mm, diameter 1.2 mm. USNM 561313.
31–33. Large form. Height 1.1 mm, diameter 2.6 mm. USNM 561313.
37–39. Type. Height 0.7 mm, diameter 1.8 mm. USNM 561312.

25–27. *Teinostoma* (*Pseudorotella*) *pycnum* (Woodring). (p. 71).
Height 0.8 mm, diameter 1.3 mm. Locality 147*b*. Middle part of Gatun formation, middle Miocene. USNM 561317.

28–30. *Teinostoma* (*Diaerecallus*) *sychnum* Woodring, n. sp. (p. 72).
Type. Height 1.1 mm, diameter 1.7 mm. Locality 147*b*. Middle part of Gatun formation, middle Miocene. USNM 561316.

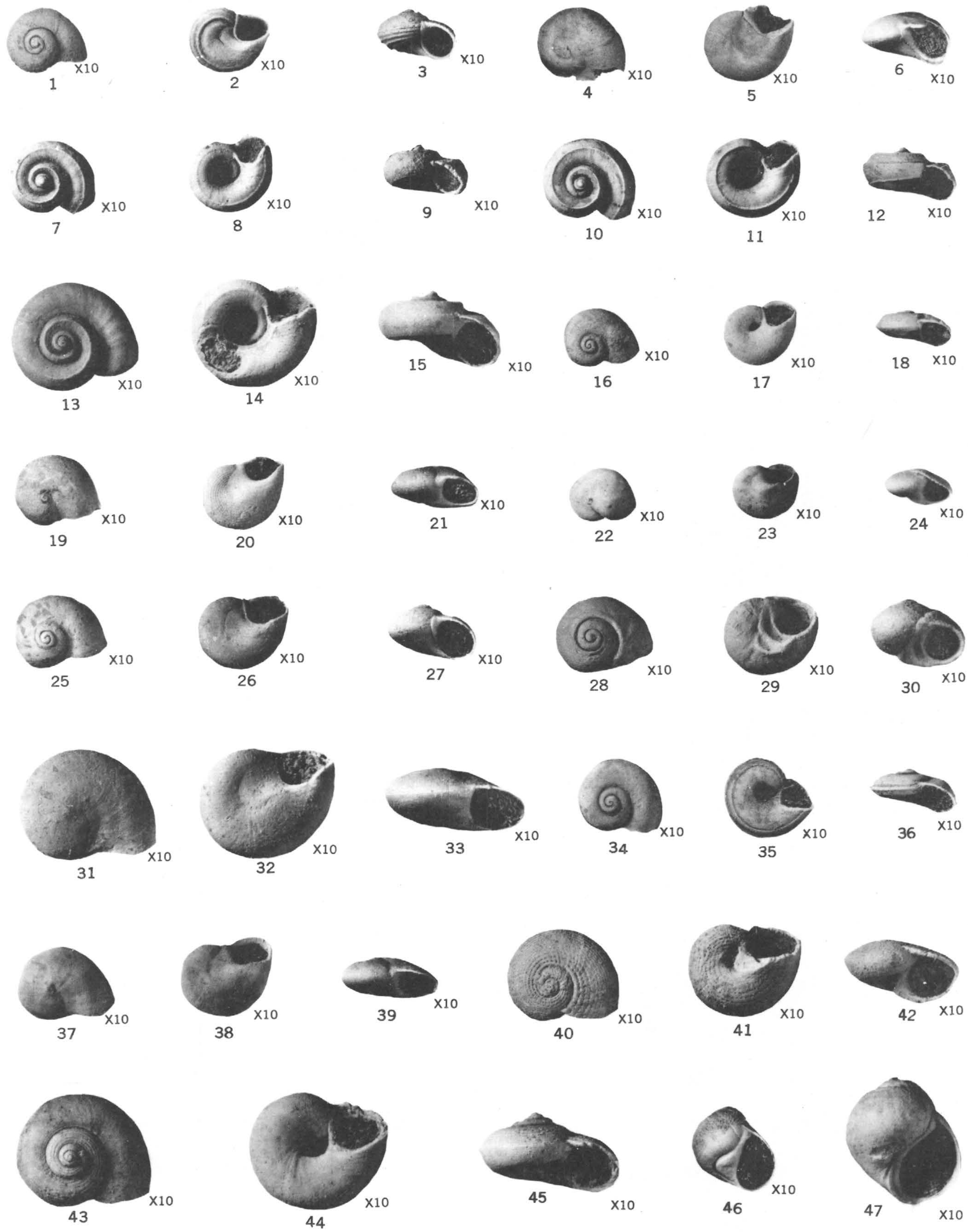
34–36. *Solariorbis* (*Hapalorbis*) *hyptius anebus* Woodring, n. subsp. (p. 75).
Type. Height 0.9 mm, diameter 1.5 mm. Locality 185. Upper part of Gatun formation, western area, late Miocene. USNM 561324.

40–42. *Teinostoma* (*Aepystoma*) *andrium* Woodring, n. sp. (p. 70).
Height 1.2 mm, diameter 2.1 mm. Locality 137. Lower part of Gatun formation, middle Miocene. USNM 561314.

43–45. *Solariorbis* (*Solariorbis*) *strongylus* Woodring, n. sp. (p. 75).
Type. Height 1.3 mm, diameter 2.4 mm. Locality 138. Lower part of Gatun formation, middle Miocene. USNM 561322.

46. *Tectonatica agna* Woodring, n. sp. (p. 88).
Type. Height 2.8 mm, diameter 2.4 mm. Locality 147*b*. Middle part of Gatun formation, middle Miocene. USNM 561348.

47. *Tricolia? syntoma* Woodring, n. sp. (p. 66).
Type. Height 2.2 mm, diameter 2.2 mm. Locality 170*a*. Middle part of Gatun formation, middle Miocene. USNM 561328.



MIDDLE AND LATE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 18

FIGURE 1–3. *Anticlimax* (*Subclimax*) *teleospira hystata* Woodring, n. subsp. (p. 73).
Type. Height 1.5 mm, diameter (incomplete) 2.7 mm. Locality 185. Upper part of Gatun formation, western area, late Miocene. USNM 561319.

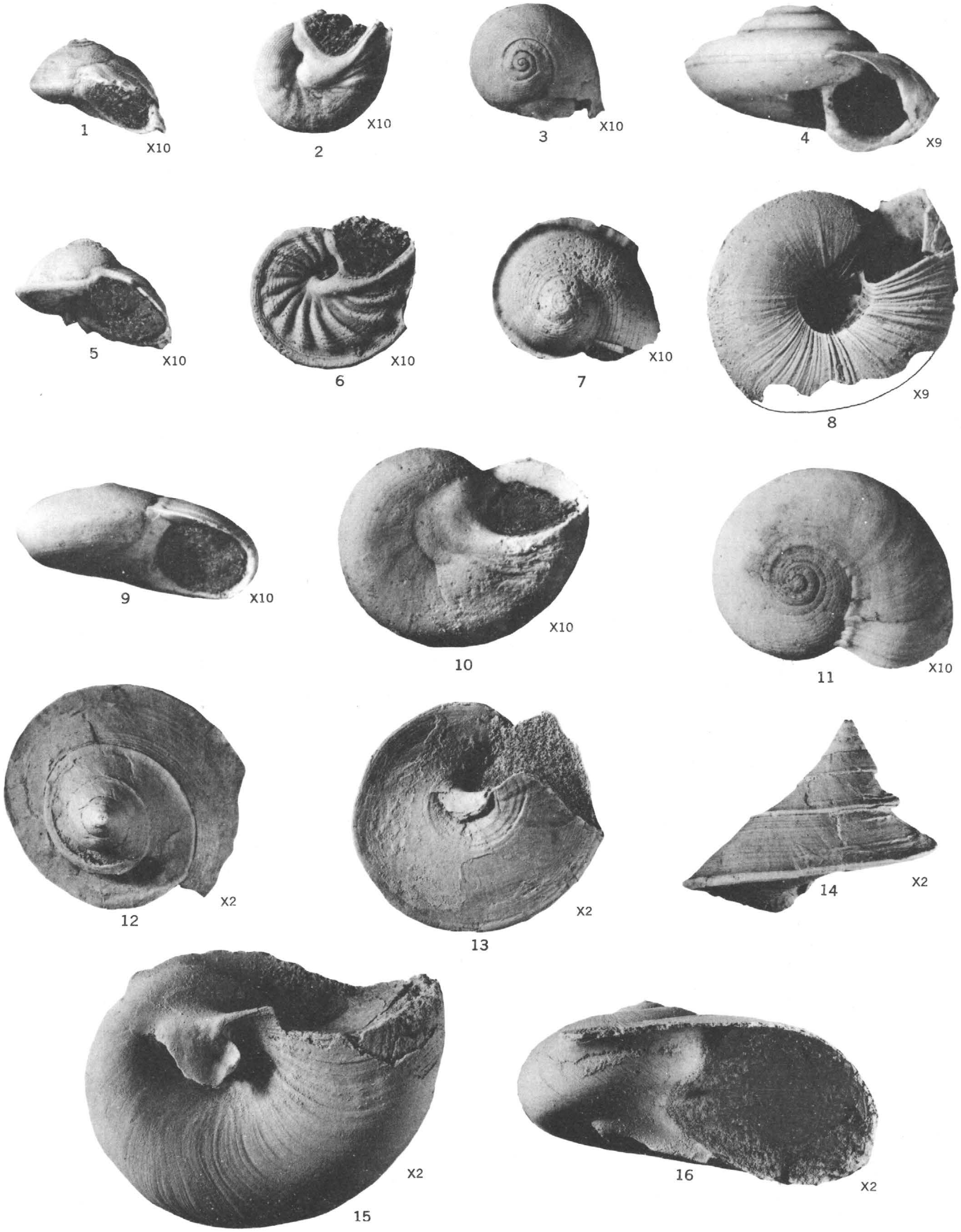
4, 8. *Episcynia megalia* Woodring, n. sp. (p. 76).
Type. Height 2.7 mm, diameter 5.3 mm. Locality 138. Lower part of Gatun formation, middle Miocene. USNM 561325.

5–7. *Anticlimax* (*Anticlimax*) *gatunensis* Pilsbry and Olsson (p. 72)
Topotype. Height 1.7 mm, diameter (incomplete) 3 mm. Locality 138. Lower part of Gatun formation, middle Miocene. USNM 561318

9–11. *Teinostoma* (*Aepystoma*) *andrium* Woodring, n. sp. (p. 70).
Type. Height 2 mm, diameter 4.7 mm. Locality 137. Lower part of Gatun formation, middle Miocene. USNM 561315.

12–14. *Calliostoma* (*Calliostoma*) *metalium* Woodring, n. sp. (p. 63).
Type. Height (almost complete, but crushed) 19.5 mm, diameter (incomplete) 24 mm. Locality 206*a*. Chagres sandstone, early Pliocene. USNM 561430.

15, 16. *Neverita* (*Hypterita*) *helicoides* (Gray) (p. 92).
Height (incomplete) 16 mm, diameter (incomplete) 34 mm. Locality 155*b*. Middle part of Gatun formation, middle Miocene. USNM 561356.



MIDDLE AND LATE MIOCENE MOLLUSKS FROM GATUN FORMATION AND EARLY PLIOCENE MOLLUSK FROM CHAGRES SANDSTONE

PLATE 19

FIGURE 1–3. *Crepidula plana* Say (p. 79).

Locality 138. Lower part of Gatun formation. USNM 561334.

1. Length 17.5 mm, width 10.6 mm, height 4 mm.

2, 3. Length 15 mm, width 10.5 mm, height 2 mm.

4, 5. *Crepidula* cf. *C. maculosa* Conrad (p. 79).

Length 28.5 mm, width 17.5 mm, approximate height 10.5 mm. Locality 155*c*. Middle part of Gatun formation. USNM 561333.

6, 7. *Crucibulum* (*Crucibulum*) *chipolanum* Dall (p. 82).

Height 16.5 mm, maximum diameter 27 mm. Locality 155*b*. Middle part of Gatun formation. USNM 561336.

8–10. *Crucibulum* (*Dispotaea*) *springvaleense* Rutsch (p. 83).

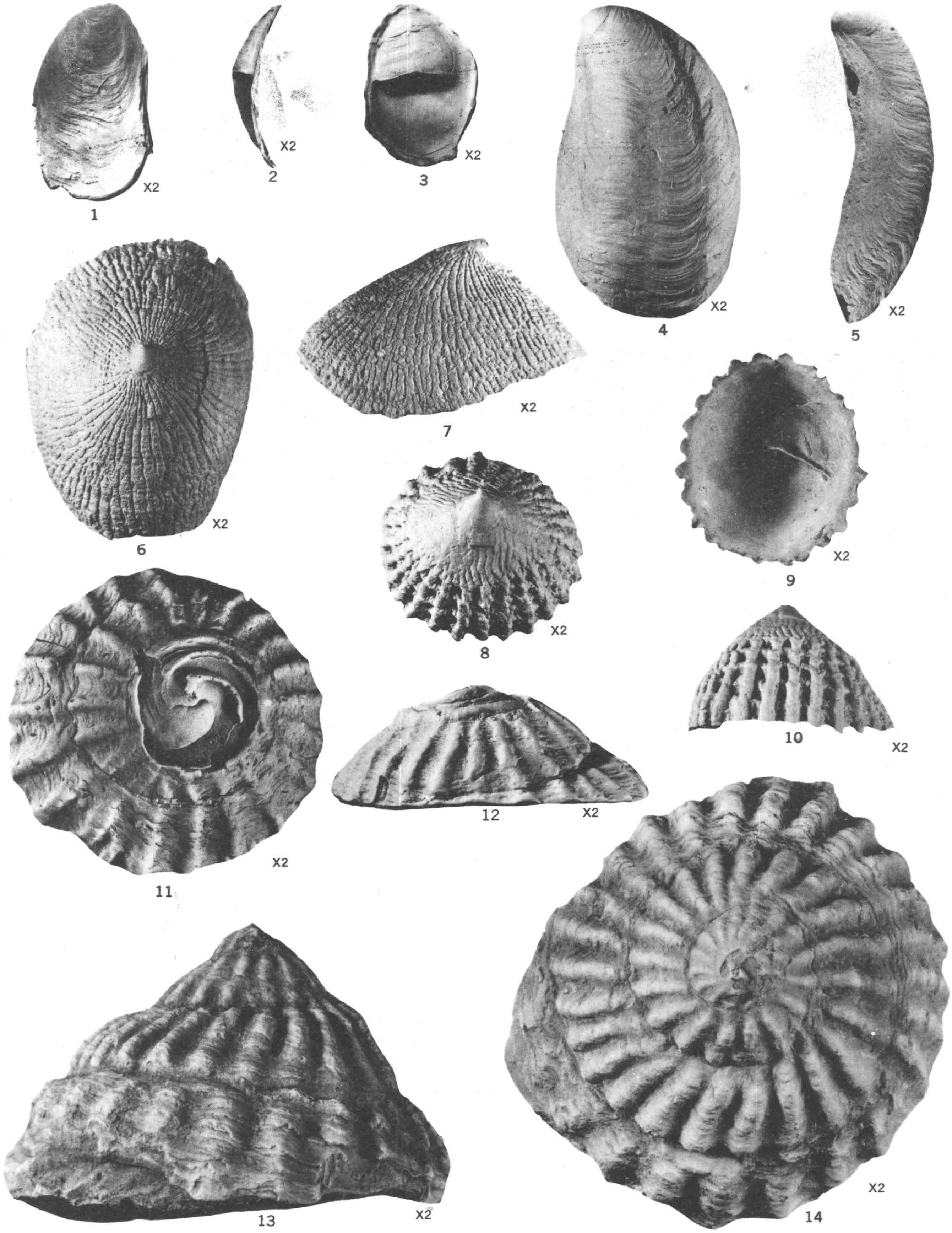
Height 11 mm, maximum diameter 19.2 mm. Locality 155*a*. Middle part of Gatun formation. USNM 561337.

11–14. *Trochita trochiformis* (Born) (p. 81).

Lower part of Gatun formation.

11, 12. Height (incomplete) 10.7 mm, maximum diameter 28.8 mm. Locality 136. USNM 561335.

13, 14. Height (almost complete) 27 mm, maximum diameter 43.5 mm. Locality 136*a*. Stanford Univ. paleont. coll. 8072.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 20

FIGURE 1–3. *Natica* (*Natica?*) *bolus* Brown and Pilsbry (p. 84).

1, 2. Height 14.5 mm, diameter 15.2 mm. Locality 159. Middle part of Gatun formation. USNM 561338.

3. Height 9.7 mm, diameter 10.2 mm. Locality 175. Upper part of Gatun formation, eastern area. USNM 561339.

4–6. *Natica* (*Naticarius*) *stenopa* Woodring, n. sp. (p. 85).

Upper part of Gatun formation, eastern area.

4, 5. Type. Height 15.2 mm, diameter 14.8 mm. Locality 177*b*. USNM 561340.

6. Paratype. Height 12 mm, diameter 11 mm. Locality 177*c*. USNM 561341.

7, 8. *Polinices canalizonalis* (Brown and Pilsbry) (p. 89).

Locality 177*b*. Upper part of Gatun formation, eastern area. USNM 561349.

7. Height 21 mm, diameter 18.7 mm.

8. Height 11 mm, diameter 10 mm.

9. *Polinices brunneus subclausus* (Sowerby) (p. 89).

Height 20.3 mm, diameter 16.7 mm. Locality 155*b*. Middle part of Gatun formation. USNM 561350.

10. *Turbo* (*Marmarostoma*) aff. *T. castaneus* Gmelin (p. 64).

Height (not quite complete) 20.5 mm, diameter (incomplete) 18 mm. Locality 155*b*. Middle part of Gatun formation. USNM 561326.

11–16. *Stigmaulax guppiana* (Toula) (p. 86).

11, 12. Height 22.5 mm, diameter 20.8 mm. Locality 155*c*. Middle part of Gatun formation. USNM 561344.

13. Length 18.5 mm, width 10.7 mm. Locality 147*g*. Middle part of Gatun formation. USNM 561345.

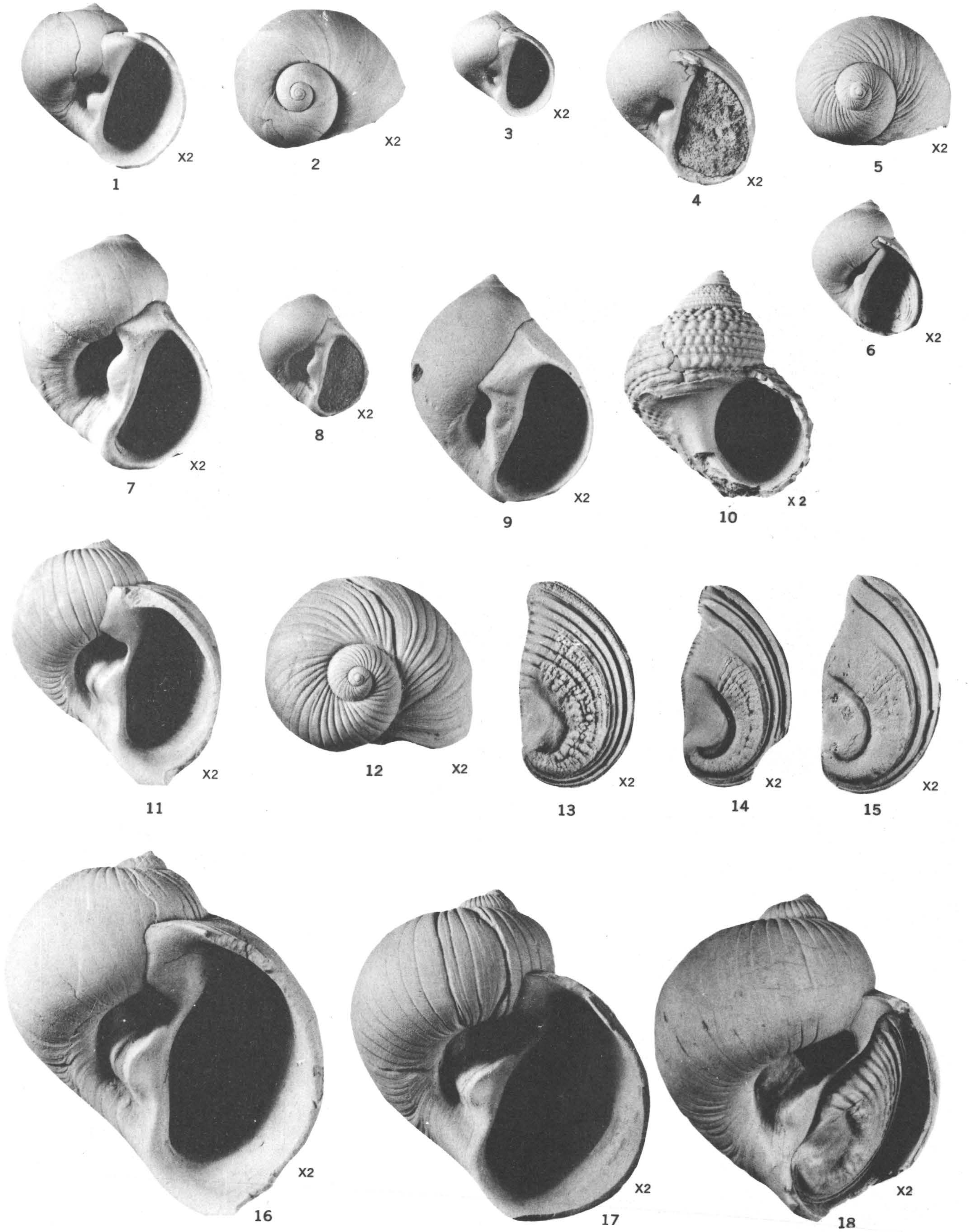
14. Length 17.5 mm, width 10 mm. Locality 147*h*. Middle part of Gatun formation. USNM 561446.

15. Length 19.5 mm, width 10.9 mm. Locality 151. Middle part of Gatun formation. USNM 561347.

16. Height 33.5 mm, diameter 30.5 mm. Locality 147*b*. Middle part of Gatun formation. USNM 561342.

17. Height 30.5 mm, diameter 29 mm. Locality 177*b*. Upper part of Gatun formation, eastern area. USNM 561343.

18. Height 31.4 mm, diameter 28 mm. Locality 142. Middle part of Gatun formation. USNM 561428.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 21

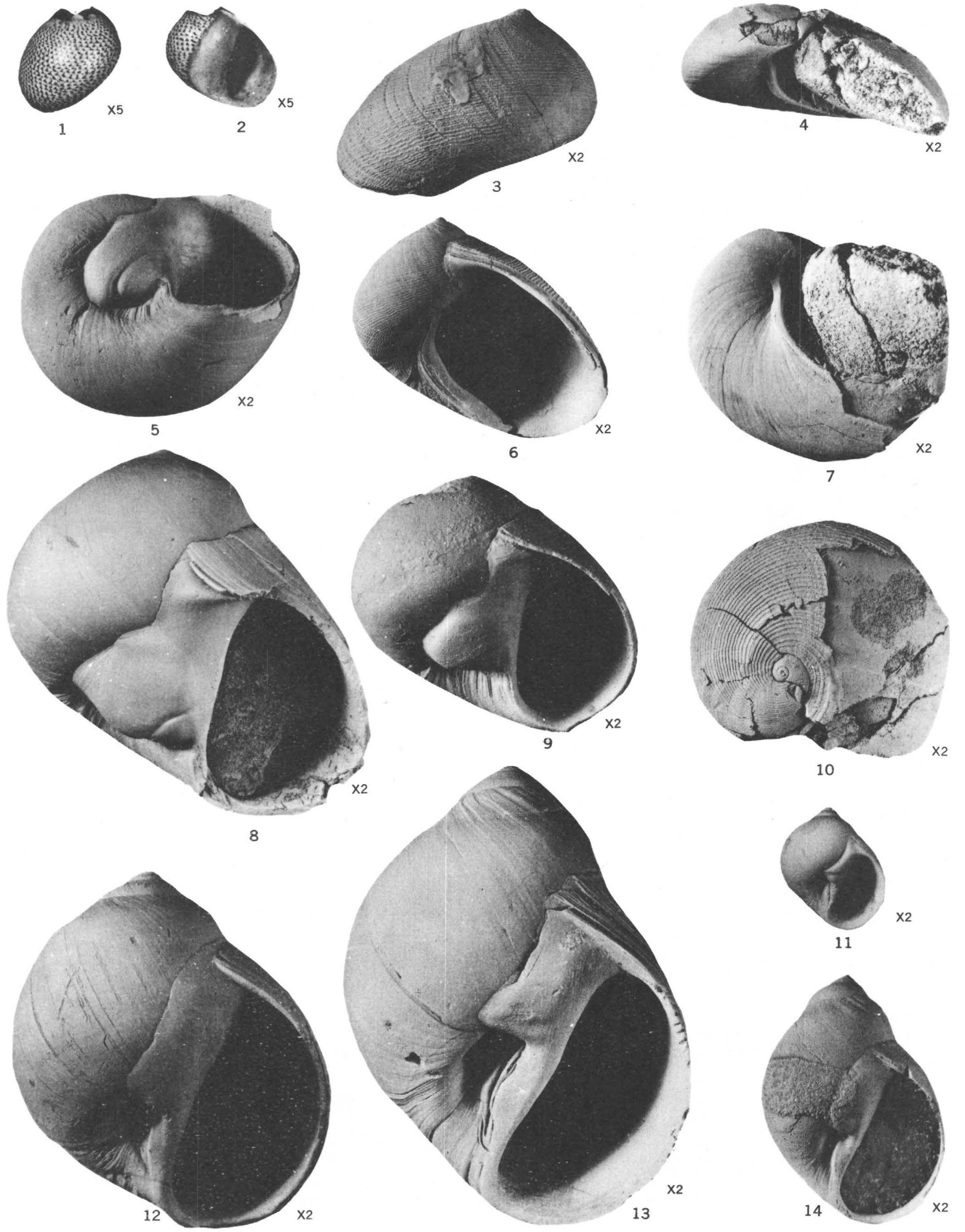
FIGURE 1, 2. *Neritina* (*Vitta?*) cf. *N. virginea* (Linné) (p. 67).
Height (incomplete), 3.6 mm, diameter 3.6 mm. Locality 161*c*. Middle part of Gatun formation, middle Miocene. USNM 561330.

3, 6. *Sinum gabbi* (Brown and Pilsbry) (p. 94).
Height 23 mm, diameter 23 mm. Locality 155*b*. Middle part of Gatun formation, middle Miocene. USNM 561357.

4, 7, 10. *Sinum euryhedra* Woodring, n. sp. (p. 93).
Type. Height (incomplete), 11 mm, diameter (incomplete) 27 mm. Locality 137*a*. Lower part of Gatun formation, middle Miocene. USNM 561441.

5, 8, 9. *Neverita* (*Glossaulax*) *reclusiana xena* Woodring, n. subsp. (p. 92).
Lower part of Gatun formation, middle Miocene.
5, 9. Type. Height 25 mm, diameter 27 mm. Locality 137. USNM 561355.
8. Large high-spired specimen. Height 34 mm, diameter (incomplete) 35 mm. Locality 137*a*. USNM 561440.

11–14. *Polinices stanislas-meunieri* Maury (p. 90).
11. Small specimen. Height 11.5 mm, diameter 10 mm. Locality 138. Lower part of Gatun formation, middle Miocene. USNM 561353.
12. Inflated specimen. Height 32.5 mm, diameter 28 mm. Locality 182. Upper part of Gatun formation, western area, late Miocene. USNM 561351.
13. Large slender specimen. Height 43.5 mm, diameter 33 mm. Locality 138a. Lower part of Gatun formation, middle Miocene. USNM 561439.
14. Slender specimen. Height 22.5 mm, diameter 16.5 mm. Locality 136. Lower part of Gatun formation, middle Miocene. USNM 561352.



MIDDLE AND LATE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 22

FIGURE 1, 2, 4. *Xenophora delecta* (Guppy) (p. 77).

Height 25 mm, diameter (incomplete) 46 mm. Locality 173. Upper part of Gatun formation, eastern area, middle Miocene. USNM 561434.

3, 5. *Calliostoma* (*Leiotrochus*) *eremum* Woodring, n. sp. (p. 63).

Type. Height (incomplete) 17.5 mm, diameter 19 mm. Locality 155*c*. Middle part of Gatun formation, middle Miocene. USNM 561311.

6–9. *Turritella mimetes* Brown and Pilsbry (p. 110).

6. Height (incomplete) 73 mm, diameter 17.5 mm. Locality 155*b*. Middle part of Gatun formation, middle Miocene. USNM 561396.
7. Height (incomplete) 56 mm, diameter 15.3 mm. Locality 185. Upper part of Gatun formation, western area, late Miocene. USNM 561397.
8. Height (incomplete) 45 mm, diameter 18 mm. Locality 155*a*. Middle part of Gatun formation, middle Miocene. USNM 561398.
9. Height (incomplete) 7 mm, diameter 2.4 mm. Locality 161. Middle part of Gatun formation, middle Miocene USNM 561399.

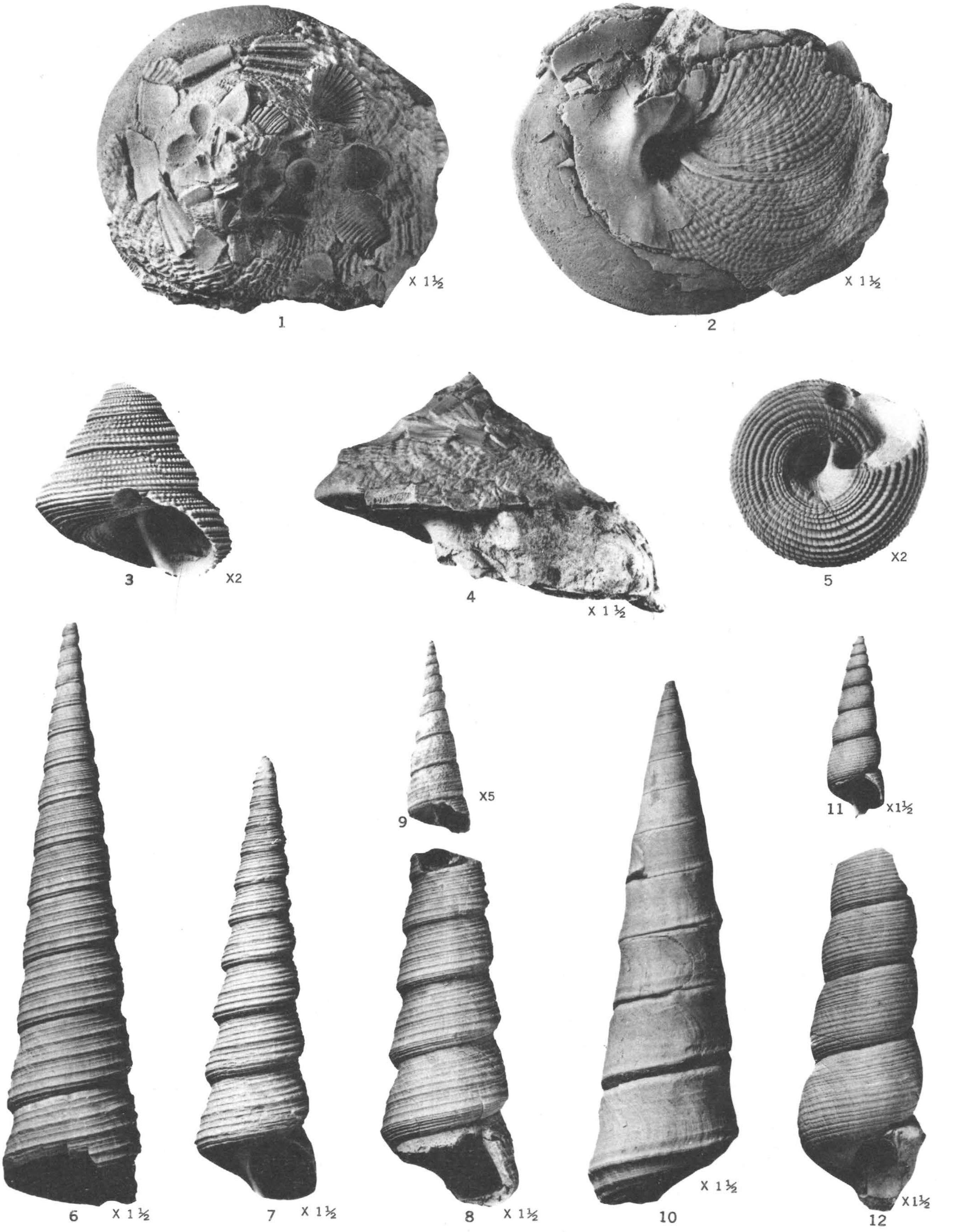
10. *Turritella bifastigata* Nelson (p. 111).

Height (not quite complete) 66 mm, diameter 18.5 mm. Locality 137. Lower part of Gatun formation, middle Miocene. USNM 561400.

11, 12. *Turritella matarucana* Hodson (p. 107).

Lower part of Gatun formation, middle Miocene.

11. Height (incomplete) 23 mm, diameter 7.5 mm. Locality 136. USNM 561391.
12. Height (incomplete) 44.5 mm, diameter 16 mm. Locality 137. USNM 561390.



MIDDLE AND LATE MIOCENE MOLLUSKS FROM GATUN FORMATION

PLATE 23

FIGURE 1, 7, 12, 13. *Turritella (Torcula) altilira altilira* Conrad (p. 102).
Middle part of Gatun formation.
1. Height (incomplete) 7.6 mm, diameter 1.2 mm. Locality 147*b*. USNM 561381.
7. Topotype. Height (incomplete) 43.5 mm, diameter 17.5 mm. Locality 150*a*. USNM 561378.
12. Height (incomplete) 73 mm, diameter 13 mm. Locality 155*b*. USNM 561379.
13. Height (incomplete) 63 mm, diameter 19 mm. Locality 159. USNM 561380.

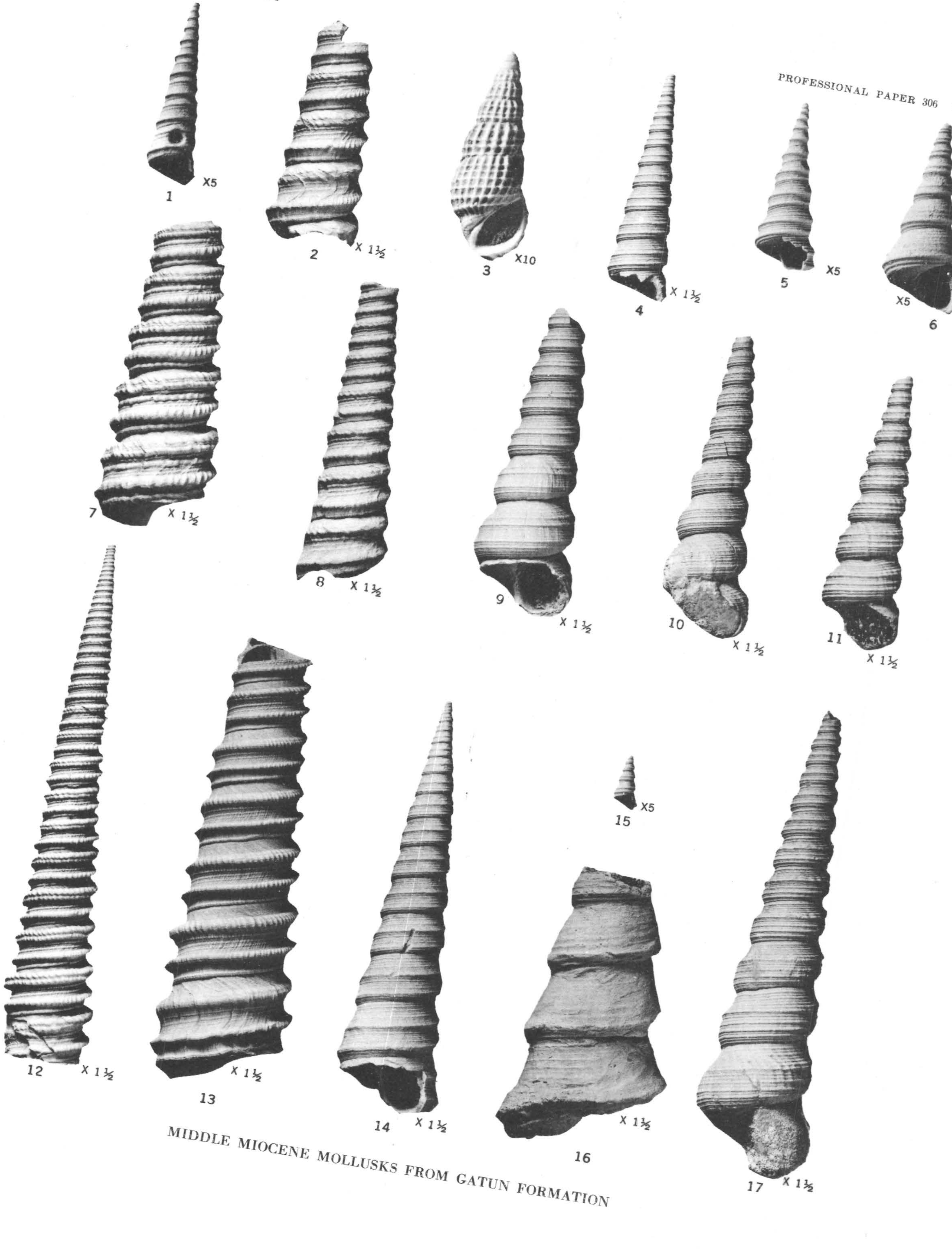
2, 8. *Turritella (Torcula) altilira praecellens* Pilsbry and Brown (p. 105).
Locality 138. Lower part of Gatun formation. USNM 561383.
2. Height (incomplete) 30.5 mm, diameter 13 mm.
8. Height (incomplete) 42 mm, diameter 12.5 mm.

3. *Rissoina (Phosinella) oncera* Woodring, n. sp. (p. 77).
Type. Height 4.3 mm, diameter 1.7 mm. Locality 177*c*. Upper part of Gatun formation, eastern area. USNM 561332.

4, 5, 9, 14. *Turritella gatunensis gatunensis* Conrad (p. 108).
4, 9. Locality 159. Middle part of Gatun formation. USNM 561392. 4, Height (incomplete) 31.4 mm, diameter 9 mm. 9, Height (incomplete) 42.5 mm, diameter 15.2 mm.
5. Height (incomplete) 7.3 mm, diameter 2.5 mm. Locality 138. Lower part of Gatun formation USNM 561394
14. Height (almost complete) 58.5 mm, diameter 15 mm. Locality 138. Lower part of Gatun formation. USNM 561393.

6, 15, 16. *Turritella abrupta* Spieker (p. 106).
Middle part of Gatun formation.
6. Height (incomplete) 8 mm, diameter 3.6 mm. Locality 161*d*. USNM 561388.
15. Height 1.8 mm, diameter 1 mm. Locality 170*a*. USNM 561389.
16. Height (incomplete) 39 mm, diameter 23 mm. Locality 144*a*. USNM 561387.

10, 11, 17. *Turritella gatunensis rhytodes* Woodring, n. subsp. (p. 109).
Locality 162*a*. Middle part of Gatun formation.
10. Height (incomplete) 41.7 mm, diameter 13 mm. USNM 561429.
11. Height (incomplete) 38.7 mm, diameter 11.8 mm. USNM 561429.
17. Type. Height (incomplete) 66 mm, diameter 16.5 mm. USNM 561395.



MIDDLE MIOCENE MOLLUSKS FROM GATUN FORMATION