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, Cocovi 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. Dacitic, 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.

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 agglomerate)—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 "*conule* 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 granulat 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

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* ex-

amined, 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. 16, 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 (Transisthmian) 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 gen-