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Vol. 39

No. 177

**RECENT MARINE MOLLUSKS FROM THE CARIBBEAN COAST
OF PANAMA WITH THE DESCRIPTION OF SOME
NEW GENERA AND SPECIES**

By

AXEL A. OLSSON AND THOMAS L. MCGINTY

December 10, 1958

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RECENT MARINE MOLLUSKS FROM THE CARIBBEAN COAST
OF PANAMA WITH THE DESCRIPTION OF SOME
NEW GENERA AND SPECIES

AXEL A. OLSSON* AND THOMAS L. MCGINTY†

ABSTRACT

Recent marine mollusks along the Caribbean coast of Panama have received little study. In this paper, about 534 species and subspecies are recorded, mostly from the Island of Bocas del Toro near the northwestern corner of the Republic. Of this number about 33 forms are described as new species or new subspecies with 4 new genera or subgenera. The material was obtained by shore collecting or by the picking of beach drift, carefully selected in the field. The main part of the Bocas collections was made in March, 1953, supplemented by material obtained by the senior author in 1917 and 1920. The expense of the field work in 1953 was partly defrayed by a grant from the American Philosophical Society.

NEW GENERA, SUBGENERA, SPECIES, AND SUBSPECIES
DESCRIBED IN THIS PAPER

GASTROPODA

New genera

<i>Decipifus</i> type species <i>D. sixaolus</i> , n. sp.	Columbellidae
<i>Risomurex</i> type species <i>Engina schrammi</i> Crosse	Muricidae

New subgenera

<i>Striovitrinella</i> type species <i>Vitrinella elegans</i> , n. sp.	Vitrinellidae
<i>Pachystremiscus</i> type species <i>Cyclostremiscus pulchellus</i> , n. sp.,	Vitrinellidae

New species

<i>Diodora fargoi</i> , n. sp.	Fissurellidae
<i>Arene (Marevaluata) bitleri</i> , n. sp.	Liottiidae
<i>Rissoa toroensis</i> , n. sp.	Rissoidae
<i>Alvania chiriquiensis</i> , n. sp.	—
<i>Nodulus megalomastomus</i> , n. sp.	—
<i>Solariorbis corylus</i> , n. sp.	Vitrinellidae
<i>Solariorbis decipiens</i> , n. sp.	—
<i>Pleuromalaxis pauli</i> , n. sp.	—
<i>Vitrinella semisculpta</i> , n. sp.	—
<i>Vitrinella (Striovitrinella) elegans</i> , n. sp.	—
<i>Vitrinorbis elegans</i> , n. sp.	—
<i>Cyclostremiscus (Pachystremiscus) pulchellus</i> , n. sp.	—
<i>Cyclostremiscus (Pachystremiscus) ornatus</i> , n. sp.	—
<i>Macromphalina pilsbryi</i> , n. sp.	—
<i>Stephopoma myrakeenae</i> , n. sp.	Vermetidae

*Research Fellow, Department of Earth Sciences, Academy of Natural Sciences of Philadelphia, Research Associate, Paleontological Research Institution.

†Research Associate, Department of Mollusks, Academy of Natural Sciences of Philadelphia, Research Associate, Paleontological Research Institution.

<i>Caecum (Bambusum) clenchi</i> , n. sp.	Caecidae
<i>Decipifus sixaolus</i> , n. sp.	Columbellidae
<i>Nassarina ? dubia</i> , n. sp.	—
<i>Acteocina inconspicua</i> , n. sp.	Acteocinidae
<i>Gibberula bocasensis</i> , n. sp.	Marginellidae
<i>Rosenia minibulla</i> , n. sp.	Stiliferidae
<i>Odostomia (Cbrysallida) jadisii</i> , n. sp.	Pyramidellidae
<i>Odostomia (Ivara) terryi</i> , n. sp.	—
<i>Miralda abbotti</i> , n. sp.	—
New subspecies	
<i>Olivella (Niteoliva) minuta marmosa</i> , n. subsp.	Olividae
<i>Persicula (Rabicea) adamsiana weberi</i> , n. subsp.	Marginellidae

PELECYPODA

<i>Pleuromeris micella</i> , n. sp.	Carditidae
<i>Philobrya inconspicua</i> , n. sp.	Philobryidae
<i>Crenella gemma</i> , n. sp.	Mytilidae
<i>Limatula hendersoni</i> , n. sp.	Limidae
<i>Strigilla pilsbryi</i> , n. sp.	Tellinidae
<i>Strigilla gabbi</i> , n. sp.	—
<i>Divaricella weberi</i> , n. sp.	Lucinidae

DEPOSITION OF TYPES

The holotypes of the above new species and subspecies have been placed in the collections of the Academy of Natural Sciences of Philadelphia.

Coral Gables, Fla. May 31st, 1957.

INTRODUCTION

The Republic of Panama is situated between the Caribbean Sea (west Atlantic) and the Pacific Ocean where the Central American land arch attains its narrowest width. Panama has the shape of a relatively narrow sigmoid, much elongated in an east-west direction, the two end limbs of the sigmoid, east and west Panama respectively, trend in a northwesterly direction. The main axis is uniformly high and mountainous, while the middle segment (middle Panama and the Canal Zone), with an opposite directional trend, is of much lower elevation and is composed of softer rock formations. Thus, it might seem, as if middle Panama had been designed by nature purposefully as the site for a future interoceanic ship canal.

A ridge of high land or mountains, commonly known as the Central Range extends through most of Panama and forms the principal water shed between the Atlantic and Pacific oceans. This is a region of old rocks, mostly pre-Tertiary igneous and metamorphics, intermixed with more Recent volcanics. Although the Central Range of Panama is now separated from the Colombian Andes by a wide gap forming the Atrato Valley, it is nevertheless a part of the great Andean mountain system of northwestern South America. Hence, Panama should be considered as a part of South America, its land area reduced in size by the orogenies which began in the Cretaceous and continued at intervals through the Tertiary. In the region of the Canal Zone, the continuity of the Central Range is interrupted by a fault zone forming a gap or low pass underlain by the younger and softer rocks of various Tertiary formations. The Chagres River, the source of which lies in a catchment basin on the Pacific slope, is hence able to worm its way around the ends of this mountain range to empty its waters into the northern ocean or the Caribbean. In eastern Panama, the Central Range is known as the Serrania de Darien, its highest parts situated along the Colombian border. From this point, the range continues westerly as a uniformly high ridge following close to the north coast and on the south bordered by the synclinal valleys of the Rio Tuyra, the Chucunaque, and the Bayano. The range ends rather sharply in Cerro Bruja, elevation about 934 meters (3,064.3 ft.) above Nombre de Dios near the eastern border of the Canal Zone. West of the Canal Zone, the Central Range is again renewed in the Serrania de Capira just south of the shores of Gatun Lake and from there continues steadily towards the west to attain its highest point in El Baru (Volcan de Chiriqui) of about 3400 meters near the Costa Rican border. In Costa Rica, the range is continued and bears the name of Cordillera de Talamanca.

During the Tertiary, small parts of Panama and much larger sections of Costa Rica and northwestern Colombia were submerged beneath the sea, forming straits or sea-ways which at times connected the Atlantic with the Pacific. During these periods of sea-transgression, the Caribbean and Pacific marine animals were free to intermingle, spread widely through the Caribbean and the Pacific realms, forming a single, fairly uniform fauna (Western or Atlantic Tethys). With the uplift of the Panama-Costa Rica land arch at the end of the Tertiary, the West Tethyan fauna became divided, the Pacific section remaining little modified, the Caribbean undergoing a greater change through extensive extermination of many of

the older groups and through the invasion of others from the north and east.

The marine mollusks of the Caribbean coast of Panama have received little attention from visiting naturalists and the records of the occurrence of such species in the literature are few in number. The principal reason, which must be ascribed to this conspicuous lack of interest in an important part of the Caribbean faunal region, is apparently the rarity of good collecting stations along the Caribbean coast of Panama as compared to the abundance and ready accessibility of such grounds on the Pacific side. Nearly the whole extent of the north coast of Panama from Colon to the Colombia border is a wild and inaccessible region, much of it under the strict control of the San Blas and Cuna Indians who do not encourage and rarely permit visitors within their lands; therefore, aside from a few shells obtained by tourists from the San Blas Indians, information on the marine molluscan life of eastern Panama is practically nonexistent. Limon Bay, situated at the Caribbean entrance to the Panama Canal, has yielded much interesting material but expanding harbor installations, pollution, and military zoning has greatly reduced the few places where some collecting can still be done. Mud dredged from the bay, as well as marl dug up from drainage canals at Colon (the latter generally considered as a Pleistocene deposit), has yielded most of the smaller species recorded from the Colon region.

Several small lots, consisting mostly of beach material, have been secured from stations scattered along the coast from Colon to the Chiriqui Lagoon. This is a long stretch of sandy beaches and rock ledges, the whole section exposed to a strong surf generated by the trade winds which blow strongly and steadily from the northeast for several months of the year. Travel along this belt of coastline must be made on foot, in the saddle, or in small coastal vessels which maintain an irregular schedule with a few villages. The places named Piña, Lagarto, and Salud are small villages near the west border of the Canal Zone and may be reached by automobile from Gatun. The more remote place names of Old Bess Point and Coco Plum, refer to small cocoanut plantations and can be reached from the Chiriqui Lagoon.

Our main collections, and those which gave incentive to this paper, were made along the northern and eastern shores of Bocas or Columbus Island at the northwestern entrance to the Chiriqui Lagoon. Our first Bocas collections were secured by the senior author in October 1917; others

in 1920. Our final and largest collection was obtained in March 1953 by the authors jointly when we were accompanied by Mr. Jay A. Weber of Miami, Florida. At this time, our best collecting grounds were found to be along the east side of the island, between Puss Head Point and Long Bay Point or about five to six kilometers north of the city of Bocas del Toro. This is a stretch of coraliferous limestone platform, interrupted or flanked by small sandy beaches. Much of the material collected in this zone consists of beach drift, carefully selected in the field, and which on sorting and picking proved extremely rich, especially in the smaller species. It is evident from the large number of species obtained by us in a relatively short time the Bocas fauna is unusually rich and would repay more extensive work, especially during the fall months of the years when the trade winds have subsided and some dredging could be undertaken in the open sea. In contrast to the excellent collecting found on the east side of the island, that on the lee shore, which is fringed by mangrove, proved poor, the bottom composed for the most part of a muddy sediment so charged with sponge spicules that our hands smarted as if we had handled nettles.

Bocas or Columbus Island (Isla de Colon on some maps) is one of the five main islands in the northern part of the deep, baylike gulf known as the "Chiriqui Lagoon", situated along the northwest coast of Panama near its border with Costa Rica. The island is nearly rectangular, its longer axis trending roughly North 45 degrees West, and covering about 78 sq. km. (30 square miles) in area. Hills in the interior of the island reach a maximum height of about 125 meters. To the southwest of Bocas Island, and separated from it by a narrow but deep channel used by fruit steamers entering the lagoon, is Providence or Bastimentos Island, of nearly the same size as Bocas but of an elongated, irregular form. South of Providence Island lies Popes Island, and beyond that to the southeast is Water Cay. At the southern corner of Bocas Island and connected to the main island only by a narrow neck of land (Haulover) is located the city of Bocas del Toro, the largest settlement in northwestern Panama and the capitol of the province of Bocas del Toro. The main part of Bocas Island is sparingly settled and that only with a small scattering of houses along the shore, the people engaged in fishing, some agricultural pursuits, mostly the harvesting of cocoanuts which grow so luxuriantly along the whole northeast coast of Panama and Costa Rica. In the interior, the island is rugged, due to its limestone formation, favoring the development of a sink-hole topography, the few small streams flowing on the surface for

only a short distance. A single road, built a few years ago during the course of oil exploration, is now abandoned and thickly overgrown and at the time of our visit was passable with difficulty for only half way. Bocas Island and the Chiriqui Lagoon offer much of interest to the naturalist and if future work be done, it should be extended throughout the lagoon, its many islands being accessible by small launch.

MARINE MOLLUSKS OF THE CARIBBEAN COAST OF PANAMA

Class GASTROPODA

Family SCISSURELLIDAE

Woodwardia cingulata (O. G. Costa). Bocas

Family FISSURELLIDAE

- Emarginula phrixodes* Dall. Bocas
Emarginula pumila (A. Adams). Bocas
Puncturella cf. *sportella* Watson. Bocas
Hemitoma octoradiata (Gmelin). Bocas, Colon
Phenacolepas hamillei (Fischer). Bocas, Colon
Hyalopatina rusbi Dall. Bocas
Diodora arcuata (Sowerby). Bocas, Colon
Diodora cayenensis (Lamarck). Bocas, Colon
Diodora dysoni (Reeve). Bocas, Colon
Diodora fargoii Olsson & McGinty, n. sp. Bocas, Colon
Diodora listeri (d'Orbigny). Bocas, Colon
Diodora minuta variegata (Sowerby). Bocas
Diodora sayi (Dall). Bocas
Diodora viridula (Lamarck). Bocas
Lucapina philippiana (Finlay). Bocas
Lucapina suffusa (Reeve). Bocas, Colon
Lucapina suffusa tobagoensis Farfante. Colon
Lucapinella limatula (Reeve). Bocas
Fissurella fascicularis Lamarck. Bocas
Fissurella angusta (Gmelin). Bocas, Colon
Fissurella barbadensis (Gmelin). Bocas, Colon
Fissurella barbouri Farfante. Bocas, Colon
Fissurella nodosa (Born). Bocas
Fissurella rosea (Gmelin). Bocas, Colon

Family ACMAEIDAE

- Acmaea antillarum* (Sowerby). Colon
Acmaea antillarum (Sowerby) subsp. Colon
Acmaea cubensis (Reeve). Bocas, Colon
Acmaea jamaicensis (Gmelin). Bocas, Colon
Acmaea pustulata (Helbling). Bocas, Colon

Family TROCHIDAE

- Calliostoma jujubinum* (Gmelin). Bocas, Colon
Calliostoma pulcher (C. B. Adams). Bocas
Calliostoma zonamestum (A. Adams). Colon
Livona pica (Linné). Bocas, Colon

- Tegula fasciata* (Born). Bocas
Tegula viridula (Gmelin). Colon
Haplocobliis swifti Vanatta. Bocas, Colon
Parviturbo rebderi Pilsbry & McGinty. Bocas
Synaptocochlea picta (d'Orbigny). Bocas

Family **TURBINIDAE**

- Turbo filosus* (Wood). Almirante
Cyclostrema cancellatum Marrayat. Bocas
Arene bileri Olsson & McGinty, n. sp. Bocas
Arene brasiliiana (Dall). Bocas, Almirante
Arene miniata (Dall). Bocas
Arene riisei Rehder. Bocas, Almirante
Astraea americana (Gmelin). Bocas
Astraea longispina (Lamarck). Bocas, Colon
Astraea caelata (Gmelin). Bocas, Colon

Family **COLLONIIDAE**

- Collonia?* sp. Bocas

Family **PHASIANELLIDAE**

- Tricolia adamsi* (Philippi). Bocas, Colon
Tricolia affinis cruenta Robertson. Bocas, Colon
Tricolia bella (M. Smith). (*pulchellus* C. B. Adams). Bocas, Colon
Tricolia tessellata (Potiez & Michaud). Bocas, Colon

Family **NERITIDAE**

- Nerita fulgurans* Gmelin. Bocas, Colon
Nerita peloronta Linné. Colon
Nerita tessellata Gmelin. Bocas
Nerita versicolor Gmelin. Bocas, Colon
Neritina virginea (Linné). Bocas, Colon
Neritina zebra (Bruguère). Bocas
Smaragdia viridis (Linné). Bocas, Colon
Smaragdia viridis viridemaris Maury. Bocas

Family **LITTORINIDAE**

- Littorina angulifera* (Lamarck). Bocas
Littorina meleagris (Potiez & Michaud). Bocas, Colon
Littorina nebulosa (Lamarck). Bocas, Colon
Littorina nebulosa tessellata Philippi. Bocas, Colon
Littorina ziczac (Linné). Bocas, Colon
Nodilittorina tuberculata (Menke). Bocas, Colon
Tectarius muricatus (Linné). Bocas

Family **TRUNCATELLIDAE**

- Truncatella bilabiata* Pfeiffer. Bocas
Truncatella scalaris (Michaud). Bocas, Colon

Family **SYNCERATIDAE**

- Syncera* sp. Bocas

Family **RISSOIDAE**

- Alvania aberrans* (C. B. Adams). Bocas
Alvania auberiana (d'Orbigny). Bocas, Colon
Alvania chiriquiensis Olsson & McGinty, n. sp. Bocas
Rissoa toroensis Olsson & McGinty, n. sp. Bocas
Rissoina albida (C. B. Adams). Bocas
Rissoina browniana d'Orbigny. Bocas, Colon
Rissoina bryerea (Montagu). Bocas, Colon

- Rissoina cancellata* Philippi. Bocas, Colon
Rissoina chesneli Michaud. Bocas, Colon
Rissoina decussata (Montagu). Bocas, Almirante, Colon
Rissoina elegantissima d'Orbigny. Bocas, Colon
Rissoina fischeri Desjardin. Bocas
Microdochus floridanus Rehder. Bocas
Nodulus megalomastomus Olsson and McGinty, n. sp. Bocas

Family **VITRINELLIDAE**

- Vitrinella blakei* Rehder. Bocas
Vitrinella elegans Olsson & McGinty, n. sp. Bocas
Vitrinella helicoidea C. B. Adams. Bocas
Vitrinella multistriata Verrill. Bocas
Vitrinella praecox Pilsbry & McGinty, Bocas
Vitrinella semisculpta Olsson & McGinty, n. sp. Bocas
Vitrinella terminalis Pilsbry & McGinty. Bocas
Teinostoma carinicollis Pilsbry & McGinty. Bocas
Teinostoma diaphana (d'Orbigny). Bocas
Teinostoma goniogyrus Pilsbry & McGinty. Bocas
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Cyclostremiscus jeannae Pilsbry & McGinty. Bocas, Colon
Cyclostremiscus ornatus Olsson and McGinty, n. sp. Bocas
Cyclostremiscus pulchellus Olsson & McGinty, n. sp. Bocas
Cyclostremiscus schrammi (Fischer). Bocas, Colon
Vitrinorbis elegans Olsson & McGinty, n. sp. Bocas
Solariorbis bartschi (Vanatta). Bocas
Solariorbis corylus Olsson & McGinty, n. sp. Bocas, Colon
Solariorbis decipiens Olsson & McGinty, n. sp. Bocas
Macromphalina pilsbryi Olsson & McGinty, n. sp. Bocas
Macromphalina sp. Bocas
Macromphalina sp. Bocas
Episcynia multicarinata Dall. Colon

Family **TURRITELLIDAE**

- Turritella* sp. Bocas

Family **ARCHITECTONICIDAE**

- Architectonica nobilis* Röding (*granulata* Lamarck). Colon
Torinia bisulcata (d'Orbigny). Bocas, Colon
Torinia cylindrica (Gmelin). Bocas, Almirante, Colon
Torinia infundibuliforme (Gmelin). Bocas, Almirante, Colon
Spirolaxis exquisita (Dall & Simpson). Bocas

Family **VERMETIDAE**

- Petalocoenobus nigricans* Dall. Bocas
Spiroglyphus sp. Bocas
Stephopoma myrakeenae Olsson & McGinty, n. sp. Bocas, Colon

Family **CAECIDAE**

- Caecum floridanum* Stimpson. Bocas, Colon
Caecum pulchellum Stimpson. Bocas, Colon

- Caecum* sp. Bocas
Caecum sp. Bocas
Caecum imbricatum Carpenter. Bocas, Colon
Caecum clenchi Olsson & McGinty, n. sp. Bocas
Caecum nebulosum Rehder. Bocas, Colon
Caecum sp. Bocas
Meioceras nitidum (Stimpson). Bocas, Colon

Family **PLANAXIDAE**

- Planaxis lineatus* (da Costa). Bocas, Colon
Planaxis nucleus (Bruguière). Bocas, Colon

Family **MODULIDAE**

- Modulus carchedonius* (Lamarck). Colon, Almirante
Modulus modulus (Linné). Almirante

Family **POTAMIDIDAE**

- Cerithidea scalariformis* (Say). Bocas

Family **CERITHIIDAE**

- Cerithium algicola* C. B. Adams. Bocas, Almirante, Colon
Cerithium eburneum Bruguière. Bocas, Colon
Cerithium floridanum Mörch. Bocas, Colon
Cerithium litteratum Born. Bocas, Colon
Cerithium variable C. B. Adams, Bocas, Colon
Batillaria minima (Gmelin). Bocas, Colon
Bittium cerithioides Dall. Bocas, Colon
Bittium varium (Pfeiffer). Bocas, Colon
Alaba incerta (d'Orbigny) (*terraricosa* C. B. Adams). Bocas, Colon
Litiopa melanostoma Rang. Bocas, Colon
Cerithiopsis abrupta Watson. Bocas
Cerithiopsis greeni (C. B. Adams). Bocas, Colon
Cerithiopsis rugulosum (C. B. Adams). Bocas
Cerithiopsis ricola Dall & Bartsch. Bocas
Cerithiopsis emersoni? (C. B. Adams). Bocas, Colon
Cerithiopsis sp. Bocas
Seila adamsi (H. C. Lea). Bocas, Colon

Family **TRIPHORIDAE**

- Triphora decorata* (C. B. Adams). Bocas
Triphora modesta (C. B. Adams). Bocas
Triphora ornata Deshayes. Bocas, Colon
Triphora turrishomae Dillwyn. Bocas

Family **JANTHINIDAE**

- Janthina janthina* (Linné). Bocas, Colon

Family **EPITONIIDAE**

- Opalia crenata* (Linné). Bocas
Opalia hotessieriana (d'Orbigny). Bocas, Colon
Opalia pumilio (Mörch). Bocas
Opalia pumilio morchiana (Dall). Bocas, Colon
Epitonium albidum (d'Orbigny). Bocas, Colon
Epitonium candeanum (d'Orbigny). Bocas, Colon
Epitonium echinaticostum (d'Orbigny). Bocas
Epitonium foliaceicostum (d'Orbigny). Bocas

- Epitonium georgettina* (Kiener). Bocas, Colon
Epitonium krebsi (Mörch). Bocas
Epitonium lamellosum (Lamarck). Bocas
Epitonium unifasciatum (Sowerby). Bocas

Family **ACLIDIDAE**

- Aclis* sp. Bocas, Colon
Schwengelia sp. Bocas

Family **MELANELLIDAE**

- Strombiformis bilineata* Alder. Bocas, Colon
Strombiformis sp. Bocas
Melanella arcuata (C. B. Adams). Bocas
Melanella intermedia (Contraire). Bocas, Colon
Melanella sp. Bocas

Family **STILIFERIDAE**

- Rosenia minibulla* Olsson & McGinty, n. sp. Bocas

Family **PYRAMIDELLIDAE**

- Odostomia abbotti* Olsson & McGinty, n. sp. Bocas, Colon
Odostomia bisuturalis Say. Bocas
Odostomia gemmulosa C. B. Adams. Bocas
Odostomia baranensis Pilsbry & Aguayo. Bocas
Odostomia jadisii Olsson & McGinty, n. sp. Bocas, Colon
Odostomia laevigata (d'Orbigny). Bocas
Odostomia terryi Olsson & McGinty, n. sp. Bocas
Odostomia sp. Bocas
Athleenia burryi Bartsch. Bocas
Triptychus nireus (Mörch). Bocas
Turbonilla pupoides (d'Orbigny). Bocas
Turbonilla sp. Bocas, Colon
Pyramidella candida Mörch. Bocas
Sayella sp. Bocas

Family **HIPPONICIDAE**

- Cheilea equestris* (Linné). Bocas, Colon
Hipponix antiquatus (Linné). Bocas, Colon
Hipponix floridanus Olsson & Harbison. Bocas
Hipponix subrufus (Lamarck). Bocas, Colon

Family **CALYPTRAEIDAE**

- Calyptraea centralis* (Conrad). Bocas
Crepidula convexa Say subsp. Bocas, Colon

Family **XENOPHORIDAE**

- Xenophora conchyliophora* (Born). Lagarto, Colon

Family **STROMBIDAE**

- Strombus gigas* Linné. Bocas, Colon
Strombus pugilis Linné. Bocas
Strombus vaninus Gmelin. Bocas, Colon

Family **LAMELLARIIDAE**

- Lamellaria pellucida* Verrill. Bocas

Family **FOSSARIDAE**

- Fossarus orbigny* Fischer. Bocas, Colon
Iselica anomala (C. B. Adams). Bocas

Family **ERATOIDAE**

- Erato maugeriae* Gray. Bocas, Colon
Trivia pediculus (Linné). Bocas
Trivia quadrivittata (Gray). Bocas

Family **CYPRAEIDAE**

- Cypraea cinerea* Gmelin. Bocas, Colon
Cypraea spurca acicularis Gmelin. Bocas, Colon
Cypraea zebra Linné (*exanthema* Linné). Bocas, Largarto, Coco Plum, Colon

Family **OVULIDAE**

- Cyphoma gibbosum* (Linné). Bocas
Neosimnia uniplicata (Sowerby). Colon

Family **NATICIDAE**

- Polinices hepaticus* (Röding) (*brunneus* Link). Bocas
Polinices lacteus (Guilding). Bocas, Colon
Natica cauvana (Linné). Bocas, Colon
Natica livida Pfeiffer. Bocas, Colon
Natica pusilla Say. Bocas
Glyphepithema floridana Rehder. Colon

Family **CASSIDIDAE**

- Morum oniscus* (Linné). Bocas, Colon
Phalium granulatum (Born). Bocas, Colon
Cassis tuberosa (Linné). Bocas
Cypraecassis testiculus (Linné). Bocas, Colon

Family **CYMATIIDAE**

- Cymatium femorale* (Linné). Colon
Cymatium nicobaricum (Röding) (*chlorostomum* Lk.). Colon
Cymatium paribenopeum (von Salis) (*costatum* Born). Bocas
Cymatium martinianum (d'Orbigny) (*Dissentoma prima* Pils.). Bocas, Colon
Cymatium muricinum (Röding) (*tuberosum* Lk.). Colon
Cymatium gemmatum (Reeve) (*gracile* of authors). Bocas, Colon
Cymatium caribbaeum Clench & Turner (formerly *cynocephalum*). Bocas, Colon
Charonia variegata (Lamarck) (*nobilis* Conrad). Bocas, Colon
Distorsio clathrata (Lamarck). Colon

Family **BURSIDAE**

- Bursa cubaniana* (d'Orbigny). Bocas, Colon
Bursa spadicea (Montfort). Colon

Family **TONNIDAE**

- Tonna maculosa* (Dillwyn). Bocas, Colon

Family **MURICIDAE**

- Murex pomum* Gmelin. Bocas, Colon
Murex woodringi Clench & Farfante. Almirante, Colon
Murex intermedia C. B. Adams. Bocas
Murex mcgintyi (M. Smith). Bocas
Typhis cancellatus (Sowerby). Bocas
Muricopsis hexagona (Lamarck). Bocas
Urosalpinx cinerea (Say). Almirante
Urosalpinx ferrugata (Conrad). Bocas
Aspella anceps (Lamarck). Bocas
Aspella elizabethae McGinty. Bocas
Aspella paupercula (C. B. Adams). Bocas
Drupa didyma Schwengel. Bocas

- Drupa nodulosa* (C. B. Adams). Bocas, Almirante, Colon
Risomurex schrammi (Crosse). Bocas, Colon
Risomurex muricoides (C. B. Adams). Bocas, Almirante, Colon
Purpura patula (Linné). Colon
Thais haemastoma floridana (Conrad). Bocas, Colon
Thais rustica (Lamarck). Bocas, Colon
Thais trinitatis (Guppy). Colon
Thais deltoidea (Lamarck). Bocas, Colon

Family **MAGILIDAE**

- Coralliophila aberrans* (C. B. Adams). Bocas
Coralliophila plicata (Wood). Bocas
Coralliophila mansfieldi McGinty. Bocas

Family **COLUMBELLIDAE**

- Pyrene ovulata* (Lamarck). Bocas
Columbella mercatoria (Linné). Bocas, Colon
Nitidella argus (d'Orbigny). Bocas, Colon
Nitidella laerigata (Linné). Bocas, Colon
Nitidella moleculina Duclos. Bocas
Nitidella nitidula (Sowerby). Bocas, Colon
Nitidella ocellata (Gmelin). Bocas
Anachis catenata? Sowerby. Almirante, Bocas, Colon
Anachis obesa (C. B. Adams). Bocas, Colon
Anachis varia (Sowerby). Bocas, Colon
Decipifus pulchellus (C. B. Adams). Bocas
Decipifus sixaolus Olsson and McGinty, n. sp. Bocas
Mitrella albella (C. B. Adams). Almirante, Colon
Mitrella fusiformis (d'Orbigny). Bocas
Mitrella lunata Say. Bocas, Colon
Mazatlania aciculata (Lamarck). Bocas
Nassarina glypta (Bush). Bocas, Colon
Nassarina maculata (C. B. Adams). Bocas
Nassarina? dubia Olsson & McGinty, n. sp. Bocas
Psarostola monilifera (Sowerby). Bocas, Colon

Family **BUCCIDAE**

- Bailya intricata* (Dall). Bocas, Almirante, Colon
Antillophos adelus Schwengel. Bocas
Engina turbinella Kiener. Bocas, Colon
Colubraria testacea (Mörch). Colon
Pisania pusio (Linné). Bocas, Colon
Monostiolum swifti (Tryon). Bocas
Cantharus auritulus (Link). Bocas
Cantharus tinctus (Conrad). Bocas

Family **MELONGENIDAE**

- Melongena melongena* (Linné). Bocas, Colon

Family **NASSARIIDAE**

- Nassarinus albus* (Say) (*ambiguus* Pulteney). Bocas, Almirante
Nassarinus albus consensus (Ravenel). Bocas, Colon
Nassarinus vibex (Say). Bocas, Almirante, Colon

Family **FASCIOLARIIDAE**

- Fasciolaria tulipa* (Linné). Bocas, Colon
Leucozonia nassa (Gmelin). Bocas, Colon
Leucozonia ocellata (Gmelin). Bocas

- Latirus brevicaudatus* (Reeve). Bocas
Latirus mcgintyi Pilsbry. Bocas
Fusilaturus cayohuesonicus (Sowerby). Bocas

Family **TURBINELLIDAE**

- Turbinella angulatus* (Solander). Bocas
Vasum mucicatum (Born). Bocas, Colon

Family **OLIVIDAE**

- Oliva reticularis* Lamarck. Bocas
Jaspidella blanesi (Ford). Bocas
Agaronia testacea (Lamarck). Bocas
Olivella bullula Reeve. Bocas
Olivella chiriquiensis Olsson. Bocas
Olivella minuta marmosa Olsson & McGinty, n. subsp.. Bocas, Colon
Olivella myrmecoön Dall. Colon

Family **MITRIDAE**

- Mitra barbadensis* Gmelin. Colon
Mitra nodulosa Gmelin. Bocas, Almirante, Colon
Mitra straminea A. Adams. Bocas
Mitra albocincta C. B. Adams. Bocas
Mitra dermestina Lamarck (*albicostata* C. B. Adams). Bocas, Almirante, Colon
Mitra banleyi (Dohrn). Bocas
Mitra banleyi gemmata Sowerby. Bocas, Colon
Mitra moisei McGinty. Bocas
Mitra puella Reeve. Bocas

Family **VOLUTIDAE**

- Voluta virescens* Solander. Colon
Enaeta reevei Dall. Bocas

Family **MARGINELLIDAE**

- Marginella aureocincta* Stearns. Bocas
Marginella cincta? Kiener. Bocas, Coco Plum
Marginella guttata Dillwyn. Bocas
Marginella isabelae Borro. Bocas
Marginella oblonga Swainson. Bocas, Colon
Persicula adamsiana weberi Olsson & McGinty, n. subsp. Bocas, Colon
Persicula catenata (Montagu). Bocas
Persicula lavalleana (d'Orbigny). Bocas
Persicula sp. Bocas, Colon
Gibberula bocasensis Olsson & McGinty, n. sp. Bocas, Colon
Hyalina albolineata (d'Orbigny). Bocas
Hyalina arena Valenciennes. Bocas, Almirante
Hyalina avena beyerleana Bern. Bocas, Colon
Hyalina pellucida Schumacher. Bocas

Family **CONIDAE**

- Conus largillierti* Kiener. Colon
Conus mus Hwass. Bocas, Colon
Conus regius Gmelin. Bocas
Conus regius cardinalis Hwass. Bocas
Conus spurius atlanticus Clench. Colon
Conus verrucosus Hwass. Bocas, Colon

Family **TEREBRIDAE**

- Terebra taurinum* Solander (*flammea* Lamarck). Colon
Terebra hastata Gmelin. Bocas

Terebra salleana Deshayes. Bocas, Colon
Terebra protexta Conrad. Bocas

Family **TURRIDAE**

Crassispira barfordiana (Reeve). Bocas, Almirante, Colon
Crassispira sp. Bocas
Drillia elatior C. B. Adams. Bocas
Carinodrillia interpleura (Dall & Simpson). Bocas
Monilispira albinodata (Reeve). Bocas
Monilispira albocincta (C. B. Adams). Bocas
Monilispira jayana (C. B. Adams). Bocas
Monilispira leucocyma (Dall). Bocas, Almirante, Colon
Monilispira sp. Bocas, Colon
"Pleurotoma" flavocincta C. B. Adams. Bocas
"Pleurotoma" fusiformis C. B. Adams. Bocas
Ibicythara muricoides (C. B. Adams). Bocas
Pyrgocythara albovittata (C. B. Adams). Bocas
Vitricythara metria (Dall). Colon
Brachycythara biconica (C. B. Adams). Almirante, Colon
"Mangelia" candidissima C. B. Adams. Bocas
"Mangelia" plicosa (C. B. Adams). Bocas, Almirante
"Mangelia" sp. Bocas
Glyphoturris diminuta (C. B. Adams). Bocas
Kurtziella quadrilineata (C. B. Adams). Bocas
Nannodiella melantica (Dall). Bocas, Colon

Family **ACTEONIDAE**

Acteon punctostriatus (C. B. Adams). Bocas

Family **HYDATINIDAE**

Micromelo undata (Bruguière). Bocas, Colon

Family **BULLIDAE**

Bulla occidentalis A. Adams. Bocas, Almirante

Family **ATYDAE**

Alys caribaea (d'Orbigny). Bocas
Alys sandersoni Dall. Bocas
Haminoea glabra A. Adams. Bocas

Family **RETUSIDAE**

Retusa sulcata (d'Orbigny). Bocas
Rhizorus acutus (d'Orbigny). Bocas
Rhizorus oxytatus (Bush). Bocas, Colon

Family **ACTEOCINIDAE**

Acteocina candei (d'Orbigny). Bocas, Colon
Acteocina inconspicua Olsson & McGinty, n. sp. Bocas
Cylichna bidentata (d'Orbigny). Colon

Family **PHILINIDAE**

Philina sagra (d'Orbigny). Bocas

Family **CAVOLINIDAE**

Creseis acicula Rang. Bocas

Family **OXYNOIDAE**

Oxynoe antillarum Mörch. Bocas

Family **ELLOBIIDAE**

- Pedipes mirabilis* (Mühlfeld). Bocas
Tralia pusila (Gmelin). Bocas
Melampus flavus (Gmelin). Bocas
Blauneria heteroclita (Montagu). Colon

Family **GADINIIDAE**

- Gadinia carinata* Dall. Bocas

Family **SIPHONARIIDAE**

- Williamia krebsi* (Mörch). Bocas

Class PELECYPODA

Family **NUCULIDAE**

- Nucula crenulata* A. Adams. Bocas, Colon
Nucula proxima Say. Bocas, Colon

Family **NUCULANIDAE**

- Nuculana acuta* (Conrad). Almirante, Coco Plum, Colon
Nuculana vulgaris Pilsbry & Brown. Colon
Yoldia perprotracta Dall. Bocas, Colon

Family **ARCIDAE**

- Arca umbonata* Lamarck. Bocas, Colon
Arca zebra Swainson. Bocas, Colon
Barbatia cancellaria (Lamarck). Bocas, Almirante
Barbatia candida (Helbling). Bocas
Barbatia domingensis (Lamarck). Bocas, Colon
Barbatia tenera (C. B. Adams). Bocas, Colon
Arcopsis adamsi (E. A. Smith). Bocas, Almirante, Colon
Anadara chemnitzii (Philippi). Bocas, Colon
Anadara notabilis (Röding). Bocas
Anadara transversa (Say). Bocas
Noetia bisulcata (Lamarck). Bocas, Colon

Family **GLYCYMERIDAE**

- Glycymeris spectralis* Nicol. Bocas

Family **MYTILIDAE**

- Crenella divaricata* (d'Orbigny). Bocas
Crenella gemma Olsson & McGinty, n. sp. Bocas
Brachidontes citrinus (Röding). Bocas
Brachidontes exustus (Linné). Bocas, Colon
Musculus lateralis (Say). Bocas
Gregariella opifex (Say). Bocas

Family **PHILOBRYIDAE**

- Philobrya inconspicua* Olsson and McGinty, n. sp. Bocas

Family **ISOGNOMONIDAE**

- Isognomon alatus* (Gmelin). Bocas
Isognomon bicolor (C. B. Adams). Bocas

Family **PTERIIDAE**

- Pinctata radiata* (Leach). Bocas

Family **PLICATULIDAE**

- Plicatula gibbosa* Lamarck. Bocas
Plicatula penicillata Carpenter. Bocas

Family **PECTINIDAE**

- Pecten ziczac* (Linné). Almirante, Colon
Aequipecten muscosus (Wood). Almirante, Colon
Cblamys imbricatus (Gmelin). Colon
Cblamys mildredae Bayer. Bocas
Cblamys sentis (Reeve). Bocas, Coco Plum, Colon
Lyropecten antillarum (Recluz). Colon

Family **SPONDYLIDAE**

- Spondylus americanus* Hermann. Bocas, Almirante, Coco Plum

Family **LIMIDAE**

- Lima lima* (Linné). Bocas
Lima scabra (Born). Bocas, Colon
Lima tenera Sowerby. Bocas
Lima pellucida C. B. Adams. Bocas
Limatula hendersoni Olsson & McGinty, n. sp. Bocas

Family **OSTREIDAE**

- Ostrea frons* Linné. Bocas
Ostrea rhizophorae Guilding. Bocas, Colon

Family **CRASSATELLIDAE**

- Crassinella guadalupensis* (d'Orbigny). Bocas, Almirante, Colon

Family **CARDITIDAE**

- Cardita gracilis* Shuttleworth. Bocas, Colon
Pleuromeris micella Olsson & McGinty, n. sp. Bocas

Family **CONDYLOCARDIIDAE**

- Carditopsis bernardi* Dall. Bocas, Colon
Carditopsis smithi (Dall). Bocas, Colon

Family **TRAPEZIIDAE**

- Coralliophaga coralliophaga* (Gmelin). Almirante

Family **DREISSENIDAE**

- Mytilopsis leucopheata* Conrad. Bocas, Colon
Mytilopsis zeteki Hertlein & Strong. Colon

Family **DIPLODONTIDAE**

- Diplodonta semiaspera* Philippi. Bocas, Colon
Diplodonta soror (C. B. Adams). Bocas, Almirante, Coco Plum, Colon

Family **LUCINIDAE**

- Lucina pensylvanica* (Linné). Bocas
Lucina trisulcata Conrad. Bocas
Lucina multilineata Tuomey & Holmes. Bocas
Lucina leucocyma Dall. Bocas
Phacoides pectinatus (Gmelin) (*jamaicensis* Lamarck). Bocas, Colon
Phacoides muricatus (Spengler). Bocas, Almirante
Phacoides radians (Conrad). Bocas
Anodontia alba Link (*chrysostoma* Philippi). Bocas, Colon
Codakia orbiculata (Montagu). Bocas, Colon

- Codakia orbiculata filata* Dall. Bocas, Almirante
Codakia orbicularis (Linné). Bocas
Codakia pectinella (C. B. Adams). Bocas, Almirante
Divaricella quadriscutata (d'Orbigny). Bocas, Coco Plum, Colon
Divaricella weberi Olsson & McGinty, n. sp. Bocas, Coco Plum, Colon

Family **CHAMIDAE**

- Chama congregata* Conrad. Bocas
Chama florida Lamarck. Bocas
Chama macerophylla Gmelin. Bocas
Pseudochama radians (Lamarck). Bocas

Family **LEPTONIDAE**

- Lepton* sp. Bocas
Montacuta floridana Dall. Bocas

Family **CARDIIDAE**

- Trachycardium muricatum* (Linné). Bocas, Colon
Trigoniocardia ceramidum (Dall). Bocas, Colon
Trigoniocardia medium (Linné). Bocas
Laericardium laerigatum (Linné). Bocas, Colon
Papyridea semisulcatum (Gray). Bocas
Papyridea soleniforme (Bruguière). Bocas

Family **VENERIDAE**

- Chione cancellata* (Linné). Bocas, Almirante, Colon
Chione granulata (Gmelin). Bocas
Chione paphia (Linné). Bocas
Chione pinchoti Pilsbry & Olsson. Colon
Anomalocardia brasiliiana (Gmelin). Bocas, Colon
Tivela mactroides (Born). Bocas, Colon
Transennella cubaniana (d'Orbigny). Bocas
Pitar subaresta (Dall). Almirante, Colon
Pitar circinata (Born). Bocas, Colon
Pitar dione (Linné). Bocas, Colon
Gouldia cerina (C. B. Adams). Bocas, Almirante, Colon
Macrocallista maculata (Linné). Bocas

Family **PETRICOLIDAE**

- Petricola lapicida* (Gmelin). Bocas, Almirante, Colon
Rupellaria typica (Jonas). Colon

Family **TELLINIDAE**

- Tellina listeri* Röding (*interrupta* Wood). Bocas
Tellina promera Dall. Bocas
Tellina tampaensis Conrad. Almirante
Tellina versicolor DeKay. Bocas, Colon
Tellina alternata Say. Bocas, Colon
Tellina angulosa Gmelin. Bocas, Coco Plum
Tellina lineata Turton. Bocas, Coco Plum, Colon
Tellina martinicensis d'Orbigny. Colon
Tellina fausta Pulteney. Bocas
Macoma brevifrons (Say). Bocas, Almirante, Colon
Strigilla carnaria (Linné). Bocas, Coco Plum
Strigilla gabbi Olsson & McGinty, n. sp. Bocas, Colon
Strigilla pilsbryi Olsson & McGinty, n. sp. Bocas
Strigilla pisiformis (Linné). Bocas, Colon
Strigilla producta Tryon. Colon

Family **SEMELIDAE**

- Semele proficua* (Pulteney). Colon
Semele nuculoides (Conrad). Bocas, Colon
Cumingia coarctata Sowerby. Bocas

Family **DONACIDAE**

- Donax denticulata* Linné. Bocas
Donax striata Linné. Bocas
Ipbigenia brasiliensis (Lamarck), Rio Biarra, Chiriqui Lagoon

Family **SANGUINOLARIIDAE**

- Sanguinolaria cruenta* (Solander). Bocas, Water Key, Coco Plum
Asaphis deflorata (Linné). Bocas
Tagelus divisus (Spengler). Bocas
Tagelus plebeius (Solander). Bocas

Family **SOLENIIDAE**

- Solecurtus cumingiannus* Dunker. Coco Plum

Family **MACTRIDAE**

- Maetra alata* Spengler. Bocas, Colon
Maetra fragilis Gmelin. Bocas, Colon

Family **CORBICULIDAE**

- Neocyrena* sp. Old Bess Point, Coco Plum

Family **MESODESMATIDAE**

- Ervilia concentrica* Gould. Bocas
Ervilia rostratula Rehder. Bocas, Colon

Family **MYACIDAE**

- Sphenia antillensis* Dall & Simpson. Bocas

Family **CORBULIDAE**

- Corbula aequivalvis* Philippi. Almirante, Colon
Carycorbula blandiana (C. B. Adams). Bocas
Carycorbula disparilis (d'Orbigny). Bocas
Juliacorbula knoxiana (C. B. Adams). Almirante

Family **GASTROCHAENIDAE**

- Rocellaria stimpsoni* Tryon. Bocas

Family **PHOLADIDAE**

- Pholas campechiensis* Gmelin. Colon
Martesia cuneiformis (Say). Colon
Martesia striata (Linné). Colon

Family **PANDORIDAE**

- Pandora* sp. Bocas

Family **THRACIIDAE**

- Thracia distorta* (Montagu). Bocas

Family **PERIPLOMATIDAE**

- Periploma inaequalvis* Schumacher. Almirante, Coco Plum

Family **VERTICORDIIDAE**

- Verticordia ornata* (d'Orbigny). Bocas, Colon

Family **CUSPIDARIIDAE**

- Cardiomya costellata* (Deshayes). Colon

Class AMPHINEURA

Family ISCHNOCHITONIDAE

- Ischnochiton limaciformis* (Sowerby). Bocas
Ischnochiton pectinatus (Sowerby). Bocas, Colon
Ischnochiton shuttleworthianus Pilsbry. Bocas

Family CHITONIDAE

- Chiton marmoratus* Gmelin. Bocas
Chiton tuberculatus Linné. Bocas
Chiton vividis Spengler. Colon
Acanthopleura granulata (Gmelin). Colon

Family ACANTHOCHITONIDAE

- Acanthochitona bembilli* Pilsbry. Colon

Class SCAPHOPODA

Family DENTALIIDAE

- Dentalium texasianum* Philippi. Colon
Dentalium disparile d'Orbigny. Almirante

Family SIPHONODENTALIIDAE

- Cadulus nitidus* Henderson. Colon
Cadulus quadridentatus acompsus Henderson. Bocas, Colon

Class CEPHALOPODA

Family SPIRULIDAE

- Spirula spirula* (Linné). Bocas, Colon

Total number of species and subspecies 534.

DESCRIPTION OF NEW SPECIES

Class GASTROPODA

Family FISSURELLIDAE

Genus *Diodora* Gray. 1821

Type species by monotypy, *Patella apertura* Montagu [= *Diodora graeca* (Linné)].

***Diodora fargoi*, new species**

Pl. 2, figs. 4, 4a, 4b

Shell small (length, 8.6 mm., height, 4.15 mm.), short, conic, the length nearly twice the height, fairly solid, the bluntly truncated apex perforated by an oblong or slightly trilobate orifice placed in the anterior one-third. The longer posterior slope is noticeably arched or convex, the shorter anterior slope nearly straight and steep. Basal margin is oblong-ovate, not quite flat, the middle zone being weakly concave, the anterior end slightly narrowed, the sides nearly straight, the marginal edge coarsely serrated by the projecting ends of the ribs in an alternating manner, the

ends of the ribs internally fluted. The sculpture is cancellated or latticed by intersecting coarse, radial riblets and coarse, concentric threads arranged symmetrically, with nine primary ribs on each side (total 18), the details of which are as follows: the primary ribs are coarse, high, narrow, and rather widely spaced, with a similar but much smaller secondary riblet in the middle of each interspace and in addition with two or three much smaller tertiary radial threads lying in each section of the divided main interspace; the concentric threads are developed in two strengths, a large, coarse, primary set of narrow, flangelike ridges which bridge across the primary interspaces (about 10 in number), packed close together on the apical section, wider and more regularly spaced towards the base, and a set of much finer, concentric threads cutting across radial ribs forming small nodes. At the intersection of the primary ribs and the concentrics, the resulting nodes are high and sharp. External color is a cream or light, greenish gray, mottled irregularly with black, the secondary riblets are often black. Internally, the callus around the orifice is quite large, sharply truncated on the posterior end, white or gray, the transmitted images of the primary ribs and concentrics showing as narrow, white bars and their intervals as interrupted black lines.

Holotype, length, 8.6 mm.; height, 4.5 mm.; width, 5.5 mm. ANSP 211878. Bocas Island.

This species differs from juvenile specimens of *D. listeri* (d'Orbigny) by its higher, more conic form, smaller, oblong orifice and finer sculpture, there being a greater difference in size between the primary and secondary riblets. *D. alta* (C. B. Adams) from the Pacific Coast of Panama is quite close to our species, but there are differences in sculptural details.

Four specimens of this interesting species are known to us.

We are naming this fine species in honor of the late Mr. William G. Fargo, a distinguished engineer and naturalist.

Genus **Puncturella** Lowe, 1827

Type species by monotypy, *Patella noachina* Linné.

Puncturella cf. **sportella** Watson

Pl. 2, fig. 7

Puncturella sportella Watson, 1883, Jour. Linn. Soc. London, vol. 17, p. 37; Watson, 1886, Challenger Report, vol. 15, part 42, Report on the Scaphopoda and Gasteropoda, p. 45, pl. 4, fig. 9. (Off Saint Thomas, north of Culebra Island, West Indies.)

Shell small, solid, with a stout, conic, caplike shape, the anterior slope nearly straight, the posterior with a small hump in the middle. The base

is ovate-elliptical with straight and parallel sides and semicircular ends. The apical whorls show a small reclining coil on the posterior side and in front of it a round orifice; in larger specimens, the apex is lost, only a stumplike base remains. The surface is much worn in all our specimens, but the original sculpture was probably coarsely reticulated with a meshlike net in which the radials and concentrics appear to have been of about equal strength; there are about 40 radial riblets all round, not quite equal in strength on the sides, crossed or intersected by about nine concentric cords.

Measurement of the largest specimen, length, 1.96 mm., height, 1.37 mm.

This shell seems closely related to *P. sportella* Watson, but our identification is tentative, pending the discovery of more perfectly preserved specimens. Our specimens are all small, probably not mature, and all much worn. The Bocas shell agrees fairly well with Watson's species by its oval-elliptical base, the two ends with an equal semicircular curve, but its surface sculpture was probably much coarser. Farfante's figures of *sportella* in Johnsonia (1947, vol. 2, No. 24) do not agree with our specimens in any way.

Bocas Island.

Family LIOTIIDAE

Genus **Arene** H. and A. Adams, 1854

Type species by subsequent designation, Woodring, 1928, *Turbo cruentatus* Megerle von Mühlfeld (*Delphinula radiata* Kiener).

Subgenus **Marevalvata** Olsson and Harbison, 1953

Type species by original designation, *Architectonica tricarinata* Stearns.

Arene (Marevalvata) bitleri, new species Pl. 2, fig. 9

The shell resembles a small *Turbo* (greater diameter 4.2 mm.), with solid, rounded whorls and a low spire. Whorls about four, the nuclear section small, smooth, one-whorled or more, but its separation from the nepionic whorl indistinct or gradational. The penultimate whorl is sculptured by four primary spiral cords, the lowest or 4th hardly showing in the anterior sutural overlap, all are coarsely beaded and separated by wide intervals, finely cross-threaded. Towards the end of the penultimate whorl, a fifth spiral is intercalated between the second (shoulder) and third spiral cords and which quickly increases in size, and on the body whorl it is as large and strongly beaded as the others. The lowest, or most anterior of the primary cords mentioned, forms the outer edge of a slightly flat-

tened base marked with three smaller spiral cords. The umbilicus is quite large, deep, margined by a large, beaded cord and with two smaller ones within. Aperture rounded, oblique, continuous, the anterior margin a little flattened; operculum unknown.

Holotype, greater diameter, 4.2 mm., height, 3.5 mm. ANSP 211891.

In shape and sculpture, this species is similar to *Liotia carinata* Dall from the Gulf of California. Named for Capt. W. S. Bitler, U. S. N. who has contributed substantially to our knowledge of the Panama fauna by his extensive collecting.

Bocas Island.

Family **RISSOIDAE**

Genus **Rissoa** (Frémenville). Desmarest, 1813

Type species by subsequent designation, P. Fischer, 1885, *R. ventricosa* Desmarest.

Rissoa toroensis, new species

Pl. 4, fig. 5

Shell small (length about, 2.35 mm.), stubby, with narrowly coronated whorls, white or glassy. Nucleus with a single, large, smooth whorl forming a low, blunt apex to the spire. Post-nuclear whorls about three are short and broad, with flat to slightly convex sides, narrowly shouldered at the suture. Sculpture consists of small, narrow, axial ribs (15 or 16 on the body whorl) which project a little above the shoulder as short knobs and below they extend across the face of the whorl and over the base to the columella. Axial interspaces are wide and flat, smooth or marked with low, indistinct, widely spaced spiral striation; aperture subovate, oblique, the outer lip thin.

Holotype, length, 2.35 mm., diameter, 1.5 mm. ANSP 211885; paratypes, ANSP 211886. Other specimens in the authors' collections.

The generic reference of this species is tentative.

Bocas Island.

Genus **Alvania** Risso, 1826

Type species by subsequent designation, ? Monterosato, 1884 (Wenz, 1939), *A. sardea* Leach in Risso. (= *montagu* Payradeau).

Alvania chiriquiensis, new species

Pl. 1, fig. 6

Shell small (length, 2.7 mm.), stout, barrel-shaped, the short, stubby spire and body whorl of about equal length, white. Nucleus large, of 1 to 1½ smooth whorls, the initial turn small. There are four post-nuclear whorls in the type; these are solid in appearance, with flat sides between

concave or deeply excavated sutures, the penultimate whorl almost as wide as the body whorl, the other two whorls much smaller and together with the nucleus form a short, stout cone. The sculpture is formed by short, straight, smooth-topped axial ribs which begin at the edge of the excavated suture above and extend down across the face of the whorl to the suture below; they are absent from the base. On the body whorl, there are about 15 ribs, the final ones widening to form a thickened lip. Axial intervals are wide and flat, marked with several incised spiral lines which form into a pattern of narrow ribbons. A spiral cord emerges from the suture to form a strong, peripheral cord and the upper edge of the base; this cord is bordered just below by a wide groove, pitted in harmony with the ends of the axial ribs above. The base itself is relatively short, sloping, and marked with several spiral lines which continue onto the thickened surface of the columella. Aperture small, ovate, the outer lip thickened, the peristome nearly continuous.

Holotype, length, 2.7 mm., diameter, 1.3 mm. ANSP 211875; paratypes ANSP 211876.

A small, *Bittium*-like species referred tentatively to *Alvania*.
Bocas Island.

Genus **Nodulus** Monterosato, 1878

Type species by subsequent designation, Cossmann, 1921, *Rissoa contorta* Jeffreys.

Nodulus megalomastomus, new species

Pl. 1, figs. 4, 4a

The shell is small (length, 1.6 mm.), stubby cylindrical, white or subtranslucent. The nucleus is relatively large and composed of $1\frac{1}{2}$ to 2 smooth, convex whorls forming a low, caplike coil. Post-nuclear whorls about four; these are flat-sided except for the first which is convex and short; on the following turns, the height gradually increases until on the last whorl, it is much higher than it is wide. Sutures fine, distinct, and in transparent shells, show as a band, the lower line being the transmitted image of the sutural union underneath the shell overlap. A section of the shell at the aperture may appear as if slightly disconnected or as if it would become so on further growth; the final section of the whorl, therefore, projects a little beyond the cylindrical outline of the shell. Aperture oblique, subcircular to subovate, the peristome more or less continuous and slightly thickened; no umbilical perforation along the pillar. Surface smooth and glossy, the growth lines not evident.

Holotype, length, 1.60 mm., diameter, .63 mm. ANSP 211906; paratype, length, 1.1 mm., diameter, .46 mm.

This species resembles the figure of *N. kelseyi* Bartsch¹ from San Diego, California, but its nucleus is larger and the sides of the whorls are longer and straighter. Rare.

Bocas Island.

Family **VITRINELLIDAE** *sensu lato*

Genus **Solariorbis** Conrad, 1865

Type species by monotypy, *S. depressus* (Lea) (as *Delphinula*). Claibornian Eocene. Alabama.

Solariorbis corylus, new species

Pl. 3, figs. 4, 4a, 4b

The shell is small (greater diameter, 2.4 mm.), subsolid and stout, white or glassy, rather high but with a strongly flattened, depressed spire bounded by a ridged shoulder, the face of the body whorl below the shoulder being wider and evenly convex. Whorls $3\frac{1}{2}$ to 4, the first one forming a small, smooth nucleus. The sutures are indistinct and bordered on the inner side by an elevated ridge which as it emerges becomes the shoulder of the body whorl. The dorsal surface between the shoulder ridge and the suture is depressed, flat; the outer or peripheral face convex, wider than the surface above the shoulder. Sculpture, except on the base, consists of fine spiral threads between grooves which may be minutely pitted or etched by fine, retractive axial cords. The base is outlined by another elevated ridgelike cord, its surface within forming a wide funnel which dips into a narrow, umbilical perforation; base sculptured with slightly coarser spirals than above, their interspaces not pitted.

Holotype, greater diameter, 2.4 mm.; lesser diameter, 2 mm.; altitude, 1.45 mm. ANSP 211909; paratype ANSP 211910.

Similar to *S. contracta* (Vanatta)² from Monkey River, Honduras, but lacks the central or peripheral keel and has a higher shell.

Bocas Island; other specimens from Colon.

Solariorbis decipiens, new species

Pl. 3, figs. 5, 5a, 5b

The shell is small, solid, subdiscoidal with a low spire, rounded, narrowly flattened or subcarinate periphery, and a white, subtranslucent surface. Whorls about three, the first belonging to a small, smooth nucleus,

¹Paul Bartsch, U. S. Nat. Museum, Proc., vol. 41, No. 1858, 1911, pp. 290, 291, fig. 3.

²Vanatta E. G., Acad. Nat. Sci. Philadelphia, Proc., vol. LXV, 1913, p. 25, pl. 2, figs. 4, 6. (as *Omalaxis funiculus contracta*).

the others enlarge regularly between closely appressed sutures. The sculpture is somewhat like that of *Anticlimax*; on the upper surface, it consists of regularly spaced, slightly inclined, wavelike riblets, their interspaces wide and sometimes containing an intercalary riblet, the whole overrun with fine, close, spiral threads except on the last quarter where the whole sculpture tends to become obsolete. The basal surface is slightly convex and encloses a small, much constricted umbilicus, its sculpture similar to that above except that the radial riblets become enlarged and humplike towards the outer side, obsolete on the final quarter. Aperture subovate and oblique.

Holotype, greater diameter, 1.25 mm.; lesser diameter, .93 mm.; altitude, .50 mm. ANSP 211914.

One specimen only. In shape and sculpture, the species resembles an immature *Anticlimax* but the periphery is rounded. There is no umbilical plug, and the spiral grooves are not pitted.

Bocas Island.

Genus *Pleuromalaxis* Pilsbry and McGinty, 1945

Type species by original designation, *Pseudomalaxis balesi* Pilsbry and McGinty.

There are two species from Bocas Island.

- I. Upper surface of whorl flattened and lying almost in the same plane.
P. balesi Pilsbry and McGinty
- II. Upper surface with the individual whorls flattened and rising in a low, shouldered spire, the sutures descending; umbilicus narrower. *P. pauli*, new species

Pleuromalaxis balesi Pilsbry and McGinty

Pseudomalaxis (Pleuromalaxis) balesi Pilsbry and McGinty, 1945, Nautilus, vol. 59, No. 1, p. 10, pl. 2, fig. 8.

A small, subtranslucent or whitish, discoidal shell with an open planorboid coil, the upper and lower surface flattened and show the spiral whorls almost equally, the periphery marked with two, strong, noded keels. The surface is neatly sculptured with narrow, elevated and widely spaced radial riblets which begin as nodes of the peripheral keel and extend across the face of the whorl to the suture, their intervals sculptured with fine spiral threads.

Rare, only a few specimens found.

Bocas Island.

Pleuromalaxis pauli, new species

Pl. 3, figs. 3, 3a

The shell is small (greater diameter, 1 mm.), white or translucent, subdiscoidal, with two strongly noded, peripheral keels and a low scalar spire formed as a result of a descending coil, the suture being placed just below the upper keel thus forming a low but sharply noded shoulder on each whorl. The peripheral zone is concave or flattened between the two keels, both surfaces (dorsal and ventral) therefore being shouldered. Whorls of the spire about $3\frac{1}{2}$, the first turn composing a small, smooth nucleus. The post-nuclear whorls enlarge regularly and are finely sculptured. The base is weakly convex and has a wide, deep umbilicus. Sculpture is similar on both lower and upper surfaces and is formed by sharp, elevated radial cords which begin as nodes along the peripheral keel and extend across the face of the whorl to the upper suture or dip into the umbilicus on the lower side, their interspaces being quite wide, flat and marked with fine spiral threads. In addition, the base has a medial cord or a minor keel, finely noded by the intersection of the radials; aperture subcircular, oblique.

Holotype, greater diameter, 1 mm.; lesser diameter, .8 mm., altitude, .46 mm. ANSP 211902.

Named for Mr. Paul L. McGinty, brother of the junior author.
Bocas Island.

Genus **Vitrinella** C. B. Adams, 1850

Type species by subsequent designation, K. J. Bush, 1897, *V. helicoidea* C. B. Adams.

Vitrinella semisculpta, new species

Pl. 3, figs. 2, 2a, 2b

Shell small, solid or porcellaneous with a slightly elevated, helicoid spire of about four whorls, the upper surface engraved with strong spiral groovings, the lower surface smooth, convex with a deep, wide umbilicus showing the inner volutions. Whorls about four, the first $1\frac{1}{2}$ turns belonging to a small, smooth nucleus, the others sculptured on their dorsal side by five or more, concave, spiral grooves which begin at the rounded periphery and extend across to the suture; aperture subovate, oblique.

Holotype, greater diameter, 2.5 mm.; lesser diameter, 2.2 mm.; altitude, 1.4 mm. ANSP 211888. Colon, Panama; paratype, greater diameter, 2.2 mm.; lesser diameter, 1.9 mm.; altitude, 1.35 mm. ANSP 211889.
Bocas Island.

Specimens from Bocas Island have smaller and more numerous spiral grooves than shells from Colon, but in the absence of good series from either locality, the value of these differences is undeterminable.

Subgenus **Striovitrinella** new subgenus

Type species, *Vitrinella* (*Striovitrinella*) *elegans*, new species.

Entire surface of shell sculptured with fine, threadlike spirals; operculum circular, thin, chitinous, with numerous, slowly enlarging spiral turns; radula taenioglossate.

Vitrinella (**Striovitrinella**) *elegans*, new species Pl. 3, figs. 1, 1a, 1b, 1c, 1d

Shell of medium size (greater diameter, 3.5 mm.), thin, white or glassy, depressed, with a low helicoid spire of about $3\frac{1}{2}$ whorls. The protoconch of about half a whorl is relatively large and smooth. Mature whorls are sculptured on both the upper and lower surfaces by submicroscopic, close-set spiral threads (there are 10 or 11 spirals visible on the penultimate whorl and about 31 on the dorsal surface of the last whorl); on the penultimate and earlier whorls these spiral threads near the suture may be broken up into beads and then resemble strings of small pearls. Umbilicus deep, scalar, the edge sharply angled, the wall within flat and marked with coarse, irregular lines of growth. Aperture oblique, the outer lip thin, weakly inflected at the umbilical corner.

Holotype, greater diameter, 3.4 mm.; lesser diameter, 2.8 mm.; height, 1.9 mm. ANSP 211877; paratypes in the authors' collections.

This is a fairly common species along the shores of Bocas Island, several were obtained alive.

Bocas Island.

Genus **Vitrinorbis** Pilsbry and Olsson, 1952

Type species by original designation, *V. callistus* Pilsbry and Olsson.

This genus was proposed for a group of minute, few-whorled discoidal species with a low, flat or concave spire, the base with a wide, open umbilicus and a strongly carinated periphery. The surface is delicately sculptured with microscopic spiral threads which give to it a soft, satiny luster. The two previously known species are Pacific, but the following one from the Caribbean appears to belong to this genus.

Vitrinorbis elegans, new species

Pl. 4, figs. 3, 3a

The shell is small (greater diameter, 1.4 to 1.7 mm.), thin, white or subtranslucent, depressed, with a large, peripheral keel. The spire is

slightly elevated, composed of $2\frac{1}{2}$ to 3 whorls of which the nuclear portion of $1\frac{1}{2}$ whorls is relatively large, smooth, helicoid in shape. The post-nuclear whorls are a little convex or vaulted by a large, angular, submedial ridge; on the inner side of this ridge the surface is flattened to depressed, the outer side a little wider and slopes convexly towards the outer suture or towards the peripheral keel. The basal section of the shell is more depressed than the upper and likewise carries a submedial ridge or angle; within this ridge the surface has the shape of a vortex which dips into a deep umbilicus showing the inner volutions of the spire whorls. Surface on both the dorsal and ventral sides has a delicate satiny texture produced by a sculpture of fine, microscopic spiral threads minutely cancellated by still finer lines of growth; in the sutural areas, the growth lines are heavier and may develop into axials nearly as large and strong as the spiral threads; aperture subovate, strongly oblique, attached weakly to the body whorl between the basal ridge and the peripheral keel; no parietal callus.

Holotype, greater diameter, 1.4 mm.; (another specimen has a greater diameter of 1.7 mm.) lesser diameter, 1.2 mm., altitude, .35 mm. ANSP 211881; paratype, ANSP 211882.

Bocas Isand.

Genus **Cyclostremiscus** Pilsbry and Olsson, 1945

Subgenus **Pachystremiscus**, new subgenus

Type species *Cyclostremiscus (Pachystremiscus) pulchellus*, new species.

Shell minute, solid, coiled in a single plane, the lower and upper surface much alike in shape and sculpture; periphery rather wide and bearing three sharp keels; aperture vertical, thickened by a large, wide, continuous peristome.

In addition to the type species, *C. pachynepion* Pilsbry and Olsson from the Pacific Coast belongs here.

Cyclostremiscus (Pachystremiscus) pulchellus, new species Pl. 4, figs. 2, 2a

The shell is minute, solid, coiled like a small ammonite, the large body whorl slightly embracing the earlier turns but with the spire showing fully only on the dorsal side. The lower and upper surfaces are almost equally depressed, the outer circumference rising as a high edge, its peripheral side armed with three sharp keels. The sculpture is closely similar on both the upper and lower surfaces and is formed by small, rather coarse,

radial threads which cover the surface quite uniformly and extend up along the sides of the peripheral keels but do not serrate their summits which remain sharp and knifelike. Umbilicus deep, its edge ornamented by a circle of small beads, its wall within by strong radials; whorls about two, the inner one belonging to a smooth nucleus. Aperture is nearly vertical, thickened by a large, wide, flattened and more or less hexagonally shaped peristome, its inner side rounded.

Holotype, greater diameter, .98 mm.; lesser diameter, .76 mm.; height, .47 mm. ANSP 211897.

This species is closely similar to *C. pachynepion* Pilsbry and Olsson from southwestern coast of Colombia but has finer sculpture and a hexagonal shaped peristome.

Bocas Island.

Cyclostremiscus (Pachystremiscus) ornatus, new species

Pl. 4, fig. 1

The shell is extremely small (greater diameter, .75 mm.), strongly depressed, planorbid, three-keeled, the lower and upper surfaces sculptured almost alike except that the upper shows a full coil, the lower only a partial one which spirals into a wide, shallow umbilicus. Outer circumference of the body whorl is strongly keeled. Whorls two, the first belonging to a small nucleus set apart from the succeeding whorl by its smooth surface. Adult sculpture is highly elaborate but on the type specimen the details are much obscured by encrustation, its main characteristics best shown by the enlarged figures. The body whorl has a strong peripheral keel, narrowly flattened and finely cross-threaded on the sides; a similarly ornate cord spirals around the dorsal mid-zone and it is bordered on each side by a wide band, the outer band with a central row of large beadlike nodes and much finer spiral threads, the inner band with two rows of small beads and spiral lines. Basal sculpture is more elaborate, there being three rows of small beads, the outer one adjacent to the peripheral keel.

Holotype, greater diameter, .76 mm.; lesser diameter, .60 mm.; altitude, .28 mm. ANSP 211880; paratypes in authors' collections.

Six specimens were obtained. There are also specimens of this species in the McGinty collection from Florida which would seem to indicate an extensive distribution through the West Indian and Caribbean region.

Bocas Island.

Genus **Macromphalina** Cossmann, 1888

Type species by original designation, *Sigaretus problematicus* Deshayes. Eocene of Paris Basin.

Macromphalina pilsbryi, new species

Pl. 3, fig. 6

The shell is small (greater diameter, 2.8 mm.), its body whorl large with a medium-height spire tipped by an erect nucleus, the base with a deep, funnel-shaped umbilicus and the surface sculptured with coarse, cordlike axials. The protoconch is a relatively large, elevated naticid coil of about two whorls, the initial turn small and smooth, the last sculptured with three or more strong spirals. Post-nuclear whorls number about two; these have rounded, convex sides, a little wider below the middle, the sutural zone widely flattened so that the profile appears as if slightly shouldered. The middle of the basal slope shows a slight angulation or ridge but not developing into a true cordlike spiral. The umbilicus has the shape of a deep funnel which reaches into the interior of the spire, its outer margin more or less angled which slightly overhangs the flat or excavated umbilical wall marked with coarse growth wrinkles. The surface is sculptured with rather coarse, inclined and slightly sinuous axial cords between incised grooves which are microscopically cross-striated; aperture oblique, semilunate, the outer lip convex, the inner one straight.

Holotype, height, 2.7 mm.; diameter, 2.8 mm. ANSP 211898; paratypes in the authors' collections.

Bocas Island.

Family **VERMETIDAE**Genus **Stephopoma** Mörch, 1860

Type species by subsequent designation, Cossmann, 1912, *S. roseum* (Quoy and Gaimard), Recent, New Zealand.

Mature conch with an irregular open coil, standing erect or lying prone and attached by its apical side to the surface of rock or shell. The protoconch is a small, planorbid or serpula-like coil of one or two whorls, lightly attached by one side, its surface covered with coarse, prickly pustules or granules.

Morton (1951, Trans. Royal Society of New Zealand, vol. 79, pt. 1, pp. 20-23) has shown that *S. nucleogranosum* Verco, of Australian waters and the type species of *Lilax* Finlay, 1927, differs only slightly from *S. roseum*; hence *Lilax* must be regarded as a strict synonym of *Stephopoma*.

The curious nuclear whorls of *Stephopoma* are common in beach drift along the Pacific Coast as far south as Peru; their recent discovery along the Caribbean coast of Panama is of considerable interest.

***Stephopoma myrakeenae*, new species**

Pl. 2, figs. 8, 8a, 8b, 8c

A small vermetid shell, solitary, or as two or more individuals intertwined in loose clusters. When solitary, the shell usually forms an erect, open spiral coil, the tube of the shell circular to roughly 4-sided in section, smooth within, its external surface smooth or coarsely roughened by lines of growth, generally with rows of scalelike projections along the edge of the attachment zone. The small protoconch is characteristic and consists of a small, fat, planorbid coil of about one whorl, the initial portion of the coil as seen from the dorsal side being smooth, the rest of the surface covered with coarse granules or pustules; on the ventral side, the initial smooth portion is not visible. Young specimens are attached by one side of the small nucleus and the earlier portions of the succeeding tube, but with growth, the shell tube rises above its attachment surface and perhaps may become free in the adult stage; color usually white, the nucleus white with yellow or brown pustules.

Holotype, length of tube, 7.2 mm. ANSP 211867.

This vermetid has not been collected alive but judging by the abundance of its protoconch in beach drift, it is evidently a common species along the Caribbean coast of Panama. Most specimens of the mature shell are much worn, indicated that the species probably lives in the intertidal zone where wave action is active. A similar species is found along the Pacific Coast of Panama.

We are naming this species for Dr. Myra Keen of Stanford University who has monographed the Vermetidae for the Treatise on Invertebrate Paleontology.

Bocas Island; Colon.

Family **CAECIDAE**

Genus **Caecum** Fleming, 1813

Type species by subsequent designation, Gray, 1847, *Dentalium trachaea* Montagu.

Subgenus **Bambusum** Olsson and Harbison, 1954

Type species by original designation, *Caecum coronellum* Dall. Pliocene of Florida.

Adult shell relatively large, curved, with little or no taper, the apertural end thickened by a stout collar with a sharp or serrate edge. Sculpture is formed by weak or strong, longitudinal and circular riblets. Posterior plug a flattened or cap-like plate with a short, eccentric mucro.—[Olsson and Harbison, *Nautilus*, vol. 68, pp. 71, 72.]

Caecum (*Bambusum*) *clenchi*, new species

Pl. 2, figs. 6, 6a

Adult shell in the shape of a relatively large (length, 4 mm.), slightly curved, nontapered tube, slightly bevelled at the posterior end. At the apertural end, the tube has a heavy, flangelike collar. Sculpture consists of about 18, strong, longitudinal riblets, triangular in section and separated by wide, flat grooves. The riblets are etched on the top and sides by cross-threads which are more strongly developed over the anterior end, weaker and subobsolete elsewhere. The collar at the apertural end is quite broad, heaviest and widest behind, with a thin or serrated edge in front. The collar is sculptured with the same number of longitudinal ribs as the general surface, their intervals appearing much wider and crossed by three or more strong threads. Posterior plug in the shape of a small cap with a prominent eccentric mucro.

Holotype, length, 4 mm.; diameter of tube, .93 mm.; diameter of collar, 1 mm. ANSP 211911; paratype, length, 4.7 mm., diameter of tube, 1 mm., diameter of collar, 1.16 mm.

Bocas Island.

Family **COLUMBELLIDAE**

Genus ***Decipifus*** new genus

Type species *D. sixaolus*, new species

Shell small, *Pbos*-like in shape and sculpture. Protoconch is relatively large, subcylindrical, formed of 1 to 1½ smooth whorls, the final section high and the apical tip inrolled. Sculpture of the mature whorl is formed by low, narrow riblets finely beaded by spirals. Aperture semielliptical with a small, indistinct canal at the suture; lip simple; columella straight, the tip of the pillar slightly twisted; no external fasciole.

Buccinum pulchellum C. B. Adams appears to belong to this genus also. The familial relations of these small species must await radular examination.

Decipifus sixaolus, new species

Pl. 2, figs. 3, 3a

Shell quite small, subfusiform, with an elevated stout spire about equal to the aperture and colored white or brown, the spiral cords being

often in the form of broken brown lines. The nucleus is large, one-whorled, with its tip immersed somewhat, the final portion high, smooth. Post-nuclear whorls about three in number are slightly convex and strongly sculptured with spiral cords crossed by less distinct axial riblets. The riblets number about 18 on the body whorl, somewhat fewer on the whorls of the spire. The first and second whorls have four spirals, six on the last whorl in the space between the sutures, and about 13 over the whole surface including the base. Aperture subovate, the siphonal canal notch quite deep, the anterior canal short, the columella straight and smooth; outer lip simple; no fasciole.

Holotype, length, 3.6 mm., diameter, 1.6 mm. ANSP 211893; paratype, ANSP 211894.

Bocas Island.

Genus *Nassarina* Dall, 1889

Type species by original designation, *Nassarina bushii* Dall.

Nassarina ? *dubia*, new species

Pl. 2, fig. 5

Shell small, (length, 6.2 mm.), subfusiform with a short, anterior canal and a high, stout spire about twice the length of the aperture; apex of the spire blunt, formed by a one-whorled smooth nucleus; post-nuclear whorls about four, the first sloping, convex, the others with a low shoulder. The sculpture is formed by strong, axial riblets, coarsely noded by intersecting cordlike spirals. The first of the post-nuclear whorls has three small, nearly equal spirals; the second and third has two spirals below the shoulder and a smaller one on the sloping shoulder area above; on the body whorl, there are two spirals on the shoulder area, two between the shoulder and the lower suture (the shoulder spiral largest) and four or five on the surface below. Pillar with a thin coat of callus, the spiral sculpture showing faintly through to simulate false lirations. Siphonal canal notch quite wide but not developing into an external fasciole.

Holotype, length, 6.2 mm., diameter, 2.3 mm. ANSP 211887.

This curious species is referred with some uncertainty to *Nassarina*; it may possibly belong to the Turridae but the growth lines are not inflected. Bocas Island.

Family **OLIVIDAE**

Genus *Olivella* Swainson, 1831

Type species by subsequent designation, Dall, 1909, *Oliva purpurata* Swainson (= *O. dama* Mawe).

Subgenus **Niteoliva** Olsson, 1956

Type species by original designation, *Olivella minute* (Link) (*nitidula* Gmelin).

Olivella (Niteoliva) minuta marmorata, new subspecies Pl. 1, figs. 2, 2a

The shell is uniformly small (length, 5.5 mm.), stout, subelliptical, the spire and aperture of nearly equal length and shape. The nucleus is relatively large and forms a prominent knoblike tip to the spire; post-nuclear whorls about four, placed between deeply grooved sutures, plain white except the body whorl which is colored. The body whorl is large, broadly elliptical in shape and marked as follows; there is a strong, brown band at the suture and another covers part of the upper surface of the fasciole, the surface between marked with a series of widely spaced, zigzag, brown lines, the main arrow in the mid-zone and pointed in the direction of rotation of the whorl. Aperture showing the characters of the subgenus, the parietal callus being strongly developed and extending to the upper suture of the last whorl, the pillar structure a narrow, plaited ribbon, and the inner side of the outer lip is minutely lirate.

Holotype, length, 5.4 mm.; diameter, 2.5 mm. ANSP 211904; paratypes in the authors' collections.

A common shell on Bocas Island and differing constantly from the typical form by its much smaller size and lighter color.

Bocas Island.

Family **ACTEOCINIDAE**Genus **Acteocina** Gray, 1847

Type species by original designation, *Acteon wetherelli* Lea (= *Tornatina canaliculata* Say).

Acteocina inconspicua, new species Pl. 4, fig. 9

The shell is small (altitude, about 2 mm.), narrowly cylindrical, smooth, white or transparent, the nucleus small, projecting prominently above the apex. Spire is completely involute in most specimens and concealed in a deep suture and overlapped by the edge of the body whorl. The body whorl is narrowly cylindrical, bevelled at the upper end and its surface forms the greater part of the whole shell. Aperture linear, the inner and outer lips parallel, a little wider in front. Parietal callus is thin, the pillar fold small and indicated mainly by a narrow ridge along the side of the columella.

Holotype, length, 2.1 mm.; diameter, 1.0 mm. ANSP 211895.

A small, inconspicuous species recognized easily by its shape, the absence of a visible spire, and its nearly smooth pillar.

Bocas Island.

Family **MARGINELLIDAE**

Genus **Gibberula** Swainson, 1840

Type species by monotypy, *G. zonata* Swainson (= *oryza* Lamarck as *Volvaria*).

Gibberula bocasensis, new species

Pl. 4, fig. 10

The shell is small (length, about 4 mm.), subcylindrical, widest and rounded above forming a shoulder on the lip side at the posterior one-fifth, white, glassy or subtranslucent. Spire low, rounded and obtuse, of a few, hardly distinguishable whorls, only a false suture showing on the final whorl. The body whorl is large and forms most of the surface of the shell. Penultimate whorl appears quite large and wide and forms most of the spire, solid as viewed from the back. Aperture long and narrow, and in a mature specimen curves upward onto the spire and reaches almost to its tip, this upward advance of the lip at the adult stage being best shown on the back by the sharp upward swing of the suture line. The outer lip is somewhat thickened, its edge flattened and slightly impressed, smooth within; columellar wall straight with seven or eight small plaits diminishing in size upward.

Holotype, length, 3.8 mm.; diameter, 1.9 mm. ANSP 211883; paratypes in the authors' collections.

Distinguished from *G. minuta* Pfr. by its larger size, longer, more cylindrical shape, and more numerous columellar plaits. Although the suture seems to show plainly as a dark line, it is merely the transmitted image of the true suture line beneath a thin, translucent marginal overlap of the body whorl onto the spire; no sutural impression shows if the surface is covered with a thin film of magnesium oxide.

Bocas Island; Colon.

Genus **Persicula** Schumacher, 1817

Type species by monotypy, *P. variabilis* Schumacher (= *persicula* Linné).

Subgenus **Rabieea** Gray, 1857

Type species by monotypy, *Persicula interrupta* (Lamarck).

Persicula (Rabicea) adamsiana weberi, new subspecies Pl. I, figs. 1, 1a

cf. *Persicula (Rabicea) adamsiana* Pilsbry and Lowe, 1932, Acad. Nat. Sci. Philadelphia, Proc., vol. 84, p. 62, pl. 4, fig. 9. (Montijo Bay, Panama.)

Shell relatively small (length, 6.5 mm. or less), ovate-cylindrical and rather solid, the two ends bluntly rounded, the spire concealed, the body whorl forming the whole external surface. Aperture as long as the shell, narrow and slightly curved, a little wider in front. The columella has four plaits of which the 2d from the anterior end is considerably the larger. Surface smooth and ornamented with broken chestnut-colored lines, of which, number 4, 5, 10, 11 and 12 counted from the anterior end are heavier than the others. The fasciole is marked with a row of large spots and a set of petal-like spots cover the apex.

Holotype, length, 6.4 mm.; diameter, 3.6 mm. ANSP 211883.

This shell should perhaps be considered as a distinct species. It is similar to *P. adamsiana* Pilsbry and Lowe from the Pacific Coast of Panama but is much smaller, the lip is less thickened and often simple.

Holotype, Piña. Bocas Island, common; Colon.

Family MURICIDAE

Genus **Risonmrex**, new genus

Type species *Engina schrammi* Crosse (1863).

Shell small, ovate to subfusiform with a stout, elevated spire and a short or medium-length anterior canal. Nucleus small formed by a single smooth whorl strongly angulated or keeled around the top, the upper surface flattened or deeply impressed so that the apex appears partly immersed. The sculpture of the mature portion of the conch is formed by low, rounded axial ribs and spirals, the primary spiral cords broken into nodes at the intersections, the whole sometimes coarsely scabrously wrinkled by lines of growth. Aperture ovate, the outer lip much thickened and strongly armed on the inner side with five or six teeth of which the 2d and 3d teeth counting from above often unite into a single, large tooth. Inner lip with a coating of enamel, the pillar ending into a heavily calloused fold. Anterior canal terminates in a short, narrow, siphonal canal.

The radula of the type species is muricid, the ribbon being long, composed of more than 165 rows of teeth (count made from a broken ribbon). Total length of ribbon, about 2.75 mm., width, 0.078 mm., width of an individual rachidian tooth, .025 mm. The rachidian tooth is rectangular in shape, the central cusp short arising from the back margin

and is bordered on each side by a large, stubby cusp. Lateral teeth are much smaller, and resemble small, slightly curved spines. The radula of *Ocenebra alveata* Kiener (as figured by Troschel³, pl. 11, fig. 10) is similar.

Caribbean species of this group have been referred to *Ocenebra*, *Engina*, *Ricinula*, and most recently to *Ocinebrina*. The type species of *Ocinebrina* Jousseaume, 1880 (*O. aciculaba* (Lamarck), a Mediterranean form) has smooth, unkeeled, nuclear whorls. Radula of *O. corallina* Scacchi as figured by Troschel (plate 11, fig. 13) is quite different, the rachidian tooth being small and narrower with more numerous sharp cusps.

Besides the type species the following species are assigned to this genus. *O. muricoides* (C. B. Adams), *O. rosea* (Reeve) (as *Ricinula*), and *O. alveata* (Kiener).

Risomurex schrammi (Crosse)

Pl. 2, figs. 2, 2a

Engina schrammi Crosse, 1863, Jour. de Conchy., 3d serie, vol. II, pp. 82, 83, pl. 1, fig. 7 Guadeloupe.

Sistrum ferrugineum rubidum Dall, 1889, Bull. Mus. Comp. Zoology, vol. 18, p. 217.

Specimens from Bocas Island and Colon have an average length of about 12 mm. The shell is broadly fusiform and of a rose or coral-red color, the primary spiral cords (eight on the body whorl) forming enlarged cordlike nodes of a lighter red, their interspaces much darker.

Bocas Island and Colon.

Risomurex muricoides (C. B. Adams)

Pl. 2, figs. 1, 1a

Fusus muricoides C. B. Adams, 1845, Boston Soc. Nat. History, Proc., vol. 2, p. 3; Clench and Turner, 1950, Occ. Papers Mollusks, vol. 1, No. 15, p. 313, pl. 39, fig. 9 Jamaica.

Tritonalia (Ocinebrina) caribbaea Bartsch and Rehder, 1939, Smith. Misc. Coll., vol. 98, No. 10, p. 7, pl. 1, fig. 1 Old Providence Island.

Ocenebra (Ocinebrina) muricoides (C. B. Adams), Tucker Abbott, 1954, Nautilus, vol. 68, No. 2, p. 44, pl. 2, fig. 2. (figure of *T. caribbaea*).

At Bocas, this species is more plentiful than *R. schrammi* from which it differs by its average smaller size, narrower, elongated ovate form, and coloration; nuclear whorls as figured; sculpture of the first post-nuclear whorl formed by strong axial ribs, the upper ends of which project prominently above the suture and against the smooth background of the nuclear whorl. On the body whorl, there are nine primary spiral cords of which cord no. 4 and no. 6 (emerging from the aperture) are largest and deep

³Troschel, F. H., 1869, Das Gebiss der Schnecken, Zweiter Band, p. 119, pl. 11, fig. 10.

white in color, the other smaller spirals being yellow. Interspaces between the primary spiral is a gray or purplish-brown.

Bocas Island; Almirante; Colon.

Family **STILIFERIDAE**

Genus **Rosenia** Schepman, 1913

Type species by monotypy; *Phasianella* (*Rosenia*) *stylifera* (Turton).

Rosenia minibulla, new species

Pl. 1, fig. 5

The shell is minute, globose, thin, white or subtransparent, with a low spire tipped by a large, erect, stumplike nucleus, white in color and porcellaneous in texture. Sutures are fine but distinct. Post-nuclear whorls about two, the first quite small, convex, with a small shoulder near the suture which shows best on the apertural side, the body whorl large, convex and inflated; surface smooth and polished, its only markings being indistinct, strongly retractive lines of growth; aperture widely ovate, oblique, the outer lip thin, flaring in the middle, the pillar side deeply concave, the wall itself with a thin coat of callus. There is no umbilical perforation.

Holotype, length, 1.80 mm.; diameter, 1.40 mm. ANSP 211892.

Like other species of the genus, this form was probably parasitic on sea urchins.

Bocas Island.

Family **PYRAMIDELLIDAE**

Genus **Odostomia** Fleming, 1817

Type species by subsequent designation, Gray, 1847, *Turbo plicatus* Montagu.

Subgenus **Chrysalida** Carpenter, 1856

Type species by original designation, *C. communis* (C. B. Adams); originally described under the genus *Chemnitzia*. Panamic-Pacific.

Odostomia (Chrysalida) gemmulosa C. B. Adams

Pl. 1, fig. 12

Odostomia gemmulosa C. B. Adams, 1850, Cont. to Conchology, No. 7, p. 109; Clench and Turner, 1950, Occ. Papers Mollusks, vol. 1, No. 15, p. 286, pl. 40, fig. 1.

This common Bocas shell agrees with the figure of *O. gemmulosa* as given by Clench and Turner (1950). There are three, coarsely noded spirals on the whorls of the spiral and upper half of the body whorl. Basal spirals, about seven, are smaller and plain; color white to glassy.

Odostomia (Chrysallida) jadisi, new species

Pl. 1, figs. 11, 11a

Shell ovate-oblong, with a medium length stout spire and a sloping base, solid, white or glassy. Nuclear whorls, one or two, depressed, and form a blunt apex. Post-nuclear whorls five or six, their height nearly half of their width, forming together a nearly straight-sided spire, each whorl flattened, slightly contracted at the suture. Sculpture is coarsely reticulated, formed by strong, narrow, vertical ribs (about 18), strongly developed between the sutures but fade out on the base, and a set of strong spiral cords; on the spiral whorls, the spirals number three or four show best as cross-ribs in the interspaces, the pits between them being quite large and rectangular. On the body whorl there are 9 or 10 spiral cords, those on the base small and indefinite, but are strong above across the main face of the whorl where they, and the ribs, enclose wide rectangular pits between them; inner lip narrow, thin, appressed closely to the body whorl, the outer lip thin and little flaring below.

Holotype, length, 3.5 mm., diameter, 1.4 mm. ANSP 211916.

Similar to *O. communis* (C. B. Adams) from Panamic-Pacific but stouter and the sutural zone less excavated. The species is named for Mr. Stewart Jadis of the Canal Zone Police force, ardent collector of Panama shells and a valued friend of the authors.

Bocas Island; Colon.

Subgenus Ivara Dall and Bartsch, 1903

Type species by monotypy, *O. terricula* Dall and Bartsch (probably misprint for *turricula*).

Odostomia (Ivara) terryi, new species

Pl. 4, fig. 4

Shell small, ovate-cylindrical, white to glassy and subtranslucent. Nuclear whorls smooth and convex, lying deeply immersed in the tip of the spire and project but little above the edge of the following whorl. Post-nuclear whorls about three; the first one convex, the others broad and high with flat to slightly convex sides and a narrow shoulder at the suture. The last whorl is much the largest, barrel-shaped, its base not set apart by any change in slope. Sculpture consists of relatively weak axial riblets and even spiral threads which cover the whole surface and produce a smooth, netlike pattern. There are about 12 axials showing on the apertural side of the body whorl. Aperture is rather large, semilunate, the outer lip thin.

Holotype, length, 2.8 mm.; diameter, 1.1 mm. ANSP 211890.

This species resembles *O. terricola* Dall and Bartsch from California but is shorter and has stronger axial sculpture. The shell is named for Mr. Robert A. Terry of Palo Alto, California, an associate and companion of the senior author on many a field expedition in Panama and Costa Rica. Bocas Island.

Genus *Miralda* A. Adams, 1863

Type species by subsequent designation, Dall and Bartsch, 1909, *Parthenia diadema* A. Adams.

Miralda havanensis (Pilsbry and Aguayo)

Pl. 1, fig. 8

Odostomia (*Miralda*) *havanensis* Pilsbry and Aguayo, 1933, *Nautilus*, vol. 46, No. 4, p. 118, pl. 6, fig. 4.

Shell small, with a stout, evenly tapered conic spire, the surface sculptured with two strong, tuberculated spiral cords, the color white or glassy. The nucleus is relatively large and forms a low, blunt apex. Post-nuclear whorls four, the first small, the others progressively larger, each whorl sculptured with two, heavy, subequal, primary spiral cords, the upper one placed near the suture forming a narrow shoulder, the other lies just below the middle, the space between them forming a deep, smooth groove. The suture lies in a similar deep groove so that the sutural zone appears as if deeply excavated. The body whorl has a small, narrow, plain spiral which emerges from the suture and forms the edge of the base; two other small spirals encircle the short, sloping surface of the base. Aside from the tubercles distributed along the two primary spiral cords, there is no other development of axial sculpture, aperture ovate, oblique, the lip sharp.

A Bocas specimen measures: length, 2.00 mm.; diameter, .90 mm.

This species resembles *O. abbotti* but has a steeper, more conic spire, simpler sculpture, and no true axials.

Bocas Island.

Miralda abbotti, new species

Pl. 1, fig. 7

Shell small, elongate-conic, white or glassy; nuclear whorls small, oblique and partly immersed in the tip of the spire; post-nuclear whorls about four, the first one being convex and sculptured with two or three low spirals, the other whorls are more heavily sculptured and have a thickened tuberculated shoulder. Second and third whorl have two strong, spiral cords of which the upper one is much enlarged, thickened and noded and forms a prominent shoulder; the other spiral below it is narrow and sharp. On the final whorl, another spiral cord emerges from the suture and

may be considered as marking the edge of the base. Space between the two primary spiral cords is wide and deep, crossed by narrow, oblique axials of which 10 show on the apertural side of the body whorl; these axials nodulate the shoulder cord but not the lower one or only slightly; no axials on base; aperture subovate, oblique.

Holotype, length, 2.0 mm.; diameter, 1.0 mm. ANSP 211912.

Similar in general characters to *M. armata* (Carpenter) from the Panamic-Pacific region but differing in details of sculpture.

Bocas Island; Colon.

Class PELECYPODA

Family CARDITIDAE

Genus *Pleuromeris* Conrad, 1867

Type species by monotypy, *P. decemcostata* Conrad (= *tridentata decemcostata* Conrad).

Pleuromeris micella, new species

Pl. 5, figs. 7, 7a

Shell small, convex, obliquely subcircular, both ends rounded but with the anterior side a trifle longer, depressed, and slightly flaring, white; umbones submedial, wide, the beaks small, prosogyrate, appressed to the hinge line and placed a little in front of the middle. The sculpture is formed by about 15, rather strong, coarse or weakly noded radial ribs; frequently one or more of the ribs along the anterior-umbonal slope show two branches which unite shortly to form a single rib below the umbo. Radial interspaces, narrow, groove-like. Inner margin of the valve is fluted by the ends of the ribs, the external sculpture showing through the texture of the shell, their interspaces as darker lines, cross-threaded.

Holotype, height, 1.6 mm.; length, 1.5 mm. ANSP 211907; paratype, height, 1.5 mm.; length, 1.6 mm. ANSP 211908.

A small, rotund and convex species in which on some specimens, the sculpture of the umbo is formed by small, straight riblets, some of which in pairs seem to unite into larger, main riblets of the adult sculpture.

Bocas Island, common.

Family PHILOBRYIDAE

Genus *Philobrya* Carpenter, 1872

(*Bryophila* Carpenter, 1864, not of Trietscke, 1825 [Lepidoptera]).

Type species by monotypy, *Bryophila setosa* Carpenter. Recent, Alaska to the Gulf of California.

Philobrya inconspicua, new species

Pl. 5, figs. 1, 1a, 1b, 1c

The shell is small, obliquely aviculiform, white, its surface almost smooth except for 10 or 11, faint, widely spaced, slightly beaded radial threads, strongest on the anterior slope, almost indistinguishable in the middle, the wide spaces between them flat and smooth, or bearing low, drapelike folds. The valve is strongly inflated through the umbonal section, impressed on the anterior side, the beaks capped by a conspicuous, subovate and obliquely placed prodissoconch bordered by a raised fringe. Hinge edentulous, the cardinal area narrow and relatively long (about half the length of the hinge line) and bearing a subcentral trigonal resilifer under the beak. Impression of the adductors and pallial line indistinct.

Holotype, height, 2.7 mm.; length, 1.7 mm. approx. (a right valve) ANSP 211865.

Bocas del Toro.

The few specimens of this minute species known to us are drift valves which have lost their outer surface and hence are thin and glassy but easily recognized by the small embryonic shell capping the beaks, closely similar to that of *Condylocardia*. On casual inspection, the surface of the disk appears smooth but a closer study under varying incidents of light reveals finely beaded radials resembling strings of small pearls, the wide space between each pair being weakly ruffled or shirred by cross undulations.

This appears to be the first species of the genus to be noticed from the tropical western Atlantic. *P. atlantica* Dall⁴ from the coast of Argentine is a larger species with stronger sculpture. Dall at first seemed to have considered the large, fringed prodissoconch of *P. atlantica* as indicating the existence of a glochidium stage, the first to be noted in a marine pelecypod. This view was contested by Bernard⁵ and shortly afterwards rejected by Dall⁶.

Family MYTILIDAE

Genus *Crenella* Brown, 1827

Type species by monotypy, *Mytilus decussatus* Montagu. Recent, North Atlantic.

Crenella gemma, new species

Pl. 4, figs. 8, 8a

The shell is small, thin, white to subtranslucent, subovate, higher than

⁴Dall, W. H., 1896, U. S. Nat. Museum, Proc., vol. 18, No. 1034, pp. 16, 17.

⁵Bernard, F., 1897, Jour. de Conchy., vol. 45, p. 10.

⁶Dall, W. H., 1902, *op. cit.*, vol. 24, No. 1264, p. 507, pl. 32, figs. 4, 5.

wide, convex, the beaks turned sharply towards the anterior side. The posterior margin is a trifle more expanded and rounded than the anterior but the general outline of the shell remains smoothly ovate, strongly convex through the middle. Surface sculptured with fine, radial threads appearing minutely nodulose on the sides, partly smooth along the middle. The hinge is weak, the denticulations strongest anteriorly under the beak and at the posterior end, lacking in the middle. Inner margin of valve plain.

Holotype, length, 1.85 mm.; height, 2.1 mm. ANSP 211873; paratype, length, 1.9 mm.; height, 2.5 mm. ANSP 211874.

Larger and more delicate than *C. divaricata* (d'Orbigny) and with much finer and softer sculpture.

Bocas Island.

Family LIMIDAE

Genus *Limatula* Wood, 1839

Type species by subsequent designation, Gray, 1847, *Lima subauriculata* Montagu.

Limatula hendersoni, new species

Pl. 4, figs. 6, 6a

Shell small, narrow, its height nearly twice its length, with submedial umbo and beak nearly equilateral, the axis of the shell being slightly oblique, equivale, closed, white or subtranslucent, convex and thin. Sculpture is formed by low, rounded, radial riblets of which the middle ones (11 or 12) are quite strong, slightly roughened by the lines of growth, the ribs on the sides fading out rapidly so that the surface appears smooth; these ribs are separated merely by lined interspaces. Hinge line not so long as the length (or width) of the shell, its cardinal area narrowly lenticular, sloping, and with a rather large, triangular pit for the resilifer. Interior smooth except for the slight fluting near the edge produced by the external sculpture.

Holotype, length or width; 1.6 mm., height, 2.9 mm. ANSP 211869; paratype, ANSP 211870.

L. subauriculata (Montagu) is similar in shape but much larger. There is a good series of this species in the collection of the U. S. National Museum from Barbados and Antiqua; other specimens in the McGinty collection from Florida and the Bahamas.

Bocas Island, fairly common.

Family **TELLINIDAE**Genus **Strigilla** Turton, 1822

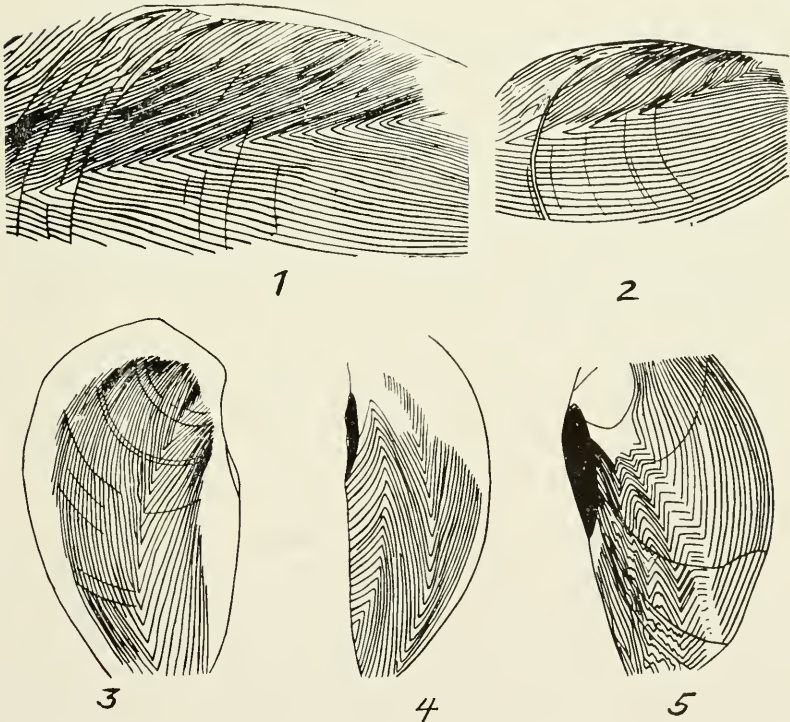
Type species by subsequent designation, Gray, 1847, *Tellina carnaria* Linné.

Species of *Strigilla* are distinguished from other tellinids by their rounded, subcircular shape, convex or depressed, and especially by the characteristic sculpture of incised lines or sulci which cross the surface of the disk diagonally and are generally bowed or strongly flexed along two principal lines of divarication. The first and principal line of divarication lies along the posterior-umbonal slope and defines the inner edge of the posterior-dorsal area; along it the sulci are sharply flexed and form a series of acute angles pointing downward or ventrally; there is a second weaker zone of flexure along the anterior-umbonal slope along which the sulci are bowed upward or dorsally; color is pure white or in shades of pink or coral red.

Seven species of *Strigilla* are known from the western Atlantic of which five occur along the Caribbean coast of Panama. These can be distinguished as follows.—

1. The posterior-dorsal area is wide with the sulci running diagonally across it, evenly spaced and straight, or fine, crowded and somewhat waved but without showing any sharp zigzag bends or strong flexing.
1. Shell small (length, 7 mm. or less), rounded and convex, pea-shaped; mostly white with rose-colored umbones *S. producta* Tryon
2. Shell larger, length more than 10 mm., depressed to slightly convex.
 - a. Length between 15 and 25 mm., subcircular to subelliptical, of medium convexity; posterior-dorsal slope flattened or evenly convex.
 - aa. Shell generally less than 20 mm.; anterior flexure often partly replaced along the umbonal slope by a smooth tract; upper limb of the pallial sinus extends completely across the interior to connect directly to the anterior adductor scar *S. carnaria* (Linné)
 - ab. Often larger, slightly more depressed; pallial sinus entire, the upper limb joined to the pallial line below, some distance behind the anterior adductor scar *S. roubergi* Mörch
 - b. Larger (length, 30 mm. or more), more strongly depressed. Posterior-dorsal area strongly angulated in the dorsal section. Light pink with deep rose-red umbones *S. gabbi*, new species

- II. Posterior-dorsal area marked with one or more secondary lines of sharp divarication, the resulting pattern, therefore, distinctly zigzagged.
 - 3. Posterior-dorsal area with a single, median line of zigzag flexure.
 - c. Shell small (length, 7 mm. or less) rounded, plump. White with rose-colored umbones *S. pisiformis* (Linné)
 - d. Shell larger (above 10 mm.), relatively solid. Color white except the umbones and interior which are often colored rose-red
S. pilsbryi, new species
 - 4. Posterior-dorsal area with two or more lines of zigzag flexure; color usually pure white *S. mirabilis* (Philippi)
(*flexuosa* Say, preoccupied)



Text figures 1 to 5. To illustrate types of sculpture on the posterior-dorsal area of some species of *Strigilla*. 1 to 3. Type A. *Carnaria* group: 1. *S. gabbi*, new species. Bocas Island; 2. *S. carnaria* (Linné). Bocas Island; 3. *S. producta* Tryon. Colon. 4. Type B. *Pisiformis* group: 4. *S. pisiformis* (Linné). Morant Bay, Jamaica. 5. Type C. *Mirabilis* group: 5. *S. mirabilis* (Philippi). Bahamas.

Strigilla pilsbryi, new species

Pl. 5, figs. 2, 2a

The shell is of medium size (length, 13 to 14.5 mm.), obliquely sub-trigonal, plump and solid. The prominent umbo is placed a little in front of the middle, its small beak flattened and appressed against the hinge margin. There is a rather large, deeply sunken lunule in the left valve, a much smaller one in the right. Hinge strong, especially so in the right valve which has a bifid posterior cardinal tooth, a deep medial socket and a simple, trigonal anterior cardinal tooth; the lateral teeth of the right valve are strong, the posterior one placed more distantly, each bordered above by a deep socket. Surface is finely sculptured by close-set, regularly spaced, concentric incised lines; at three points, these lines show bends or divarications; a secondary bend in the middle of the posterior-dorsal area with the angles pointing towards the beak; the primary line of divarication along the border of the posterior-dorsal area with angles pointing downward; and the third along the anterior-umbonal slope along which the incised lines are merely bowed inward or dorsally. The anterior slope may be weakly folded. Color mostly white except for the top of the umbones and beaks which may be rose-red, the interior of the shell usually more strongly colored. Adductor impressions deep, the pallial sinus large and ample, highest at the posterior one-third, its upper limb thence descending and connecting to the anterior adductor scar near its lower edge; inner margin of valve smooth.

Holotype, length, 13.3 mm.; height, 13.5 mm.; semidiameter, 4.2 mm. (a left valve). ANSP 211915, Bocas del Toro, paratypes, Bocas del Toro. Other specimens seen: Monkey Point, Nicaragua, USNM 125430; Belize and Punta Gorda, British Honduras, USNM 150339; Livingston, Guatemala, ANSP 45887.

Strigilla gabbi, new species

Pl. 5, figs. 3, 3a

The shell is large, obliquely subovate to subcircular, inequilateral and depressed. The flattened umbo is placed near the anterior one-third, the anterior side hence being short, well rounded and often a little folded, its margin then showing a shallow indentation; posterior-dorsal margin descending, nearly straight and bordered in each valve by an angle limiting a narrow, flattened posterior-dorsal area somewhat larger in the right valve. There is a small, narrow escutcheon in the left valve, lacking in the right. Lunule small, narrow and deeply sunken, larger in the left valve. Sculpture as normal for the genus consists of incised lines or sulci across the

mid-zone of the disk which are fairly coarse, steeply inclined to the margin at angles of 60 to 90 degrees; they are much finer and crowded on the posterior-dorsal slope. The principal line of divarication is placed at the posterior one-third where it forms a line of sharp, acute angles pointing ventrally; the second line of flexure extends along the anterior one-third and shows the incised lines as bowed convexly upward, often partly replaced there by a smooth tract; a much smaller line of flexure is sometimes developed close to the anterior end, the sulci there conforming to the shallow, marginal indentation. Pallial sinus deep, its upper limb reaching to the lower edge of the anterior adductor scar or just below it. Color more or less banded in tones of white and dull pink, the bands outlined by deeper concentric growth lines, the tip of the umbo and beak colored a deep red. Internal color is pink with two narrow white rays under the principal line of flexure; hinge teeth and margin of valve white.

Holotype, length, 33.3 mm.; height, 30.05 mm.; diameter, 12.8 mm., Colon, Panama. H. Johnson; ANSP 218881.

Paratype, length, 35 mm.; height, 30.5 mm.; diameter, 12.6 mm., ANSP 53379, Costa Rica, Wm. M. Gabb.

Similar to *S. disjuncta* Carpenter (sometimes as *sincera* Hanley) of the Panamic-Pacific zone and almost as large but more circular in form, the posterior-dorsal area is more angular and the color is pink, whereas *S. disjuncta* is nearly always white. Along the Caribbean coast of northern Colombia at Puerto Colombia to Colon, Bocas del Toro, Panama, and Costa Rica.

Family LUCINIDAE

Genus *Divaricella* von Martens, 1880

Type species by monotypy, *Lucina angulifera* von Martens (= *Lucina ornata* Reeve).

Divaricella weberi, new species

Pl. 4, figs. 7, 7a

Shell relatively small (length, 7.7 mm. or less), subcircular, convex and solid. Umbone from the outside appears wide and medially placed but when seen from the inside is seen to be slightly anterior, its small beak facing forward above a small, deeply sunken lunule. The nepionic shell with close-set, non-divaricating concentric threads is small and inconspicuous. Sculpture as normal for the genus is formed by evenly spaced, incised lines, the single zone of divarication forming rather wide, obtuse

angles pointing dorsally. Fine radial lines show unequally in different specimens; these give rise to a crenulate margin in unworn specimens, also showing around the edge of the different resting intervals. Some shells show an evenly convex surface indicating continuous growth but usually the surface is divided into several steplike bands by deep concentric grooves, crenulated on their sides. Hinge with strongly developed cardinal and lateral teeth; color white or glassy.

Holotype, length, 7.7 mm.; height, 8 mm.; semidiameter, 3.4 mm. (a right valve). ANSP 211871.

This small, distinctive *Divaricella* is plentiful in beach drift from Coco Plum, associated with the larger, less common *D. quadrisulcata*, differing by its much smaller size, rounder, more convex, solid shell, strong hinge and crenulated ventral margin. *D. pilula* (C. B. Adams) may be similar but its descriptions calls for a larger shell and Clench's⁷ figure seems to show a weaker hinge like that of *D. quadrisulcata* with which it was united by Dall. *D. weberi* is most similar to small forms of *D. paupercula* Dall from the Panama-Pacific faunal area but that species has generally a much thinner shell as well as reaching a larger size when fully grown.

Holotype, ANSP 211871, Coco Plum, Panama.

Named for Mr. Jay A. Weber of Miami, Florida, companion of the authors on the visit to Bocas del Toro in 1953.

Family CONDYLOCARDIIDAE

Genus *Condylocardia* (Munier-Chalmas), Bernard, 1896

Type species by original designation, *C. pauliana* (Munier-Chalmas), Bernard.

Condylocardia bernardi (Dall)

Pl. 5, fig. 6

Carditopsis bernardi Dall, 1903, Wagner Free Inst. Sci. Philadelphia, Trans., vol. 3, pt. 6, p. 1438, pl. 53, fig. 10.

This small species was first described as a Pliocene fossil from Port Limon, Costa Rica, but is also common in beach drift at Colon and Bocas Island. Similar to *C. smithii* (Dall) (*C. floridensis* Pilsbry and Olsson), the other Recent species but has a wider, more oblique shape, and more numerous ribs.

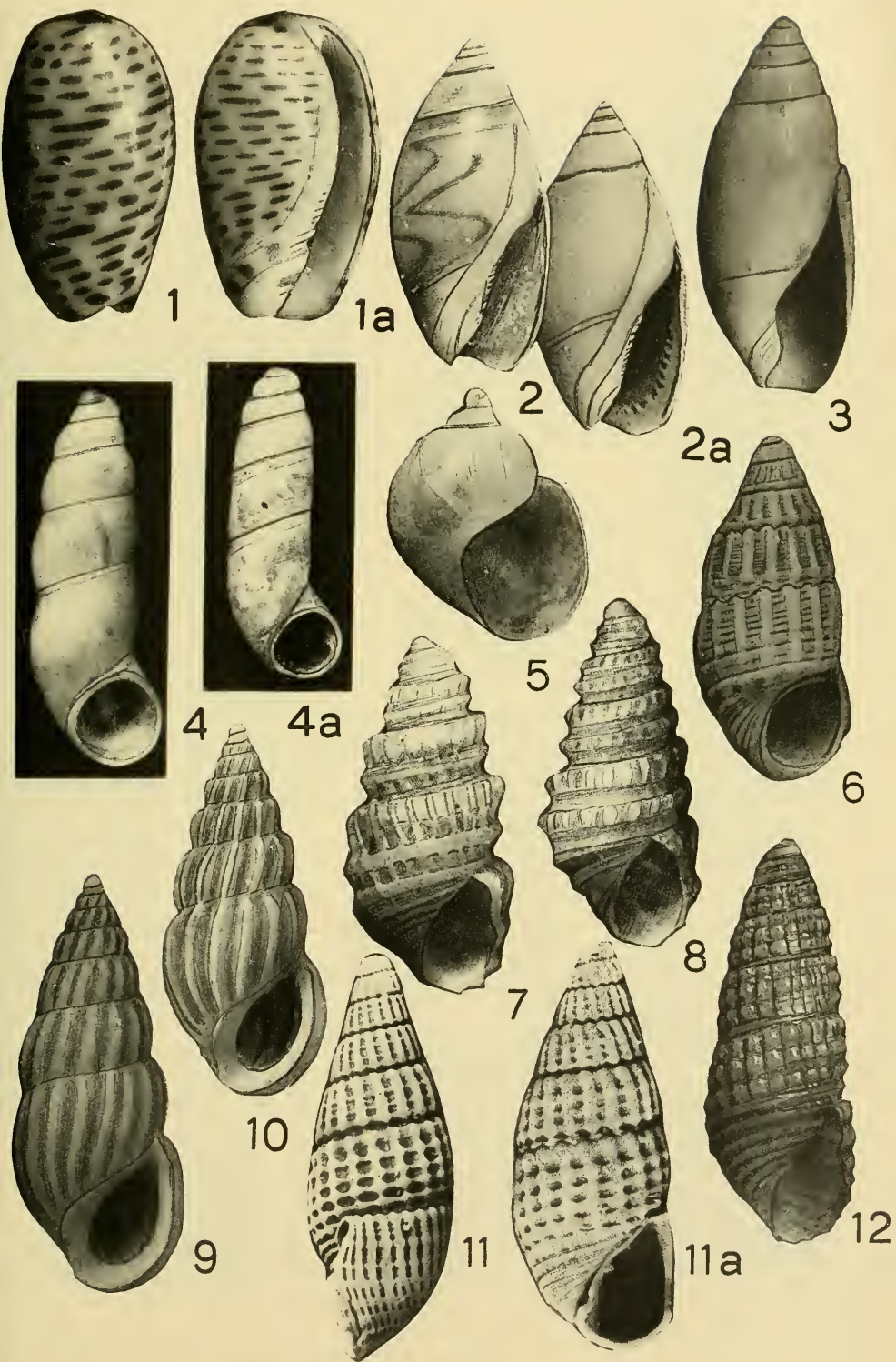
Bocas Island and Colon.

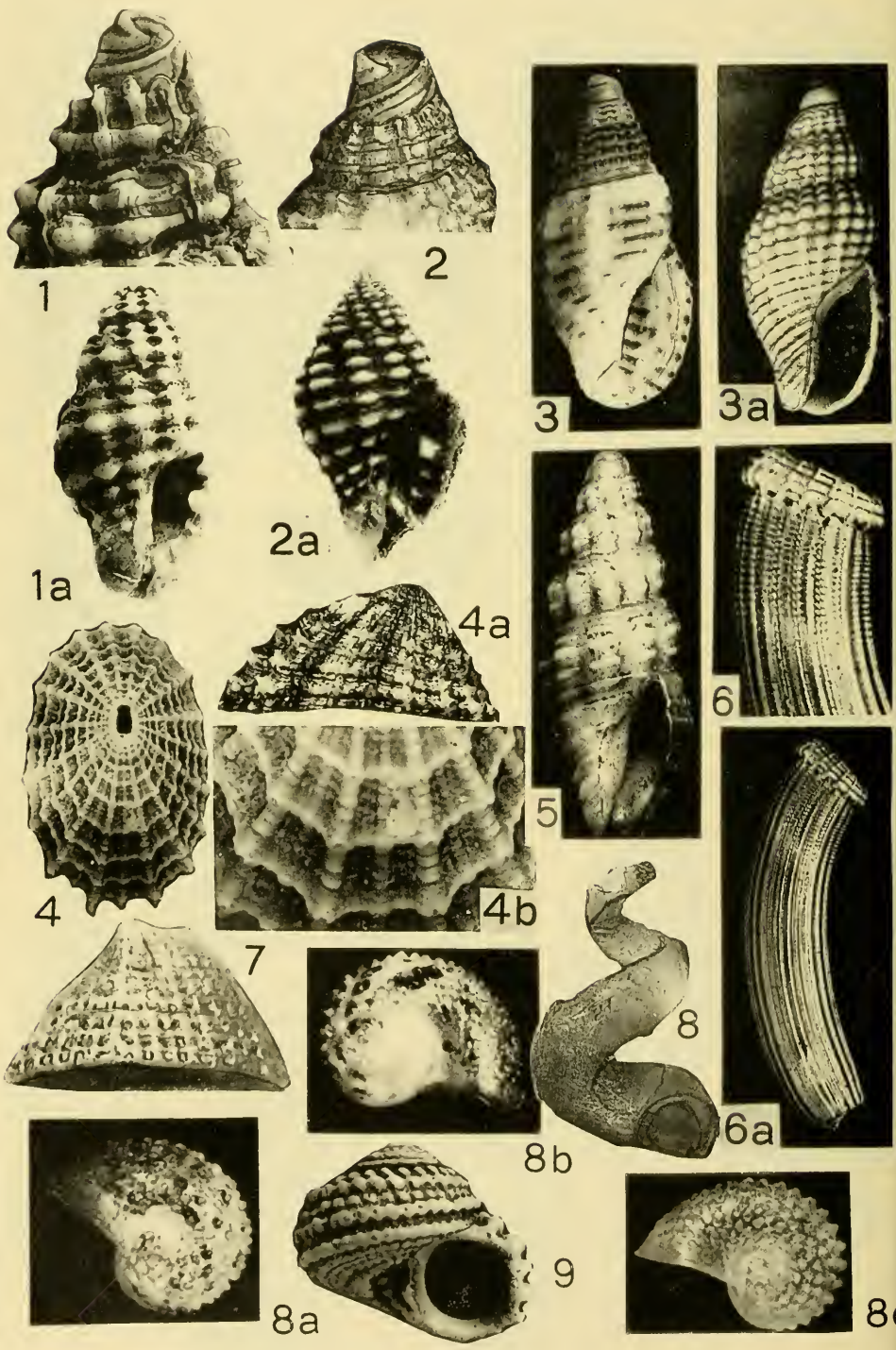
⁷Clench, W., 1950, Occ. Pap. Moll., vol. 1, No. 15, p. 324, pl. 46, figs. 11-12.

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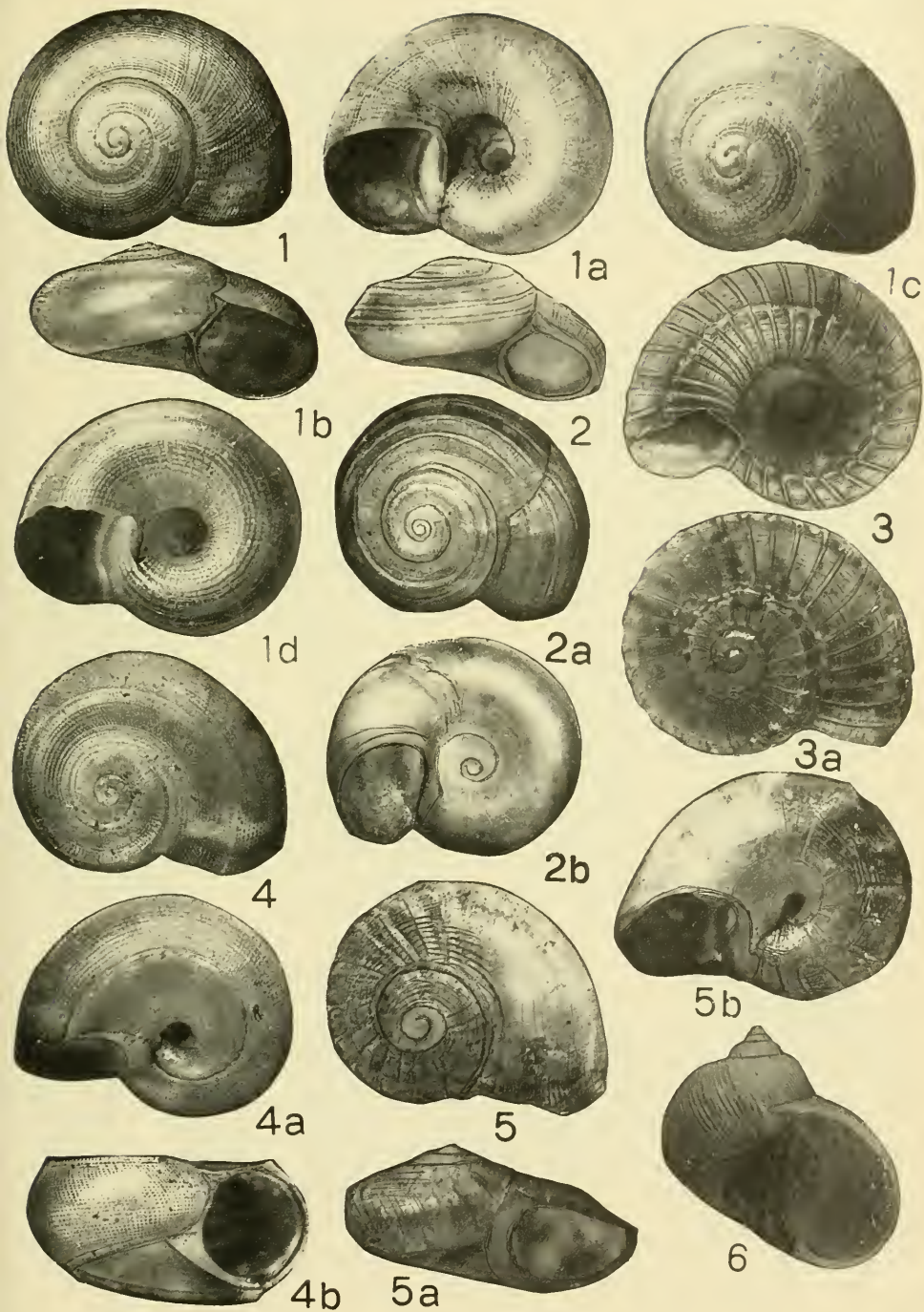


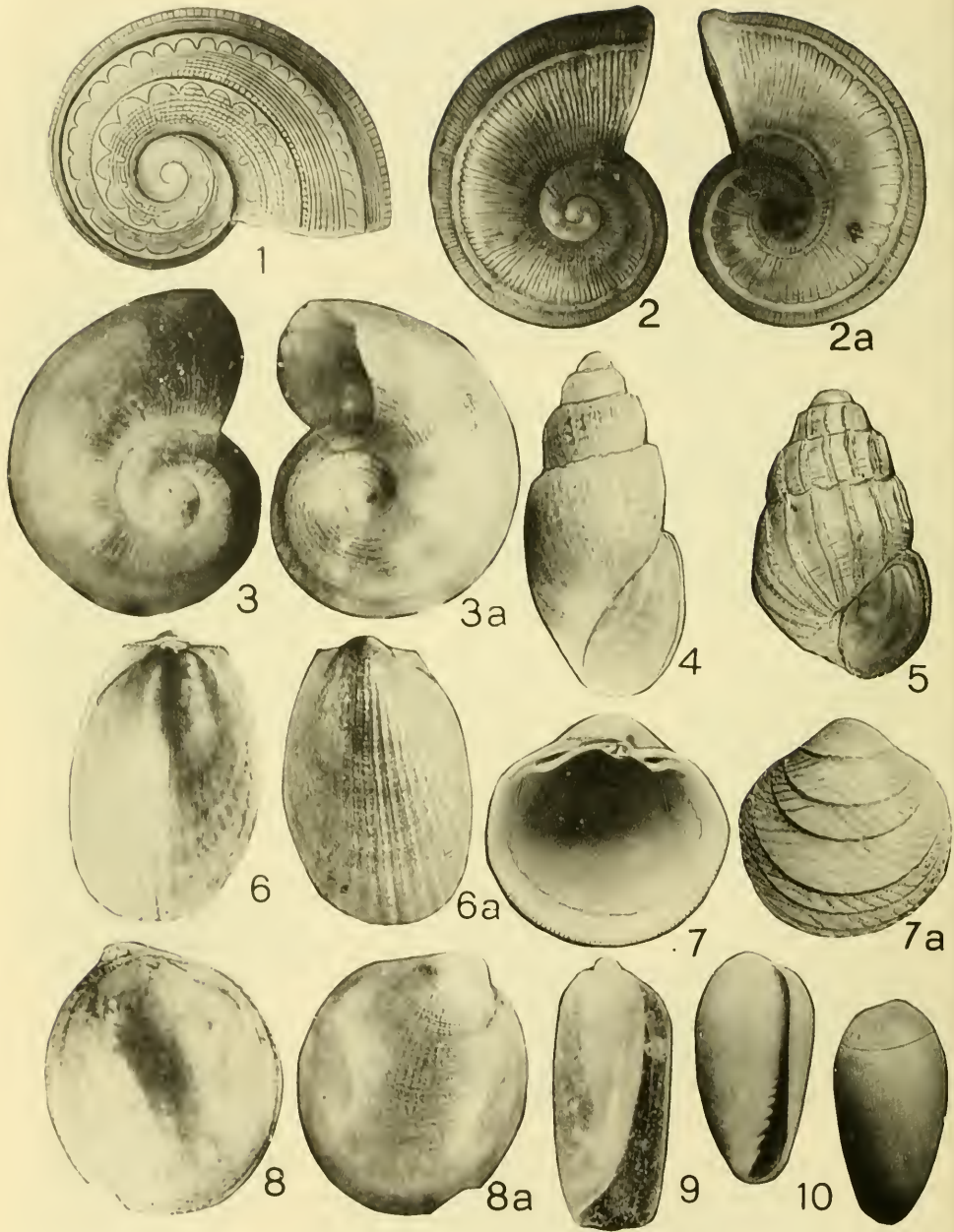
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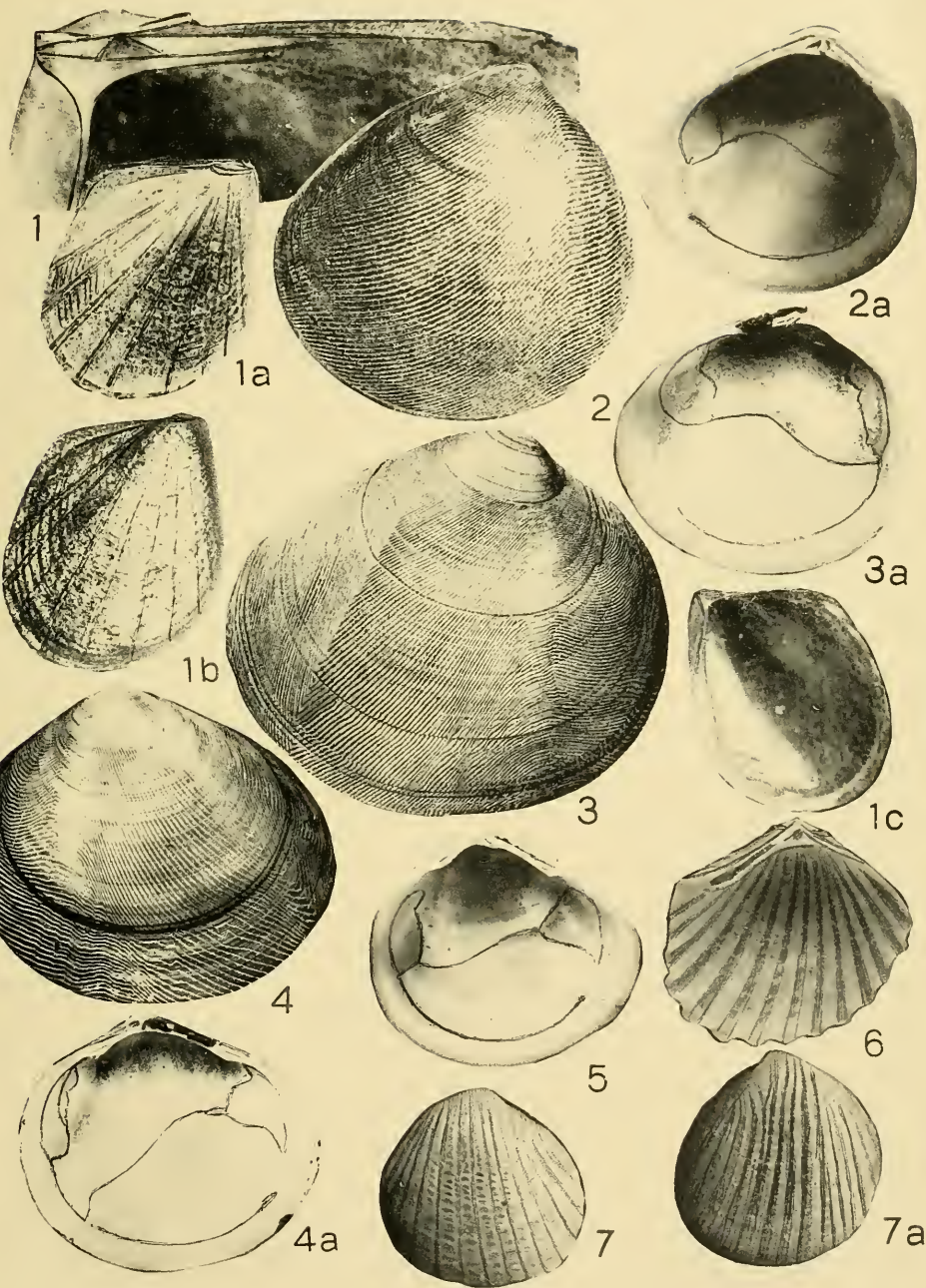


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AGE, CORRELATION, AND BIOSTRATIGRAPHY OF
THE UPPER TOCUYO (SAN LORENZO) AND POZÓN
FORMATIONS, EASTERN FALCÓN, VENEZUELA

By

WALTER H. BLOW

The British Petroleum Company, Limited

February 9, 1959

This work was first completed in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of Science of the University of London, England

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AGE, CORRELATION, AND BIOSTRATIGRAPHY OF THE UPPER TOCUYO (SAN LORENZO) AND POZÓN FORMATIONS, EASTERN FALCÓN, VENEZUELA

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The British Petroleum Company, Limited

ABSTRACT

H. H. Renz (1948) proposed a biostratigraphical subdivision of the Agua Salada group, eastern Falcón, Venezuela, based almost entirely on the occurrence of benthonic Foraminifera. The present work critically re-examines this biostratigraphy in the light of new evidence from a detailed traverse along the Pozón-El Mene Road. The stratigraphical distribution of both benthonic and planktonic Foraminifera has been investigated. Evidence from this traverse shows that a direct correlation between the planktonic foraminiferal biozones used in Trinidad and the subdivisions of Renz can be achieved. Furthermore, whereas, in southern Trinidad, Miocene sediments above the *Globorotalia menardii* Zone, Lengua formation are devoid of planktonic Foraminifera, corresponding sediments in eastern Falcón often contain abundant planktonic faunas. Investigations show that, using planktonic Foraminifera, a further subdivision of these higher sediments is possible. Three new biozones are proposed within these middle to upper Miocene sediments.

Since the section in eastern Falcón is largely undisturbed by tectonic complications, a confirmation of H. M. Bolli's (1950, 1957) planktonic zonation based on surface and subsurface sections within the Ciperó-Lengua formations (southern Trinidad) is possible. Bolli's biozones are shown to have more than local validity whereas the benthonic foraminiferal zonation of Renz is strongly influenced by ecological conditions.

The age and a trans-Atlantic correlation of these eastern Falcón Miocene sediments is discussed in the light of evidence seen recently in Sicily and Malta.

A number of evolutionary studies have been made within the Oligocene and Miocene Orbulinidae and Globorotaliidae, and five lineages have been distinguished and are discussed. In some of these lineages, evolutionary changes appear to have occurred in a repetitive manner. The first occurrence and evolution of *Globigerina bulloides* is discussed. Reference is also made to the evolution and first occurrence of the genus *Orbulina* d'Orbigny, whilst the wall structure and morphology of the genus *Sphaeroidinella* Cushman, 1927 is discussed in some detail.

One hundred seventy-four species of benthonic Foraminifera (including two new species) and 72 species or subspecies of planktonic Foraminifera (including ten new forms) are described or discussed.

The name Tocuyo is substituted for San Lorenzo, a term which is pre-occupied by the name San Lorenzo formation in California (Arnold, 1906).

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I. INTRODUCTION

PAST WORK

In 1948, H. H. Renz made a detailed study of the benthonic Foraminifera of the Agua Salada group, District of Acosta, eastern Falcón, Venezuela, (Maps 1, 2). He erected a biostratigraphic term based almost entirely on the stratigraphic distribution of these bottom-living forms. Renz, in his detailed study, also reviewed the biostratigraphical and lithostratigraphical studies of many earlier workers, notably Thomas (1924), Senn (1935), Cushman and Renz (1941), and Renz (1942). Much of the stratigraphical terminology used by these earlier workers has become obsolete and superseded by Renz's (1948) detailed and comprehensive work.

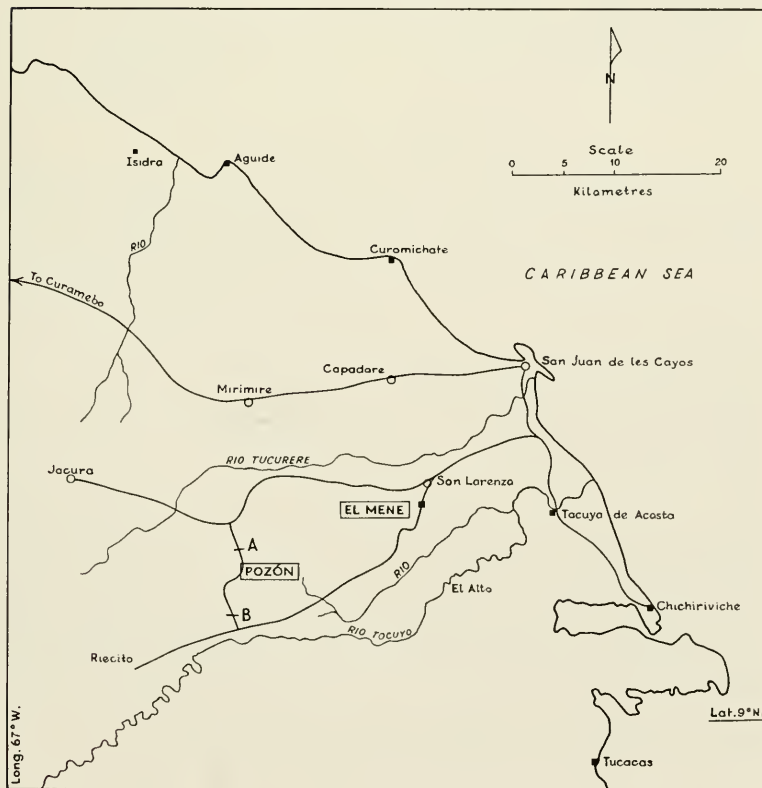


MAP 1. Geographical position of Eastern Falcón and Trinidad.

LEGEND: Area of map 2 shaded thus 

MAP 2.

Sketch map of the Eastern Falcón, Venezuela, Region showing the geographical position of the POZÓN - EL MENE ROAD SECTION (A - B)



Renz (1948, p. 8) pointed out that the term "Agua Salada Group" first appeared in a paper published in 1937 (Wiedenmayer) although this term has been used as early as 1919 in private reports to oil companies by M. L. Thomas.

The Agua Salada group has been divided on lithological grounds into two formations, *i.e.*, an older San Lorenzo formation¹ (type locality at El Mene de Acosta) and a younger Pozón formation (type locality at Pozón). Renz (1948 pp.8-27) also reviewed the lithology of these two formations (including work by J. C. Griffiths) and pointed out that the following lithological subdivisions have been generally recognized by field geologists employed by oil companies operating in the area:—

OJO DE AGUA FORMATION

Agua Salada group	{	Huso Clay member	} Pozón Formation	
		Husito Marly-Clay member		
		Policarpio "Greensand" member		
				} San Lorenzo Formation (Tocuyo fm.)
		Menicito Clay member		
El Salto Sand member				

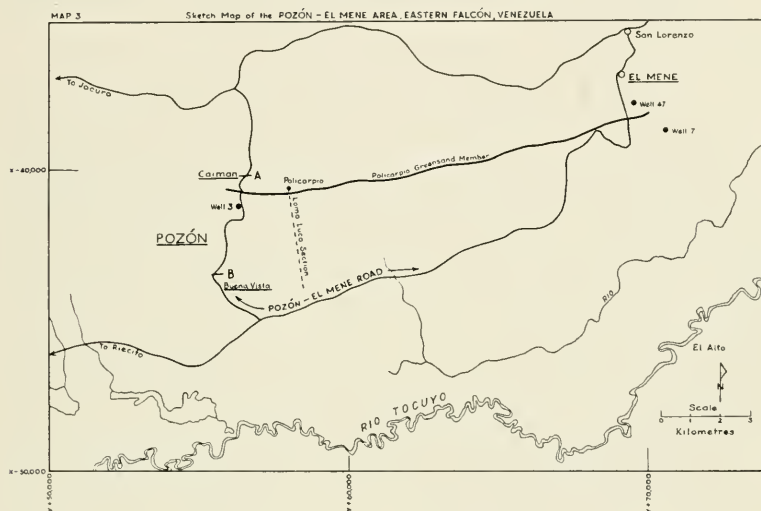
GUACHARACA FORMATION

Renz (1948, pp.38-76) erected the following biostratigraphical subdivisions for the San Lorenzo and Pozón formations based almost entirely on the occurrence of benthonic Foraminifera:—

		OJO DE AGUA FORMATION
<i>Robulus senni</i> Zone	}	} Pozón Formation
<i>Marginulinopsis basispinosus</i> Zone		
<i>Valvulineria herricki</i> Zone		
<i>Globorotalia fohsi</i> Zone		
<i>Siphogenerina transversa</i> Zone	}	} San Lorenzo Formation (Tocuyo fm.)
<i>Robulus wallacei</i> Zone		
<i>"Uvigerinella" sparsicostata</i> Zone (part)		
		GUACHARACHA FORMATION

¹ See Appendix I, concerning the validity of this formational name and proposal of substitution of the name Tocuyo for San Lorenzo.

The type section of the Pozón formation was chosen by Renz along the Loma Luca traverse (see Map 3) whilst the type section for the San Lorenzo formation was chosen at El Mene de Acosta.



Renz (1948, pp.69-76) further subdivided his *Robulus senni* Zone into three "Zonules":—

Elphidium poeyanum-Reussella spinulosa Zonule,

Textularia panamensis Zonule,

Vaginulinopsis superbus-Trochammina cf. pacifica Zonule

but pointed out that these zonules could be recognized only in the Pozón area and not in the El Mene area to the east of Pozón (see Map 2). The relationship of Renz's biostratigraphical subdivisions to the generally accepted lithological subdivisions is shown on the right-hand side of Chart 1 and on Map 4.

Renz (1948, p.38 *et seq.*) considered the San Lorenzo formation to be of middle and upper Oligocene age whilst the Pozón formation was considered to range from upper Oligocene to Miocene (Tortonian) times. However, when assessing these ages ascribed by Renz, it is necessary to remember that Renz (1948, p. 26) placed

the Aquitanian in the Oligocene and considered the Miocene to commence with the Burdigalian stage. The present writer discusses these age relationships in some detail at a later stage in this study, but would state here that, following the recommendation of the U. S. Geological Survey, he regards the Aquitanian as basal Miocene.

SCOPE OF THE PRESENT WORK AND MATERIAL

Whereas in eastern Falcón the biostratigraphical subdivisions of the Agua Salada group were, previous to this study, made in terms of mainly benthonic Foraminifera (Senn, 1935; Cushman and Renz, 1941; Renz, 1948), in southern Trinidad the emphasis has been to use planktonic Foraminifera (mainly because of their abundance) for the zonation of the Ciperó and Lengua formations (Cushman and Stainforth, 1945; Stainforth, 1948a; Bronnimann, 1951; Bolli, 1950, 1951, 1957) so that a direct correlation between the areas was not possible previous to this study.

It was suggested to the writer by Dr. H. G. Kugler and Dr. H. M. Bolli that an investigation of the planktonic Foraminifera of the Agua Salada group would permit a direct comparison to be made between the benthonic biostratigraphy of Renz and the planktonic biostratigraphy used in southern Trinidad. This investigation has now not only provided a confirmation of the succession of biozones recognized in Trinidad but has also shown that these planktonic biozones have more than local validity. The eastern Falcón succession (in contrast to the succession in southern Trinidad) appears to be complete and not so much disturbed by penecontemporaneous slumping and reworking of Foraminifera. Consequently, the present study has enabled some further refinements to be made to the planktonic biostratigraphy of the Caribbean Miocene. This study also emphasizes the value of planktonic Foraminifera for long distance correlation of heterotopic sediments.

This work is based on the faunal analysis (of both planktonic and benthonic Foraminifera) of over 700 closely spaced auger and pit samples collected by Dr. R. Muhlemann from a detailed traverse, along or off-set, from the north to south section of the Pozón-El Mene Road between Caiman and Buena Vista (Maps 1,

2, 3 and 4). Map 4 shows in detail the positions of Muhlemann's samples which are, in general, equally spaced and follow consecutively between the "key" samples actually indicated. The geographical relationship of this section as shown on Map 4 is given by reference to the letters "A" and "B" on Maps 2 and 3.

This Pozón-El Mene Road section, which is about 2,000 metres west of Renz's Loma Luca section, extends from the upper part of the San Lorenzo (Tocuyo) formation through the Pozón formation into the overlying Ojo de Agua formation. Since this Pozón-El Mene Road traverse was sampled in detail and each sample collected at intervals of approximately five metres, it has been possible to make a close check on the ranges of the Foraminifera described in this paper. Also it has been possible to make some evolutionary studies for some groups of planktonic Foraminifera.

In addition to the samples collected by R. Muhlemann from the Pozón-El Mene Road, the original samples used by Renz from the Loma Luca (Renz, 1948—Table No. 4) were available to the writer so that it was possible to note with precision the factors governing the position of Renz's various zonal boundaries. Furthermore, samples from the nearly completely cored Pozón Well 3 and El Mene Wells 7 and 47 were also investigated.

The writer (Blow, 1956) published a preliminary correlation between the two biostratigraphies, and Chart 1 shows this correlation in the light of further evidence. Map 4 shows in detail the relationship of the zonal boundaries of both types of biostratigraphies to each other and in conjunction with the sequence of samples studied along the Pozón-El Mene Road traverse.

II. PLANKTONIC BIOSTRATIGRAPHY OF THE UPPER TOCUYO² AND POZÓN FORMATIONS

Based on the stratigraphical occurrence of planktonic Foraminifera the author has been able to recognize the following biostratigraphical subdivisions of the upper part of the Tocuyo formation and the Pozón formation as seen in the detailed traverse along,

² Hereafter, Tocuyo, see Appendix, will be used in place of San Lorenzo formation.

or off-set from, the Pozón-El Mene Road between Caiman and Buena Vista (see Maps 2, 3, and 4—points marked “A” and “B”):—

10. *Globigerina bulloides* Zone
9. *Sphaeroidinella seminulina* Zone
8. *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone
7. *Globorotalia mayeri* Zone (*s.l.*)

}	<i>Gr. mayeri</i> / <i>G. nepenthes</i>	Subzone
}	<i>Gr. mayeri</i> / <i>Gr. linguaensis</i>	Subzone
6. *Globorotalia fohsi robusta* Zone
5. *Globorotalia fohsi lobata* Zone
4. *Globorotalia fohsi fohsi* Zone
3. *Globorotalia fohsi barisanensis* Zone
2. *Globigerinatella insueta* Zone (*s.l.*)

}	<i>G. insueta</i> / <i>G. bispherica</i>	Subzone
}	<i>G. insueta</i> / <i>G. triloba</i>	Subzone
1. *Catapsydrax stainforthi* Zone

The base of the Pozón formation (as represented by the base of the Policarpio “Greensand” member) occurs within the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone. The zonal boundaries of the zones are defined on Map 4 and the direct correlation of these planktonic zones with Renz’s (1948) benthonic zones is also given on the same Map.

The planktonic zones and their associated subzones are discussed below and the diagnostic faunal elements of each zone are briefly noted. The complete benthonic and planktonic foraminiferal content of each interval is summarized on Chart 2 and Chart 3 respectively.

1. *Catapsydrax stainforthi* Zone, Tocuyo formation (in part)

This zone is defined by the limited occurrence together of *Catapsydrax dissimilis* (Cushman and Bermudez) and *Globigerinatella insueta* Cushman and Stainforth. *Globoquadrina rohri* (Bolli) only occurs in the lower part of this interval. *Catapsydrax unicavus* Bolli, Loeblich, and Tappan does not range higher than the top of this zone and although *Catapsydrax stainforthi* Bolli, Loeblich, and Tappan is not limited to this interval, it is a conspicuous member of the zone's fauna.

The base of this zone is not seen in the Pozón-El Mene Road traverse but, from evidence seen in the subsurface sections of Pozón Well 3 and El Mene Wells 7 and 47, the lower boundary of the *Robulus wallacei* Zone (Renz, 1948, p. 45) still occurs within the co-existence of *Catapsydrax dissimilis* and *Globigerinatella insueta* so that the topmost part of Renz's "*Uvigerinella*" *sparsicositata* Zone can be correlated with the basal part of this planktonic biozone.

2. *Globigerinatella insueta* Zone (*s.l.*), Tocuyo formation (upper part) and Pozón formation (lower part)

This zone spans the uppermost part of the Tocuyo formation and the basal part of the Pozón formation as seen in the Pozón area of eastern Falcón.

The writer recognizes two subzones within this zone which are based on the evolution of *Globigerinoides bispherica* Todd (as emended by Blow, 1956, p. 62) from *Globigerinoides triloba triloba* (Reuss). The zone is distinguished by the presence of *Globigerinatella insueta* Cushman and Stainforth but *Catapsydrax dissimilis* (Cushman and Bermudez) and *Catapsydrax unicavus* Bolli, Loeblich, and Tappan are absent.

2a. *Globigerinatella insueta*/*Globigerinoides triloba* Subzone

This subzone is separated from the overlying subzone by the absence of *Globigerinoides bispherica*. *Catapsydrax stainforthi* occurs in this interval but does not range to the top of the subzone. *Globigerinoides diminuta* Bolli first occurs in the upper part of the interval but does not become common until the interval of the

overlying *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone. *Globigerinoides triloba triloba* (Reuss) is particularly common in this interval.

Robulus wallacei (Hedberg) becomes extinct in this interval and last occurs in Sample RM 19179 (see Map 4).

2b. *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone

This subzone is characterized by the occurrence together of *Globigerinatella insueta* and *Globigerinoides bispherica*. The evolution of *Orbulina* and *Biorbulina* from *Globigerinoides bispherica* via *Porticulasphaera glomerosa* (Blow) and *Porticulasphaera transitoria* (Blow), respectively, occurs within the upper part of this subzone (Blow, 1956).

Globigerinoides diminuta Bolli also characterizes this interval and, although it ranges from the uppermost part of the underlying subzone, it does not range into the overlying *Globorotalia fohsi barisanensis* Zone. *Globorotalia menardii archeomenardii* (Bolli) first appears within this subzone.

Globorotalia Fohsi "Zone" (s.l.), Pozon Formation (in Part)

Before discussing the next four zones, which are based on the subspecies of *Globorotalia fohsi*, it is necessary to outline a short historical review of Bolli's work (Bolli, 1950, 1957) with reference both to the various subspecies of the species and to their biostratigraphical usage.

Bolli (1950) recognized that certain other types of *Globorotalia* show evolutionary relationships to the form described by Cushman and Ellisor (1939) as *Globorotalia fohsi*. Bolli established, by detailed study of continuous surface and subsurface sections in the Ciperó formation of southern Trinidad, that there was a gradational sequence extending from a form recorded by LeRoy (1939) as *Globorotalia barisanensis* to a form described by Bermudez (1949) as *Globorotalia lobata*. Bolli (1950) considered these two latter types as subspecies of the "central type" *Globorotalia fohsi*; at the same time Bolli also recognized that the evolutionary trend continued beyond the subspecies "lobata" and distinguished a fourth and final subspecies as *Globorotalia fohsi robusta*. These phylogenetic studies were adopted by other authors (Bronnimann,

1951a) who used the occurrence of these various subspecies to define subzones of the *Globorotalia fohsi* Zone. Later (Bolli, 1957), these subzones were afforded the biostratigraphical rank of zones. The present writer agrees with this later view since it has become established that the intervals in question can be recognized not only in various parts of Trinidad but also in eastern Falcón. Furthermore, since the zonation is based on a well-defined evolutionary sequence, biological principles suggest that the zonal boundaries should be isochronous within the limits imposed by the rates of faunal migration and genetic interchange.

The term *Globorotalia fohsi* "Zone" (*s.l.*) is retained in the present work purely as a convenience when discussing the range of some of the Foraminifera.

3. *Globorotalia fohsi barisanensis* Zone, Pozón formation (in part)

This zone is distinguished by the presence of *Globorotalia fohsi barisanensis* (LeRoy), *Orbulina suturalis* Bronnimann, *Orbulina universa* d'Orbigny, and *Biorbulina bilobata* (d'Orbigny) combined with the absence of *Globigerinatella insueta* Cushman and Stainforth. *Globigerinoides bispherica* Todd persists only into the extreme basal part of the zone. Below this zone, and within the underlying *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi barisanensis* is small and with a generally rather lobulate periphery with fairly well-incised sutures. However, in this zone, *Globorotalia fohsi barisanensis* has less deeply incised sutures and the periphery is practically nonlobulate. Furthermore, the ventral side shows a tendency to be rather more definitely vaulted than in the earlier forms of the subspecies.

Globorotalia scitula scitula (Brady) appears for the first time in the uppermost part of this zone.

4. *Globorotalia fohsi fohsi* Zone, Pozón formation (in part)

This zone is characterized by the presence of *Globorotalia fohsi fohsi* Cushman and Ellisor and *Globorotalia menardii prae-menardii* (Cushman and Stainforth). *Globorotalia scitula gigantea* Blow, subsp. nov. appears in the upper part of this interval for the first time.

Siphogenerina transversa Cushman becomes extinct at about the middle part of this interval (Sample No. RM 19376—see Map

4) whilst *Valvulineria herricki* (Hadley) first appears in its uppermost part (Sample No. RM 19381).

H. H. Renz (1948) recognized a "*Globorotalia fohsi* Zone" between his *Siphogenerina transversa* and *Valvulineria herricki* Zones and reference to the sample originally used by Renz (see Renz, 1948, Table No. 4-samples filed in the collections of Texaco Trinidad Inc., Pointe-à-Pierre) showed that the samples referred to by him as his "*Globorotalia fohsi* Zone" contain forms referable to the subspecies *Globorotalia fohsi fohsi* Cushman and Ellisor and *Globorotalia fohsi lobata* (Bermudez). Hence it appears that the "*Globorotalia fohsi* Zone" of H. H. Renz is equivalent to part of the *Globorotalia fohsi fohsi* and the *Globorotalia fohsi lobata* Zones as used by Bolli (1957) and the present writer.

5. *Globorotalia fohsi lobata* Zone, Pozón formation (in part)

This zone is characterized by the presence of *Globorotalia fohsi lobata* and *Globorotalia menardii praemenardii*. *Globorotalia scitula gigantea* Blow, subsp. nov. is also present whilst *Globigerina bulbosa* LeRoy and *Sphaeroidinella seminulina kochi* (Caudri) appear for the first time within this zone.

6. *Globorotalia fohsi robusta* Zone, Pozón formation (in part)

This zone is distinguished by the presence of *Globorotalia fohsi robusta* Bolli. *Globorotalia menardii menardii* (d'Orbigny) develops from *Globorotalia menardii praemenardii* (Cushman and Stainforth) in the middle part of this interval, and *Sphaeroidinella dehiscentes subdehiscentes* Blow, subsp. nov. occurs for the first time in the uppermost part of this zone. *Sphaeroidinella seminulina kochi* (Caudri) becomes fairly common in this zone.

7. *Globorotalia mayeri* Zone (*s.l.*), Pozón formation (in part)

This zone is characterized by the continuing presence of *Globorotalia mayeri* Cushman and Ellisor after the extinction of *Globorotalia fohsi robusta*. *Globoquadrina altispira globosa* Bolli reappears from the base of the interval and although *Globorotalia lenguaensis* Bolli first appears in the topmost part of the underlying interval it only forms a significant component of the fauna in this zone.

The writer recognizes two subzones within this interval in eastern Falcón:

7a. *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone

This subzone is characterized by the co-existence of *Globorotalia mayeri* and *Globorotalia linguaensis* combined with the absence of both *Globorotalia fohsi robusta* and *Globigerina nepenthes* Todd. *Globigerinoides bollii* Blow, sp. nov. first occurs at the base of the subzone.

7b. *Globorotalia mayeri*/*Globigerina nepenthes* Subzone

This subzone is characterized by the co-existence of *Globorotalia mayeri* and *Globigerina nepenthes*. *Globigerinoides bollii* and *Sphaeroidinella dehiscens subdehiscens* both become common within this interval.

Marginulinopsis basispinosus (Cushman and Renz) first occurs in sample RM 19671 within this interval (see Map 4).

8. *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation (in part)

This zone is distinguished by the continuation of *Globigerina nepenthes* Todd after the extinction of *Globorotalia mayeri* Cushman and Ellisor. *Globorotalia menardii menardii* is often abundant and typical. *Globorotalia acostaensis* Blow, sp. nov. occurs for the first time within this zone whilst *Globigerina bulloides* d'Orbigny develops from *Globigerina praebulloides* Blow, sp. nov. in the middle part of this interval.

Occasional specimens of *Globigerina apertura* Cushman have also been observed in the upper part of this zone. Transitional forms to *Globorotalia menardii miocenica* Palmer also appear at the top of this zone.

9. *Sphaeroidinella seminulina* Zone, Pozón formation (in part)

This zone is marked by the continuing presence of both subspecies of *Sphaeroidinella seminulina*, i.e., *Sphaeroidinella seminulina seminulina* (Schwager) and *Sphaeroidinella seminulina kochi* (Caudri), but it is highly likely that the latter subspecies becomes extinct before the former.

Although the possibility exists that the upper limit of this zone is influenced to some extent by facies change, evidence seen

in two subsurface sections on the Island of Cubagua (see Map 1) also shows the same extinction of both subspecies of *Sphaeroidinella seminulina* within similar planktonic assemblages as seen in this Pozón-El Mene Road section. Also, in the Cubagua subsurface sections there is no apparent change of facies.

10. *Globigerina bulloides* Zone, Pozón formation (in part)

Following the disappearance of *Sphaeroidinella seminulina* (Schwager) there is no further change in the composition of the planktonic faunas which tend to become rather impoverished in the section under consideration. However, some isolated samples show fairly rich planktonic assemblages which contain typical specimens of *Globorotalia menardii menardii*, *Globigerina bulloides*, *Orbulina universa*, *Globigerinoides triloba immatura*, and *Globigerinoides bollii* amongst others.

Occasional specimens of *Sphaeroidinella dehiscens subdehiscens* occur, but no specimens of the *Sphaeroidinella seminulina* group have been observed.

The designation of this interval must be regarded as only provisional since *Globigerina bulloides* continues to the present time. Investigations of uppermost Miocene/Pliocene planktonic assemblages from other areas might show that another planktonic species with a more rigorously defined biostratigraphical occurrence may prove to be a better zonal index.

III. FACIES VARIATION IN THE UPPER TOCUYO AND POZÓN FORMATIONS

There are some differences in the stratigraphical distribution of benthonic Foraminifera as recorded by H. H. Renz (1948) from his Loma Luca section and that noted by the writer in the study of the Pozón-El Mene Road traverse. Most of these discrepancies in the Tocuyo and lower part of the Pozón formation do not appear to be of importance from the point of view of biostratigraphical interpretation. These minor variations in stratigraphical distribution are noted under "Occurrence" in the relevant parts of the Systematic Record associated with this work. However, in the upper part of the Pozón formation these discrepancies do become

important. Thus the writer has noted the occurrence together of *Marginulinopsis basispinosus* (Cushman and Renz) with *Valvulineria herricki* (Hadley) which was not recorded by Renz. Also, the occurrence of *Valvulineria herricki* is often only sporadic and seems to occur only under apparently limited ecological conditions. In general, it is often necessary to examine a number of samples from either a section or locality to decide, unambiguously, their position in the biostratigraphy of Renz. This is especially so in the upper part of the Pozón formation where the evidence suggests an approach to rhythmic or cyclic conditions of deposition.

Before discussing some of these effects of variation of environment on the stratigraphical distribution of benthonic Foraminifera it is useful to review the general conclusions drawn by Renz for the depositional conditions of the Tocuyo and Pozón formations. These conclusions are summarized below and show that there is an overall and generalized trend towards shallow-water conditions in the upper part of the Pozón formation.

Zone (Renz, 1948)

Robulus wallacei Zone
(at El Mene)

Normal marine, open sea, deposition at medium depth (200-600 metres) along a continental shelf in tropical latitudes.

Siphogenerina transversa
Zone
(at El Mene)

Normal marine, open sea, deposition at medium depth (200-600 metres) along a continental shelf in tropical latitudes.

Globorotalia fohsi Zone
(of Renz, 1948, at Pozón)

Normal marine, open sea, deposition at medium depth (200-600 metres) along a continental shelf in tropical latitudes.

Valvulineria herricki Zone
(at Pozón)

Normal marine, open sea, deposition at medium depth (200-600 metres) along a continental shelf in tropical latitudes.

<p><i>Marginulinopsis basispinosus</i> Zone (at Pozón)</p>	<p>Normal marine, open sea, deposition at medium depth (200-600 metres) along a continental shelf in tropical latitudes.</p>
<p><i>Robulus senni</i> Zone (at Pozón)</p>	<p>Normal marine environment at a shallow depth (littoral-neritic) of about 100 metres in tropical latitudes.</p>
<p><i>Vaginulinopsis superbus- Trochammmina</i> cf. <i>pacifica</i> Zonule (at Pozón)</p>	<p>Normal marine environment at a shallow depth (littoral-neritic) of about 100 metres in tropical latitudes.</p>
<p><i>Textularia panamensis</i> Zonule (at Pozón)</p>	<p>Normal marine environment at shallow depths (neritic) of about 50 metres near a tropical coast.</p>
<p><i>Elphidium poeyanum- Reussella spinulosa</i> Zonule (at Pozón)</p>	<p>Marine to brackish water lagoonal condition with very shallow, warm water conditions.</p>

(Note: For the equivalence of the planktonic zones to those of Renz—see Chart 1 and Map 4).

The environmental conditions of the *Robulus wallacei* Zone and the *Siphogenerina transversa* Zone as seen in the Pozón-El Mene Road section at Pozón do not appear to be significantly different from the conditions seen at El Mene and as summarized above. However, a noteworthy feature of these zones in the Pozón area is the occurrence of intervals with assemblages of mainly large agglutinated species often with complex wall and chamber structures, such as: *Cyclammmina cancellata* Brady, *Alveovalvulinella pozonensis* (Cushman and Renz), *Gravellina narivaensis* Bronnemann, *Valvulina flexis* Cushman and Renz, *Alveolophragmium* spp., and robust species of *Haplophragmoides*. These assemblages are similar to the assemblages of the Nariva formation of southern Trinidad; but whereas the Nariva formation extends from the

Globorotalia kugleri Zone through the *Catapsydrax dissimilis* Zone and into the *Catapsydrax stainforthi* Zone, in eastern Falcón the similar assemblages extend stratigraphically higher into the *Globigerinatella insueta* Zone (*s.l.*). Stainforth (1948a, 1952a) considered these assemblages of agglutinated species to indicate a turbid water environment and Kugler (1953) related this turbid environment to the occurrence of turbidity flows in a subsiding trough. These assemblages of agglutinated forms from the *Catapsydrax stainforthi* Zone and the *Globigerinatella insueta* Zone (*s.l.*). Tocuyo and Pozón formations, occur several times and are separated by assemblages of calcareous forms, often with abundant planktonics, suggestive of a depositional depth between 200 and 600 metres. The writer considers that these assemblages of robust and complex agglutinated species represent periods of localized deepening and downwarping with minor turbidity flows giving rise to temporary turbid conditions. This view is supported by observations of Lowman (1949) who pointed out that certain agglutinated species (including *Cyclammina*) have an optimum depth occurrence of about 1400 metres in the Gulf of Mexico at the present day.

Above the *Marginulinopsis basispinosus* Zone, Pozón formation (*i.e.*, above the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone) and within the intervals of the *Robulus senni* Zone and the *Vaginulinopsis superbus-Trochammina cf. pacifica* Zonule as well as in the *Textularia panamensis* Zonule there occur frequent repetitions of faunal assemblages in the Pozón-El Mene Road section.

In the *Robulus senni* Zone and in the *Vaginulinopsis superbus-Trochammina cf. pacifica* Zonule these repetitions consist of intervals with *Uvigerina isidroensis* Cushman and Renz, *Bolivina imporcata* Cushman and Renz and *Bolivina simplex* Cushman and Renz, alternating with the "normal" zonal assemblages containing *Robulus senni* Cushman and Renz, *Vaginulinopsis superbus* (Cushman and Renz), *Cassidulina subglobosus* Brady, *Cibicides* spp., *Globigerina* spp., and *Globorotalia* spp.

In the *Textularia panamensis* Zonule a three-fold repetition occurs. Assemblages with *Eponides parantillarum* Galloway and

Heminway, *Nonion incisus* (Cushman), *Cancriis sagra* (d'Orbigny), *Cibicides americanus* (Cushman), *Globigerina* spp., and *Globorotalia* spp. are followed by assemblages with *Uvigerina isidroensis* Cushman and Renz, *Bolivina impercata* Cushman and Renz, and *Bolivina simplex* Cushman and Renz. This last assemblage is followed in turn by a mainly "arenaceous" assemblage with *Textularia panamensis* Cushman, *Textularia pozonensis* Cushman and Renz, and thin-walled *Trochammina* spp. It is considered that the *Uvigerina isidroensis*-*Bolivina impercata*-*Bolivina simplex* assemblage represents an environment shallower than that represented by the assemblage with the *Eponides*-*Cancriis*-*Cibicides*-*Globigerina*-*Globorotalia* fauna, but deeper than environment represented by the mainly "arenaceous" assemblage with *Textularia panamensis*-*Textularia pozonensis*-*Trochammina* spp.

It is because of this repetition of faunal assemblages that no clear distinction can be made between the *Robulus senni* Zone and the *Vaginulinopsis superbus*-*Trochammina* cf. *pacifica* Zone in the Pozón-El Mene Road section.

A further point concerning the composition of the faunas throughout the upper Tocuyo and Pozón formations which needs clarification is the proportion of planktonic specimens to benthonic specimens present in each of the zones. Renz (1948) analysed the faunal composition of each of his zones by calculating the percentage of each foraminiferal family in the assemblage. This method of analysis depends on the number of species recognized in each genus belonging to the family and, since Renz recognized only a few planktonic species, the Orbulinidae and Globorotaliidae were, in general, underestimated.

The writer made a count of the number of planktonic and benthonic specimens occurring in representative samples from each zone. The results of this count and Renz's percentages of planktonic families are compared in the following table (Table 1):—

Table 1

Zone	% of Planktonic Families (Renz, 1948)	Count of Planktonic Specimens	Count of Benthonic Specimens	Ratio P:B (Approx.)	Approx. % of Planktonic Specimens in Fauna
<i>Robulus scalacci</i> Zone	Globigerinidae 1.5%	923	417	11:5	70%
<i>Siphogenerina transversa</i> Zone	Globorotaliidae Globigerinidae 1.5% 2.3% 3.8%	957	278	7:2	78%
<i>Globorotalia fohsi</i> Zone (of Renz, 1948)	Globorotaliidae Globigerinidae 2.0% 3.9% 5.9%	1117	421	3:1	75%
<i>Valsulinera herricki</i> Zone	Globorotaliidae Globigerinidae 1.9% 3.8% 5.7%	959	306	3:1	75%
<i>Margulinopsis basispinosus</i> Zone	Globorotaliidae Globigerinidae 2.6% 5.3% 7.9%	729	276	13:5	72%
<i>Textularia panamensis</i> Zone	Globigerinidae 16.7%	53	209	1:4	20%

Note: Globigerinidae of Renz, 1948 = Orbulinidae of this work.

Stainforth (1948a, p. 1320) made counts of planktonic and benthonic specimens for the Cipero formation of southern Trinidad and gave the following results:—

Zone II (*Globigerinatella insueta* Zone)
2,197 pelagic to 37 benthonic specimens (59:1).

Zone III (*Globorotalia fohsi* Zone)
2,984 pelagic to 119 benthonic specimens (25:1).

Stainforth (1948a, p. 1323) also gave the following percentages (no. of species and varieties as percentages of the Cipero fauna)

Globigerinidae 4.7% (= Orbulinidae of this work)

Globorotaliidae 1.6%

but pointed out that these two families form more than 90% of the fauna in number of specimens within the Cipero formation.

Although the Cipero and Tocuyo/Pozón formations cannot be considered as having been deposited under similar conditions, the figures summarized above show that planktonic specimens are present both in sufficient numbers and variety in the sediments of the Tocuyo and Pozón formations to enable a correlation with the Cipero and Lengua formations of southern Trinidad to be made.

IV. CORRELATION OF THE UPPER TOCUYO AND POZÓN FORMATIONS (EASTERN FALCÓN) WITH THE SOUTHERN TRINIDAD SUCCESSION

Cushman and Stainforth (1945), Stainforth (1948a), Bronnimann (1951), Suter (1951), Kugler (1953, 1954), Bolli (1950, 1951, 1957), and Higgins (1955), amongst other authors, have discussed various aspects of the stratigraphy of the post-Eocene deposits in southern Trinidad. The results of their studies is given in a generalized and diagrammatic form on the left-hand side of Chart 1 for sediments above the level of the *Catapsydrax dissimilis* Zone. The right-hand side of this same chart shows the lithostratigraphy and benthonic biostratigraphy of H. H. Renz (1948) together with the planktonic biostratigraphy for the upper part of the Tocuyo and Pozón formations. The correlation between the two areas can be regarded as being firmly established, for the sediments of the two areas, between the *Catapsydrax stainforthi* Zone and the top of the *Globorotalia mayeri* Zone (*s.l.*).

The Tocuyo and Pozón formations appear to have been deposited under conditions of lower tectonic intensity as compared with the depositional conditions which seem to have operated in the area of southern Trinidad at this time. Both Kugler (1953) and Bolli (1957) refer to evidence within the upper Cipero formation and Lengua formation which suggests that penecontemporaneous large-scale slumping and turbidity flows occurred during the deposition of these formations, indicating tectonic movements of high intensity. These features, which relate to an environment of high tectonic intensity, appear to be absent in the Tocuyo and Pozón formations. The lithofacies and biofacies of these latter formations suggest deposition over a continental shelflike area which was, in general, fairly stable.

Because the Tocuyo and Pozón formations were deposited under fairly stable conditions and have subsequently not been much disturbed by post-depositional tectonics, it has been possible to add some further refinements to the planktonic biostratigraphy proposed by Bolli (1957) for southern Trinidad. Furthermore, whereas in southern Trinidad the mainly planktonic foraminiferal faunas of the Lengua formation are replaced upwards by the mainly agglutinated foraminiferal faunas of the Cruse and Forest formations, in eastern Falcón and the Pozón formation continues with an abundant planktonic component to a much higher stratigraphical level. This has led to the necessity of redefining the *Globorotalia menardii menardii* Zone as used by Bolli (1957) and earlier workers. In southern Trinidad, the upper limit of the *Globorotalia menardii menardii* Zone has been taken at the change of biofacies to mainly agglutinated faunas. It has long been recognized by workers in Trinidad that the upper surface of this *Globorotalia menardii menardii* Zone is diachronous since there is known to be an interdigitation and transition between the Lengua formation and the lower part of the overlying Cruse formation. Because of these factors, the writer uses the partial occurrence of *Globigerina nepenthes* Todd above the extinction of *Globorotalia mayeri* Cushman and Ellisor to define a new interval, part of which is equivalent to the *Globorotalia menardii menardii* Zone of southern Trinidad. However, because of the well-established usage of the term "*Globorotalia*

menardii menardii" the zone is designated the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone. It is worthy of note that the Lengua/lower Cruse transition beds (Bolli, 1951; Kugler, 1953) also contain *Globigerina nepenthes* (Bolli, 1957). The writer has also observed this species in occasional "streaks" of calcareous faunas seen in subsurface sections of the middle to upper Cruse formation in the Barrackpore area of southern Trinidad, but has not observed *Globigerina nepenthes* in some calcareous faunas associated with the lower Forest Clay (Guapo beds—Suter, 1951 = base of the Forest formation, southern Trinidad). Hence, it is tentatively suggested that the major part of the Cruse formation lies within the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone as defined from the Pozón formation. The writer has observed *Sphaeroidinella seminulina seminulina* (Schwager) in the calcareous facies of the lower Forest Clay of southern Trinidad and it seems likely that part, at least, of the Forest formation can be correlated with the interval ascribed to the *Sphaeroidinella seminulina* Zone as defined in the Pozón formation.

It is emphasized, however, that a correlation between southern Trinidad and eastern Falcón, above the level of the Lengua formation, must still remain tentative owing to the lack of adequate planktonic faunas in the Cruse and Forest formations.

Below the top of the *Globorotalia mayeri* Zone (*s.l.*) the correlation between the two areas may be regarded as well established, although the subdivision of the *Globorotalia mayeri* Zone (*s.l.*) has not been recognized in Trinidad. It appears likely that a large part of the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone is missing in southern Trinidad, although it is noteworthy that Bolli (1957, fig. 18), showed *Globigerina nepenthes* as first appearing slightly above the base of his *Globorotalia mayeri* Zone in the Lengua formation. The *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone may however be represented either in the mainly non-planktonic foraminiferal assemblages of the Karamat formation, or by the heterogenous assemblages of the Río Claro Boulder bed (Suter, 1951; Kugler, 1953). An unconformity or disconformity is known to be present between the Ciperó and Lengua formations in some areas of southern Trinidad (Kugler, 1953).

Bolli (1957, p.101) pointed out that the previous study of the present writer (Blow, 1956) regarding the first occurrence of *Globigerinoides bispherica* within the *Globigerinatella insueta* Zone (*s.l.*) would permit a further subdivision of this zone. This subdivision is formally proposed in the present work and two subzones are proposed within the *Globigerinatella insueta* Zone (*s.l.*) in eastern Falcón. As Bolli (1957) implied, the *Globigerinatella insueta*/*Globigerinoides triloba* Subzone and *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone can be recognized in southern Trinidad.

V. TENTATIVE CORRELATION OF THE LOWER TOCUYO AND GUACHARACA FORMATIONS (EASTERN FALCÓN) WITH THE SOUTHERN TRINIDAD SUCCESSION

Although this work is based essentially on the samples collected by R. Muhlemann from the Pozón-El Mene Road traverse, and the main object of the study has been to achieve a correlation of the upper part of the Tocuyo formation and the Pozón formation with their equivalent sediments in southern Trinidad, other samples from the subsurface sections of Pozón Well No. 3 and El Mene Wells No. 7 and 47 (see Map 3) were also studied. These subsurface sections penetrate the lower part of the Tocuyo formation and most of the Guacharaca formation.

It appears that the upper part of the "*Uvigerinella*" *sparsicostata* Zone belonging to the lower part of the Tocuyo formation (Renz, 1948, p.30) can be correlated with the basal part of the *Catapsydrax stainforthi* Zone and the *Catapsydrax dissimilis* Zone. The lower part of the "*Uvigerinella*" *sparsicostata* Zone belonging to the upper part of the Guacharaca formation probably correlates with the *Globorotalia kugleri* Zone (Bolli, 1957). Finally, the middle and lower parts of the Guacharaca formation appear to be equivalent to the *Globigerina ciperensis ciperensis* Zone, *Globorotalia opima opima* Zone and the *Globigerina ampliapertura* Zone as established by Bolli for the lower part of the Cípero formation of southern Trinidad (see Chart 4).

CHART 4. Provisional Correlation of the lower Part of the Tocuyo and Guacharaca Formations.

AGE	PLANKTONIC BIOZONES (Bolli 1957) (As established for the L.Cipero Formation)	FORMATIONS E. FALCÓN	
MIOCENE (AQUITANIAN)	<i>Catapsydrax dissimilis</i> Zone	"Globigerina" <i>sparisicostata</i> Zone	SAN LORENZO FORMATION
	<i>Globorotalia kugleri</i> Zone		?
OLIGOCENE ?	<i>Globigerina ciperoensis ciperoensis</i> Zone	GUACHARACA FORMATION	
	<i>Globorotalia opima opima</i> Zone		
	<i>Globigerina ampliapertura</i> Zone		
EOCENE		CERRO MISIÓN	

Tocuyo should be substituted for San Lorenzo formation

VI. AGE OF THE GUACHARACA, TOCUYO, AND POZÓN FORMATIONS

Renz (1948, pp. 50-55) considered his *Siphogenerina transversa* Zone to extend from the upper Chattian to the lower Aquitanian. Both these stages were ascribed to the upper Oligocene so that the boundary between the Tocuyo and Pozón formations was considered to occur within the upper Oligocene. Recent work by Eames (1953), Drooger (1956), Eames and Clarke (1957), and the present writer (Blow, 1957) has shown that the ages ascribed by Renz need some modification.

Eames and Clarke (1957) and Blow (1957) have pointed out that *Orbulina* appears for the first time in the uppermost Aquitanian in various parts of the world including the East African and Mediterranean regions, whilst the first occurrence of this form has also been shown to occur in the upper part of the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone in both southern Trinidad and eastern Falcón (Blow, 1956). Blow (1957) also pointed out that the planktonic faunas seen in the Aquitanian and Burdigalian of Sicily and Malta can be matched in Trinidad and Venezuela and he has correlated the Burdigalian/Aquitanian boundary as seen in Sicily and Malta with the boundary between the *Globorotalia fohsi barisanensis* Zone and the *Globigerinatella insueta* Zone (*s.l.*) of the Caribbean region. Blow (1957) also reviewed evidence given by Ruscelli (1956) from the Rio Mainia section in Italy and tentatively correlated the Helvetian/Burdigalian boundary with the boundary between the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and the *Globorotalia mayeri* Zone (*s.l.*). This correlation was based essentially on the record by Ruscelli of *Globorotalia mayeri* in the Burdigalian and its absence in the Helvetian of the Rio Mainia section.

However, Ruscelli (1953, p.165) recorded *Globorotalia mayeri* Cushman and Ellisor in the Helvetian of Rio Mazzapiedi-Castellania in Italy where it occurs with *Globorotalia menardii menardii*. The writer also notes that Ruscelli (1956) did not record this latter species from the Burdigalian of the Rio Mainia, and he, therefore,

now tentatively places the Helvetian/Burdigalian boundary at the top of the *Globorotalia foysi robusta* Zone in the Caribbean (see Chart 1), since *Globorotalia menardii menardii* (d'Orbigny) first appears only in the upper part of this interval.

The writer has not observed *Globorotalia mayeri* in the Tortonian of Sicily, but has observed *Globorotalia acostaensis* Blow sp. nov. commonly in this interval. Since *Globorotalia acostaensis* shows some resemblance to *Globorotalia mayeri*, it is possible that records of the latter species in the Tortonian (i.e., Giannotti, 1953) may be incorrect and possibly referable to *Globorotalia acostaensis*.

The writer now points out that the origin and first occurrence of *Globorotalia acostaensis* is above the extinction of *Globorotalia mayeri*, in sediments now regarded by the writer as being equivalent to the Vindobonian.

Furthermore, *Globigerina bulloides* d'Orbigny, as distinct from *Globigerina praebulloides* Blow, sp. nov., has only been seen in Tortonian strata in Sicily, not in earlier Miocene stages. In this study it is also pointed out that *Globigerina bulloides* develops from *Globigerina praebulloides* in the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone in eastern Falcón. Again the writer has observed *Sphaeroidinella seminulina seminulina* (Schwager) and *Sphaeroidinella dehiscens subdehiscens* Blow, subsp. nov. in the Tortonian of Sicily, but has not observed *Globigerina nepenthes* Todd in this interval.

Finally, Blow (1957) pointed out that *Globigerina ciproensis ciproensis* Bolli has been found in Sicily within the lower part of the Aquitanian as defined by the occurrence together of *Miogypsina globulina* (Michelotti) (= *Miogypsina irregularis* (Michelotti)—an invalid name, (fide Dr. F. E. Eames) and *Miogypsinella* [*Miogypsinoides*] *complanata* (Schlumberger), and he regarded at least part of the *Globigerina ciproensis ciproensis* Zone of the Caribbean as belonging to the Aquitanian which, in agreement with Eames (1953), is here considered to be lower Miocene.

Hence, based on the conclusions of Eames and Clarke (1957) and the writer's studies, it is considered that the Guacharaca formation should be regarded as Oligocene with some lower Aquitanian (basal Miocene) in its upper part. The Tocuyo formation comes a

little higher in the Aquitanian, and the Pozón formation extends from uppermost Aquitanian throughout the Burdigalian into the Vindobonian (see Charts 1 and 4).

VII. EVOLUTION OF SOME OLIGOCENE AND MIOCENE GLOBOROTALIIDAE AND ORBULINIDAE

Following the extinction of the characteristic, and often morphologically complex, Eocene planktonic Foraminifera, such as *Hantkenina*, *Truncorotaloides*, *Globigerinatheka barri* Bronnimann, and *Porticulasphaera mexicana* (Cushman), there is a considerable reduction in the number of species belonging to the Orbulinidae and Globorotaliidae. Only a few species of these families persists from the upper Eocene to the lower Oligocene. With the exception of *Catapsydrax*, these lower Oligocene forms are of comparatively simple morphology.

The reduction in planktonic foraminiferal species at the Eocene-Oligocene boundary is only surpassed in intensity by the almost complete break at the Cretaceous-Tertiary boundary. In a similar way to the primitive lower Paleocene *Globigerina* and *Globorotalia* fauna, it is found that the lower Oligocene planktonic foraminiferal fauna rapidly begins to expand again into numerous new species and genera. The cause of such catastrophic reductions of certain faunal groups may possibly have been occasioned by comparatively minor, although world-wide, changes in environmental condition, such as a sudden lowering of mean sea temperature.

The most remarkable reduction in number of species at the end of the Eocene occurs within the Globorotaliidae. In the Caribbean area, it appears that only one species of *Globorotalia* persists in the lower Oligocene, i.e., *Globorotalia opima* Bolli. This species appears to be the ancestor of the lineage shown on Text-Figure 1 (Lineage I). In the lower Aquitanian (*Catapsydrax dissimilis* Zone), *Globorotalia scitula praescitula* Blow is first observed and this form is believed to be the ancestor of the lineage shown on Text-Figure 2 (Lineage II). However, the origin of *Globorotalia scitula praescitula* itself, and the origins of some other uppermost Oligocene or lowermost Miocene species of *Globorotalia*, such as

Globorotalia obesa Bolli and *Globorotalia kugleri* Bolli, are still not clear.

Amongst the apparently unspecialized *Globigerina* species which exist either in upper Oligocene or lowermost Miocene times are *Globigerina praebuloides* Blow, *Globigerina juvenilis* Bolli, and *Globigerina* cf. *trilocularis* d'Orbigny (of Bolli, 1957), these forms seem to be the respective ancestors of the lineages shown on Text-Figures 3, 4 and 5 (Lineages III, IV and V).

In the discussion of the lineages below, only the main features of the evolutionary series are noted; further details are given in the appropriate parts of the "Systematic Record" where some other possible evolutionary inter-relationships are noted in addition.

LINEAGE I (See Text-Fig. 1)

Three branches of this lineage are distinguished:—

- (i) *Globorotalia opima* (s.l.) → *Globorotalia acostaensis*,
Branch
- (ii) *Globorotalia opima* (s.l.) → *Globorotalia mayeri*,
Branch
- (iii) *Globorotalia mayeri* → *Globorotalia fohsi* (s.l.),
Branch

Branch (i).—*Globorotalia opima nana* Bolli is a small form with four to five chambers in the last whorl; they are spherical in shape inflated, and rather embracing. *Globorotalia opima opima* Bolli developed first as a short-lived independent off-shoot from *Globorotalia opima nana*; the evolution to *Globorotalia opima opima* being characterized by a considerable increase in size of the test and the coiling becoming slightly tighter.

Globorotalia opima continuosa Blow develops from *Globorotalia opima nana* Bolli in the basal part of the *Catapsydrax stainforthi* Zone. The two forms are closely related but *Globorotalia opima continuosa* differs from *Globorotalia opima nana* in having a more strongly arched aperture with a more distinctive lip, and also in having ovate or subspherical chambers as compared with the spherical chambers of *Globorotalia opima nana*. The

test of "*continua*" remains thick but tends to become parallel-sided. *Globorotalia acostaensis* Blow develops from *Globorotalia opima continua* in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone after the extinction of *Globorotalia mayeri* Cushman and Ellisor. The evolution of *Globorotalia acostaensis* from *Globorotalia opima continua* is characterized by an increase in size of the test which remains thick or even becomes relatively thicker; the number of chambers in the last whorl increases, and the chambers become much inflated and broad. Further, the apertural lip of *Globorotalia acostaensis* is usually even more well developed than it is in *Globorotalia opima continua*.

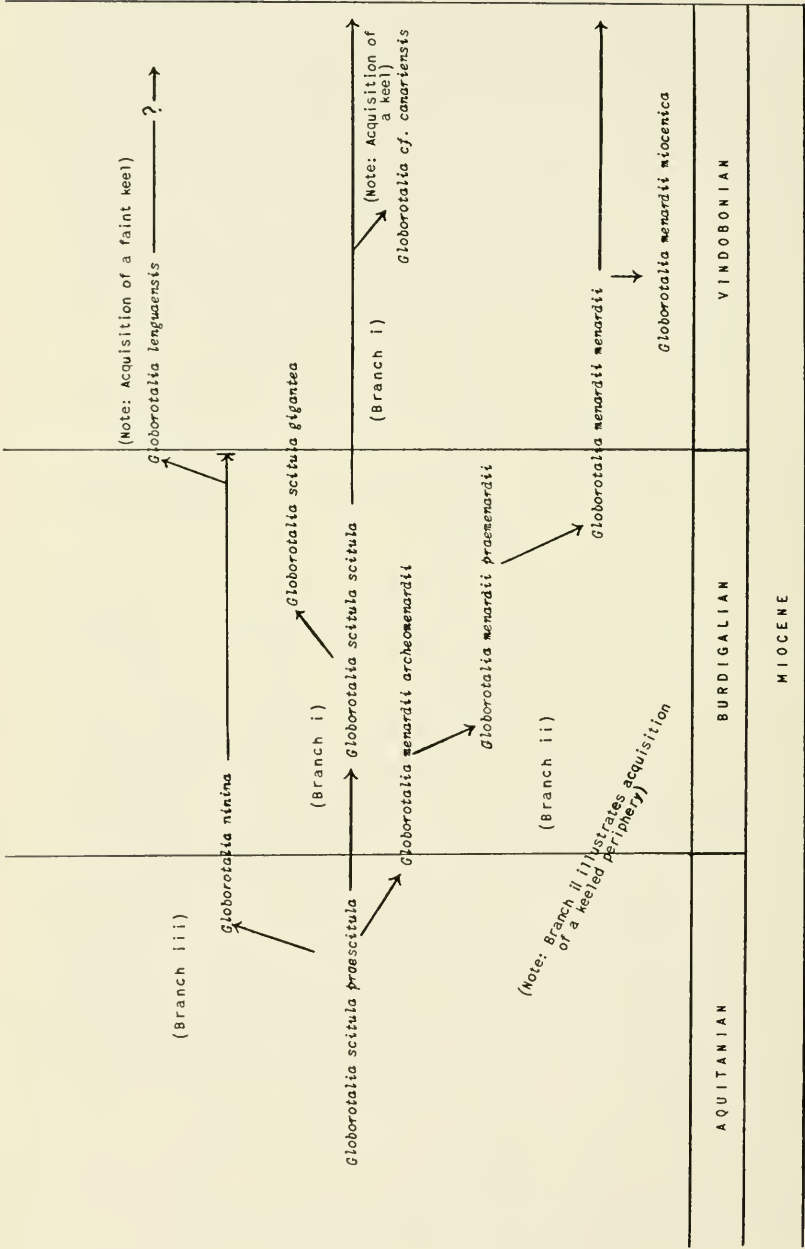
Branch (ii).—The evolution of *Globorotalia mayeri* Cushman and Ellisor from *Globorotalia opima nana* Bolli is characterized by an increase in size of the test which becomes relatively thinner; the number of chambers in the last whorl also increases, the chambers becoming less inflated and narrow. The apertural lip of *Globorotalia mayeri* is not strongly developed.

Although the same general evolutionary trends prevailed in the evolution of *Globorotalia mayeri* and *Globorotalia acostaensis*, there are considerable differences of detail especially in regard to chamber shape and relative dimensions of the test. Furthermore, the trends operated at two distinctly different intervals of time.

Branch (iii).—Bolli (1957, p.118) suggested that *Globorotalia fohsi barisanensis* (LeRoy) might have developed from *Globorotalia mayeri* Cushman and Ellisor in the *Catapsydrax dissimilis* Zone. The present writer regards this origin for *Globorotalia fohsi barisanensis* as being most likely. The derivation of *Globorotalia fohsi barisanensis* from *Globorotalia mayeri* involves the chambers becoming more tangentially elongate and the sutures of the spiral side becoming more strongly curved. The subsequent evolution of the *Globorotalia fohsi* group, with the gradual attainment of an acute periphery which in turn becomes keeled, has been discussed by Bolli (1950).

LINEAGE II (see Text-Fig. 2)

Three branches of this lineage are distinguished:—



Text-Figure 2. Lineage II. (Not strictly to scale.)

For *Globorotalia "minima"* read *minima*.

- (i) *Globorotalia scitula* (*s.l.*) → *Globorotalia* cf. *canariensis*,
Branch
- (ii) *Globorotalia scitula praescitula* → *Globorotalia menardii*
(*s.l.*), Branch
- (iii) *Globorotalia scitula praescitula* → *Globorotalia minima* →
→ *Globorotalia linguaensis*, Branch

Branch (i).—*Globorotalia scitula praescitula* Blow has rather elongate chambers as seen from the spiral side and a subacute axial periphery, as well as a distinctly convex to rather vaulted umbilical side. *Globorotalia scitula scitula* (Brady) develops from “*praescitula*” by the gradual attainment of a more equally biconvex test and a less lobate equatorial periphery; also, the chambers become almost hemispherical as seen from the spiral side and relatively less elongate tangentially as compared with their breadth. *Globorotalia scitula gigantea* Blow develops in turn from *Globorotalia scitula scitula* (Brady), mainly by a considerable increase in test size and by the test becoming virtually equally biconvex.

Forms which are referred to in this study as *Globorotalia* cf. *canariensis* (d’Orbigny) appear to develop from *Globorotalia scitula scitula* (Brady) by the development of a thin but distinctive keel and by the test becoming more compressed.

Branch (ii).—*Globorotalia menardii archeomenardii* (Bolli) appears to develop from *Globorotalia scitula praescitula* Blow by the attainment of rather angular rhomboidal-shaped chambers as seen from the side view. The periphery gradually becomes increasingly acute and ineventually a thin keel appears on the last few chambers, this keel subsequently extending throughout the whole test. *Globorotalia menardii praemenardii* (Cushman and Stainforth) developed from “*archeomenardii*” by the attainment of a more lobate equatorial periphery and more chambers as well as a more rapidly opening spire. *Globorotalia menardii menardii* (d’Orbigny) developed from “*praemenardii*” by the gradual development of raised sutures on the spiral side and a much more massive keel. *Globorotalia menardii miocenica* Palmer evolved from *Globorotalia menardii menardii* by the development of a strongly vaulted umbilical side and a flat spiral side.

Branch (iii).—*Globorotalia minima* (Akers) appears to develop from *Globorotalia scitula praescitula* Blow by the adoption of a less lobate equatorial periphery and the acquisition of more chambers in the last whorl. The last two chambers remain elongate tangentially, but the early chambers become almost equally as broad as long. *Globorotalia linguaensis* Bolli is considered to have developed from *Globorotalia minima* by the adoption of a more circular equatorial profile with the spire opening less rapidly so that all the chambers are almost equally as broad as long. The axial periphery becomes subacute to acute and a faint keel may develop on some or all of the chambers in specimens of *Globorotalia linguaensis* from stratigraphically higher horizons.

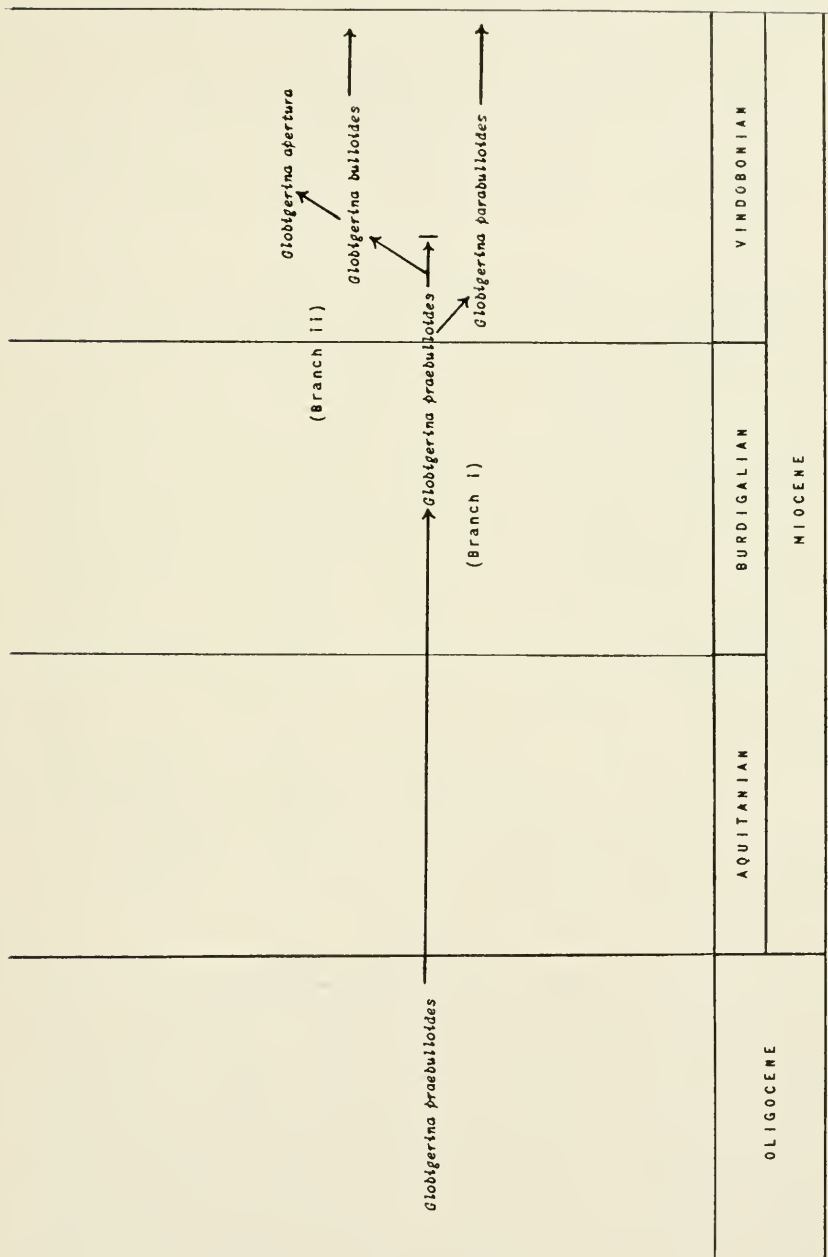
LINEAGE III (see Text-Fig. 3)

Two branches of this lineage are distinguished:—

- (i) *Globigerina praebulloides* → *Globigerina parabulloides*,
Branch
- (ii) *Globigerina praebulloides* → *Globigerina bulloides* →
→ *Globigerina apertura*, Branch

Branch (i).—*Globigerina praebulloides* Blow has a weakly trochospiral test with four to five chambers in the last whorl. The chambers are appressed, slightly embracing, and increase fairly rapidly in size as added, so that the equatorial profile is ovate. The aperture is not strongly arched and is without a lip or distinctly thickened rim. *Globigerina parabulloides* Blow developed from “*praebulloides*” by the adoption of a smaller aperture which possesses a distinct lip or thickened rim. The equatorial profile remains distinctly elongate in the direction of the last chamber.

Branch (ii).—*Globigerina bulloides* d’Orbigny developed from *Globigerina praebulloides* by the adoption of a more highly arched aperture, a more strongly trochospiral test, a deeper umbilicus, and chambers which increase regularly but not rapidly in size as added, so that the equatorial profile is subcircular. *Globigerina apertura* Cushman developed from *Globigerina bulloides* by the coiling becoming looser so that the umbilicus becomes wider, and also by the aperture becoming highly arched with a distinct thickened rim.



Text-Figure 3. Lineage III. (Not strictly to scale.)

LINEAGE IV (see Text-Fig. 4)

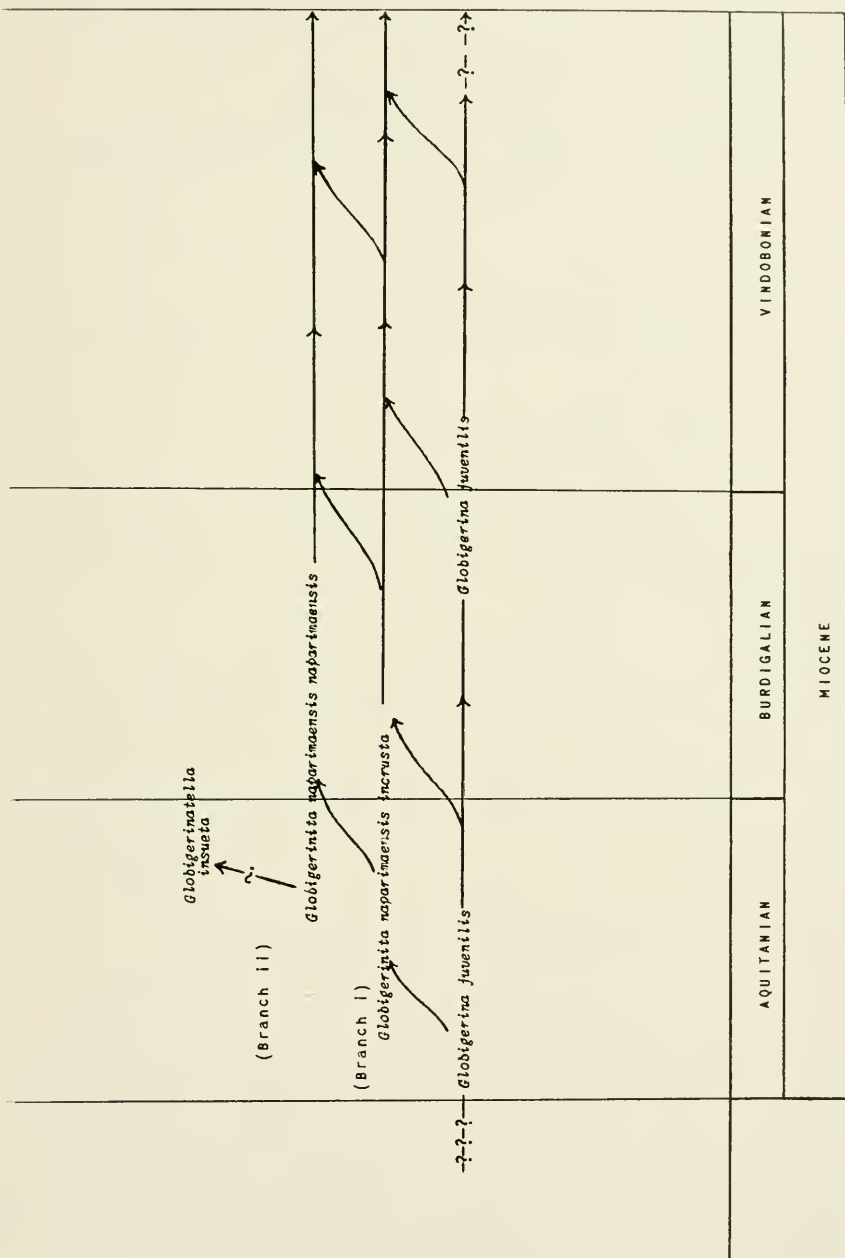
Two branches are distinguished within this lineage:—

- (i) *Globigerina juvenilis* → *Globigerinita naparimaensis* (*s.l.*),
 Branch
- (ii) *Globigerinita naparimaensis* (*s.l.*), → ? → *Globigerinatella*
insueta, Branch

Branch (i).—*Globigerina juvenilis* Bolli has three to four inflated chambers in the last whorl and the narrow, elongate and slit-like aperture possesses a distinctive lip. *Globigerinita naparimaensis incrusta* (Akers) appears to have developed from *Globigerina juvenilis* by the apertural lip of this latter form becoming attached to the ventral surface of the opposing chamber and forming a bulla which, however, only has infralaminar apertures in line with the sutures of the primary chambers. *Globigerinita naparimaensis naparimaensis* Bronnimann developed from “*incrusta*” by the bulla becoming more inflated and embracing more of the primary chambers, and also by the adoption of infralaminar apertures in the suture between the bulla and the primary chambers; it also retains the infralaminar apertures in line with the sutures between the primary chambers. It is considered possible that the evolution

Globigerina juvenilis → *Globigerinita naparimaensis incrusta* →
 → *Globigerinita naparimaensis naparimaensis*
 may have occurred a number of times throughout the Miocene in a repetitive and heterochronous manner. Further details of this possible repetitive evolution are discussed in the “Systematic Record.”

Branch (ii).—It seems likely that *Globigerinatella insueta* Cushman and Stainforth developed from *Globigerinita naparimaensis naparimaensis* Bronnimann. Some early forms of *Globigerinatella insueta* show only a single “primary” bulla without “secondary” bullae, either in the form of areal pustules or collar-like growths, although the primary chambers are embracing. Dissection of these early forms also shows that there are multiple apertures in the primary chambers, so that there is no longer one single primary aperture as seen in *Globigerinita*, but supplementary sutural and areal apertures as well. It is believed that the following trends have



Text-Figure 4. Lineage IV. (Not strictly to scale.)

occurred in the evolution of *Globigerinatella insueta* from *Globigerinita naparimaensis naparimaensis*:—

- (a) Primary chambers become embracing.
- (b) The single primary aperture of *Globigerinita* becomes multiple, *i.e.*, adoption of supplementary apertures of two kinds:—
 - (i) Supplementary apertures in the sutural positions between the primary chambers.
 - (ii) Supplementary apertures in the area of the primary chambers.
- (c) Possible adoption of areal apertures in the area of the primary bulla.
- (d) "Secondary" bullae develop which may either take the form of pustule-like growths or collar-like growths which may cover part of both the primary chambers and the primary bulla.

LINEAGE V (see Text-Fig. 5)

Two major branches are distinguished within this lineage:—

- (i) *Globigerina cf. trilocularis* → *Globigerinoides triloba*
 - Globigerinoides*
 - ↑ *rubra*
 - ↘ (*s.l.*), Branch
 - Globigerinoides*
 - obliqua*
- (ii) *Globigerina cf. trilocularis* → *Globigerinoides triloba (s.l.)* →
 - ↑ *Biorbulina*
 - *Globigerinoides bispherica*, Branch
 - ↘ *Orbulina*

Branch (i).—Bolli (1957) recorded a form which he considered as comparing well with the figures given by Fornasini of d'Orbigny's *Globigerina trilocularis*. Bolli (1957, p.110) pointed out that in the *Globorotalia kugleri* Zone (= Lower Aquitanian) of southern Trinidad, specimens of *Globigerina cf. trilocularis* and *Globigerinoides triloba immatura* LeRoy are indistinguishable except that

LeRoy's form possesses supplementary sutural apertures. A similar relationship has also been seen in the *Globorotalia kugleri* Zone of eastern Falcón. In the early forms of *Globigerinoides triloba immatura*, supplementary apertures are only present in the suture between the last and penultimate chambers, but in specimens from stratigraphically higher horizons supplementary apertures appear in the sutures between the penultimate and earlier chambers. The apertures of *Globigerinoides triloba immatura* are only slightly arched, and this form has a last chamber which only slightly embraces the earlier part of the test; the last chamber is slightly smaller in volume than the rest of the earlier chambers combined.

Globigerinoides triloba sacculifera (Brady) developed from *Globigerinoides triloba immatura* by the production of an elongate, saclike last chamber which has a slightly higher arched primary aperture.

Globigerinoides triloba altiapertura Bolli appears also to have developed from *Globigerinoides triloba immatura* by the adoption of rounded and highly arched primary and supplementary apertures; also by the chambers becoming slightly more inflated and better separated one from the other. *Globigerinoides obliqua* Bolli is considered to have developed from *Globigerinoides triloba altiapertura* in the basal part of the *Catapsydrax dissimilis* Zone by developing an elongate aperture which, however, remains fairly highly arched; the early chambers remain spherical, but later chambers become laterally compressed in an oblique manner.

Globigerinoides rubra (d'Orbigny) is considered possibly to have originated from *Globigerinoides triloba altiapertura* by the reduction of the number of chambers in the last whorl to 3 from the usual $3\frac{1}{2}$ to 4 which are present in the last whorl of *Globigerinoides triloba altiapertura*. At the same time, the primary and supplementary apertures become symmetrically placed with respect to the suture between the earlier chambers. Later forms of *Globigerinoides rubra* show a tendency to become rather high-spined.

Branch (ii).—*Globigerinoides triloba triloba* (Reuss) developed from *Globigerinoides triloba immatura* LeRoy by the last chamber gradually embracing more of the earlier test and by the primary and supplementary apertures becoming completely slitlike

and more elongate as compared with the slightly arched apertures of "*immatura*". Blow (1956) discussed the evolution of *Globigerinoides bispherica* Todd from *Globigerinoides triloba triloba*, and also the evolution of *Biorbulina* and *Orbulina* from Todd's species via *Porticulasphaera transitoria* and *Porticulasphaera glomerosa*, respectively.

VIII. SOME NOTES ON THE TAXONOMY OF THE FORAMINIFERA

(a) Benthonic Foraminifera.

Although the present biostratigraphical studies made by the writer for the Tocuyo and Pozón formations have been largely concerned with the stratigraphical distribution of planktonic Foraminifera, it was found to be necessary to analyse the benthonic foraminiferal content of each sample in the section so as to arrive at a direct correlation between the two types of foraminiferal biostratigraphies.

During this study the opportunity has been taken to examine and, where necessary, revise the taxonomy of the benthonic fauna as proposed by H. H. Renz in 1948. In general, Renz's taxonomy has been maintained with few exceptions. The most important changes are listed below whilst some other minor changes are noted in the relevant parts of the "Systematic Record":—

Blow	Renz (1948)
<i>Alveovalvulinella</i> <i>pozonensis</i>	<i>Liebusella pozonensis</i>
<i>Alveolophragmium?</i> <i>carinatum</i>	<i>Haplophragmoides carinatum</i>
<i>Alveolophragmium</i> <i>venezuelanum</i>	<i>Haplophragmoides emaciatum</i>
<i>Bolivina pseudobeyrichi</i>	<i>Bolivina alata</i>
<i>Glandulina laevigata</i>	<i>Pseudoglandulina laevigata</i>
<i>Gyroidinoides altiformis</i>	<i>Gyroidinoides soldanii altiformis</i>
<i>Gyroidinoides</i> cf. <i>zealandica</i>	<i>Gyroidinoides</i> cf. <i>soldanii</i>
<i>Nodosaria caribbeana</i>	<i>Nodosaria raphanistrum</i> car- <i>ibbeana</i>

<i>Nodosaria comatus</i>	<i>Pseudoglandulina comatula</i>
<i>Pseudonodosaria incisa</i>	<i>Pseudoglandulina incisa</i>
<i>Rectoglandulina gallowayi paucicostata</i>	<i>Pseudoglandulina gallowayi paucicostata</i>
<i>Stilostomella verneuili</i>	<i>Ellipsonodosaria? verneuili</i>
<i>Vaginulina subtiliuus</i>	<i>Astacolus subtiliuus</i>

In addition to these changes, the following benthonic Foraminifera were observed in the Pozón-El Mene Road section but were not mentioned by Renz in 1948:—

- Ammodiscus muhlemani* Blow, sp. nov.
- Gravellina narivaensis* Bronnimann
- Lagena asperoides* Galloway and Morrey
- Lagena nuttalli* Galloway and Heminway
- Lagenonodosaria acostaensis* Blow, sp. nov.
- Uvigerina cubana* Palmer and Bermudez

The stratigraphical distribution of the benthonic Foraminifera observed in the Pozón-El Mene Road section is given on Chart 2.

(b) *Planktonic Foraminifera*

Recently, Bolli, Loeblich, and Tappan (1957) made a detailed revision of the taxonomy of the planktonic Foraminifera. With one minor exception, their recommendations are followed in this work. These authors also made recommendations as to the terminology used in the description of the morphology of the planktonic forms. These recommendations are also closely followed.

SYSTEMATIC RECORD

All holotypes, paratypes, and hypotypes, as well as any other figured specimens, have been deposited in the collections of the United States National Museum, Washington, D.C., U.S.A.

The classification followed in this Systematic Record is based upon that proposed by Cushman (1950) but with some modifications due to recent work by various authors. The main changes affect the classification of the planktonic Foraminifera where the recommendations of Bolli, Loeblich, and Tappan (1957) are followed with the exception of the taxonomic position of the genus *Hastigerinella*. *Hastigerinella* is, in this work, placed in the family Globorotaliidae.

Phylum **PROTOZOA**Order **FORAMINIFERA**Family **AMMODISCIDAE**Genus **AMMODISCUS** Reuss. 1861***Ammodiscus incertus*** (d'Orbigny)

Operculina incerta d'Orbigny, 1839, "Foraminifères", in de la Sagra, Histoire physique, politique et naturelle de l'île Cuba, p. 49, pl. 6, figs. 16, 17 (*vide* Ellis and Messina. 1940 *et seq.*).

Ammodiscus incertus (d'Orbigny), (Cushman), 1918, U.S. Nat. Mus., Bull. 104, pt. 1, p. 95, pl. 39, figs. 1-8.

Remarks:—Species shows wide variation, partly due to the type of material incorporated in the test; spiral suture usually distinct and the second chamber rounded in cross-section.

Hypotype:—From Sample No. RM 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625734.

Occurrence:—Occurs mainly in arenaceous facies faunas of the *Globigerinatella insueta* Zone (*s.l.*) but also as isolated specimens in the *Globorotalia fohsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations.

Ammodiscus mublemanni Blow, sp. nov.

Pl. 6, figs. 1a-b

Diagnosis:—Test small, usually compressed, agglutinated, but with much calcareous cement; proloculum small and indistinct, followed by an undivided or nonconstricted second chamber forming a planispiral coil of about 7 to 10 whorls. The second chamber, which only increases slowly in size, has a rounded cross-section. Spiral suture usually distinct; wall smoothly finished and almost translucent; maximum diameter of holotype, 0.42 mm.

Remarks:—This form is usually observed deformed and compressed, but occasional specimens indicate that the cross-section of the second chamber is round. The adventitious material selected is fine-grained, and the form has a characteristic translucent appearance.

Holotype:—From Sample No. RM 19180, auger line near Pozón, eastern Falcón; Plate 6, figs. 1a-b, deposited in U.S.N.M. collection, No. 625691.

Occurrence:—This form seems to be restricted to mainly “arenaceous facies faunas” of the *Globigerinatella insueta* Zone (*s.l.*) Tucuyo and Pozón formations. Also observed in the Nariva formation of southern Trinidad.

Genus **GLOMOSPIRA** Rzehak, 1888

Glomospira gordialis (Jones and Parker)

Glomospira gordialis (Jones and Parker), Cushman, 1928, Cushman Lab. Foram. Res., Contr., vol. 4, p. 87, figs. 7-8.

Hypotype:—From Sample, No. RM 19283, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625736.

Occurrence:—Scarce, observed in the *Globigerinatella insueta* Zone (*s.l.*); also infrequently in samples from the *Globorotalia fohsi* “Zone” (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*), Tucuyo and Pozón formations.

Family **LITUOLIDAE**

Genus **ALVEOLOPHRAGMIUM** Stschedrina, 1936

Alveolophragmium? carinatum (Cushman and Renz)

Haplophragmoides carinatum Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 2., pl. 1, fig. 1.

Remarks:—*Alveolophragmium? carinatum* differs from *Alveolophragmium venezuelanum* Maync in the larger number of chambers and somewhat more compressed test which has a distinctly keeled periphery. The sutures are slightly raised. The specimens observed do not show details of the aperture but appear to have a labyrinthic or alveolar wall structure and are, therefore, referred tentatively to the genus *Alveolophragmium* Stschedrina, 1936. The specimens also appear identical to Cushman and Renz’s species.

Hypotype:—From Sample, No. RM 19136, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625737.

Occurrence:—Occurs mainly in arenaceous facies faunas from the *Catapsydax stainforthi* Zone, and in the *Globigerinatella insueta* Zone (*s.l.*), but, occasional specimens have been observed in all zones below the base of the *Sphaeroidinella seminulina* Zone, Tucuyo and Pozón formations.

Alveolophragmium venezuelanum Maync

Pl. 6, fig. 2

Nov. Haplophragmium emaciatum Brady, 1884, Challenger Exped. Rept., Zool., vol. 9, pt. 22, p. 305, pl. 33, figs. 26-28.

Haplophragmoides emaciatum Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 142, pl. I, figs. 6a-b.

Alveolophragmium venezuelanum Maync, 1952, Cushman Found. Forum. Res., Contr., vol. III, pts. 3 & 4, p. 142, pl. 26, figs. 1-3, 5.

Remarks:—Maync (1952) transferred Renz's (1948) species to the genus *Alveolophragmium* Stschedrina and considered this species to be distinct from that described by Brady (1884). The specimens observed by the writer are similar to those illustrated by Renz (1948, p.142) and show clearly the alveolar nature of the test wall.

Hypotype:—From Sample, No. RM 19136, auger line near Pozón, eastern Falcón; Plate 6, fig. 2, deposited in U.S.N.M. collection, No. 625739.

Occurrence:—Generally scarce throughout the upper part of the Tocuyo formation and in the *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia foysi* "Zone" (*s.l.*), Pozón formation.

Genus **AMMOBACULITES** Cushman, 1910**Ammobaculites** cf. **strathearnensis** Cushman and LeRoy

cf. *Ammobaculites strathearnensis* Cushman and LeRoy, 1938, Jour. Pal., vol. 12, No. 2, p. 122, pl. 22, figs. 1a, 1b, 2a, 2b (*vide* Ellis and Messina, 1940 *et. seq.*).

Ammobaculites cf. *strathearnensis* Cushman and LeRoy, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 113, pl. 1, figs. 7,8.

Remarks:—This species shows a rather wide variation in morphology, especially in the degree to which the last few chambers uncoil and in the depth of the umbilicus. Test compressed; wall structure smooth, composed of fine grains.

Hypotype:—From sample, No. RM 19136, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625740.

Occurrence:—Occurs rarely, mainly in arenaceous facies faunas from the *Catapsydrax stainforthi* Zone and in the *Globigerinatella insueta* Zone (*s.l.*). Occasional specimens have been observed throughout the *Globorotalia foysi* Zone (*s.l.*), and possibly in the *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations .

Genus **CYCLAMMINA** Brady, 1876**Cyclammina cancellata** Brady

Cyclammina cancellata Brady, 1884, Challenger Exped. Rept., Zool., vol. 9, p. 351, pl. 37, figs. 8-16.

Remarks:—Both Glaessner (1945) and Cushman (1950) refer to the labyrinthic interior of this genus. Bronnimann (1951c) suggested that the term “labyrinthic” should not be used in connection with this form and described the interior as being subdivided into regularly arranged alveoles normal to the outer cortex. Maync (1952, p.48), however, retained the term “labyrinthic” and pointed out that the attribute “labyrinthic” should be applied only to the wall and septal structure and not to the complex nature of the actual chambers.

Hypotype:—From sample, No. RM 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625741.

Occurrence:—Occurs in variable abundance in the Tocuyo and Pozón formations below the *Sphaeroidinella seminulina* Zone but particularly common in the *Globigerinatella insueta* (*s.l.*), where it occurs in arenaceous facies faunas and often associated with comparatively rich, mainly planktonic faunas.

It has been suggested that an abundance of this species indicates a deepwater turbid environment (Kugler, 1953).

Genus **HAPLOPHRAGMOIDES** Cushman, 1910**Haplophragmoides coronatum** (Brady)

Trochammina coronata Brady, 1879, Quart. Jour. Micr. Sci., London, vol. 19, p. 58, pl. 5, fig. 15 (*vide* Ellis and Messina, 1940 *et seq.*).

Remarks:—This species is always observed much deformed, but appears to be planispirally coiled throughout.

Hypotype.—From sample, No. RM 19181, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625743.

Occurrence:—Occurs mainly in arenaceous facies faunas from the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Family **TEXTULARIIDAE**Genus **TEXTULARIA** DeFrance, 1824**Textularia crassisepta** Cushman

Textularia crassisepta Cushman, 1911, U.S. Nat. Mus., Bull. 71, p. 24, text-fig. 41 (*vide* Ellis and Messina, 1940, *et seq.*).

Hypotype:—From sample, No. RM 19279, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625744.

Occurrence:—Scarce, but observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*) and in the lower to middle part of the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

***Textularia excavata* Cushman**

Textularia excavata Cushman, 1913, U.S. Nat. Mus., Proc., vol. 44, No. 1973, p. 634, pl. 79, fig. 5 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample No. RM 19279, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625746.

Occurrence:—Scarce, only seen in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), and *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

***Textularia isidroensis* Cushman and Renz**

Textularia isidroensis Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 4, pl. 1, fig. 7.

Hypotype:—From sample No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625748.

Occurrence:—Scarce, only seen in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), and *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

***Textularia leuzingeri* Cushman and Renz**

Textularia leuzingeri Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 3, pl. 1, fig. 2.

Hypotype:—From sample No. RM 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection No. 625749.

Occurrence:—Scarce, only seen in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

***Textularia panamensis* Cushman**

Pl. 7, fig. 3

Textularia panamensis Cushman, 1918, U.S. Nat. Mus., Bull. 103, p. 63, pl. 20, fig. 1 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample No. 20131, auger line near Pozón, eastern Falcón; Plate 7, fig. 3, deposited in U.S.N.M. collection, No. 625750.

Occurrence:—Scarce in the lower part of the *Sphaeroidinella seminulina* Zone but becomes common in the middle to upper part of this zone and in the lower part of the *Globigerina bulloides* Zone, Pozón formation.

Textularia pozonensis Cushman and Renz

Textularia pozonensis Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 4, pl. 1, fig. 6.

Hypotype:—From sample, No. RM 20131, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625752.

Occurrence:—Scarce in the lower part of the *Sphaeroidinella seminulina* Zone but becomes common in the middle to upper part of this zone and in the lower part of the *Globigerina bulloides* Zone, Pozón formation.

Genus **VULVULINA** d'Orbigny, 1826

Vulvulina spinosa miocenica Cushman

Vulvulina spinosa Cushman var. *miocenica* Cushman, 1932, Cushman Lab. Foram. Res., Contr., vol. 8, p. 80, pl. 10, fig. 10 (*vide* Renz, 1948).

Vulvulina spinosa Cushman var. *miocenica* Cushman, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 179, pl. 11, fig. 1.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625753.

Occurrence:—Scarce, only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Family **VERNEUILINIDAE**

Genus **GAUDRYINA** d'Orbigny, 1839

Gaudryina leuzingeri Cushman and Renz

Gaudryina leuzingeri Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 6, fig. 13.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625755.

Occurrence:—Scarce, only observed in a few samples from the *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia foysi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Gaudryina thalmani Cushman and Renz

Gaudryina thalmani Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 7, fig. 14.

Hypotype:—From sample, No. RM 19265, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625756.

Occurrence:—Scarce, only observed in a few samples from the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, Pozón formation.

Subgenus **PSEUDOGAUDRYINA** Cushman, 1936

Gaudryina (*Pseudogaudryina*) **bullbrookii** Cushman

Gaudryina (*Pseudogaudryina*) *bullbrookii* Cushman, 1936, Cushman Lab. Foram. Res., Spec. Pub. No. 6, p. 16, pl. 2, fig. 16.

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625758.

Occurrence:—Generally scarce and only occurs in isolated samples but ranges from the *Catapsydrax stainforthi* Zone, Tocuyo formation, to the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Gaudryina (*Pseudogaudryina*) **jacksonensis abnormis** Cushman and Renz

Gaudryina (*Pseudogaudryina*) *jacksonensis* Cushman var. *abnormis* Cushman and Renz, 1944, Cushman Lab. Foram. Res., Contr., vol. 20, pt. 3, p. 78.

Gaudryina jacksonensis Cushman var. *abnormis* Cushman and Renz, Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Pub. 25.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625760.

Occurrence:—Fairly common in the *Catapsydrax stainforthi* Zone but has only been observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Genus **PSEUDOCLAVULINA** Cushman, 1936

Pseudoclavulina **carinata** (Cushman and Renz)

Clavulina carinata Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 8, pl. 1, fig. 18.

Remarks:—This species shows a fairly large triangular initial part with three chambers per whorl followed by 2-3 rounded, uniserial chambers with a circular terminal aperture. The aperture in the adult has a short neck and is without a tooth. The uniserial chambers are comparatively distinct, more so than the initial ones; wall rough.

Hypotype:—From sample, No. RM 19286, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625762.

Occurrence:—Generally scarce in the Tocuyo and Pozón formations below the middle part of the *Sphaeroidinella seminulina* Zone.

Family VALVULINIDAE

Genus ALVEOVALVULINELLA Bronnimann, 1953

Alveovalvulinella pozonensis (Cushman and Renz) Pl. 6, fig. 4

Liebusella pozonensis Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, p. 9, figs. 1, 2.

Liebusella pozonensis var. *crassa* Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, p. 10, pl. 2, figs. 3-4.

Alveovalvulinella pozonensis (Cushman and Renz), Bronnimann, 1953, Cushman Found. Foram. Res., Contr., vol. IV, pt. 3, p. 91, text-figs. IV, V, plate 15, fig. 3.

Remarks:—Bronnimann transferred this species from the genus *Liebusella* Cushman, 1933 to a new valvulinid genus *Alveovalvulinella* mainly because of the alveolated, not "labyrinthic", nature of the test wall. The early part of the test consists of more than three chambers in a whorl later reducing to three, then two and eventually becoming uniserial. The uniserial part often comprises most of the test. Wall often appears translucent showing the alveoles. Aperture terminal in uniserial part of the test.

Hypotype:—From sample, No. RM 19175, auger line near Pozón, eastern Falcón; Plate 6, fig. 4, deposited in U.S.N.M. collection, No. 625763.

Occurrence:—In Trinidad it is diagnostic for, and restricted to, the Nariva clays and silts, whilst in the Pozón section it occurs mainly in arenaceous facies faunas from the *Catapsydrax stainjorthi* Zone and *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations. It also occurs in isolated samples from the *Globorotalia fohsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Genus GRAVELLINA Bronnimann, 1953

Gravellina narivaensis Bronnimann Pl. 6, fig. 5

Gravellina narivaensis Bronnimann, 1953, Cushman Found. Foram. Res., Contr., vol. IV, pt. 3, p. 87, pl. 15, fig. 9, text-fig. 1.

Hypotype:—From sample, No. RM 19181, auger line near Pozón, eastern Falcón; Plate 6, fig. 5, deposited in U.S.N.M. collection, No. 625765.

Occurrence:—Generally scarce and only observed in arenaceous facies faunas from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations. In Trinidad it is considered diagnostic for the Nariva formation.

Genus **SCHENCKIELLA** Thalmann, 1942

Schenckiella cf. cyclostomata (Galloway and Morrey)

cf. *Verneuilina cyclostomata* Galloway and Morrey, 1929, Bull. Amer. Pal., vol. 15, No. 55, p. 33, pl. 5, fig. 2.

Schenckiella cf. cyclostomata (Galloway and Morrey), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 163, pl. II, fig. 16.

Remarks:—Usually observed as immature specimens without the uniserial chambers.

Hypotype:—From sample, No. RM 19181, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625767.

Occurrence:—Fairly common in the Tocuyo and Pozón formations below the *Globorotalia menardii mendarii*/*Globigerina nepenthes* Zone.

Schenckiella pallida (Cushman)

Clavulina communis d'Orbigny var. *pallida* Cushman, 1927, Calif. Univ. Scripps Inst. Oceanography, Bull. Tech. Ser., vol. 1, p. 138, pl. 3, fig. 1.

Listerella pallida (Cushman), Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 8, p. 147, pl. 16, figs. 37-39.

Schenckiella pallida (Cushman), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 163, pl. II, figs. 17-18.

Hypotype:—From sample, No. RM 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625769.

Occurrence:—Common in all zones of the Tocuyo and Pozón formations below and in the lower part of the *Sphaeroidinella seminulina* Zone.

Genus **TEXTULARIELLA** Cushman, 1927

Textulariella miocenica Cushman

Textulariella miocenica Cushman, 1936, Cushman Lab. Foram. Res., Spec. Pub. 6, p. 45, pl. 6, figs. 17, 19.

Hypotype:—From sample, No. RM 19112, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625771.

Occurrence:—Fairly common in the *Catapsydrax stainforthi* Zone and the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations but only observed as single specimens in isolated

samples from the *Globorotalia fohsi barisanensis* Zone, Pozón formation.

Genus **VALVULINA** d'Orbigny, 1826

Valvulina flexis Cushman and Renz

Valvulina flexis Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 7, figs. 16-17.

Hypotype:—From sample, No. RM 19210, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625773.

Occurrence:—Only observed in arenaceous facies faunas from the *Catapsydrax stainforthi* Zone, and from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Family **MILIOLIDAE**

Genus **PYRGO** Defrance, 1824

Pyrgo spp. indet.

Remarks and occurrence:—A number of specimens of this genus occur in the *Sphaeroidinella seminulina* and *Globigerina bulloides* Zones, Pozón formation but are always abraded, broken or merely preserved as steinkerns and cannot be safely speciated.

Genus **QUINQUELOCULINA** d'Orbigny, 1826

Quinqueloculina spp. indet.

Remarks and occurrence:—A number of specimens of this genus occur in the *Sphaeroidinella seminulina* and *Globigerina bulloides* Zones, Pozón formation but are always abraded, broken, or merely preserved as steinkerns and cannot be safely speciated.

Genus **SIGMOILINA** Schlumberger, 1887

Sigmoilina celata (Costa)

Spiroloculina celata Costa, 1855, R. Accad. Sci. Napoli, Mem., vol. 2, p. 126, pl. 1, fig. 14 (*vide* Ellis and Messina, 1940 *et seq.*).

Sigmoilina celata (Costa), Cushman, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, p. 82.

Hypotype:—From sample, No. RM 19151, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625775.

Occurrence:—Generally scarce but observed in samples from all zones of the Tocuyo and Pozón formations below, and in the lower part of the *Sphaeroidinella seminulina* Zone.

Genus **TRILOCULINA** d'Orbigny, 1826

Triloculina spp. indet.

Remarks and occurrence:—A number of specimens of this

genus occur in the *Sphaeroidinella seminulina* and *Globigerina bulloides* zones, Pozón formation, but are always abraded, broken or merely preserved as steinkerns and cannot be safely speciated.

Family TROCHAMMINIDAE

Genus **TROCHAMMINA** Parker and Jones, 1859

Trochammina cf. *pacifica* Cushman Pl. 7, fig. 6

cf. *Trochammina pacifica* Cushman, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, No. 11, p. 39, pl. 6, fig. 3 (*vide* Ellis and Messina, 1940 *et seq.*).

Trochammina cf. *pacifica* Cushman, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 172, pl. III, figs. 4a-b, 5a-b.

Remarks:—The writer's specimens are similar to those illustrated by Renz (1948). Most specimens occur as axially compressed forms and do not allow unambiguous specific identification. Renz's remarks (1948, p. 173) apply to the writer's specimens.

Hypotype:—From sample, No. RM 19849, auger line near Pozón, eastern Falcón; Plate 7, fig. 6, deposited in U.S.N.M. collection, No. 625777.

Occurrence:—Occasional specimens have been observed in the uppermost part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone but the species only becomes common in the lower and middle parts of the *Sphaeroidinella seminulina* Zone. Rather scarce in the upper part of this latter zone and in the basal part of the overlying *Globigerina bulloides* Zone, Pozón formation.

Family LAGENIDAE

Genus **ASTACOLUS** Montfort, 1808

Astacolus *ovatus* Galloway and Heminway Pl. 6, fig. 7

Astacolus ovatus Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Islands, p. 334, pl. 8, figs. 10a-b.

Remarks:—This species shows a trace of a faint keel on the slightly convex dorsal side. Initial coil consisting of 5-6 chambers which appear to be in contact with the proloculum. Sutures of the later chambers strongly convex towards the aperture, meeting the dorsal side obliquely; test oval in cross-section.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 6, fig. 7, deposited in U.S.N.M. collection, No. 625779.

Occurrence:—Scarce in samples from the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations. Also occurs in isolated samples from the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Genus **DENTALINA** d'Orbigny, 1826

Dentalina cf. advena (Cushman)

cf. *Nodosaria advena* Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 79, pl. 14, fig. 12 (*vide* Ellis and Messina, 1940 *et seq.*).

Dentalina cf. *advena* (Cushman), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 130, pl. IV, fig. 27.

Hypotype:—From sample, No. RM 19281, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625780.

Occurrence:—Only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Genus **FRONDICULARIA** DeFrance, 1826

Frondicularia advena Cushman

Frondicularia inaequalis Brady (*non* Costa), 1884, Challenger Exped. Rep., Zool., vol. 9, p. 521, pl. 66, figs. 8-12.

Frondicularia advena Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 141, pl. 20, figs. 1-2 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19435, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection No. 625781.

Occurrence:—Only observed in isolated samples from the *Globorotalia fohsi lobata* and *Globorotalia fohsi robusta* Zones, also from the *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Frondicularia alazanensis Nuttall

Frondicularia alazanensis Nuttall, 1932, Jour. Pal., vol. 6, p. 17, pl. 3, fig. 15.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625783.

Occurrence:—Scarce, observed in samples from the *Catapsydrax stainforthi* Zone, Tocuyo formation, and in the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone and *Globorotalia fohsi fohsi* Zone, Pozón formation.

Frondicularia inaequalis Costa

Frondicularia inaequalis Costa, 1855, R. Acad. Sci. Napoli, Mem., vol. 2, p. 372, pl. 3, fig. 3 (*vide* Ellis and Messina, 1940 *et seq.*).

non Frondicularia inaequalis Brady, 1884, Challenger Exped. Rep., Zool., vol. 9, p. 521, pl. 66, figs. 8-12.

Hypotype:—From sample, No. RM 19450, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection No. 625784.

Occurrence:—Only seen in a few samples from the *Globorotalia fohsi robusta* Zone, Pozón formation.

Frondicularia sagittula lanceolata van den Broeck

Frondicularia alata Brady (*non* d'Orb.), 1884, Challenger Exped. Rep., Zool., vol. 9, p. 522, pl. 44, figs. 3-5.

Frondicularia sagittula var. *lanccolata* van den Broeck, Cushman, 1923, U.S. Nat. Mus., Bull. 104, pl. 4, p. 143, pl. 20, fig. 4, pl. 21, fig. 1 (*vide* Renz, 1948).

Remarks:—This form shows great variation within the Tocuyo and Pozón formations, and it is difficult to decide upon characters that are constant for the species and subspecies. The size and relative thickness of the test are subject to variation as is also the relative size of the proloculum in megalospheric forms. Only megalospheric forms have been recognized in the Falcón material. Occasional isolated prolocula have also been observed.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625785.

Occurrence:—Generally rather scarce throughout the Tocuyo and Pozón formations below the base of the *Sphaeroidinella seminulina* Zone.

Genus **LAGENA** Walker and Jacob, 1798

Lagena asperoides Galloway and Morrey

Pl. 6, fig. 8

Lagena asperoides Galloway and Morrey, 1929, Bull. Amer. Pal., vol. 15, No. 55, p. 19, pl. 2, fig. 6.

Remarks:—A distinctive species, thick walled, and with a spherical chamber supporting a rather long neck; wall pustulose with rounded papillae.

Hypotype:—From sample, No. RM 19180, auger line near Pozón, eastern Falcón; Plate 6, fig. 8, deposited in U.S.N.M. collection, No. 625787.

Occurrence:—Renz (1948) did not record this species from the Agua Salada group but Cushman and Stainforth (1945) re-

corded its occurrence in the Cipero formation of southern Trinidad. In eastern Falcón it occurs, but rarely, in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Lagena nuttalli Galloway and Heminway

Pl. 6, fig. 9

Lagena nuttalli Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Islands, vol. 3, pt. 4, p. 346, pl. 10, fig. 8.

Remarks:—The neck of this species is enlarged forming almost a second chamber; ornamented with longitudinal costae.

Hypotype:—From sample, No. RM 19179, auger line near Pozón, eastern Falcón; Plate 6, fig. 9, deposited in U.S.N.M. collection, No. 625788.

Occurrence:—Not recorded by Renz (1948) in the Agua Salada group but is comparatively common in the Cipero formation of southern Trinidad (Cushman and Stainforth, 1945). Observed infrequently in samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Genus **LAGENONODOSARIA** Silvestri, 1900

Lagenonodosaria acostaensis Blow, sp. nov.

Pl. 7, fig. 10

Diagnosis:—Test fairly large, consisting of three to four globular or subglobular chambers, separated by fairly deeply incised sutures; last chamber with a long, slender, sometimes slightly hispid neck with a phialine lip; neck without multiple collars; test generally strongly costate and costae often produced into short spines over the posterior part of each chamber; costae become weak or absent in the sutural regions also over the first formed chamber; last chamber slightly more separated from the penultimate chamber than is the case with the earlier chambers; often with a pronounced basal spine; maximum length of holotype, 0.62 mm.

Remarks:—This form is distinguished from *L. scalaris* (Batsch) by the presence of more deeply incised sutures and the absence of multiple collars on the long narrow neck.

Holotype:—From sample, No. RM 19444, auger line near Pozón, eastern Falcón; Plate 7, fig. 10, deposited in the U.S.N.M. collection, No. 625693.

Occurrence:—Generally scarce in the *Globigerinatella insueta* Zone (*s.l.*) but becomes fairly common in the *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Genus **LINGULINA** d'Orbigny, 1826

Lingulina grimsdalei Cushman and Renz

Lingulina grimsdalei Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 14, pl. 3, fig. 1.

Hypotype:—From sample, No. RM 19150, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625789.

Occurrence:—Scarce, only observed in isolated samples from the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation.

Lingulina prolata (Guppy)

Gonatosphaera prolata Guppy, 1894, Zool. Soc. London, Proc., p. 651, pl. 41, figs. 14-19 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625790.

Occurrence:—Rare, only observed in samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Genus **MARGINULINA** d'Orbigny, 1826

Marginulina cf. striatula Cushman

cf. *Marginulina striatula* Cushman, 1913, U.S. Nat. Mus., Bull. 71, p. 79, pl. 23, fig. 4 (*vide* Ellis and Messina, 1940 *et seq.*).

Marginulina cf. striatula Cushman, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 145, pl. IV, figs. 15-16.

Remarks:—The specimens observed by the writer are similar to those figured by Renz (1948) and tentatively referred to *Marginulina striatula* Cushman. Cushman mentioned the presence of fine costae on his specimens, but these are not present on the writer's material, nor are they shown on Renz's illustrations.

Hypotype:—From sample, No. RM 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625792.

Occurrence:—Generally scarce and only observed in isolated samples from the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation; also from the *Globigerinatella insueta*/*Globigerinoides bispherica* Sub-

zone, *Globorotalia fohsi* "Zone" (*s.l.*), and *Globorotalia mayeri* Zone (*s.l.*) and *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

***Marginulina subbullata* Hantken**

Marginulina subbullata Hantken, Palmer, 1940, Soc. Cubana hist. nat., Mem., vol. 14, No. 4, p. 279.

Remarks:—The megalospheric forms show only two chambers in the initial coil, and the sutures of the last chambers become horizontal resembling some species ascribed by Loeblich and Tappan (1955) to their new genus *Pandaglandulina*. The microspheric forms have between three and five chambers in the initial coil.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, near Falcón; deposited in U.S.N.M. collection, No. 625794.

Occurrence:—Generally ubiquitous throughout the Tocuyo formation and nearly all of the Pozón formation but does not occur in the rather shallow-water assemblages of the *Globigerina bulloides* Zone. Common in the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*), and in the *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Genus **MARGINULINOPSIS** Silvestri, 1904

***Marginulinopsis basispinosus* (Cushman and Renz)**

Pl. 6, fig. 11

Marginulina basispinosa Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 13, pl. 2, figs. 16-18.

Marginulinopsis basispinosus (Cushman and Renz), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 145, pl. 1V, figs. 8a-b, 9, 10.

Remarks:—This form has an initial coil of between three and five chambers in contact with the proloculum followed by usually 3-5, uniserial chambers arranged at right-angles to the axis of coiling. The species is rather variable; some forms show the initial coil and first chamber of the uniserial part rather compressed or triangular in cross-section, in others all the chambers are rounded or elliptical. Ornamentation may be either costate or papillate or a combination of both, whilst in some forms ornamentation is wanting on the last two or three chambers and much reduced on the earlier chambers. Often with several radially directed spines on the initial coiled chambers.

Hypotype:—From sample, No. RM 20025, auger line near Pozón, eastern Falcón; Plate 6, fig. 11, deposited in U.S.N.M. collection, No. 625796.

Occurrence:—Renz (1948) used the occurrence of this species to define his *Marginulinopsis basispinosus* Zone, Pozón formation, (= upper part *Globorotalia mayeri* Zone (*s.l.*), *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and basal part *Sphaeroidinella seminulina* Zone). In the Falcón region it is restricted to this interval, but evidence seen in subsurface sections on the Island of Cubagua shows that it ranges higher into the *Sphaeroidinella seminulina* Zone, indicating that its disappearance in Pozón may be due to ecological rather than stratigraphical reasons.

Genus **NODOSARIA** Lamarek, 1812

Nodosaria caribbeana (Hedberg)

Pl. 6, fig. 12

Nodosaria raphanistrum (Linné) var. *caribbeana* Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 671, pl. 91, fig. 1.

Remarks:—Hedberg (1937, p. 671) stated “Due to the uncertainty regarding the exact characters possessed by Linné’s species, it seems desirable to make a new variety of the form common in the Tertiary of the Caribbean region.”

The writer feels that, in view of this uncertainty concerning Linné’s species and since this form is common in the Oligo-Miocene of the Caribbean, it should be considered as a distinct species.

The form shows a wide variability in the degree of constriction between adjacent chambers; even within the one specimen, well separated chambers occur adjacent to chambers practically in contact with each other. The costate ornamentation also shows great variability both within the species group and within a single specimen; in some cases the costae cross the septal necks unchanged whilst in others they become much weaker.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 6, fig. 12, deposited in U.S.N.M. collection, No. 625797.

Occurrence:—Common throughout the upper part of the Tocuyo formation, in the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone and in the *Globorotalia fohsi* “Zone” (*s.l.*).

Rather scarce in the *Globorotalia mayeri* Zone (*s.l.*), *Globorotalia menardii menardii*, *Globigerina nepenthes* Zone and *Sphaeroidinella seminulina* Zone (lower part), Pozón formation.

***Nodosaria comatus* (Batsch)**

Nautilus comatus Batsch, 1791, Testaceorum arenulae marinae tabulae sex . . . (Sechs Kupfertafeln mit Conchylien des Seesandes), pp. 1, 4 (*vide* Ellis and Messina, 1940 *et seq.*)

Nodosaria comata Brady, 1884, Challenger Exped. Rept., Zool., vol. 9, p. 509, pl. 64, figs. 1-5.

Nodosaria comatula Cushman, 1923, U.S. Nat. Mus., Bull. 104, pt. 3, p. 83, pl. 14, fig. 5 (*vide* Renz 1948).

Pseudoglandulina comatula (Cushman), Cushman, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, p. 87.

Remarks:—Loeblich and Tappan (1955) discussed the validity of the genus *Pseudoglandulina* Cushman (the type species of which is this species) and they pointed out that *Pseudoglandulina* Cushman, 1929 must be considered a junior synonym of *Nodosaria* Lamarck, 1812, and is, therefore, invalid.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625799.

Occurrence:—Although Renz (1948) only reported this species from the *Robulus wallacci* Zone and *Siphogenerina transversa* Zone (= *Catapsydrax stainforthi* Zone to lower part *Globorotalia fohsi fohsi* Zone), the present writer has observed this form in the *Globorotalia fohsi lobata* and *Globorotalia fohsi robusta* Zones, and the *Globorotalia mayeri* Zone (*s.l.*); furthermore, occasional specimens have been observed in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and the lowermost part of *Sphaeroidinella seminulina* Zone, Pozón formation.

It is associated in the Pozón formation with mainly planktonic assemblages and is absent in faunas containing abundant *Uvigerina isidroensis*, *Bolivina imporcata* and *Bolivina simplex*; the abundance of these latter forms suggests rather shallow-water conditions.

Brady (1884) and others recorded the occurrence of this species at depths of circa 800 metres.

***Nodosaria? longiscata* d'Orbigny**

Nodosaria longiscata d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 32, pl. 1, figs. 10-12. (*Fide* Ellis and Messina, 1940 *et seq.*).

Remarks:—This distinctive and well-known species is characterized by the elongate but narrow chambers with rather poorly defined constrictions between adjacent chambers. Specimens showing bulbous, inflated prolocula are not infrequent. In the material from Pozón, specimens showing the form and characters of the aperture have not been observed, and, therefore, unambiguous generic identification is not possible. Some broken specimens show in end view what appears to be a multiple wall structure consisting of two rather thick concentric layers. It is doubtful if D'Orbigny's drawing of an end view actually shows the aperture but more likely an end view of a broken specimen. In view of the absence of specimens showing undoubted apertural characters this species is only doubtfully referred to the genus *Nodosaria*.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection No. 625800.

Occurrence:—Common in the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation and in the Pozón formation below the *Globorotalia mayeri* Zone (*s.l.*); scarce in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

***Nodosaria nuttalli* Hedberg**

Nodosaria nuttalli Hedberg, 1937, Jour. Pal., vol. 11, p. 673, pl. 91, fig. 6.

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625802.

Occurrence:—Fairly common or common in the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation; also in the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, *Globorotalia fohsi* "Zone" (*s.l.*), Pozón formation.

***Nodosaria schlichti* Reuss**

Nodosaria (Nodosaria) schlichti Reuss, 1870, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber., vol. 62, Abt. 1, p. 472, pl. 6, figs. 29-31 (*vide* Ellis and Messina 1940 *et seq.*).

Nodosaria schlichti Reuss, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 147, pl. IV, fig. 25, pl. V, fig. 5.

Hypotype:—From sample, No. RM 19283, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625804.

Occurrence:—Generally scarce but observed in all zones below the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Tocuyo and Pozón formations.

Nodosaria stainforthi Cushman and Renz

Nodosaria stainforthi Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 15, pl. 3, fig. 4.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625806.

Occurrence:—Generally scarce in the upper part of the Tocuyo formation and in the Pozón formation, below the *Globorotalia mayeri* Zone (*s.l.*), but sometimes several specimens occur in single samples from the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone where the faunas are suggestive of a deeper than usual environment.

Nodosaria vertebralis (Batsch)

Nautilus (Orthoceras) vertebralis Batsch, 1791, Testaceorum arenulae marinae tabulae sex... (Sechs Kupfertafeln mit Conchylien des Seesandes), pt. 3, No. 6, pl. 2, figs. 6a-b. (*vide* Ellis and Messina, 1940 *et seq.*).

Nodosaria vertebralis (Batsch), Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 671, pl. 91, fig. 2.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625808.

Occurrence:—As for *Nodosaria stainforthi* with which it is often associated.

Genus **PLANULARIA** DeFrance, 1824

Planularia clara Cushman and Jarvis

Planularia clara Cushman and Jarvis, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, pt. 1, p. 7, pl. 2, figs. 14-15.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625809.

Occurrence:—Although Renz (1948) recorded this form not higher than his *Valvulineria herricki* Zone, Pozón formation, the writer has observed specimens associated with *Marginulinopsis basispinosus*. It is rare in the *Globigerinatella insueta* Zone (*s.l.*) but becomes fairly common in the *Globorotalia fohsi* "Zone (*s.l.*). Isolated specimens occur in the *Globorotalia mayeri* Zone (*s.l.*), the

Globorotalia menardii menardii/*Globigerina nepenthes* Zones and in the lowermost part of the *Sphaeroidinella seminulina* Zone, Pozón formation.

Planularia venezuelana Hedberg

Planularia venezuelana Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 670, pl. 90 figs. 14a-b.

Hypotype:—From sample, No. RM 19281, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625811.

Occurrence:—Scarce and only observed in the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, Tocuyo and Pozón formations.

Genus **PSEUDONODOSARIA** Boomgaard, 1949

According to Loeblich and Tappan (1955, p. 6), this genus was defined by Boomgaard as follows:

Test free, uniserial and rectilinear throughout, chambers embracing strongly in the early portion, later chambers inflated, less embracing and separated by constricted sutures; sutures horizontal; aperture terminal, radiate.

Pseudonodosaria incisa (Neugeboren)

Pl. 7, fig. 13

Glandulina incisa Neugeboren, 1850, Siebenb. Ver. Naturw., Hermannstadt, Verh. Mitt., Jah. 1, No. 4, p. 52, pl. 1, figs. 7a-b (*vide* Ellis and Messina, 1940 *et seq.*).

Pseudoglandulina incisa (Neugeboren), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 154, pl. V, fig. 16.

Remarks:—This species has the characters required for inclusion in Boomgaard's genus. It has no trace of a biserial early stage. The early chambers are strongly embracing whilst the last chamber is well separated from the earlier chambers and fairly inflated. Aperture terminal, radiate.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; Plate 7, fig. 13, deposited in U.S.N.M. collection, No. 625813.

Occurrence:—Generally scarce and often occurs as single specimens in samples from the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, *Globigerinatella insueta*/*Globigerina bispherica* Subzone, *Globorotalia fohsi* "Zone" (*s.l.*), *Globorotalia mayeri* Zone (*s.l.*), and *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Tocuyo and Pozón formations.

Genus **RECTOGLANDULINA** Loeblich and Tappan, 1955

Loeblich and Tappan (1955), gave the following diagnosis for their genus:

Test free, uniserial, with chambers increasing rapidly in diameter and strongly overlapping, sutures horizontal and parallel, never strongly depressed; wall calcareous; aperture terminal, radiate.

Loeblich and Tappan further remarked that *Rectoglandulina* differs from *Pseudonodosaria* Boomgaardt, 1949 in having all the chambers closely appressed and with the later chambers not separated by constricted sutures.

Rectoglandulina gallowayi paucicostata (Cushman and Renz)

Pl. 6, fig. 14

Pseudoglandulina gallowayi Cushman var. *paucicostata* Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 16, pl. 3, fig. 5.

Remarks:—This species appears to have the characters required for inclusion in *Rectoglandulina*. The last suture is only slightly constricted. The strongly costate ornamentation makes it difficult to judge to what extent the chambers overlap.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 6, figure 14, deposited in U.S.N.M. collection, No. 625814.

Occurrence:—Generally rather scarce and only observed in samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Genus **ROBULUS** Montfort, 1808**Robulus americanus** (Cushman)

Cristellaria americana Cushman, 1918, U.S. Geol. Surv., Bull. 676, p. 50, pl. 10, figs. 5-6.

Robulus americanus (Cushman), Cushman and Cahill, 1933, U.S. Geol. Surv., Prof. Paper 175-A, p. 12, pl. 3, figs. 6a-c.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625815.

Occurrence:—Generally common throughout all zones of the Tocuyo and Pozón formations below the *Globigerina bulloides* Zone, in which only isolated specimens occur. The species varies considerably in frequency from sample to sample throughout the suc-

cession, being rare in samples containing abundant *Uvigerina isidroensis*, *Bolivina simplex*, and *Bolivina imporcata*.

***Robulus americanus grandis* (Cushman)**

Cristellaria americana Cushman var. *grandis* Cushman, 1920, U.S. Geol. Surv. Prof. Paper 128-B, p. 68, pl. 11, fig. 2 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625816.

Occurrence:—Fairly common in most zones below the *Globigerina bulloides* Zone, Pozón formation, but varies considerably in frequency from sample to sample. General distribution is similar to the parent species.

***Robulus americanus spinosus* (Cushman)**

Cristellaria americana Cushman var. *spinosa* Cushman, 1918, U.S. Geol. Surv., Bull. 676, p. 51, pl. 10, fig. 7.

Remarks:—This subspecies is distinguished from the parent species by the spines which extend radially from the peripheral part of the sutures. The spines are variable, both in length and thickness.

Hypotype:—From sample, No. RM 19181, auger line Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625817.

Occurrence:—Generally scarce in the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations. It becomes fairly common or common in the *Globorotalia mayeri* Zone (*s.l.*), *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and in the lower part of the *Sphaeroidinella seminulina* Zone, Pozón formation. Isolated specimens also occur in the upper part of the *Sphaeroidinella seminulina* Zone and in the *Globigerina bulloides* Zone. This subspecies seems to prefer a somewhat shallower environment than the parent species.

***Robulus arcuato-striatus carolinianns* Cushman**

Robulus arcuato-striatus (Hantken) var. *carolinianus* Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, p. 4, pl. 1, fig. 9 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625818.

Occurrence:—Scarce and only observed in isolated samples from the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

***Robulus calcar* (Linné)**

Nautilus calcar Linné, 1767, *Systema naturae*, 12th ed., vol. 1, p. 1162, No. 272 (*vide* Renz, 1948.).

Robulus calcar (Linné), Galloway and Morrey, 1929, *Bull. Amer. Pal.*, vol. 15, No. 55, p. 20, pl. 2, fig. 10.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625819.

Occurrence:—Generally common in the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations. It becomes scarce and sporadic in occurrence within the *Globorotalia menardii menardii* *Globigerina nepenthes* Zone and in the *Sphaeroidinella seminulina* Zone; occasional specimens have been observed in the *Globigerina bulloides* Zone, Pozón formation.

***Robulus clericii* (Fornasini)**

Robulus clericii (Fornasini), Cushman, 1929, *Cushman Lab. Foram. Res., Contr.*, vol. 5, p. 84, pl. 12, figs. 16-17.

Remarks:—Renz (1948, p. 158) discussed the variability of this form within the Agua Salada group and pointed out that this species and *Robulus chambersi* Garrett, 1939 can only be distinguished in extreme cases.

Hypotype:—From sample, No. RM 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625820.

Occurrence:—Generally fairly common in all zones of the Tocuyo and Pozón formations below the *Globorotalia menardii menardii* *Globigerina nepenthes* Zone. Occasional specimens have been observed in the *Sphaeroidinella seminulina* Zone, Pozón formation.

***Robulus formosus* (Cushman)**

Cristellaria formosa Cushman, 1923, *U.S. Nat. Mus., Bull.* 104, pt. 4, p. 110, pl. 29, fig. 1; pl. 30, fig. 1 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19182, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625822.

Occurrence:—Scarce and only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*), and in the *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations.

Robulus hedbergi Cushman and Renz

Robulus hedbergi Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 10, pl. 2, fig. 9.

Hypotype:—From sample, No. RM 19112, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625823.

Occurrence:—Scarce and only seen in isolated samples from the *Catapsydrax stainforthi* Zone and the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Robulus iotus (Cushman)

Cristellaria iota Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 111, pl. 29, fig. 2; pl. 30, fig. 1 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19178, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625824.

Occurrence:—Scarce, only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*) and in the *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations.

Robulus melvilli Cushman and Renz

Robulus melvilli Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 12, pl. 2, fig. 12.

Hypotype:—From sample, No. RM 19116, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625825.

Occurrence:—Generally scarce but observed throughout all zones of the Tocuyo and Pozón formations, below the middle part of the *Sphaeroidinella seminulina* Zone.

Robulus nuttalli Cushman and Renz

Robulus nuttalli Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 11, pl. 2, fig. 10.

Hypotype:—From sample, No. RM 19181, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625826.

Occurrence:—Generally scarce and only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), and from the *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Robulus occidentalis torridus (Cushman)

Cristellaria occidentalis Cushman var. *torrida* Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 105, pl. 25, fig. 1 (*vide* Ellis and Messina, 1940 *et seq.*).

Robulus occidentalis (Cushman) var. *torridus* (Cushman), Cushman and Jarvis, 1930, Jour. Pal., vol. 4, No. 4, p. 357, pl. 32, figs. 8a-b.

Hypotype:—From sample, No. RM 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625827.

Occurrence:—Fairly common in all zones of the Tocuyo and Pozón formations below the *Sphaeroidinella seminulina* Zone.

Robulus protuberans (Cushman)

Cristellaria protuberans Cushman, 1918, U.S. Nat. Mus., Bull. 103, p. 61, pl. 22, fig. 2 (*vide* Ellis and Messina, 1940 *et seq.*).

Robulus protuberans (Cushman), Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Islands, vol. 3, pt. 4, p. 351, pl. 11, figs. 13a-b.

Hypotype:—From sample, No. RM 19151, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625828.

Occurrence:—Scarce, only observed in isolated samples from the *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation.

Robulus senni Cushman and Renz

Pl. 6, fig. 15

Robulus senni Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 12, pl. 2, figs. 14-15.

Remarks:—This form shows considerable variation in the degree of uncoiling and thickness of the test. Earlier forms seem to be thicker and less uncoiled than later forms. It is possible that it may be related to *Robulus subaculeatus glabratus* Cushman.

Hypotype:—From sample, No. RM 19820, auger line near

Pozón, eastern Falcón; Plate 6, figure 15, deposited in U.S.N.M. collection, No. 625829.

Occurrence:—Common in the upper part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and in the *Sphaeroidinella seminulina* Zone, Pozón formation. Renz (1948) used the partial occurrence of this species to define his *Robulus senni* Zone. The upper boundary of this *Robulus senni* Zone is strongly influenced by facies with the incoming of somewhat impoverished facies faunas in the Pozón area; whilst at El Mene de Acosta, environmental conditions were such that the “normal” faunas of the *Robulus senni* Zone continued to a higher stratigraphical level. Hence, the upper boundary of the “zone” is strongly diachronous between the two areas. Indeed, in the Pozón-El Mene Road section there is an alternation and interdigitation of facies so that it is not always possible to separate unambiguously the *Robulus senni* “Zone” from the *Trochammina* cf. *pacifica*-*Vaginulinopsis superbus* Zone.

***Robulus subaculeatus glabratus* (Cushman)**

Cristellaria subaculeata Cushman var. *glabrata* Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 124, pl. 32, fig. 4 (*vide* Ellis and Messina, 1940 *et seq.*).
Robulus subaculeatus (Cushman) var. *glabratus* (Cushman), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 160, pl. III, figs. 20-21.

Remarks:—This subspecies shows considerable variation in morphology. The earlier forms are often tightly coiled and have a generally stoutly built test with strongly developed ornamentation. Later forms show a considerable degree of uncoiling with less well-developed ornamentation and a somewhat more compressed test.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625830.

Occurrence:—Common in the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta* Zone (*s.l.*), Tocuyo formation and Pozón formation; also in the *Globorotalia fohsi* “Zone” (*s.l.*), and the *Globorotalia mayeri* Zone (*s.l.*); occasional specimens have been observed in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

***Robulus suteri* Cushman and Renz**

Robulus suteri Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 10, pl. 2, figs. 5-8.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625832.

Occurrence:—Generally scarce but observed in samples from all zones of the Tocuyo and Pozón formations below the top of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone.

Robulus vortex (Fichtel and Moll)

Nautilus vortex Fichtel and Moll, 1798, Test. Micro., p. 33, pl. 2, figs. d-i (fide Ellis and Messina, 1940 *et seq.*).

Cristellaria vortex (Fichtel and Moll), Brady, 1884, Challenger Exped., Rept. Zool., vol. 9, p. 548, pl. 69, figs. 14-16.

Robulus vortex (Fichtel and Moll), Renz, 1948, Geol. Soc., Amer., Mem. 32, p. 161.

Hypotype:—From sample, No. RM 19340, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625834.

Occurrence:—Scarce, only observed in isolated samples from the *Globorotalia fohsi* "Zone" (*s.l.*), Pozón formation.

Robulus wallacei (Hedberg)

Pl. 6, figs. 16, 17

Marginulina wallacei Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 670, pl. 90, figs. 15-17.

Robulus wallacei (Hedberg), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 161, pl. IV, figs. 19-20.

Remarks:—Hedberg described this form as belonging to the genus *Marginulina*, but Renz included the species in the genus *Robulus*. It shows considerable variation in morphology. The earlier forms are closely coiled with well-developed ornamentation and with characteristic tangential "cross-bars". The later forms show the last 2-3 chambers uncoiled and often devoid of ornamentation. In the uncoiled forms, the last chamber may be rather pointed and the aperture subterminal and not peripheral as in the earlier more tightly coiled chambers. Ornamentation is variable and generally later forms show a rather more weakly developed ornamentation.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; Plate 6, figure 17, deposited in U.S.N.M. collection, No. 625835; Plate 6, figure 16, from sample RM 19179, also deposited in U.S.N.M. collection, No. 625836.

Occurrence:—Renz used this form to define his *Robulus wallacei* Zone, Tocuyo formation, which is equivalent to the *Catap-*

sydrax stainforthi Zone plus the *Globigerinatella insueta*/*Globigerinoides triloba* Subzone. It is often abundant in this interval to which it appears restricted.

Genus **SARACENARIA** DeFrance, 1824

Saracenaria italica acutocarinata (Cushman)

Cristellaria italica (DeFrance) var. *acutocarinata* Cushman, 1917, U.S. Nat. Mus., Proc., vol. 51, No. 2172, p. 661 (*vide* Renz, 1948).

Saracenaria italica DeFrance var. *acutocarinata* (Cushman), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 162, pl. V, fig. 19.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625837.

Occurrence:—Scarce and only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Saracenaria italica carapitana Franklin

Saracenaria italica DeFrance var. *carapitana* Franklin, 1944, Jour. Pal., vol. 18, p. 312, pl. 45, fig. 14.

Hypotype:—From sample, No. RM 19181, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625839.

Occurrence:—Scarce and only occurs sporadically in samples from the *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia foehsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Saracenaria latifrons (Brady)

Cristellaria latifrons Brady, 1884, Challenger Exped., Rept., Zool., vol. 9, p. 544, pl. 113, figs. 11a-b.

Saracenaria latifrons (Brady), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 162, pl. V, fig. 22.

Hypotype:—From sample, No. RM 19279, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625841.

Occurrence:—Scarce and only observed in isolated samples from the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, and the *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Saracenaria schencki Cushman and Hobson

Saracenaria schencki Cushman and Hobson, 1935, Cushman Lab. Foram. Res., Contr., vol. 11, pt. 3, p. 57, pl. 8, fig. 11 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19116, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625843.

Occurrence:—Scarce but occurs sporadically in isolated samples from all zones of the Tocuyo and Pozón formations below and in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone.

***Saracenaria senni* Hedberg**

Saracenaria senni Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 674, pl. 90, figs. 18a-b.

Hypotype:—From sample, No. RM 19116, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625845.

Occurrence:—Scarce, only seen in isolated samples from the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation.

Genus **VAGINULINA** d'Orbigny, 1826

***Vaginulina alazanensis* Nuttall**

Vaginulina alazanensis Nuttall, 1932, Jour. Pal., vol. 6, No. 1, p. 17, pl. 1, fig. 11.

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625847.

Occurrence:—Scarce, only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi barisanensis* Zone and *Globorotalia fohsi fohsi* Zone, Tocuyo and Pozón formations.

***Vaginulina subtiluus* (Nuttall)**

Pl. 7, fig. 18

Astacolus subtiluus (Nuttall), Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Islands, vol. 3, pt. 4, p. 335, pl. 8, figs. 11a-b.

Remarks:—The initial coil is small, consisting of three or four chambers in contact with the proloculum. Sutures of the later chambers are directed towards the aperture at the ventral margin but become transverse and horizontal, meeting the dorsal margin very nearly at right angles. Test much compressed. This species

seems to be best placed in the genus *Vaginulina* as emended by Bartenstein (1948).

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; Plate 7, figure 18, deposited in U.S.N.M. collection, No. 625849.

Occurrence:—Fairly common in the *Catapsydrax stainforthi* Zone and recorded in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Genus VAGINULINOPSIS Silvestri, 1904

Vaginulinopsis superbus (Cushman and Renz) Pl. 6, fig. 19

Marginulina superba Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 14, pl. 2, figs. 19-20.

Vaginulinopsis superbus (Cushman and Renz), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 177, pl. IV, figs. 17a-b, 18.

Hypotype:—From sample, No. RM 19849, auger line near Pozón, eastern Falcón; Plate 6, fig. 19, deposited in U.S.N.M. collection, No. 625850.

Remarks:—Occasional specimens have been observed in the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, becoming fairly common in the lower part of the *Sphaeroidinella seminulina* Zone but rather scarce in the middle to upper part of the same zone. It does not persist into the *Globigerina bulloides* Zone.

Family POLYMORPHINIDAE

Genus GLANDULINA d'Orbigny, 1826

Glandulina laevigata d'Orbigny

Nodosaria (Glandulina) laevigata d'Orbigny, 1826, Ann. Sci. Nat., Paris, sér. 1, vol. 7, p. 252, pl. 10, figs. 1-3 (*vide* Ellis and Messina, 1940 *et seq.*).

Pseudoglandulina laevigata (d'Orbigny), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 154, pl. V, figs. 14-15.

Remarks:—The specimens observed by the writer appear to be typical of the species and show the biserial early stage.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625852.

Occurrence:—Generally scarce, but observed in all zones of the Tocuyo and Pozón formations below the *Sphaeroidinella seminulina*

lina Zone. Often occurs associated with mainly planktonic faunas.

Genus **GUTTULINA** d'Orbigny, 1839

Guttulina irregularis (d'Orbigny)

Globulina irregularis d'Orbigny, 1846, Foraminifères fossils du bassin tertiaire de Vienne (Autriche), p. 226, pl. 13, figs. 9-10. (*vide* Ellis and Messina, 1940 *et seq.*).

Guttulina irregularis (d'Orbigny), Cushman and Ponton, 1932, Florida Geol. Surv., Bull. 9, p. 64, pl. 9, figs. 10-12.

Hypotype:—From sample, No. RM 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625854.

Occurrence:—Scarce and only observed in a few isolated samples from the *Globigerinatella insueta*/*Globigerinoides triloba* Subzone and in the lower part of the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, Tocuyo formation. It is usually associated with mainly planktonic faunas.

Guttulina jarvisi Cushman and Ozawa

Guttulina jarvisi Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., vol. 77, No. 2829, p. 39, pl. 8, figs. 4-5.

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625856.

Occurrence:—Scarce and only observed in a few samples from the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, Pozón formation.

Family **NONIONIDAE**

Genus **ELPHIDIUM** Montfort, 1808

Elphidium poeyanum (d'Orbigny)

Pl. 7, fig. 20

Polystomella poeyana d'Orbigny, 1839, "Foraminifères" in de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, p. 55, pl. 6, figs. 25-26 (*vide* Ellis and Messina, 1940 *et seq.*).

Elphidium poeyanum (d'Orbigny), Cushman, 1930, U.S. Nat. Mus., Bull. 104, p. 25, pl. 10, figs. 4-5 (*vide* Renz, 1948).

Remarks:—A fairly distinctive form with rather inflated chambers and moderately depressed sutures. The retral processes are not well marked.

Hypotype:—From sample, No. RM 20131, auger line near Pozón, eastern Falcón; Plate 7, figure 20, deposited in U.S.N.M. collection, No. 625858.

Occurrence:—Observed in isolated samples from the upper part of the *Sphaeroidinella seminulina* Zone and infrequently in the lower part of the overlying *Globigerina bulloides* Zone, but becomes comparatively common in the higher part of this latter zone indicating an approach to brackish-water conditions. It is common in the Ojo de Agua formation which overlies the Pozón formation, where it is often associated with Chara seeds.

Genus **NONION** Montfort, 1808

Nonion affinis (Reuss)

Nonionina affinis Reuss, 1851, Deutsch. Geol. Ges., Zeitschr., vol. 3, p. 72, pl. 5, figs. 32a-b (*vide* Ellis and Messina, 1940 *et seq.*).

Nonion affine (Reuss), Cushman, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, p. 89, pl. 13, fig. 24.

Hypotype:—From sample, No. RM 19181, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625860.

Occurrence:—Generally scarce but occurs in the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*), and *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations. This species of *Nonion* seems to occur in a possible deepwater environment as evidenced by its association with mainly planktonic faunas.

Nonion costiferus* (Cushman)

Nonionina costifera Cushman, 1926, Cushman Lab. Foram. Res., Contr., vol. 1, p. 90, pl. 13 (*vide* Ellis and Messina, 1940 *et seq.*).

Nonion costiferum (Cushman), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 148, pl. VI, figs. 5a-b, pl. XII, figs. 6a-b.

Hypotype:—From sample, No. RM 19360, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625862.

Occurrence:—Ubiquitous, occurring in all zones of the upper Tocuyo and Pozón formations below and in the *Sphaeroidinella seminulina* Zone. Varies considerably in frequency and often associated with *Bolivina imborcata* and *Uvigerina isidroensis*, suggestive of a rather shallow but clear water environment.

Nonion incisus kernensis Kleinpell

Nonion incisum (Cushman) var. *kernensis* Kleinpell, 1938, Amer. Assoc. Petr. Geol., Spec. Pub., p. 232.

Nonion incisum (Cushman) var. *kernensis* Kleinpell, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 148, pl. VI, figs. 4a-b.

* Montfort used *Nonion* in masculine gender.—Ed.

Hypotype:—From sample, No. RM 19360, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625864.

Occurrence:—Similar to *Nonion costiferus* but often occurs as well with mainly shallow-water arenaceous assemblages in the *Sphaeroidinella seminulina* Zone and *Globigerina bulloides* Zone, Pozón formation.

***Nonion pompilioides* (Fichtel and Moll)**

Nautilus pompilioides Fichtel and Moll, 1798, Testacea microscopica aliaque minuta ex generibus Argonauta et Nautilus, p. 31, pl. 2, figs. a-c, 1803 reprint. (Fide Ellis and Messina, 1940 *et seq.*).

Nonion pompilioides (Fichtel and Moll), Cushman, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, p. 89, pl. 13, figs. 25a-b.

Hypotype:—From sample, No. RM 19181, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625866.

Occurrence:—Fairly common in the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta* Zone (*s.l.*), and *Globorotalia fohsi barisanensis* Zone, Tocuyo and Pozón formations. Also observed in isolated samples containing mainly planktonic assemblages from the *Globorotalia fohsi fohsi* Zone and *Globorotalia fohsi lobata* Zone, Pozón formation.

Family **HETEROHELICIDAE**

Genus **PLECTOFRONDICULARIA** Liebus, 1903

***Plectofrondicularia californica* Cushman and Stewart**

Plectofrondicularia californica Cushman and Stewart, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, p. 39, pl. 6, figs. 9-11 (*fide* Ellis and Messina, 1940 *et seq.*).

Plectofrondicularia californica Cushman and Stewart, Cushman, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, p. 90, pl. 13, figs. 18-19.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625868.

Occurrence:—Generally scarce and only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

***Plectofrondicularia floridana* Cushman**

Plectofrondicularia floridana Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 41, pl. 8, fig. 1 (*fide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625870.

Occurrence:—Fairly common in all zones of the Tucuyo and Pozón formations below the *Sphaeroidinella seminulina* Zone, but only observed as single specimens in isolated samples within the lower to middle part of this latter zone.

Plectofrondicularia cf. longistriata LeRoy

cf. *Plectofrondicularia longistriata* LeRoy, 1939, *Natuurk. Tijdschr. Nederl. Indie*, deel 99, afl. 6, p. 241, pl. 5, figs. 4-6 (*vide* Ellis and Messina, 1940 *et seq.*).

cf. *Plectofrondicularia longistriata* LeRoy, 1944, *Colorado School Mines, Quart.*, vol. 39, No. 3, p. 25, pl. 1, fig. 51; pl. 5, fig. 38.

Remarks:—The specimens seen in Falcón are usually broken and fragmentary and, therefore, only tentatively referred to LeRoy's species, although they seem to agree in general characteristics. The costae are rather variable, sometimes being well developed and in other specimens being weakly developed.

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625872.

Occurrence:—Scarce and only observed as single specimens in isolated samples from the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, *Globorotalia fohsi* "Zone" (*s.l.*), *Globorotalia mayeri* Zone (*s.l.*) and *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Plectofrondicularia mansfieldi Cushman and Ponton

Plectofrondicularia mansfieldi Cushman and Ponton, 1931, *Cushman Lab. Foram. Res., Contr.*, vol. 7, p. 60, pl. 8, figs. 1a-b (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19410, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625874.

Occurrence:—Fairly common in *Globorotalia fohsi lobata* Zone and *Globorotalia fohsi robusta* Zone but scarce in the *Globorotalia mayeri* Zone (*s.l.*), the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and in the lower part of the *Sphaeroidinella seminulina* Zone, Pozón formation.

Family **BULIMINIDAE**

Genus **ANGULGERINA** Cushman, 1927

Angulogerina illingi Cushman and Renz

Angulogerina illingi Cushman and Renz, 1941, *Cushman Lab. Foram. Res., Contr.*, vol. 17, pt. 1, p. 21, pl. 3, figs. 19-20.

Angulogerina yumuriana Palmer, 1941, Soc. cubana hist. nat., Mem., vol. 15, No. 2, p. 186, pl. 15, fig. 8.

Angulogerina illingi Cushman and Renz, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 114, pl. VII, figs. 31, 32a-b.

Remarks:—Generally rather similar to *Angulogerina cooperensis* Cushman but has a more carinate and triangular test with a virtual absence of ornamentation.

Hypotype:—From sample, No. RM 19507, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625876.

Occurrence:—Only seen in isolated samples from the *Globorotalia fohsi robusta* Zone, and in the *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Genus **BOLIVINA** d'Orbigny, 1839

Bolivina advena Cushman

Bolivina advena Cushman, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, No. 8, p. 29, pl. 5, fig. 1 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19791, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625878.

Occurrence:—Scarce in the upper part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone but fairly common in the *Sphaeroidinella seminulina* Zone, Pozón formation.

Bolivina alazanensis Cushman

Bolivina alazanensis Cushman, 1926, Cushman Lab. Foram. Res., Contr., vol. 1, p. 82, pl. 12, figs. 1a-b (*vide* Ellis and Messina, 1940 *et seq.*).

Remarks:—The sutures of this form are distinctly limbate and the marginal part of the chambers strongly directed towards the initial end of the test. The median suture forms a distinct ridge.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625880.

Occurrence:—Only seen in isolated samples from the *Catapsydrax stainforthi* Zone, Tocuyo formation.

Bolivina byramensis Cushman

Bolivina caelata Cushman var. *byramensis* Cushman, 1923, U.S. Geol. Surv., Prof. Paper 133, p. 19, pl. 1, fig. 9.

Bolivina byramensis Cushman, 1937, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 69, pl. 8, figs. 18-20.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625882.

Occurrence:—Fairly common in the *Catapsydrax stainforthi* Zone but rather scarce in the *Globigerinatella insueta* Zone (*s.l.*), and *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Bolivina caudriae Cushman and Renz

Bolivina caudriae Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 19, pl. 3, figs. 13-14.

Remarks:—This species appears to be closely related to *Bolivina arta* Macfadyen but is generally smaller and with a less compressed test. Also this species has curved sutures.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625884.

Occurrence:—Only observed in isolated samples from the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Bolivina imporeata Cushman and Renz

Bolivina floridana Cushman var. *imporeata* Cushman and Renz, 1944, Cushman Lab. Foram. Res., Contr., vol. 20, pt. 3, p. 78.

Bolivina imporeata Cushman and Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 118, pl. VII, figs. 3a-b.

Remarks:—Originally described as a variety of *Bolivina floridana* Cushman, but this form appears to be distinctly different from this species considering the more elongate nature of its test and chambers. Some specimens show elongate gently tapering tests with the last two chambers rather inflated.

Hypotype:—From sample, No. RM 19320, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625886.

Occurrence:—Occurs throughout the Pozón formation and often especially abundant in *Globorotalia fohsi* "Zone" (*s.l.*) but becomes scarce in the *Globigerina bulloides* Zone, Pozón formation.

Bolivina isidroensis Cushman and Renz

Bolivina isidroensis Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 17, pl. 3, fig. 8.

Hypotype:—From sample, No. RM 19320, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625888.

Occurrence:—Common in the *Globorotalia fohsi* "Zone" (*s.l.*), *Globorotalia mayeri* Zone (*s.l.*), and *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone but becomes scarce in the *Sphaeroidinella seminulina* Zone, Pozón formation.

***Bolivina marginata multicostata* Cushman**

Bolivina marginata Cushman var. *multicostata* Cushman, 1930, Florida Geol. Surv., Bull., pt. 6, pl. 8, figs. 13-14 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19784, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625890.

Occurrence:—Only observed by the writer in the upper part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and in the lower part of the *Sphaeroidinella seminulina* Zone, Pozón formation. Renz (1948), however, recorded this species as occurring nearly throughout all of the upper Tocuyo and Pozón formations.

***Bolivina pisciformis* Galloway and Morrey**

Pl. 6, fig. 21

Bolivina pisciformis Galloway and Morrey, 1929, Bull. Amer. Pal., vol. 15, No. 55, p. 36, pl. 5, fig. 10.

Remarks:—This species has a broad test in which the marginal ends of the chambers are strongly directed to the initial end. This species resembles *Bolivina alazanensis* Cushman but has narrower chambers.

It differs from *Bolivina alata* (Seguenza), with which it has been confused, by having broader later chambers.

Hypotype:—From sample, No. RM 19320, auger line near Pozón, eastern Falcón; Plate 7, figure 21. deposited in U.S.N.M. collection, No. 625892.

Occurrence:—This species seems to be restricted to, and is fairly common in, the *Catapsydrax stainforthi* Zone, *Globigerina-tella insueta* Zone (*s.l.*) and *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

***Bolivina pozonensis* Cushman and Renz**

Bolivina pozonensis Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 16, pl. 3, fig. 6.

Remarks:—This species is distinct from *Bolivina mantaensis* Cushman, largely because of this species' "coarsely perforate wall structure". The fine longitudinal costae mentioned by Cushman and Renz in their type description seem to be a variable feature. In some specimens these costae are pronounced; in others, costae can only be observed when the specimen is moistened.

Hypotype:—From sample, No. RM 19460, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625894.

Occurrence:—Fairly common in the *Globorotalia fohsi robusta* Zone, *Globigerina mayeri* Zone (*s.l.*) and in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone. It becomes scarce in the lower part of the *Sphaeroidinella seminulina* Zone, Pozón formation.

***Bolivina pseudobeyrichi* Cushman**

Pl. 6, fig. 22

Non Bolivina beyrichi Reuss var. *alata* (Seguenza), Brady, 1884, Challenger Exped. Rept., Zool., vol. 9, p. 422, pl. 53, figs. 2-4.

Bolivina beyrichi var. *alata* Cushman (*non* Seguenza), 1911, U.S. Nat. Mus., Bull. 71, pt. 2, p. 35, text-Fig. 57, (*vide* Drooger, 1953).

Bolivina pseudobeyrichi Cushman, 1937, Contr. Cushman Lab. Foram. Rec., Spec. Pub. 9, p. 139, pl. 19, figs. 4, 5 (*vide* Drooger, 1953).

Bolivina alata Renz (*non* Seguenza), 1948, Geol. Soc. Amer., Mem. 32, p. 116, pl. VII, fig. 26; pl. XII, figs. 12 a-b.

Remarks:—This species appears to be related to *Bolivina beyrichi* Reuss but possesses a more-or-less continuous keel of clear shell material between the peripheral spines. Drooger (1953, p. 131) pointed out that most West Indian references of *Bolivina alata* are different from Seguenza's type.

Hypotype:—From sample, No. RM 19400, auger line near Pozón, eastern Falcón; Plate 6, figure 22, deposited in U.S.N.M. collection, No. 625895.

Occurrence:—Occurs, but is scarce, in the *Globorotalia fohsi* "Zone" (*s.l.*) and in the lower part of the *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

***Bolivina simplex* Cushman and Renz**

Bolivina interjuncta Cushman var. *simplex* Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt 1, p. 20, pl. 3, fig. 15.

Bolivina simplex Cushman and Renz, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 119, pl. VII, figs. 4a-b.

Non Bolivina simplex Phleger and Parker, 1951, Geol. Soc. Amer., Mem. 46, pt. 2, p. 14, pl. 7, figs. 4-6.

Remarks:—Renz elevated the Cushman and Renz variety to specific rank in 1948. *Bolivina simplex* Phleger and Parker, 1951 is distinctly different from the strongly costate species of Cushman and Renz.

Hypotype:—From sample, No. RM 19789, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625897.

Occurrence:—First observed, and scarce, in the *Globorotalia fohsi fohsi* Zone, but becomes abundant in the upper part of *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and common in the overlying *Sphaeroidinella seminulina* Zone, Pozón formation. The distribution and abundance of this form seems to be closely controlled by ecological conditions since it occurs in floods in isolated samples but may be scarce in stratigraphically adjacent samples.

***Bolivina suteri* Cushman and Renz**

Bolivina suteri Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 18, pl. 3, fig. 9.

Remarks:—A distinctive form with highly inflated chambers and incised sutures.

Hypotype:—From sample, No. RM 19450, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625899.

Occurrence:—Only observed in a few samples from the *Globorotalia fohsi robusta* Zone and *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

***Bolivina thalmanni* Renz**

Bolivina thalmanni Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 120, pl. XII, figs. 13a-c.

Remarks:—This species is quite distinctive mainly because of its coarse reticulate ornamentation, but it may be related to *Bolivina cancellata* Bermudez.

Hypotype:—From sample, No. RM 19536, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625901.

Occurrence:—Observed only in isolated samples from the *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Genus **BULIMINA** d'Orbigny, 1826

Bulimina alazanensis Cushman

Bulimina alazanensis Cushman, 1927, Jour. Pal., vol. 1, p. 161, pl. 25, fig. 4 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19445, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625903.

Occurrence:—Occurs, but is scarce, in the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta* Zone (*s.l.*) but becomes common to abundant in the *Globorotalia fohsi lobata* Zone, the *Globorotalia fohsi robusta* Zone, and in the *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations. Scarce in sediments younger than the latter zone.

Bulimina alligata (Cushman and Laiming)

Pl. 6, fig. 23

Bulimina inflata Seguenza var. *alligata* Cushman and Laiming, 1931, Jour. Pal., vol. 5, No. 2, p. 107, pl. 11, figs. 17a-b (*vide* Ellis and Messina, 1940 *et seq.*).

Remarks:—The writer considers that this form is distinct from *Bulimina inflata*, and accordingly it is elevated to specific rank. The costae are fairly weak but arranged generally in longitudinal lines. The chambers are axially longer than in *Bulimina inflata*, especially the last chamber, but the spines are not so well pronounced. The aperture is also rather more elongate than in *Bulimina inflata* Seguenza.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 6, figure 23, deposited in U.S.N.M. collection, No. 625905.

Occurrence:—Seems to be restricted to the upper Tocuyo formation and the Pozón formation below the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone.

Bulimina falconensis Renz

Bulimina falconensis Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 121, pl. VI, figs. 15a-b.

Remarks:—Renz (1948) considered his species to be identical

with *Bulimina buchiana* Cushman and Ponton, 1932. However, the name *Bulimina buchiana* was used by D'Orbigny in 1846; hence *Bulimina buchiana* Cushman and Ponton, 1932 is a homonym of *Bulimina buchiana* d'Orbigny, 1846 and, therefore, invalid.

Bulimina falconensis is probably closely related to *Bulimina sculptis* Cushman, 1923 (*non* Renz, 1942) but can be distinguished from the latter species by the less regular costae some of which do not reach the initial end of the test. The chambers of *Bulimina sculptis* Cushman are more inflated than in *Bulimina falconensis*.

Hypotype:—From sample, No. RM 19460, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625907.

Occurrence:—Scarce in the *Globorotalia fohsi lobata* Zone but becomes fairly frequent in the *Globorotalia fohsi robusta* Zone and in the *Globorotalia mayeri/Globorotalia linguaensis* Subzone, Pozón formation.

***Bulimina inflata* Seguenza**

Bulimina inflata Seguenza, 1862, *Accad. Gioenia Sci. Nat., Atti., ser. 2, vol. 18, p. 109, pl. 1, fig. 10 (fide Ellis and Messina, 1940 et seq.)*.

Hypotype:—From sample, No. RM 19300, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625909.

Occurrence:—Fairly common throughout the upper Tocuyo and Pozón formations, although it only occurs sporadically in the uppermost part of the *Sphaeroidinella seminulina* Zone.

***Bulimina pupoides* d'Orbigny**

Bulimina pupoides d'Orbigny, 1846, *Foraminifères fossiles du bassin tertiaire de Vienne (Autriche)*, p. 185, pl. 11, figs. 11-12. (*Fide Ellis and Messina, 1940, et seq.*)

Remarks:—The form is rather variable: in some forms the last chamber embraces most of the earlier test; in others as many as three or four earlier whorls are visible. However, all gradations exist between these two extremes. Some forms have a fairly well-developed basal projection.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625911.

Occurrence:—This species appears to have a similar stratigraphical and ecological distribution to *Bulimina (Globobulimina) perversa* Cushman.

Subgenus **GLOBOBULIMINA** Cushman, 1927**Bulimina (Globobulimina) perversa** Cushman

Bulimina pyrula d'Orbigny var. *perversa* Cushman, 1921, U.S. Nat. Mus., Bull. 100, vol. 4, p. 163, text-figs 2a-c.

Bulimina (Globobulimina) perversa Cushman, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 122, pl. VI, fig. 16.

Remarks:—This form shows rather variable morphology: some specimens tend to be rather more elongate, others are almost as broad as long, but all transitions occur.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625913.

Occurrence:—This form seems to be strongly influenced by ecological conditions since its occurrence is often sporadic and variable, often associated with rather poor mainly "arenaceous faunas". Generally scarce in all zones below the middle part of the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

Genus **BULIMINELLA** Cushman, 1911**Buliminella basistriata nuda** Howe and Wallace

Buliminella basistriata Cushman and Jarvis var. *nuda* Howe and Wallace, 1932, Louisiana Dept. Cons. Geol. Bull., No. 2, p. 60, pl. 11, fig. 4 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625915.

Occurrence:—Occurs in variable abundance throughout the upper Tocuyo and Pozón formations. It is especially abundant in the lower part of the *Sphaeroidinella seminulina* Zone. It is strongly influenced by ecological conditions and often occurs in floods but may become scarce in samples only a few feet stratigraphically higher or lower.

Genus **ENTSOLENIA** Ehrenberg, 1848**Entosolenia marginata** (Walker and Boys)

Serpula (Lagena) marginata Walker and Boys, 1784, Test, Min., p. 2, pl. 1, fig. 7 (*vide* Beckmann, 1953).

Lagena marginata (Walker and Boys), Beckman, 1953, Eclog. Geol. Helv., vol. 46, No. 2, p. 358, pl. 20, fig. 5.

Remarks:—This form shows the presence of a distinct internal tube. Test is rather compressed with a peripheral flange of clear

shell material. Aperture at the end of a distinct and fairly long neck which is elliptical in cross-section.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625917.

Occurrence:—Ubiquitous and fairly common in all zones below the base of the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

Genus **REUSSELLA** Galloway, 1933

Reussella spinulosa (Reuss)

Pl. 7, fig. 24

Ternuculina spinulosa Reuss, 1859, Akad. Wiss. Wien Denkschr., vol. 1, p. 374, fig. 12 (*vide* Ellis and Messins, 1940 *et seq.*).

Reussella spinulosa (Reuss), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 156. pl. VII, figs. 16-17.

Hypotype:—From sample, No. RM 20131, auger line near Pozón, eastern Falcón; Plate 7, figure 24, deposited in U.S.N.M. collection, No. 625919.

Occurrence:—Renz recorded this species as being restricted to his *Elphidium poeyanum-Reussella spinulosa* Zonule (= part of *Globigerina bulloides* Zone, Pozón formation), but the present writer has observed isolated specimens stratigraphically lower and associated with *Vaginulinopsis superbus*. It is closely associated with some species of *Rotalia*, and its occurrence is strongly governed by ecological conditions. It may be common in a particular sample but may be rare or absent in stratigraphically adjacent samples. It has been observed in varying frequency from the *Sphaeroidinella seminulina* Zone and *Globigerina bulloides* Zone, Pozón formation.

Genus **SIPHOGENERINA** Schlumberger, 1883

Siphogenerina kugleri Cushman and Renz

Siphogenerina kugleri Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 22, pl. 3, figs. 21-22.

Hypotype:—From sample, No. RM 19282, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625921.

Occurrence:—Scarce, only observed in samples from the *Globigerinatella insueta/Globigerinoides bispherica* Subzone and *Globorotalia fohsi fohsi* Zone, Pozón formation.

Siphogenerina lamellata Cushman

Siphogenerina lamellata Cushman, 1918, U.S. Geol. Surv., Bull. 676, p. 55, pl. 12, fig. 3.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625923.

Occurrence:—Common or abundant in all zones of the upper Tocuyo and Pozón formations below the *Sphaeroidinella seminulina* Zone. Occasional specimens have been observed in the middle to lower part of this latter zone. The disappearance of this species may be due to ecological rather than stratigraphical reasons.

Siphogenerina multicostata Cushman and Jarvis

Siphogenerina multicostata Cushman and Jarvis, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, p. 14, pl. 3, fig. 6 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625925.

Occurrence:—Generally scarce but observed in samples from the *Globigerinatella insueta* Zone (*s.l.*) and in the *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Siphogenerina senni Cushman and Renz

Siphogenerina senni Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 22, pl. 3, figs. 21-22.

Siphogenerina cummingsi Galloway and Heminway, 1941, New York Acad. Sci., vol. 3, pt. 4, p. 433, pl. 34, figs. 6-7.

Siphogenerina yumuriana Palmer, 1941, Soc. cubana hist. nat., Mem., vol. 15, No. 2, p. 185, pl. 15, figs. 3-4.

Siphogenerina senni Cushman and Renz, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 165, pl. VII, figs. 29a-b, 30.

Hypotype:—From sample, No. RM 19116, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625927.

Occurrence:—Rather scarce, but observed in samples from the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta* Zone (*s.l.*), and in the *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Siphogenerina transversa Cushman

Pl. 6, fig. 25

Siphogenerina raphanus (Parker and Jones) var. *transversus* Cushman, 1918, U.S. Nat. Mus., Bull. 103, p. 64, pl. 22, fig. 8 (*vide* Ellis and Messina, 1940 *et seq.*).

Siphogenerina transversa Cushman, Cushman and Parker, 1931, Cushman Lab. Foram. Res., Contr., vol. 7, p. 10, pl. 2, figs. 5, 6 (*vide* Renz, 1948).
Siphogenerina transversa Cushman, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 166, pl. VII, figs. 27, 28, pl. XII, fig. 9.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; Plate 6, fig. 25, deposited in U.S.N.M. collection, No. 625929.

Occurrence:—Renz used this species as the zonal index for his *Siphogenerina transversa* Zone. It does not range higher than the middle part of the *Globorotalia foysi foysi* Zone. Common to abundant in the *Catapsydrax stainforthi* Zone, and in the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations, but becomes comparatively scarce thereafter. Since there is no apparent change of facies over the interval covering the disappearance of this form, it is considered that its disappearance is due to stratigraphical reasons alone.

Genus **STILOSTOMELLA** Guppy, 1894

***Stilostomella verneuili* (d'Orbigny)**

Dentalina verneuili d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 48, pl. 2, figs. 7-8. (*Fide* Ellis and Messina, 1940 *et seq.*).

Ellipsonodosaria? verneuili (d'Orbigny), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 131, pl. VIII, fig. 3-5.

Remarks:—The specimens observed in the Pozón-El Mene Road section appear to be typical for the species. Stainforth (1952b) specifically mentions this species as included in the genus *Siphonodosaria* and gave cogent reasons why *Ellipsonodosaria* should be placed in synonymy with *Nodosarella*. The latter genus, however, has a crescentic aperture whilst the species "*verneuili*" possesses a round aperture with a short collar-like neck. Later, Stainforth (1952c) pointed out that the genus *Stilostomella* has priority over the genus *Siphonodosaria*.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625931.

Occurrence:—Common in all zones of the upper Tocuyo and Pozón formations, below the base of the *Sphaeroidinella seminulina* Zone.

Genus **UVIGERINA** d'Orbigny, 1826**Uvigerina auberiana attenuata** Cushman and Renz

Uvigerina auberiana d'Orbigny var. *attenuata* Cushman and Renz, Cushman Lab. Foram. Res., Contr., vol. 17, p. 21, pl. 3, fig. 17.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625932.

Occurrence:—Generally rather scarce in all zones of the upper Tocuyo and Pozón formations below the *Globorotalia menardii* *menardii*/*Globigerina nepenthes* Zone.

Uvigerina capayana Hedberg

Uvigerina pygmaea d'Orbigny var. *capayana* Hedberg, 1937, Jour. Pal., vol. 11, p. 677, pl. 91, fig. 19.

Uvigerina capayana Hedberg, Cushman and Edwards, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, p. 80, pl. 14, fig. 1 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625934.

Occurrence:—Generally common in all zones of the upper Tocuyo and Pozón formations below the *Globorotalia menardii* *menardii*/*Globigerina nepenthes* Zone but scarce in this latter zone.

Uvigerina carapitana Hedberg

Uvigerina carapitana Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 677, pl. 91, fig. 20.

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625936.

Occurrence:—Generally common in all zones of the upper Tocuyo and Pozón formations below the lower to middle part of the *Sphaeroidinella seminulina* Zone.

Uvigerina cubana Palmer and Bermudez

Pl. 8, fig. 26

Uvigerina cubana Palmer and Bermudez, 1936, Soc. cubana hist. nat., Mem., vol. 10, p. 292, pl. 17, figs. 5-6.

Remarks:—This species appears to be closely related to *Uvigerina gallowayi* Cushman, 1926 and possibly to *Uvigerina bartula* Macfadyen.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 8, fig. 26, deposited in U.S.N.M. collection, No. 625938.

Occurrence:—Scarce and only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

***Uvigerina gallowayi basicordata* Cushman and Renz**

Uvigerina gallowayi Cushman var. *basicordata* Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 21, pl. 3, fig. 18.

Hypotype:—From sample, No. RM 19283, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625940.

Occurrence:—Only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

***Uvigerina cf. hannai* Kleinpell**

cf. *Uvigerina californica* Hanna (*non* Cushman), 1928, Bull. Amer. Assoc. Petr. Geol., vol. 12, pl. 9, fig. 3 (*vide* Kleinpell, 1938).

cf. *Uvigerina hannai* Kleinpell, 1938, Amer. Assoc. Petr. Geol., Spec. Publ., p. 294.

Uvigerina cf. hannai Kleinpell, Renz, 1948 (*pars*), Geol. Soc. Amer., Mem. 32, p. 174, pl. XII, figs. 16a-b (not fig. 17).

Remarks:—The writer's specimens do not show the costae over the earlier chambers as shown by Renz (1948, pl. XII, fig. 17) and as mentioned by Kleinpell (1938, p. 294). However, the specimens appear to be identical to some figured by Renz (1948, pl. XII, figs. 16a-b) and only show the slightest trace of rather irregular fine costae when the specimens are moistened. The writer's specimens are only tentatively assigned to Kleinpell's species.

Hypotype:—From sample, No. RM 19405, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625942.

Occurrence:—Scarce in the *Globorotalia fohsi fohsi* Zone but becomes common in the *Globorotalia fohsi lobata* Zone, *Globorotalia fohsi robusta* Zone and also in the *Globorotalia mayeri* Zone (*s.l.*). Only occasional specimens have been seen in the lower part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

***Uvigerina isidroensis* Cushman and Renz**

Uvigerina isidroensis Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 20, pl. 3, fig. 16.

Uvigerina hispidocostata Cushman and Todd, 1945, Cushman Lab. Foram. Res., Spec. Pub. 15, p. 51, pl. 7, figs. 27, 31 (*vide* Ellis and Messina, 1940 *et seq.*).

Remarks:—This form shows considerable variation. The typical form is strongly costate with the costae not quite covering the last chamber; however, in other forms the costae are wanting on the last chamber but small poorly formed pustules may be present. All transitions between forms with costae over the complete test and forms with pustules over the last chamber are present. The number of chambers is also variable. Usually about 4-5 whorls are present but sometimes as many as seven are observed with the last chamber becoming rather pointed, and the aperture centrally placed.

Hypotype:—From sample, No. RM 19282, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625944.

Occurrence:—Ubiquitous but varies greatly in frequency. Generally rather scarce in the mainly planktonic facies of the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta* Zone (*s.l.*), and in the *Globorotalia mayeri* Zone (*s.l.*). Often common or abundant in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, and in the *Sphaeroidinella seminulina* Zone but becomes scarce in the overlying *Globigerina bulloides* Zone, Tocuyo and Pozón formations. The distribution of this form is strongly dependent on ecological conditions, some samples from the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and *Sphaeroidinella seminulina* Zone have over 95% of the total fauna present as this species. It is often associated with *Bolivina imporcata* and *Bolivina simplex*.

***Uvigerina rustica* Cushman and Edwards**

Uvigerina rustica Cushman and Edwards, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, p. 83, pl. 14, fig. 6 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625946.

Occurrence:—Generally rather scarce in all zones of the upper Tocuyo and Pozón formations below the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone.

Genus **VIRGULINA** d'Orbigny, 1826

***Virgulina pontoni* Cushman**

Virgulina pontoni Cushman, 1932, Cushman Lab. Foram. Res., Contr., vol. 8, p. 17, pl. 3, fig. 7 (*vide* Ellis and Messina, 1940 *et seq.*).

Virgulina pontoni Cushman, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 178, pl. VI, fig. 18.

Hypotype:—From sample, No. RM 19405, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625948.

Occurrence:—Fairly common in the *Globorotalia fohsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Family ROTALIIDAE

Genus CANCRIS Montfort, 1808

Canceris panamensis Natland

Canceris panamensis Natland, 1938, Scripps Inst. Oceanog., Bull. Tech. Ser., vol. 4, No. 5, p. 148, pl. 6, figs. 1a-c (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625950.

Occurrence:—Common in all zones of the upper Tocuyo and Pozón formations below the *Globigerina bulloides* Zone.

Canceris sagra (d'Orbigny)

Rotalia sagra d'Orbigny, 1839, "Foraminifères", in de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, p. 77, pl. 5, figs. 13-15 (*vide* Ellis and Messina, 1940 *et seq.*).

Canceris sagra (d'Orbigny), Cushman, 1931, U.S. Nat. Mus., Bull. 104, pt. 8, p. 74, pl. 15, fig. 2 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19340, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625952.

Occurrence:—Occurs rarely and only sporadically in the *Globorotalia fohsi* "Zone" (*s.l.*) and in the *Globorotalia mayeri* Zone (*s.l.*) but becomes relatively common in the upper part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and in *Sphaeroidinella seminulina* Zone; scarce in the *Globigerina bulloides* Zone, Pozón formation.

Genus EPONIDES Montfort, 1808

Eponides crebbisi Hedberg

Eponides crebbisi Hedberg, 1937, Jour. Pal., vol. 11, p. 679, pl. 92, figs. 1a-c.

Remarks:—The sinuous umbilical sutures makes this species distinctive.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625954.

Occurrence:—Common or fairly common in the upper part of the Tocuyo formation and in the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*), but only occurs in isolated samples from the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Eponides parantillarum Galloway and Heminway

Eponides parantillarum Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Islands, vol. 3, pt. 4, p. 374, pl. 18 figs. 1a-c.

Remarks:—This form appears to be closely related to *Eponides antillarum* (d'Orbigny).

Hypotype:—From sample, No. RM 19849, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625956.

Occurrence:—Fairly common in, and apparently restricted to, the middle to upper part of the *Sphaeroidinella seminulina* Zone, Pozón formation.

Eponides umbonatus ecuadorensis (Galloway and Morrey)

Rotalia ecuadorensis Galloway and Morrey, 1929, Bull. Amer. Pal., vol. 15, No. 55, p. 26, pl. 3, figs. 13a-c

Eponides umbonatus (Reuss) var. *ecuadorensis* (Galloway and Morrey), Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 679, pl. 91, fig. 22.

Remarks:—This form shows a strongly vaulted umbilical side and a convex spiral side; sutures not depressed, radial on the spiral side and slightly sinuous umbilically. Chambers, as seen from spiral side, are rather narrow but elongate tangentially. Umbilicus closed, aperture interiomarginal, sutural, rather short, midway between the keeled periphery and the umbilicus. The subspecies is distinguished from the parent species by virtue of the slightly sinuous umbilical sutures and umbilical plug.

This form shows a combination of many of the characters used by Brotzen (1942) to differentiate *Gyroidina* and *Eponides*.

Hypotype:—From sample, No. RM 19320, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625958.

Occurrence:—Rather scarce in the upper part of the Tocuyo formation and in the *Globigerinatella insueta* Zone (*s.l.*) but becomes common or even abundant in samples from the *Globorotalia*

fohshi "Zone" (*s.l.*), *Globorotalia mayeri* Zone (*s.l.*), and *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone. Becomes rare and only occurs sporadically in the lower part of the *Sphaeroidinella seminulina* Zone, Pozón formation.

Genus **GYROIDINA** d'Orbigny, 1826

Gyroidina parva Cushman and Renz

Gyroidina parva Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 23, pl. 4, fig. 2.

Hypotype:—From sample, No. RM 19340, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625960.

Occurrence:—Occurs throughout the upper part of the Tocuyo and Pozón formations. Usually rather scarce below the *Globorotalia fohsi fohsi* Zone and above the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, but common or abundant especially in the *Globorotalia fohsi robusta* Zone and *Globorotalia mayeri* Zone (*s.l.*).

Genus **GYROIDINOIDES** Brotzen, 1942

Gyroidinoides altiformis (R. E. and K. C. Stewart) Pl. 7, figs. 27a-c

Gyroidina soldanii d'Orbigny var. *altiformis* R. E. and K. C. Stewart, 1930, Jour. Pal., vol. 4, p. 67, pl. 9, fig. 2.

Gyroidinoides soldanii (d'Orbigny) var. *altiformis* (R. E. and K. C. Stewart), Renz, 1948, Geol. Soc. Amer., Mem 32, p. 140, pl. VIII, figs. 13a-c.

Remarks:—This form is different from D'Orbigny's illustrations of the species "*soldanii*" and from *Gyroidinoides* cf. *zelandica* Finlay. The sutures of the spiral side are distinct and the spiral suture well marked throughout. Sutures between the chambers are fairly deeply incised. The writer considers that this form is worthy of specific status and it is elevated accordingly.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 7, figs. 27a-c, deposited in U.S.N.M. collection, No. 625962.

Occurrence:—Fairly common in all zones of the Pozón formation below the base of the *Sphaeroidinella seminulina* Zone and in the upper part of the Tocuyo formation. Occasional specimens have been observed in samples from the upper part of the *Sphaeroidinella seminulina* Zone. The disappearance of this form in eastern

Falcón seems to be due to ecological rather than stratigraphical reasons.

Gyroidinoides byramensis campester (Palmer and Bermudez)

Eponides byramensis (Cushman) var. *campester* Palmer and Bermudez, 1941, Soc. cubana hist. nat., Mem., vol. 15, No. 2, p. 192.

Gyroidinoides byramensis (Cushman) var. *campester* (Palmer and Bermudez), Renz, 1948, Geol. Soc. Amer., Mem. 32, pp. 139-140, pl. VIII, figs. 15a-b; pl. IX, fig. 1.

Eponides campester Palmer and Bermudez, Bermudez, 1949, Cushman Lab. Foram. Res., Special Pub. 25, p. 245, pl. 16, figs. 40-42.

Remarks:—The present writer agrees with Renz (1948) that this species is best placed within the genus *Gyroidinoides* Brotzen, 1942 on account of the distinctive open umbilicus. Faint traces of an apertural lip have been observed which serve to substantiate the generic allocation. The subspecies differs from the parent species in having slightly limbate sutures and a less vaulted umbilical surface.

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625964.

Occurrence:—Generally scarce but has been observed in samples from the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*), and *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Gyroidinoides planulata (Cushman and Renz)

Gyroidina planulata Cushman and Renz, 1941, Cushman Lab. Foram. Res., vol. 17, pt. 1, p. 23, pl. 4, fig. 1.

Gyroidinoides planulata (Cushman and Renz), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 140, pl. VIII, figs. 11a-c.

Hypotype:—From sample, No. RM 19282, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection No. 625966.

Occurrence:—Scarce, only observed in the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, *Globorotalia fohsi barisanensis* Zone, and *Globorotalia fohsi fohsi* Zone, Pozón formation.

Gyroidinoides venezuelana Renz

Gyroidinoides venezuelana Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 141, p. XII, figs. 21a-c.

Remarks:—Renz considers his species related to *Gyroidina laevigata* d'Orbigny but distinguished from D'Orbigny's species by the more sharply edged periphery and less inflated chambers. Renz further stated that his species is also related to *Gyroidinoides planulata* Cushman and Renz which, however, has a rounded periphery.

Hypotype:—From sample No. RM 19305, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625968.

Occurrence:—Scarce in the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations but becomes fairly common in the *Globorotalia foehsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*) and rather scarce in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone and only observed in isolated samples from the *Sphaeroidinella seminulina* Zone, Pozón formation.

***Gyroidinoides cf. zelandica* (Finlay)**

Pl. 8, figs. 28a-c

cf. *Gyroidina zelandica* Finlay, 1939, Roy. Soc. New Zealand, Trans. Proc., vol. 69, pt. 3, p. 323, pl. 28, figs. 138-140 (*vide* Ellis and Messina, 1940 *et seq.*).

Gyroidina cf. soldanii Galloway and Heminway (*non* d'Orbigny), 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Islands, vol. 3, pt. 4 p. 377, pl. 15, figs. 7a-c.

Gyroidinoides cf. soldanii Renz (*non* d'Orbigny), 1948, Geol. Soc. Amer. Mem. 32, p. 140, pl. VIII, figs. 14a-c.

Remarks:—Renz (1948) tentatively referred some species identical to those seen by the writer to *Gyroidinoides soldanii* (d'Orbigny). However, D'Orbigny's figure of *Gyroidina soldanii* shows radial sutures on the spiral side and a well-marked spiral suture throughout; furthermore the umbilical side is not highly vaulted.

The specimens seen in the Tocuyo and Pozón formations agree closely with Finlay's species although the eastern Falcón specimens have a slightly wider umbilicus. Cushman and Stainforth (1948) figured a form as *Gyroidina girardana* (Reuss) var. *perampla* which also appears to be close to both Finlay's *G. zelandica* and the writer's specimens. However, since Finlay's species has priority and the eastern Falcón material resembles both *G. girardana* var. *perampla* and *G. zelandica* equally closely, they are tentatively

referred to the latter species. Finlay (1939) considered his species as being related to *Gyroidinoides altiformis* (R. E. and K. C. Stewart) and the specimens seen here also show a similar relationship.

Hypotype:—From sample, No. RM 19283, auger line near Pozón, eastern Falcón; Plate 8, figures 28a-c, deposited in U.S.N.M. collection, No. 625970.

Occurrence:—Scarce, only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia fohsi fohsi* Zone, Pozón formation.

Genus **PULVINULINELLA** Cushman, 1926

Pulvinulinella culter (Parker and Jones)

Planorbulina fareta (Fichtel and Moll) var. *ungeriana* (d'Orbigny) subvar. *culter* Parker and Jones, 1865, Roy. Soc. London, Phil. Trans., vol. 155, p. 382, pl. 9, figs. 1a-b (*vide* Cushman, 1929).

Pulvinulinella culter (Parker and Jones), Cushman, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, p. 100, pl. 14, fig. 13.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625972.

Occurrence:—Scarce and only observed in isolated samples from the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta/Globigerinoides triloba* Subzone, Tocuyo formation, and the lower part of the *Globigerinatella insueta/Globigerinoides bispherica* Subzone, Pozón formation.

Pulvinulinella jarvisi Cushman and Renz

Pulvinulinella jarvisi Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 24, pl. 4, fig. 4.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625974.

Occurrence:—Observed only in samples from the *Globigerinatella insueta/Globigerinoides bispherica* Subzone and *Globorotalia fohsi* "Zone" (*s.l.*), Pozón formation.

Genus **ROTALIA** Lamarck, 1804

Rotalia beccarii (Linné)

Nautilus beccarii Linné, 1767, Systema Naturae, 12th ed., vol. 1, p. 1162. (*Fide* Ellis and Messina, 1940 et seq.).

Rotalia beccarii (Linné), Cushman, 1928, Cushman Lab. Foram. Res., Contr., vol. 4, p. 103, pl. 15 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 20131, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625976.

Occurrence:—Only observed by the writer in the middle to upper part of the *Sphaeroidinella seminulina* Zone and in the *Globigerina bulloides* Zone, Pozón formation. It becomes common in the overlying Ojo de Agua formation.

Genus **SIPHONINA** Reuss, 1850

Siphonina pozonensis Cushman and Renz

Siphonina pozonensis Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 24, pl. 4, fig. 3.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625978.

Occurrence:—Occurs in varying frequency in the upper part of the Tocuyo formation and throughout the Pozón formation below the *Globigerina bulloides* Zone. Most frequent in the *Globorotalia fohsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*) but becomes scarce in the *Sphaeroidinella seminulina* Zone.

Genus **VALVULINERIA** Cushman, 1926

Valvulineria herricki (Hadley)

Pl. 8, figs. 29a-b

Cibicorbis herricki Hadley, 1934, Bull. Amer. Pal., vol. 20, p. 26, pl. 5, figs. 1-3 (*vide* Renz, 1948).

Cibicides kugleri Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 27, pl. 4, fig. 11.

Valvulineria herricki (Hadley), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 177, pl. VIII, figs. 10a-c.

Hypotype:—From sample, No. RM 19405, auger line near Pozón, eastern Falcón; Plate 8, figures 29a-b, deposited in U.S.N.M. collection, No. 625980.

Occurrence:—Renz (1948) used the partial occurrence of this species to define his *Valvulineria herricki* Zone. The present writer has observed specimens in the uppermost part of the *Globorotalia fohsi fohsi* Zone, *Globorotalia fohsi lobata* Zone, *Globorotalia fohsi robusta* Zone, and *Globorotalia mayeri* Zone (*s.l.*), Pozón formation. Some specimens have been noted associated with *Marginulinopsis basispinosus*.

The distribution of this form seems to be strongly influenced by ecological conditions since it is most frequent in sample con-

taining an appreciable planktonic component and absent in samples with a rich *Uvigerina isidroensis-Bolivina imporcata-Bolivina simplex* assemblage.

Valvulineria inaequalis lobata Cushman and Renz

Valvulineria inaequalis (d'Orbigny) var. *lobata* Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 23, pl. 3, fig. 24.

Hypotype:—From sample, No. 19180, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625982.

Occurrence:—Scarce, only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), and from the *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Family AMPHISTEGINIDAE

Genus AMPHISTEGINA d'Orbigny, 1826

Amphistegina cf. lessonii d'Orbigny

cf. *Amphistegina lessonii* d'Orbigny, 1826, Ann. Sci. Nat., Paris, sér. 1, vol. 7, p. 304, Modèles No 98 (*vide* Renz, 1948).

Remarks:—Most of the specimens present in the Pozón section are broken and abraded.

Hypotype:—From sample, No. RM 19888, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625983.

Occurrence:—Occurs mainly in the uppermost part of the Pozón formation (Huso Clay member).

Family CASSIDULINIDAE

Genus CASSIDULINA d'Orbigny, 1826

Cassidulina carapitana Hedberg

Cassidulina carapitana Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 680, pl. 96, figs. 6a-b.

Remarks:—Hedberg (1937, p. 680) remarked that his species belongs to the group of *Cassidulina laevigata* d'Orbigny but can be distinguished from this species since the sutures of *Cassidulina carapitana* are more sharply curved in the umbonal areas than in D'Orbigny's species.

Hypotype:—From sample, No. RM 19283, auger line near

Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625985.

Occurrence:—Common in all zones of the upper Tocuyo and Pozón formations below the middle part of the *Sphaeroidinella seminulina* Zone. The disappearance of this form seems to be due to ecological rather than stratigraphical reasons.

Cassidulina crassa d'Orbigny

Cassidulina crassa d'Orbigny, 1839, Voyage dans l'Amérique Méridionale; "Foraminifères", vol. 5, pt. 5, p. 56, pl. 7, figs. 18-20. (*Fide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625987.

Occurrence:—Common in all zones of the Pozón formation below the middle to upper part of the *Sphaeroidinella seminulina* Zone but rather scarce in the Tocuyo formation.

Cassidulina delicata Cushman

Cassidulina delicata Cushman, 1927, California Univ., Scripps Inst. Oceanog., Bull. Tech. ser., vol. 1, p. 168, pl. 6, fig. 5 (*fide* Renz 1948).

Hypotype:—From sample, No. 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625989.

Occurrence:—Scarce and only observed in the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone and *Globorotalia foehsi barisanensis* Zone, Pozón formation.

Cassidulina laevigata d'Orbigny

Cassidulina laevigata d'Orbigny, 1826, Ann Sci. Nat., Paris, sér. 1, vol. 7, p. 282, pl. 15, figs. 4-5 (*fide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625991.

Occurrence:—Fairly common in all zones of the Pozón formation below the *Globigerina bulloides* Zone and in the upper part of the Tocuyo formation; especially common in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone.

Cassidulina subglobosa Brady

Cassidulina subglobosa Brady, 1881, Roy. Micr. Soc., Quart. Jour., new ser., vol. 21, p. 60 (*fide* Ellis and Messina, 1940 *et seq.*).

Remarks:—The aperture of this form is normal to the axis of coiling.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625993.

Occurrence:—Ubiquitous although rather scarce. Ranges throughout the upper Tocuyo and Pozón formations.

Cassidulina subglobosa horizontalis Cushman and Renz

Cassidulina subglobosa Brady var. *horizontalis* Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 26, pl. 4, fig. 8.

Remarks:—This subspecies has the aperture parallel to the axis of coiling. Other characters are similar to the parent species.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625995.

Occurrence:—Scarce and does not occur above the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Genus **CASSIDULINOIDES** Cushman, 1927

Cassidulinoides erecta Cushman and Renz

Cassidulinoides erecta Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contrib., vol. 17, p. 25, pl. 4, figs. 6-7.

Hypotype:—From sample, No. RM 19320, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625996.

Occurrence:—Scarce, only observed in a few samples from the *Globorotalia fohsi* "Zone" (*s.l.*), Pozón formation.

Genus **EHRENBURGIA** Reuss, 1850

Ehrenbergina caribbea Galloway and Heminway

Ehrenbergina caribbea Galloway and Heminway, 1941, New York Acad. Sci., Sci Surv. Porto Rico and Virgin Islands, vol. 3, pt. 4, p. 426, pl. 32, figs. 4a-d.

Ehrenbergina caribbea Galloway and Heminway, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 131, pl. 1X, figs. 17a-b.

Hypotype:—From sample, No. RM 19355, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625997.

Occurrence:—Scarce and only observed in samples from the *Globorotalia fohsi* "Zone" (*s.l.*) and *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Family **CHILOSTOMELLIDAE**

Genus **CHILOSTOMELLA** Reuss, 1850

Chilostomella ovoidea Reuss

Chilostomella ovoidea Reuss, 1850, K. Akad. Wiss. Wien, Math.-Nat. Cl., Denkschr., vol. 1, p. 380, pl. 48, fig. 12 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 625999.

Occurrence:—Scarce, only seen in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia fohsi* "Zone" (*s.l.*) Tocuyo and Pozón formations. Usually badly preserved. According to Renz (1948) ranges throughout the Tocuyo formation and most of the Pozón formation.

Genus **PULLENIA** Parker and Jones, 1862**Pullenia bulloides** (d'Orbigny)

Nonionina bulloides d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 107, pt. 5, figs. 9-10. (*vide* Ellis and Messina, 1940 *et seq.*).

Pullenina bulloides (d'Orbigny), Kleinpell, 1938, Amer. Assoc. Petr. Geol., Spec. Pub., p. 338, pl. 5, figs. 10, 13.

Hypotype:—From sample, No. RM 19284, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626001.

Occurrence:—Generally rather scarce but observed in all zones of the Tocuyo and Pozón formations below the *Sphaeroidinella seminulina* Zone.

Pullenia salisburyi R. E. and K. C. Stewart

Pullenia salisburyi R. E. and K. C. Stewart, 1930, Jour. Pal., vol. 4, p. 72, pl. 8, fig. 2 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19283, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626003.

Occurrence:—Scarce and only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*), and *Globorotalia mayeri* Zone (*s.l.*), Tocuyo and Pozón formations.

Genus **SPHAEROIDINA** d'Orbigny, 1826**Sphaeroidina variabilis** Reuss

Sphaeroidina variabilis Reuss, 1851, Deutsch. Geol. Ges., Zeitschr., vol. 3, p. 88, pl. 7, figs. 61-64 (*vide* Ellis and Messina, 1940 *et seq.*).

Sphaeroidina variabilis Reuss, Cushman, 1929, Cushman Lab. Forum. Res., Contr., vol. 5, p. 101, pl. 14, figs. 15a-c.

Remarks:—This species shows considerable variation in size. Large specimens seem to be associated with mainly planktonic faunas. Dwarf specimens occur with *Uvigerina isidroensis-Bolivina simplex* and *Bolivina imporcata* assemblages in the lower to middle part of the *Sphaeroidinella seminulina* Zone.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626005.

Occurrence:—Occurs throughout the upper part of the Tocuyo and Pozón formations below the middle part of the *Sphaeroidinella seminulina* Zone. Most frequent in the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*) and in the *Globorotalia mayeri* Zone (*s.l.*).

Family HANTKENINIDAE

Subfamily CASSIGERINELLINAE

Genus CASSIGERINELLA Pokorný, 1955

Cassigerinella chipolensis (Cushman and Ponton) Pl. 7, figs. 30a-c

Cassidulina chipolensis Cushman and Ponton, 1932, Florida Geol. Surv., Bull., No. 9, p. 98, pl. 15, figs. 2a-c.

Cassidulina chipolensis Cushman and Ponton, Cushman and Stainforth, 1945, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 64, pl. 12, fig. 5

Cassigerinella chipolensis (Cushman and Ponton), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 108, pl. 22, figs. 3a-c.

Hypotype:—From sample, No. RM 19304, auger line near Pozón, eastern Falcón; Plate 7, figures 30a-c, deposited in U.S.N.M. collection, No. 626007.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the upper part of the *Globorotalia fohsi robusta* Zone, Tocuyo and Pozón formations.

Subfamily HASTIGERININAE

Genus HASTIGERINA Thompson, 1876

Cushman named the genus *Globigerinella* in 1927 with *Globigerina aequilateralis* Brady as the type species. Brady remarked in his type description of *Globigerina aequilateralis* that the test is "planospiral and symmetrical" but also remarked that his species approached "*Hastigerina* in general form". The apertures of Brady's species, as seen from his illustrations, are not interiomarginal, equatorial-symmetrical but asymmetric with an umbilical prolongation.

Brady also illustrated a section of his species which shows that the early stages are trochospiral, and the form is not planispiral throughout. Cushman (1927) noted in the type description of *Globigerinella* that his genus was "trochoid in the young, at least in the microspheric form", whilst Thompson (1876) defined *Hastigerina* (type species, *Hastigerina murrayi* Thompson=*Nonionina pelagica* d'Orbigny, 1839) as being trochospiral in the early stages but becoming planispiral later. As far as the writer is aware, the only difference between Cushman's and Thompson's type species are those of degree, not kind, and relate mainly to the presence or absence of coarse or fine spines. The actual nature of the spines in either form does not appear to be different. Since there does not appear to be any fundamental difference in morphology, the writer regards *Globigerinella* Cushman, 1927, as a junior synonym of *Hastigerina* Thompson, 1876.

Bolli, Loeblich, and Tappan (1957) also came to the same conclusions as the present writer concerning the validity of *Globigerinella* Cushman, 1927.

No typical specimens of *Hastigerina* (= *Globigerinella* of authors) seem to occur before the Miocene (probably not earlier than Burdigalian); species referred to *Globigerinella* from the Cretaceous by various authors (including Tappan, 1943 and Bronnemann, 1952b) seem to be more likely referable to *Biglobigerinella* Lalicker, 1948 or *Planomalina* Loeblich and Tappan, 1946.

It seems likely that *Hastigerina* has developed from a *Globorotalia* species close to *Globorotalia obesa* Bolli. In some gerontic forms of *Globorotalia obesa* from the *Globorotalia fohsi* "Zone" (*s.l.*), the last chamber shows the aperture extending over and on to the periphery, at least as far as the median line. As pointed out above, the aperture in *Hastigerina* is asymmetrical with a distinct ventral prolongation; this ventral prolongation is thought to be homologous with the interiomarginal, umbilical-extraumbilical aperture of *Globorotalia*. The stratigraphical occurrence of *Hastigerina* supports the view that it may possibly have been derived from the Miocene globorotalid stock.

Hastigerina aequilateralis (Brady)**Hastigerina aequilateralis aequilateralis** (Brady) Pl. 8, figs. 31a-b*Globigerina aequilateralis* Brady, 1879, Quart. Jour. Micr. Sci., London, n.s. vol. 19, p. 285, figs. 18-21 (*fide* Ellis and Messina, 1940 *et seq.*).*Globigerinella aequilateralis* (Brady), Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 280, pl. 21, fig. 51.*Hastigerina cf. aequilateralis* (Brady), Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 108, pl. 22, figs. 1a-2b.

Remarks:—Brady's figures show that there is considerable variation in the degree of involution present in this form. It seems that Recent specimens often show a greater degree of uncoiling than is present in the Miocene forms which do, however, show this tendency in the last chamber. The writer distinguishes this subspecies not entirely on the degree of involution but, more essentially, on the shape of the chambers and the nature of the aperture. This subspecies is distinguished from *Hastigerina aequilateralis involuta* (Cushman) by having subspherical, fairly well-separated chambers and by having a more distinctly asymmetric aperture which does not extend far on to the dorsal side.

Hypotype:—From sample, No. RM 20065, auger line near Pozón, eastern Falcón; Plate 8, figs. 31a-b, deposited in U.S.N.M. collection, No. 626009.

Occurrence:—Ranges from the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone to the *Globigerina bulloides* Zone, Pozón formation.

Hastigerina aequilateralis involuta (Cushman) Pl. 8, figs. 32a-b*Globigerina aequilateralis* Brady, var. *involuta* Cushman, 1917, U.S. Nat. Mus., Proc., vol. 51, No. 2172, p. 662. (Figures in Cushman, 1921, U.S. Nat. Mus., Bull., No. 100, vol. 4, p. 293, figs. 11a-11c.). (*fide* Ellis and Messina, 1940 *et seq.*).

Remarks:—This subspecies is distinguished from *Hastigerina aequilateralis aequilateralis* (Brady) in having closely appressed, ovate chambers which are distinctly pointed towards the umbilicus. This subspecies is generally more involute and has the aperture extending further over onto the dorsal side of the test (although it is still asymmetric with a distinct umbilical prolongation) than in *Hastigerina aequilateralis aequilateralis* (Brady).

Hypotype:—From sample, No. RM 20053, auger line near Pozón, eastern Falcón; Plate 8, figs. 32a-b, deposited in U.S.N.M. collection, No. 626011.

Occurrence:—Ranges from the middle part of the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone to the upper part of the *Sphaeroidinella seminulina* Zone, Pozón formation.

Family **ORBULINIDAE**

Subfamily **GLOBIGERININAE**

Genus **GLOBIGERINA** d'Orbigny, 1826

Globigerina angustiumblicata (Bolli) Pl. 7, figs. 33a-c, 34

Globigerina ciproensis angustiumblicata Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 109, pl. 22, figs. 12a-13c.

Remarks:—Bolli (1957) originally described this form as a subspecies of *Globigerina ciproensis* Bolli, but in a recent letter to the writer he agreed that this form is now better considered as a distinct species.

Globigerina angustiumblicata shows several significant differences from the two remaining subspecies of *Globigerina ciproensis*. Firstly, as Bolli (1957, p. 109) pointed out in his original description, the rate at which the chambers increase in size is distinctly greater than in either *Globigerina ciproensis ciproensis* or *Globigerina ciproensis angulisuturalis*. In this form the test is slightly more trochospiral and has a smaller and less deep umbilicus than in either of the two subspecies of *Globigerina ciproensis*. Another important feature seen in this form is that the aperture shows a tendency towards an interiomarginal, umbilical-extraumbilical position as well as having a distinct lip. Finally, the range of this species is much more extended than that of *Globigerina ciproensis ciproensis* and *Globigerina ciproensis angulisuturalis*.

Hypotype:—From sample, No. RM 19507, auger line near Pozón, eastern Falcón; Plate 7, figs. 33a-c, deposited in U.S.N.M. collection, No. 626013.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the *Globigerina bulloides* Zone, Tocuyo and Pozón formations.

Globigerina apertura Cushman Pl. 8, figs. 35a-b

Globigerina apertura Cushman, 1918, U.S. Geol. Surv., Bull., No. 676, p. 57, pl. 12, figs. 8a-c (*vide* Ellis and Messina, 1940 *et seq.*).

Remarks:—This species shows a large, high-arched aperture with a distinct thickened rim. The umbilicus is wide, and the chambers rather loosely coiled.

The writer's specimens compare excellently with Cushman's figured holotype, described from the Miocene of Virginia, U.S.A.

Globigerina apertura Cushman differs from *Globigerina ampliapertura* Bolli, 1957 by having looser coiling, a wider umbilicus, inflated and well-separated chambers. *Globigerina ampliapertura* is restricted to the uppermost Eocene and lowermost Oligocene whilst *Globigerina apertura* does not appear until the middle to upper Miocene.

Globigerina apertura is considered to be related to *Globigerina bulloides* d'Orbigny since *Globigerina apertura* first appears slightly later than *Globigerina bulloides*. Transitional forms between these two species are present in some samples from the upper part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone. However, *Globigerina apertura* may be distinguished from *Globigerina bulloides* by the very large and highly arched aperture, the distinctive apertural rim and the looser coiling.

Hypotype:—From sample, No. RM 19791, auger line near Pozón, eastern Falcón; Plate 8, figs. 35a-b, deposited in U.S.N.M. collection No. 626015.

Occurrence:—Ranges from the upper part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone to the *Sphaeroidinella seminulina* Zone, Pozón formation. This species may prove to be a most useful and restricted marker.

***Globigerina bradyi* Wiesner**

Pl. 7, fig. 36

Globigerina sp., Brady, 1884, Challenger Exped., Rept., Zool., vol. 9, p. 82, figs. 8, 9.

Globigerina bradyi Wiesner, 1931, Die Foraminiferen der deutschen Südpolar-Expedition 1901-1903. In: Drygalski, Deutsche Südpolar-Expedition 1901-1903, 1931, Bd. 20, (Zool. Bd. 12), p. 133 (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerina bradyi Wiesner, Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 110, pl. 23, figs. 5a-c.

Remarks:—The specimens observed in the Pozón-El Mene Road section compare well with Brady's figures and those figured by Bolli (1957) from southern Trinidad. Bolli (1957) remarked

that this species may be synonymous with *Globigerinoides minuta* Natland (1938) which has sutural supplementary apertures around the base of the last chamber. However, none of the writer's specimens show secondary sutural apertures and they are, therefore, assigned to Wiesner's species.

Bolli (1957) also remarked that *Globigerina juvenilis* Bolli shows a close relationship to this species, but the present writer regards both *Globigerina juvenilis* and *Globigerina bradyi* as being distinct. The latter species is distinctly more trochospiral and the chambers less inflated than in *Globigerina juvenilis*.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 7, fig. 36, deposited in U.S.N.M. collection, No. 626017.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the *Globigerina bulloides* Zone, and Pozón formations.

***Globigerina bulbosa* LeRoy**

Pl. 9, figs. 37a-c

Globigerina bulbosa LeRoy, 1944, Colorado School Mines, Quart., vol. 39, No. 3, pt. 1, p. 39, pl. 3, figs. 26, 27.

Remarks:—This species, which was originally described by LeRoy from the Miocene of central Sumatra, shows radially elongate and rather bulbous chambers. The chambers increase rapidly in size as added. In the eastern Falcón specimens, the aperture is seen to possess a thin lip.

This species seems to be related to *Globigerina foliata* Bolli but differs from the latter species by having radially elongate, not spherical, chambers, and in being less trochospiral with a slightly more open type of coiling.

Forms which appear to be transitional between *Globigerina foliata* and *Globigerina bulbosa* occur in the basal part of the *Globorotalia fohsi lobata* Zone. According to a letter received from H. M. Bolli, this species has now been observed in samples from the Cipero and Lengua formations of southern Trinidad.

Hypotype:—From sample, No. RM 19480, auger line near Pozón, eastern Falcón; Plate 9, figures 37a-c, deposited in U.S.N.M. collection, No. 625719.

Occurrence:—Ranges from the lower part of the *Globorotalia fohsi lobata* Zone to the upper part of the *Sphaeroidinella seminulina* Zone, Pozón formation.

***Globigerina bulloides* d'Orbigny**

Pl. 9, figs. 38a-c

Globigerina bulloides d'Orbigny, 1826, Ann. Sci. Nat., Paris, sér. 1, vol. 7, p. 277. Modèles nos. 17, 76 (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerina bulloides d'Orbigny, Cushman, 1941, (*pars*), Cushman Lab. Foram. Res., Contr., vol. 17, p. 38, pl. 10, figs. 3-7.

Remarks:—The writer's concept of this species is restricted to forms similar to those illustrated by Cushman (1941) as topotypes from Rimini, Italy. Cushman's illustrations agree excellently with topotype material examined by the writer and kindly supplied by the United States National Museum, Washington, D.C.

Forms referable to *Globigerina bulloides* show four chambers in the last whorl with a moderately arched interiomarginal, umbilical aperture and a fairly wide and deep umbilicus. The chambers are inflated, spherical, well separated and increase regularly in size. The test is distinctly trochospiral with usually 2½-3 convolutions visible on the dorsal side. The equatorial periphery is lobate and has a subcircular profile.

The specimens from eastern Falcón compare well with the topotypes figured by Cushman and are regarded as being typical. They first appear in sediments which are considered to be not older than middle Miocene. Bolli (1950, p. 1) also pointed out that *Globigerina bulloides* probably does not appear earlier than middle Miocene.

Globigerina diplostoma Reuss, *Globigerina concinna* Reuss, and *Globigerina quadrilatera* Galloway and Wissler all seem to be closely related to *Globigerina bulloides*. A study of Recent *Globigerina bulloides* from the North Sea (north-east of Scotland—material kindly supplied by H. M. Bolli) and the Gulf of Paria, the Atlantic Ocean, as well as the writer's Miocene material from eastern Falcón, shows that there are transitional forms from *Globigerina bulloides*, with four chambers in the last whorl, to *Globigerina concinna* Reuss with five well-developed chambers in the last whorl. These transitional forms show the fifth chamber variable

in size, with all gradations from rudimentary to well developed. It seems likely, therefore, that *Globigerina concinna* should be regarded as a subspecies of *Globigerina bulloides*.

The study of these *Globigerina bulloides* populations has also shown that some otherwise typical but small forms often have an aberrant final chamber and appear similar to either *Globigerina diplostoma* or, more especially, to *Globigerina quadrilatera*. It is possible that these two forms should be considered synonymous with *Globigerina bulloides* or *Globigerina concinna*.

Hypotype:—From sample, No. RM 19791, auger line near Pozón, eastern Falcón; Plate 9, figures 38a-c, deposited in U.S.N.M. collection, No. 626019.

Occurrence:—Ranges from the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone to the *Globigerina bulloides* Zone, Pozón formation.

***Globigerina eamesi* Blow, sp. nov.**

Pl. 9, figs. 39a-c

Diagnosis of species:—Test strongly trochospiral with 11-12 chambers arranged in about three whorls and with four chambers in the last whorl; chambers subspherical, inflated but somewhat embracing, also increasing regularly and fairly slowly in size as added; equatorial periphery lobate; equatorial profile subcircular; axial periphery rounded. The sutures of the spiral side and umbilical side are depressed, radial to slightly curved. Umbilicus small, usually almost closed; aperture an elongate slit with a thin lip, interiomarginal, umbilical; wall calcareous, perforate, thin and fragile, rough to distinctly spinose, often with thick spines. Maximum diameter of holotype, 0.34 mm.

Remarks:—This species is characterized by the rough to spinose wall which is also thin and fragile. It differs from *Globigerina foliata* Bolli by being more trochospiral, in having a very small umbilicus, a slitlike aperture and in the chambers being less well separated.

This species is named after Dr. F. E. Eames (Chief Palaeontologist, The British Petroleum Co. Ltd., London) in recognition of his contributions to Miocene stratigraphy and also in appreciation

of the encouragement he has given the author during the preparation of this work.

Holotype:—From sample, No. RM 19778, auger line near Pozón, eastern Falcón; Plate 9, figures 39a-c, deposited in U.S.N.M. collection, No. 625695.

Occurrence:—Ranges from the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone to the *Sphaeroidinella seminulina* Zone, Pozón formation.

***Globigerina falconensis* Blow, sp. nov.**

Pl. 9, figs. 40a-c, 41

Diagnosis of species:—Test low trochospiral with 10-12 chambers arranged in about $2\frac{1}{2}$ whorls and with 4 chambers in the last whorl; chambers subspherical, slightly embracing, especially the last, increasing regularly and rather slowly in size as added; equatorial periphery lobate; axial periphery rounded; sutures of the spiral and umbilical sides radial, depressed but not much incised; umbilicus small but deep, sometimes almost closed by the strongly developed lip of the last chamber; aperture an elongate low arch or sometimes rather slitlike with a well-developed lip, interiomarginal, umbilical; wall calcareous, rather coarsely perforate. Maximum diameter or holotype, 0.34 mm.

Remarks:—This species is distinguished from *Globigerina foliata* Bolli in having slightly embracing chambers and an elongate aperture with a well-developed apertural lip.

Holotype:—From sample, No. RM 19285, auger line near Pózon, eastern Falcón; Plate 9, figures 40a-c, deposited in U.S.N.M. collection, No. 625697. Plate 9, figure 41, paratype, also deposited in U.S.N.M. collection, No. 625698.

Occurrence:—Ranges from the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone to the *Globigerina bulloides* Zone, Tocuyo and Pozón formations.

***Globigerina foliata* Bolli**

Pl. 10, figs. 42a-c

Globigerina foliata Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 111, pl. 24, figs 1a-c.

Remarks:—This species is distinguished by having almost spherical and well-separated chambers which increase rapidly as

size is added. The last chamber, however, is often smaller than the penultimate chamber.

Hypotype:—From sample, No. RM 19697, auger line near Pozón, eastern Falcón; Plate 10, figures 42a-c, deposited in U.S.N.M. collection, No. 626021.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the upper part of the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

***Globigerina juvenilis* Bolli**

Pl. 10, figs. 43a-b

Globigerina juvenilis Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 113, pl. 24, figs. 5a-6.

Remarks:—This small species has inflated chambers, a small umbilicus and thin, finely perforate walls. The aperture is a narrow elongate slit usually with a thin but distinctive lip.

In some forms, which are still probably referable to this species, the lip abuts closely onto the ventral surface of the opposing chamber appearing much like a narrow bulla. These forms appear transitional to *Globigerinita*.

Bolli (1957) considered that this species may possibly represent the juvenile state of *Globigerinita naparimaensis* Bronnimann, but the present writer is inclined to view that this form is a distinct species from which *Globigerinita* developed heterochronously at various levels throughout the Miocene.

Hypotype:—From sample, No. RM 19507, auger line near Pozón, eastern Falcón; Plate 10, figures 43a b, deposited in U.S.N.M. collection, No. 626023.

Occurrence:—Ranges throughout all zones of the Tocuyo and Pozón formations as seen in the Pozón-El Mene Road Section.

***Globigerina nepenthes* Todd**

Pl. 8, figs. 44, 45

Globigerina nepenthes Todd, 1956, U.S. Geol. Surv., Prof. Paper 280-H, p. 301, pl. 78, fig. 7.

Globigerina nepenthes Todd, Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 111, pl. 24, figs. 2a-c.

Remarks:—This distinctive species shows trends towards becoming more tightly coiled and the chambers more strongly embracing. Concomitant with these trends, there is also a further

trend wherein the wall becomes thicker and the aperture less strongly arched so that later forms of the species appear rather *Sphaeroidinella*-like (Pl. 8, fig. 45).

Hypotype:—From sample, No. RM 20026, auger line near Pozón, eastern Falcón; Plate 8, figure 44, deposited in U.S.N.M. collection No. 626025. Figure 45, from sample, No. RM 20065, also deposited in U.S.N.M., collection, No. 626027.

Occurrence:—Ranges from the base of the *Globorotalia mayeri*/*Globigerina nepenthes* Subzone to the top of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Globigerina parabulloides Blow, sp. nov.

Pl. 10, figs. 46a-c

Diagnosis of species:—Test trochospiral with 9-10 chambers arranged in about three whorls and with four chambers in the last whorl; chambers ovate to subspherical, inflated and rather embracing, sometimes slightly appressed, increasing moderately rapidly in size as added so that the equatorial profile of the test appears distinctly elongate in the direction of the last chamber; equatorial periphery strongly lobate; axial periphery rounded; sutures of the spiral side depressed, radial to slightly curved; sutures of the umbilical side depressed but not deeply incised, radial; umbilicus small, rather shallow; aperture a low arch restricted in lateral extent to the umbilical depression, interiomarginal, umbilical, and with a distinct lip or thickened rim; wall calcareous, perforate, rather thick; maximum diameter of holotype, 0.34 mm.

Remarks:—This species differs from *Globigerina praebulloides* Blow, sp. nov. in having a laterally restricted aperture with a distinctive lip or thickened rim, a small and shallow umbilicus, a distinctly more trochospiral test which is more precisely coiled and inflated chambers.

This species differs from *Globigerina bulloides* d'Orbigny in having a much smaller and restricted aperture, a smaller umbilicus, less deeply incised sutures and an elongate equatorial profile. *Globigerina parabulloides* is considered to be descended from *Globigerina praebulloides* but appears earlier than *Globigerina bulloides*.

Transitional forms from *Globigerina praebulloides* to *Globi-*

gerina parabulloides occur in the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone.

Holotype:—From sample, No. RM 19791, auger line near Pozón, eastern Falcón; Plate 10, figures 46a-c, deposited in U.S.N.M. collection, No. 625699.

Occurrence:—Ranges from the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone to the *Globigerina bulloides* Zone, Pozón formation.

Globigerina praebulloides Blow, sp. nov. Pl. 8, figs. 47a-c; Pl. 9, 48

Globigerina aff. *bulloides* d'Orbigny, Stainforth, 1948, (*pars*), Jour. Pal., vol. 22, No. 2, p. 118, pl. 25, figs. 14, 15 (*non* figs. 16-18).

Diagnosis of species:—Test weakly trochospiral with 8-9 chambers arranged in about 2½ whorls, with usually 4, occasionally 5, chambers in the last whorl. The fifth chamber, when present, only rudimentary or small; chambers ovate, not much inflated but appressed and often slightly embracing, increasing rapidly in size as added so that the equatorial profile of the test appears distinctly elongate in the direction of the last chamber; equatorial periphery lobate; axial periphery rounded; sutures of the spiral and umbilical sides depressed but rather shallow, radial to slightly curved; umbilicus small and not deep; aperture a low to moderate arch, interiomarginal, umbilical; wall calcareous, perforate; maximum diameter of holotype, 0.30 mm.

Remarks:—This species differs from *Globigerina bulloides* d'Orbigny in having an elongate, not subcircular, equatorial profile, and chambers which are normally ovate, appressed and often slightly embracing. The chambers increase more rapidly in size in this species and the coiling is less trochospiral and not so precise as in *Globigerina bulloides*. This species also differs from *Globigerina bulloides* in having a comparatively smaller, less strongly arched aperture and the test is consistently smaller in size.

Stainforth (1948b, p. 118) noted the same characters as recorded above for forms he referred to as *Globigerina* aff. *bulloides* "form A", from the Oligocene of Ecuador; however, Stainforth described two different forms as *Globigerina* aff. *bulloides*, and his "form B" (Stainforth, 1948b, p. 121—explanation of plate 25, figs.

16-18) seems referable to the genus *Globorotalia*.

Globigerina praebulloides is considered as being ancestral to both *Globigerina bulloides* and *Globigerina parabulloides*.

Holotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 8, figures 47a-c, deposited in U.S.N.M. collection, No. 625701. Figured paratype (Pl. 9, fig. 48) also deposited in U.S.N.M. collection, No. 625702.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Tocuyo and Pozón formations.

Genus **GLOBOQUADRINA** Finlay, 1947

The species referred to this genus have several features in common. One of the most important biocharacters is the peculiar toothlike flap (or projection) which restricts and modifies the aperture and projects into the umbilical depression. This toothlike flap is regarded as being distinctly different from a normal lip seen in some species of *Globigerina*. In *Globoquadrina* the umbilical teeth (Bolli, Loeblich, and Tappan, 1957) lie within the umbilical depression, are usually pointed and often elongate, with an asymmetric outline as viewed from above.

Normally the aperture, in the various adult species of *Globoquadrina* discussed here, is interiomarginal, umbilical, but shows a tendency towards an interiomarginal, umbilical-extraumbilical position in some species, especially in juvenile forms or in the earlier chambers as seen in broken specimens.

Members of this genus typically show lateral compression of the later chambers.

Globoquadrina dehiscens dehiscens (Chapman, Parr, and Collins)

Two groups of forms, which are regarded as subspecies, have been observed in the Pozón-El Mene Road section. The form described as *Globoquadrina quadraria* (Cushman and Ellisor) 1939, is regarded as being close to *Globoquadrina dehiscens*, and it is not possible to separate these two forms when dealing with a population. However, the type described as *Globoquadrina quadraria* var. *advena* Bermudez is distinctive and appears to have a different

stratigraphical range. Bermudez's variety is, however, regarded as being closely related to *Globoquadrina dehiscens*, and since the name given by Chapman, Parr, and Collins in 1934 has priority, the variety "*advena*" is considered as a subspecies of *Globoquadrina dehiscens* (Chapman, Parr, and Collins).

Globoquadrina dehiscens dehiscens (Chapman, Parr, and Collins)

Pl. 8, figs. 49a-c

Globorotalia dehiscens Chapman, Parr, and Collins, 1934, Linn. Soc. London, Jour. Zool., vol. 38, No. 262, p. 569, pl. 11, figs. 36a-c (*vide* Ellis and Messina, 1940 *et seq.*).

Remarks:—This subspecies possesses a fairly wide umbilicus, also distinctive asymmetrical umbilical teeth. The chambers are generally not much embracing, and the sutures are distinct. It often shows much lateral compression of the later chambers, with a resultant quadrate outline.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 8, figures 49a-c, deposited in U.S.N.M. collection, No. 626028.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the lower part of the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

Globoquadrina dehiscens advena Bermudez

Pl. 8, figs. 50a-b

Globoquadrina quadraria (Cushman and Ellisor) var. *advena* Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 287, pl. 22, figs. 36-38.

Remarks:—This subspecies possesses a comparatively small, sometimes almost closed, umbilicus. The chambers are closely coiled and embracing, with the sutures indistinct.

In general, the test appears rather quadrate, but it may appear almost subspherical owing to the tight coil, embracing chambers, and the lateral compression of the later chambers.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 8, figs. 50a-b, deposited in U.S.N.M. collection, No. 626030.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the *Globorotalia mayeri*/*Globorotalia languaensis* Subzone, Tocuyo and Pozón formations.

Globoquadrina altispira (Cushman and Jarvis)**Globoquadrina altispira altispira** (Cushman and Jarvis) Pl. 8, figs. 51a-c*Globigerina altispira* Cushman and Jarvis, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 1, p. 5, pl. 1, figs. 13a-c. 14 (*vide* Ellis and Messina, 1940 *et seq.*).*Globoquadrina altispira altispira* (Cushman and Jarvis), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 111, pl. 24, figs. 7a-8b.

Remarks:—This subspecies possesses axially elongate and often fairly strongly laterally compressed chambers. Distinct asymmetrical umbilical teeth occur.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 8, figures 51a-c, deposited in U.S.N.M. collection, No. 626032.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the basal part of the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone, Tocuyo and Pozón formations.

Globoquadrina altispira globosa Bolli Pl. 11, figs. 52a-c*Globoquadrina altispira globosa* Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 111, pl. 24, figs. 9a-10c.

Remarks:—This subspecies is distinguished from *Globoquadrina altispira altispira* (Cushman and Jarvis) by having more globular and less axially elongate chambers. Well-marked, slightly asymmetrical umbilical teeth are present.

Hypotype:—From sample, No. RM 19542, auger line near Pozón, eastern Falcón; Plate 11, figures 52a-c, deposited in U.S.N.M. collection, No. 626034.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the top of the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone and then reappears at the base of the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone ranging up to the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Tocuyo and Pozón formations. The subspecies does not seem to occur in the intervening *Globorotalia fohsi* "Zone" (*s.l.*) either in southern Trinidad or in eastern Falcón.

Globoquadrina larmeui Akers Pl. 11, figs. 53a-c*Globoquadrina larmeui* Akers, 1955, Jour. Pal., vol. 29, No. 4, p. 661, pl. 65, figs. 4a-4c.

Remarks:—The specimens from eastern Falcón compare well with the figures given by Akers. As Akers (1955) remarked this species is closer to the genus *Globigerina* than other recorded species of the genus *Globoquadrina*. However, the umbilical teeth are distinctive and the aperture shows a slight tendency towards an interiomarginal, umbilical-extraumbilical position.

The umbilicus of this species is shallow especially when compared to other species of *Globoquadrina*.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 11, figures 53a-c, deposited in U.S.N.M. collection, No. 625721.

Occurrence:—Occurs from the top of the *Catapsydrax stainforthi* Zone to the *Globorotalia mayeri*/*Globigerina nepenthes* Subzone. Tocuyo and Pozón formations.

Globoquadrina pozonensis Blow, sp. nov.

Pl. 10, figs. 54a-c, 55, 56

Diagnosis of species:—Test distinctly trochospiral with 11-12 chambers arranged in about $2\frac{1}{2}$ whorls and with 4-5 chambers in the last whorl; chambers subspherical to ovate but sometimes rather appressed and also slightly compressed laterally; equatorial periphery lobate; equatorial profile subcircular; axial periphery rounded; sutures of the spiral and umbilical sides radial and depressed; umbilicus rather small but deep; aperture a rather small arched opening with a distinct umbilical tooth; in the adult generally interiomarginal, umbilical, but in some specimens (Pl. 10, fig. 55) interiomarginal, umbilical-slightly extraumbilical; apertures of the early chambers and in juvenile specimens distinctly interiomarginal, umbilical-extraumbilical; wall calcareous, coarsely perforate and often rather rough to slightly spinose; maximum diameter of holotype, 0.28 mm.

Remarks:—This species shows a distinctly interiomarginal, umbilical-extraumbilical aperture in the early chambers which becomes generally interiomarginal, umbilical in the adult. The umbilical teeth, although small, are distinct. The sutures are usually distinct, notwithstanding the rather appressed and laterally compressed chambers seen in some specimens.

Globoquadrina pozonensis distinguished from *Globoquadrina altispira globosa* Bolli by the rather more appressed chambers, relatively smaller umbilicus, relatively smaller aperture and consistently smaller test and by the coarsely perforate and rather rough wall.

Holotype:—From sample, No. RM 20065, auger line near Pozón, eastern Falcón; Pl. 10, figures 54a-c, deposited in U.S.N.M. collection, No. 625703. (Figured paratypes from same sample also deposited in U.S.N.M.)

Occurrence:—Ranges from the *Globorotalia mayeri*/*Globigerina nepenthes* Subzone to the *Globigerina bulloides* Zone, Pozón formation.

***Globoquadrina rohri* (Bolli)**

Pl. 11, figs. 57a-c

Globigerina rohri Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 109, pl. 23, figs. 1a-4b.

Remarks:—Bolli (1957) placed his species in the genus *Globigerina* and did not mention the occurrence of umbilical teeth. Bolli also pointed out that in his specimens the umbilicus is small and almost closed. Most of the writer's specimens also show the nearly closed umbilicus, but some specimens show a rather wider umbilicus and a well-marked asymmetrical umbilical tooth; in other respects these specimens show no further differences in morphology.

Bolli (1957) recorded this species as occurring not higher than the *Catapsydrax dissimilis* Zone but the writer's specimens come from the lower part of the overlying *Catapsydrax stainforthi* Zone, and the more open umbilicus may be a more advanced feature of some phylogenetic significance. These forms with the wider umbilicus and distinctive umbilical teeth show some features in common with the *Globoquadrina dehiscens* group and it seems likely that *Globoquadrina rohri* may be the ancestor of *Globoquadrina dehiscens*.

Holotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcon; Plate 11, figures 57a-c, deposited in U.S.N.M. collection, No. 626036.

Occurrence:—Occurs only in the lower part of the *Catapsydrax stainforthi* Zone, Tocuyo formation.

Globoquadrina venezuelana (Hedberg)

Pl. 11, figs. 58a-c, 59

Globigerina venezuelana Hedberg, 1937, Jour. Pal., vol. 11, No. 8, p. 681, pl. 92, figs. 7a-b.

Remarks:—This species is referred to the genus *Globoquadrina* Finlay, as Finlay (1947) suggested. Inspection of Hedberg's (1937) type figure 7a shows a pointed umbilical tooth projecting into the umbilicus; this feature has been seen in all the writer's specimens, although the umbilical teeth may be small and in some cases rudimentary.

Bolli (1957) discussed the variation in size and shape of the chambers of this species as seen in the Ciperó and Lengua formations of southern Trinidad, and a similar variation is seen in eastern Falcón. However, the differences in morphology seem to be variable and not sufficiently constant for taxonomic subdivision of the species. Besides the variation in lateral compression of the chambers as noted by Bolli (1957), the writer has noted that forms with a closed or nearly closed umbilicus and with small umbilical teeth are most frequent from the *Catapsydrax stainforthi* Zone to *Globorotalia fohsi fohsi* Zone, whilst forms with comparatively more open umbilici and more distinct umbilical teeth occur most frequently from the *Globorotalia fohsi lobata* Zone to the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone. In the *Sphaeroidinella seminulina* Zone and in the *Globigerina bulloides* Zone only the forms with the larger umbilici and more distinctive umbilical teeth have been observed. (See fig. 59.)

Hypotype:—From sample, No. RM 19188, auger line near Pozón, eastern Falcón; Plate 11, figures 58a-c, deposited in U.S.N.M. collection No. 626038. Plate 11, figure 59, from sample, No. RM 19542, deposited in U.S.N.M. collection, No. 626040.

Occurrence:—Ranges throughout the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone to *Globigerina bulloides* Zone), Tocuyo and Pozón formations.

Genus **GLOBIGERINOIDES** Cushman, 1927

Globigerinoides triloba (Reuss)

The writer agrees with the views of Bolli (1957, p. 112) regarding the relationship of both *Globigerinoides sacculifera* (Brady)

and a form recorded by LeRoy (1939) as *Globigerinoides sacculifera immatura* to *Globigerinoides triloba* (Reuss). Forms transitional between these species are often difficult to place with certainty. This is especially so for *Globigerinoides triloba* (Reuss) and *Globigerinoides sacculifera immatura* LeRoy, whilst a study of the ontogeny of *Globigerinoides sacculifera* (Brady) shows that it is only the possession of a saclike, elongate final chamber which distinguishes this form from *Globigerinoides sacculifera immatura* LeRoy. These closely related forms, which appear practically at the same time in the *Globorotalia kugleri* Zone (Bolli, 1957), are treated here as subspecies of *Globigerinoides triloba* (Reuss), since Reuss's name has priority. Bolli (1957) described another form, which is closely related to this group, as *Globigerinoides triloba altiapertura*.

***Globigerinoides triloba triloba* (Reuss)** Pl. 11, figs. 60a-b

Globigerina triloba Reuss, 1850, K. Akad. Wiss., Wien, Math.-Nat. Cl., Denkschr., vol. 1, p. 374, pl. 47, figs. 11a-d (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerinoides triloba (Reuss), Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 62, text-fig. 1, Nos. 1-3.

Globigerinoides triloba triloba (Reuss), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 112, pl. 25, figs. 2a-c.

Remarks:—This is distinguished from *Globigerinoides triloba immatura* LeRoy in having a more inflated final chamber which embraces more of the earlier test. It has, in general, a more elongate and narrower primary aperture than *Globigerinoides triloba immatura* LeRoy.

Holotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 11, figures 60a-b, deposited in U.S.N.M. collection, No. 626125.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the *Globigerina bulloides* Zone, Tocuyo and Pozón formations.

***Globigerinoides triloba altiapertura* Bolli** Pl. 10, figs. 61a-b

Globigerinoides triloba altiapertura Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 113, pl. 25, figs. 7a-8.

Remarks:—This subspecies is distinguished from other sub-

species of the *triloba* group by having a large and highly arched primary aperture. It is distinguished from *Globigerinoides bollii* Blow, sp. nov. by having inflated, spherical chambers, and larger supplementary apertures; the chambers are, moreover, not embracing.

Hypotype:—From sample, No. RM 19152, auger line near Pozón, eastern Falcón; Plate 10, figures 61a-b, deposited in U.S.N.M. collection, No. 626127.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the lower part of the *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation.

***Globigerinoides triloba immatura* LeRoy** Pl. 11, figs. 62a-b

Globigerinoides sacculiferus (Brady) var. *immatura* Leroy, 1939, *Natuurk. Tijdschr. Nederl.-Indië*, deel 99, afl. 6, p. 263, pl. 3, figs. 19-21 (*vide* Ellis and Messina, 1940, *et seq.*).

Globigerinoides triloba immatura LeRoy, Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 113, pl. 25, figs. 3a-4c.

Remarks:—This subspecies differs from *Globigerinoides triloba sacculifera* (Brady) by not having a saclike elongate final chamber.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 11, figures 62a-b, deposited in U.S.N.M. collection, No. 626129.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the *Globigerina bulloides* Zone, Tocuyo and Pozón formations.

***Globigerinoides triloba sacculifera* (Brady)** Pl. 11, figs. 63a-b

Globigerina sacculifera Brady, 1877, *Geol. Mag.*, n.s. decade 2, vol. 4, No. 12, p. 535, figures in Brady, 1884, *Challenger Exped. Rept. Zool.*, vol. 9, pl. 90, figs. 15 and 16 (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerinoides triloba sacculifera (Brady), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 113, pl. 25, figs. 5a-6.

Remarks:—This subspecies is distinguished by the characteristic saclike, final chamber. Both the primary and the dorsal supplementary apertures of the last chambers seem to be rather more strongly arched than the apertures of the last chamber of *Globigerinoides triloba immatura* LeRoy.

Hypotype:—From sample, No. RM 19697, auger line near Pozón, eastern Falcón; Plate 11, figures 63a-b, deposited in U.S.N.M. collection, No. 626131.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the *Globigerma bulloides* Zone, Tocuyo and Pozón formations.

***Globigerinoides bispherica* Todd**

Pl. 11, fig. 64

Globigerinoides bispherica Todd, 1954, Amer. Jour. Sci., vol. 252, No. 11, p. 681, pl. 1, figs. 1a-c.

Globigerinoides bispherica Todd, Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 62, text-fig. 1, Nos. 4-8; text-fig. 2, Nos. 10-11.

Globigerinoides bispherica Todd, Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 114, pl. 27, figs. 1a-b.

Remarks:—Blow (1956) emended the original description of Todd (1954) in order to recognize *Porticulasphaera glomerosa* (Blow). As emended, *Globigerinoides bispherica* shows two to four apertures along the suture between the last and earlier chambers. The last chamber embraces about 15 to 35 percent of the penultimate and earlier chambers. The primary aperture is still distinct, although it is elongate and often partially constricted by ingrowths of clear shell material which tend to subdivide it.

This species is regarded as the ancestor of *Porticulasphaera glomerosa* (Blow) and *Porticulasphaera transitoria* (Blow).

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 11, figure 64, deposited in U.S.N.M. collection, No. 626133.

Occurrence:—Ranges from the base of the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone to the lower part of the *Globorotalia fohsi barisanensis* Zone, Tocuyo, and Pozón formations.

***Globigerinoides bollii* Blow, sp. nov.**

Pl. 10, figs. 65a-c

Diagnosis of species:—Test trochospiral with four chambers in the last whorl; equatorial periphery lobate; axial periphery rounded; chambers subspherical or ovate, much embracing; sutures of the spiral and umbilical sides depressed but often indistinct, radial to slightly curved; umbilicus small, often almost completely closed; primary aperture interiomarginal, umbilical, the opening

almost completely circular but generally rather small; supplementary apertures on the spiral side, sutural, small; usually only one present, situated in the suture between the last chamber and its predecessor, although an additional supplementary aperture may be present in the suture between the penultimate and antepenultimate chambers; wall calcareous, perforate, often rather thick; maximum diameter of holotype, 0.34 mm.

Remarks:—This species differs from *Globigerinoides obliqua* Bolli in having much more embracing chambers, a small, almost circular, primary aperture, and in the last few chambers not showing any lateral and oblique compression. A characteristic of this species is the “cut-in” nature of the umbilical margin of the primary aperture. Early forms of this species only show one supplementary aperture on the spiral side which is situated in the suture between the last and penultimate chambers. However, in later forms from the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, an additional supplementary aperture appears in the suture between the penultimate and antepenultimate chambers.

This species seems to have a different origin from that of the *Globigerinoides triloba* group. According to Bolli (1957), *Globigerinoides triloba* (Reuss) appears to originate in the *Globorotalia kugleri* Zone and to develop from a form recorded by him as *Globigerina* cf. *trilocularis* d'Orbigny. However, *Globigerinoides bollii* does not appear until the basal part of the *Globorotalia mayeri*/*Globigerina nepenthes* Subzone and seems to have originated from a *Globigerina* sp., which has an otherwise similar morphology to this species but does not have supplementary apertures. This *Globigerina* sp. is scarce and appears to be limited to the upper part of the *Globorotalia fohsi robusta* Zone.

This species is named after Dr. H. M. Bolli in recognition of the valuable training the writer received from him whilst in Trinidad.

Holotype:—From sample, No. RM 19697, auger line near Pozón, eastern Falcón; Plate 10, figures 65a-c, deposited in U.S.N.M. collection, No. 625717.

Occurrence:—Ranges from the base of the *Globorotalia may-*

eri/Globorotalia linguaensis Subzone to the *Globigerina bulloides* Zone, Pozón formation.

Globigerinoides diminuta Bolli

Pl. 13, figs. 66a-b

Globigerinoides diminuta Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 114, pl. 25, figs. 11a-c.

Remarks:—This species is distinguished from *Globigerinoides rubra* (d'Orbigny) by its more embracing chambers, its distinctly quadrate outline, and its consistently smaller size.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 13, figures 66a-b deposited in U.S.N.M. collection, No. 626135.

Occurrence:—Ranges from the upper part of the *Globigerinatella insueta/Globigerinoides triloba* Subzone to the top of the *Globigerinatella insueta/Globigerinoides bispherica* Subzone, Tocuyo and Pozón formations. It is a useful marker for this interval.

Globigerinoides mitra Todd

Pl. 13, fig. 67

Globigerinoides mitra Todd, 1956, U.S. Geol. Surv., Prof. Paper 280-H, p. 302, pl. 78, figs. 3,6.

Globigerinoides mitra Todd, Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 114, pl. 26, figs. 1a-4.

Remarks:—Only a few specimens of this particularly high-spired and large species of *Globigerinoides* have been observed in the Pozón formation.

The occurrence of this species seems to be strongly influenced by ecological conditions and to occur in faunas which are suggestive of a deepwater environment.

The observed specimens appear to be typical and compare well with those figured by both Todd and Bolli in spite of the comparatively poor preservation and adherent matrix.

Hypotype:—From sample, No. RM 19507, auger line near Pozón, eastern Falcón; Plate 13, figure 67, deposited in U.S.N.M. collection, No. 626137

Occurrence:—Only observed in isolated samples from the *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Globigerinoides obliqua Bolli

Pl. 11, figs. 68a-b

Globigerinoides obliqua Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 113, pl. 25, figs. 9a-10c

Remarks:—This species is distinguished from the *Globigerinoides triloba* group by having the last, or last few, chambers compressed in a lateral and oblique manner. Although Bolli (1957) referred to his species as having a small umbilicus, there is a general trend, in sediments above the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone, towards the coiling becoming more lax and the umbilicus becoming larger. Also, concomitant with this trend towards laxity of coiling, the chambers become increasingly more separated.

A typical feature of this species is the elongate, although arched, primary aperture.

Holotype:—From sample No. RM 19444, auger line near Pozón, eastern Falcón; Plate 11, figures 68a-b, deposited in U.S.N.M. collection, No. 626041.

Occurrence:—Ranges throughout the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone to *Globigerina bulloides* Zone), Tocuyo and Pozón formations.

Globigerinioides rubra (d'Orbigny) Pl. 11, fig. 70; Pl. 13, figs. 69a-b

Globigerinoides subquadrata Bronnimann, in Todd, Cloud, Low, and Schmidt, 1954, Amer. Jour. Sci., vol. 252, p. 680, pl. 1, fig. 5.

Globigerinoides rubra (d'Orbigny), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 113, pl. 25, figs. 12a-13b.

Remarks:—This species is distinguished by the position of the primary and supplementary sutural apertures which are always symmetrically placed above the suture between two earlier chambers.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcon; Plate 13, figures 69a-b, deposited in U.S.N.M. collection, No. 626043. Plate 11, figure 70, from sample, No. RM 20131, deposited in U.S.N.M. collection, No. 626045.

Occurrence:—Ranges throughout all zones of the upper Tocuyo and Pozón formations and is common to abundant below the lower part of the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone. The species becomes scarce and has only been observed infrequently in the upper part of the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone and the *Globorotalia mayeri*/*Globigerina nepenthes*

Zone, but it becomes fairly frequent again in the *Sphaeroidinella seminulina* and the *Globigerina bulloides* Zones, Pozón formation.

Genus **SPHAEROIDINELLA** Cushman, 1927

Cushman erected this genus in 1927 with *Sphaeroidina dehiscens* Parker and Jones as the type species. However, the generic description of Cushman is somewhat misleading since he states "Test in early stages like *Globigerina* with coarsely cancellate surface". Cushman did not mention the characteristic thick and "polished" wall of the adult. *Sphaeroidinella dehiscens* (Parker and Jones) possesses a thick wall with a smooth outer surface which appears rather glassy and "polished" in reflected light. The writer made sections of *Sphaeroidinella dehiscens dehiscens* (Parker and Jones), *Sphaeroidinella dehiscens subdehiscens* Blow, subsp. nov. and *Sphaeroidinella seminulina seminulina* (Schwager) and found the wall structure similar in each of these forms. The typical wall structure is shown in the camera lucida drawing (Pl. 12, fig. 72) of a section of *Sphaeroidinella dehiscens subdehiscens*.

In thin section, the wall of *Sphaeroidinella* appears to be composed of three layers:

(a) a thin external "cortex", (b) a thick middle layer, (c) a thin inner layer (see fig. 72, Pl. 12)

(a) *External Cortex*.

The actual structure of the outer cortex is difficult to determine but, between crossed nicols, shows interference colours of a lower order than either the middle or innermost layer. It is thought that this outer cortex may be lamellar in structure but it cannot be considered as "imperforate" since pores are present but are much reduced in size as compared with the pores present in the middle and innermost layers. In reflected light this cortex appears hyaline and smooth with a polished appearance.

The outer cortex also appears more liable to alteration and solution than the other layers since it has been noticed that pyritization and limonitization often affect the cortex but not the inner layers. Further, the writer has noticed specimens in which the cortex has been removed from a part of the test, so exposing the middle layer which then appears very coarsely perforate. In *Sphaeroidinella dehiscens subdehiscens* Blow, subsp. nov., for a specimen

0.35 mm. maximum dimension, this outer cortex (over the chambers) is in the order of 0.005 mm. to 0.006 mm. thick as compared with a total wall thickness of between 0.05 mm. and 0.06 mm. In the apertural and sutural regions of the test the cortex becomes much thicker (see fig. 72, Pl. 12).

(b) *Thick Middle Layer.*

This thick middle layer comprises most of the test wall and is in the order of between 0.045 mm. and 0.055 mm. thick. The structure of this layer appears to be coarsely radial with large "bundles of fibres" arranged approximately at right-angles to the test surfaces. The pores are large in this layer, being about 0.008 to 0.01 mm. in diameter but becoming, abruptly, much narrower at the junction of the outer cortex and this layer. It also seems likely that not all the pores present in this layer continue to the exterior via the cortex. The large pores of this layer can be seen through the glassy outer cortex in reflected light.

(c) *Innermost Layer.*

This layer also appears to be radial in structure but rather finely so. The writer has not observed any significant difference in the diameter of the pores within this layer and as seen in the middle layer.

***Sphaeroidinella dehiscens* (Parker and Jones)**

The writer now considers that certain Miocene forms previously referred to this species (Stainforth, 1948b; Weiss, 1955) should be separated at subspecific-level from the Pliocene to Recent, typical *Sphaeroidinella dehiscens* such as those figured by Wiseman and Ovey (1950, pl. 3 fig. 4), Phleger, Parker, and Pierson (1953, pl. 2, fig. 19), and also Kane (1953, pl. 2, fig. 23). The writer is indebted to Miss R. Todd (U. S. Geological Survey, Washington, D.C.) who sent specimens of Recent *Sphaeroidinella dehiscens* from near Bikini Atoll, Marshall Islands. Following the examination of this Recent material, as well as specimens from the Pliocene and Pleistocene of Sicily, two subspecies of this form should be distinguished as *Sphaeroidinella dehiscens dehiscens* (Parker and Jones) and *Sphaeroidinella dehiscens subdehiscens* Blow, subsp. nov.

Sphaeroidinella dehiscens dehiscens (Parker and Jones)

Sphaeroidina bulloides d'Orbigny var. *dehiscens* Parker and Jones, 1865, Roy. Soc. London, Phil. Trans., vol. 155, p. 369, pl. 19, figs. 5a-c (*vide* Ellis and Messina 1940 *et seq.*).

Remarks:—In *Sphaeroidinella dehiscens dehiscens* the test is large with the chambers much embracing and with little external trace of the sutures between the penultimate and earlier chambers. The apertures are deep-set, elongate, with very strongly crenulate margins. Furthermore, in typical specimens of this form a distinct and well-marked supplementary aperture occurs in addition to the primary umbilical aperture.

Sphaeroidinella dehiscens subdehiscens Blow, subsp. nov.

Pl. 12, figs. 71a-c, 72

Sphaeroidinella rutschi Cushman and Renz, Renz, 1948. (*pars*), Geol. Soc. Amer., Mem. 32, p. 167, pl. X, fig. 1c (refigured paratype), *non* figs. 1a-1b (refigured holotype).

Sphaeroidinella dehiscens Stainforth (*non* Parker and Jones), 1948, Jour. Pal., vol. 22, No. 2, p. 124, pl. 26, fig. 20.

Sphaeroidinella dehiscens Weiss, (*non* Parker and Jones), 1955, Micropalaeontology, vol. 1, p. 313, pl. 3, figs. 28-29.

Sphaeroidinella rutschi Cushman and Renz, Bolli, 1957, U. S. Nat. Mus., Bull., No. 215, p. 115, pl. 26, figs. 6a-7b.

Diagnosis of subspecies:—Test low trochospiral with three, seldom with three and one half, chambers in the last whorl; chambers, in general, rather embracing, sutures not depressed but usually fairly distinct, especially the suture between the last and earlier chambers; equatorial periphery slightly lobate with the test appearing ovate in equatorial profile; axial periphery rounded; umbilicus small or closed; aperture interior marginal, umbilical, an elongate slit or low arch, often with thickened and crenulate margins composed essentially of a thickening of the outer cortex; wall calcareous, thick, composed of an outer cortex and a thick inner part which is radial in structure; inner part coarsely perforate, outer part smooth and glassy in reflected light; maximum diameter of holotype, 0.50 mm.

Remarks:—This subspecies is distinguished from *Sphaeroidinella dehiscens dehiscens* (Parker and Jones) by its less embracing chambers, more distinctive sutures, less deeply set aperture, absence of supplementary apertures, a slightly more lobate equa-

torial periphery and a generally smaller overall test size. It is interesting to observe that C. D. Redmond (in Stainforth, 1948b, p. 124) recorded this form from the Miocene of Colombia, but did not regard it as typical *Sphaeroidinella dehiscens dehiscens*.

Recently, the writer observed this subspecies in Sicily where, in the uppermost Miocene/basal Pliocene, transitional forms to *Sphaeroidinella dehiscens dehiscens* occur. Transitional forms from *Sphaeroidinella seminulina seminulina* (Schwager) (Pl. 12, fig. 73) occur in the uppermost part of the *Globorotalia fohsi robusta* Zone both in Trinidad and eastern Falcón.

Holotype:—From sample, No. RM 19514, auger line near Pozón, eastern Falcon; Plate 12, figures 71a-c, deposited in U.S.N.M. collection No. 625705.

Occurrence:—Ranges from the uppermost part of the *Globorotalia fohsi robusta* Zone to the *Globigerina bulloides* Zone, Pozón formation.

***Sphaeroidinella seminulina* (Schwager)**

The type illustrated by Schwager (1866, p. 256, pl. 7, fig. 112, *vide* Ellis and Messina, 1940, *et seq.*) shows a form with the last chamber distinctly smaller than the penultimate and third chambers combined whereas in *Sphaeroidinella dehiscens subdehiscens* Blow, subsp. nov. the last chamber is approximately equal to the penultimate and third chambers combined. The aperture of Schwager's type is almost symmetrically placed with respect to the suture between the penultimate and third chamber, restricted to the umbilical region, not greatly elongated and without distinctly crenulate margins. It is possible, judging from Schwager's illustration, that the aperture of his form is lipped whilst the sutures seem to be fairly well marked.

Some apparently primitive forms have been observed from the *Globigerinatella insueta* Zone (*s.l.*) (Pl. 12, figs. 74, 75) which appear close indeed to Schwager's type. The features of importance, separating these primitive forms from *Sphaeroidinella dehiscens subdehiscens*, seem to be the rather open and less narrow aperture, absence of distinct crenulate margins and the less embracing chambers.

Further, the aperture in Schwager's type is more nearly restricted to the umbilical area and is not an elongate, rather slitlike opening extending greatly along the suture between the last and earlier chambers as it is in *Sphaeroidinella dehiscens subdehiscens*.

The *Sphaeroidinella seminulina-Sphaeroidinella dehiscens* group is complex and still requires further work, but at present the writer feels justified in recognizing two subspecies of *Sphaeroidinella seminulina* although further subdivision of this species may prove to be necessary.

***Sphaeroidinella seminulina seminulina* (Schwager)**

Pl. 12, figs. 74, 75, 76, 77a-c

Globigerina seminulina Schwager, 1866, Geol. Theil, Bd. 2, Abt. 2, p. 256, pl. 7, fig. 112 (*vide* Ellis and Messina, 1940 *ct. seq.*).

Globigerina seminulina Schwager, LeRoy, 1941, Colorado School Mines, Quart., vol. 36, No. 1, pt. 1, p. 44, pl. 3, fig. 108.

Sphaeroidinella grimsdali (Keijzer), Bolli, 1957 (*pars*), U.S. Nat. Mus., Bull., No. 215, p. 114, pl. 26, figs. 8-11, *non* figs. 12a-c.

Remarks:—Within the plexus now assigned to this subspecies two generalized groupings can be distinguished. The first "group" is centered around forms similar to that illustrated in figure 75, Plate 12, with forms similar to those illustrated in figures 74 and 76, Plate 12 forming the extremes of variation. The second "group" is centered around forms similar to that illustrated in figures 77a-c but also shows gradation to *Sphaeroidinella seminulina kochi* (Caudri).

In the *Globigerinatella insueta* Zone (*s.l.*) and in the *Globorotalia fohsi barisanensis* Zone the first "group" predominates but does continue to the *Sphaeroidinella seminulina* Zone. Above the *Globorotalia fohsi barisanensis* Zone the second "group" predominates and in the basal part of the *Globorotalia fohsi lobata* Zone forms transitional to *Sphaeroidinella seminulina kochi* appear. Whilst *Sphaeroidinella seminulina kochi* can be considered as quite distinctive with a markedly different stratigraphical range, the two "groups" of *Sphaeroidinella seminulina seminulina* recognized here seem to form a closely interwoven evolving plexus, and the writer does not feel fully justified in making any further taxonomic subdivision. However the second "group" (figures 77a-c, Pl. 12) is

similar to LeRoy's *Sphaeroidinella multiloba* (LeRoy, 1944, pt. 2, p. 91, pl. 4, figs. 7-9) and further work may allow recognition of LeRoy's type as a distinct subspecies of *Sphaeroidinella seminulina* (Schwager). In this connection it is useful to point out that LeRoy (1944, p. 91) stated that his type might "represent a more matured phase of *Globigerina seminulina* Schwager". Bolli (1957, p. 114) pointed out that during the course of evolution the tests of this species tend to become larger and the last whorl may consist of three or four chambers. However, the forms mentioned by Bolli as having five or six chambers are now referred to *Sphaeroidinella seminulina kochi*. In addition to the trends noted by Bolli, there seems to be a further trend wherein the chambers become more inflated and better separated whilst the coiling becomes more lax. It is emphasized, however, that both "groups" are present in sediments above the *Globorotalia fohsi barisanensis* Zone and that *Sphaeroidinella dehiscens subdehiscens* Blow, subsp. nov. appears to develop from the first "group" in the uppermost part of the *Globorotalia fohsi robusta* Zone. Figure 73, Plate 12, illustrates a form which appears to be transitional between the two forms.

Hypotype:—From sample, No. RM 19820, auger line near Pozón, eastern Falcón; Plate 12, figures 77a-c, deposited in U.S.N.M. collection, No. 625727. (Other illustrated specimens also deposited in U.S.N.M.)

Occurrence:—Ranges from the upper part of the *Globigerina-tella insueta*/*Globigerinoides triloba* Subzone to the top of the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

***Sphaeroidinella seminulina kochi* (Caudri)**

Pl. 12, figs. 78, 79

Globigerina sp. Koch, 1923, Bericht. Schweiz. Pal. Ges., vol. 18, p. 355, text-figs. 8a-b (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerina kochi Caudri, 1934, "Tertiary deposits of Soemba", p. 144. (*vide* Ellis and Messina, 1940 *et seq.*).

Sphaeroidinella kochi (Caudri), Glaessner, 1943, Roy. Soc. Victoria, Proc., vol. 55 (new ser.), pt. 1, p. 69 (list).

Sphaeroidinella grimsdali (Keijzer), Bolli, 1957 (*pars*), U.S. Nat. Mus. Bull. 215, p. 114, pl. 26, figs. 12a-c, *non* figs. 8-11.

Remarks:—This subspecies is distinguished from *Sphaeroidinella seminulina seminulina* (Schwager) by having five or six

(occasionally seven) chambers in the last whorl, a more open umbilicus, a fairly strongly arched aperture and well-separated chambers which tend to be distinctly elongated radially. The test wall in this subspecies tends to be less thick but appears to be composed of the three layers discussed previously.

Hypotype:—From sample, No. RM 19507, auger line near Pozón, eastern Falcón; Plate 12, figure 79, deposited in U.S.N.M. collection, No. 625729. Figure 78, deposited in U.S.N.M. collection, No. 626046.

Occurrence:—Ranges from the lower part of the *Globorotalia foysi lobata* Zone to the upper part of the *Sphaeroidinella seminulina* Zone, Pozón formation.

Subfamily ORBULININAE

Genus BIORBULINA Blow, 1956

In this genus the penultimate (not the ultimate) chamber embraces the earlier part of the test whilst at least some of the apertures are areal.

Biorbulina bilobata (d'Orbigny)

Pl. 13, figs. 80, 81

Globigerina bilobata d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 164, pl. 9, figs. 11-14, (*vide* Ellis and Messina, 1940 *et seq.*).

Biorbulina bilobata (d'Orbigny), Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 69, text-fig. 2, no. 16.

Hypotype:—From sample, No. RM 19304, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626047. (Figures 80, 81, Plate 13, reproduced from Blow, 1956, text-fig. 2, No. 16, and text-fig. 3, respectively).

Occurrence:—Ranges from the upper part of the *Globigerinata* *insueta*/*Globigerinoides bispherica* Subzone to the *Globigerina bulloides* Zone, Pozón formation.

Genus ORBULINA d'Orbigny, 1839

Blow (1956) emended the original diagnosis of *Orbulina* to include only those forms in which the last chamber either completely or almost completely embraces the earlier part of the test and where, at least, some of the apertural pores are areal in position.

Orbulina suturalis Bronnimann

Pl. 13, figs. 82a-b

Orbulina suturalis Bronnimann, 1951 (*pars*), Cushman Found. Foram. Res., Contr., vol. 2, pt. 4, p. 135, text-fig. 2, Nos. 1-2, 5-8, 10; text-fig. 3, nos. 3-8, 11, 13-16, 18, 20-22; text-fig. 4, Nos. 2-4, 7-12, 15-16, 19-22.

Orbulina suturalis Bronnimann, Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 66, text-fig. 2, Nos. 5-7.

Orbulina suturalis Bronnimann, Bolli, 1957, U. S. Nat. Mus., Bull., No. 215, p. 115, pl. 27, fig. 4.

Remarks:—The last chamber does not quite completely envelop all the earlier chambers and some of the apertural pores may still be in the sutural positions.

Hypotype:—From sample, No. RM 19304, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626048. (Figures 82a-b, Plate 13, reproduced from Blow, 1956, text-fig. 2, Nos. 6-7.)

Occurrence:—Ranges from the uppermost part of the *Globiginatella insueta*/*Globigerinoides bispherica* Subzone to the *Globigerina bulloides* Zone, Pozón formation.

Orbulina uniuersa d'Orbigny

Pl. 13, fig. 83

Orbulina uniuersa d'Orbigny, 1839, "Foraminifères", in de la Sagra Histoire physique, politique et naturelle de l'île de Cuba, p. 2, pl. 1, fig. 1 (*vide* Ellis and Messina, 1940 *et seq.*).

Orbulina uniuersa d'Orbigny, Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 66, text-fig. 2, Nos. 8-9.

Remarks:—In this species the last chamber completely envelops the earlier part of the test. The apertures are distributed irregularly over the area of the last chamber, but in some advanced forms the apertural pores seem to be absent and the minute perforations then appear to take over the functions of the apertural pores.

Hypotype:—From sample, No. RM 19304, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626049. (Figure 83, Plate 13, reproduced from Blow, 1956, text-fig. 2, No. 9.)

Occurrence:—Ranges from the uppermost part of the *Globiginatella insueta*/*Globigerinoides bispherica* Subzone to the *Globigerina bulloides* Zone, Pozón formation.

Genus **PORTICULASPHAERA** Bolli, Loeblich, and Tappan, 1957

The type species of this genus is the short-lived middle Eocene

form *Globigerina mexicana* Cushman but the generic definition given by Bolli, Loeblich, and Tappan (1957) also seems to fit the species previously described by the writer (Blow, 1956) as *Globigerinoides glomerosa* and *Globigerinoides transitoria*. These species are short-lived Miocene forms and there is no genetic relationship with the middle Eocene *Porticulasphaera mexicana* (Cushman). Bolli (1957, p. 115) remarked that it may be expected that further comparative studies will reveal morphological differences which may allow the distinction of the species named by the writer as a separate genus. In this connection the validity of *Candorbulina* Jedlitschka, 1934 needs further investigation.

The writer agrees with Bolli (1957) that "*glomerosa*" and "*transitoria*" should be removed from the genus *Globigerinoides* Cushman, 1927, since they do not have a distinct primary umbilical aperture or open umbilicus in the adult. Further, these species cannot be included in the genera *Orbulina* d'Orbigny, 1839 or *Biorbulina* Blow, 1956 since none of the apertures are areal in position but are all confined to the sutures.

The forms described below are considered ancestral to *Orbulina* and *Biorbulina* and reference is made to Blow (1956) for description of species and subspecies as well as a discussion of evolutionary trends.

Porticulasphaera glomerosa (Blow)

***Porticulasphaera glomerosa curva* (Blow)** Pl. 13, figs. 84a-b

Globigerinoides glomerosa curva Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 64, text-fig. 1, Nos. 9-14.

Porticulasphaera glomerosa curva (Blow), Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 115, pl. 27, fig. 7.

Remarks:—This subspecies shows the last chamber embracing between 40 and 70 percent of the earlier test and with four to eight slitlike apertures present in the suture between the last and earlier chambers.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626050. (Figures 84a-b, Plate 13, holotype, reproduced from Blow, 1956, text-fig. 1, Nos. 10, 11.)

Occurrence:—Ranges from the middle part of the *Globigerin-*

atella insueta/*Globigerinoides bispherica* Subzone to the basal part of the *Globorotalia fohsi barisanensis* Zone, Pozón formation.

Porticulasphaera glomerosa glomerosa (Blow) Pl. 14, figs. 85a-b

Globigerinoides glomerosa glomerosa Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 65, text-fig. 1, Nos. 15-19; text-fig. 2, Nos. 1-2.

Porticulasphaera glomerosa glomerosa (Blow), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 115, pl. 27, fig. 8.

Remarks:—This subspecies shows the last chamber embracing more than 75 percent of the earlier test and with numerous slitlike (not rounded) apertures in the suture between the last and earlier chambers.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626051. (Figures 85a-b, Plate 14, holotype, reproduced from Blow, 1956, text-fig. 1, Nos. 18-19.)

Occurrence:—Ranges from the upper part of the *Globigerinata* *atella insueta*/*Globigerinoides bispherica* Subzone to the basal part of the *Globorotalia fohsi barisanensis* Zone, Pozón formation.

Porticulasphaera glomerosa circularis (Blow) Pl. 14, figs. 86a-b

Globigerinoides glomerosa circularis Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 65, text-fig. 2, Nos. 3, 4.

Porticulasphaera glomerosa circularis (Blow), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 115, pl. 27, fig. 2.

Remarks:—This form differs from *Orbulina suturalis* Bronnmann in that all the apertural pores are confined to the sutural positions.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626052. (Figures 86a-b, Plate 14, holotype, reproduced from Blow, 1956, text-fig. 2, Nos. 3, 4.)

Occurrence:—Ranges from the upper part of the *Globigerinata* *tella insueta*/*Globigerinoides bispherica* Subzone to the middle part of the *Globorotalia fohsi barisanensis* Zone, Pozón formation.

Porticulasphaera transitoria (Blow) Pl. 14, figs. 87a-b

Globigerinoides transitoria Blow, 1956, Micropaleontology, vol. 2, No. 1, p. 65, text-fig. 2, Nos. 12-15.

Porticulasphaera transitoria (Blow), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 115, pl. 27, fig. 3.

Remarks:—This species differs from *Porticulasphaera glomerosa* (Blow) in that it is the penultimate chamber which embraces the earlier test and not the ultimate chamber as in *Porticulasphaera glomerosa*. The apertures are short discrete slits confined to the sutural positions.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626053. (Figures 87a-b, Plate 14, holotype, reproduced from Blow, 1956, text-fig. 2, Nos. 12, 13.)

Occurrence:—Ranges from the middle to the upper part of the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, Pozón formation.

Subfamily CATAPSYDRACINAE

Genus **CATAPSYDRAX** Bolli, Loeblich, and Tappan, 1957

This genus shows a characteristic bulla which covers the primary aperture and the umbilical part of the test. The infralaminar apertures are large and unrestricted, but sometimes have thin lips or thickened margins.

Catapsydrax dissimilis (Cushman and Bermudez) Pl. 12, figs. 88a-c, 89, 90

Globigerina dissimilis Cushman and Bermudez, 1937, Cushman Lab. Foram. Res., Contr., vol. 13, pt. 1, p. 25, pl. 3, figs. 4-6 (*vide* Ellis and Messina, 1940 *et seq.*).

Catapsydrax dissimilis (Cushman and Bermudez), Bolli, Loeblich, and Tappan, 1957, U.S. Nat. Mus., Bull. No. 215, p. 36, pl. 7, figs. 6-8.

Catapsydrax dissimilis (Cushman and Bermudez), Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 116.

Remarks:—This species shows a bulla of variable size, normally with three infralaminar apertures. One such aperture occurs at one end of the bulla, the two others at the other end; the margins surrounding these infralaminar apertures are normally thickened. The chambers are generally inflated.

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; Plate 12, figures 88a-c, deposited in U.S.N.M. collection, No. 626054. Other figured specimens also deposited in U.S. National Museum.

Occurrence:—Ranges from the base of the Pozón-El Mene

Road section to the top of the *Catapsydrax stainforthi* Zone, To-cuyo formation.

Catapsydrax stainforthi Bolli, Loeblich, and Tappan

Pl. 14, figs. 91a-c, 92, 93

Catapsydrax stainforthi Bolli, Loeblich, and Tappan, 1957, U.S. Nat. Mus., Bull. No. 215, p. 37, pl. 7, figs. 11a-c.

Catapsydrax stainforthi Bolli, Loeblich, and Tappan, Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 116.

Remarks:—This species typically shows four moderately inflated chambers in the last whorl; the bulla then has four infralaminar apertures supported on tubelike extensions of the bulla along the sutural depressions between the primary chambers. The infralaminar apertures have small but distinctive lips. Occasionally five primary chambers occur in the last whorl; in these cases (figure 93, Plate 14), the bulla shows a corresponding number of infralaminar apertures.

Hypotype:—From sample, No. RM 19152, auger line near Pozón, eastern Falcón; Plate 14, figures 91a-c, deposited in U.S.N.M. collection, No. 626056. Other figured specimens deposited in U.S. National Museum.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) almost to the top of the *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, To-cuyo formation.

Catapsydrax unicavus Bolli, Loeblich, and Tappan Pl. 15, figs. 94a-c

Catapsydrax unicavus Bolli, Loeblich, and Tappan, 1957, U.S. Nat. Mus., Bull. No. 215, p. 37, pl. 7, figs. 9a-c.

Catapsydrax unicavus Bolli, Loeblich, and Tappan, Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 116.

Remarks:—This species shows a single infralaminar aperture, the peripheral part of the bulla being closed. The chambers are depressed and rather more embracing than in *Catapsydrax dissimilis* (Cushman and Bermudez).

Hypotype:—From sample, No. RM 19117, auger line near Pozón, eastern Falcón; Plate 15, figures 94a-c, deposited in U.S.N.M. collection, No. 626058.

Occurrence:—Ranges from the base of the Pozón-El Mene

Road section to the top of the *Catapsydrax stainforthi* Zone, Tucuyo formation.

Genus **GLOBIGERINATELLA** Cushman and Stainforth, 1945

Globigerinatella insueta Cushman and Stainforth

Pl. 15, figs. 95, 96, 97, 98

Globigerinatella insueta Cushman and Stainforth, 1945, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 69, pl. 13, figs. 7-9.

Globigerinatella insueta Cushman and Stainforth, Bronnimann, 1950, Cushman Found. Foram. Res., Contr., vol. 1, pts. 3-4, pp. 80-82, pl. 13, figs. 1-12; pl. 14, figs. 1-13.

Remarks:—Reference is made to the remarks regarding the possible origin of this monotypic genus and to Bronnimann (1950) who has discussed the morphology of this species in detail.

In addition to the morphological types described by Bronnimann (1950), some specimens of this form show what appears to be a large "primary bulla" which has areal and/or infralaminar apertures; these in turn may be covered by "pustule-like" or "collar-like" secondary bullae.

Figure 97, Plate 15, illustrates a form with uncovered areal apertures in the primary bulla but also having "secondary bullae" covering the infralaminar apertures along the contact suture of the "primary bulla" and the true primary chambers. Figure 98 illustrates a form with "areal pustules" ("secondary bullae") covering the areal apertures of the large primary bulla. This form also has "collar-like" secondary bullae covering the infralaminar apertures of the primary bullae; these collar-like secondary bullae also extend along the sutures of the true primary chambers.

It is not always readily apparent whether or not the "final chamber" should be considered as a bulla or a true primary chamber since areal apertures also occur in the primary chambers of earlier ontogenetic stages (see figure 96, Plate 15; also Bronnimann, 1950); but the wall structure of the "final chamber" in some specimens suggest that they are, in fact, large and much inflated bullae.

Hypotype:—From sample, No. RM 19188, auger line near Pozón, eastern Falcón; Plate 15, figure 98, deposited in U.S.N.M. collection, No. 626059. Figure 95, Plate 15, from sample, No. RM

19117, also deposited in U.S.N.M. collection, No. 626061.

Occurrence:—Ranges from the base of the *Catapsydrax stainforthi* Zone to the top of the *Globigerinatella insucta*/*Globigerinoides bispherica* Subzone, Tocuyo and Pozón formations.

Genus **GLOBIGERINITA** Bronnimann, 1951

Globigerinita naparimaensis Bronnimann

Globigerinita naparimaensis naparimaensis Bronnimann Pl. 15, figs. 99a-c

Globigerinita naparimaensis Bronnimann, 1951, Cushman Found. Foram. Res., Contr., vol. II, pt. 1, p. 18, text-figs. 1-14.

Remarks:—*Globigerinita naparimaensis naparimaensis* is distinguished from *Globigerinita naparimaensis incrusta* (Akers) by its possession of infralaminar apertures along the contact suture of the bulla with the primary chambers as well as its having infralaminar apertures in line with the sutures of the primary chambers. The bulla of this subspecies is more inflated and often embraces more of the primary chambers than in *Globigerinita naparimaensis incrusta*.

Hypotype:—From sample. No. RM 19304, auger line near Pozón, eastern Falcón; Plate 15, figures 99a-c, deposited in U.S.N.M. collection, No. 626062.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the top of the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

Globigerinita naparimaensis incrusta (Akers) Pl. 15, figs. 100, 101

Globigerinita incrusta, Akers, 1955, Jour. Pal., vol. 29, No. 4, p. 655, pl. 65, figs. 2a-2d.

Remarks:—Aker's species is regarded as being closely related to *Globigerinita naparimaensis* Bronnimann, and since there appears to be complete gradation between the two forms, it is considered that Aker's type is best placed as a subspecies of *Globigerinita naparimaensis*.

During the examination of the samples from the Pozón-El Mene Road section it was found that samples from a particular but fairly short interval often had a predominance of either *Globigerinita naparimaensis naparimaensis* or *Globigerinita naparimaen-*

sis incrusta with a corresponding reduction in the prevalence of the other subspecies. This relative abundance is then often reversed in succeeding or preceding intervals. Furthermore, some intervals show forms apparently transitional from *Globigerina juvenilis* Bolli to *Globigerinita naparimaensis incrusta* but in other intervals these transitional forms are either absent or scarce. From these observations it may be considered that a repetitive and heterochronous derivation of *Globigerinita* seems likely (see Text-fig. 4).

Globigerinita naparimaensis incrusta is distinguished from *Globigerinita naparimaensis naparimaensis* by the absence of infralaminar apertures not in line with the sutures of the primary chambers, a less inflated and embracing bulla which sometimes shows short tubelike extensions along the sutures of the primary chambers. This subspecies has a generally smaller overall test size.

Figure 101, Plate 15, illustrates a form which appears transitional to *Globigerina juvenilis* where it seems that the apertural lip of this latter species has become attached to the ventral surface of the opposing chamber. It seems that the distinction between *Globigerinita* and *Globigerina juvenilis* is best made where the "apertural lip" shows definite attachment to the opposing chamber and the ends of the bulla so-formed are restricted.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate No., figure 100, deposited in U.S.N.M. collection, No. 625723. (Figure 101, Plate 15, from same sample, also deposited in U.S.N.M. collection.)

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the lower part of the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

Genus **GLOBIGERINOITA** Bronnimann, 1952

Globigerinoita morugaensis Bronnimann Pl. 15, figs. 102a-c

Globigerinoita morugaensis Bronnimann, 1952, Cushman Found. Foram. Res., Contr., vol. III, pt. 1, p. 26, text-fig. 1, figs. a-m; text-fig. 2, figs. a-h.

Globigerinoita morugaensis Bronnimann, Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 116.

Hypotype:—From sample, No. RM 19697, auger line near Pozón, eastern Falcón; Plate 15, figures 102a-c, deposited in U.S.N.M. collection, No. 626064.

Occurrence:—Ranges from the middle part of the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone to the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Genus **GLOBOROTALOIDES** Bolli, 1957

This genus shows a *Globorotalia*-like early stage which is followed by a *Globigerina*-like intermediate stage and a final *Catapsydrax*-like stage wherein a bulla-like chamber partly or completely covers the umbilical part of the earlier test. It appears that the intermediate stage may be omitted in some cases and the early *Globorotalia*-like stage is followed immediately by the stage with the bulla-like final chamber.

Globorotaloides variabilis Bolli Pl. 16, figs. 103 a-c, 104, 105

Globorotaloides variabilis Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 117, pl. 27, figs. 15a-20c.

Remarks:—The specimens illustrated in figures 104 and 105, Plate 16, and showing the *Globigerina*-like and *Globorotalia*-like stages respectively, were dissected (Blow, 1955) from forms similar to that illustrated in figures 103a-c, Plate 16, and possessing a bulla-like final chamber.

Hypotype:—From sample, No. RM 19697, auger line near Pozón, eastern Falcón; Plate 16, figures 103a-c, deposited in U.S.N.M. collection, No. 626066. (Figures 104, 105, Plate 16, also deposited in U.S.N.M. collection.)

Occurrence:—Typical specimens range from the middle part the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone to the middle part of the *Sphaeroidinella seminulina* Zone, Pozón formation. Occasional immature and poorly preserved forms occur in the *Catapsydrax stainforthi* Zone and in the *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, which are only tentatively referred to this species but which may possibly be referable to *Globorotaloides suteri* Bolli.

Family **GLOBOROTALIIDAE**

Subfamily **GLOBOROTALIINAE**

Genus **GLOBOROTALIA** Cushman, 1927

Globorotalia acostaensis Blow, sp. nov. Pl. 17, figs. 106a-c, 107

?*Globigerina dutertrei* Wiseman and Ovey (*non* d'Orbigny), 1950, Geol. Assoc., Proc., vol. 61, p. 65, pl. 2, figs. 1a-c.

Diagnosis of species:—Test low trochospiral; spire opening regularly but fairly rapidly, with 11-13 chambers composing the spire, usually with 5-6 chambers in the last whorl. Equatorial periphery strongly lobate, with the test appearing subcircular in equatorial profile; axial periphery rounded with the test appearing thick and parallel-sided in side view; chambers ovate or subspherical, generally inflated but not well separated; often the last chamber is much reduced in size compared with its predecessor, and it also occasionally becomes somewhat displaced towards the umbilical side (fig. 107, Pl. 17). Spiral side slightly convex, almost flat, or occasionally slightly concave due to the inflated nature of the chambers of the last whorl. Umbilical side generally slightly convex, with a small but usually deep umbilicus; sutures of the spiral and umbilical sides radial, depressed; aperture interiomarginal, umbilical-extraumbilical, arched, with a distinctive lip. Maximum diameter of holotype, 0.36 mm.

Remarks:—This form differs from *Globorotalia mayeri* Cushman and Ellisor in having more inflated chambers, a thicker test, completely radial sutures, a more distinctive apertural lip, and a more rapidly opening spire. It differs from *Globorotalia opima continua* Blow, subsp. nov. in having more numerous and more inflated chambers in the last whorl, although transitional forms occur in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone (lower part). It differs from *Globigerina dutertrei* d'Orbigny in having less globular and less well-separated chambers. The aperture of *Globigerina dutertrei* appears to be umbilical only in D'Orbigny's figures. The specimen figured by Wiseman and Ovey as *Globigerina dutertrei* (1950, pl. 2, figs. 1a-c) shows an interiomarginal, umbilical-extraumbilical aperture with a distinct lip, and the writer believes this specimen to be identical with *Globorotalia acostaensis*.

Globorotalia acostaensis first appears after the extinction of *Globorotalia mayeri*.

Holotype:—From sample, No. RM 19791, auger line near Pozón, eastern Falcón; Plate 17, figures 106 a-c, deposited in U.S.N.M. collection, 625707.

Occurrence:—Ranges from the *Globorotalia menardii men-*

ardii/*Globigerina nepenthes* Zone to the *Globigerina bulloides* Zone, Pozón formation.

Globorotalia birnageae Blow, sp. nov.

Pl. 17, figs. 108a-c

Diagnosis of species:—Test low trochospiral; spire opening regularly but fairly slowly, with usually six chambers in the last whorl; equatorial profile almost circular; equatorial periphery slightly lobate; axial periphery rounded, with the test appearing rather parallel-sided in side view; chambers slightly elongated tangentially as viewed from the spiral side, not inflated, but usually embracing; last chamber often smaller than its predecessor; spiral side flat to slightly convex; umbilical side slightly convex; sutures of the spiral side curved, slightly depressed; sutures of the umbilical side radial, slightly depressed, sometimes rather indistinct; umbilicus, small, often completely closed; aperture slitlike with a distinctive lip, interiomarginal, umbilical-extraumbilical; wall calcareous, finely perforate; maximum diameter of holotype, 0.22 mm.

Remarks:—This species differs from *Globorotalia kugleri* Bolli in having less deeply incised sutures, rather tangentially elongated chambers, a closed or almost closed umbilicus, fewer chambers in the last whorl, and a less highly arched aperture which has a more distinctive lip. It differs from *Goborotalia mayeri* Cushman and Ellis in being consistently much smaller in size, in the closed (or almost closed) umbilicus, and also in having slightly more tangentially elongated chambers as seen from the spiral side. It differs from *Globorotalia opima continuosa* Blow, subsp. nov. in having more chambers in the last whorl. It also differs from *Globorotalia fohsi barisanensis* (LeRoy) in having a more circular outline and a less convex (not vaulted) umbilical side.

The species is named after Miss G. N. Birnage, Librarian of the Palaeontological Department, The British Petroleum Company Limited, London, in recognition of her assistance in compiling this work.

Holotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 17, figures 108a-c, deposited in U.S.N.M. collection, No. 625709.

Occurrence;—Ranges from the uppermost part of the *Globigerinatella insueta*/*Globigerinoides triloba* Subzone to the basal part of the *Globorotalia fohsi barisanensis* Zone, Tocuyo and Pozón formations.

Globorotalia* cf. *canariensis (d'Orbigny)

Pl. 17, figs. 109a-c

cf. *Rotalina canariensis* d'Orbigny, 1839, Foraminifères des îles Canaries, in Barker-Webb and Berthelot, Hist. nat. des îles Canaries, vol. 2, pt. 2, (Zool.), p. 130, pl. 1, figs. 34-36. (Fide Ellis and Messina, 1940 *et seq.*).

Remarks:—In the upper part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone some forms which otherwise closely resemble *Globorotalia scitula scitula* (Brady) develop thin but distinctive keels. These forms are tentatively referred to D'Orbigny's species, which is described as being depressed and carinate throughout. Concomitant with the development of the keel, the test appears to become rather more depressed than in typical *Globorotalia scitula scitula*. However, the writer's specimens are small compared with Recent specimens of *Globorotalia canariensis* (d'Orbigny) and are generally less lobate. No forms referable to the species described by D'Orbigny have been observed by the writer below the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, and it is possible that the writer's specimens may represent early forms of typical *Globorotalia canariensis*. Maximum diameter observed, 0.27 mm.

Hypotype:—From sample, No. RM 19804, auger line near Pozón, eastern Falcón; Plate 17, figures 109a-c, deposited in U.S.N.M. collection, No. 626068.

Occurrence:—Scarce and only observed from the uppermost part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone to the *Globigerina bulloides* Zone, Pozón formation.

Globorotalia fohsi Cushman and Ellis

Reference is made to the work of Bolli (1950) for a description of the subspecies and also for a complete discussion of the evolutionary inter-relationship between the various subspecies.

Globorotalia fohsi barisanensis (LeRoy)

Pl. 17, figs. 110, 111a-c

Globorotalia barisanensis LeRoy, 1939, *Natuurk. Tijdschr. Nederl. Indië*, vol. 99, pt. 6, p. 265, pl. 1, figs. 8-10 (*vide* Ellis and Messina, 1940 *et seq.*).

Globorotalia fohsi barisanensis LeRoy, Bolli, 1950, *Cushman Found. Foram. Res., Contr.*, vol. 1, pts. 3 and 4, p. 88, pl. 15, figs. 6a-c.

Globorotalia fohsi barisanensis LeRoy, Bolli, 1957, *U. S. Nat. Mus., Bull. No. 215*, p. 119, pl. 28, figs. 8a-c.

Remarks:—Within the *Catapsydrax stainforthi* Zone and in the *Globigerinatella insueta* Zone (*s.l.*) this subspecies shows a generally lobate equatorial periphery, and has fairly deeply incised sutures on the spiral side (Pl. 17, fig. 110). In the *Globorotalia fohsi barisanensis* Zone it has a less lobate periphery, less deeply incised sutures, and a more definitely vaulted umbilical side.

Hypotype:—From sample, No. RM 19304, auger line near Pozón, eastern Falcón; Plate 17, figures 111a-c, deposited in U.S.N.M. collection, No. 626069. Figure 110, Plate 17 from sample No. RM 19188, also deposited in U.S.N.M. collection, No. 626071.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the basal part of the *Globorotalia fohsi fohsi* Zone, Tocuyo and Pozón formations.

Globorotalia fohsi fohsi Cushman and Ellisor

Pl. 17, figs. 112a-c

Globorotalia fohsi Cushman and Ellisor, 1939, *Cushman Lab. Foram. Res., Contr.*, vol. 15, p. 12, pl. 2, figs. 6a-c (*vide* Ellis and Messina, 1940 *et seq.*).

Globorotalia fohsi Cushman and Ellisor, Renz, 1948, *Geol. Soc. Amer., Mem.* 32, p. 137, pl. XI, figs. 2a-c.

Globorotalia fohsi fohsi Cushman and Ellisor, Bolli, 1950, *Cushman Found. Foram. Res., Contr.*, vol. 1, pts. 3 and 4, p. 88, pl. 15, figs. 4a-c.

Globorotalia fohsi fohsi Cushman and Ellisor, Bolli, 1957, *U.S. Nat. Mus., Bull. No. 215*, p. 119, pl. 28, figs. 9a-10c.

Remarks:—This subspecies shows an acute but not keeled peripheral margin, although some peripheral thickening may occur; the umbilical side is vaulted, and the sutures of the spiral side are not incised.

Hypotype:—From sample, No. RM 19367, auger line near Pozón, eastern Falcón; Plate 17, figures 112a-c, deposited in U.S.N.M. collection, No. 626072.

Occurrence:—Ranges from the base of the *Globorotalia fohsi*

fohsi Zone to the basal part of the *Globorotalia fohsi lobata* Zone, Pozón formation.

Globorotalia fohsi lobata (Bermudez)

Pl. 16, figs. 113a-c

Globorotalia lobata Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 286, pl. 22, figs. 9-11.

Globorotalia fohsi lobata Bermudez, Bolli, 1950, Cushman Found. Foram. Res., Contr., vol. 1, pts. 3 and 4, p. 88, pl. 15, figs. 7-8c.

Globorotalia fohsi lobata Bermudez, Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 119, pl. 28, figs. 13a-14b.

Remarks:—This subspecies shows a “cocks-comb” appearance of the last few chambers which typically also possess a fairly strong keel. Some peripheral thickening may also occur on the earlier chambers which, however, do not possess a keel.

Hypotype:—From sample, No. RM 19426, auger line near Pozón, eastern Falcón; Plate 16, figures 113a-c, deposited in U.S.N.M. collection, No. 626074.

Occurrence:—Ranges from the base of the *Globorotalia fohsi lobata* Zone to the basal part of the *Globorotalia fohsi robusta* Zone, Pozón formation.

Globorotalia fohsi robusta Bolli

Pl. 16, figs. 114a-c

Globorotalia fohsi robusta Bolli, 1950, Cushman Found. Foram. Res., Contr., vol. 1, pts. 3 and 4, p. 89, pl. 15, figs. 3a-c.

Globorotalia fohsi robusta Bolli, Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 119, pl. 28, figs. 16a-c.

Remarks:—This subspecies is carinate throughout, but the strength of the keel is variable; in some late forms the keel is massive with much secondary peripheral thickening.

Hypotype:—From sample, No. RM 19470, auger line near Pozón, eastern Falcón; Plate 16, figures 114a-c, deposited in U.S.N.M. collection, No. 626076.

Occurrence:—Restricted to the *Globorotalia fohsi robusta* Zone, Pozón formation.

Globorotalia linguaensis Bolli

Pl. 17, figs. 115a-c

Globorotalia linguaensis Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 120, pl. 29, figs 5a-c.

Remarks:—This species is distinguished from *Globorotalia minima* (Akers) by the less convex umbilical side and the more

circular equatorial profile; the spire opens less rapidly than in Akers' species. The aperture is longer in *Globorotalia linguaensis* and extends further towards the periphery than in *Globorotalia minima*. Some later forms of *Globorotalia linguaensis* show a faint keel. Maximum diameter of hypotype, 0.3 mm.

Hypotype:—From sample, No. RM 19507, auger line near Pozón, eastern Falcón; Plate 17, figures 115a-c, deposited in U.S.N.M. collection, No. 626078.

Occurrence:—Ranges from the uppermost part of the *Globorotalia fohsi robusta* Zone to the top of the *Sphaeroidinella seminudina* Zone, Pozón formation.

Globorotalia mayeri Cushman and Ellisor Pl. 18, figs. 116a-c

Globorotalia mayeri Cushman and Ellisor, 1939, Cushman Lab. Foram. Res., Contr., vol. 15, pt. 1, p. 11, pl. 2, figs. 4a-c (*vide* Ellis and Messina, 1940 *et seq.*).

Globorotalia mayeri Cushman and Ellisor, Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 118, pl. 28, figs. 4a-c.

Remarks:—*Globorotalia mayeri* Cushman and Ellisor differs from *Globorotalia acostaensis* Blow, sp. nov. in having slightly curved or sinuous sutures on the spiral side, less inflated and narrower chambers, as well as a thinner test.

Hypotype:—From sample, No. RM 19188, auger line near Pozón, eastern Falcón; Plate 18, figures 116a-c, deposited in U.S.N.M. collection, No. 626080.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the top of the *Globorotalia mayeri* Zone, Pozón formation.

Globorotalia menardii (d'Orbigny)

Globorotalia menardii archeomenardii (Bolli) Pl. 18, figs. 117a-c

Globorotalia archeomenardii Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 119, pl. 28, figs. 11a-c.

Remarks:—Bolli's type is here considered as a subspecies of *Globorotalia menardii* (d'Orbigny). It is distinguished from *Globorotalia menardii praemenardii* (Cushman and Stainforth) by the strongly convex spiral side and the rather angular rhomboidal shape of the chambers as seen in side view. In early forms of this subspecies from the *Globigerinatella insueta*/*Globigerinoides bis-*

pherica Subzone a keel seems to be present only on the last few chambers, although some peripheral thickening may be present on the earlier chambers. Also, in these early forms, the chambers are rather elongate tangentially and the writer considers it likely that this form developed from *Globorotalia scitula praescitula* Blow, subsp. nov. In the uppermost part of the *Globorotalia fohsi barisanensis* Zone, forms transitional to *Globorotalia menardii praemenardii* occur.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; Plate 18, figures 117a-c, deposited in U.S.N.M. collection, No. 626082.

Occurrence:—Ranges from the base of the *Globigerinatella insueta/Globigerinoides bispherica* Subzone to the basal part of the *Globorotalia fohsi fohsi* Zone, Tocuyo and Pozón formation.

***Globorotalia menardii praemenardii* (Cushman and Stainforth)**

Pl. 18, figs. 118a-c

Globorotalia praemenardii Cushman and Stainforth, 1945, Cushman Lab. Foram. Res., Spec. Pub. 14, p. 70, pl. 13, fig. 14.

Globorotalia praemenardii Cushman and Stainforth, Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 120, pl. 29, figs. 4a-c.

Remarks:—This form is distinguished from *Globorotalia menardii menardii* (d'Orbigny) by the absence of distinctly limbate and raised sutures on the spiral side and also by the more equally biconvex test. It is distinguished from *Globorotalia menardii archemenardii* (Bolli) by the more lobate equatorial periphery and the less convex spiral side. Forms transitional to *Globorotalia menardii menardii* (d'Orbigny) occur in the middle part of the *Globorotalia fohsi robusta* Zone.

Hypotype:—From sample, No. RM 19367, auger line near Pozón, eastern Falcón; Plate 18, figures 118a-c, deposited in U.S.N.M. collection, No. 626084.

Occurrence:—Ranges from the base of the *Globorotalia fohsi fohsi* Zone to the upper part of the *Globorotalia fohsi robusta* Zone, Pozón formation.

***Globorotalia menardii menardii* (d'Orbigny)** Pl. 18, figs. 119a-c, 120a-c

Rotalia ("Rotalie") *menardii* d'Orbigny, 1826, Ann. Sci. Nat., Paris, sér. 1, vol. 7, p. 273, Modèles No. 10 (*fide* Ellis and Messina, 1940 *et seq.*).

Globorotalia menardii (d'Orbigny), Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 120, pl. 29, figs. 6a-10b.

Remarks:—The form described by D'Orbigny in 1826 is here regarded as being the "central type" for a closely related series of forms which show gradual evolutionary changes. Although this subspecies shows a considerable variation in size, characters such as the distinctive keel, slightly convex spiral side and the only moderately convex umbilical side are common features. The writer distinguishes this subspecies from *Globorotalia menardii praemenardii* (Cushman and Stainforth) by the presence of a stronger keel and the distinctly limbate, often raised sutures on the spiral side.

Both the spiral and umbilical sides are less convex in this subspecies than in *Globorotalia menardii praemenardii*.

Hypotype:—From sample, No. RM 19507, auger line near Pozón, eastern Falcón; Plate 18, figures 120a-c, deposited in U.S.N.M. collection, No. 626086 Figures 119a-c, from sample, No. RM 19470, also deposited in U.S.N.M. collection, No. 626087.

Occurrence:—Ranges from the middle part of the *Globorotalia fohsi robusta* Zone to the top of the Pozón formation. It persists to the present time.

***Globorotalia menardii miocenica* Palmer**

Pl. 19, figs. 121a-c

Globorotalia menardii miocenica Palmer, 1945, Bull. Amer. Pal., vol. 29, No. 115, p. 70, pl. 1, fig. 10.

Remarks:—This subspecies differs from *Globorotalia menardii menardii* (d'Orbigny) in having a strongly vaulted umbilical side, an almost flat spiral side, a weaker keel, and less limbate sutures. The maximum and minimum diameters of the test are distinctly unequal so that the test of this form appears elongate in equatorial profile.

Hypotype:—From sample, No. RM 19791, auger line near Pozón, eastern Falcón; Plate 19, figures 121a-c, deposited in U.S.N.M. collection, No. 626088.

Occurrence:—Forms transitional from *Globorotalia menardii menardii* (d'Orbigny) occur in the uppermost part *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, but typical specimens

occur rarely only in the *Sphaeroidinella seminulina* Zone, Pozón formation.

Globorotalia minima (Akers)

Pl. 19, figs. 122a-c

Globorotalia canariensis (d'Orbigny) var. *minima* Akers, 1955, Jour. Pal., vol. 29, No. 4, p. 659, pl. 65, figs. 3a-3d.

Akers (1955) referred his variety to *Globorotalia canariensis* (d'Orbigny) but merely remarked that his variety differs from D'Orbigny's species in being smaller in size. Akers' figures show a form with a fairly vaulted umbilical side and a rounded to subacute, not keeled, periphery, whereas D'Orbigny's species has a depressed test with a well-marked keel. Examination of samples from eastern Falcón shows that Akers' variety should be considered as a distinct species. Since Akers did not give a description of his type, a description based on specimens from Pozón is given here. These Pozón specimens compare excellently with the figures given by Akers.

Description:—Test low trochospiral; spire opening rapidly, with usually six chambers in the last convolution. As seen from the spiral side the chambers are almost equally as broad as long with the exception of the last two chambers. The sutures of the spiral side are not much depressed and are moderately curved. The sutures of the umbilical side are slightly sinuous to almost radial. Equatorial periphery only slightly lobate; axial periphery rounded to subacute, not keeled; aperture interiomarginal, umbilical-extraumbilical, a low arch with a thin short lip; umbilicus small or closed; wall calcareous, finely perforate; maximum diameter of hypotype, 0.28 mm.

Remarks:—The size and morphology of the specimens from the Pozón-El Mene Road section compare excellently with Akers' figures. Akers gave 0.22 mm. as the maximum diameter of his holotype which is about the average for the specimens observed by the writer. This species may be ancestral to *Globorotalia linguaensis* Bolli.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; Plate 19, figures 122a-c, deposited in U.S.N.M. collection, No. 625725.

Occurrence:—Ranges from the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone to the *Globorotalia fohsi robusta* Zone, Pozón formation.

***Globorotalia minutissima* Bolli**

Pl. 19, figs. 123a-c

Globorotalia minutissima Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 119, pl. 29, figs. 1a-c.

Hypotype:—From sample, No. RM 19304, auger line near Pozón, eastern Falcón; Plate 19, figures 123a-c, deposited in U.S.N.M. collection, No. 626089.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the *Sphaeroidinella seminulina* Zone, Pozón formation.

***Globorotalia obesa* Bolli**

Pl. 19, figs. 124a-c

Globorotalia obesa Bolli, 1957, U.S. Nat. Mus., Bull., No. 215, p. 119, pl. 29, figs. 2a-3.

Remarks:—This species is distinctive by virtue of its highly inflated spherical chambers. The aperture is without either lip or rim. In some specimens showing gerontic features there is an additional chamber which extends somewhat over and on to the spiral side, the aperture becoming nearly interiomarginal, peripheral.

Hypotype:—From sample, No. RM 19480, auger line near Pozón, eastern Falcón; Plate 19, figures 124a-c, deposited in U.S.N.M. collection, No. 616091.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the *Globigerina bulloides* Zone, Pozón formation.

***Globorotalia opima* Bolli**

***Globorotalia opima continnosa* Blow, subsp. nov.**

Pl. 19, figs. 125a-c

Diagnosis of subspecies:—Test low trochospiral; spire opening rather rapidly, with four chambers in the last whorl; equatorial periphery lobate; axial periphery rounded, with the test appearing rather parallel-sided in side view; the sutures of the spiral and umbilical sides depressed, radial; chambers ovate to subspherical, but not well separated; umbilicus narrow, deep; aperture with a

distinctive lip, interiomarginal, umbilical-extraumbilical, a comparatively high arch which tends to be somewhat elongate normal to the axis of coiling at the periphery, giving a "coma-shaped" appearance in side view (Plate 19, figure 125c). Wall calcareous rather coarsely perforate; maximum diameter of holotype 0.26 mm.

Remarks:—This form differs from *Globorotalia opima nana* Bolli in having ovate or only merely subspherical chambers, a higher arched aperture with a more distinctive apertural lip, and a rather more coarsely perforate wall structure. Forms transitional to *Globorotalia opima nana* occur in the *Catapsydrax stainforthi* Zone, whilst forms transitional to *Globorotalia acostaensis* Blow, sp. nov. occur in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone.

Holotype:—From sample, No. RM 19542, auger line near Pozón, eastern Falcón; Plate 19, figures 125a-c, deposited in U.S.N.M. collection, No. 625711.

Occurrence:—Ranges from the *Catapsydrax stainforthi* Zone to the *Sphaeroidinella seminulina* Zone, Tocuyo and Pozón formations.

***Globorotalia scitula* (Brady)**

***Globorotalia scitula scitula* (Brady)**

Pl. 19, figs. 126a-c

Pulvinulina scitula Brady, 1884, Roy. Soc. Edinburgh, Proc., vol. 11, p. 716. Figures in Brady, 1884, Challenger Exped. Rept., Zool., vol. 9, pl. 103, figs. 7a-c.

Globorotalia canariensis Cushman and Stainforth (*non* d'Orbigny), 1945, Cushman Lab. Foram. Res., Spec. Pub. 14, p. 70, pl. 13, figs. 12a-c.

Globorotalia canariensis Renz (*non* d'Orbigny), 1948, Geol. Soc. Amer., Mem. 32, p. 136, pl. XI, figs. 3a-b.

Globorotalia scitula (Brady), Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 120, pl. 29, figs. 11a-12c.

Description:—Test low-trochospiral; spire opening fairly rapidly with four to five (occasionally six) chambers in the last whorl; equatorial periphery slightly to moderately lobate; axial periphery subacute to rounded, not keeled; spiral side slightly convex; umbilical side convex to slightly vaulted; the sutures of the spiral side are depressed, sinuous to nearly radial; chambers as seen from the spiral side nearly as broad as long, almost hemispherical; umbilicus small or almost closed, fairly shallow; aperture interiomarginal, umbilical-extraumbilical, with a distinct lip; wall calcareous, finely

perforate, smooth, often appearing glassy; maximum diameter of hypotype, 0.33 mm.

Remarks:—This subspecies differs from *Globorotalia scitula praescitula* Blow, subsp. nov. in having almost hemispherical chambers, a less vaulted umbilical side and less deeply incised sutures on the spiral side. The periphery is subacute to rounded as compared with the more acute periphery of *Globorotalia scitula praescitula*. It differs from *Globorotalia scitula gigantea* Blow, subsp. nov. in being smaller and in the almost complete lack of peripheral thickening and ventral pustules.

Hypotype:—From sample, No. RM 19367, auger line near Pozón, eastern Falcón; Plate 19, figures 126a-c, deposited in U.S.N.M. collection, No. 626093.

Occurrence:—Ranges from the uppermost part of the *Globorotalia fohsi barisanensis* Zone to the *Globigerina bulloides* Zone, Pozón formation. The subspecies persists to Recent.

***Globorotalia scitula gigantea* Blow, subsp. nov.** Pl. 16, figs. 127a-c

Diagnosis of subspecies:—Test trochospiral; spire opening fairly rapidly, with four to five chambers in the last whorl. Equatorial periphery lobate; axial periphery rounded to subacute, not keeled but often with much peripheral thickening; test generally biconvex; sutures of the spiral side depressed and strongly curved; sutures of the umbilical side slightly sinuous to radial; chambers almost hemispherical as seen from the spiral side; aperture interior-marginal, umbilical-extraumbilical, a low arch with a distinct lip; wall calcareous, perforate, often with distinct pustules in the umbilical sutural positions and over the umbilical surface of the earlier chambers; maximum diameter of holotype 0.59 mm.

Remarks:—In general morphology this subspecies is similar to *Globorotalia scitula scitula* (Brady) but differs in being much larger. Two groups co-exist with mean diameters averaging 0.28 mm. and 0.54 mm. with few specimens greatly departing from the two means; the larger-sized group is assigned to this subspecies and shows the presence of much peripheral thickening and pustules on the umbilical side. The test is also generally more equally biconvex than in *Globorotalia scitula scitula* (Brady).

Holotype:—From sample, No. RM 19480, auger line near Pozón, eastern Falcón; Plate 16, figures 127a-c, deposited in U.S.N.M. collection, No. 625715.

Occurrence:—Ranges from the upper part of the *Globorotalia fohsi fohsi* Zone to the lower part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Globorotalia scitula praescitula Blow, subsp. nov. Pl. 19, figs. 128a-c

Diagnosis of subspecies:—Test a fairly low trochospiral; spire opening regularly but not rapidly, with four to five chambers in the last whorl; equatorial profile ovate to subcircular; equatorial periphery lobate; axial periphery subacute but not keeled, although some peripheral thickening occurs on the earlier chambers; sutures of the spiral side depressed and strongly curved; sutures of the umbilical side depressed, slightly sinuous to radial; spiral side convex, umbilical side distinctly convex to rather vaulted; chambers longer than broad, elongate tangentially as seen from the spiral side; umbilicus small, sometimes closed, but often fairly deep; aperture interior-marginal, umbilical-extraumbilical, a low arch with a thin lip; wall calcareous, finely perforate, not glassy; maximum diameter of holotype, 0.30 mm.

Remarks:—This subspecies differs from *Globorotalia scitula scitula* (Brady) in having more tangentially elongate chambers, a more convex umbilical side, and a less finely perforate wall texture; the periphery is also generally more acute but transitional forms occur in the upper part of the *Globorotalia fohsi barisanensis* Zone.

Holotype:—From sample, No. RM 19152, auger line near Pozón, eastern Falcón; Plate 19, figures 128a-c, deposited in U.S.N.M. collection, No. 625713.

Occurrence:—Ranges from the base of the Pozón-El Mene Road section (*Catapsydrax stainforthi* Zone) to the top of the *Globorotalia fohsi barisanensis* Zone, Pozón formation.

Genus **HASTIGERINELLA** Cushman, 1927

This genus possesses a lipped interior-marginal, umbilical-extra-

umbilical aperture, at least in the earlier stages (Pl. 16, fig. 130). The typical "club-shaped" and radially elongate chambers do not seem to appear until later ontogenetic stages; the earlier chambers are usually ovate or only slightly radially elongate. Because of the nature and position of the aperture the writer believes that this genus has evolved repeatedly from a *Globorotalia*-like ancestor and not via *Hastigerina* as inferred by Cushman (1950, pl. 27).

In this study the writer notes that *Hastigerinella* appears before *Hastigerina* although both occur in the Miocene.

***Hastigerinella bermudezi* Bolli**

Pl. 16, figs. 129a-b, 130

Hastioerina bermudezi Bolli, 1957, U.S. Nat. Mus., Bull. No. 215, p. 112, pl. 25, figs. 1a-c.

Remarks:—This species shows spherical to ovate early chambers with a distinct *Globorotalia*-like aperture (Pl. 16, fig. 130). The later chambers become club-shaped with the aperture extending on to the periphery. The test is less trochoid than in *Hastigerinella rhumbleri* Galloway, 1933 (= *Hastigerina digitata* Rhumbler, 1911, non *Globigerina digitata* Brady, 1879), and the chambers less elongate. It seems likely that the various *Hastigerinella* species also appear independently from a "globorotalid-stock" since this species has a restricted range and does not appear to be closely related to the typically Recent *Hastigerinella rhumbleri* Galloway.

Hypotype:—From sample, No. RM 19290, auger line near Pozón, eastern Falcón; Plate 16, figures 129a-b, deposited in U.S.N.M. collection, No. 626095. (Figure 130, Plate 16 also deposited in U.S.N.M. collection.)

Occurrence:—Ranges only from the upper part of the *Globigerinatella insueta* *Globigerinoides bispherica* Subzone to the basal part of the *Globorotalia fohsi fohsi* Zone, Pozón formation.

Family ANOMALINIDAE

Genus ANOMALINA d'Orbigny, 1826

***Anomalina atazanensis* Nuttall**

Anomalina atazanensis Nuttall, 1932, Jour. Pal., vol. 6, p. 31, pl. 8, figs. 4, 8, 9.

Hypotype:—From sample, No. RM 19285, auger line near

Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626097.

Occurrence:—Rather rare and seems to be restricted to samples from the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, *Globorotalia fohsi barisanensis* Zone and *Globorotalia fohsi fohsi* Zone, Pozón formation.

Genus **ANOMALINOIDES** Brotzen, 1942

Anomalinoides trinitatensis (Nuttall)

Truncatulina trinitatensis Nuttall, 1928, Geol. Soc. London, Quart. Jour., vol. 84, p. 97, pl. 7, figs. 3, 5, 6 (*vide* Ellis and Messina, 1940 *et seq.*).

Anomalinoides trinitatensis (Nuttall), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 115, pl. X, figs. 11a-c.

Remarks:—This form is rather similar to *Cibicides nucleatus* (Seguenza); however, in *Anomalinoides trinitatensis* the aperture extends much further towards the umbilicus, whereas in *Cibicides nucleatus* the umbilical part of the aperture is confined to the peripheral part of the basal suture of the last chamber.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626098.

Occurrence:—Occurs from the *Catapsydrax stainforthi* Zone, Tocuyo formation, to the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation. Often common, especially in the *Globorotalia fohsi fohsi* Zone and in the *Globorotalia mayeri* Zone (*s.l.*).

Genus **CIBICIDES** Montfort, 1808

Cibicides americanus (Cushman)

Cibicides americanus (Cushman), Cushman and Cahill, 1933, U.S. Geol. Surv., Prof. Paper 175-A, p. 34, pl. 13, figs. 2a-c (*vide* Ellis and Messina, 1940 *et seq.*).

Remarks:—This species is thin-walled and fragile and has a fairly well-marked narrow carina. Aperture on the spiral side has a thin liplike extension. Involute both on the spiral and umbilical sides. It differs from *Cibicides mantaensis* (Galloway and Morrey) in having a narrow carina and slightly depressed sutures.

Hypotype:—From sample, No. RM 20104, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626100.

Occurrence:—Generally scarce throughout the Pozón formation but becomes relatively common in some impoverished faunas from the topmost part of this formation, *i.e.*, in the upper part of the *Sphaeroidinella seminulina* Zone and *Globigerina bulloides* Zone.

Cibicides earsteni Cushman and Ellisor

Cibicides earsteni Cushman and Ellisor, 1939, Cushman Lab. Foram. Res., Contr., vol. 15, p. 13, pl. 2, figs. 8a-c (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19282, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626102.

Occurrence:—Fairly common and occurs in the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, *Globorotalia fohsi* "Zone" (*s.l.*), *Globorotalia mayeri* Zone (*s.l.*) and in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

Cibicides concentricus (Cushman)

Cibicides concentricus (Cushman), Cushman, 1930, Florida Geol. Surv., Bull. No. 4, p. 61, pl. 12, fig. 4 (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19522, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626104.

Occurrence:—Scarce in the *Globigerinatella insueta* Zone (*s.l.*) and in the *Globorotalia fohsi* "Zone" (*s.l.*) but fairly common in the *Globorotalia mayeri* Zone (*s.l.*) and in the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone. Only observed in isolated samples from the *Sphaeroidinella seminulina* Zone, Pozón formation.

Cibicides compressus Cushman and Renz

Cibicides floridanus (Cushman) var. *compressa* Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 1, p. 26, pl. 4, fig. 9.

Cibicides compressus Cushman and Renz, Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 127, pl. X, figs. 9a-c.

Remarks:—Renz (1948) considered this form to be sufficiently distinctive from *Cibicides floridanus* Cushman to be considered as a distinct species. The present writer's view is that the species shows little variation, except in size, and, therefore, agrees with Renz's conclusions.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626106.

Occurrence:—Often common in samples from the *Globigerinatella insueta* Zone (*s.l.*), *Globorotalia fohsi* "Zone" (*s.l.*) *Globorotalia mayeri* Zone (*s.l.*) and from the *Globorotalia menardii*/*Globigerina nepenthes* Zone, Tocuyo and Pozón formations. Isolated specimens have been observed in the *Sphaeroidinella seminulina* Zone and *Globigerina bulloides* Zone, indicating that its virtual disappearance is due to ecological rather than stratigraphical reasons.

***Cibicides falconensis* Renz**

Cibicides falconensis Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 128, pl. XI, figs. 6a-c.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626108.

Occurrence:—Fairly common in the *Catapsydrax stainforthi* Zone and *Globigerinoides insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation, but rather scarce or scarce in the *Globigerinatella insueta*/*Globigerinoides bispherica* Subzone, *Globorotalia fohsi* "Zone" (*s.l.*), and lower part of the *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

***Cibicides mantaensis* (Galloway and Morrey)**

Cibicides mantaensis (Galloway and Morrey), Hedberg, 1937, Jour. Pal., vol. 11, p. 683, pl. 92, figs. 12a-c.

Remarks:—This species is involute both on the spiral and umbilical sides and appears closely related to *Cibicides americanus* Cushman but differs from the latter species in having limbate, slightly raised sutures. The part of the aperture on the spiral side is covered by a small liplike plate.

Hypotype:—From sample. No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626110.

Occurrence:—Fairly common in the *Catapsydrax stainforthi* Zone, *Globigerinatella insueta*/*Globigerinoides triloba* Subzone, Tocuyo formation; also in the *Globigerinatella insueta*/*Globigerinoides*

bispherica Subzone and *Globorotalia foshi* "Zone" (*s.l.*), Pozón formation.

***Cibicides matanzasensis* (Hadley)**

Cibicides matanzasensis (Hadley), Palmer, 1941, Soc. cubana hist. nat., Mem., vol. 15, p. 295, pl. 28, figs. 6a-c.

Remarks:—The part of the aperture on the spiral side of this species is not clearly marked. Spiral side evolute but strongly involute umbilically. Sutures meet the periphery nearly at right-angles and are raised. Chambers numerous, about 12-14 in the last whorl only slowly increasing in size as added.

Hypotype:—From sample, No. RM 19285, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626112.

Occurrence:—Generally scarce in all zones below the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, Pozón formation.

***Cibicides perlucida* Nuttall**

Cibicides perlucida Nuttall, 1932, Jour. Pal., vol. 6, p. 33, pl. 8, figs. 10-12.

Remarks:—Umbilical side strongly vaulted; spiral side slightly convex with the sutures rather indistinct and strongly oblique to the periphery.

Hypotype:—From sample. No. RM 19117, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626114.

Occurrence:—Scarce and only observed in isolated samples from the *Catapsydrax stainforthi* Zone, Tocuyo formation.

Genus **LATICARININA** Galloway and Wissler, 1927

***Laticarinina pauperata* (Parker and Jones)**

Laticarinina pauperata (Parker and Jones), Cushman, 1931, U.S. Nat. Mus., Bull. No. 104, pt. 8, p. 114, pl. 20, fig. 4; pl. 21, fig. 1 (*vide* Ellis and Messina, 1940 *et. seq.*).

Remarks:—This distinctive form, with its wide peripheral flange and generally compressed test, has been considered as a planktonic species. Its association with predominantly deepwater mainly planktonic assemblages supports this view; however, Cush-

man suggested that it may be pseudoplanktonic, being attached to floating seaweed.

Hypotype:—From sample, No. RM 19280, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626115.

Occurrence:—Occurs, but is scarce, in the *Catapsydrax stainforthi* Zone and *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations. Occasional specimens have been observed in mainly planktonic assemblages from the *Globorotalia fohsi* "Zone" (*s.l.*), Pozón formation.

Genus **PLANULINA** d'Orbigny, 1826

Planulina dohertyi (Galloway and Morrey)

Cibicides dohertyi Galloway and Morrey, 1929, Bull. Amer. Pal., vol. 15, No. 55, p. 30, pl. 4, figs. 7a-c.

Planulina dohertyi (Galloway and Morrey), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 150, pl. X, figs. 6a-b.

Hypotype:—From sample, No. RM 19255, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626117.

Occurrence:—Scarce and only observed in isolated samples from the *Globigerinatella insueta* Zone (*s.l.*) and *Globorotalia fohsi* "Zone" (*s.l.*), Tocuyo and Pozón formations.

Planulina marialana Hadley

Planulina marialana Hadley, 1934, Bull. Amer. Pal., vol. 20, No. 70A, p. 27 pl. 4, figs. 4-7 (*vide* Renz, 1948).

Hypotype:—From sample, No. RM 19210, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626119.

Occurrence:—Scarce and only observed in samples from the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

Planulina mexicana Cushman

Planulina mexicana Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, p. 113, pl. 23, figs. 5a-b (*vide* Ellis and Messina, 1940 *et seq.*).

Hypotype:—From sample, No. RM 19181, auger line near Pozón, eastern Falcón; deposited in U.S.N.M. collection, No. 626121.

Occurrence:—Generally scarce but observed in the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations, also in the *Globorotalia fohsi* "Zone" (*s.l.*), and *Globorotalia mayeri* Zone (*s.l.*), Pozón formation.

Planulina subtenuissima (Nuttall)

Anomalina subtenuissima Nuttall, 1928, Geol. Soc. London, Quart. Journ., vol. 84, p. 100, pl. 7, figs. 13, 15, text-fig. 6 (*vide* Renz, 1948).

Planulina subtenuissima (Nuttall), Renz, 1948, Geol. Soc. Amer., Mem. 32, p. 151, pl. XI, figs. 4a-b.

Hypotype:—From sample, No. RM 19285, auger line near Pozón; eastern Falcón; deposited in U.S.N.M. collection, No. 626123.

Occurrence:—Generally scarce and only observed in the *Globigerinatella insueta* Zone (*s.l.*), Tocuyo and Pozón formations.

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APPENDIX I

NOTE ON THE VALIDITY OF THE NAME "SAN LORENZO
 FORMATION", DISTRICT OF ACOSTA,
 EASTERN FALCÓN, VENEZUELA

In a private letter, dated 12th August, 1957, Dr. H. G. Kugler drew the writer's attention to certain facts concerning the validity of the term "San Lorenzo formation" as applied to certain beds which lie between the Pozón and Guacharaca formations in the District of Acosta, State of Falcón, Venezuela. Unfortunately, Dr. Kugler's most valuable comments only reached the writer after the present study had been finalized and all the charts draughted.

In his letter, Dr. Kugler referred to the following statements concerning a valid formational name in southern California, U.S.A., *i.e.*, San Lorenzo formation. "Oligocene": southern California (Santa Cruz Mountains region).

(a) R. Arnold (1906, U.S. Geol. Surv., Prof. Paper 47, p. 16) stated, "San Lorenzo formation. Essentially a series of grayish "muddy" shales and fine sandstones, typically exposed along the bed of the San Lorenzo River about 2 miles above Boulder Creek, Santa Cruz County. Extends W. from type locality in Big Basin, on N. side of which it rests conformably against older yellowish sandstones of Butano Ridge, possibly Oligocene in age." This statement

by Arnold was later slightly modified by Atwill as follows:

(b) E. R. Atwill (1935, Amer. Assoc. Petr. Geol., Bull., vol. 19, no 8, p. 1204) stated, "Recent work points to the conclusion type San Lorenzo may range from Oligocene (or even Eocene) to Miocene."

(c) R. A. Liddle (1928, The geology of Venezuela and Trinidad, p. 397, stated, "Upper Oligocene shales, sandstones and limestones included in the Agua Clara, Quiros, El Mene, Curamichate, La Planchada and Tocuyo horizons constitute the major producing horizon of western and north-western Venezuela".

Dr. Kugler pointed out that the "Tocuyo horizon" of Liddle (1928) is obviously synonymous with A. Senn's (1935) "El Mene sand formation". Renz (1948, p. 9) rightly abandoned the term "El Mene sand formation" because of its inadequate definition as well as its preoccupation by such terms as El Mene de Buchivacoa and Barinas (see also Hedberg, 1938). However, it appears that a mistake was made in introducing the term "San Lorenzo formation" without having first consulted the Stratigraphic Lexicon.

Dr. Kugler goes on to say in his letter, "In view of these statements by Arnold and Atwill on a valid formation, I recommend you to drop the term "San Lorenzo formation" and introduce the term "*Tocuyo formation*". According to the "Lexico estratigrafico de Venezuela" (1956) the term "Tocuyo" has not been used for any formation or member.

Following these comments and the recommendations by Dr. Kugler, the writer proposes that the term "Tocuyo formation" should be substituted for the term "San Lorenzo formation", District of Acosta, State of Falcón, Venezuela.

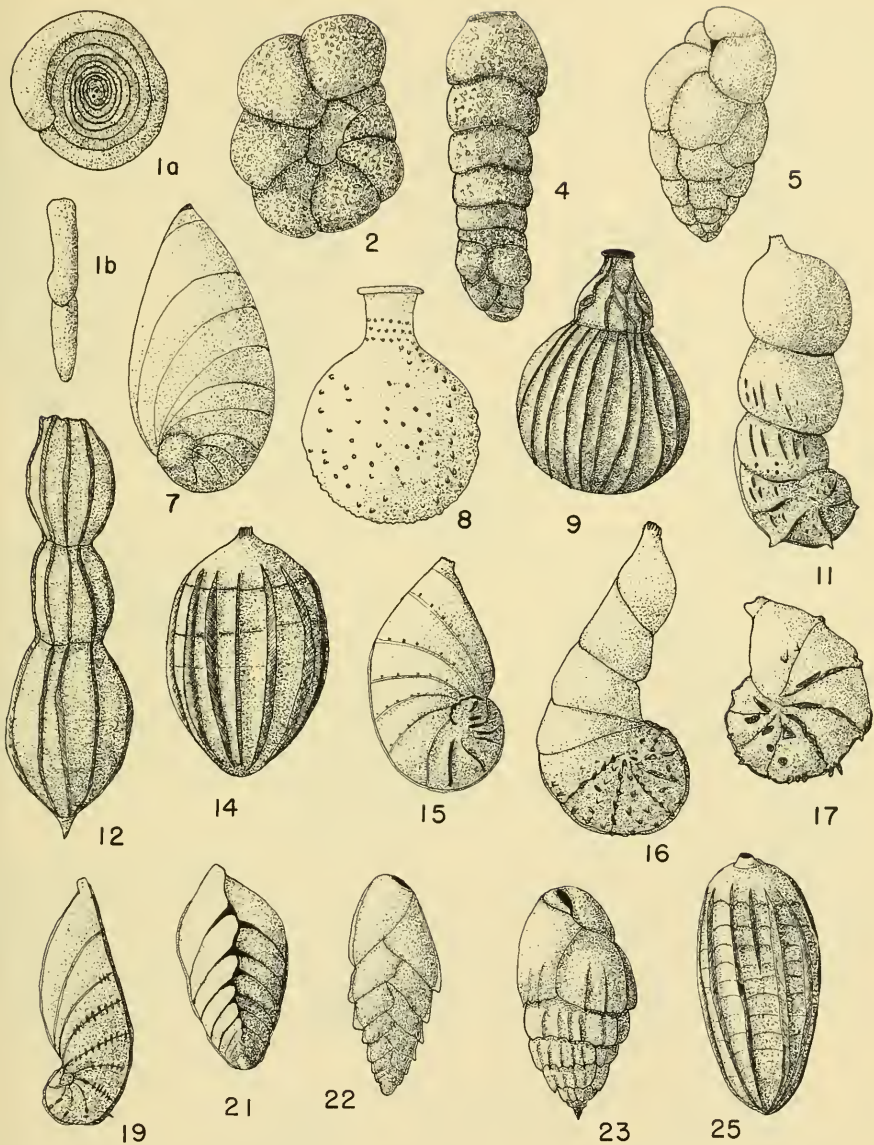
The writer wishes to express his sincere appreciation for Dr. Kugler's comments and for permission to quote from his letter of the 12th August, 1957.

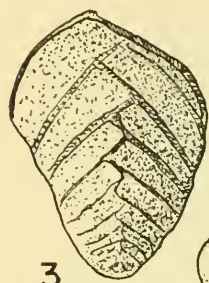
PLATES

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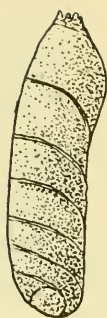
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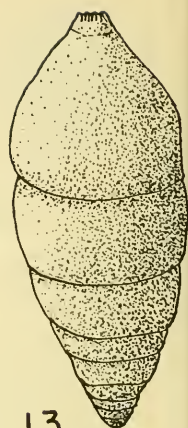


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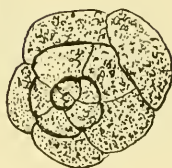
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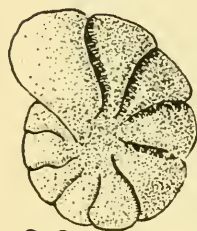
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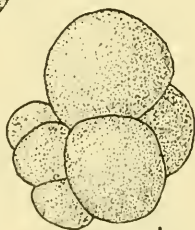
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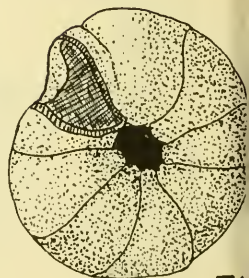
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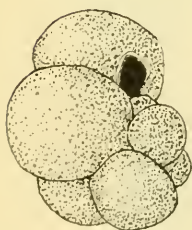
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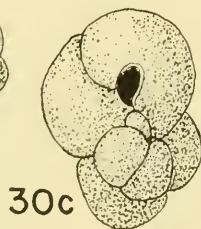
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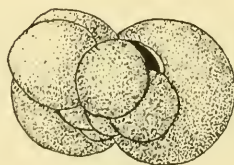
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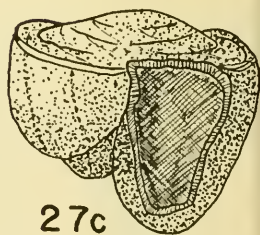
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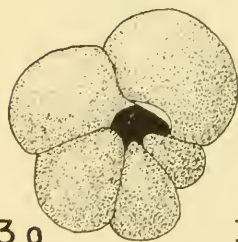
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33c



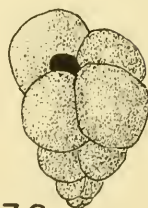
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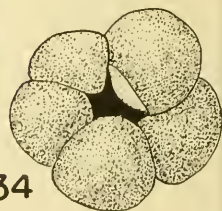
33a



33b



36



34

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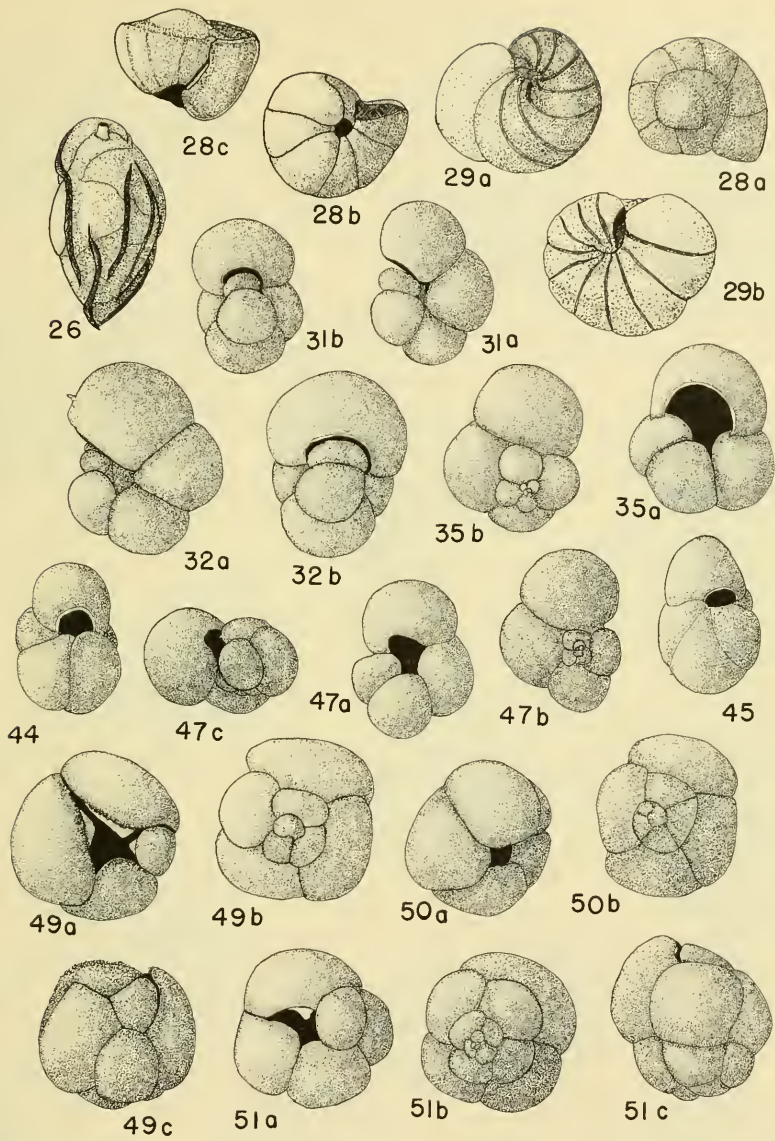
(For figures 1, 2, 4, 5, 7-9, 11, 12, 14-17, 19, 21-23 see Plate 6; 26, 28, 29, 31, 32, 35 see Plate 8.)

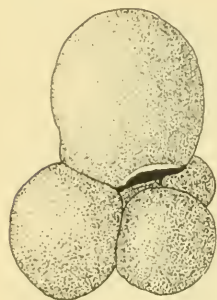
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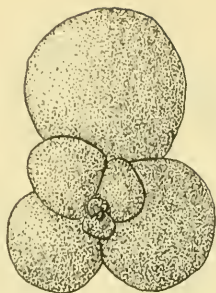
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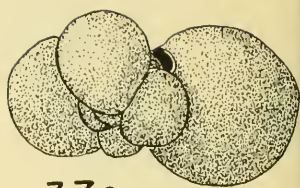




37a



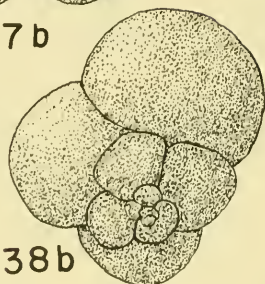
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37c



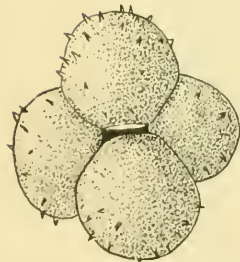
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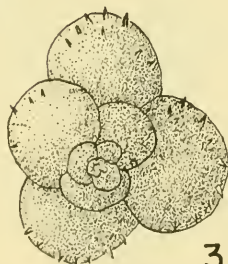
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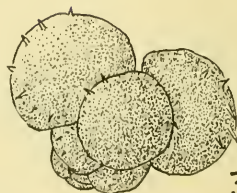
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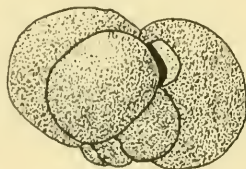
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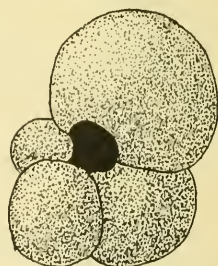
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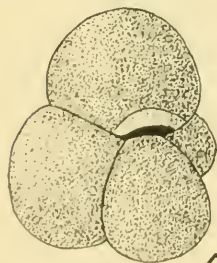
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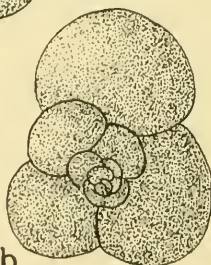
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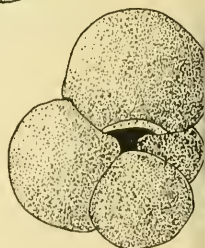
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40a



40b



41

Explanation of Plate 9

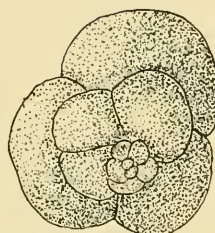
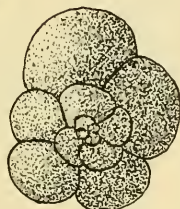
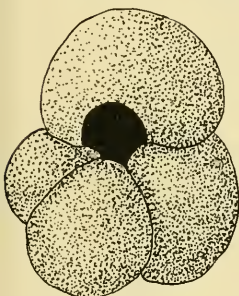
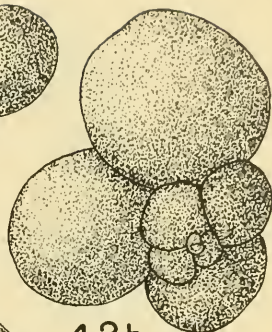
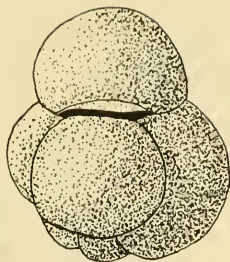
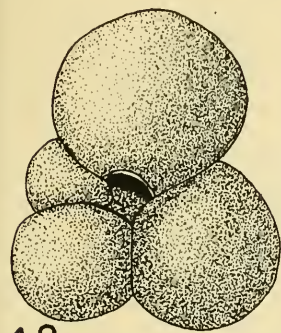
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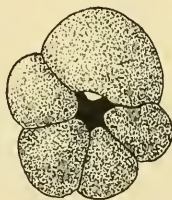
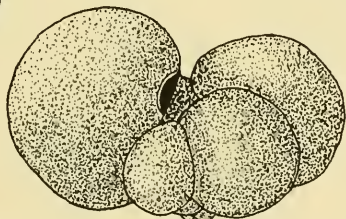
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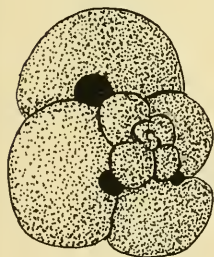


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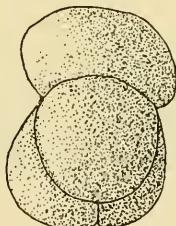
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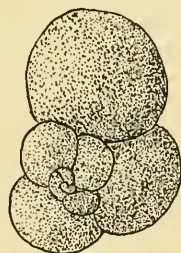
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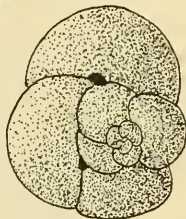
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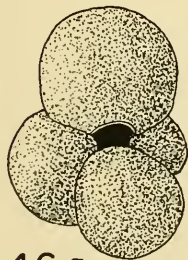
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46 b



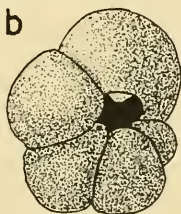
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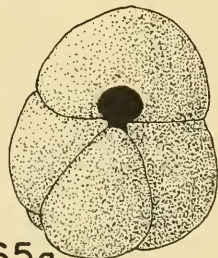
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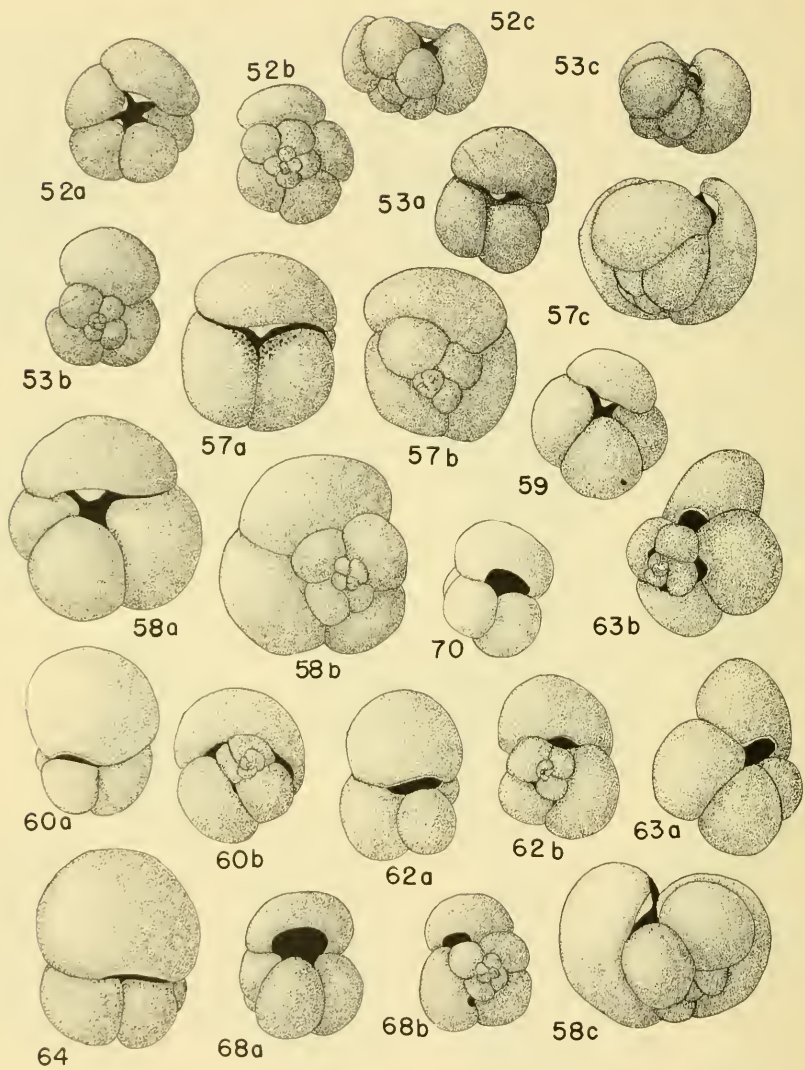
46 c



54 a



65 a



Explanation of Plate 11

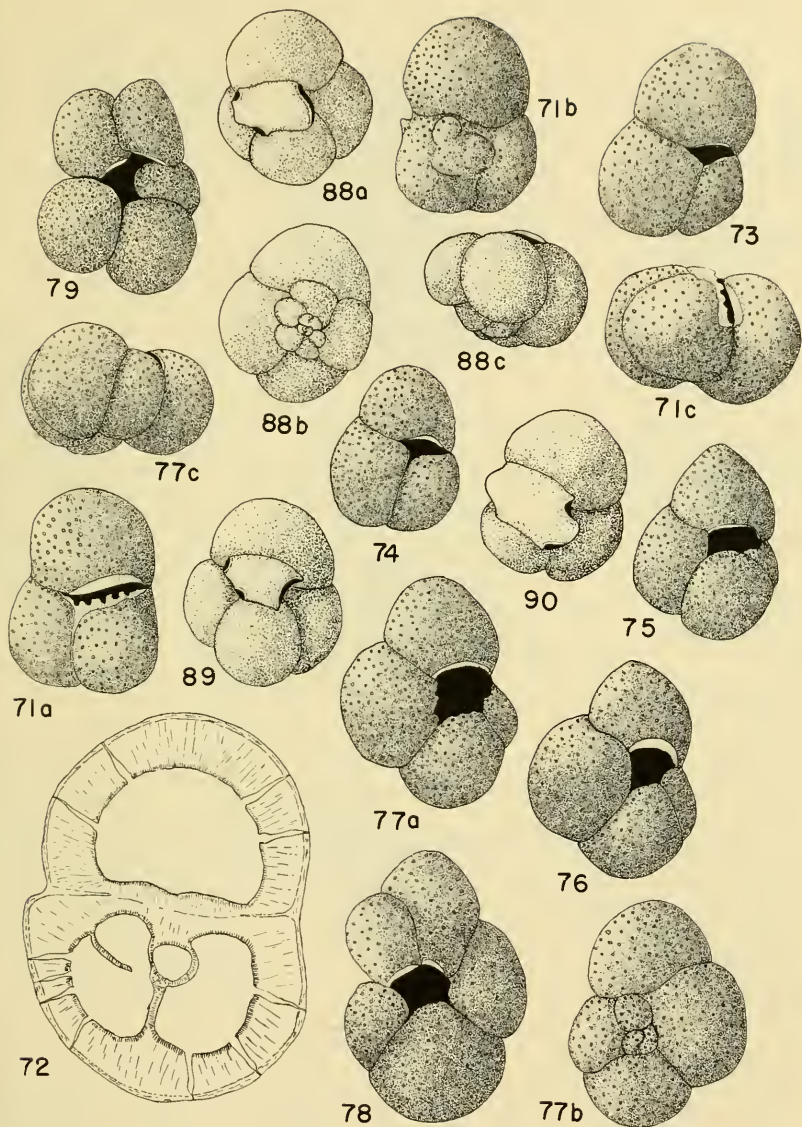
(For figures 54-56, 61, 65 see Plate 10; figures 66, 67, 69 see Plate 13.)

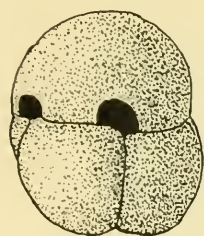
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Explanation of Plate 12

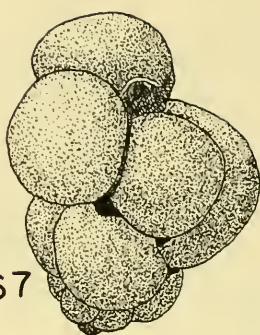
(For figures 80-84 see Plate 13; figures 85-87 see Plate 14.)

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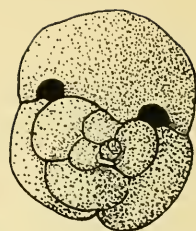




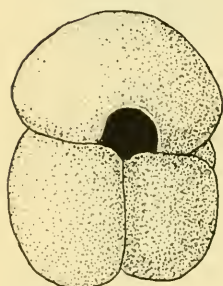
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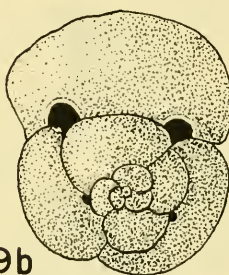
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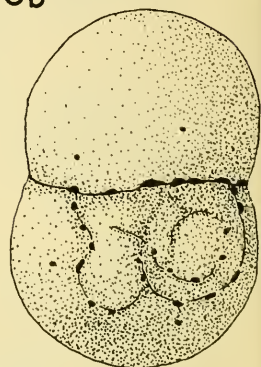
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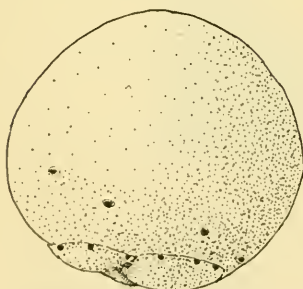
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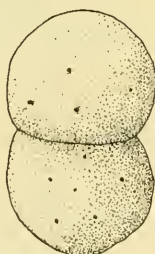
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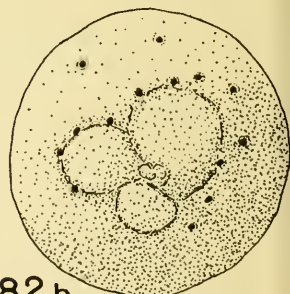
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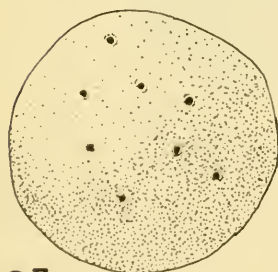
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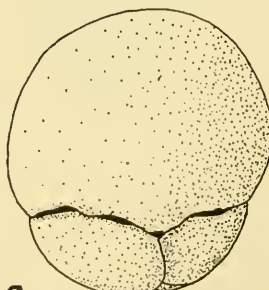
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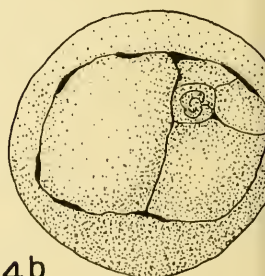
82 b



83



84 a



84 b

Explanation of Plate 13

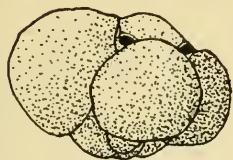
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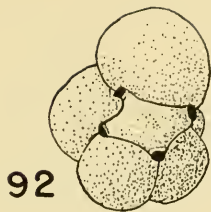
Explanation of Plate 14

(For figures 88-90 see Plate 12.)

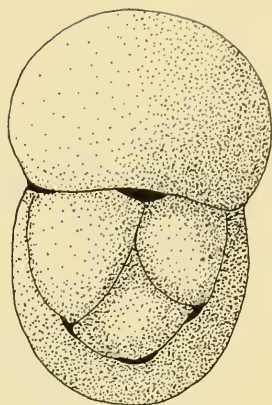
Figure	Page
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93. Catapsydrax stainforthi Bolli, Loeblich, and Tappan	204
Hypotype, X100, USNM, No. 626057 from Sample RM 19152; umbilical view of a specimen showing five infralaminar apertures.	



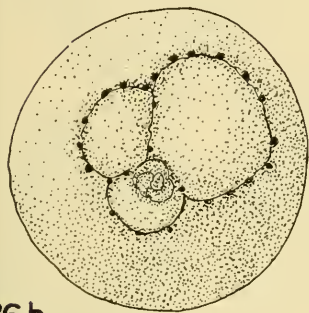
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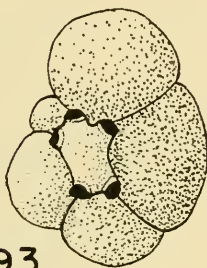
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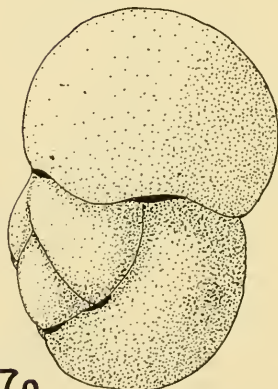
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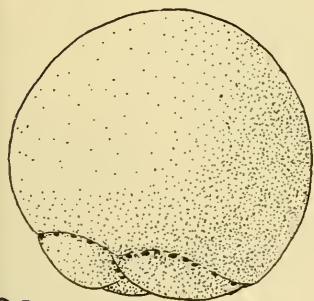
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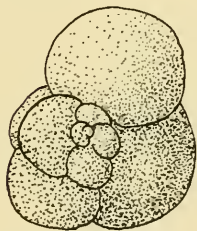
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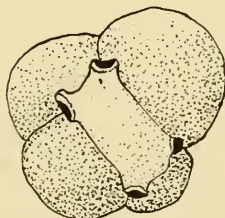
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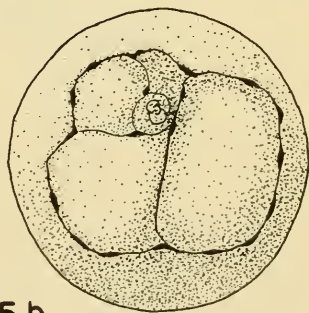
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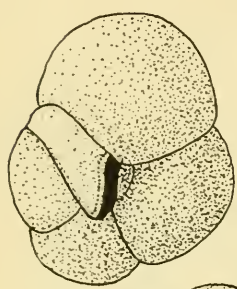
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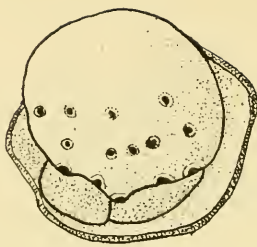
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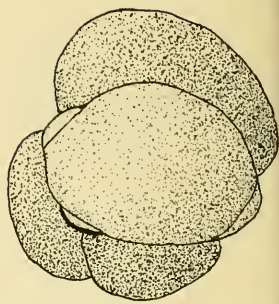
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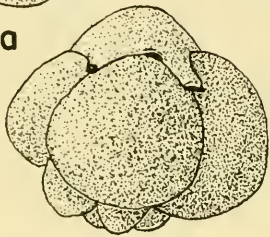
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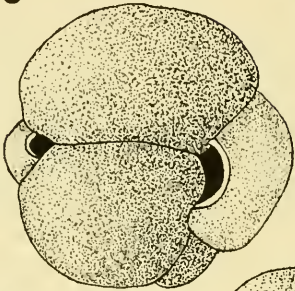
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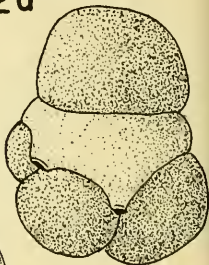
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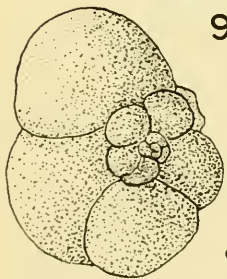
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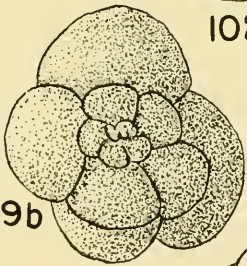
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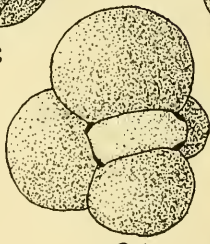
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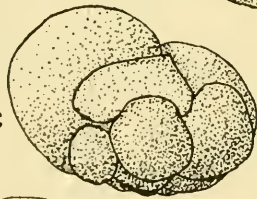
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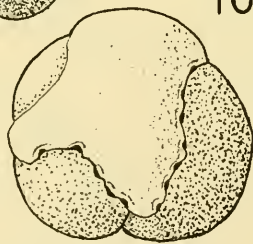
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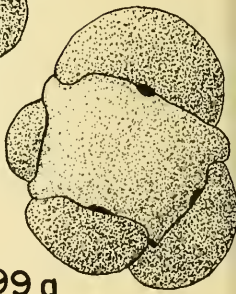
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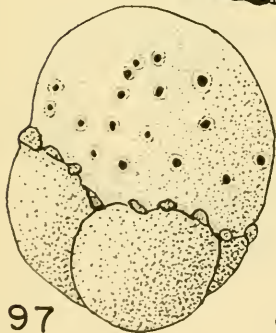
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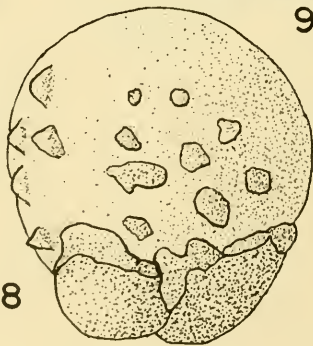
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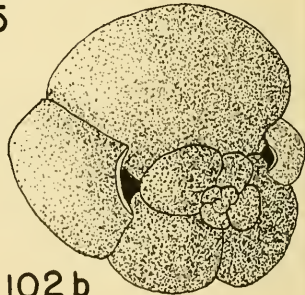
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97



98



102b

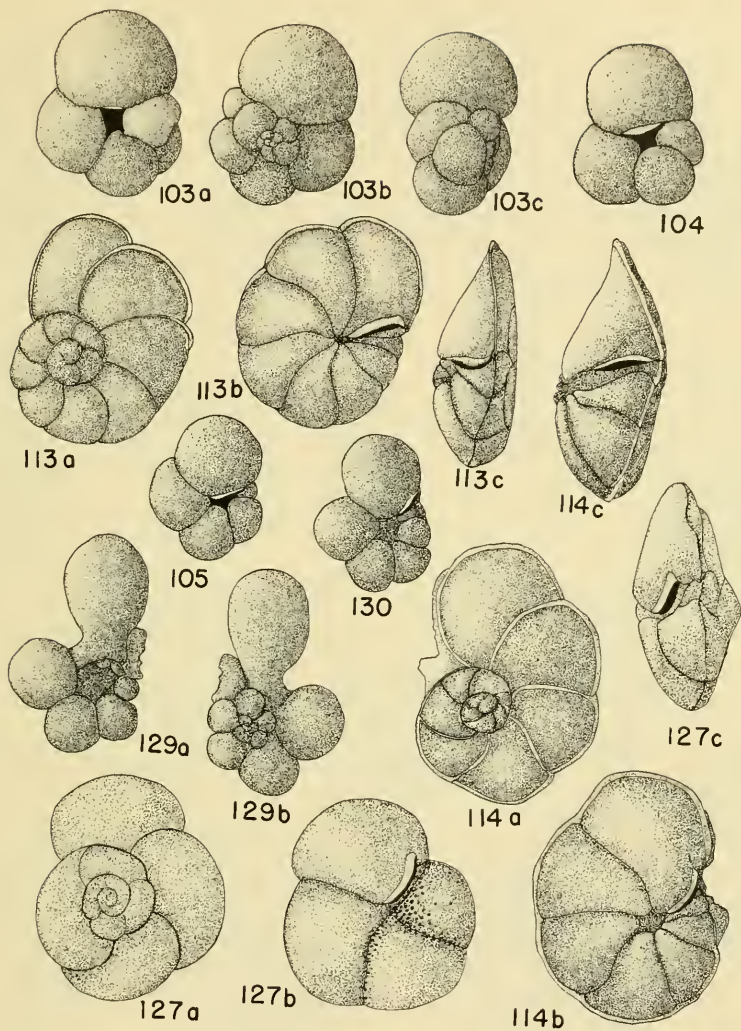
Explanation of Plate 15

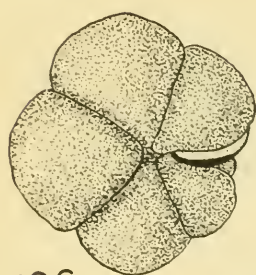
Figure	Page
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Hypotype, X100, USNM, No. 626060 from Sample RM 19188; umbilical view of a specimen with the last chamber partly removed and showing the supplementary sutural and areal apertures of the earlier ontogenetic stages.	
97. <i>Globigerinatella insueta</i> Cushman and Stainforth	205
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98. <i>Globigerinatella insueta</i> Cushman and Stainforth	205
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Explanation of Plate 16

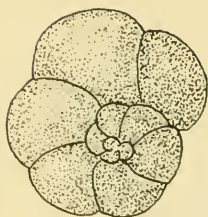
(For figures 106-112, 115 see Plate 17; figures 116-120 see Plate 18; figures 121-126, 128 see Plate 19.)

Figure	Page
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Hypotype, X50, USNM, No. 626066 from Sample RM 19697; fig. 103a, umbilical view showing the bulla-like final chamber; fig. 103b, spiral view; fig. 103c, side view.	
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130. Hastigerinella bermudezi Bolli	222
X50, USNM, No. 626096 from Sample RM 19290; umbilical view of an immature form showing the lipped interiangular, umbilical-extraumbilical aperture.	

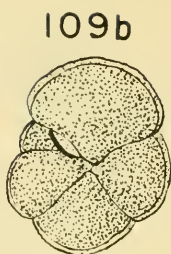




106a



108a



109b



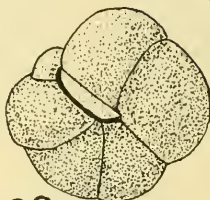
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110



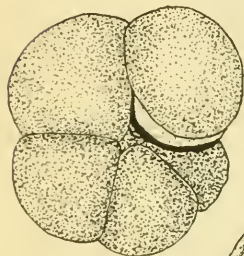
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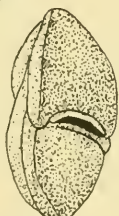
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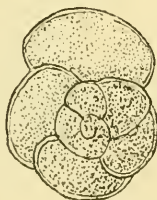
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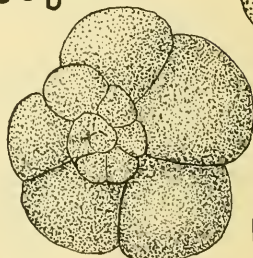
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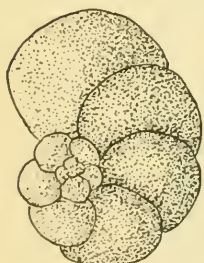
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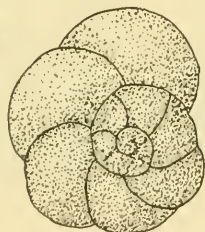
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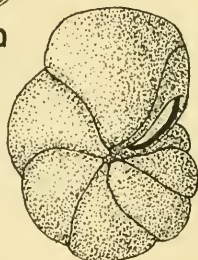
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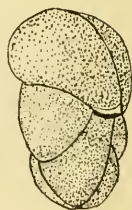
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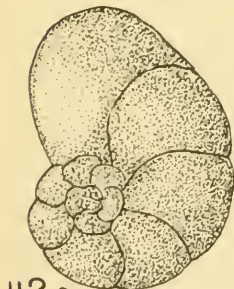
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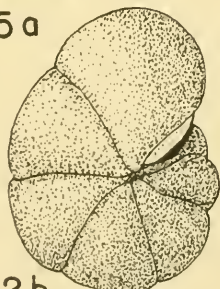
111b



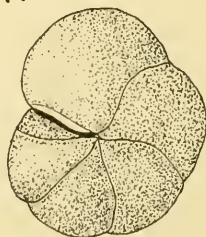
108c



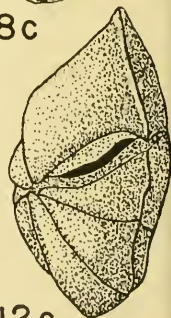
112a



112b



115b



112c

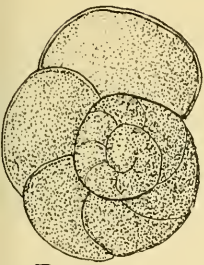
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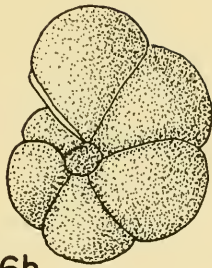
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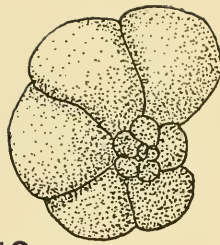
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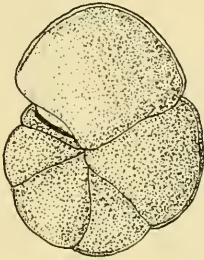
116a



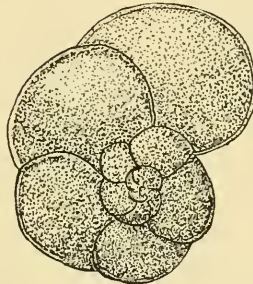
116c



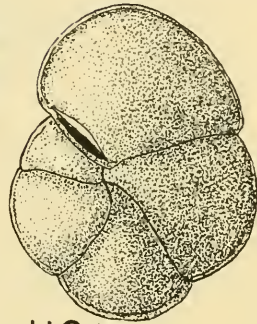
117c



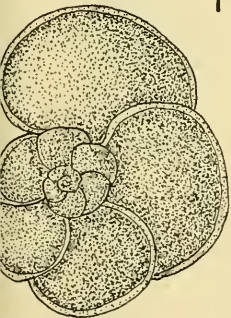
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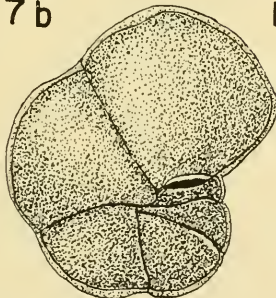
118a



118b



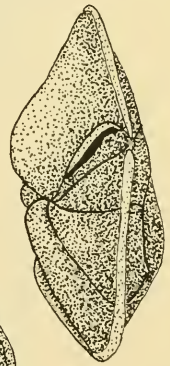
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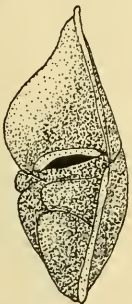
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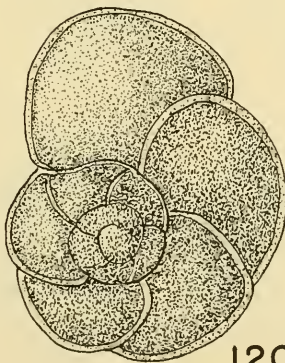
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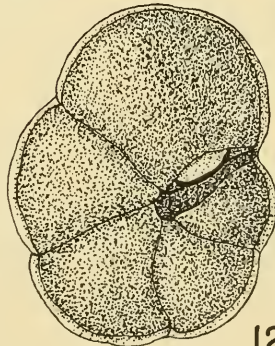
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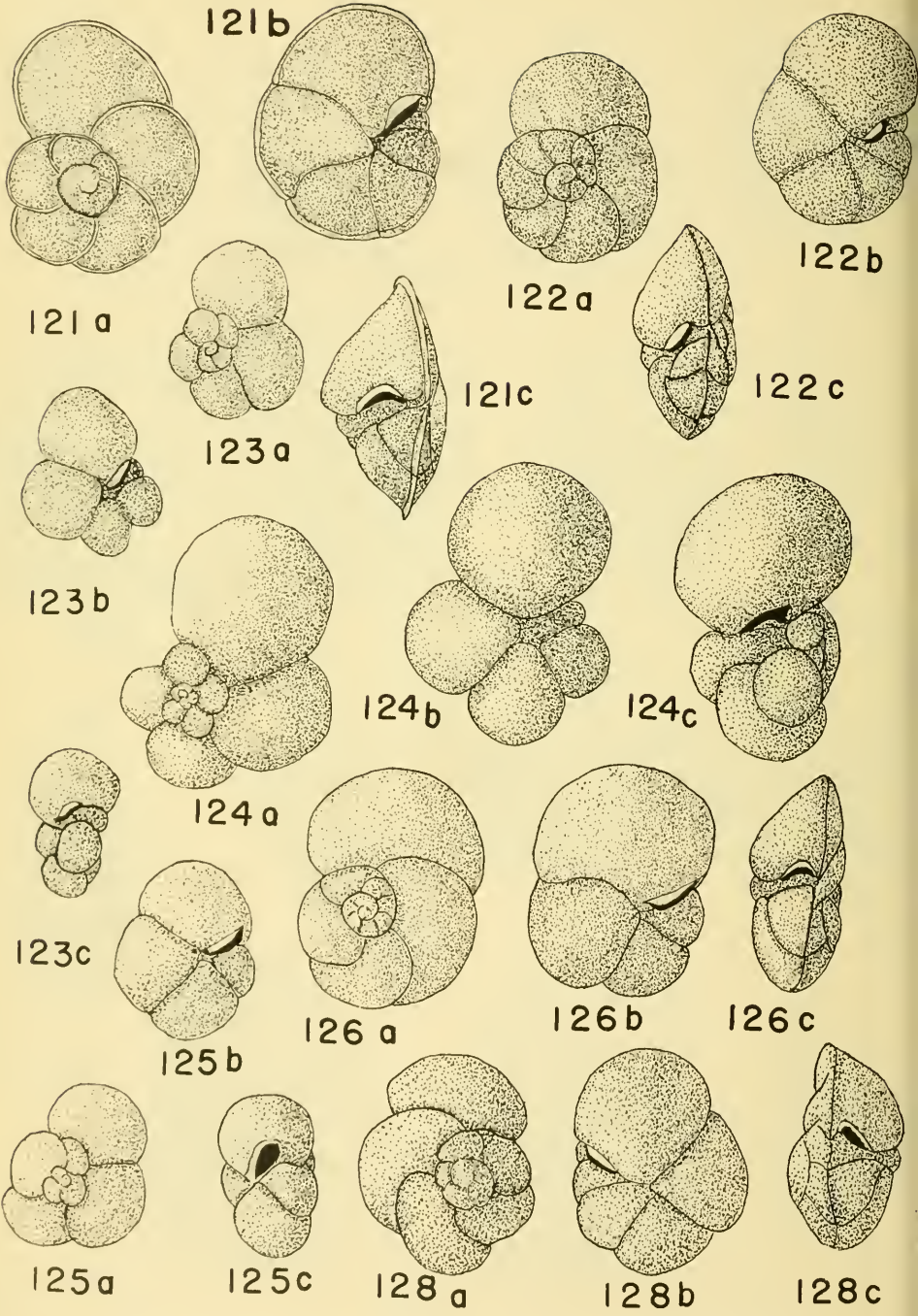
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No. 179

**PLANKTONIC FORAMINIFERA FROM THE CRETACEOUS
OF TRINIDAD, B. W. I.**

HANS M. BOLLI

Venezuelan Atlantic Refining Company,
Caracas

April 1, 1959

Paleontological Research Institution
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PLANKTONIC FORAMINIFERA FROM THE CRETACEOUS OF TRINIDAD, B. W. I.

HANS M. BOLLI

Venezuelan Atlantic Refining Company, Caracas

ABSTRACT

Thirty-three species and subspecies of planktonic Foraminifera from the Lower and Upper Cretaceous of Trinidad are described or listed and their stratigraphic ranges shown on a table. The following species are described as new: *Planomalina blowi*, *P. maridalensis*, *P. saundersi*, *Praeglobotruncana crassa*, *P. modesta*, *P. robri*, and *Globigerina kugleri*. While the zonation of the Upper Cretaceous formations remains unchanged, five foraminiferal zones are proposed for the still incompletely known Lower Cretaceous Toco, Cuche, and Maridale formations.

INTRODUCTION

This paper is supplementary to a number of earlier publications on Cretaceous planktonic Foraminifera from Trinidad (Bartenstein, Bettenstaedt, and Bolli, 1957; Bolli, 1951, 1957a, 1957b; Bolli, Loeblich, and Tappan, 1957; Bronnimann, 1952a). Its purpose is to describe or list and to give the stratigraphic ranges of those planktonic species of the genera *Planomalina*, *Hastigerinoides*, *Biglobigerinella*, *Schackoina*, *Leupoldina*, *Praeglobotruncana*, *Rugoglobigerina*, *Globigerina*, and *Hastigerinella* which were either not described or whose stratigraphic ranges were not shown on the range chart in Bolli (1957a). Remarks are also made on some changes of the generic position of a number of species described by Bronnimann (1952a).

All specimens figured in this report are deposited in the U. S. National Museum, Washington, D. C.

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STRATIGRAPHY

Most of Trinidad's known Lower Cretaceous is of Barremian age. The foraminiferal fauna of the Cuche, Toco, and Tompire formations, which was described by Bartenstein, Bettenstaedt, and Bolli (1957) is predominantly benthonic. Only one planktonic species (*Globigerina kugleri*) is known from the lower Barremian Toco formation of the Northern Range. No attempt is made to subdivide this formation at the present time. The

characteristic *Lenticulina* (*L.*) *barri* is used as the zonal marker for the whole formation. The type locality is situated in Toco Bay on the north-east coast of Trinidad (Bartenstein, Bettenstaedt, and Bolli, 1957, text fig. 3). No planktonic Foraminifera have so far been encountered in the probably slightly older Tompire formation.

The middle Barremian—? lower Aptian Cuche formation is here divided into two zones. Three planktonic species are recorded from the lower, *Lenticulina* (*L.*) *ouachensis ouachensis* zone. This zone includes the following localities described by Bartenstein, Bettenstaedt, and Bolli (1957, p. 11-12): Station Road, Remanie Boulder Bed, Plaisance Hill West and Plaisance Hill East in Pointe-a-Pierre, and Tabaquite-Nariva Road in the Central Range. The richest foraminiferal fauna occurs in the Station Road locality, which, although lithologically not typical for the Cuche formation, is taken as the type locality for the zone. The age of this zone ranges from middle Barremian to probably upper Barremian (Bartenstein, Bettenstaedt, and Bolli, 1957, p. 63).

The upper, *Leupoldina protuberans* zone of the Cuche formation is so far known only from a slip-mass in the Piparo River of the Central Range (Bolli, 1957*b*, text fig. 1). In addition to *Globigerina kugleri* and *Praeglobotruncana infracretacea* which range up from the lower zone, six new planktonic species and subspecies belonging to the genera *Planomalina*, *Schackoina*, *Leupoldina*, and *Hastigerinella* appear in this zone. The benthonic fauna is transitional between the underlying *Lenticulina* (*L.*) *ouachensis ouachensis* zone and the *Biglobigerinella barri* zone of the Maridale formation. The *Leupoldina protuberans* zone is considered to be of lower Aptian age.

The Aptian-Albian Maridale formation is known only in the form of slip-masses (see *e.g.* Bartenstein, Bettenstaedt, and Bolli, 1957, text fig. 2). The formation is divided into a lower, *Biglobigerinella barri* zone, and an upper, *Praeglobotruncana robri* zone. The type locality for the former is situated in front of the estate house of Maridale Estate, Eastern Central Range (Co-ordinates N: 349360 links; E: 580120 links). A map showing the position of this locality will be given in Bartenstein, Bettenstaedt, and Bolli's paper on the Foraminifera of the Maridale formation which is now in preparation. Compared with the Cuche formation there is a marked increase in planktonic Foraminifera in a rich microfauna that also includes many Radiolaria species. Besides several planktonic species which range up from the underlying *Leupoldina protuberans* zone, there are a number

of new forms present in the *Biglobigerinella barri* zone. Three species, including the zonal marker, were found to be restricted to the zone. The age of the *Biglobigerinella barri* zone is considered to be upper Aptian-lower Albian.

Boulders of Maridale formation lithology and containing a benthonic foraminiferal fauna resembling that of the *Biglobigerinella barri* zone occur reworked in the upper Eocene Plaisance conglomerate in Pointe-a-Pierre, situated immediately northeast of the Station Road locality of the Cuche formation (see Bartenstein, Bettenstaedt, and Bolli, 1957, text fig. 2). The planktonic fauna of these boulders is sufficiently different from that of the *Biglobigerinella barri* zone to justify the erection of a separate zone. The zonal marker *Praeglobotruncana robri* and *Planomalina* cf. *apsidostroba* are both restricted to this zone. A number of species known from the *Leupoldina protuberans* and *Biglobigerinella barri* zones are absent in the *Praeglobotruncana robri* zone but appear again in the Cenomanian. The probable reason for this is a less favorable environment for these species in the *Praeglobotruncana robri* zone. The *Praeglobotruncana robri* zone is considered to be of middle-upper Albian age.

The biostratigraphic zonation of Trinidad's Upper Cretaceous has already been discussed in detail (Bolli, 1957a). Reference is made to that publication for zonal descriptions. It may be pointed out again that in the Upper Cretaceous part of the accompanying chart are plotted all those species belonging to the families Hantkeninidae, Globorotaliidae, Globotruncanidae, and Orbulinidae which were not shown on the chart of Bolli (1957a). The two range charts are, therefore, complementary.

SYSTEMATIC DESCRIPTIONS

Family **Hantkeninidae** Cushman, 1927

Subfamily **Planomaliniinae** Bolli, Loeblich, and Tappan

Genus **Planomalina** Loeblich and Tappan

Planomalina cf. **apsidostroba** Loeblich and Tappan Pl. 20, fig. 1

1946. *Planomalina apsidostroba* Loeblich and Tappan, Jour. Paleont., v. 20, No. 3, p. 257, pl. 37, figs. 22-23.

Stratigraphic range.—*Praeglobotruncana robri* zone, Maridale formation, Albian.

Locality.—Figured type (USNM 626323) from the *Praeglobotruncana robri* zone, Maridale formation; boulder from trench on east side of

the Cuche locality "Station Road" in Pointe-a-Pierre (see Bartenstein, Bettenstaedt, and Bolli, 1957, p. 11); sample K. R. 23148.

Remarks.—The Trinidad specimens clearly show the relict apertures which are typical for the genus. Compared with the holotype of *Planomalina apsidostroba*, the sutures of the Trinidad specimens are not limbate and are curved forward to a lesser degree.

***Planomalina blowi* Bolli, n. sp.**

Pl. 20, figs. 2, 3

Description.—*Shape of test.* Planispiral, biumbilicate, involute, distinctly lobate. *Wall.* Calcareous, finely perforate. *Chambers.* Spherical, four-five in last whorl, increasing fairly rapidly in size; those of earlier whorls usually not visible. *Sutures.* Radial, deeply depressed. *Aperture.* A long, low slit, bordered by a rim or lip; equatorial. Relict apertures of earlier chambers of last whorl present but often not clearly visible in examined material.

Dimension.—Largest diameter of holotype, 0.31 mm.

Stratigraphic range.—*Leupoldina protuberans* zone, Cuche formation.

Locality.—Holotype (USNM 263603) and figured paratype (USNM 266304) from the type locality of the *Leupoldina protuberans* zone, Cuche formation; Piparo River, Central Range, Trinidad (see text fig. 1 in Bolli, 1957b); sample Bo. 529.

Remarks.—*Planomalina blowi*, n. sp., differs from other Cretaceous *Planomalina* species, such as *P. maridalensis*, *P. saundersi*, and *P. escheri*, s. l., in possessing distinct spherical chambers.

The species is named for Dr. Walter H. Blow, in recognition of his contributions on planktonic Foraminifera.

***Planomalina escheri* (Kaufmann), s.l.**

Pl. 20, figs. 7, 8

1952. *Globigerinella escheri escheri* (Kaufmann), Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 46-49, text figs. 22, 23.

1952. *Globigerinella escheri clavata* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 49-51, pl. 1, figs. 12, 13, text figs. 24-26.

Stratigraphic range.—*Biglobigerinella barri* zone, Maridale formation to *Abathomphalus mayaroensis* zone, Guayaguayare formation.

Locality.—Figured hypotypes (USNM 626319-20) from the *Globotruncana concavata* zone, Naparima Hill formation; Texaco well Marac No. 1, south Trinidad; from core 8332-62 feet.

Remarks.—Reference is made to Bronnimann (1952a) who described the subspecies *Globigerinella escheri escheri* and *G. escheri clavata*. The two subspecies are closely related and transitional forms are common

(Bronnimann, 1952a, p. 48). According to Bronnimann they have identical stratigraphic ranges. The present writer agrees with this though he finds the ranges to be more extended than those proposed by Bronnimann. Although no relict apertures could be seen on the available rather poorly preserved material, it is likely that they are present, as it is the case in other Cretaceous planispiral planktonic species. It is for this reason that the species is here placed in *Planomalina*.

Planomalina maridalensis Bolli, n. sp.

Pl. 20, figs. 4-6

Description.—*Shape of test*. Planispiral, biumbilicate, early whorls only partly visible, equatorial periphery distinctly lobate, axial periphery rounded. *Wall*. Calcareous, finely perforate. *Chambers*. Spherical in early stage, becoming somewhat compressed laterally in last whorl. About 10 chambers arranged in $2-2\frac{1}{2}$ whorls; the four-five slightly elongate chambers of the last whorl increase fairly rapidly in size. Their longest axis is directed slightly forward. *Sutures*. Radial to oblique. *Aperture*. A medium to low arch, bordered by a lip or rim, equatorial. Relict apertures of penultimate and earlier chambers visible in well-preserved specimens.

Dimension.—Largest diameter of holotype, 0.32 mm.

Stratigraphic range.—*Biglobigerinella barri* zone, Maridale formation.

Locality.—Holotype (USNM 626329) and figured paratypes (USNM 626330-31) from the type locality of the *Biglobigerinella barri* zone, Maridale formation; Maridale Estate, in front of estate house, Eastern Central Range, Trinidad (Co-ordinates N: 349360 links; E: 580120 links); sample Bo. 530.

Remarks.—*Planomalina maridalensis* Bolli, n. sp., differs from *P. saundersi* Bolli, n. sp., in having laterally compressed instead of elongated and somewhat pointed chambers.

Planomalina messinae messinae (Bronnimann)

1952. *Globigerinella messinae messinae* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 42-44, pl. 1, figs. 6, 7, text figs. 20a-g.

Stratigraphic range.—*Globotruncana fornicata* zone, Naparima Hill formation to *Abathomphalus mayaroensis* zone, Guayaguayare formation.

Remarks.—Although no relict apertures are visible on the rather poorly preserved material, it is probable that they are present as in other Cretaceous planispiral planktonic species. It is for this reason that the present author places this subspecies and also *Globigerinella messinae subcarinata* Bronnimann in the genus *Planomalina*.

Planomalina messinae subearinata (Bronnimann)

1952. *Globigerinella messinae subearinata* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 44-45, pl. 1, figs. 10, 11, text figs. 21a-m.

Stratigraphic range.—*Abathomphalus mayaroensis* zone, Guayaguayare formation.

Remarks.—See remarks under *Planomalina messinae messinae*.

Planomalina saundersi Bolli, n. sp.

Pl. 20, figs. 9-11

Description.—*Shape of test*. Planispiral, stellate, biumbilicate, evolute. *Wall*. Calcareous, finely perforate. *Chambers*. Spherical in early stage, in last whorl becoming more and more elongate and pointed at the outer end; 12-15 chambers arranged in $2\frac{1}{2}$ whorls. The five-six chambers of the last whorl increase fairly rapidly in size. The position of the last chamber is often slightly oblique. *Sutures*. Radial, depressed. *Aperture*. A long, low slit, bordered by a rim or lip, equatorial. Relict apertures of earlier chambers of last whorl present but often not clearly visible in examined material.

Dimension.—Largest diameter of holotype, 0.36 mm.

Stratigraphic range.—*Biglobigerinella barri* zone, Maridale formation.

Locality.—Holotype (USNM 626307) and figured paratypes (USNM 626305-6) from the type locality of the *Biglobigerinella barri* zone, Maridale formation; Maridale Estate, in front of estate house, Eastern Central Range, Trinidad (Co-ordinate N: 349360 links; E: 580120 links); sample Bo. 530.

Remarks.—*Planomalina saundersi* Bolli, n. sp., resembles *Hastigerinella subcretacea* Tappan in general shape but differs in being planispiral and in having the chambers of the last whorl more pointed at the outer end. It differs from other Cretaceous *Planomalina* species in possessing more elongate chambers.

The species is named for Mr. John B. Saunders in recognition of his contributions on Trinidad foraminiferal faunas.

Planomalina turrensis (Bronnimann)

1952. *Globigerinella turrensis* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 51-52, pl. 1, figs. 4, 5, text figs. 27a-m.

Stratigraphic range.—*Globigerina washtensis* zone to *Rotalipora appenninica appenninica* zone, Gautier formation.

Remarks.—The specimens described by Bronnimann from the Gautier formation are rather poorly preserved, the umbilical areas often filled with

matrix. The distinct, arched, equatorial aperture of the last chamber reaches from one umbilical area into the opposite. This would suggest that relict apertures in earlier chambers are probably present, as is the case in other Cretaceous planispiral planktonic species. It is for this reason that *Globigerinella tururensis* is here placed in the genus *Planomalina*.

Genus **Hastigerinoides** Bronnimann

Hastigerinoides alexanderi (Cushman)

1952. *Hastigerinoides alexanderi* (Cushman), Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 53-54, text figs. 28a-m.

Stratigraphic range.—*Globotruncana concavata* zone, Naparima Hill formation.

Genus **Biglobigerinella** Lalicker

Biglobigerinella barri Bolli, Loeblich, and Tappan

1957. *Biglobigerinella barri* Bolli, Loeblich, and Tappan, U. S. Nat. Mus., Bull. 215, p. 25, pl. 1, figs. 13-18b.

Stratigraphic range.—*Biglobigerinella barri* zone, Maridale formation.

Subfamily **Hantkeniniinae** Cushman

Genus **Schackoina** Thalmann

Schackoina gandolfii Reichel

Pl. 20, figs. 12-18

1947. *Schackoina gandolfii* Reichel, Eclogae Geol. Helv., v. 40, No. 2, p. 397-400, text figs. 3a-g, 6 No. 3.

1952. *Hastigerinoides robri* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 55, pl. 1, figs. 8, 9, text figs. 29a-f.

Stratigraphic range.—*Rotalipora appenninica appenninica* zone, Gautier formation to *Globotruncana renzi* zone, Naparima Hill formation.

Locality.—Figured hypotypes (USNM 626341-47) from the type locality of the *Rotalipora appenninica appenninica* zone, Gautier formation; in the Gautier River (right side branch of Cunapo River), at junction of waterfall branch, north of Chert Hill, 1¼ miles southeast of Mamon Guaico-Tamana Road, Eastern Central Range, Trinidad (Coordinates N: 331460 links; E: 520400 links); sample K. R. 8385A.

Remarks.—It was pointed out (Bolli, 1957b, p. 273) that the specimens described by Bronnimann (1952a) are likely to belong to *Schackoina*. A close examination of many specimens, of which a few are figured here, confirmed this assumption. Further, *Hastigerinoides robri* appears to be synonymous with *Schackoina gandolfii*.

Schackoina multispinata (Cushman and Wickenden) Pl. 20, fig. 19

1950. *Hantkenina multispinata* Cushman and Wickenden, Contr. Cushman Lab. Foram. Res., v. 6, pt. 2, p. 40, pl. 6, figs. 4-6.

Stratigraphic range.—*Abathomphalus mayaroensis* zone, Guayaguayare formation.

Locality.—Figured hypotype (USNM 626340) from the *Abathomphalus mayaroensis* zone, Guayaguayare formation; Texaco well Guayaguayare No. 163, southeast Trinidad; from core 5588-98 feet.

Schackoina pustulans pustulans Bolli

1958. *Schackoina pustulans pustulans* Bolli, Eclogae Geol. Helv., v. 50, No. 2 (1957), p. 274, pl. 1, figs. 1-4.

Stratigraphic range.—*Leupoldina protuberans* zone, Cuche formation to *Rotalipora appenninica appenninica* zone, Gautier formation.

Schackoina pustulans quinquecamerata Bolli

1958. *Schackoina pustulans quinquecamerata* Bolli, Eclogae Geol. Helv., v. 50, No. 2 (1957), p. 274, pl. 1, figs. 6, 7.

Stratigraphic range.—*Leupoldina protuberans* zone, Cuche formation to *Rotalipora appenninica appenninica* zone, Gautier formation.

Schackoina reicheli Bolli

1958. *Schackoina reicheli* Bolli, Eclogae Geol. Helv., v. 50, No. 2 (1957), p. 275, pl. 1, figs. 8-10.

Stratigraphic range.—*Leupoldina protuberans* zone, Cuche formation to *Biglobigerinella barri* zone, Maridale formation.

Leupoldina protuberans Bolli

Pl. 20, fig. 20

1958. *Leupoldina protuberans* Bolli, Eclogae Geol. Helv., v. 50, No. 2 (1957), p. 277, pl. 2, figs. 1-13.

Stratigraphic range.—*Leupoldina protuberans* zone, Cuche formation to *Rotalipora appenninica appenninica* zone, Gautier formation.

Locality.—Figured hypotype (USNM 626348) from the type locality of the *Rotalipora appenninica appenninica* zone, Gautier formation; in the Gautier River (right side branch of Cunapo River), at junction of waterfall branch, north of Chert Hill, 1¼ miles southeast of Mamon Guatico-Tamana Road, Eastern Central Range, Trinidad (Co-ordinates N: 331460 links; E: 520400 links); sample K. R. 8385A.

Family **Globorotaliidae** Cushman, 1927Genus **Praeglobotruncana** Bermudez**Praeglobotruncana crassa** Bolli, n. sp.

Pl. 21, figs. 1, 2

Description.—*Shape of test*. Low trochospiral, equatorial periphery lobate. *Wall*. Calcareous, finely perforate. *Chambers*. Spherical in early stage, becoming slightly compressed laterally in the final whorl, giving the test a "thick" appearance. Approximately 15 chambers arranged in about three whorls. The five chambers of the last whorl increase moderately in size. *Sutures*. Radial, depressed on spiral and umbilical side. *Umbilicus*. Narrow, deep. *Aperture*. A low arch, interiomarginal, umbilical-extraumbilical. *Coiling*. Random.

Dimension.—Largest diameter of holotype, 0.44 mm.

Stratigraphic range.—*Globotruncana inornata* zone to *Globotruncana concavata* zone, Naparima Hill formation.

Locality.—Holotype (USNM 626315) and figured paratype (USNM 626316) from the *Globotruncana renzi* zone, Naparima Hill formation; Texaco well Marac No. 1, south Trinidad; from core 9347-9403 feet.

Remarks.—*Praeglobotruncana crassa*, n. sp., differs from *P. gautierensis* in possessing only five chambers in the last whorl, in having the chambers slightly compressed laterally, and in the smaller and deeper umbilicus.

Praeglobotruncana gautierensis (Bronnimann)

Pl. 21, figs. 3-6

1952. *Globigerina gautierensis* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 11-14, pl. 1, figs. 1-3, text figs. 2a-m.

Stratigraphic range.—*Biglobigerinella barri* zone, Maridale formation to *Rotalipora appenninica appenninica* zone, Gautier formation.

Locality.—Figured paratypes (USNM 626309-10) from the type locality of the *Rotalipora appenninica appenninica* zone, Gautier formation; in the Gautier Rive (right side branch of Cunapo River), at junction of waterfall branch, north of Chert Hill, 1¼ miles southeast of Mamon Guaico-Tamana Road, Eastern Central Range, Trinidad (Co-ordinates N: 331460 links; E: 520400 links); sample K. R. 8385A. Figured hypotypes (USNM 626324, 626328) from the *Praeglobotruncana robri* zone, Maridale formation; boulder from trench on east side of the Cuche locality "Station Road" in Pointe-a-Pierre, Trinidad (see Bartenstein, Bettenstaedt, and Bolli, 1957, p. 11); sample K. R. 23148.

Remarks.—Examination of better preserved material shows that the forms described by Bronnimann as *Globigerina gautierensis* and *Globigerina cretacea* possess distinctly interiomarginal, umbilical-extraumbilical apertures and thus belong in the genus *Praeglobotruncana*. Typical *P. gautierensis* have six-seven chambers in the last whorl. Similar forms with only five chambers are here described as *P. cf. gautierensis*. These forms have a slightly different stratigraphic range. Bronnimann (1952a, p. 14, text fig. 3) described such forms as *Globigerina cretacea* d'Orbigny.

Praeglobotruncana cf. gautierensis (Bronnimann) Pl. 21, figs. 7, 8
1952. *Globigerina cretacea* d'Orbigny, Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 14-16, text figs. 3a-m.

Stratigraphic range.—*Globigerina wasbitensis* zone, Gautier formation to *Globotruncana renzi* zone, Naparima Hill formation.

Locality.—Figured type (USNM 626311) from the type locality of the *Rotalipora appenninica appenninica* zone, Gautier formation; in the Gautier River (right side branch of Cunapo River), at junction of waterfall branch, north of Chert Hill, 1¼ miles southeast of Mamon Guatico-Tamana Road, Eastern Central Range, Trinidad (Co-ordinates N: 331460 links; E: 520400 links); sample K. R. 8385A. Figured type (USNM 626312) from the *Rotalipora appenninica appenninica* zone, Gautier formation; Trinidad Petroleum Development well Moruga No. 15, south Trinidad; core 9579-98 feet.

Remarks.—See under *Praeglobotruncana gautierensis*.

Praeglobotruncana infracretacea (Glaessner) Pl. 21, figs. 9-10; Pl. 22, fig. 1
1937. *Globigerina infracretacea* Glaessner, Studies in Micropaleontology, Univ. Moscow, p. 28, pl. 1.

Stratigraphic range.—*Lenticulina (L.) ouachensis ouachensis* zone, Cuche formation to *Praeglobotruncana robri* zone, Maridale formation.

Locality.—Figured hypotypes (USNM 626295-96) from the *Lenticulina (L.) ouachensis ouachensis* zone, Cuche formation; Plaisance Hill West, on the east side of the tennis court in the General Manager's residence, Pointe-a-Pierre, Trinidad (see Bartenstein, Bettenstaedt, and Bolli, 1957, u. 12); sample Rz. 437. Figured specimen with fewer chambers than the typical forms (USNM 626294) from the Remanie Boulder bed, outcrop on the coast, about 450 feet northeast of the Pointe-a-Pierre Bathing Jetty, Trinidad (see Bartenstein, Bettenstaedt, and Bolli, 1957, p. 12); sample K. 8187A.

***Praeglobotruncana modesta* Bolli, n. sp.**

Pl. 22, fig. 2

Description.—*Shape of test*. Small, low trochospiral, equatorial periphery lobate, axial periphery rounded. *Wall*. Calcareous, finely perforate. *Chambers*. Small, spherical, about 12-15, arranged in two-three whorls. The seven-eight chambers of the last whorl increase slowly in size. *Sutures*. Radial, depressed on spirial and umbilical side. *Umbilicus*. Fairly wide. *Aperture*. A low arch, interiomarginal, umbilical-extraumbilical. *Coiling*. Random.

Dimension.—Largest diameter of holotype, 0.21 mm.

Stratigraphic range.—*Biglobigerinella barri* zone, Maridale formation to *Rotalipora appenninica appenninica* zone, Gautier formation.

Locality.—Holotype (USNM 626308) from the type locality of the *Rotalipora appenninica appenninica* zone, Gautier formation; in the Gautier River (right side branch of Cunapo River), at junction of waterfall branch, north of Chert Hill, 1¼ miles southeast of Mamon Guaiico-Tamana Road, Eastern Central Range, Trinidad (Co-ordinates N: 331460 links; E: 520400 links), sample K. R. 8385A.

Remarks.—*Praeglobotruncana modesta*, n. sp., differs from *P. gautierensis* and *P. rohri* in its much smaller size and more open umbilicus.

***Praeglobotruncana planispira* (Tappan)**

Pl. 22, figs. 3, 4

1943. *Globigerina planispira* Tappan, Jour. Paleont., v. 17, No. 5, p. 513, pl. 83, fig. 3.

Stratigraphic range.—*Globotruncana inornata* zone to *Globotruncana stuarti* zone, Naparima Hill formation.

Locality.—Figured hypotypes (USNM 626317-18) from the *Globotruncana inornata* zone, Naparima Hill formation; Trinidad Petroleum Development well Moruga No. 15, south Trinidad; from core 6980-7005 feet.

Remarks.—*Praeglobotruncana planispira* has a distinct interiomarginal, umbilical-extraumbilical aperture and is, therefore, removed from the genus *Globigerina* under which it was described originally. Typical specimens are restricted in Trinidad to the *Globotruncana inornata* zone, though specimens that probably belong to this species are found throughout the Naparima Hill formation.

***Praeglobotruncana rohri* Bolli, n. sp.**

Pl. 22, figs. 5-7

Description.—*Shape of test*. Low trochospiral, equatorial periphery slightly lobate, axial periphery rounded. *Wall*. Calcareous, finely perforate.

Chambers. Spherical in early stage, later becoming somewhat compressed on the anterior and posterior ends; 20-25 chambers, arranged in three whorls; the seven-nine chambers of the last whorl increase moderately in size. *Sutures.* Radial, depressed on spiral and umbilical side. *Umbilicus.* Fairly narrow, deep. *Aperture.* A long, medium to low arch with a rim above, interiomarginal, umbilical-extraumbilical. *Coiling.* Ratio of dextral to sinistral coiling approximately 2:1.

Dimension.—Largest diameter of holotype, 0.39 mm.

Stratigraphic range.—*Praeglobotruncana robri* zone, Maridale formation.

Locality.—Holotype (USNM 626326) and figured paratypes (USNM 626325, 626327) from the *Praeglobotruncana robri* zone, Maridale formation; boulder from trench on east side of the Cucho locality "Station Road" in Pointe-a-Pierre (see Bartenstein, Bettenstaedt, and Bolli, 1957, p. 11); sample K. R. 23148.

Remarks.—*Praeglobotruncana robri*, n. sp., resembles *Rotalipora roberti* (Gandolfi) in general shape and number and arrangement of chambers. It differs, however, from this species in having a narrower umbilicus and in the absence of supplementary sutural apertures.

The species is named for Dr. Karl Rohr in recognition of his extensive geological work in Trinidad, B.W.I.

Family Globotruncanidae Brotzen, 1942

Genus *Rugoglobigerina* Bronnimann

Rugoglobigerina hantkeninoides (Bronnimann)

1952. *Plummerella hantkeninoides hantkeninoides* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 37-39, pl. 3, figs. 1-3, text figs. 17a-k.

1952. *Plummerella hantkeninoides costata* Bronnimann, *ibid.*, p. 39-40, pl. 3, figs. 4-6; text figs. 18a-c.

1952. *Plummerella hantkeninoides inflata* Bronnimann, *ibid.*, p. 40-42, pl. 3, figs. 7-9, text figs. 19a-m.

Stratigraphic range.—*Abathomphalus mayaroensis* zone, Guayaguaysera formation.

Remarks.—*Plummerella* was found to be a homonym and the name was changed by Bronnimann (1952b) to *Plummerita*. Bolli, Loeblich, and Tappan (1957) placed *Plummerita* in synonymy with *Rugoglobigerina*. The three subspecies erected by Bronnimann have an identical stratigraphic distribution which is shown on the accompanying range chart under *Rugoglobigerina hantkeninoides*, s. l.

Rugoglobigerina macrocephala Bronnimann

1952. *Rugoglobigerina macrocephala macrocephala* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 25-27, pl. 2, figs. 1-3, text figs. 9a-s.

1952. *Rugoglobigerina macrocephala ornata* Bronnimann, *ibid.*, p. 27-28, pl. 2, figs. 4-6, text figs. 10a-i.

Stratigraphic range.—*Globotruncana inornata* zone, Naparima Hill formation to *Abathomphalus mayaroensis* zone, Guayaguayare formation.

Remarks.—The stratigraphic ranges of Bronnimann's two subspecies are almost identical; on the accompanying range chart they are combined under *Rugoglobigerina macrocephala, s. l.*

Rugoglobigerina reicheli Bronnimann

1952. *Rugoglobigerina reicheli reicheli* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 18-20, pl. 3, figs. 10-12, text figs. 4a-m., 5a-i.

1952. *Rugoglobigerina reicheli pustulata* Bronnimann, *ibid.*, p. 20-23, pl. 2, figs. 7-9, text figs. 6a-m, 7a-i.

1952. *Rugoglobigerina reicheli hexacamerata* Bronnimann, *ibid.*, p. 23-25, pl. 2, figs. 10-12, text fig. 8.

Stratigraphic range.—*Globotruncana stuarti* zone, Naparima Hill formation to *Abathomphalus mayaroensis* zone, Guayaguayare formation.

Remarks.—The three closely related subspecies have identical stratigraphic ranges which are shown on the accompanying range chart under *Rugoglobigerina reicheli, s. l.*

Rugoglobigerina rugosa (Plummer)

1926. *Globigerina rugosa* Plummer, Texas Univ. Bull. 2644, p. 38, pl. 2, fig. 10.

Stratigraphic range.—*Globotruncana inornata* zone, Naparima Hill formation to *Abathomphalus mayaroensis* zone, Guayaguayare formation.

Remarks.—Reference is made to Bronnimann (1952a) who split *Rugoglobigerina rugosa* into three closely related subspecies: *R. rugosa rugosa*, *R. rugosa pennyi*, and *R. rugosa rotundata*. The stratigraphic ranges of the three subspecies are almost identical; on the accompanying range chart they are shown under *R. rugosa, s. l.*

Rugoglobigerina scotti (Bronnimann)

1952. *Trititella scotti* Bronnimann, Bull. Amer. Paleont., v. 34, No. 140, p. 57-58, pl. 4, figs. 4-6, text figs. 30a-m.

Stratigraphic range.—*Abathomphalus mayaroensis* zone, Guayaguayare formation.

Remarks.—Bolli, Loeblich, and Tappan (1957) placed *Trititella* in synonymy with *Rugoglobigerina*.

Family **Orbulinidae** Schultze, 1854Subfamily **Globigerininae** Carpenter, 1862Genus **Globigerina** d'Orbigny**Globigerina cretacea** d'Orbigny

Pl. 22, figs. 8, 9.

1840. *Globigerina cretacea* d'Orbigny, Soc. Géol. France, Mém., v. 4, No. 1, p. 34, pl. 3, figs. 12-14.

Stratigraphic range.—*Rotalipora appenninica appenninica* zone, Gautier formation to *Globotruncana renzi* zone, Naparima Hill formation.

Locality.—Figured hypotypes (USNM 626313-14) from the *Globotruncana inornata* zone, Naparima Hill formation; Trinidad Petroleum Development well Moruga No. 15, south Trinidad from core 6980-7005 feet.

Remarks.—The figured specimens compare well with D'Orbigny's drawings. The apertures are distinctly umbilical. It appears likely that the Rugoglobigerinas have developed from this species.

Globigerina graysonensis Tappan

Pl. 23, figs. 1, 2

1940. *Globigerina graysonensis* Tappan, Jour. Paleont., v. 14, No. 2, p. 122, pl. 19, figs. 15-17.

Stratigraphic range.—*Lenticulina* (L.) *ouachensis ouachensis* zone, Cuche formation; probably extending into the Aptian/Albian.

Locality.—Figured hypotypes (USNM 626292-93) from the *Lenticulina* (L.) *ouachensis ouachensis* zone, Cuche formation; Trinidad Northern Areas well Montserrat No. 1, Western Central Range, Trinidad; from cores 7102-7262 feet.

Remarks.—*Globigerina graysonensis* is a small form with considerable variation in the convexity of the spiral side (e. g. figs. 16 and 17 in Tappan, 1940).

Globigerina kugleri Bolli, n. sp.

Pl. 23, fig. 3-5

Description.—*Shape of test*. Small, trochospiral, spiral side slightly to distinctly convex, equatorial periphery lobate. *Wall*. Calcareous, finely perforate. The specimens found in the Cuche and Toco formations are invariably pyritised. *Chambers*. Spherical in early stage, may become slightly compressed laterally in the last whorl; about 10 arranged in 2½ whorls; the usual four chambers of the last whorl increase fairly rapidly in size. *Sutures*. On spiral and umbilical side radial, depressed. *Umbilicus*. Fairly small. *Aperture*. A distinct, fairly high arch, often with a rim; interior-marginal, umbilical. *Coiling*. Random.

Dimension.—Largest diameter of holotype, 0.28 mm.

Stratigraphic range.—*Lenticulina* (*L.*) *barri* zone, Toco formation to *Leupoldina protuberans* zone, Cuche formation.

Locality.—Holotype (USNM 626289) and figured paratypes (USNM 626290-91) from the *Lenticulina* (*L.*) *ouachensis ouachensis* zone, Cuche formation; Trinidad Northern Areas well Montserrat No. 1, Western Central Range, Trinidad; from cores 7102-7262 feet.

Remarks.—The only other known Cretaceous *Globigerina* species that has an arrangement of chambers comparable to that of *Globigerina kugleri*, n. sp., is *Globigerina washitensis* Carsey. It differs from this species in its smaller size and in the absence of the characteristic honeycomb pattern on the chamber surface.

The species is named for Dr. Hans G. Kugler in recognition of his contributions to the geology of Trinidad.

***Globigerina washitensis* Carsey**

Pl. 23, figs. 6, 7

1926. *Globigerina washitensis* Carsey, Texas Univ. Bull., No. 2612, p. 44, pl. 8, fig. 2.

Stratigraphic range.—*Globigerina washitensis* zone, Gautier formation.

Locality.—Figured hypotypes (USNM 626321-22) from the *Globigerina washitensis* zone, Gautier formation; Texaco well Marac No. 1, south Trinidad; from core 9853-91 feet.

Remarks.—The Trinidad specimens clearly show the characteristic honeycomb pattern on the chamber surface.

Genus ***Hastigerinella*** Cushman

***Hastigerinella* aff. *subcretacea* Tappan**

Pl. 23, figs. 10-13

1943. *Hastigerinella subcretacea* Tappan, Jour. Paleont., v. 17, No. 5, p. 513-14, pl. 83, figs. 4a-c.

Stratigraphic range.—*Leupoldina protuberans* zone, Cuche formation to *Rotalipora appenninica appenninica* zone, Gautier formation.

Locality.—Figured types (USNM 626299-626302) from the type locality of the *Leupoldina protuberans* zone, Cuche formation; Piparo River, Central Range, Trinidad (see text fig. 1 in Bolli, 1957b); sample Bo. 529.

Remarks.—The Trinidad forms differ slightly from the holotype in that the last elongate chambers are more radial in position than in the holo-

type where they are inclined to be directed forward. *Hastigerinella subcretacea* appears to be closely related to *Praeglobotruncana infracretacea* (Glaessner). Figures 8 and 9 of Plate 23 show specimens that can be regarded as transitional between these two species.

No typical representatives of the genus *Hastigerinella* are known from the pre-Miocene and it can, therefore, be assumed that the Miocene-Recent species of this genus are not direct descendants from species described from the Cretaceous as *Hastigerinella*. For convenience and until clear distinguishing morphological characters can be established, the Lower Cretaceous species is here, for the time being, included in *Hastigerinella*.

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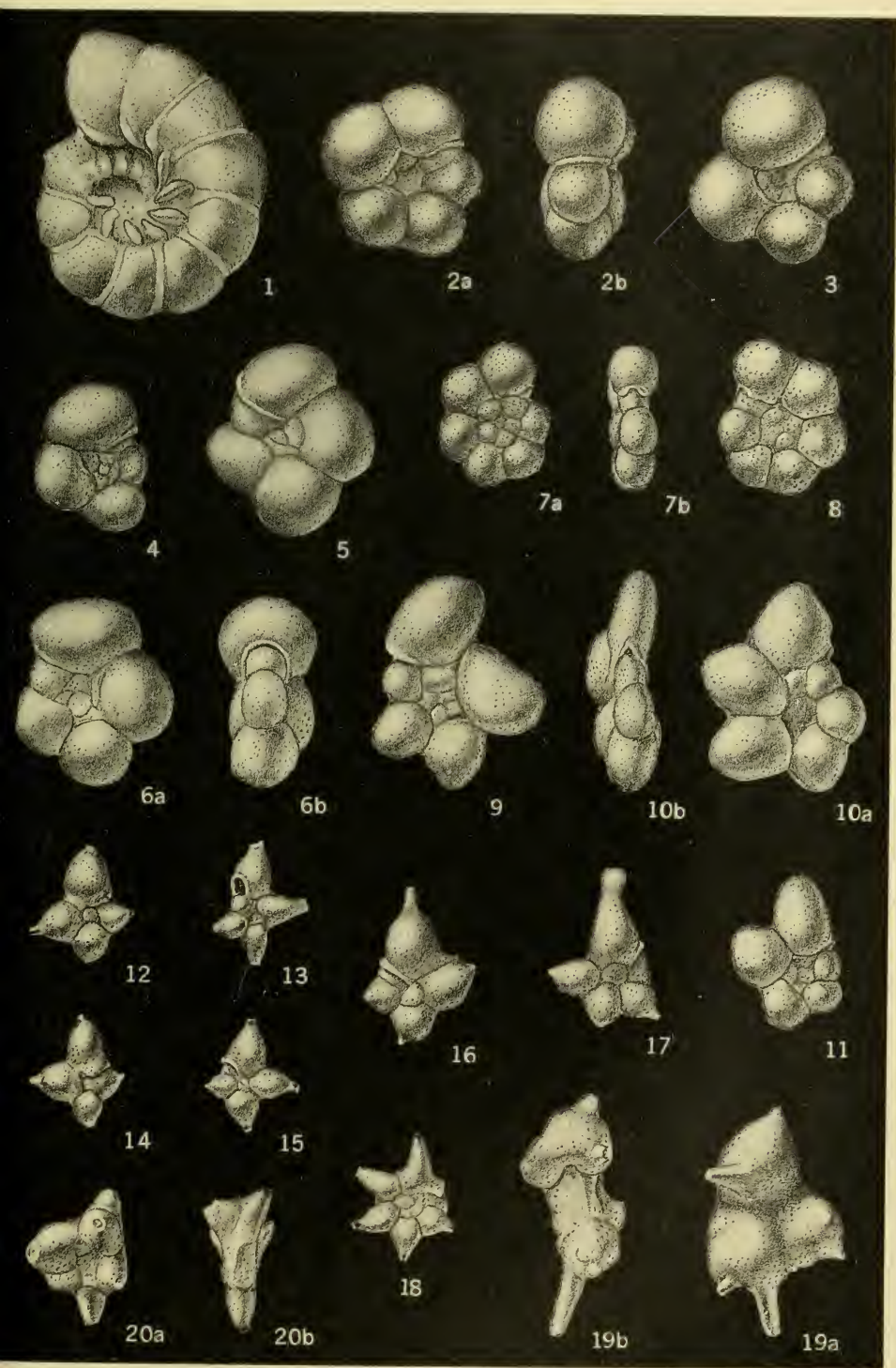
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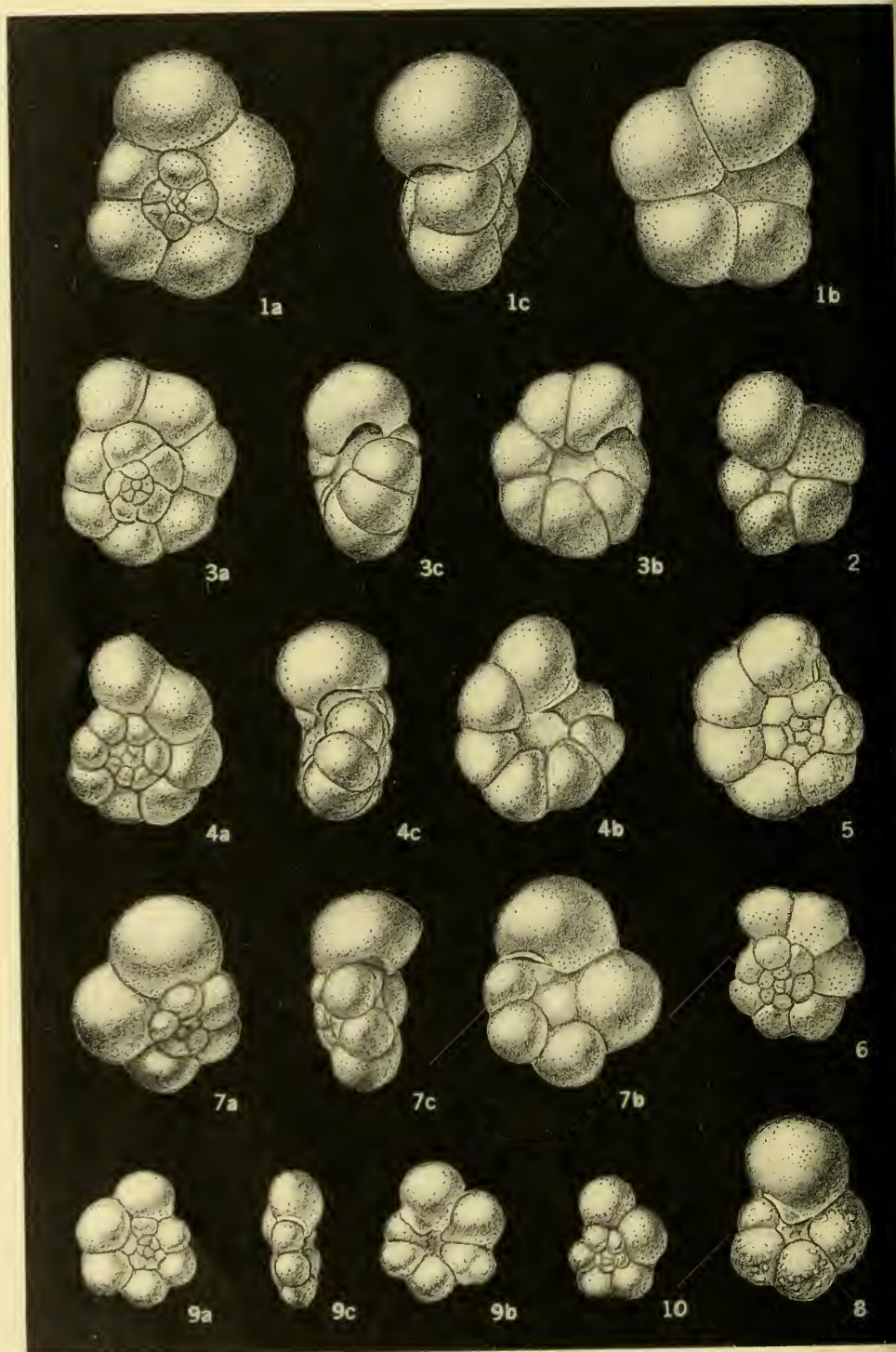
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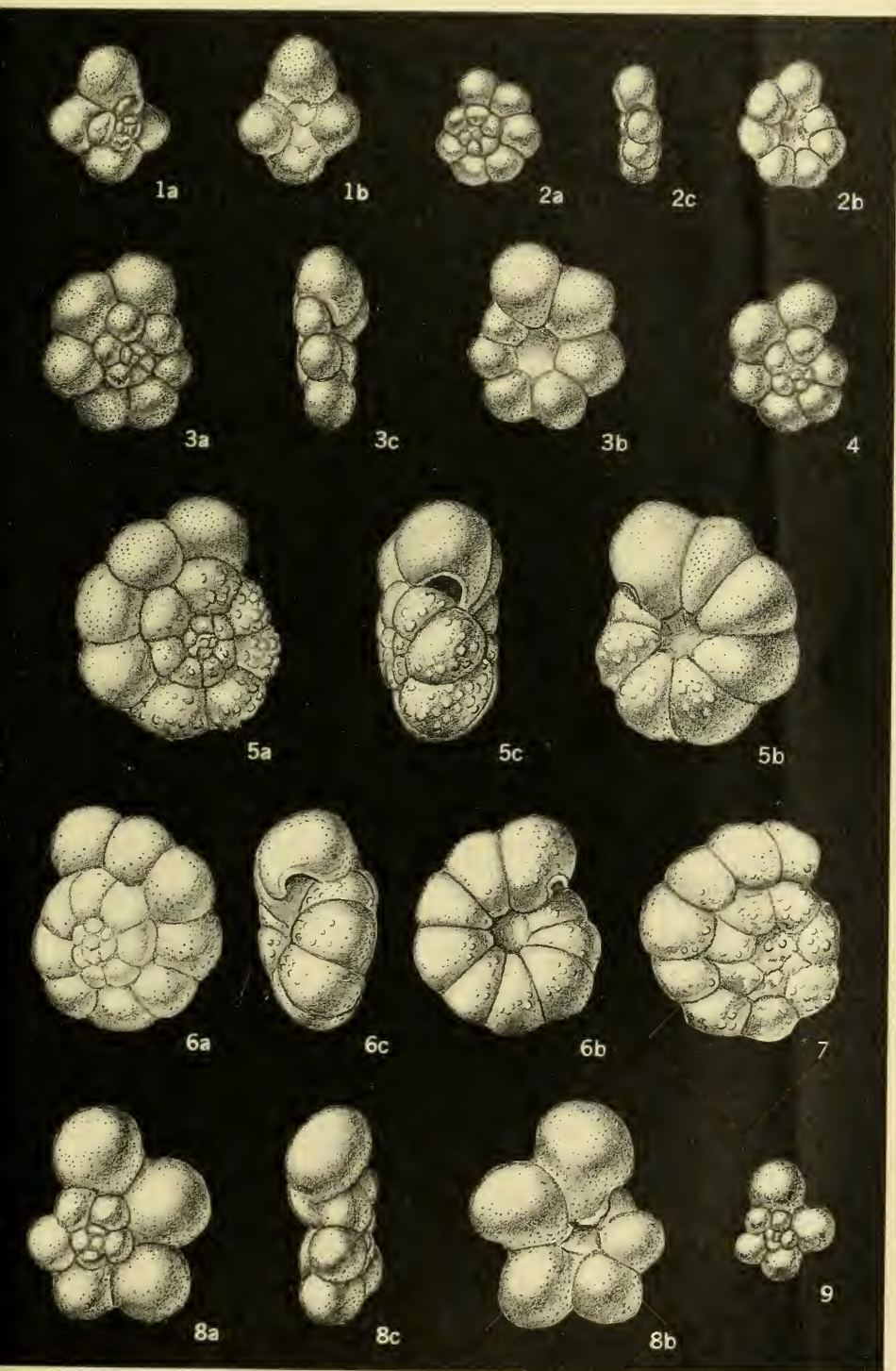
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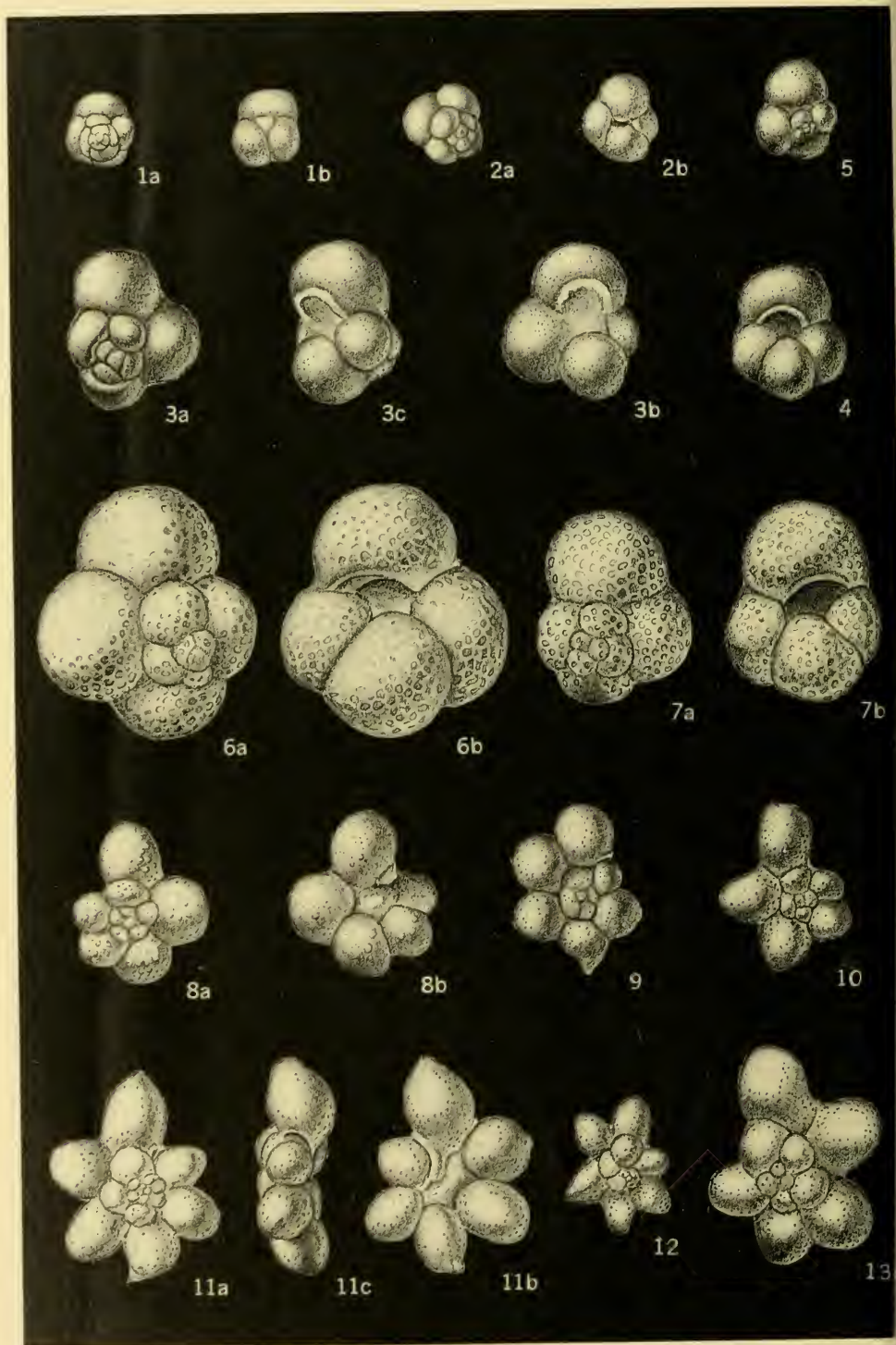
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STUDY OF SOME AMERICAN MIOCENE LAMELLIBRANCHS
AND COMPARISON WITH RELATED EUROPEAN SPECIES

By

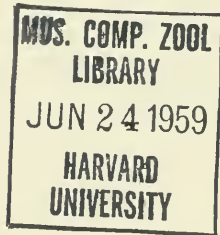
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STUDY OF SOME AMERICAN MIOCENE LAMELLIBRANCHS AND COMPARISON WITH RELATED EUROPEAN SPECIES

DENISE MONGIN

Centre National de la Recherche Scientifique
Paris, France

ABSTRACT

An analytical study of 30 species of Miocene lamellibranchs from the rich beds of Chesapeake Bay (Maryland and Virginia). A comparison with related forms of western Europe, although furnishing interesting systematic and biologic conclusions, does not establish any equivalents between the Miocene stages of the two continents.

OUTLINE

- I. (1) Stratigraphic introduction and (2) summary of earlier comparisons of the two Miocenes
- II. 1. Arcidae—Glycymeridae—Vulsellidae
2. Pectinidae
3. Astartidae—Isocardiidae—Veneridae
- III. Stratigraphic remarks on the Miocene of Chesapeake Bay
- IV. Preliminary conclusions

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I. (1) STRATIGRAPHIC INTRODUCTION

The Miocene of the Atlantic Coastal Plain of the United States, that is to say, the East Coast of the continent, consists of broad, subhorizontal outcrops of sands and marls slightly inclined to the east, containing diatomaceous beds, and about 100 meters thick. They form high cliffs dominating the sea, notably at Chesapeake Bay (between Baltimore, Maryland, at the north and Yorktown, Virginia, at the south) and along the coast of Virginia, the Carolinas, and Florida.

These fossiliferous Atlantic series are divided into two different zoological subprovinces; one includes the beds to the north of Cape Hatteras, the other, the Miocene, to the south of this cape.

In the province north of Cape Hatteras, American geologists have distinguished four stages. From top to bottom they are:

Yorktown formation	}	Chesapeake group
St. Marys formation		
Choptank formation		
Calvert formation		

The beds of Chesapeake Bay are rich in mollusks and the beaches are strewn with these shells often of large size. The fauna has been fully studied by American paleontologists, such as Conrad, Dall, J. Gardner, Martin and Glenn, Mansfield, L. M. Schoonover (Kent) and H. I. Tucker-Rowland.

A large number of species abound in these "faluns", and it was impossible to examine them all in a few months' stay. It has been necessary to limit this study to the principal lamellibranchs, the most abundant or the most characteristic of the different beds described by the paleontologists.

For a comparative study between America and western Europe, I have attempted to relate the American shells to a "group" belonging to the same genus in Europe. The word "group" is to be understood in this work as analogous to subgenus, and where there is no subgenus, the group includes

close species having common characters and linked with a predominant member (for example, the group of *Pecten arcuatus* Tour. or the group of *Arca diluvii* Lk.).

But most often, the American species belong to different genera or subgenera localized in the New World, on the Atlantic seaboard, and in California. A comparative examination in such case tends toward a parallel between European and American subgenera.

At the moment, observations appear to be most interesting and fruitful from the systematic point of view, as in the case of the subgenera *Plagi-ocentium* (Pectinidae) and *Ashtarotha* (Astartidae). Thus, while the results obtained have not been conclusive as to the Miocene correlation of the two continents, the comparison of 30 specimens permits remarks of biologic and climatic interest to be made on the evolution of the groups and on the existence of zoological provinces of the Miocene.

I. (2) SUMMARY OF COMPARISONS BETWEEN THE AMERICAN AND EUROPEAN MIOCENE

1830. T. A. Conrad found the Chesapeake group equivalent to the upper Tertiary of Europe.
1836. W. B. Rogers was the first to recognize the Miocene in the Maryland beds.
1837. T. A. Conrad found a correlation between the Miocene of Maryland-Virginia and the Crag of England.
1845. Charles Lyell declared that the Chesapeake group more nearly approached the Miocene of Touraine and Bordeaux.
1845. W. Lonsdale concluded from the polyps that the climate was like that of the Faluns of Touraine but colder than that of Bordeaux.
1881. A. Heilprin established the Virginian (middle Atlantic Miocene) as equivalent to the Second Mediterranean stage of Austria and Touraine and the Marylandian as contemporary with the First Mediterranean of Saucats and Leognan.
1898. W. H. Dall wrote that the Chesapeake group corresponds to the Helvetian of Europe.
1904. W. H. Dall compared the Miocene of Maryland with the Miocene of northern Europe (Belgium, Germany, Denmark) which, however, was not so cold. He made a detailed comparative study of vertebrate and invertebrate genera. He indicated that the Mio-

- cene of Carolina more closely approached the Mediterranean Basin, but found no American equivalent to the European *Congeria* beds.
1909. The Countess Lecointre likewise analysed the genera of the two continents and reached Dall's conclusions.
1924. T. W. Vaughan thought that the Chesapeake group is Tortonian.
1924. J. Gardner wrote that the Tampa formation is equal to the Aquitanian, Chipola formation to the Langhian, Oak Grove to the Miocene of Eggenburg, Chesapeake group to the Miocene of North Germany (Tortonian) (because of the presence of *Ecphora* which, however, does not exist in Europe), Yorktown, Duplin, and Choctawatchee to the Pontian.
1924. W. P. Woodring stated that the mollusks of the Antilles and of the Mediterranean are close, especially those of the Helvetian of Italy, maximum of the transgression. The genetically identical genera in the two regions result from migration, but not along the northern shores of the Atlantic where the temperature was too cold, nor by the open sea which the larvae did not have sufficient time to cross during their short pelagic life. It is preferable to assume a series of high-lows across the southern rim of the Atlantic.
1924. G. Stefanini thought that the American Miocene, in the absence of *Clypeaster* (habitually tropical) and the presence of *Echinocardium* and of the perforate *Scutella*, can be likened to the Loire Basin.
1924. J. Cottreau, regarding the echinids of the Mediterranean, stated that the genera and species can be compared to those of the Antilles.
- 1925-1927. K. Kautsky likewise studied the affinities of the two continents, classed the European fauna in two provinces—boreal and Mediterranean—the Basin of Aquitaine being intermediate. He compared the gastropod genera especially and reached Dall's conclusions of 1904.
1933. R. C. Moore in the *Historical Geology* gave the following equivalents: Calvert=Aquitainian, Choptank=Burdigalian, St. Marys=Helvetian.
1936. W. C. Mansfield (with Stephenson and Cooke) declared that the Chesapeake group is entirely Vindobonian and that the Yorktown formation is Sahelian.

1940. N. Leriche compared the fishes and concluded that Calvert and Choptank are Burdigalian, St. Marys is Vindobonian, Yorktown and Duplin are Sahelian.
1943. J. Gardner gave a table showing other correlations (always because of *Ecphora*); Calvert is Helvetian, Choptank and St. Marys are Tortonian, and Yorktown formation would be of the Sahelian.
1956. J. McLean, Jr., studying the Foraminifera of the Yorktown formation, concluded that the Yorktown constitutes the uppermost Miocene of Virginia but cannot be compared to the terminal stages of the European Miocene, *i. e.*, Sarmatian, Pontian, or Sahelian. The Sarmatian Foraminifera form a species group different from that of the Yorktown.
1957. J. McLean, Jr., worked on the Ostracoda of the Yorktown formation and concluded that these beds seem to be closer to the *Ecphora-Cancellaria* facies of the Choctawatchee formation of Florida, than to any other fauna.

It is evident from a historical review of the question that equivalents between the Miocene of America and Europe are difficult to establish, especially by a study of the mollusks and fishes, inasmuch as malacologists and paleontologists up to the present have not reached agreement.

II. COMPARISON OF CERTAIN LAMELLIBRANCHS OF THE AMERICAN AND EUROPEAN MIOCENE

Family **ARCIDAE**

Arca (Anadara) idonea Conrad

Pl. 24, fig. 1a-d; Text-fig. 1

1832. *Arca idonea* Conrad, Fossil Shells of the Tertiary Formations North America, p. 16, pl. I, fig. 5.

1898. *Scapharca idonea* (Conrad), Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 639.

1904. *Arca (Scapharca) idonea* (Conrad), Glenn, Maryland Geol. Sur., Miocene, p. 389, pl. 106, figs. 1, 2.

1916. *Arca idonea* (Conrad), Sheldon, Paleont. Amer. vol. I, p. 41, pl. IX, figs. 14-17.

The specimens studied at the U. S. National Museum coming from two different beds show two variations in this species:

1. The specimens from St. Marys River, Maryland, (Coll. Mollusks Department, No. 13155) have 29 or 30 rather flat, closely placed ribs.

On the posterior keel, they are divided into three or four striae toward the pallial margin. Shell convexity is medium.

2. The other specimens from Jones Point, Essex County, Virginia, (Coll. Paleont.) are generally convex with prominent beak, high ligamental area, fewer (27 average) and prominent ribs separated by fairly wide interspaces; the striae of the posterior ribs often effaced.

Summing up, the *Arcas* of Virginia are generally convex, rugose, with fewer (27 instead of 29) and more prominent ribs than those of the Marylandian *Arcas*. But the specimens from these two localities have, beside variations in the same specific characters, another variability in common: their shape is never the same, either short (d. u. p.¹ longer than the d. a. p.), or long with a well-developed posterior ridge and much greater convexity.

Arca idonea is, therefore, a variable species, especially according to outcrops.

Comparison.—Noting the statement of Cossmann and Peyrot regarding the ligamental area of *Arca* (1912, fasc. 4, p. 273), one might at first suppose that the adults of *A. idonea* belong to the group of *A. turoniensis* Dujardin (in Cossmann and Peyrot, pl. 8, fig. 8) by their ligamental and circumscribed by a groove (text-fig. 1).

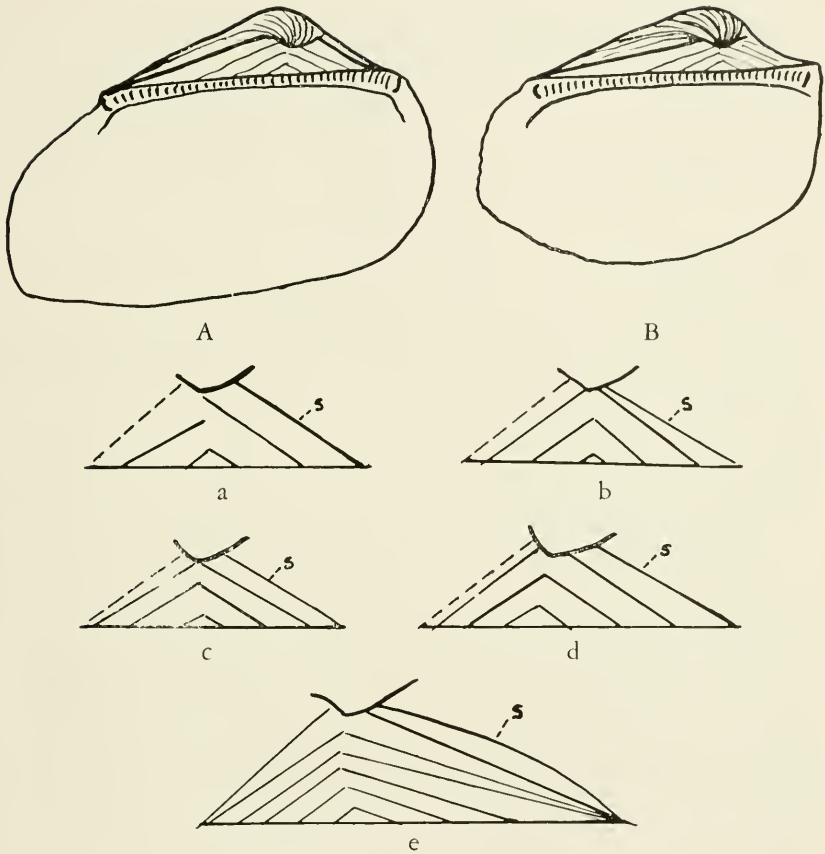
But a study of the evolution of the chevrons of this area from the young valves shows that the groove of the posterior side (s) represents in fact one-half of the first chevron. On the young (fig. a) one sees only one chevron and one posterior groove, or three grooves; then the grooves develop under the first (figs. b, c, d) and the line "s" of the first chevron is pushed backward to the limit of the posterior side (fig. e). If one counts the lines of the anterior and posterior sides, there is always an extra one on the posterior, for it lacks the groove which limits the anterior side.

Accordingly *A. idonea* belongs not to the group of *A. turoniensis* (fig. A) but to that of *A. diluvii* Lk. (fig. B) which does not have an anterior groove.

Moreover, the young forms of *A. idonea* (3 cm. of d. a. p.) are close to *A. diluvii* Lk., Miocene species of Europe, and especially to the *forma latesulcata* Nyst of the Helvetian of Belgium and Germany (Nyst, 1843, pl. 18, fig. 8; Kautsky, 1925, pl. 1, fig. 10; Glibert, 1945, p. 38; Ijspeert, 1942, p. 46, pl. 2, fig. 7).

1 d. u. p. = umbono-pallial diameter

d. a. p. = antero-posterior diameter



Text-fig. 1. Ligamental area of *Anadara*. 1A. *A. turoniensis* Duj. 1B. *A. diluvii* Lk.
 1a-1b. Evolution of the groove S limiting ligamentary area of *A. idonea* Conrad.

A. idonea and *A. latesulcata* have the same external and internal shape, the same number of ribs (25-27), but the American shells have a wider hinge, especially at the center under the beak. Finally, the specific primordial character which separates the European species from the large individuals of *A. idonea* is the sculpture of the ribs; on the posterior ridge, five or six of them have longitudinal striae. On the anterior side they are divided in two by a groove. This is not characteristic of *A. diluvii* and *A. latesulcata*.

Stratigraphic distribution of Arca diluvii Lk.—

Miocene	Helvetian-Tortonian of Italy, Austria and Eastern Europe, France, Belgium, Holland, and Germany ²
Pliocene	Rhône Valley, Algeria, Italy, England, Atlantic Coast
Pleistocene	Mediterranean
Recent	Mediterranean (excluding the Adriatic), Atlantic Ocean (Cape Verde)

Distribution of Arca latesulcata.—Helvetian of Belgium and Germany

Distribution of Arca idonea.—St. Marys formation of Maryland and Virginia, Alum Bluff of Florida

Arca (Anadara) staminea Say

Pl. 24, figs. 2 a-b

1832. *Arca staminea* Say, Amer. Conch., pt. IV, pl. 36, fig. 2.

1904. *Arca (Scapharca) staminea* (Say), Glenn, Maryland Geol. Sur., Miocene, p. 387, pl. 105, figs. 2-6.

1917. *Arca staminea* (Say), Sheldon, Paleont. Amer., vol. I, No. 1, pp. 39-40, pl. 9, figs. 7-11.

1941. *Anadara staminea* (Say), Schoonover, Bull. Amer. Paleont., vol. 25, No. 94B, p. 22, pl. I, figs. 5-7, pl. 2, fig. 4.

The last author carefully studied the species, giving its chief characters and form variations according to the zones: thicker and more inflated in zone 19 of Choptank formation than in zone 17. As to the grooves which divide the ribs, they are variable; in specimens from zone 19, they are almost absent save a few to the anterior side or to the posterior side. The division of the ribs is manifested rather as a tendency; in 20 specimens studied, only three have grooved ribs over the entire surface of the shell.

Under these conditions (with nonsulcated ribs), *A. staminea* belongs to the group of *A. turoniensis* Dujardin of the European Miocene (*in* Dollfuss and Dautzenberg, p. 350, pl. 30, figs. 17-31) and *A. cardiiformis* Basterot (of the Aquitanian-Burdigalian of Aquitania) (*in* Cossmann and Peyrot, 1912, v. 2, p. 154, pl. 8, figs. 17-21).

Analogies between *A. staminea*, *A. turoniensis*, and *A. cardiiformis*:
trapezoidal form of shell (interior view)
angular posterior side, globular shell

² The stage equivalents for the Miocene of Belgium and Germany have been taken up in the recent work of Hinsch (1952) in which, for example, the Helvetian includes the Hemmoorer Stufe, the Bolderian and the Houthaelan layer; and the Tortonian includes the Anversian.

irregular chevrons on the ligamental area
transverse nodules on the ribs which are 27 to 30 on the two
species

Differences between the species:

<i>A. staminea</i>	<i>A. turoniensis</i> and <i>cardiiformis</i>
tendency of the ribs to be divided by a longitudinal groove	ribs never divided
posterior side angular beak turned toward front	posterior side moderately angular beak slightly turned forward

The ligamental area and the chevrons cannot be compared as they are not visible in the photos of *A. turoniensis*.

The young valves greatly resemble *A. cardiiformis* Cossmann and Peyrot which is globular and trapezoidal, but the outline is, at the same time, different, and the French shell does not have the divided ribs anteriorly and posteriorly.

Horizons.—Choptank formation (zones 17 and 19) of Maryland.

Area (*Anadara*) *subrostrata* Conrad

1841. *Arca subrostrata* Conrad, Acad. Nat. Sci. Philadelphia, Proc., vol. I, p. 30.
1898. *Scapharca* (*Anadara*) *subrostrata*, Conrad, Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 655.
1904. *Arca* (*Scapharca*) *subrostrata* Conrad, Glenn, Maryland Geol. Sur., Miocene, p. 585, pl. 104, figs. 2-3.
1916. *Arca subrostrata* Conrad, Sheldon, Paleont. Amer., vol. I, No. 1, p. 51, pl. XII, figs. 1-4.
1941. *Anadara subrostrata* Conrad, Schoonover, Bull. Amer. Paleont., vol. 25, No. 94B, p. 21, pl. 1, figs. 2-4.

This species is close to three European species with grooved ribs:

- Arca sulcicostata* Nyst of the Anversian of Belgium
Arca daneyi Cossmann and Peyrot of the lower Burdigalian of Aquitania (France)
Arca umbonaria Mayer of the Helvetian of Touraine (France)

Differences between *A. subrostrata* and:

1. *A. sulcicostata* Nyst (1843, p. 257, pl. XVIII, fig. 9):
A. subrostrata is shorter as to d. a. p., its posterior margin is angular, and its ribs may be many times grooved as in the specimens of L. Schoonover. The number of chevrons is variable in this species.
2. *A. daneyi* Cossmann and Peyrot (1914, v. 2, p. 160, pl. 7, figs. 22-25) of the Burdigalian of Aquitania (France):

The d. a. p. is shorter, the posterior margin more nearly square, and the hinge thicker in the American shell.

3. *A. umbonaria* Mayer (in Dollfuss and Dautzenberg, pl. 27, figs. 13-18): This Touraine species is elongated in the antero-posterior direction, its ribs are flattened, and only those of the anterior side are grooved.

In brief, *A. subrostrata* differs from all the European *Anadaras* by its sulcated ribs over the entire surface. This is not a characteristic of the European species which have fine ribbings only at the anterior and posterior ends.

Occurrence.—Calvert formation of Maryland.

Family GLYCYMERIDAE

Three characteristic species exist in the Miocene of Maryland-Virginia:

Glycymeris parilis (Conrad), Calvert formation (zone 10).

G. americana Defrance, Yorktown formation, Pliocene and Quaternary.

G. subovata (Say), Choptank, Yorktown, and Duplin formation

Glycymeris parilis (Conrad)

1843. *Pectunculus parilis* Conrad, Acad. Nat. Sci. Philadelphia, Proc., vol. I, p. 306.

1845. *Pectunculus parilis* Conrad, Fossils Medial Tertiary, p. 64, pl. 36, fig. 2.

1904. *Glycymeris parilis* (Conrad), Glenn, Maryland Geol. Sur., Miocene, p. 393, pl. 107, figs. 1-2.

1941. *Glycymeris parilis* (Conrad), Schoonover, Bull. Amer. Paleont., vol. 25, No. 94B, p. 15, pl. 1, figs. 1-8.

This species belongs to the living group of *G. pilosus* L. (specimen studied, Coll. U. S. Nat. Mus. No. 199883) but is distinguished by its weaker convexity, its less prominent beak, and its more oval form in the umbono-pallial direction.

The ornamentation was doubtless the same, but the fossil shells of *G. parilis* do not show the fine longitudinal striae of *G. pilosus*; on the contrary, they bear inside radiating grooves habitually covered by the periostracum in the living forms.

G. parilis closely approaches *G. deshayesi* Mayer (in Glibert, 1945, p. 44, pl. 1, fig. 13) in the absence of chevrons on the ligamental area, its small beak, its oval shape in the large forms.

Note that in *Glycymeris* in general, the number of teeth is variable as is also the width of the ligamental area which grows with the form of the individual while the number of teeth decreases.

Glycymeris americana (Defrance)

1826. *Pectunculus americanus* Defrance, Dict. Sci. Nat., vol. 39, p. 225.

1832. *Glycymeris americana* (Defrance), Mansfield, Florida State Geol. Sur., Bull. 8, p. 39, pl. II, fig. 7.

1943. *Glycymeris americana* (Defrance), Gardner, U. S. Geol. Sur., Prof. Pap. 199A, p. 27, pl. 1, figs. 16-21.

1953. *Glycymeris americana* (Defrance), Nicol, Jour. Paleont., vol. 27, No. 8, p. 451-5.

From the point of view of external sculpture, this species approaches *Glycymeris saucatsensis* Mayer (*in* Cossmann and Peyrot, 1914, p. 136, pl. 7, fig. 1, 2) of the Burdigalian-Helvetian of Aquitania, both having fine radial striae on the high-rounded ribs and equally weak shell convexity.

But the two species differ in that *G. americana* has a weaker beak, effaced chevrons, and more distinct external ribs.

Note that *G. americana* is distinguished from *G. parilis* by its rounded ribs separated by broader furrows, its fine, better preserved costulation, and its weaker convexity.

European *Glycymeris* of the same group:

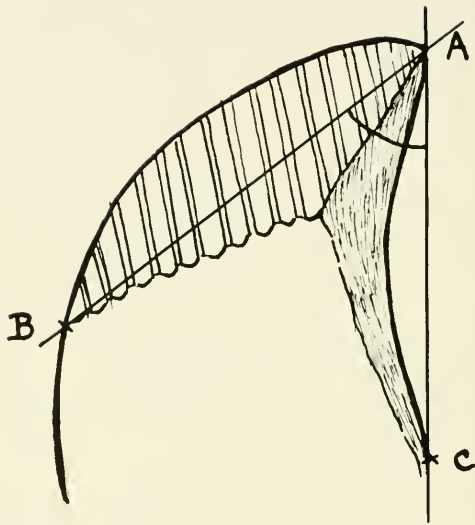
Living: *G. pilosus* L. (*in* Bucquoy, Dollfuss, and Dautzenberg, p. 199, pl. 33), equilateral form, fine growth lines, periostracum covered with brown hairs, interior of valves brown-colored. Mediterranean.

G. glycymeris L. (*in* B., D., and D., p. 195, pl. 34), inequilateral, flame brown-colored, white interior, growth folds coarse and prominent. Atlantic.

G. bimaculatus Poli (*in* B. D., and D., p. 202, pl. 35) equilateral form of large size, brown with concentric zones, more numerous and more symmetrical chevrons of the ligamental area, the latter high. Mediterranean. It represents, in my opinion, the giant form of *G. pilosus*.

Fossil: *G. pilosus deshayesi* Mayer (*in* Glibert, 1945, p. 44, pl. 1), of the European Miocene. This species is the ancestral form of *G. pilosus*. It is equivalent to *G. bimaculatus* Cossmann and Peyrot (pl. 7, fig. 3).

G. saucatsensis Mayer (*in* Cossmann and Peyrot, p. 6, figs. 29, 30) of the Burdigalian-Helvetian of Bordeaux.



Text-fig. 2. *Isognomon maxillata* (Lk.). Diagram showing the apical angle: 53° .

Family VULSELLIDAE

Isognomon maxillata (Lamarck)

Pl. 24, figs. 3a-b; Text-fig. 10

1819. *Perna maxillata* Lamarck, Animaux sans vertèbres, t. VII, p. 142, 2^{ème} éd., Deshayes, 1836 t. VII, p. 78.

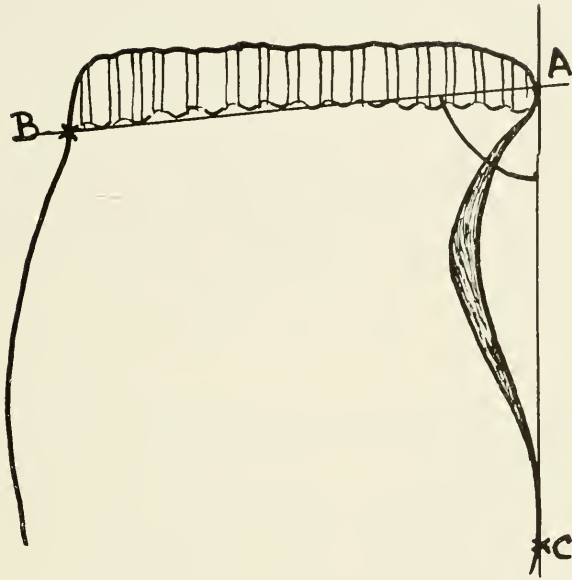
1840. *Perna maxillata* Lamarck, Conrad, Fossils Medial Tertiary, p. 52, pl. 27, fig. 1.

1904. *Melina maxillata* (Lamarck), Glenn, Maryland Geol. Sur., Miocene, p. 383, pls. 52, 53.

1898. *Perna* cf. *maxillata* Lamarck, Sacco, Terziari Piemonte e Liguria, t. XXV, p. 26, pl. VII, fig. 1.

Thirty-nine specimens studied of which four were complete and three were internal molds (Coll. Nat. Museum, Wash., D. C.)

Description.—Large *Mytilus*-shaped shell, with pointed beak and posterior side forming a regularly rounded arc; ligamental area generally broad, but sometimes narrow and long, the specific character is the apical angle (Text-fig. 2) which varies between 42 and 53 degrees. Number of grooves are generally 16 to 19.



Text-fig. 3. *Isognomon soldanii* (Deshayes). Diagram showing the apical angle: 85°.

Dimensions of adult specimen.—

d. u. p. 19.9 cm. d. a. p. 10.5 cm.
 thickness 5.5 cm. (the greatest width)

Similarities and differences.—In 1836, Deshayes separated this species from the European shell, *P. soldanii* Deshayes, which has a greater number of ligamentary grooves. This character is clear in Sacco's figures (vol. XXV, pl. 12, figs. 2-6) who, however, considered the number of grooves of little importance and thought that *P. soldanii* is a variation of *P. maxillata* Lk. In fact, he found in Italy, many shells provided with the more widely spaced ligamental grooves as in the American species.

A more important character is that of the shape and of the apical angle: *I. maxillata* is always ovoid, *Mytilus*-formed, with an apical angle of 42 to 53 degrees, while *I. soldanii* is quadrangular, with an apical angle of 85 degrees (Text-fig. 3). To measure this angle, the line AB is arbitrarily traced from the beak to the inferior limit of the ligamental area. Good figures of *I. soldanii* are printed in Hoernes (Tertiar Wien, 1856, p. 378, pl. 53, fig. 1) and in Sacco (Terziari Piemonte e Liguria, vol.

XXV, pl. 7, fig. 3). The figures 4 and 5 of Sacco are young specimens which have a ligamental area not entirely developed, an incomplete number of pits, and a mytiloid form which will change later.

Horizons.—Lower Miocene of New Jersey, Calvert, Choptank, and St. Marys formations of Maryland, Virginia, and North Carolina. D. Nicol (1953, p. 707) estimated the time-range as 8 million years.

Horizons of P. soldani Deshayes.—Upper Burdigalian of Provence (abundant) and Helvetian of Drôme (South of France). Miocene and Pliocene of Italy (abundant in the Pliocene), Burdigalian-Helvetian of Austria.

No *Isognomon* exists in the northern basin; Touraine, Belgium, Germany.

One other species, *I. burdigalensis* Cossmann and Peyrot, is found in the Aquitanian of Aquitania in the nepionic, sporadic state, the temperature doubtless being colder.

In zone 2 of St. Marys formation, at Powells Lake Spillway, near Williamsburg, Virginia, there is a bed of *I. maxillata* in which the ligamental area differs from those of the syntypes; the grooves are fewer (11 to 12) and more widely spaced.

This *Isognomon*, of which I have been able to collect only three incomplete specimens, seems to belong to a different species, but it is necessary to have other specimens for its determination.

Biologic remarks.—*Isognomon* of the present time, living among the coral reefs, is a tropical genus. It, therefore, indicates in the Miocene sea of Chesapeake Bay and Virginia a period of warm water.

Family PECTINIDAE

For the study of this family, I have tried to correlate the principal American species with the groups established by Deperet and Roman (1902) for the genus *Pecten* and by J. Roger (1939) for the genus *Chlamys*.

Group *Pecten subarcuatus* Tournouer

Pecten raveneli Dall

1898. *Pecten raveneli* Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 721, pl. 29, fig. 10.

This Pliocene species of Florida and North Carolina have been studied in an effort to learn whether the groups of Deperet and Roman can be found in America.

Dall's type (Coll. U. S. Nat. Mus.) has a convex right valve while the left is concave. There are 26 ribs on the right valve and 22 on the left; these are prominent, rounded, and ornamented with concentric lamellae. The interspaces on the right valve are narrow; those on the left valve are broad.

These characters cause the species to resemble the group of *P. arcuatus* Tournouer (*in* Deperet and Roman, 1902, pl. 10, pl. 1) despite the more numerous ribs of *P. raveneli*.

Another peculiarity also brings it close to the group of Pectens with grooved ribs on the right valve (Deperet and Roman, 1902, p. 23): *P. kochi* Locard, *P. reghiensis* Seg., *P. fraasi* Fuchs, and *P. grayi* Michelotti (*in* Sacco, pl. 19, figs. 4-17).

Like these Pectens, *P. raveneli* has the ribs of the right valve divided by a groove, but this appears only in the lower part of the shell in *P. raveneli*. The left valve differs greatly in the European species: in *P. reghiensis* Seg. (*in* Deperet and Roman, 1902, p. 24, pl. 2, fig. 6; 1905, p. 85, pl. 10, fig. 1), the less numerous ribs (12 to 13) carry a groove and there are striae in the interspaces, while the left valve of *P. raveneli* has 20 simple ribs with rectangular section.

Dall compared his species to *P. medius* Lk. of the Red Sea as to dimensions and shape, but the living shell has fewer ribs, smooth not grooved.

Hence, because of its sulcated ribs, *P. raveneli* is close to *P. reghiensis* Seg. of the Pliocene of the Mediterranean and the Atlantic, and on the other hand, because of its left valve, it approaches the group of *P. subarcuatus* Tournouer.

There is in Europe, also, another species which links these two groups, *P. difficilis* Fuchs (*in* Deperet and Roman, p. 16, pl. 1, figs. 13-15). It is rare and exists only in the Miocene of Persia, but it proves that the group of *P. arcuatus* may include species with grooved ribs.

Horizon.—Pliocene of Caloosahatchee marls (Florida) and North Carolina. It corresponds to the Astian (Pliocene) of Europe.

Group *Pecten complanatus* Sowerby³

Pecten humphreysii Conrad

Pl. 25, figs. 1a-b

1842. *Pecten humphreysii* Conrad, Nat. Hist. Bull. Proc., vol. 2, p. 194 pl. II, fig. 2.

³ Contrary to the opinion of some authors, I consider *P. complanatus* as an independent group and not belonging either to the living group of *P. jacobaeus* (Deperet and Roman, 1902) or to the group of *P. maximus* (Glibert, 1946, p. 60).

1904. *Pecten humphreysii* Conrad, Glenn, Maryland Geol. Sur., Miocene, p. 372, pl. 98, figs. 10-12.
 1936. *Pecten humphreysii* Conrad, Tucker-Rowland, Amer. Midland Naturalist, vol. 17, No. 2, p. 478, pl. 3, fig. 3; pl. 4, fig. 10.
 1941. *Pecten humphreysii* Conrad, Schoonover, Bull. Amer. Paleont., vol. 25, No. 94B, p. 114, pl. 2, figs. 1-2.

Comparison of this species has been made with certain specimens of *P. complanatus* Sowerby (1826, v. 6, p. 586) of the Scaldisian of Anvers (= Pliocene of Belgium) (in Coll. U. S. Nat. Mus., No. 325687).

Affinities with the group *P. complanatus* Sowerby:

Right valve:—Same sculpture, flat valves, smooth, narrow interspaces, trace of secondary sculpture near the beak and the pallial margin; fine longitudinal grooves and concentric striae, same inner ribs bordered by two ridges and prolonged toward the beak.

Left valve.—Flat with a "thumb mark" near the beak, and inflated lateral areas, ribs with traces of grooves, broad interspaces.

<i>P. humphreysii</i>	<i>P. complanatus</i>
<i>right valve</i> : teeth almost effaced;	distinct divergent teeth;
7-8 principal ribs	11-12 principal ribs
<i>left valve</i> : 7 rounded ribs; smooth interspaces	11 rectangular ribs; interspaces with one or two longitudinal striae

According to the figures of *Pecten westendorpianus* Nyst (1843, p. 285, pl. VII (XVIII), fig. 10) of the Diestian (= Pontian, after Hinsch, 1953), this Belgian species seems close to the shell from Plum Point, Maryland, same shape, same number of ribs, similar concentric, lamellar sculpture, and hinge, likewise without teeth.

But having found a specimen of this species in the collection of the Institut Catholique de Paris, it seems that they nevertheless differ in secondary sculpturing, which, strong in *P. westendorpianus*, is effaced in *P. humphreysii*. I have only seen this secondary ornamentation on a young American shell of 14 mm. d. a. p. which has five longitudinal grooves on the ribs of the right valve where they are grouped two by two, as in *P. westendorpianus*. (*loc. cit.*, pl. 1, fig. 1). The Belgian species is also more convex than its American relative.

Hence, because of the strong ribbing and the greater convexity of *P. westendorpianus*, one cannot assume the identity of the two species, but only their close relationship and so include them in the same group.

Moreover, *P. humphreysii* belongs to the lower Miocene of the United States, Calvert formation, and these Belgian species occur in the terminal Miocene and the Pliocene.

Group *Cblamys varia* L.

***Cblamys* (*Placopecten*) *clintonia* (Say)** Pl. 25, figs. 2a-d

1824. *Pecten clintonius* Say, Acad. Nat. Sci. Philadelphia, Jour., vol. 4, p. 135, pl. IX, fig. 2.

1898. *Pecten* (*Placopecten*) *clintonius* (Say), Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 725, 6.

1936. *Pecten* (*Cblamys*) *clintonius* (Say), Mansfield, Jour. Paleont., vol. 10, No. 3, p. 178, pl. 22, fig. 4.

1938. *Cblamys* (*Placopecten*) *clintonius* (Say), Tucker-Rowland, Mém. Mus. R. Hist. Nat. Belgique, sér. 2, fasc. 13, pl. 1, fig. 11.

1943. *Cblamys* (*Placopecten*) *clintonia* (Say), Gardner, U. S. Geol. Sur., Prof. Pap. 199A, p. 37, pl. 6, figs. 1-4.

This species has been likened by certain authors to *P. magellanicus* Gmelin, 1792, of the present Atlantic (Cape Hatteras to Labrador) (studied in Coll. U. S. Nat. Mus.), but it differs from the Recent species in having:

A less shallow byssal sinus; a greater number of ear ribbings (15 instead of 10); coarser valve sculpture with ribs well separated; broad chondrophore pit with two, more or less, prominent folds starting from the base of the pit (see Pl. 25, figs. 2 c-d); thick cardinal margin, the inward ribs more prominent; many arrested growth lines on large shells.

Davenport (1938) thought that these lines indicate a winter's arrested growth because of the cold.

In *C. clintonia*, five such lines on shells of 10 cm. would indicate an age of five years, and for a shell of 12 cm., eight years (?).

C. clintonia and *C. magellanica* are members of the same group—the subgenus *Placopecten* Verrill, 1897 (see Tucker-Rowland, 1938, p. 51).

In my opinion, the *Placopectens* belong to the group of the living *C. varia* L. because of the weak convexity of the valves and especially because of the dense sculpturing—numerous radial ribs, microscopic oblique striae in the intervals and, on the inner face, small simple ribs on the pallial margin.

But the American subgenus is separated from the European species by the rounded shape of the shells, the sinus not shallowed at the right ears which are always less developed on the two valves than in the *C. varia* L. group. (Pl. 25, figs. 2 a-d).

The nearest related species compared by the authors (Woods, 1851; Roger, 1939) to *C. clintonia* is *C. princeps* Sowerby (1823, v. 6, pl. 542) of the Pliocene which has coarser ornamentation—90 ribs instead of the 140 on *C. clintonia*. This coarse ribbing is reflected also in the interior of the shell of *C. princeps* Sowerby (Roger, pl. 24, fig. 5).

Horizon.—*C. clintonia* characterizes a zone in the lower portion of the Yorktown formation of Virginia and North Carolina; it appears also in the St. Marys formation of the two states but not in Maryland.

***Chlamys (Placopecten) marylandica* (Wagner)**

1839. *Pecten marylandicus* Wagner, Acad. Nat. Sci. Philadelphia, Jour., 1 ser., vol. 8, p. 51, pl. 2, fig. 2.
 1898. *Pecten (Placopecten ?) marylandicus* Wagner, (part) Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 728.
 1904. *Pecten (Chlamys) marylandicus* Wagner, Glenn, Maryland Geol. Sur., Miocene, p. 376, pl. 99, fig. 6.
 1938. *Chlamys (Placopecten) marylandicus* (Wagner), Tucker-Rowland, Mém. Mus. roy. d'Hist. Nat. Belgique, ser. 2, fasc. 13, p. 54, pl. 4, fig. 13; pl. 5, fig. 16.
 1941. *Chlamys (Placopecten) marylandicus* (Wagner), Schoonover, Bull. Amer. Paleont., vol. 25, No. 94b, p. 26, pl. 3, figs. 4-5.

The principal characteristic of this species is the ornamentation:

At the beak, there are only 17 ribs and at the pallial margin 64. Each rib divides into two parts which become equal ribs; at the same time an intercalated rib appears which also becomes equal to two others. In the interspaces are fine, concentric striae, and near the pallial margin one to three rows of small scales are visible.

C. marylandica is close to *C. multistriata* Poli of the European Miocene.

Left valve analogies: declining posterior ear, 20 ribs at the summit giving 64 at the pallial margin, increase of ribs by division and intercalation, scales on the lateral ribs only.

Left valve differences: on *C. multistriata*, the ribs increase by intercalation only, the ears have 15 to 20 striae instead of the 12 on *C. marylandica*, and finally there are no scales on the ribs of the latter.

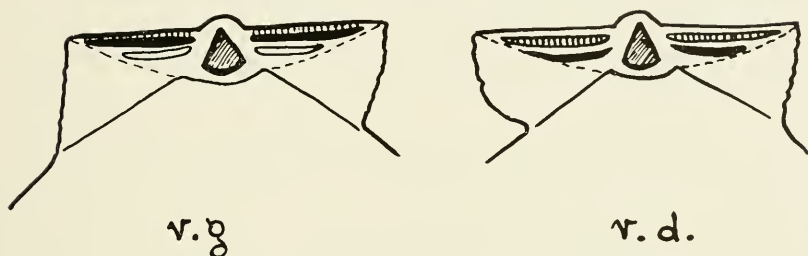
Right valve analogies: anterior ear similar, rising winglike, same number of ribs at the beak and pallial margin, same shape of shell, the d. u. p. greater than the d. a. p.

Right valve differences: *C. multistriata* has divaricate striae in the intervals, and no rib develops between the others.

It is to be noted that the subgenus *Placopecten* does not exist in Europe, or at least, has never been recognized.

Horizon.—Choptank formation of Maryland (zone 17).

"Section" *Plagioctenium* Dall, 1898



Text-fig. 4. Hinge of *Plagioctenium* Dall.

(v.g. = left valve; v.d. = right valve)

Type species, *Pecten ventricosus* Sowerby (= *Pecten circularis* Sowerby) (of the present Pacific) by original designation.

1898. *Plagioctenium* Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 696.

1925. *Plagioctenium* Dall, Woodring, Carnegie Inst. Washington, vol. 366, p. 68.

1926. *Plagioctenium* Dall, Gardner, U. S. Geol. Sur., Prof. Pap. 142-A, p. 48.

1938. *Plagioctenium* Dall, Tucker-Rowland, Mém. Mus. roy. d'Hist. Nat. Belgique, sér. 2, fasc. 13, p. 32.

Dall's text.—

Resembling *Aequipecten* but without radial striation, the concentric sculpture in looped lamellae; the ribs strong, frequently smooth above; the submargins impressed below the subequal auricles; the valves well inflated with a tendency to oblique growth in the adult.

To this very natural group belong nearly all the shallow-water *Pecten*s of our coasts, such as *P. irradians* Lam., *P. gibbus* L., *P. dislocatus* Say, *P. ventricosus* Sby., *P. nucleus* L., *P. purpuratus* Lam., *P. eboreus* Conrad, *P. comparabilis* T. and H., and other numerous fossils species.—(Dall, 1898, p. 695) (Tucker-Rowland, 1938, p. 32-35.)

Remarks.—Both valves convex, numerous smooth ribs more or less square section, without radial ribbing, but with noticeable striae on the ribs and intervals; large ears, especially on the posterior and with diverging striae which seem to continue the ribs of the shell by reason of the characteristic noted by J. Roger (*in litt.*) "passage graduel de la surface de la coquille à celle de l'oreillette postérieure et bord libre orthogonal de celle-ci."

Hinge: right valve—cardinal margin folded and bordered below by a groove perpendicularly striated. Beneath, another fold—chondrophore pit forming a "balcony" in the interior of the shell. Left valve: on cardinal margin, a fine, perpendicularly striated fold is above a groove (Text.-fig. 4).

The species of this section are:

Cblamys circularis (Sow.) (= *C. ventricosa* (Sow.) Recent.

Type species.

C. gibba L. N. Q. A. + America

C. irradians Lk. Pleistocene. Recent. America

C. nuclea L. Recent. America

C. purpurata Lk. Recent. Pacific

C. eborea Conrad Miocene. America

C. comparabilis T. and H. Pliocene, Florida. Recent. America

The Miocene species of this group existing north of Cape Hatteras are: *C. gibba* L. and *C. eborea* Conrad with subspecies; *C. urbannaensis* Mansfield, *C. yorkensis* Conrad, *C. watsonensis* Mansfield, and *C. comparabilis* T. and H.

The section (or group) *Plagiectenium* does not exist in Europe according to J. Roger (1939, p. 92) who thought, furthermore, that *Plagiectenium* would correspond to the subgenus *Argopecten* Monterosato (1889, p. 21) of Europe. In my opinion, the two groups are different, for I have been able to study the type species: *P. ventricosus* Sow. of the Pacific, *P. (Argopecten) philippii* Recluz (= *P. solidulus* Reeve) in the collections of the U. S. National Museum of Washington, D. C.

The *Argopectens* differ from the *Plagiecteniums* by their small size, their much smaller ears—especially the posterior—by the indications of secondary costulation on the ribs of the lateral areas and the concentric lamellae closely set in the interspaces. (*C. scabrella* Lk. of the European Neogene, for example, belongs to the *Argopectens*.)

But, I have remarked that the *Plagiecteniums*, although nonexistent in Europe, have a certain relationship with the group of *Flabellipecten bessi* And. (in Deperet and Roman, 1910, p. 119, pl. 13, figs. 2, 3). I have been able to compare the shells of *C. gibba* and *C. eborea* with those of *F. bessi* and *F. leithajanus* Partsch (in Coll. Lab. Paleont. Mus. Paris).

It is known that *Flabellipecten* Sacco (1897, v. 24, p. 55), is charac-

terized by smooth, somewhat depressed ribs, plano-convex left valve, large equal ears and a weak byssal sinus, exactly the intermediary form between *Pecten* and *Cblamys*. Now, *Plagiectenium*, especially the fossil form, has the same general characters listed above.

And, among the *Flabellipectens*, the group of *F. besseri* And. with that species and *F. leithajanus* Partsch, approach even more closely the American section in having about the number of smooth ribs (20 to 22 in Europe, 22 to 25 in America), similar apical angle, and a left valve lacking lateral areas.

But that peculiarity of *Plagiectenium*, the gradual passage from the ear to the shell surface, does not exist in *Flabellipecten*.

The hinges are also different in the two groups. Those of the *Flabellipectens* always flatter, the folds forming no projection on the hinge plate as in the *Plagiecteniums* which always have a stronger hinge.

Distribution of Flabellipecten.—Originating in the Aquitanian of Provence, they multiplied during the Miocene of all southern Europe, being particularly abundant in the Mediterranean, in Aquitania, and in Morocco. They are rare in Austria, Touraine, and Poland, absent in Belgium.

During the Pliocene, their importance diminished in the Mediterranean especially, and they disappeared in the upper Pliocene and Quaternary.

Their stratigraphic distribution, during the Miocene, shows that this subgenus lived in a temperate warm climate, similar to this of the actual Mediterranean. It developed in good conditions, in the Mesogean sea and the Atlantic waters of Aquitaine, had difficulties in Austria and Touraine, in a colder environment, and it could not reach Belgium and the North Sea.

Its extinction in the Mediterranean Pliocene may be explained by the change of climate: the waters were colder and there was an appearance of nordic species (Roger, 1939, p. 275).

In the present epoch, the authors: Deperet and Roman (1912, Monographie des Pectinidés néogènes de l'Europe, vol. II: Genre *Flabellipecten*. Mém. Soc. Géol. Fr., n. 26, t. XVIII, p. 162) cited two living species in the Pacific Ocean: in Japan, *Pecten caurinus* Gould and *Pecten floridus* Gmelin, in California.

But, "*P. floridus* Gmelin" is thought to be *P. stearnsii diegensis* Dall (Grant and Gale, 1931, p. 223), so it cannot be a *Flabellipecten*. As to *P. caurinus* Gould, it belongs to the subgenus *Patinopecten* of which J. Roger (1939, p. 264) remarked also the affinities with the *Flabellipectens*.

To know if *Flabellipectens* are still living in the present seas, we have to consider *Patinopecten* of the Pacific Ocean.

Comparison of Flabellipecten and Patinopecten.—Dall (1898, vol. III, pt. II, p. 695) created the section *Patinopecten* for certain equivalved species with small ribs, "flat on the right valve, and sometimes dichotomous; smaller and rounder on the left valve, with invisible concentric sculpture, inconspicuous; radial striae absent or obsolete; subequal ears; valves nearly equilateral."

The type species is *P. caurinus* Gould (*in* Arnold, 1906, p. 101, pl. 38, fig. 1; pl. 39, figs. 1, 2) of the lower Pliocene of California (studied from a specimen in Coll. Lab. Paleont. Mus. Paris): a large form (15 cm. in diameter) with the two valves subequally convex, smooth lateral areas, large ears, and ribs with obsolete costulae.

Such characters bring it closer to *Chlamys solarium* Lk. (*in* Dollfuss and Dautzenberg, pl. 41, figs. 1, 2). This shell of the Mediterranean and Aquitanian Miocene is rare in Touraine and does not exist further north as the *Flabellipectens* do. In my opinion, it would constitute the giant form of *F. besseri* And.

Flabellipecten and *Patinopecten* are close, but cannot be confused. Consequently it appears as though *Flabellipecten* Sacco does not exist among the living species.

This group of species—*besseri*, *solarium*, *leithajanus*, form the transition between *Flabellipecten* and *Chlamys*.

In short, there were in the Miocene seas three related groups which developed in three different provinces: *Flabellipecten* in "Mésogée" of Europe in the Helvetian; *Plagiostenium*, in the American Atlantic, in upper Miocene and in the Pliocene; *Patinopecten* in the American Pacific in lower Pliocene and Recent.

But while the European group appears in the Helvetian, *Plagiostenium* appears in the terminal Miocene in the Yorktown formation of Virginia and *Patinopecten* in the lower Pliocene in California.

The probable origin of these subgenera is probably located in the Mediterranean. Only in the upper Miocene would they have emigrated to the west coast of America, leaving the Mediterranean which had become too cold during the Pliocene and giving, by mutation, the subgenus *Plagiostenium* which spread to the West Indies, where it is now living.

In the lower Pliocene, *Plagioctenium* passed into the Pacific where ecologic changes brought about another mutation: *Patinopecten*, which is found today in the Pacific off the coast of Japan.

***Chlamys (Plagioctenium) eborea* (Conrad)**

1833. *Pecten eboreus* Conrad, Amer. Jour. Sci., vol. 23, p. 341.

1898. *Pecten (Plagioctenium) eboreus* Conrad, Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 749.

1938. *Chlamys (Plagioctenium) eboreus* (Conrad), Tucker-Rowland, Mém. roy. d'Hist. Nat. Belgique, sér. 2, fasc. 13, p. 40, pl. II, fig. 12.

1943. *Chlamys (Aequipecten) eborea* (Conrad), Gardner, U. S. Geol. Sur., Prof. Pap. 199A, p. 36, p. 7, figs. 1-5-6.

This fossil does not belong to any European group, because it is part of the group *Plagioctenium* (see preceding pages).

At first glance, it closely approaches *Chlamys calaritana* Meneghini, 1857 (*in* Roger, p. 14, pl. 1, fig. 6) of the Helvetian-Tortonian of Europe which belongs to the group of *C. rotundata* Lk. These two shells do have the same shape, the same number of rounded ribs separated by narrow interspaces, the same sculpture and similar ears. But *C. eborea* has a smaller apical angle, the left valve more convex than the right, and has no lateral areas. The two species are not of the same group.

Chlamys solarium L. (*in* Dollfuss and Dautzenberg, pl. 41) (= *C. besseri* Hoernes, p. 63, figs. 1-5) also present strong analogies, but they are as artificial as the others, only the external ornament is the same.

Horizons.—Yorktown of Virginia, North Carolina; Choctawatchee formation (Miocene) of Florida and Pliocene of Florida.

Group of *Chlamys (Gigantopecten) ziziniæ* (Blank.)

(*in* Mongin, 1948-52, p. 141)

***Chlamys condylomata* (Dall)**

Pl. 25, figs. 3a-d

1898. *Pecten (Nodipecten) condylomatus* Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 729, pl. 34, figs. 14-15.

1926. *Chlamys (Nodipecten) condylomata* (Dall), Gardner, U. S. Geol. Sur. Prof. Pap. 142A, p. 46, pl. XII, figs. 3-4.

This curious species, in my opinion, does not belong to the subgenus *Nodipecten* Dall, of which I have been able to study the type species, the living species *N. nodosus*, of the American Atlantic (Coll. U. S. Nat. Mus.).

Comparison shows the following differences:

<i>P. nodosus</i>	<i>P. condylomatus</i>
left valve regularly convex	left valve flat, but later deformed by concentric humps which are directional changes in shell growth
right valve slightly convex like the left valve	right valve deeply convex
ribs with round, pimples not affecting shell form	ribs with concentric humps giving shell a form articulated in three different planes

P. condylomatus seems to belong to the group of *P. ziziniæ* Blank. (in Deperet and Roman, p. 905, p. 80, pl. 9, figs. 3-5), which I have attributed to the subgenus *Gigantopecten* Rovereto after a study of the large shells of Provence (1948-52, p. 14). The latter shows that the small-formed species, *ziziniæ*, like a *Pecten*, upon enlarging, presents shells of *Gigantopecten* of the group *tournali* de Serres (in Roger, p. 16).

The *Gigantopecten*s are transitional between *Chlamys* and *Pecten*, for the adult has two convex valves like *Chlamys* and a weak byssal sinus like *Pecten*.

C. condylomata (Dall) is like the young *P. ziziniæ* but with a well-marked byssal sinus, proving that the group clearly belongs to *Chlamys*. Not being abundant in America, one may suppose it has not reached its adult form, as in Europe.

The nearest European shells are two specimens of *Chlamys albina* von Teppner of the Helvetian of Touraine (in Roger, 1939, pl. 12, figs. 2, 3). But the American species keeps its individuality by its secondary sculpture formed by fine radial striae on the ribs and interspaces. This ridging does not appear on European shells save, sporadically, on *C. albina* (Roger, p. 26, 23d line).

C. (G.) ziziniæ is a Mediterranean species of the Burdigalian, *C. (G.) albina* is of the Mediterranean and the Atlantic during the Helvetian.

C. (G.) condylomata comes from the lower Miocene of Chipola formation of Florida (which corresponds to the Burdigalian). (Specimens studied in Coll. U. S. Nat. Mus. and Paleont. Res. Inst. Ithaca, N. Y.).

Summing up, *Gigantopecten* has certain characters of *Pecten* in the young: left valve flat, right valve convex; in growing, the left valve tends to become convex by successive malformations to take on the character of *Chlamys*.

***Chlamys jeffersonia* (Say)**

Pl. 27, fig. 3

1824. *Pecten jeffersonius* Say, Acad. Nat. Sci. Philadelphia, Jour., vol. IV, 1st ser. p. 133, pl. IX, fig. 1.

1840. *Pecten jeffersonius* Say, Conrad, Fossils Medial Tertiary, p. 46, pl. XXII, fig. 1.

1898. *Pecten (Lyropecten) jeffersonius* Say, Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. IV, p. 722.

1904. *Pecten (Chlamys) jeffersonius* Say, Glenn, Maryland Geol. Sur., Miocene, p. 378, pl. C, fig. 2.

This large pectinid is linked to the Gigantopectens by its large size (greater d. a. p.: 180 mm., greater d. u. p.: 172 mm.), its thick shell, its two convex valves with from eight to ten ribs, weak byssal sinus, large subequal ears and absence of ctenolium.

But, *C. jeffersonia* diverges from the Gigantopectens, such as *C. condylomata*, by the lack of hinge teeth and by its secondary sculpture on the ribs. Scales and striae on the ribs do not exist on any European species of this group, except on *C. gallica* Mayer-Eymar (*in* Roger, 1939, pl. 15, fig. 1, pl. 16, fig. 1) of the Helvetian of Aquitania and the Pliocene of Languedoc, which bears traces of them, and also on *Chlamys latissima* Brocchi (*in* Sacco, 1897, p. 32, pl. IX, fig. 5; pl. X, figs. 1-5) of the Mediterranean Pliocene which has striae in the interspaces of ribs.

Finally, *C. jeffersonia* differs too widely from these European species to permit a comparison with the specimens themselves.

On the other hand, *C. jeffersonia* differs from *C. madisonia* in having: finer secondary sculpture (27 striae on one rib and one interval), convex closely set, square ribs; convex shell, especially the right valve; 10 ribs instead of the 16-17 on *C. madisonia*; weak byssal sinus, narrow chondrophore pit.

Horizons.—St. Marys formation and Yorktown formation.

Variations of the species.—There are three variations of *Chlamys jeffersonia*:

I. Variation *septenaria* Say, 1824, Acad. Nat. Sci. Philadelphia, Jour., vol. IV, 1st ser., p. 136, pl. IX, fig. III; Glenn and Martin, Maryland Geol. Sur., Miocene, 1904, p. 379, pl. VI, fig. 4.

This differs from the species in the number of ribs (7 instead of 10 or 11), its square ribs, and finer striae.

It may be compared with the European *Chlamys latissima* Brocchi and its variation *praecedens* Sacco (1897, pl. X, figs. 4 to 8), but the latter has cardinal teeth, a smooth shell, and less rectangular ribs.

Horizon.—Yorktown formation of Virginia and North Carolina, Duplin marl of Georgia.

II. Variation *palmyrensis* Mansfield, 1936, Jour. Paleont., vol. 10, No. 3, p. 187, pl. 23, fig. 3.

The holotype (in coll. U. S. Nat. Mus. 373075) differs from the species in having only five ribs.

It can be likened to *Chlamys latissima* Brocchi (*forma platypleuros* figured in Roger, 1939, pl. 18, fig. 1) of the Pliocene of Italy by its five ribs, but on the Yorktown species, ribs are broader, pallial border broadly undulated, and secondary ornamentation much finer.

Horizon.—Yorktown formation of North Carolina.

III. Variation *edgecombensis* Conrad, 1862, Acad. Nat. Sci. Philadelphia, Proc., vol. XIV, p. 291, Glenn and Martin, 1904, p. 379, pl. C, fig. 3.

Studied on the syntypes (in Coll. U. S. Nat. Mus.) from Tarboro, Edgecombe County, North Carolina.

This form is distinguished from *Chlamys jeffersonia* by a more visible thread in the intervals.

Horizon.—Yorktown formation of Virginia and North Carolina.

Group *Chlamys opercularis* L. (*Aequipecten*)

***Chlamys santamaria* Tucker**

1934. *Chlamys* (*Lyropecten*) *santamaria* Tucker, Amer. Midland Naturalist, vol. 15, no. 5, p. 615, pl. 26, fig. 2.

1938. *Chlamys* (*Lyropecten*) *santamaria* Tucker, Tucker-Rowland, Mém. Mus. roy. d'Hist. Nat. Belgique, ser. 2, fasc. 13, p. 16, pl. 1, figs. 5-6; pl. II, fig. 10.

This species has no European equivalent, but it is part of the group of *Chlamys opercularis* L. to judge from the contour, the ears, the ctenolium, and the convexity of the shell. The sculpture consists of many fine, scaly striae and in the interspaces, one row of spines, stronger than the others, reaches far to the beak.

This last characteristic distinguishes *C. santamaria* from *C. madisonia* (Say), where the sculpture is coarser and consists of three rows of spines only.

Horizon.—St. Marys formation in Maryland.

The variation *middlesexensis* Mansfield (1936, p. 187, pl. 22, figs. 5, 6; Tucker-Rowland, 1938, p. 17, pl. 2, fig. 12; pl. 3, fig. 7) differs from the species in its more convex valves, longer ears, shallower byssal notch,

more prominent and squarer ribs. The sculpture is similar but lacks the strong ridging in the interspaces.

This variation has been studied with Mansfield's types (Coll. U. S. Nat. Mus.) and with specimens from Goldsboro, Wayne County, North Carolina (No. 25369 Coll. Pal. Res. Inst. Ithaca, N. Y.).

The young shells are like those of *C. madisonia*, but I have found no European equivalent for the adults.

Horizon.—St. Marys formation at Urbanna, Middlesex County, Virginia.

Useful characters which are helpful in distinguishing *C. santamaria*, *C. middlesexensis*, and *C. edgecombensis* are noted in the following table:

<i>C. santamaria</i>	<i>C. middlesexensis</i>	<i>C. edgecombensis</i>
ctenolium with four teeth	ctenolium with three teeth (on type) but not in others	no ctenolium
byssal notch marked		byssal notch faint
apical angle sharp	same angle as <i>santamaria</i>	apical angle not sharp
fan-shaped form	same form as <i>santamaria</i>	rounded form
weak convexity	medium convexity	strong convexity in large specimens
median ridge of interspaces marked	median ridge not evident	median ridge marked
broad, rounded ribs	broad, rectangular ribs	narrower ribs than the others

Chlamys madisonia (Say)

Pl. 26, figs. 1a-b, 2a-h; Pl. 27, fig. 2

1824. *Pecten madisonius* Say, Acad. Nat. Sci. Philadelphia, Jour., vol. IV, 1st ser., p. 134.

1840. *Pecten madisonius* Say, Conrad, Fossils Medial Tertiary, p. 49, pl. XXIV, fig. 1.

1938. *Chlamys (Lyropecten) madisonia* (Say), Tucker-Rowland, Mém. Mus. roy. d'Hist. Nat. Belgique, sér. 2, fasc. 13, p. 9, pl. I, fig. 1-2; pl. IV, fig. 8.

1939. *Chlamys madisonia* (Say), Roger, Mém. Soc. Géol. France, 40, p. 346.

1941. *Chlamys (Lyropecten) madisonius* (Say), Schoonover, Bull. Amer. Paleont., vol. 25, No. 94B, p. 28, pl. 2-5.

1945. *Pecten madisonius* Say, Glibert, Mém. Mus. roy. d'Hist. Nat. Belgique, 103, p. 59.

1943. *Chlamys (Lyropecten) madisonia* (Say), Gardner, U. S. Geol. Sur., Prof. Pap. 199A, p. 32, pl. 4, fig. 5; pl. 9, fig. 7.

Chlamys madisonia is the most important and the most abundant species of the Pectinidae of the Maryland and Virginia Miocene. It has been much studied by American paleontologists.

With L. Schoonover, I think it is necessary to separate the species into two groups: the large specimens of Choptank formation and the small and medium shells of the Calvert. Moreover, the statistical study shown bears out this conclusion.

1. The large shells of *C. madisonia* (Say).

These specimens 12-15 cm. diam., are thick, especially toward the beak, ribs produced into the interior to the muscle scar are strongly marked. The inner surface is lumpy, irregular, often deformed by scars or shell repairs. The pallial margin is sometimes double. The hinge is thick, the cardinal line is 0.5 cm. wide with longitudinal striae. The deep, striated ligamental pit protrudes into the interior of the shell. The right auricle of the right valve is that of *Chlamys* with its deep byssal notch and well-preserved ctenolium. There are never teeth on the hinge.

The thickened and deformed appearance of the shells hints that these large specimens did not live under normal conditions. Attached byssally to the substratum and closely crowded, it may be their valves were battered against each other and injured as they were tossed by the currents, or the scars may have been pathological.

After death, the dissociated shells, tumbled by the seas, pierced by boring algae and rock borers, served as a base for bryozoa, polyps, and worms. It is in such state that they are found in the cliffs of the Choptank formation.

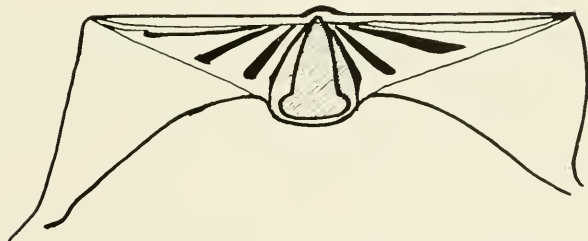
The large individuals of the Calvert formation collected at Davidsonville, Maryland, by Dr. H. Vokes (Coll. Johns Hopkins Univ.) differ from the above by their slender shells and by the threads dividing the inner ribs. This particular form results, perhaps, from special local conditions—a phase of more brackish or estuarial waters.

After Dall (1898) all authors have placed *C. madisonia* in the subgenus *Lyropecten* Conrad (1855, p. 71, pl. 3, fig. 15) of which the type species is *Pecten estrellanus* Conrad (1855) (neotype, U. S. Nat. Mus. 13317)⁵.

However, the chief characteristic of this subgenus indicated by Conrad is the present of oblique and irregular teeth on each side of the chondrophore pit, and *C. madisonia* has no teeth. It, therefore, does not belong to *Lyropecten* Conrad (Text-fig. 5).

The subgenus *Nodipecten* Dall, (the type species is the living *N. nodosus*), has a hinge with teeth, but no ctenolium. Furthermore, it has

⁵ *Lyropecten estrellanus* Conrad seems to belong to the group of *Chlamys scabrinuscula* Matheron (1842, Catalogue, p. 187, pl. 30, fig. 8-9). The hinge of the latter does not have the oblique hinge teeth but shows in the same place a triangular fold of each side. Its beak is much less prominent, the ear ridges more numerous and finer. *L. estrellanus* has only four of them. The shape and the sculpturing are much the same in the two species.



Text-fig. 5. *Lyropecten estrellanus* (Conrad). Wild Horse Canyon, Calif. Miocene. Coll. USNM 3586. Hinge shows three teeth in the left valve and two in the right, a triangular fold inside the pit of the chondrophore.

nodules on the ribs, and the pallial margin is waved. This is not the case with *C. madisonia* which, therefore, is not a *Nodipecten*, contrary to the opinion of paleontologists.

This species can no longer be likened to the subgenus *Gigantopecten* Rovereto, 1899 (*Macrochlamys* Sacco, 1897) widely distributed in Europe and northern Africa during the Miocene.

Indeed, the European shells of *Gigantopecten* have well-marked cardinal teeth, no byssal notch, equal and straight ears, thick, plain and smooth ribs, quite contrary to *C. madisonia*. It must be pointed out, also, that the left valve of *Gigantopecten* has a flattened, "thumbmarked" apex and growth marks such as are never seen on the American species.

Summing up, the large *C. madisonia* is never encountered in any European subgenus.

Kautsky (1925, p. 14) finds *C. madisonia* close to *Pecten brummeli* Nyst (*in* Glibert, 1945, p. 57, pl. 3, fig. 12) which, however, belongs to another genus. Only the sculpture has a certain, although artificial, similarity.

There are subspecies of *C. madisonia* in the lower and upper zones of the Choptank formation:

a. *C. madisonia sayana* (Dall) (1898, p. 725, pl. 26, fig. 6) in Alum Bluff beds and Chipola formation. According to authors this would be the ancestral form of the species; it has more threads in the interspaces, round and flattened ribs, and no delicate concentric sculpture like *C. radians* (Nyst).

The number of ribs studied on 44 left valves and 47 right valves of the specimens figured by Dall (Coll. U. S. Nat. Mus.) and coming from Oak Grove, Florida, gives a polygon of frequency of which the mode is 15 for the left valve and 16 for the right (Text-fig. P II).

b. *C. madisonia richardsi* Tucker-Rowland (1938, p. 14, pl. 3, figs. 4, 5) of St. Marys formation. This subspecies has 17 ribs on both valves. The concentric ornamentation near the beak shows delicate threads only in the interspaces. Further down, there are three scarcely visible radial threads on the ribs and one in the interspaces.

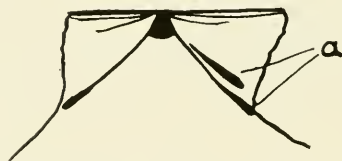
C. richardsi Tucker-Rowland can be likened, perhaps, to *C. bollenensis* Mayer-Eymar (in Fontannes, 1880, Pliocène Vallée Rhône, p. 189) which first appears in the Miocene and characterizes the Mediterranean Pliocene.

2. The small and medium shells of Calvert formation.

These Plum Point, Maryland, (zone 10) specimens are different from the large one of the Choptank formation, as L. Schoonover has written.

They belong to the living group of *Cblamys opercularis* L. which corresponds to the subgenus *Aequipecten*.

Comparison with *C. opercularis* (Linné) from the Atlantic and its subspecies *audouini* Payraudeau (in Bucquoy, Dollfuss, and Dautzenberg, v. II, pl. 17, fig. 3-8) from the Mediterranean.



Text-fig. 6. *Cblamys madisonia* (Say). Young individual showing (a) auricular lamellae. Calvert fm.

Resemblances—same form, d. a. p. equal to d. u. p. (see statistical table); lateral margins short and excavated; left valve more convex than right; same evolution of ornament near the beak—transversal striae passing over the ribs and into the spaces (Text-fig. 6); about 1 cm. from the beak, ribs bear a row of scales, and, further down, three rows with one row appearing in the interspace. When the shells exceed 4 cm., there may be many scaly lines in the spaces and on the sides of the ribs (pl. 5, fig. 2; pl. 2, fig. 3 of Schoonover). On the interior of the left valve appear two auricular lamellae, the second disappearing late on the larger shells. The nepionic specimens of *C. opercularis* of the Belgian Pliocene are the same as those of young *C. madisonia*.

However, there are fewer ribs on *C. madisonia* (see statistic study), the rib section is squarer, and the ornamentation spiner.

The group *C. opercularis* L. includes many species: *C. angelonii* Nyst and its *forma caillaudi* Nyst; *C. radians* Nyst; *C. zenonis* C. R.; *C. pavonacea* Font.; *C. gentoni* Font.; *C. malvinae* Dub.

The European species closest to *C. madisonia* are: *Chlamys radians* Nyst (in Glibert, 1945, p. 65, pl. III, fig. 5) of the European Miocene and its variation *combaluzieri* Mongin (1948-1952, p. 132); the living *C. audouini* L. of the Mediterranean; and *C. angelonii forma caillaudi* Nyst (ms. in Glibert, 1945, Mém. R. Mus. Hist. Nat. Belgique, pl. IV, figs. 2e-2j).

Before continuing the comparative study, however, it is necessary to mention the divers variations of *C. madisonia* of the Calvert formation and already described by the authors.

1. The variation distinguished by L. Schoonover (1941, pp. 28-36) and which has for types those figured on plate 4, figures 1-3. (The other figures, pl. 5, figs. 1, 2 and pl. 2, fig. 6, are of the variation *acanikos* Gardner which I have studied in the collection of the Paleontological Research Institution, Ithaca, New York).

2. The variation *acanikos* Gardner (1926, p. 46, pl. 11, figs. 1, 2) which is also in the Chipola formation.

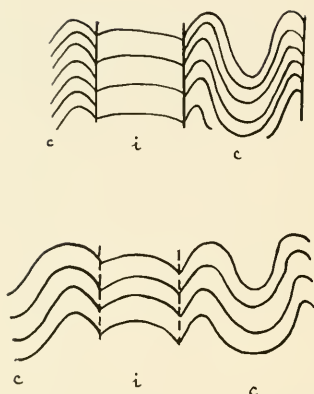
3. The variation *bassleri* Tucker-Rowland (1938, pl. 13, pl. 5, fig. 1).

As these three forms are bound to one another by many intermediaries, it would be preferable to group the three variations under the same name for the greater convenience of paleontologists. The name "*calvertensis*" would be most useful and would show that this variation is found in the Calvert formation.

Comparison with *C. radians* Nyst (in Glibert, 1945, Mém. Mus. roy. d'Hist. Nat. Belgique, p. 65, pl. 3, fig. 5):

The concentric ornamentation near the beak is the same; the two species have fine transversal striae over the ribs and in the interspaces, but in *C. radians* they form a horizontal line at the base of the rib, and the striae which cover the ribs are twice as numerous as those of the interspaces, while in *C. madisonia*, each stria corresponds to another, without forming a longitudinal ridge like in *C. radians* (Text-fig. 7).

The shape is the same, and there are the same number of ribs (see statistical study).



Text-fig. 7. 7a. Top figure. *Chlamys radians* (Nyst). Enlarged details of secondary ornamentation of the ribs (c) and their interspaces (i). 7b. Lower figure. *Chlamys madisonia* (Say). Same detail of the ribs (c) and their interspaces (i).

There are the same rows of scales on the ribs (three) and in the interspaces (one or two).

Characteristic microscopic striae appear on the left valve as on *C. radians* Nyst (in Mongin, 1952, pl. 2, fig. 28).

But *C. radians* has a much shorter left ear on the right valve than the anterior, and the two valves are equally convex; while *C. madisonia* has a long left ear, and the right valve is less convex than the left.

The variation *acanikos* Gardner is close to *C. radians combaluzieri* Mongin (1948, p. 132), *C. seniensis* Dollfuss and Dautzenberg (1920, pl. 37, fig. 19) (Combaluzier, 1932, pl. 10, figs. 5, 6) of the Burdigalian of Provence (South France) and the Helvetian of Touraine (West France).

STATISTICAL STUDY OF CHLAMYS MADISONIA (Say)⁵

Two types of measurements have been used on *Chlamys madisonia* (Say) (Coll. Geol. Dept., Johns Hopkins Univ.).

1. The number of radial ribs for which 457 shells have been examined in the Calvert formation (200 left valves and 257 right valves) and 416 specimens in the Choptank formation (189 left valves and 227 right valves).

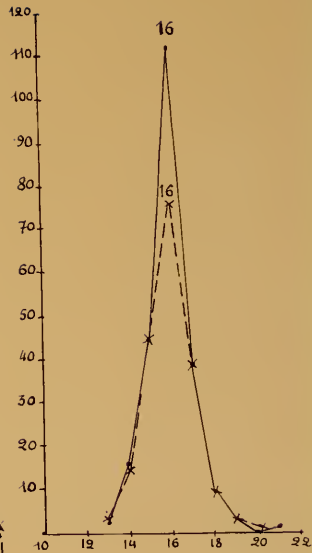
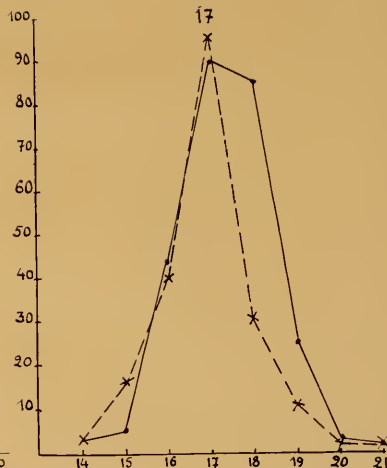
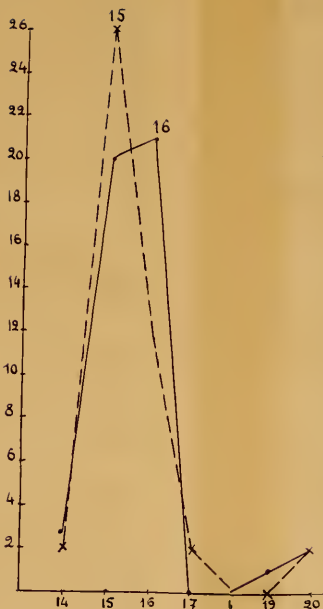
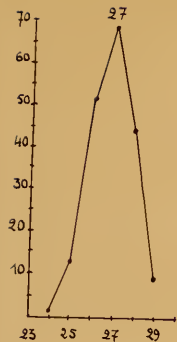
⁵ For this work the method and the notations of M. Lamotte (1953, p. 31 *et seq.*) have been used.

P I

P II

P III

P IV



POLYGONS OF FREQUENCY

P I. Number of ribs of *Arca idonea* Conrad; 185 specimens from James Point, Va.

P II. Number of ribs of *Chlamys sayana* (Dall); 44 left valves and 7 right valves. Solid line: right valves; dashed line: left valves.

P III. Number of ribs of *Chlamys madisonia* (Say), of the Calvert fm.; 200 left valves and 257 right valves. Solid line: right valves; dashed line: left valves.

P IV. Number of ribs *Chlamys madisonia* (Say) of the Choptank fm.; 189 left valves and 227 right valves. Solid line: right valve; dashed line: left valves.

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Statistical Study of the number of ribs of *Chlamys madisonia*

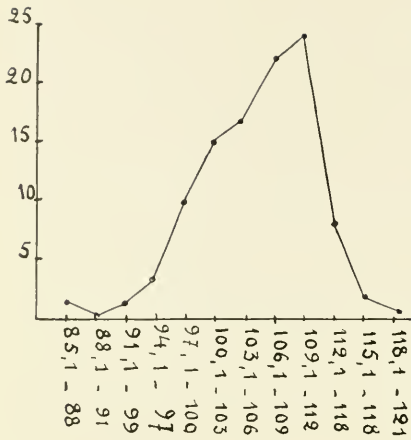
	<i>C. madisonia</i> (Say)				<i>C. radians</i> (in Gilbert) (300 indiv.)		<i>C. opercularis</i> (in Roger) 2 valves— (fossil shells)
	Calvert fm.		Choptank fm.		v. l.	v. r.	
	v. l.	v. r.	v. l.	v. r.			
f	200	257	189	227	150	150	400
A	17	17	16	16	18	18	19
X	16,9	17,346	17,936	15,97	17,726	18,153	19,143
6	1,975	1,09	1,155	0,981	1,391	1,294	1,418

Statistical study of the ratio: $\frac{d. u. p.}{d. a. p.} \times 100:$

f	104	107	96	119	150	150
A	110,5	106	107,5	97	100	100
X	106,03	105,55	101,2	101,51	100,89	101,0
6	6,52	16,5	8,83	6,75	2,846	2,783

frequency = f
mode = A
arithmetical mean = X
quadratic variation = 6

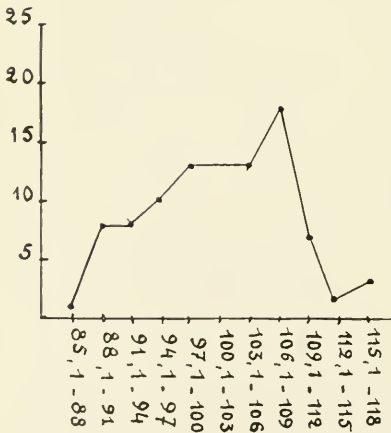
P V



P VI



P VII



P VIII



Chlamys madisonia (Say)

P V. Ratio $\frac{d. v. p}{d. a. p} \times 100$.

Right valves. P VII. Ratio $\frac{d. v. p}{d. a. p} \times 100$.

Calvert fm., left valves. P VI. Same ratio as P V

Choptank fm., left valves. P VIII. Same

ratio as P VII, right valves.

The polygons of frequency obtained PII and PIII have shown: $A = \text{mode} = 17$ for the left and right valves of Calvert formation; $A = \text{mode} = 16$ for the left and right valves of Choptank formation.

The other measures ($x = \text{arithmetical mean}$, $s = \text{quadratic variation}$) are given in the accompanying table where are also noted similar measurements made by Glibert on *C. radians* (1945, p. 68) of the Anversian of Belgium and by J. Roger (1939, p. 128) on *C. opercularis* L. of the European Pliocene and Quaternary.

In this way, one concludes that it is the *Cblamys* of the Calvert formation which most nearly approaches *C. radians* Nyst, the mode A having only a difference of 1. For values of $x = \text{arithmetical mean}$, the difference is 0.716 for the left valves and 0.807 for the right valves.

On the contrary, the shells of the Choptank formation with $A = 16$ different from that of the Calvert shells must, therefore, be separated from the latter.

They can no longer be compared to *C. radians* ($A = 18$) and *C. opercularis* ($A = 19$).

2. The ratio: $\frac{\text{d.u.p.}}{\text{d.a.p.}} \times 100$, for which 426 shells have been measured:
- 104 left valves and 107 right valves of Calvert formation
 - 96 left valves and 119 right valves of Choptank formation
- d.u.p. umbono-pallial-diameter
d.a.p. antero-posterior-diameter

When the ratio $\frac{\text{d.u.p.}}{\text{d.a.p.}} \times 100$ is greater than 100, the shells are oval.

When it is less than 100, the valves are transverse.

The polygons of frequency PV and PVI show that the majority of fossils of the Calvert formation are oval ($A: 103.1$ to 112), and the measurements show them to be of small and medium size.

The polygons of frequency PVII and PVIII give a heterogeneous population for Choptank formation, the small shells are oval and the large valves are transverse.

One can conclude, therefore, that the variation in the Calvert formation (*calvertensis* ?) is separable from the type species. In the Plum Point beds, *C. madisonia* is in process of development, while in Choptank formation it has attained maturity, even gigantism, since in Europe the species of the same group never reach this large size.

The total number of measurements made on *C. madisonia* was 1299. *Horizons*.—The species appears in the "diatomaceous earth" of the Calvert and continues to expand into the upper zones, "Plum Point marls," and into the Choptank where it reaches maximum abundance, from New Jersey to Virginia in passing through the rich Maryland beds.

D. Nicol (1953) p. 707) estimated its duration as 3 million years.

Family ASTARTIDAE

In the United States, four principal species of *Astarte* belong to the subgenus *Ashtarotha* Dall:

Astarte cuneiformis Conrad (zone 10 and 14 of Calvert formation)

A. thisphila Glenn (zones 16 and 17 of Choptank formation)

A. obruta Conrad (zones 18 and 19 of Choptank formation)

A. undulata Say (in Gardner, 1943, p. 57, pl. 12, fig. 25-31)
(St. Marys and Yorktown formations)

Principal characteristics.—*A. cuneiformis* Conrad is pointed posteriorly. *A. thisphila* Say has flattened beaks and coarse concentric ribs. *A. obruta* Say has inflated beaks and no concentric ribs.

The subgenus *Ashtarotha* Dall includes shells with flattened beaks, pointed, with coarse ribs at the beginning of growth and which disappear in the middle of the shells, the posterior side is cuneiform (Chavan, 1949, p. 509).

In Europe the same group is represented by:

Astarte concentrica Goldfuss (1827 in Glibert, 1945, p. 97, pl. 6, fig. 2) of the Helvetian-Tortonian of Belgium. It is different from *A. concentrica* Conrad (1834, p. 133) of Yorktown formation of Virginia and North Carolina (in Gardner, 1943, p. 59, pl. 12, figs. 32-34). The species of Goldfuss has priority for keeping the name of *concentrica*.

A. tauroscalarata Sacco (1897, p. 27, pl. 6, figs. 28-32) of the Helvetian of Italy.

A. teschi Heering (1950, p. 21, pl. 3) of the Miocene of Peel (Holland).

A. sallomacensis Cossmann and Peyrot, (v. 2, p. 19, pl. 1, figs. 26-32) of the Helvetian of Aquitania (France).

Astarte thisphila Glenn

1904. *Astarte thisphila* Glenn, Maryland Geol. Sur., Miocene, p. 355, pl. 94, figs. 7-9.

Comparison of A. thispbila and A. tauroscalarata Sacco (1898, Piemonte, v. 28, pl. 6, figs. 28-32).—They are of the same triangular form although the American species is more pointed, the same sculpture formed by coarse, concentric ribs widely spaced toward the pallial margin. The hinge appears thicker on the Italian species.

The other species vary from *A. thispbila* by their different ornament: *A. teschi* Herring has stair-formed concentric ribs; *A. sallomacensis* C. and P. has fine convex grooves near the beak, and the shell form is not triangular; *A. concentrica* Goldfuss (not Conrad) has concentric ribs regularly proceeding to the pallial margin.

Astarte obruta Conrad

1834. *Astarte obruta* Conrad, Acad. Nat. Sci. Philadelphia, Jour., 1st ser. vol. VII, p. 150.

1903. *Astarte obruta* Conrad, Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. VI, p. 1490.

1904. *Astarte obruta* Conrad, Glenn, Maryland Geol. Sur., Miocene, p. 354, pl. 94, figs. 5, 6.

Comparison of A. obruta C. and A. omalii Jonkaiere, 1823 (in Glibert, 1945, p. 111, pl. 9, fig. 2).—These two species are large, rounded, smooth, and appear close, but they do not belong to the same group. *A. omalii* Jonkaiere is an *Isocrassina* Chavan (1949, p. 509).

On *A. obruta*, which is an *Ashtarotha*, the beak is flattened and angular for it is bounded on both sides by two sharp keels separating it from the lunule and the escutcheon; the ornament consists of coarse, thick-spaced ribs.

On *A. omalii* (specimens studied from Anvers, Belgium (Coll. U. S. Nat. Mus., No. 325667), the beak is rounded, not flattened, and the keels which border it are not sharp. The ribs are fine and close near the beak.

Biological remarks.—The subgenera *Isocrassina* Chavan and *Ashtarotha* Say are not cold water forms but lived in temperate waters (see Conclusions).

Family ISOCARDIIDAE

Genus **GLOSSUS** Poli, 1795 (*Isocardia* Lk., 1799)

Because this error in name has been criticized by many American authors, Dr. Nicol studied and determined the matter of nomenclature (1951, Washington Acad. Sci., Jour., vol. 41, No. 6, pp. 142-6).

Glossus Poli, 1795, must be given priority, taking account of Poli's work, although he did not use binomial nomenclature.

Isocardia cor L., 1767, then becomes *Glossus humanus* (Linné), 1758, by the same rule of priority.

In the United States, the most common species is *Glossus fraternus* Say, 1824 (Acad. Sci. Philadelphia, Jour., vol. 4, p. 143, pl. 11, fig. 1) which includes three subspecies (succeeding each other in time):

Glossus fraternus marylandicus (Schoonover) (1941, p. 57, pl. 9, figs. 4-6; pl. 10, figs. 4-6) = *G. fraternus glenni* (Gardner), (1943, p. 68, pl. 16, figs. 1, 2) of the Calvert and Choptank formations.

The shell is generally small, d. a. p. = 6.5 cm., d. u. p. = 5.5 cm., shape often oblong, keel accentuated, convexity medium.

G. fraternus Say type (in Glenn and Martin, 1904, pl. 85, figs. 3, 4) of St. Marys and Yorktown formations.

The shell is of normal size, d. a. p. 7.5 cm., d. u. p. 6.5 cm., the form is rounded, the keel is weak, the hinge thick.

G. fraternus carolinus (Dall), (1900, vol. III, pt. V, p. 1067, pl. 46, fig. 22) of Yorktown formation (Pl. 27, figs. 4a-d).

The shell is of large size, d. a. p.: 11.3 cm., d. u. p.: 9 cm., the keel is effaced and the hinge is thick, general form more elongate than in the species.

In short, the three species succeed each other as follows:

<i>G. marylandicus</i>	<i>G. fraternus</i>	<i>G. carolinus</i>
Calvert	St. Marys	Yorktown
Choptank	Yorktown	

Dall (1900, p. 1068) thought that *G. carolinus*⁶ is an ancestor of the living *Glossus humanus* (= *Isocardia cor*). This is not my opinion, for the latter descends from *G. boernesii*, a round form without keel, while *G. carolinus* belongs to the group of the keeled *Glossus*.

The "large species"⁷ *G. fraternus* closely approaches the large species *G. lunulatus* Nyst of the Belgian and German Miocene (Nyst, 1835, p. 13, pl. 3, fig. 53) (in Glibert, 1945, p. 135, pl. 9, fig. 1).

As for *G. marylandicus*, the young specimens are close to *G. lunulatus cypriniiformis* (Glibert, pl. 9, fig. 1g) with their carinate posterior shape and smallish beak, while the adult *G. marylandicus* is clearly comparable to

6 The specimen figured by J. Gardner (pl. 11, fig. 5) is broken and does not give the general appearance of the shell; the hinge is small. It does not correspond to the species studied.

7 In French, "grande espèce" means type species with variations and subspecies. (in Cuénot, L., 1936, L' espèce, Ed. Doin, Paris.)

those of *G. lunulatus* type. Only a detailed study of the hinge (figs. 1c, 1d) shows slight difference between the two species; that of the American species is thicker; the tooth 2b of the left valve is larger; moreover the upper cardinal margin is not incurved below the beak as in *G. lunulatus*, it is regularly rounded. The other characters of the shell are identical; convexity, beaks, other teeth, muscle scars, and concentric striation.

It can be said, therefore, that:

G. marylandicus (Calvert-Choptank) closely corresponds to *G. lunulatus* and *cypriniformis* (Helvetian-Tortonian).

Family VENERIDAE

Genus *Antigona* Schumacher, 1817

Type species, *Antigona lamellaris* (Gray) of present Pacific of Australia (studied in Coll. Nat. Mus. Wash., D. C., 76401).

The shell has strong concentric lamellar ribs; the radial ribs are weaker and not present in all species. The lunule and ligament are well marked. The hinge is that of *Venus* plus a lateral anterior tooth A II of the left valve which corresponds to a little socket in the right valve, the pallial sinus is small and pointed. The anterior part of the shell is enlarged in front because of this supplementary tooth.

The subgenus *Netara* Frizzel (1936, p. 46, type species, *A. staminea* Conrad) is not described by the author, and it is not known on what characters he based this separation.

Antigona staminea (Conrad)

1839. *Cytherea staminea* Conrad, Fossils Medieval Tertiary, cover of No. 1, pl. 21, fig. 1.

1903. *Cytherea (Artena) staminea* (Conrad), Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. VI, p. 1279.

1904. *Cytherea (Antigona) staminea* (Conrad), Glenn, Maryland Geol. Sur., Miocene, p. 314, pl. 76, fig. 6, 7.

1927, 29. *Antigona (Antigona) staminea* (Conrad), Palmer, Palaeont. Amer., vol. 1, No. 5, p. 329, pl. 27, figs. 2, 4, 5, 9-11, 14.

1941. *Antigona (Antigona) staminea* (Conrad), Schoonover, Bull. Amer. Paleont., vol. 25, No. 94B, p. 61, pl. 11, figs. 6-8.

The genus *Antigona* Schumacher is close to the subgenus *Ventricolidea* Sacco (1911, v. 28, p. 31) named by the latter for *V. multilamella* Lk., a Miocene and Recent species which has a lateral anterior tooth in the left valve.

This tooth appears in the genus *Ventricola* Roemer, 1857 for example: *V. rugosa*, (Chemnitz), a living species.

The two genera, *Ventricolidea* and *Antigona*, have strong concentric ribs (radial ribs do not exist in all species of *Antigona*), interior crenulations of the pallial margin, definite lunule and corselet, the same hinge with three divergent teeth and one lateral anterior AII of the left valve, the same short and pointed pallial sinus.

But Glibert (1945, p. 186), as well as Frizzell (1936, p. 57), indicated that *Ventricolidea* equals *Dosina* Gray, 1831, of which the type species is *D. zelandica* Gray (Powell, 1946, p. 15, fig. 3).

In comparing *V. multilamella* Lk. of Italy (Coll. Nat. Mus. Wash. no. 20316) and *Dosina zelandica* (in Marwick, 1925-27, pl. 44, figs. 118, 119, 121) (Powell, 1946, pl. 15, fig. 3), I note that the two species belong to the same genus called *Dosina* by priority.

But is *Dosina* equivalent to *Antigona*? Almost all authors separate them into two different genera or different subgenera, except Thiele (1931) who made *Dosina* the synonym of *Venus*.



Text-fig. 8. *Antigona lamellaris* (Gray). Type species. Hinges of left and right valves.



Text-fig. 9. *Dosina multilamella* (Lk.) Type species. Hinge of left valve.



Text-fig. 10. *Dosina zelandica* Marwick. Hinge of the right valve.



Text-fig. 11. *Antigona staminea* (Conrad). Hinge of left valve.

Differences between Dosina and Antigona.—*Dosina* is characterized by having only concentric sculpture, one small lateral anterior tooth and a rounded cardinal plateau; while in *Antigona*, the tooth AII being larger, the hinge is enlarged toward the front as well as the anterior part of the shell.

Note, also, that AII of *Antigona* is found exactly on the prolongation of tooth 2a which is turned forward, but in *Dosina*, tooth 2a is turned more toward the base and forms an angle with tooth AII (Text-figs. 8-11).

Thus, *Antigona* and *Dosina*, though close, can be separated, *Dosina* being a possible subgenus of *Antigona*, as K. Palmer indicated (1927, p. 118).

Resemblances of the species.—A single shell appears, according to the figures, similar to *A. staminea* of the European Miocene: *Venus scalaris* Bronn (1831, Ital. Gebiell., p. 100) (*in Sacco*, v. 28, p. 41, pl. 9, fig. 44) of the Tortonian-Pliocene of Italy. Sacco classed this with *Clausinella* although he mentioned (p. 41) that this shell has a lateral anterior tooth in the adult specimens which excludes it from the genus *Clausinella*.

Further, Bronn, in the *Index Paleontologicus* (1848, v. N-Z, p. 1360) wrote that *Venus scalaris* is equivalent to *Dosina* sp. ? He recognized this subgenus.

Hence, *Antigona staminea* and *Dosina scalaris* Bronn, despite the artificial barriers formulated by malacologists, perhaps belong to the same species. To make certain, it would be necessary to see specimens of *D. scalaris* Bronn.

Horizon of A. staminea.—Calvert formation of Maryland.

Genus **CALLISTA** Mörch 1853

Type species, *Venus chione* L. (fixed by Meek, 1876). This genus is sometimes differentiated from the genus *Macrocallista* Dall, 1902, type species, *Venus gigantea* Gmelin.

I have examined specimens of *Venus chione* L. of the Mediterranean and those of *V. gigantea* Gmelin of Florida (Coll. U. S. Nat. Mus.) and believe that *Callista* and *Macrocallista* belong to the same genus, the only difference being that the former is rounded and the later elongate.

Callista marylandica (Conrad)

1833. *Cytherea marylandica* Conrad, Amer. Jour. Sci., 1st ser., vol. 23, p. 343.

1903. *Macrocallista (Chionella) marylandica* (Conrad), Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. III, pt. VI, p. 1255.

1904. *Macrocallista marylandica* (Conrad), Glenn, Maryland Geol. Sur., Miocene, p. 311, pl. 74, figs. 1-2.

1927, 29. *Callista marylandica* (Conrad), Palmer, Paleont. Amer., vol. I, No. 5, p. 76, pl. XI, figs. 2, 3; pl. XII, figs. 10, 11.

This species is extremely close to *Callista italica* (Def.) figured in Cossmann and Peyrot (1910, p. 381, pl. 15, fig. 19; pl. 16, fig. 56), in Hoernes (1870, pls. 17, 18, *C. pedemontana*), in Dollfuss and Dautzenberg (1902, p. 213, pl. 15, figs. 1-7), in Sacco (1900, v. 28, p. 15, pl. 2, figs. 15-18).

They have the same size, the same rounded form with a somewhat high d. u. p., a smooth shell without radial ribs, marked only by growth lines, and chiefly the same hinge. Compare the figuration of *C. marylandica* (in Glenn, pl. 74, figs. 1-2) with the photograph of Cossmann and Peyrot (pl. 15, fig. 9).

I must point out, however, that the anterior tooth AII of the left is a little larger than that of the American species which brings about a slight thickening of the cardinal plateau in the anterior region. Another difference lies in the pallial margin which accords with the posterior margin of the shell by a rounded curve in *C. italica* and is more pointed in *C. marylandica*.

The growth lines are much more accentuated on *C. italica*, but this character is not fixed (*i. e.*, not specific) and is due to ecological conditions.

One other striking characteristic in the American species is the thickening of the shell anteriorly under the beak. This calcite layer, its thickness varying with the shells, appears superadded by the animal, perhaps playing a role in defense or in adaptation to a new biologic environment.

Horizons of C. marylandica.—Calvert, Choptank, and St. Marys formations of Maryland in zones 10, 14, 17.

D. Nicol (1953, p. 707) estimated its time span as three million years.

Horizons of C. italica.—Aquitanian of Italy and Provence, Burdigalian of southwest France, Helvetian-Tortonian of Europe (except Belgium and Germany), Pliocene of France and Italy.

III. SOME STRATIGRAPHIC REMARKS ON THE MIOCENE OF CHESAPEAKE BAY

CHOPTANK FORMATION

1. *Scientists' Cliffs.*—The shore is dominated by a cliff 25 to 30 meters high where new strata are frequently exposed when storms, by uprooting trees, bring down large blocks of sediments upon the beach.

The cliff shows the following section, the zones of the Chesapeake Bay stages being those adopted by G. B. Shattuck (*in* Maryland Geological Survey, 1904):

Zone 18-20—yellow sandy clay without fossils (7 m.)

Zone 17 —very fossiliferous yellow sands, true shell marl with beds of *Chlamys madisonia*, *Mercenaria*, *Dosinia*, *Callista marylandica*, *Cardium laqueatum* (we have collected a large number of species). (2 m.)

Zone 16 —blue, sandy clay in fossils (7 m.)

The fossils of zone 17 are rarely in place except some large-formed *Chlamys madisonia* and some specimens of *Mercenaria* and *Cardium*. The oysters are rare and not in beds. Like *C. madisonia*, they are encrusted by algae. These fossils have been accumulated on beaches by the currents of transgression just as one finds shells today on the seashore. In this shell marl, also, one finds, as always in the fossiliferous layers of the Miocene, mollusks from all depths now reassembled in the same level, not in place.

The facies of zone 17 is the same as that of the Faluns of Saucats and Touraine because of the substratum formed by sands and soft marls of the Oligocene or Eocene. It is found to be on the continental shelf slightly dipping with certain beach facies as described by J. Gardner. There are few gastropods in this zone.

Calvert Beach.—At Calvert Beach, zone 16, which outcrops from sea level to a height of three meters, is formed from compact blue marls with beds abounding in *Turritella plebeia*. One also finds *Glossus fraternus*, *Arca staminea*, *Phacoides contractus*, *Cardium laqueatum*.

Zone 17 is extremely fossiliferous here as elsewhere with numerous *Chlamys madisonia* of large size and an abundance of polyyps. But the outstanding feature at Calvert Beach is the presence of a rich bed of *Isognomon maxillata* Des.

This bed of *Isognomon* in place, one meter thick and several hundred long, includes thousands of individuals and an interesting biologic association with *Astraelia palmata*. It shows the existence in the Miocene of Chesapeake Bay, noted as containing a cold water fauna, a bed of corals, living along with *Perna* in a warm water fauna. (See Conclusions.)

The associated species in this bed are: *Chlamys madisonia*, *Mercenaria campechiensis*, *Callista marylandica*, *Calyptrea centralis*, and *Ecphora quadricostata*,—or about 25 species collected in a short time.

The list of fossils shows us that this coral bed developed on a soft layer of marl (zone 16) and at a depth of 25 to 100 meters in the coralline zone. It is local and not found further on where, on the contrary, we have seen, to the north of Calvert Beach, a fine bed of *Panopaea americana* associated with the same fauna of zone 17.

ST. MARYS FORMATION

Little Cove Point.—Along the cliff, the "drab clay": zone 23 outcrops at its base. Here are few shells in a compact blue marl; *Panopaea*, *Thracia*, *Pitar*, *Cardium*, *Natica*, *Leda*, crustaceans.

Now submerged in the sea, lies the fossiliferous level 22 from which fossils, mingled with living shells, are brought up onto the beach by the storms.

Here are *Ecphora quadricostata*, *Buccinofusus*, *Busycon*, *Natica*, *Turritella*, *Mercenaria*, and small gastropods.

Above zone 23, lies a curious, ferruginous Pleistocene stratum with a conglomerate of quartz pebbles and dark gritstone.

In this layer of the St. Marys, no *Cblamys jeffersonia* is found and, in general, few pelecypods, but there are numerous gastropods.

POWELLS LAKE SPILLWAY (VIRGINIA) OUTCROP

This outcrop is found to the southeast of Williamsburg, near the highway. Situated along a stream, it is difficult to see, but it is very fossiliferous.

The fossils collected are *Cblamys santamaria middlesexensis*, *Cblamys eborea urbannaensis*, *Ostrea disparilis*, *Chione latilirata*, *Cardita granulata*, and finally, a bed of *Isognomon maxillata* new variation, (which differs from the species in having fewer ligamentary sockets).

All of these fossils are indicative of St. Marys formation, which Mansfield noticed (*in* Gardner, 1943, p. 5, 7, 13). The determination of the age of this bed at Powells Lake Spillway was given by the author in 1955 to James McLean, Jr., (1956, p. 309), who showed me this outcrop.

YORKTOWN FORMATION

At Carter's Grove, the section is visible along the James River on the MacCrea Estate, Virginia, where a high cliff shows the two zones of this formation.

From top to bottom:

Zone 2

- red sands (Pleistocene (3 m.)
- bed with *Chama congregata* (0 m. 50)
- red sands (1 m. 50)
- fossiliferous sands with glauconite *Mercenaria rileyi*, *Chlamys jeffersonia*, *Panopaea*, *Crassatellites*, *Teredo*, . . . (0 m. 50)
- sands with *Chama congregata* and some *Barbatia centenaria* (6-7 m.)
- shell sands with *Chlamys jeffersonia* in place and *Mercenaria tetrica* in coarse yellow sands with corals and numerous fossils (30 species collected within a short time), the most abundant being *Chlamys jeffersonia*, *Mercenaria rileyi*, *Mercenaria tridacnoides*, *Crassatellites undulatus*, *C. cyclopterus*, *Glycymeris subovata*, and *G. subovata tuomeyi*, *Astarte undulata* (2 m.)

Zone 1

- yellow sands with *Chlamys clintonia* and *Ostrea disparilis* in place (this bed is found at water level at the base of the cliff).

An interesting fact appears in this cliff; the facies evolves from the bottom to the top of the cliff; at its foot the series are clearly marine, with beds of large *Chlamys* in a phase of transgression, with *Mercenaria* in place and a rich fauna in a largely oxygenated environment.

With the *Chama* zones, there appears a marly phase, hydrogenated, quieter, more stable, where the Chamas must not have lived according to their habitual way of life as they did not seem fixed. *Barbatias* mingled with the Chamas in these muddy, tranquil depths.

As one looks toward the top of the cliff, glauconite is seen to appear in the *Chama* beds, the sands become increasingly dark and glauconitic before becoming definitely continental with traces of unfossiliferous red clays. Above, a recurrence of coarse, glauconitic sands with *Chama*, indicates that these layers always belong to the Miocene and not to the Quaternary. Finally, the section terminates with beds of purely red clay.

It is evident that here in this section, one witnesses the end of the Miocene of Virginia by a progressive regression of the sea episode (with

Chama) and the establishment of a continental regime which will continue throughout the Pliocene.

I cannot say whether this section is constant in the Miocene of Virginia and North Carolina, not having had occasion to visit other beds of this region.

J. McLean, Jr., wrote (1956, p. 303) that the facies and fauna of Yorktown formation indicate the middle and upper neritic zone (between 25 and 100 meters in depth) of saline waters and an open sea with alternating warm and cold faunas. The fossils of Carter's Grove would show lower depths, with some fluctuations in the period of the *Chama*-beds.

Southwest of Yorktown, in the Moore House Cliff, Virginia,⁸ the beds are covered by the Pleistocene but are very fossiliferous.

From top to bottom, the section of the base of the cliff shows:

layer with *Crepidula costata* in a yellow sand

layer with *Chlamys*, very fossiliferous in a coarse sand; *Chlamys jeffersonia edgecombensis*, *Ostrea sculpturata*, *Mercenaria tri-dacnoides* and *M. rileyi*, *Glycymeris subovata*, *Astarte undulata*, *Mulinia congesta*, *Turritella alticostata*, *Busycon maximum*, a total of 15 species collected in a short time in this bed.

layer with *Crepidula costata* in a yellow sand

layer with *Turritella alticostata* in a yellowish sandstone.

The layer with *Crepidula* is interesting to note as it contains three associated species: *C. costata*, *C. plana*, and *C. fornicata* which are still living and again because they are scattered in marly sands. *Arca* (*Barbatia*) *centenaria* is also found.

The layer of *Chlamys* contains beds of *Ostrea sculpturata* in place with many fixed acorn barnacles. These, like *Chlamys*, lived in a disturbed environment, shown by coarse sands; transgression facies, with boring organisms, polyps, barnacles, algae in contrast with the muddy, calm habitat of *Crepidula*.

The presence of *Turritella alticostata* indicates Mansfield's zone 2 (in Gardner, 1943, p. 7), although there are no *Chamas* at Yorktown.

Mansfield's zone 1, with *Chlamys clintonia*, is not seen at Yorktown.

⁸ This field trip was possible with the friendly help of J. McLean, Jr. and his family. The author is much indebted to them.

IV. PRELIMINARY CONCLUSIONS

After this fragmentary study of the lamellibranchs of the Miocene of Maryland and Virginia and some brief considerations given to the beds, it is not possible to reach any conclusion, but certain interesting comments can be made concerning: (1) both the relationships and the differences of European and American species and (2): the characteristics of the lamellibranchs studied from a biologic and a climatic point of view.

1. *The relationships of European and American species.*—Contrary to the opinion of some authors, they are not marked or, if evident, are often superficial and do not withstand a close examination of the species.

These affinities do not go beyond the stage of the subgenus or group.

I have been able to link American species to European groups, but I have not succeeded in finding the same species in both continents.

The only ones that might be considered identical, judging from the illustrations of the European species, are:

Antigona staminea and *Venus scalaris*

Glossus (= *Isocardia*) *marylandicus* and *G. lunulatus*—*cypriniformis*

Chlamys madisonia, *calvertensis* and the young of *Chlamys radians*

By continuing the detailed study of the mollusks, it is probable that other almost identical species may be found.

Earlier malacologists who have studied the question have discovered some analogies between the two continents, especially among the gastropods.

Kautsky (1927) indicated great similarities between the *Isocardias* and the *Carditas*, the *Nuculidae* and the *Nuculanidae*, the *Dentalia* and, again, especially among the gastropods.

But in his conclusions, Kautsky practically restated those of Dall, as did also the Countess Lecointre (1909).

J. Gardner (1924, p. 860) also likened European and American genera and linked the Chipola formation to the Burdigalian by the affinities of the *Carditidae* and *Lucinidae*. She wrote further that the Chesapeake group may be Tortonian by analogy with the Tortonian of Germany (Holstein) and on the strength of a single specimen of *Ecphora quadricostata* (Say) (1826, Acad. Nat. Sci. Philadelphia, Jour., vol. IV, 1st ser., p. 127, pl. VII, fig. 5) which might be similar to *Stenomphalus wiechmanni* v.

Koenen (1872, p. 179, pl. 1, fig. 2, 10b) represented by a poor drawing.⁹ The European species would rather approach *Ecphora tricostata* Glenn and Martin of Calvert formation (1904, Maryland Geol. Sur., p. 209, pl. 52, figs. 5-8).

As a matter of fact, we can see that equivalents are difficult to establish between the two continents.

In general it can be said that the American species are more ornate than their European relatives. They always have a secondary ornamentation formed by fine ribbings or scales on the back of the ribs and in the interspaces. This occurs in *Anadara (idonea, staminea, and subrostrata)*, all *Chlamys (condylamata, jeffersonia, septenaria, edgcombensis)* and *Astarte (thispbila, for example)*.

In Maryland and Virginia, the shells are almost always of gigantic dimensions, as, for example, *Mercenaria rileyi*, *Mercenaria tridacnoides*, *Chlamys jeffersonia* (which reaches a diameter of 18 cm.), *Chlamys madisonia*, *Crassatellites*.

One observes, likewise, that a close analogy exists between the young individuals of close species (*Chlamys madisonia* and *Chlamys radians*). This denotes a common origin for the species, but where to place that origin?

The problem will remain unsolved as long as contemporary Miocene beds are not found in Europe and America. Unfortunately, the mollusks cannot furnish a key.

In my opinion, the stratigraphy alone, studied in detail at Chesapeake Bay and in Virginia, would furnish interesting results similar to those indicated in the study of the Yorktown formation.

2. *Characteristics of the lamellibranchs studied from the point of view of climate.*—The paleontologists have always considered the Neogene mollusks of the East Coast as a cold water fauna, particularly on account of the numerous *Astarte* collected in the beds.

But if the majority of Astartidae live in boreal seas, this fact is not true for certain genera and subgenera of *Astarte* as studied by A. Chavan (1949, p. 509).

Astarte borealis Chemnitz, for example, characteristic of the Arctic Ocean, belongs to the subgenus *Triodonta*, Agassiz (emend. *pro Triodonta*

⁹ But *Stenomphalus wiechmanni* is rare in Germany, differs from *Ecphora*, and is of smaller size.

Schumacher) while the other *Astarte* belong to different subgenera not at all boreal. Thus, *Astarte*, from the Miocene of Chesapeake Bay, is of the subgenus *Ashtarotha* Say which is in no wise characteristic of a cold fauna since at the present time it does not live in Arctic or Antarctic waters. This subgenus is probably from a temperate climate like the subgenus *Isocrassina* Chavan (1949, p. 509)

I note, in fact, that in the beds of Chesapeake Bay, *Ashtarotha* most often lived in company with *Isognomon*, *Glycymeris*, *Anadara*, the large *Chlamys*, *Venericardia*, all genera typical of tropical or temperate waters.

This fact is especially striking for the *Isognomon*s which form rich and flourishing beds in the strata of Maryland and Virginia. These mollusks live among the coral reefs and could not tolerate another climate.

Chamas, likewise, are a part of the tropical fauna, another reason for concluding that the Yorktown formation is not of a cold sea.

The only genera of cold or boreal waters are *Nucula*, *Nuculana*, *Saxicava*, and *Panopaea*, but these lamellibranchs are not numerous in the Chesapeake Miocene and do not form banks or biostromes like the other genera.

Panopaea, noted for being of a cold fauna, can accommodate itself to warm temperatures as well as to cold. During the Miocene more than 100 species were distributed at a great number of points in Europe and the world. There were four in the Burdigalian of Provence which have a tropical character (Mongin, 1948-1952, p. 188, 219), and also in the Miocene of Aquitania, Austria, Italy, Touraine, Denmark, and Belgium. This genus is, therefore, climatically cosmopolitan.

Hence, it is not evident that the Miocene of North America is of a colder climate than that of Europe, although a greater number of boreal genera are found there. The detailed study of the stratigraphy and petrography of the Chesapeake strata will doubtless show the alternation of cold and warm currents which flowed through the Miocene sea of that region. A study of the superposition of beds or their lateral extension along with a careful analysis of the fauna of each level would be necessary.

Another indication of the temperature and biological conditions of the waters of that epoch is given us by the morphological aspect of the shells. They are generally thick, and according to many biologists for example, Pelsener (1935), large, thick shells, denote a temperature between 20 and 30 degrees Centigrade of high salinity (Tasch, 1953, p. 426) and disturbed waters.

I do not agree with Tasch (1953), when he says that gigantism is found in cold water fauna. This statement is contrary to the observations of other biologists who have studied reefs and tropical formations.

But I admit that shells of large, generally thick forms exist only in zones 17 and 19 of the Choptank formation, certain layers of St. Marys of Virginia, and Yorktown formation.

The fossils of Calvert formation are of medium size and normal thickness.

In summing up, one can now more easily imagine the picture of the Miocene sea of this region after a study of the fauna and stratigraphy such as J. Gardner has made (1917, Johns Hopkins Univ. Circ. No. 293, p. 36), but with the addition of some new ideas.

During the period of the Calvert formation, the beds of marly sands indicate to us a bottom of sand and mud in tranquil waters at a depth of 20 to 25 fathoms. The mollusks were burrowers—*Corbula*, *Mercenaria*, *Callista*, *Glossus*—or some free forms such as *Pecten*, big *Chlamys*, and beds of oysters which lived easily in these calm, slightly saline waters, with muddy bottoms, and doubtless, near an estuary.

During the Choptank formation, the facies change often in the course of ages; one sees there a multitude of climatic changes such as T. Soot-Ryen claimed for the Miocene in general (1932).

Beds of marly sands, blue or yellow, poor in fossils and having the same biology as the Calvert horizons, calm and muddy waters, alternate with beds which are extremely rich in fossils. These extraordinary accumulations of lamellibranchs of zone 17 and 19 of the Choptank indicate a transgressive episode of waters stirred by strong currents and bringing in from great depths of the sea genera such as the large *Chlamys madisonia*, the large *Mercenaria* and the big *Cardium* (*C. laqueatum*). Their valves, usually disassociated, have been tumbled by the waters and are covered with acorn barnacles and polyps; they have also been encrusted by algae. Rich beds of coelenterates and *Perna* flourished also sometimes on these shores.

In Maryland, during the St. Marys formation, the blue clays ("drab clay") contained a fine fauna of gastropods living either in the algal growths or in the sandy and gravelly depths. In Virginia, the facies was often that of Choptank, transgressive with large specimens of *Chlamys*, oysters, *Perna* and *Mercenaria* (Powells Lake).

Finally, at the end of the Miocene, in the Yorktown, came the same beds of large Pectinidae, gigantic *Mercenaria*, and a multitude of species of

all sizes and families, always indicative of an exuberant life as in the present-day tropical seas. The water of that epoch was no longer cold.

After a marly episode in which the Chamas and Crepidulas flourished, one sees, as I have already written, the marine facies becoming more and more episodic as one goes higher in the series; continental interrelations slip into the layers and finally the last beds of *Chama congregata* give place to azoic red sands.

The end of the Miocene is written in the cliffs of Carter's Grove, as in Europe the end comes in the terminal series of the Tortonian, the brackish conditions of the Sarmatian and the continental formations of the Pontian. But equivalents cannot be drawn between the continents.

During the Miocene, as at the present time, Europe and America formed two different zoological and climatic provinces, and analogies are both dangerous and useless.

In America there is certainly a stage of the Burdigalian age, another that may be Helvetian and another which corresponds to the terminal Vindobonian, but it is difficult to say whether the stages of Chesapeake Bay correspond to the principal stages of Europe.

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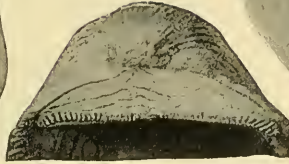
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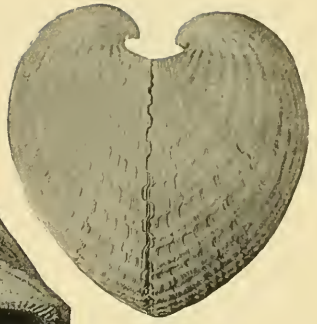
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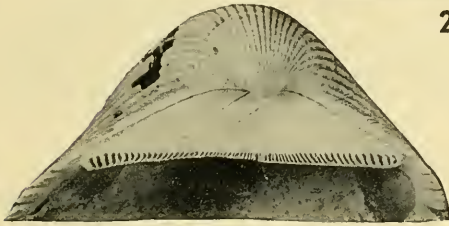
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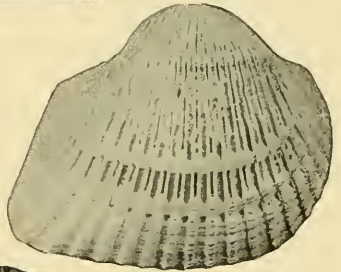
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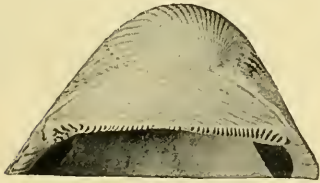
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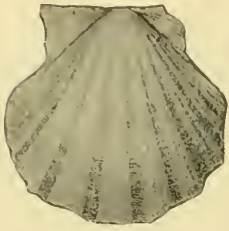
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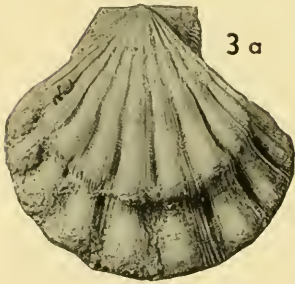
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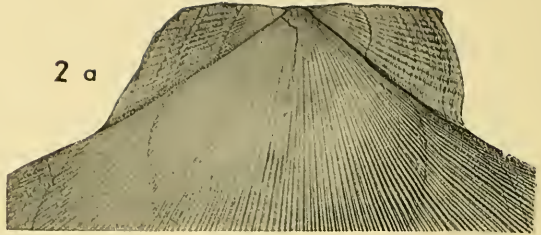
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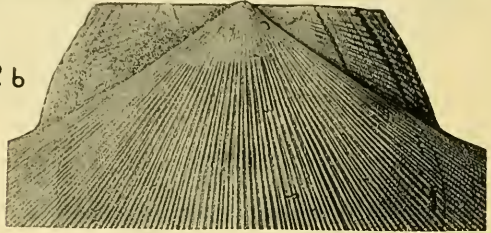
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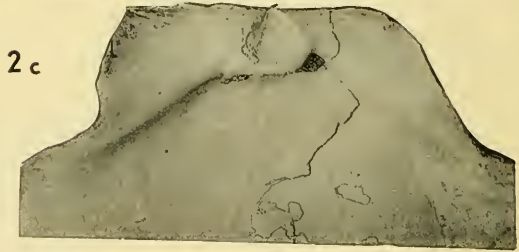
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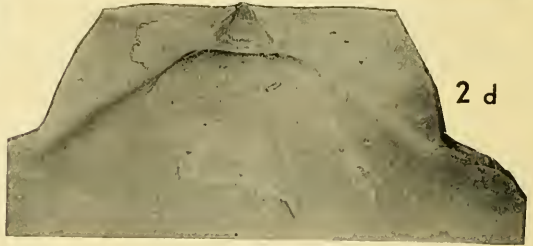
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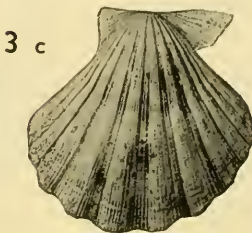
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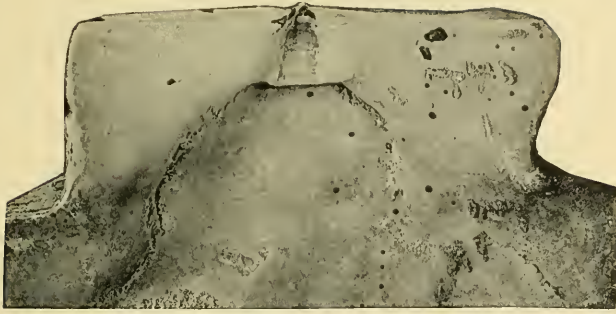
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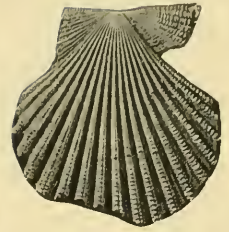
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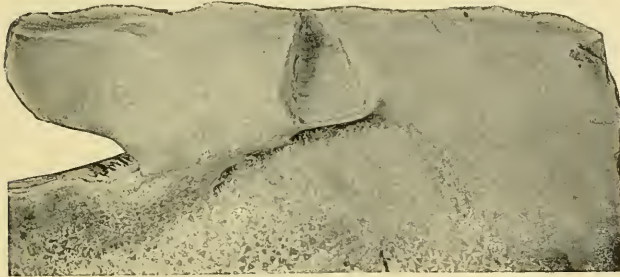
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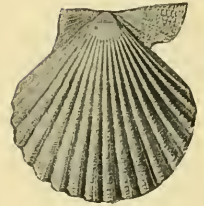
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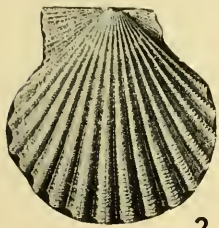
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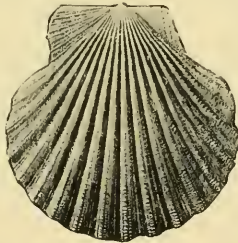
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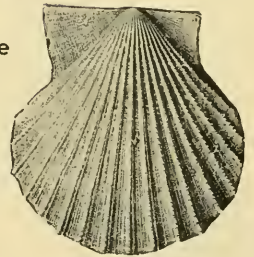
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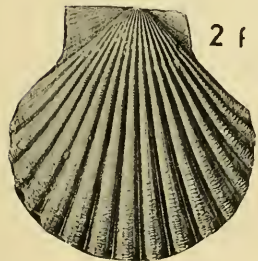
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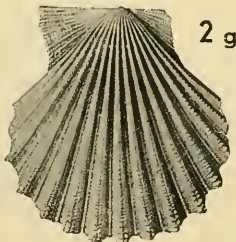
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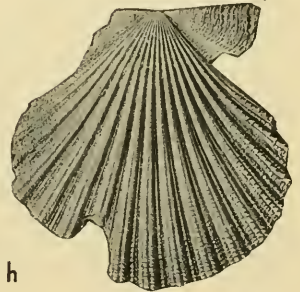
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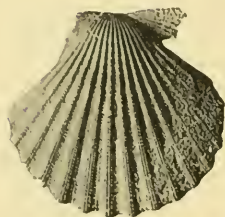
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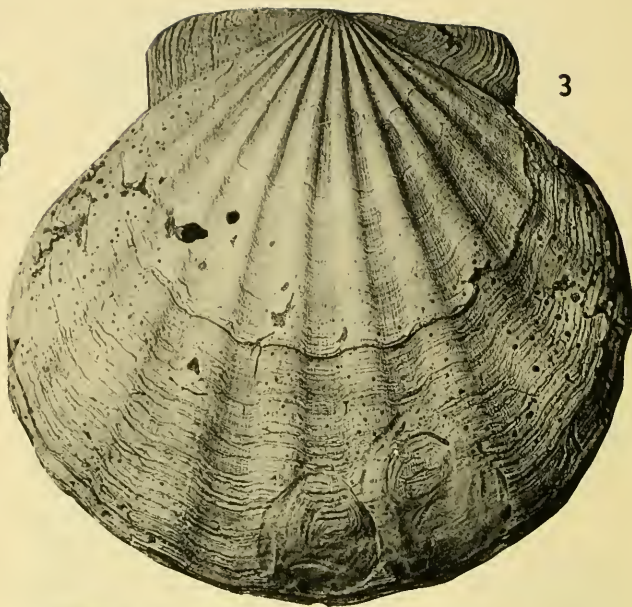
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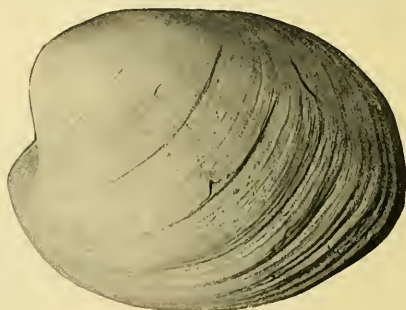


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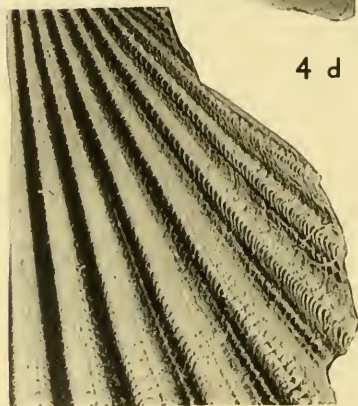


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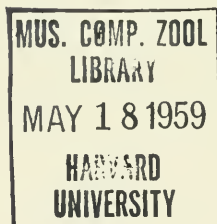
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NAMES OF AND VARIATION IN CERTAIN INDO-PACIFIC CAMERINIDS*

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ABSTRACT

Operculinella Yabe (1918) and *Operculinoides* Hanzawa (1935) are demonstrated by the variation which occurs in the species *Operculina ammonoides* (Gronovius) and *O. venosa* (Fichtel and Moll) to be synonyms of *Operculina* d'Orbigny, 1826. The generic and specific names which have been applied to these two Indo-Pacific species are discussed. These species occur abundantly in warm water at various localities in the Indo-Pacific area at depths of 8 to 62 fathoms. The species *O. bartschi* Cushman and *O. complanata* (Defrance) are introduced for comparison with the other two species.

INTRODUCTION

Yabe (1918, p. 126) erected the generic name *Operculinella* based on the species "*Nummulites*" *cumingii* (Carpenter) (1895). Later, Hanzawa (1935, p. 18) gave the generic name *Operculinoides* to certain species from America which had been assigned previously to the genus *Operculina*. *Operculina willcoxi* (Heilprin) was designated by Hanzawa as the type species.

Although *Operculinoides* was accepted immediately and widely used in America, the name *Operculinella* has had less acceptance. Glaessner (1945, p. 174) wrote: "*Operculinella* Yabe, 1918, has recently been restricted to a rare form (*O. cumingii* Carpenter s. str.) with a high flange of flat semi-circular evolute chambers (Hanzawa, 1939)." Cole (1953, p. 33) stated "*Operculinella* is not a valid subgenus as its broadly flaring, complanate border is a gerontic development . . . Median and transverse sections cannot be distinguished from similar sections of various species assigned to *Operculinoides*."

Barker (1939, p. 308) wrote: "I am not yet convinced as to the advisability of splitting up the group into so many genera, as in all cases forms can be found intergrading from one so-called genus into another." Although Barker made this dissent, these generic names have been used to the present.

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During the past several years numerous collections by field parties of the U. S. Geological Survey from various Pacific islands have become available for study. As certain of these samples contained abundant and often well-preserved specimens of camerinids, it was important to identify these specimens correctly. Moreover, it was discovered that many of the fossil specimens were similar to, if not identical with, species still living in the Indo-Pacific region.

Therefore, a two-fold problem arose as confusion existed not only at the generic level, but also at the specific one. Authors have in many instances used the specific names *O. venosa* and *O. cumingii* interchangeably, and specimens of the variable species *O. ammonoides* have been assigned numerous names including *O. venosa*.

Therefore, it became desirable to study as many Recent specimens as possible. Through the kindness of Dr. G. Arthur Cooper specimens which Cushman (1921, p. 383) identified as *Opeculina venosa* from the Philippine and adjacent seas were made available from the collections of the U. S. National Museum. Moreover, two of the original *Albatross* samples were sent so that specimens for thin sections could be obtained. Mrs. Esther R. Applin sent a sample from Espiritu Santo, New Hebrides, and she kindly gave permission to use this material. In addition, fossil material was available from several localities in other island groups.

The various localities used in this study follow:

LOCALITIES

Recent material

- Locality 1. *Albatross* station D 5141, latitude 6° 09' 00" N., longitude 120° 58' 00" E., at a depth of 29 fathoms.
2. *Albatross* station D 5142, latitude 6° 06' 10" N., longitude 121° 02' 40" E., at a depth of 21 fathoms.
3. Espiritu Santo, New Hebrides, through the courtesy of Mrs. Esther R. Applin.

Fossil material

4. Station IS-F 310a-56, Ishigaki-shima, Yaeyama-guntō Ryūkyū-rettō; deposit of gray sandy clay exposed in the north bank of the east branch of the Nagura-gawa about 2.45 miles from the mouth of the river. The clay deposit

is overlain unconformably by coarse stream terrace deposits of Recent age. About a 7 foot section of clay is exposed and the base was not seen. The clay has conspicuous vertical joints spaced 1 to 4 feet apart. (Grid location: Army Map Service L 791, Sheet 2920 111 is 195993).

5. Station IS-M-149-56, Ishigaki-shima, Yaeyama-guntō, Ryūkyū-rettō; small patch of Ryūkyū limestone 1.1 mile north of the village of Kainan along the west bank of the upper course of the Miyara-gawa in central Ishigaki-shima. The exposure extends from the level of the stream channel to about 50 feet above the channel. The limestone is either plastered against or interfingered with unfossiliferous terrace gravels called the Nagura gravel (Grid location: Army Map Service L 791, Sheet 2920 111 is 224995).
6. Nakōshi, Haneji-mura, Okinawa-jima, through the courtesy of the late T. Wayland Vaughan (reference: Yabe and Hanzawa, 1925, p. 39).
7. Djaing Langit, Tabalong District, southeastern Borneo, collected by A. Tobler, through the courtesy of the late T. Wayland Vaughan (reference: Douvillé, 1905, p. 448).
8. L 444, Oneata, Lau Islands, Fiji (reference: Ladd and Hoffmeister, 1945, p. 90).

The specimens used in this study will be deposited in the U. S. National Museum.

STATUS OF THE GENERIC NAMES

OPERCULINA, *OPERCULINELLA* AND *OPERCULINOIDES*

Operculinella Yabe (1918, p. 126) is assumed to be involute in the initial stage and develops later a broadly flaring complanate border. Examination of numerous specimens of *Operculinella cumingii* (= *O. venosa*) from the *Albatross* material demonstrated that the majority of the specimens are completely involute and without a rim (fig. 14, Pl. 28). Some specimens develop a slight rim (fig. 13, Pl. 28) and exceptional specimens develop a wide rim (fig. 17, Pl. 28; Hanzawa, 1939, pl. 15, figs. 6-8). In all of these specimens the alar prolongations extend to the umbilical plugs (figs. 1, 2, 11, 13, 14, Pl. 29).

Typical specimens of *Operculinella cumingii* (= *O. venosa*) do not differ, either in external appearance or in internal structure, from *Operculinoides willcoxi* (Heilprin) which is the type species of *Operculinoides* Hanzawa (1935). Moreover, specimens which have been referred traditionally to *Operculinoides* develop a marked rim which is similar in every respect to the one shown by exceptional specimens of the type species of *Operculinella* (see: Vaughan and Cole, 1941, figs. 4, 9, pl. 9; Cole, 1958a, figs. 5, 6, pl. 29). Thus, there does not appear to be any valid criteria by which *Operculinella* and *Operculinoides* can be distinguished from each other.

Typical specimens assigned to *Operculina complanata* (fig. 16, Pl. 29) are evolute, and there are no alar prolongations. The earlier whorls are not separated from each other by a cavity but are covered by a solid layer. However, in certain species, as *Operculina ammonoides*, individuals from a single population run the gamut from those which resemble *Operculinoides* (figs. 8, 10, Pl. 29) with elongate alar prolongations to others with short alar prolongations (fig. 6, Pl. 29) to others which are entirely comparable to *Operculina* (figs. 3, 12, Pl. 29). As there is complete gradation in a single species from *Operculinoides* to *Operculina*, it is apparent that only one genus can be recognized.

The kind of coiling, therefore, in the genus *Operculina* can not be used as one of the diagnostic features of the genus. However, the tendency of the individuals of a single species to maintain one or the other kinds of coiling may be used as a specific character. Thus, the individuals of a given species may be involute normally, whereas in another species they may be evolute, and, finally, other species may have individuals which grade from those which are involute to others which are evolute.

The test of involute species of *Operculina* of the kind of *O. venosa* does not differ fundamentally from that of *Camerina*. The only criterion which is of importance in separating the two genera is the increase in height of the chambers of the median section in *Operculina*, whereas those of *Camerina* increase gradually in height but never have a marked increase.

Although *Planocamerinoides* Cole (1958b, p. 262) (= *Assilina* of authors) is defined as possessing an evolute test, there are indications that in some species assigned to this genus there is intergradation from evolute individuals to involute ones (Gill, 1953, pl. 13, figs. 15, 16, 19.) Therefore, it is probable that *Planocamerinoides* will prove to be a synonym of

Camerina. If this is so, the parallelism in the development of the test will be the same in *Camerina* as it is in *Operculina*.

STATUS OF THE SPECIES *OPERCULINA AMMONOIDES* AND *OPERCULINA VENOSA*

The confusion in the use of the specific names *O. ammonoides* and *O. venosa* will be discussed in the systematic part of this article. At this point the question may be raised whether there are two species or one inasmuch as certain specimens (figs. 1, 15, Pl. 28) assigned to *O. ammonoides* resemble others (fig. 14, Pl. 28) referred to *O. venosa*.

Examination of populations which were available, as well as those described in the literature, has shown that the involute, unornamented specimens of *O. ammonoides* are normally accompanied by evolute, highly ornamented specimens. However, the populations of *O. venosa* which have been examined do not have evolute, highly ornamented specimens associated with the involute specimens.

If only a single specimen of the involute kind were available, particularly in thin section, it would be difficult to differentiate between *O. venosa* and *O. ammonoides*. However, if abundant specimens are available, the variability of coiling in *O. ammonoides* should make it readily identifiable.

Moreover, if well-preserved, involute specimens are available, it is comparatively easy to distinguish the two species. *O. venosa* has heavy, limbate sutures which have a marked recurvature at their distal ends, whereas the sutures of *O. ammonoides* appear as much lighter lines across the surface of the test and they do not have the marked distal recurvature.

STRATIGRAPHIC RANGE OF

OPERCULINA AMMONOIDES AND *OPERCULINA VENOSA*

Douvillé (1905, p. 448) identified specimens from Borneo as *Operculina niasi* (Verbeek). These specimens were associated with *Lepidocyclina* and *Miogypsina* in sediments which are assigned to Tertiary *f.* Fortunately, the late T. Wayland Vaughan had given me a small, but apparently representative collection of these specimens, four of which are illustrated (fig. 6, Pl. 28; fig. 7, Pl. 29; figs. 6, 7, Pl. 31).

These evolute specimens are not only identical with certain specimens referred to the evolute kind of *O. ammonoides*, but also later examination of the sample demonstrated that they were accompanied by several specimens of the involute kind.

Cole (1957, p. 330) found *Operculina ammonoides* in samples from Saipan Island in strata assigned to Tertiary *e*. Therefore, this species ranges in the Pacific area from Tertiary *e* (lower Miocene) to Recent.

Operculina venosa (= *O. cumingii*) occurs on Guam Island in association with *Lepidocyclina* and *Cycloclypeus* (*Katacycloclypeus*) in strata which are assigned to Tertiary *f* (middle Miocene) (Cole, ms.). This species has been recorded elsewhere from Tertiary *f* strata of the Lau Islands, Fiji (Cole, 1945, p. 276).

ECOLOGY

Chapman and Parr (1938, p. 291) wrote: "This species (*O. ammonoides*) is widely distributed in shallow water in the tropical Indo-Pacific region. On the Barrier Reef, it appears to be found in shallower water than *O. bartschi*." If the data given by Cushman (1921) are analyzed (Table I), it appears that in the Philippine and adjacent seas the average depth of occurrence of the two species is approximately the same. In this area the average depth for *O. ammonoides* is 28 fathoms, whereas *O. bartschi* occurred at an average depth of 31 fathoms. *O. venosa* occurred in this same area at an average depth of 19 fathoms.

From the limited data available it appears that all three species develop best in shallow, warm water of the Indo-Pacific area.

The fossil specimens of *O. ammonoides* from locality 4 were accompanied by rare specimens of *Baculogypsinoides spinosus* Yabe and Hanzawa, *Calcarina spengleri* (Gmelin), and *Heterostegina suborbicularis* d'Orbigny. The fossil specimens of *O. complanata* from locality 5 were associated with extremely rare specimens of *Amphistegina madagascariensis* d'Orbigny and *Baculogypsinoides spinosus* Yabe and Hanzawa.

The average depth at which *Heterostegina* occurred in the vicinity of Bikini and the Philippine Islands was 25 to 32 fathoms (Cole, 1958 c, p. 750). These data check closely with depth occurrence of the *Operculina*. In the *Albatross* samples numerous *Heterostegina suborbicularis* occur with *O. venosa*.

Table 1.—Depths of occurrence in Recent seas

Species	Reference	Number of localities	Minimum depth (fathoms)	Maximum depth (fathoms)	Number of localities reported common or frequent	Minimum and maximum depths at which reported common or frequent (fathoms)	Average depth at which reported common or frequent (fathoms)
<i>O. venosa</i>	P. 384 ⁽¹⁾	20	10	554	10	19-37	19
	P. 144 ⁽²⁾	5	10	27	3	11-27	21
	P. 299 ⁽³⁾	1	—	—	—	—	8
	P. 78 ⁽⁴⁾	2	—	—	1	—	45
<i>O. ammonoides</i>	P. 380 ⁽¹⁾	10	18	170	4	22-38	28
	P. 6, 50 ⁽⁵⁾	3	17	25	—	—	20
	P. 78 ⁽⁴⁾	6	44	162	2	58-66	62
<i>O. bartschi</i>	P. 377 ⁽¹⁾	38	18	1,105	9	19-52	31

(1) Cushman, 1921
 (2) Hofker, 1933
 (3) Chapman and Parr, 1938
 (4) Hanzawa, 1948
 (5) Cushman, 1924

DESCRIPTION OF SPECIES

Family Camerinidae

Genus *Operculina* d'Orbigny, 1826

- Operculina ammonoides* (Gronovius)** Pl. 28, figs. 1-11, 15; Pl. 29, figs. 3-10, 12, 15; Pl. 30, figs. 2-8; Pl. 31, figs. 5-7
1781. *Nautilus ammonoides* Gronovius, Zooph. Gron., p. 282, pl. 19, figs. 5, 6.
1924. *Operculina guimairdi* d'Orbigny, Cushman, Carnegie Inst. Washington, v. 21, p. 50, pl. 17, fig. 7.
1924. *Operculinella venosa* Cushman, *non* Fichtell and Moll, *idem*, p. 50, 51, pl. 17, fig. 7.
1925. *Operculina (Operculinella) venosa* Yabe and Hanzawa, *non* Fichtel and Moll, Tohoku Imp. Univ., Sci. Rep., 2d ser. (Geol.), v. 7, No. 2, p. 49-51, pl. 5, figs. 1-27; pl. 6, figs. 1-5; pl. 7, figs. 1-10.
1935. *Operculinella venosa* Hanzawa, *non* Fichtel and Moll, Tohoku Imp. Univ., 2d ser. (Geol), v. 18, No. 1, p. 23, pl. 1, figs. 31-41.
1938. *Operculina ammonoides* (Gronovius), Chapman and Parr, Roy. Soc. Victoria, Proc., v. 50, Pt. 1, n. ser., p. 290-292, pl. 17, figs. 12-16, text fig. 5 (additional references).
1939. *Operculina ammonoides* (Gronovius), Hanzawa, Jap. Journ. Geol. Geog., v. 16, Nos. 3, 4, p. 229, 230, pl. 15, figs. 1a, b, 3a, b, 4, 5, 10; pl. 16, figs. 3-7.
1953. *Operculina ammonoides* (Gronovius), Carter, Journ. Paleont., v. 27, No. 2, p. 240, 241, pl. 34, figs. 4-6.
1953. *Operculina complanata japonica* Carter, *non* Hanzawa, *idem*, p. 241-250, pl. 33, figs. 1-12; pl. 34, figs. 7, 8.
1957. *Operculinoides* sp., Puri, Paleont. Soc. India, v. 2, p. 104, pl. 12, figs. 6-8.
1957. *Operculina* sp., Puri, *idem*, p. 105, pl. 13, figs. 1-4.
1957. *Operculinoides* sp., Puri, *idem*, p. 105, pl. 13, figs. 5-8.

The illustrations show the external appearance and internal structure of specimens assigned to this species. In most cases thin sections were prepared from each of the variants. In the explanation of the plates a reference is given after each thin section to the variant which duplicates the external appearance of the specimen from which the thin section was made. Measurements of the specimens which are illustrated follow in Tables 2-4.

Discussion.—Yabe and Hanzawa (1925, p. 49) discussed this species under the name *Operculina (Operculinella) venosa* (Fichtel and Moll) and illustrated Recent specimens from Apia Harbor, Uporu, Samoa Islands, and fossil specimens from Nakôshi, Haneji-mura, Okinawa-jima. These excellent photomicrographs conclusively demonstrate the gradation from slightly evolute, unornamented specimens to those which are evolute and highly ornamented. Later, Hanzawa (1935, p. 23) gave under the name *Operculinella venosa* another excellent series of photomicrographs which illustrate the variable characters of this species.

Table 3.—Measurements of median sections of *O. ammonoides*

Specimen	Pl. 30			Pl. 31				
	Fig. 2	Fig. 5	Fig. 6	Fig. 8	Fig. 3	Fig. 4	Fig. 6	Fig. 7
Kind of test	Involute	Slightly evolute	Evolute	Evolute	Evolute	Evolute	Evolute	Evolute
Height .. mm.	1.9	1.96	2.78	2.65	1.65	1.6	2.05	2.1
Width .. mm.	1.65	1.67	2.5	2.5	1.4	1.35	1.9	1.85
Embryonic chambers:								
Diameter of initial chamber μ	80	70	60	60	30	65	50	45
Diameter of second chamber μ	50 x 110	40 x 80	30 x 90	30 x 80	20 x 35	30 x 70	40 x 75	30 x 50
Distance across both chambers .. μ	150	120	100	110	65	115	100	90
Number of volutions	3	3 $\frac{1}{2}$	4	4 $\frac{1}{8}$	3 $\frac{3}{4}$	3	3 $\frac{1}{2}$	3 $\frac{3}{4}$
Chambers in first volution	10	9	10	8	7	9	10	8
Chambers in final volution	18	23	27	23	19	16	21	20
Total number of chambers	45	53	71	70	48	37	55	60
Locality	3	4	4	4	6	6	7	7

Table 4.—Measurements of transverse sections of *O. ammonoides*

	Pl. 29										
	Pl. 30					Pl. 29					
Specimen	Fig. 7	Fig. 10	Fig. 8	Fig. 6	Fig. 12	Fig. 15	Fig. 5	Fig. 4	Fig. 3	Fig. 9	Fig. 7
Height	2.05	1.88	2.2	2.75	2.15	1.51	3.1	4.1	1.4	1.95	2.65
Thickness	0.9	0.81	0.88	0.57	0.48	0.83	0.66	0.56	0.45	0.36	0.82
Diameter of umbonal plugs	μ	150	250	150	160	110	230	150	160	110	380
Locality			3					4		6	7

Chapman and Parr (1938, p. 290) correctly recognized that the Recent and fossil specimens which Yabe and Hanzawa referred to *O. venosa* should be assigned to *Operculina ammonoides* (Gronovius). Hanzawa (1939) accepted the conclusion of Chapman and Parr regarding the specimens which previously had been assigned to *O. venosa*. However, Hanzawa (1939, p. 230) included questionably in the synonyms of *O. ammonoides* specimens which Chapman and Parr (1938, pl. 27, figs. 21, 22) identified as *Operculinella venosa*. Moreover, he did not accept the conclusion of Chapman and Parr (1938, p. 293) that *O. cumingii* was a synonym of *O. venosa*.

Authors included under *O. ammonoides* specimens from the Atlantic Ocean which Cushman (1931, p. 108) correctly considered to be *Hyalinea balthica* (Schroeter). Thus, many of the older illustrations and references to *O. ammonoides* are incorrect.

***Operculina bartschi* Cushman**

Pl. 28, fig. 16

1921. *Operculina bartschi* Cushman, U. S. Nat. Mus., Bull. 100, v. 4, p. 376, 377, text fig. 13.

1938. *Operculina bartschi* Cushman, Chapman and Parr, Roy. Soc. Victoria, Proc., v. 50, Pt. 1, n. ser., p. 292, 293, pl. 17, figs. 17-20; text fig. 6.

The specimen illustrated (fig. 16, Pl. 28) has a height of 4.4 mm. and a width of 3.6 mm. There is a slightly elevated area over the embryonic chambers with a diameter of 0.75 mm., the surface of which is covered with slightly projecting, closely packed bosses of clear shell material which have diameters of about 120 μ . Two whorls show clearly, the last of which has 18 chambers. The sutures are limbate and beaded. The chamber walls between the sutures have several rows of small beads. The spiral suture is not depressed.

A median section of a specimen with a height of 3.35 mm. and a width of 2.75 mm. exposes 4 whorls with 16 chambers in the final volution. There are 8 chambers in the first volution and 48 chambers in entire test. The initial chamber has an internal diameter of 50 μ and the second chamber has diameters of 30 μ by 70 μ . The distance across both chambers is 85 μ . This specimen is a megalospheric one.

Discussion.—A representative specimen of this species (fig. 16, Pl. 28) is illustrated for comparison with the microspheric specimen (fig. 10, Pl. 28) of *O. ammonoides* with which it might be confused. The microspheric specimen of *O. ammonoides* (fig. 10, Pl. 28) has a height of 3.95 mm. and width of 3.3 mm. The initial coils lie below a slightly elevated

area with a diameter of 1.2 mm. This area is bounded by a depressed suture which separates it from the final volution. The central area has projecting, widely separated papillae with diameters of about 80 μ . The sutures across the final volution are elevated and strongly beaded. The marginal cord is thick and its edge is elevated above the general surface of the adjacent chamber walls.

A median section (fig. 5, Pl. 31) made from a similar specimen of *O. ammonoides* has a height of 4.1 mm. and a width of 4.2 mm. There are $5\frac{1}{2}$ volutions with 8 chambers in the first volution and 28 chambers in the final volution. The total number of chambers in the test is 100. The distance across the two embryonic chambers is 30 μ .

Operculina complanata (Defrance) Pl. 29, fig. 16; Pl. 31, figs. 2-4.

1945. *Operculina complanata japonica* Hanzawa, Cole, Bernice P. Bishop Mus., Bull. 181, p. 278, pl. 12, figs. D-G; pl. 13, figs. F-I.

Three specimens are illustrated. Hanzawa (1935, p. 22) in designating certain specimens as a variety of *O. complanata* questioned whether this should be done. He wrote: "Although it is a question whether the discrimination of the *Operculina* . . . by means of surface ornamentation and number of chambers in the last whorl is taxonomically admissible or not, I tentatively assign the *Operculina* . . . to a new subspecies . . ."

Cole (1958 b) demonstrated in American species of *Operculinoides* (= *Operculina*) the variation which occurs. Therefore, it is doubtful if this subspecies should be retained.

Operculina venosa (Fichtel and Moll) Pl. 28, figs. 12-14, 17, 18; Pl. 29, figs. 1, 2, 11, 13, 14; Pl. 30, figs. 1, 9, 10; Pl. 31, fig. 1

1798. *Nautilus venosus* Fichtel and Moll, Test. Micro., p. 59, pl. 8, figs. e-b.

1859. *Amphistegina cumingii* Carpenter, Philos. Trans., p. 32, pl. 5, figs. 13-17.

1884. *Nummulites cumingii* (Carpenter), Brady, Challenger Rep. (Zool.), v. 9, p. 749, pl. 112, figs. 11-13; text fig. 22.

1918. *Operculinella cumingii* (Carpenter), Yabe, Tohoku Imp. Univ., 2nd ser. (Geol.), v. 4, No. 3, p. 122-126, pl. 17, figs. 8-12.

1921. *Operculina venosa* (Fichtel and Moll), Cushman, U. S. Nat. Mus., Bull. 100, v. 4, p. 383, 384.

1938. *Operculinella venosa* (Fichtel and Moll), Chapman and Parr, Roy. Soc. Victoria, Proc., v. 50, Pt. 1, n. ser., p. 293, pl. 17, figs. 21, 22, text fig. 7.

1939. *Operculinella cumingii* (Carpenter), Hanzawa, Jap. Journ. Geol. Geog., v. 16, Nos. 3, 4, p. 228, 229, pl. 15, figs. 6a, b, 8a, b; pl. 16, figs. 1, 2, 10.

1939. *Operculina* sp. Hanzawa, *idem*, p. 229, pl. 15, figs. 9a, b, 11; pl. 16, figs. 8, 9, 10.

Measurements of the specimens which are illustrated are given in Tables 5-7.

Table 5.—Measurements of specimens of *O. venosa* used for external appearance

Specimen	Pl. 28				
	Fig. 14	Fig. 13	Fig. 18	Fig. 17	Fig. 12
Height mm.	2.0	2.48	3.3	3.7	2.7
Width mm.	2.0	2.3	2.8	3.0	2.6
Flange	None	Slight	Moderate	Moderate	Slight
Width of flange mm.	—	0.25	0.6	0.55	0.1
Diameter of umbonal plug μ	160	None	200	200	400

Table 6.—Measurements of median sections of *O. venosa*

Specimen	Pl. 30		
	Fig. 1	Fig. 9	Fig. 10
Height mm.	2.4	2.82	3.15
Width mm.	2.0	2.68	3.0
Embryonic chambers:			
Diameter of initial chamber μ	80	50	60
Diameter of second chamber μ	40 x 90	30 x 60	40 x 100
Distance across both chambers μ	130	90	130
Number of volutions	4 $\frac{1}{4}$	5 $\frac{1}{4}$	4 $\frac{1}{4}$
Chambers in first volution	7	8	6
Chambers in final volution	17	16	12
Total number of chambers ...	56	66	38

Table 7.—Measurements of transverse sections of *O. venosa*

Specimen	Pl. 29				
	Fig. 2	Fig. 11	Fig. 14	Fig. 13	Fig. 1
Heightmm.	2.87	3.05	2.9	4.4	3.35
Thicknessmm.	1.18	1.28	1.5	1.72	1.4
Width of flangemm.	—	—	—	1.45	1.0
Thickness of flangemm.	—	—	—	0.25	0.17
Diameter of umbonal plugs μ	280	220	160	—	—

Discussion.—Yabe (1918, p. 126) erected the genus *Operculimella* with "*Nummulites*" *cumingii* as the type species. Later, Yabe and Hanzawa (1925, p. 49) considered this species to be a synonym of *O. venosa*. However, the specimens which they illustrated as *O. venosa* are *O. ammonoides*, a fact which Chapman and Parr (1938, p. 290) recognized. Later, Hanzawa (1939, p. 228) stated "*Nautilus venosus* Fichtel and Moll may possibly belong to the genus *Operculina*, and may not be identical with *N. cumingii* (Carpenter)." At that time Hanzawa retained *Operculimella cumingii* (Carpenter) as a distinct genus and species, but he accepted Chapman and Parr's (1938, p. 290) assignment of fossil and Recent specimens, previously called *O. venosa*, to the species *O. ammonoides*. However, Hanzawa (1939, p. 229) included "*Nautilus*" *venosus* Fichtel and Moll as a synonym of *O. ammonoides*.

Although the type illustrations of *O. venosa* are generalized drawings, they show several critical characters. The test is completely involute, evenly lenticular and certain of the septa bifurcate before they reach the periphery. Moreover, the septa are represented as being limbate and broad.

These characters are shown clearly by the specimens in the present collection. The bifurcation of the sutures shows in four of those illustrated (fig. 14, Pl. 28, lower and left parts; figs. 13, 18, Pl. 28, lower parts; fig. 17, right part). This kind of sutural pattern was not observed in any of the specimens assigned to *O. ammonoides*. Moreover, Carpenter and Brady illustrated specimens which they assigned to *O. cumingii* (= *O. venosa*) as possessing bifurcated sutures.

Thus, *O. cumingii* is a synonym of *O. venosa*. *O. venosa* is a recognizable species, distinct from *O. ammonoides*.

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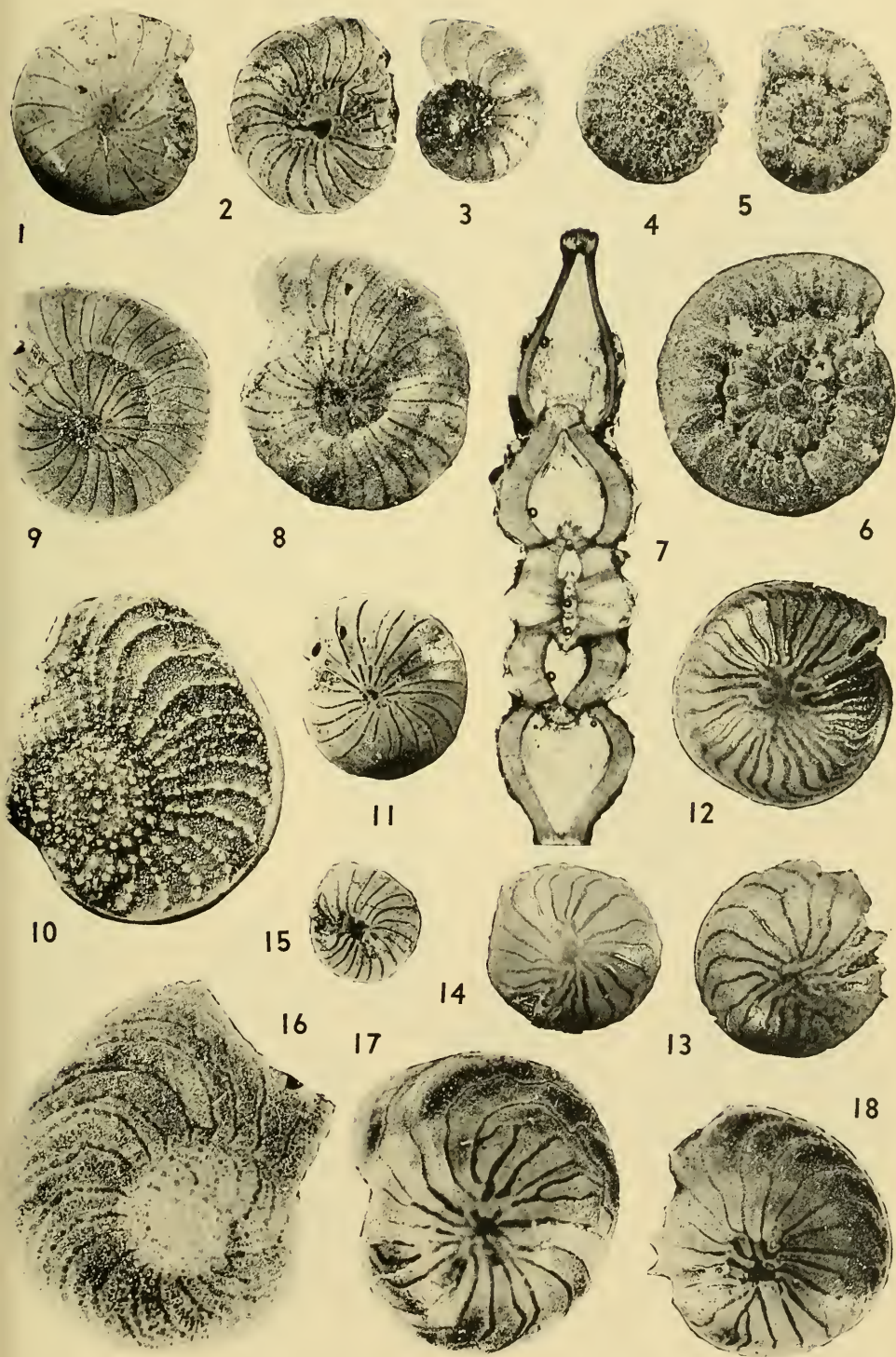
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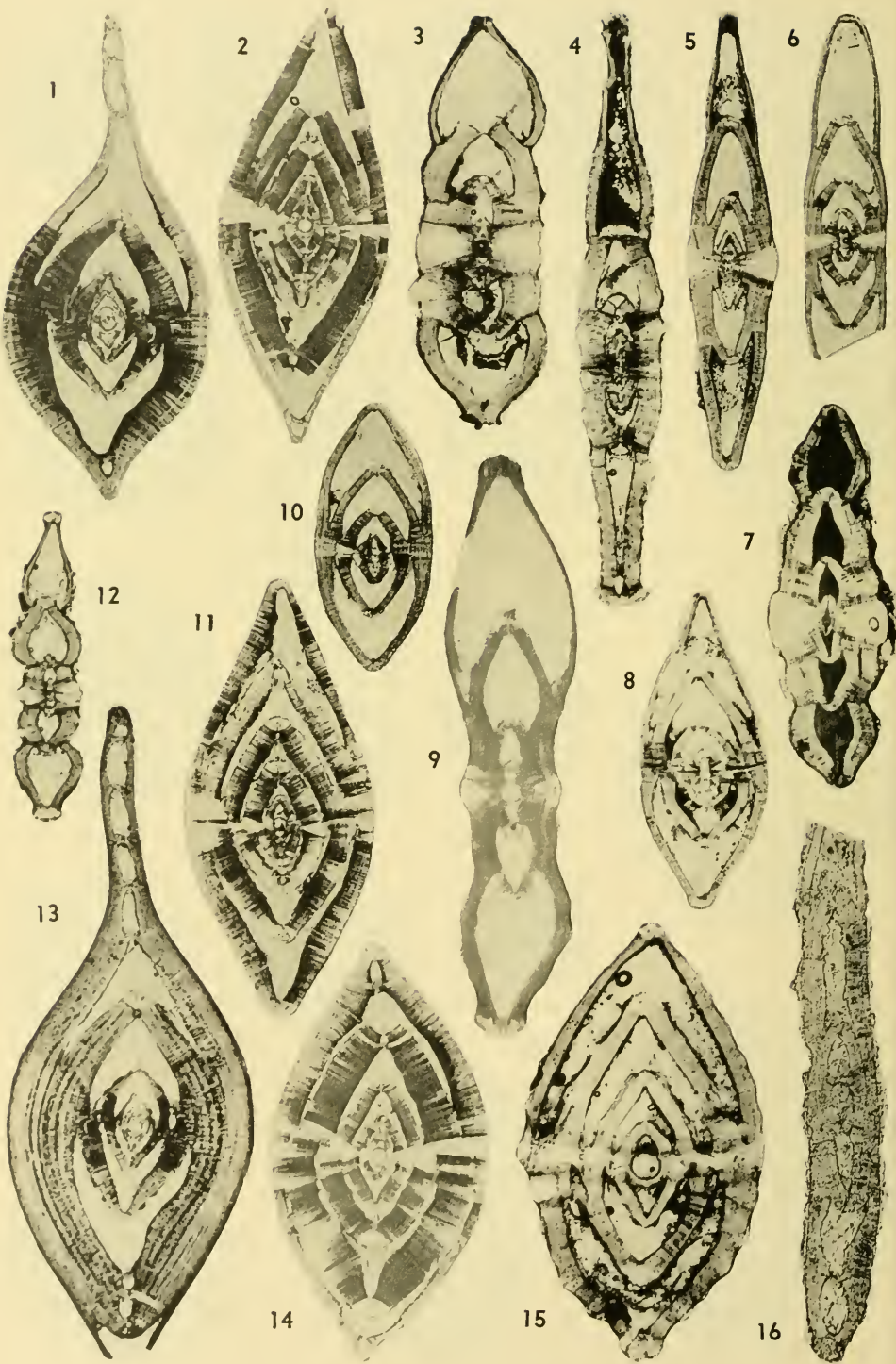
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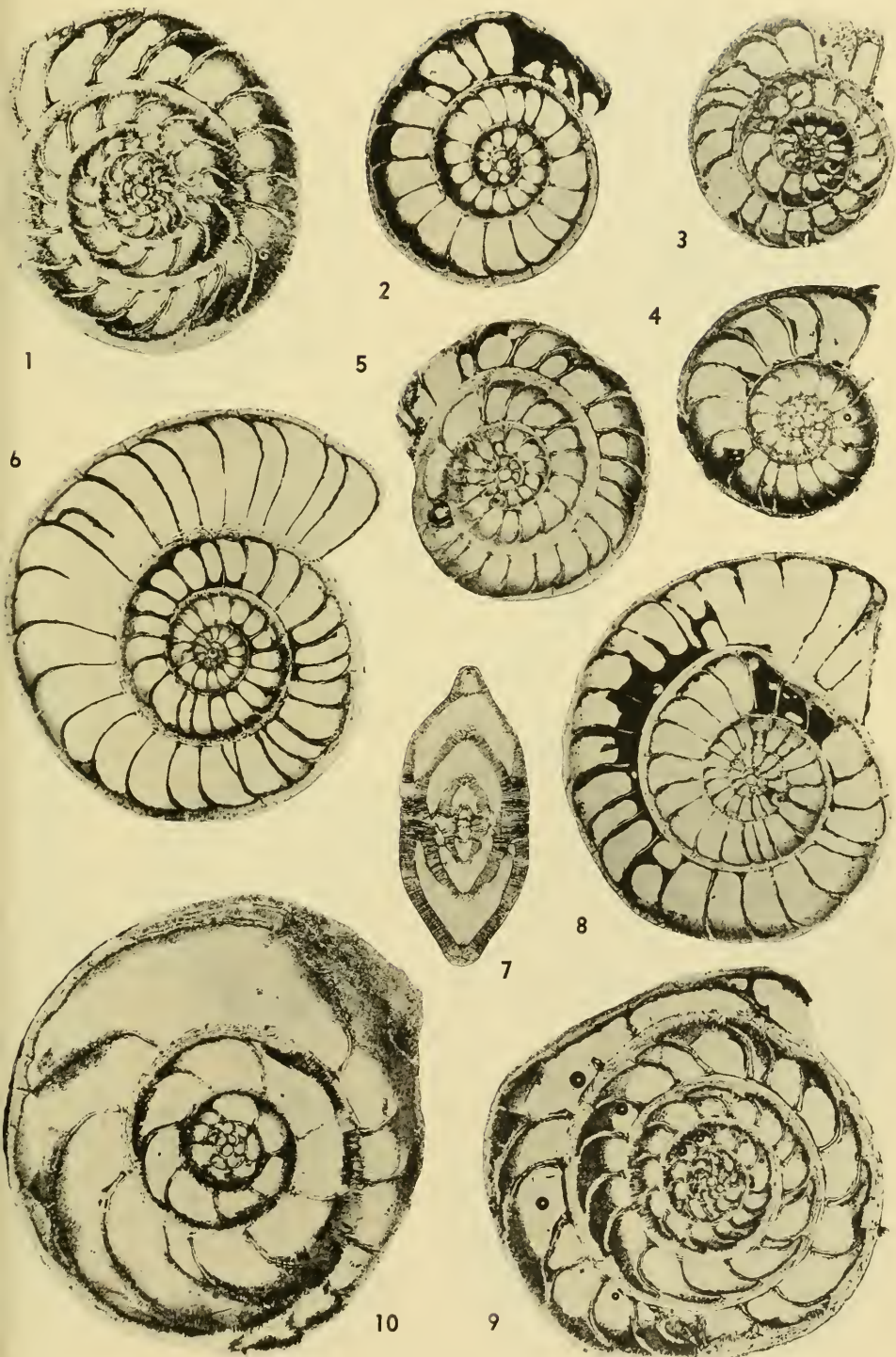


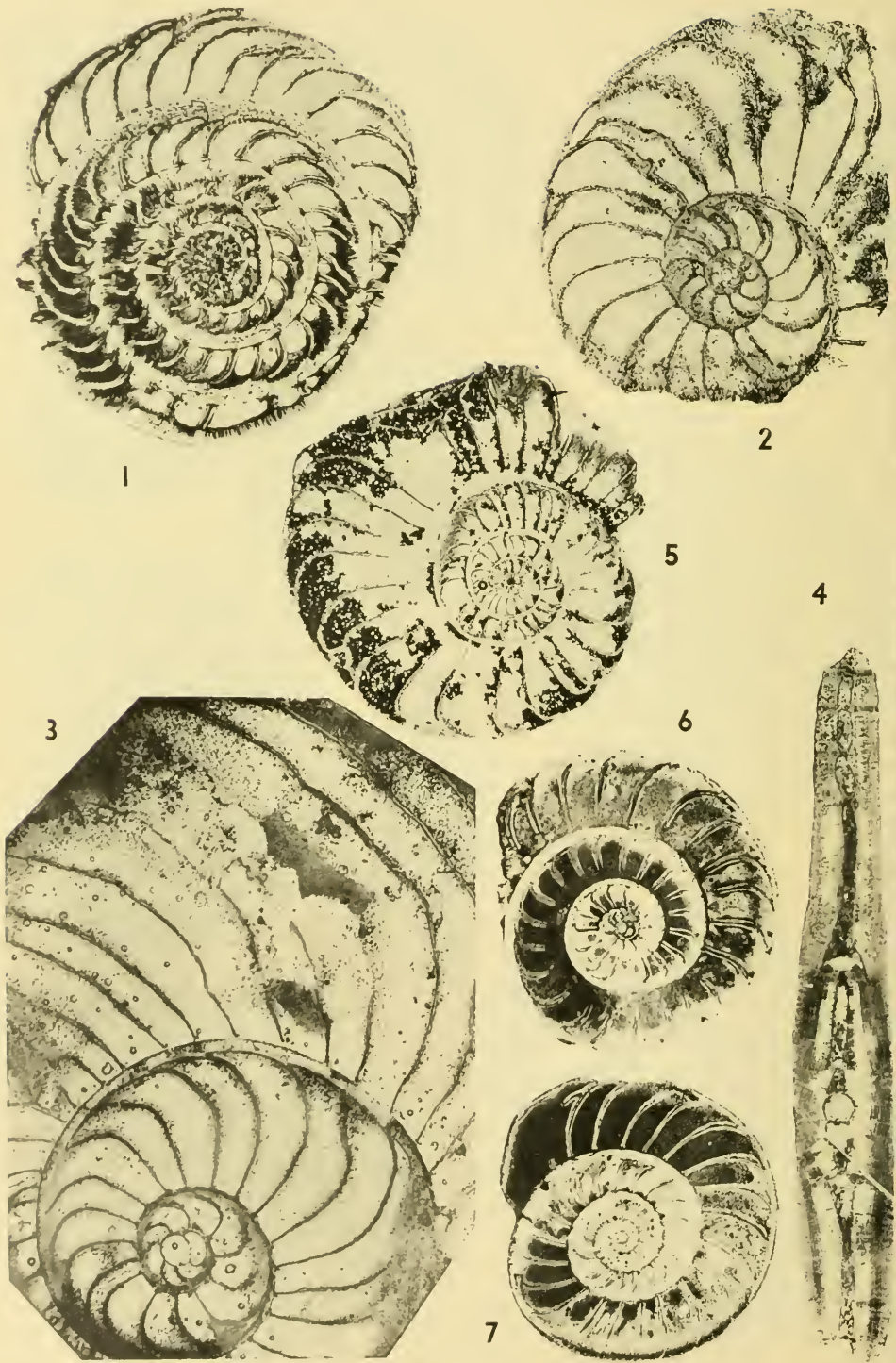
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**FAUNAL ASSOCIATIONS AND THE STRATIGRAPHIC POSITION
OF CERTAIN AMERICAN PALEOCENE AND EOCENE
LARGER FORAMINIFERA**

By

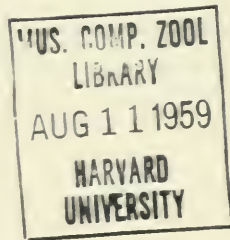
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FAUNAL ASSOCIATIONS AND THE STRATIGRAPHIC POSITION
OF CERTAIN AMERICAN PALEOCENE AND
EOCENE LARGER FORAMINIFERA*

W. STORRS COLE
Cornell University, Ithaca, New York

ABSTRACT

Two larger foraminiferal faunas, the *Operculina catenula* fauna of supposed upper Paleocene age, and, the *Pseudophragmina (Proporocyclina) tobleri* fauna of probable middle Eocene age, are discussed and analyzed. Certain species in these faunas are illustrated. General remarks are given on the American species of *Discocyclina (Discocyclina)* and their stratigraphic range.

INTRODUCTION

During the initial phase of the study of American larger Foraminifera a single species was often described from a sample without any mention made of the entire associated fauna. Vaughan (1924, p. 814) first described *Orbitoclypeus (?) cristensis* from the El Cristo well no. 1 at a depth of 3775 to 3785 feet. Later, he (1929a, p. 164) described *Actinosiphon semmesi* from this same sample. Finally, Barker (1939, p. 326) recorded the presence of *Camerina pellatispiroides* (= *Operculina catenula*).

Moreover, the species were based upon relatively few thin sections, and there was not any attempt made to evaluate either individual differences or the influence of environment upon the development of the individuals. Thus, new specific names were given to specimens from other geographic areas because the original species were described incompletely.

Therefore, the essential fact that a given fauna might be widely distributed around the Caribbean region was obscured by the multiplicity of specific names which were given and by the incomplete data on the composition of the faunas at various localities.

This study is primarily an attempt to analyze a widely distributed and compact fauna which occurs in the lower Tertiary of the Caribbean area. As one of the easily recognized and often dominant species is *Operculina catenula* Cushman and Jarvis, this zone is given that name. The exact stratigraphic position of this zone is still in doubt, but the available evidence indicates that it is high Paleocene. However, it may extend into the lower part of the lower Eocene.

*The cost of the printed plates has been contributed by the William F. E. Gurley Foundation for paleontology of Cornell University.

As new evidence regarding the stratigraphic position of *Pseudophragmina* (*Proporocyclina*) *tobleri* Vaughan and Cole at Soldado Rock, Trinidad, was found during this investigation, the stratigraphic position of this species and the species which are associated with it are evaluated.

The specimens will be deposited temporarily in the Cole collection, and, eventually, will be transferred to the U. S. National Museum.

LOCALITIES

United States

Caledonia, Alabama. Uppermost Paleocene in the creek bottom, just west of the store at Caledonia, about $\frac{1}{4}$ mile south of the center of sec. 29, T. 11 N., R. 10 E., Wilcox Co., Alabama. Specimens supplied by the late Helen Jeanne Plummer. See: Cushman (1944, p. 29) for the associated smaller Foraminifera.

Barbados

S-990, Barbados. Left bank of the Canegarden River, 103 m. south of locality S-79, in flat on south flank of small anticline (Vaughan, 1945, p. 17). Specimens supplied by the late T. Wayland Vaughan.

Trinidad

El 1440, Soldado Rock. Specimens supplied by H. G. Kugler. See: Vaughan and Cole, 1941, pl. 2, for exact location.

K 3878, Soldado Rock. Specimens supplied by H. G. Kugler. See: Vaughan and Cole, 1941, pl. 2, for exact location.

Cuba

Cuba 11863. From the south side of a cut on the Central Highway, 2 km. west of Madruga and about 100 meters east of the Cane line railroad overpass to Central San Antonio, Habana Province (= D. K. Palmer's sta. 757). Specimens supplied by the late Donald W. Gravell. See: Sachs, 1957, p. 106, for associated larger Foraminifera.

THE OPERCULINA CATENULA FAUNA

GEOGRAPHIC DISTRIBUTION

Operculina catenula under various specific names (Cole, 1953*b*, p. 35; Sachs, 1957, p. 107; Cole, 1958*a*, p. 270) has long been known from Haiti, Trinidad, Mexico, Venezuela, Barbados, Cuba, and the southern United States. Table I shows the important geographic localities at which the species was found and certain of the names given to it.

TABLE 1.—The *Operculina catenula* zone

Names used in this article	Geographic areas of occurrence and the names used previously								
	Mexico	Trinidad		Cuba	Venezuela		Barbados	United States	
	Vaughan, 1924, 1929a; Barker, 1939.	Soldado Rock Vaughan and Cole, 1941; Caudri, 1944	Lizard Springs Vaughan, 1945	Sachs, 1957	Caudri, 1944	Cizancourt, 1951	Vaughan, 1945	Alabama Vaughan, 1936	Georgia Cole and Herrick, 1953
<i>Actinosiphon semmesi</i> Vaughan	<i>Actinosiphon semmesi</i> Vaughan				<i>Lepidobitoides</i> cf. <i>planasi</i> M. G. Ruten	<i>Actinosiphon barbadensis</i> (Vaughan)	<i>Lepidocyclina (Polylepidina) barbadensis</i> Vaughan		
<i>Discocyclina (Discocyclina) bakeri</i> Vaughan and Cole		<i>Discocyclina (Discocyclina) bakeri</i> Vaughan and Cole		<i>Discocyclina (Discocyclina) bakeri</i> Vaughan and Cole		<i>Discocyclina (Discocyclina) bakeri</i> Vaughan and Cole	<i>Discocyclina (Discocyclina) bakeri</i> Vaughan and Cole		
<i>eristensis</i> (Vaughan)	<i>Orbitoclypeus (?) eristensis</i> Vaughan	<i>Hexagonocyclina meandrica</i> Caudri		<i>Discocyclina (Discocyclina) eristensis</i> (Vaughan)	<i>Hexagonocyclina meandrica</i> Caudri	<i>Discocyclina (Discocyclina) eristensis</i> (Vaughan)			
<i>weaveri</i> Vaughan		<i>Discocyclina (Discocyclina) grimsdalei</i> Vaughan and Cole	<i>Discocyclina (Discocyclina) fonsiacertensis</i> Vaughan	<i>Discocyclina (Discocyclina) mestieri</i> Vaughan	<i>Discocyclina aguerreveri</i> Caudri	<i>Discocyclina (Discocyclina) aguerreveri</i> Caudri	<i>Discocyclina (Discocyclina) grimsdalei</i> Vaughan and Cole <i>D. (D.) mestieri</i> Vaughan	<i>Discocyclina blanpiedi</i> Vaughan	
<i>Operculina catenula</i> Cushman and Jarvis	<i>Camertina pellatiprionides</i> Barker	<i>Ranikothalia antillea</i> (Hanzawa)	<i>Miscellanea antillea</i> (Hanzawa)	<i>Operculinoides bermudezi</i> (D. K. Palmer)	<i>Ranikothalia antillea</i> (Hanzawa)	<i>Nummulites (Operculinoides) bermudezi</i> (D. K. Palmer)	<i>Miscellanea antillea</i> (Hanzawa)		<i>Operculinoides georgianus</i> Cole and Herrick
<i>Pseudophragmina (Atbecocyclina) stephensoni</i> (Vaughan)		<i>Pseudophragmina (Atbecocyclina) soldadensis</i> Vaughan and Cole		<i>Pseudophragmina (Atbecocyclina) stephensoni</i> (Vaughan)	<i>Pseudophragmina (Atbecocyclina) cf. cooki</i> (Vaughan)	<i>Pseudophragmina (Atbecocyclina) cooki</i> (Vaughan)	<i>Pseudophragmina (Atbecocyclina) soldadensis calebardensis</i> Vaughan	<i>Discocyclina cooki</i> Vaughan	<i>Pseudophragmina (Atbecocyclina) stephensoni</i> (Vaughan)

This species is usually accompanied by other species to form a definite faunal association. One locality (Alabama) at which *O. catenula* has not been found to date is given on Table I as the species recorded from this locality are associated with *O. catenula* elsewhere.

STRATIGRAPHIC POSITION

The best evidence for the stratigraphic position of the *Operculina catenula* zone is obtained from the southern United States and Mexico. Cole and Herrick (1953, p. 50) found *O. catenula* (= *Operculinoides georgianus* Cole and Herrick) in wells in Georgia in association with *Pseudophragmina* (*Athecocyclina*) *stephensoni* in beds of Midway age.

In Alabama *P. (A.) stephensoni* [= *P. (A.) cookei* (Vaughan)] occurs in the Salt Mountain limestone in association with *Discocyclina* (*Discocyclina*) *weaveri* (= *D. (D.) blanpiedi* Vaughan). The Salt Mountain limestone until recently has been considered to be equivalent to the Nanafalia formation (Toulmin, 1955, p. 215, fig. 5). Loeblich and Tappan (1957, p. 177) placed the Salt Mountain limestone below the lower Eocene Nanafalia formation so that it is the uppermost unit of the Paleocene Midway group.

D. (D.) weaveri according to Stephenson (Muir, 1936, p. 101) occurs at its type locality in Mexico in association with *Ostrea thirsae* Gabb and *Turritella* aff. *humerosa* Conrad. Miss Gardner (1945, p. 7) wrote: "the faunas characterized by an abundance of *Ostrea thirsae* and of *Turritella sanjuanensis* of the *T. humerosa* group have been referred to the upper Midway . . . A similar assemblage, together with *Discocyclina weaveri* Vaughan . . . was collected . . . from the Tanlajás formation in the Plaza in San Antonio, San Luis Potosí."

D. (D.) weaveri and *P. (A.) stephensoni* have not been found in the same sample in Mexico. Muir (1936, p. 104) noted: "The evidence at present available indicates that *D. stephensoni* occurs at a lower stratigraphic level than *Discocyclina weaveri* Vaughan." Vaughan (1945, p. 101) reported that *P. (A.) stephensoni* was found at two localities, one "on Río San Juan, opposite Rancho Viejo, China, and the other was along brecha on crest of structure, China, in association with *Ostrea thirsae* Gabb. According to Dr. Julia Gardner the stratigraphic horizon is high Midway (Paleocene), which would be the equivalent of the basal lower Chicon-tepec." Therefore, it would seem that *D. (D.) weaveri* and *P. (A.)*

stephensoni occur in the same zone in Mexico, and that this zone is high Midway.

P. (A.) macglameriae Vaughan is considered to be an ecological variant of *P. (A.) stephensoni*. This species was described from a "glaucinite bed, directly overlying the Coal Bluff lignite bed or the Naheola marl" (Vaughan, 1945, p. 103). The age is given as Paleocene, Midway group.

Thus, all the available evidence is suggestive that *P. (A.) stephensoni* is a high Paleocene species. As this species is commonly associated with *Operculina catenula*, it seems probable that this zone should be assigned a Paleocene age.

THE PSEUDOPHRAGMINA (PROPOROCYCLINA) TOBLERI FAUNA

STRATIGRAPHIC POSITION

In examining samples from Soldado Rock, Trinidad, kindly forwarded to me by Dr. Hans Kugler, topotype specimens of *Pseudophragmina (Proporocyclina) tobleri* Vaughan and Cole were recovered from sample K. 3878 (see: Vaughan and Cole, 1941, p. 15 for location). These specimens are associated with microspheric specimens which were named *Discocyclina (Discocyclina) bullbrooki* Vaughan and Cole (1941, p. 59).

Vaughan and Cole (1941, p. 27) stated concerning these species: "At Soldado Rock *Discocyclina (Discocyclina) bullbrooki* and *Pseudophragmina (Proporocyclina) tobleri* occur at a horizon above the typical 'Jacksonian' of Kugler's section." Caudri (1944, p. 385) in referring to these two species correctly noted: "These larger Foraminifera have nothing in common either with the Paleocene or the typical upper Eocene of this very small islet. . . . The fauna of smaller Foraminifera, which was studied by H. H. Renz, has several species in common with the typical Soldado Paleocene . . . the most acceptable explanation seems to be that it originated from a high-Paleocene (or perhaps lower or middle?) Eocene marl. . . ."

Therefore, it was of considerable interest to find *P. (P.) tobleri* in another sample from Soldado Rock. This sample El 1440 (see: Vaughan and Cole, 1941, pl. 2, for location) contained not only *P. (P.) tobleri*, but also specimens of *Discocyclina (Discocyclina) anconensis* Barker, a species which Vaughan (1945, p. 18) recorded from numerous middle Eocene localities in Barbados. In addition, microspheric specimens of a *Discocy-*

clina which are similar to *D. (D.) bullbrooki* were found. Seemingly, *D. (D.) bullbrooki* is the microspheric form of *D. (D.) anconensis*.

Thus, the *P. (P.) tobleri* zone may be assigned provisionally to the middle Eocene. *P. (P.) tobleri* belongs to the Type II group (Cole, 1958*b*, p. 413) of the subgenus *Proporocyclina* of which the other two species are known to occur only in the middle Eocene.

THE STATUS OF DISCOCYCLINA (DISCOCYCLINA) IN THE AMERICAS

Vaughan (1945, p. 112) listed 21 American species and one subspecies which he assigned to *Discocyclina (Discocyclina)*. These species were assumed to have a stratigraphic distribution from Paleocene through the upper Eocene. However, Caudri (1944, p. 385) postulated that *Discocyclina (Discocyclina)* did not occur in the American upper Eocene.

Since the appearance of Vaughan's paper, Cole and Gravell (1952, p. 714) transferred *Pseudophragmina (Proporocyclina) marginata* to *Discocyclina (Discocyclina)* and suppressed the following species which Vaughan listed: *D. (D.) californica*, *D. (D.) crassa* and *D. (D.) harrisoni*. Cole (1953*a*, p. 33) demonstrated that *D. (D.) minima* should be placed in the genus *Asterocyclina*.

Thus, Vaughan's list would have shown 18 supposedly valid species and one subspecies at the beginning of this study. This study demonstrates that this listing can be reduced by 7 species and the subspecies, leaving a total of 11 supposedly valid species in *Discocyclina (Discocyclina)*.

A revised listing of American species of *Discocyclina (Discocyclina)* follows:

- **D. (D.) anconensis* Barker, 1932
- **barkeri* Vaughan and Cole, 1941
- caudriae* Vaughan, 1945
- **cristensis* (Vaughan), 1924
- cubensis* (Cushman), 1919
- **marginata* (Cushman), 1919
- meroensis* W. Berry, 1930
- pustulosa* (Cushman), 1919
- sheppardi* Barker, 1932
- turnerensis* Vaughan, 1945
- **weaveri* Vaughan, 1929

The five-starred species are seemingly valid ones and can be identified readily. It is suspected that two of the remaining six species are synonyms inasmuch as *D. (D.) caudriæ* has many of the characteristics of *D. (D.) weaveri* and *D. (D.) cubensis* is similar to *D. (D.) marginata*. The other four species are inadequately described.

There are probably not more than six valid species of *Discocyclina* (*Discocyclina*) in the Americas. The apparent range of the subgenus is Paleocene through the middle Eocene.

DESCRIPTION OF SPECIES

Family Camerinidae

Genus *Operculina* d'Orbigny, 1826

1959. *Operculinoides* Hanzawa, Cole, Bull. Amer. Paleont., v. 39, No. 181, p. 352.

Operculina catenula Cushman and Jarvis

1932. *Operculina catenula* Cushman and Jarvis, U. S. Nat. Mus. Proc., v. 80, Art. 14, p. 42, pl. 12, figs. 13a, b.

1957. *Operculinoides bermudezi* (D. K. Palmer), Sachs, Contrib. Cushman Found. Foram. Res., v. 8, Pt. 3, p. 107-113, pl. 14, figs. 1-27 (additional references).

1958. *Operculina catenula* Cushman and Jarvis, Cole, Bull. Amer. Paleont., v. 38, No. 173, p. 270.

For a complete analysis of this species see Cole (1953b, 1958a) and Sachs (1957).

Family Orbitoididae

Genus *Actinosiphon* Vaughan, 1929

Actinosiphon semmesi Vaughan

1929. *Actinosiphon semmesi* Vaughan, Jour. Paleont., v. 3, No. 2, p. 164-166, pl. 21, figs. 1-3 (Chicontepec formation).

1944. *Lepidorbitoides* cf. *planasi* M. G. Ruttén, Caudri, Bull. Amer. Paleont., v. 28, No. 114, p. 366, 367, pl. 1, fig. 3; pl. 2, fig. 10; pl. 3, fig. 14 (Paleocene).

1945. *Lepidocyclina* (*Polylepidina*) *barbadensis* Vaughan, Geol. Soc. Amer., Mem. 9, p. 49, 50, pl. 19, figs. 5-9 (Paleocene).

1951. *Actinosiphon barbadensis* (Vaughan), Cizancourt, Géol. Soc. France, Mem. 64, p. 57, pl. 5, fig. 9 (Paleocene).

1951. *Actinosiphon barbadensis* (Vaughan) forma *globulosa* Cizancourt, *idem*, p. 58, pl. 5, fig. 3 (Paleocene).

1951. *Actinosiphon barbadensis* (Vaughan) forma *garapatensis* Cizancourt, *idem*, p. 58, pl. 5, figs. 4, 6, 8 (Paleocene).

1951. *Actinosiphon barbadensis* (Vaughan) forma *caudriæ* Cizancourt, *idem*, p. 58, pl. 5, figs. 5, 7 (Paleocene).

1951. *Actinosiphon* cf. *semmesi* Vaughan, Cizancourt, p. 58, 59, pl. 5, fig. 21 (Paleocene).

Caudri (1944, p. 366) identified small orbitoids from San Juan de los Morros, State of Guarico, Venezuela, as *Lepidorbitoides* cf. *planasi* M. G. Rutten. Although *Lepidorbitoides* is a well-established Upper Cretaceous genus, she believed that this genus continued into the Paleocene. Later, she (1948, p. 473) discussed and illustrated specimens from other Caribbean localities of Paleocene age which she believed should be referred to the genus *Lepidorbitoides*.

Vaughan (1945, p. 49) referred small orbitoids from the Joes River mudflows of Barbados to *Lepidocyclina* (*Polylepidina*) *barbadensis*. If this generic identification were correct, the genus *Lepidocyclina* would have a longer stratigraphic range than had been known previously as it had been thought that the most primitive subgenus, *Polylepidina*, of *Lepidocyclina* appeared in the American middle Eocene. Caudri (1948, p. 479) decided that *Lepidocyclina* (*Polylepidina*) *barbadensis* should be referred to the genus *Lepidorbitoides*.

Cizancourt (1951, p. 61) correctly assigned the specimens which Caudri referred to *Lepidorbitoides* and which Vaughan believed to be *Lepidocyclina* (*Polylepidina*) to the Paleocene genus *Actinosiphon*.

The equatorial chambers of *Actinosiphon* are arranged in regular, radiating rows (Vaughan, 1929, pl. 21, fig. 1). This is not the arrangement found in either *Lepidorbitoides* or *Polylepidina*.

Family **Discocyclinidae**

Genus **Discocyclina** Gümbel, 1870

Subgenus **Discocyclina** Gümbel, 1870

Discocyclina (**Discocyclina**) **anconensis** Barker Pl. 33, figs. 1, 2, 6-10

1932. *Discocyclina anconensis* Barker, Geol. Mag., v. 69, p. 303, 304, pl. 21, figs. 1, 4; text fig. 1.

1941. *Discocyclina* (*Discocyclina*) *bullbrooki* Vaughan and Cole, Geol. Soc. Amer., Sp. Pap. 30, p. 59, 60, pl. 21, figs. 4, 5; pl. 22, figs. 1, 2.

1945. *Discocyclina* (*Discocyclina*) *anconensis* Barker, Vaughan, Geol. Soc. Amer., Mem. 9, p. 32-35, pls. 7-10, 20, 21; pl. 22, figs. 2-3b.

Megalospheric specimens (Pl. 33, figs. 9, 10) from sample El 1440, Soldado Rock, Trinidad, are identical with specimens (Pl. 33, fig. 8) from Barbados identified by Vaughan as *D. (D.) anconensis* Barker. Associated with these specimens are microspheric specimens (Pl. 33, fig. 7) which were identified as *D. (D.) bullbrooki* Vaughan and Cole.

At the type locality (K 3878) of *D. (D.) bullbrooki* only microspheric specimens were found, one of which is illustrated (Pl. 33, fig. 6).

Seemingly, *D. (D.) bullbrooki* is the microspheric form of *D. (D.) anconensis*. Inasmuch as the specific name *D. (D.) anconensis* has priority, the name *D. (D.) bullbrooki* must be suppressed.

Discocyclina (Discocyclina) barkeri Vaughan and Cole

1941. *Discocyclina (Discocyclina) barkeri* Vaughan and Cole, Geol. Soc. Amer., Sp. Pap. 30, p. 57, 58, pl. 18, figs. 4-7; pl. 21, figs. 1, 2.
 1957. *Discocyclina (Discocyclina) barkeri* Vaughan and Cole, Contrib. Cushman Found. Foram. Res., v. 8, Pt. 3, p. 113-115, pl. 15, figs. 1-12 (additional references).

Discocyclina (Discocyclina) cristensis (Vaughan)

1957. *Discocyclina (Discocyclina) cristensis* (Vaughan), Sachs, Contrib. Cushman Found. Foram. Res., v. 8, Pt. 3, p. 115-117, pl. 16, figs. 1-9 (references and discussion).

Discocyclina (Discocyclina) weaveri Vaughan

Pl. 33, figs. 3-5

1929. *Discocyclina weaveri* Vaughan, U. S. Nat. Mus. Proc., v. 76, Art. 3, p. 5-7, pl. 1, figs. 1, 2 (basal part of the Chicontepec formation).
 1929. *Discocyclina weaveri parvipapillata* Vaughan, *idem*, p. 7, 8, pl. 1, figs. 3, 4, 4a (basal part of the Chicontepec formation).
 1936. *Discocyclina blaupiedi* Vaughan, Jour. Paleont., v. 10, No. 4, p. 254-256, pl. 41, figs. 1-7 (Salt Mountain limestone).
 1941. *Discocyclina (Discocyclina) grimsdalei* Vaughan and Cole, Geol. Soc. Amer., Sp. Pap. 30, p. 58, 59, pl. 18, figs. 8, 9; pl. 19, figs. 1-3; pl. 21, fig. 3 (lower Eocene).
 1944. *Discocyclina aguerreverei* Caudri, Bull. Amer. Paleont., v. 28, No. 114, p. 361, 362, pl. 2, figs. 8, 11; pl. 3, fig. 13; pl. 4, fig. 17 (Paleocene).
 1945. *Discocyclina (Discocyclina) mestieri* Vaughan, Geol. Soc. Amer., Mem. 9, p. 37, 38, pl. 12, figs. 1-6 (Paleocene).
 1945. *Discocyclina (Discocyclina) grimsdalei* Vaughan and Cole, Vaughan, *idem*, p. 39-42, pl. 6, figs. 11, 12; pl. 13; pl. 14 (Paleocene to middle Eocene).
 1945. *Discocyclina (Discocyclina) fonslacertensis* Vaughan, *idem*, p. 72, 73, pl. 24, figs. 3-6; pl. 26, fig. 3 (lower Eocene?).
 1957. *Discocyclina (Discocyclina) mestieri* Vaughan, Sachs, Contrib. Cushman Found. Foram. Res., v. 8, Pt. 3, p. 117-119, pl. 17, figs. 1, 11, 12 (Paleocene).

Vaughan (1945, pl. 26, figs. 3, 4) gave excellent illustrations of vertical sections of *D. (D.) weaveri* and *D. (D.) fonslacertensis*. These demonstrate that the internal structures are the same. These illustrations should be compared with the Cuban specimen (Pl. 33, fig. 3) which has the same internal features. Earlier, Vaughan (1929b, pl. 1, fig. 1) illustrated the embryonic and equatorial chambers of *D. (D.) weaveri*. This illustration shows the initial chamber completely enclosed by the second chamber, but the two chambers are in contact along a limited part of the wall of the second chamber. The illustrations (Vaughan, 1945, pl. 24, figs. 5, 5a, 6) of the embryonic chambers of *D. (D.) fonslacertensis* show the initial chamber partially embraced by the second chamber. However, these three equatorial sections are not exactly centered and are slightly oblique. There-

fore, the differences in the relationship of the initial chamber to the second chamber in these specimens is the result of the plane of the section rather than a difference in the arrangement of the chambers themselves. Obviously, *D. (D.) fonslacertensis* is a synonym of *D. (D.) weaveri*.

Equatorial sections (Vaughan, 1945, pl. 13, figs. 1, 2, 5) of *D. (D.) grimsdalei* are identical with those of *D. (D.) weaveri*. Although the type illustration (Vaughan and Cole, 1941, pl. 21, fig. 3) of a vertical section of *D. (D.) grimsdalei* shows a compressed specimen with a depressed central area, Vaughan (1945, pl. 13, fig. 6) illustrated other specimens assigned to this species which are inflated. This inflated specimen has the same internal structure in vertical section as does *D. (D.) weaveri* (compare fig. 4, pl. 1, Vaughan, 1929*b*, with fig. 6, pl. 13, Vaughan, 1945). Thus, *D. (D.) grimsdalei* is a synonym of *D. (D.) weaveri*.

Although the illustrations of *D. (D.) mestieri* (Vaughan, 1945, pl. 12, figs. 1-6) are poor, it is obvious this species is the same as *D. (D.) weaveri*. Moreover, *D. (D.) mestieri* occurs in Barbados (Vaughan, 1945, p. 18) in the same samples in which Vaughan reported *D. (D.) grimsdalei*. Vaughan identified the compressed specimens as *D. (D.) grimsdalei* and certain of the inflated specimens as *D. (D.) mestieri*.

Sachs (1957, p. 117) identified Cuban specimens as *D. (D.) mestieri*. Additional specimens from Cuba are illustrated (Pl. 33, figs. 3-5). These specimens form an integrated series from compressed individuals (Pl. 33, fig. 4) (= *D. (D.) grimsdalei*) to inflated specimens (Pl. 33, fig. 3) (= *D. (D.) fonslacertensis*).

Two other species should be considered: *D. (D.) blanpiedi* Vaughan (1936, p. 254) and *D. (D.) aguerreverei* Caudri (1944, p. 361). The illustrations of both of these species are substandard, but it seems that only one species is represented. Although some uncertainty must exist until additional specimens of *D. (D.) blanpiedi* can be studied, it seems probable that *D. (D.) blanpiedi* is another synonym of *D. (D.) weaveri*.

Genus *Pseudophragmina* H. Douvillé, 1923

Subgenus *Proporocyclina* Vaughan and Cole, 1940

Pseudophragmina (Proporocyclina) tobleri Vaughan and Cole

Pl. 32, figs. 5-12

1941. *Pseudophragmina (Proporocyclina) tobleri* Vaughan and Cole, Geol. Soc. Amer., Sp. Pap. 30, p. 62, pl. 21, fig. 6; pl. 22, figs. 3, 4.

1945. *Pseudophragmina (Proporocyclina) tobleri* Vaughan and Cole, Vaughan, Geol. Soc. Amer., Mem. 9, p. 94, pl. 37, figs. 4, 5.

Topotypes (Pl. 32, figs. 5, 6, 8, 11, 12) from sample K 3878, Soldado Rock, Trinidad, are illustrated. Specimens (Pl. 32, figs. 7, 9, 10) from sample El 1440, Soldado Rock, Trinidad, which are identical with the topotypes are illustrated for comparison.

An enlarged view of the embryonic and periembrionic chambers of a microspheric specimen is given as figure 12, Plate 32.

Subgenus **Athecocyclina** Vaughan and Cole, 1940

Pseudophragmina (Athecocyclina) stephensoni (Vaughan) Pl. 32, figs. 1-4

1929. *Discocyclina stephensoni* Vaughan, U. S. Nat. Mus. Proc., v. 76, Art. 3, p. 16, pl. 6, figs. 1-4 (probably Chicontepec formation).
 1936. *Discocyclina cookei* Vaughan, Jour. Paleont., v. 10, No. 4, p. 256-259, pl. 42, figs. 1-6 (Salt Mountain limestone).
 1941. *Pseudophragmina (Athecocyclina) soldadensis* Vaughan and Cole, Geol. Soc. Amer., Sp. Pap. 30, p. 62, 63, pl. 19, figs. 4-8 (lower Eocene).
 1944. *Pseudophragmina (Athecocyclina) cookei* (Vaughan), Cole, Florida Geol. Sur., Bull. 26, p. 87, 88, pl. 3, fig. 12; pl. 8, fig. 20; pl. 26, figs. 6, 7; pl. 27, fig. 5 (Salt Mountain limestone).
 1944. *Pseudophragmina (Athecocyclina)* cf. *cookei* (Vaughan), Caudri, Bull. Amer. Paleont., v. 28, No. 114, p. 364-366, pl. 1, figs. 5, 6; pl. 3, fig. 12; pl. 4, figs. 18, 20 (Paleocene).
 1945. *Pseudophragmina (Athecocyclina) soldadensis* var. *calebardensis* Vaughan, Geol. Soc. Amer., Mem. 9, p. 46-49, pl. 17; pl. 18 (Paleocene).
 1945. *Pseudophragmina (Athecocyclina) cookei* (Vaughan), Vaughan, *idem*, p. 100, pl. 45, figs. 1, 2.
 1945. *Pseudophragmina (Athecocyclina) stephensoni* (Vaughan), Vaughan, *idem*, p. 101, pl. 45, figs. 3, 4.
 1945. *Pseudophragmina (Athecocyclina) macglameriae* Vaughan, *idem*, p. 102, 103, pl. 46 (Paleocene).
 1953. *Pseudophragmina (Athecocyclina) stephensoni* (Vaughan), Cole and Herrick, Bull., Amer. Paleont., v. 35, No. 148, p. 8-10, pl. 2, figs. 4-11 (Paleocene).
 1957. *Pseudophragmina (Athecocyclina) stephensoni* (Vaughan), Sachs, Contrib. Cushman Found. Foram. Res., v. 8, Pt. 3, p. 118, 119, pl. 17, figs. 4-10 (Paleocene).

The illustration (Pl. 32, fig. 1) of a Cuban specimen should be compared with those of the specimen from Georgia (Cole and Herrick, 1953, pl. 5, fig. 7), and of the syntype from Mexico (Cole and Herrick, 1953, pl. 5, fig. 8). Obviously, all these specimens should be referred to one species.

Vaughan (1945, pl. 45) demonstrated that the equatorial sections of *P. (A.) stephensoni* and *P. (A.) cookei* are identical. The vertical sections of these two species are the same (compare fig. 4, pl. 42, Vaughan, 1936, and figs. 6, 7, pl. 26, Cole, 1944, with figs. 7, 8, pl. 5, Cole and Herrick, 1953, and fig. 1, Pl. 32). Therefore, *P. (A.) cookei* is a synonym of *P. (A.) stephensoni*.

Caudri (1944, p. 365) stated that the "difference between *A. soldadensis* and *A. cookei* would lie chiefly in the number of lateral layers, the former having only 4-5 layers and the latter as many as 8-9." Specimens from Georgia identified as *P. (A.) stephensoni* have from five to nine layers of lateral chambers. The shape of the embryonic and periembrionic chambers which Vaughan (1945, p. 48) stressed as a specific difference is variable.

Vaughan (1945, p. 48) wrote: "The embryonic chambers of *P. stephensoni* (pl. 45, figs. 3, 4) and *P. cookei* (pl. 45, figs. 1, 2) are surrounded by an uninterrupted and apparently unsubdivided periembrionic annulus." Yet, careful inspection of one of his illustrations (pl. 45, fig. 3) of the embryonic chambers of *P. (A.) stephensoni* shows that the first periembrionic annulus is incomplete and actually has its initial part in contact with the initial embryonic chamber. Moreover, if this illustration (pl. 45, fig. 3) is compared with the one which he (Vaughan, 1945, pl. 17, fig. 4a) gave of *P. (A.) soldadensis calebardensis*, it will be seen that they are nearly identical. Thus, *P. (A.) soldadensis* and the subspecies *calebardensis* are synonyms of *P. (A.) stephensoni*.

P. (A.) macglameriae Vaughan is similar to *P. (A.) stephensoni*. However, the lateral chambers and the equatorial layer have higher openings in *P. (A.) macglameriae* (Pl. 32, figs. 3, 4) than in *P. (A.) stephensoni*. The relationship of *P. (A.) macglameriae* to *P. (A.) stephensoni* is the same as that which Cole (1958b, p. 420) demonstrated to be present in *Pseudophragmina (Proporocyclus) flintensis*. Specimens in certain ecological situations tend to develop more fragile tests with thinner walled chambers than do specimens of the same species in different ecological environments. Thus, *P. (A.) macglameriae* is an ecological variant of *P. (A.) stephensoni*.

If the interpretation is correct that all the species of *Pseudophragmina (Atheocyclus)*, formerly recorded from the American Paleocene and lower Eocene, represent one species, there is only one other species in this subgenus, namely, *P. (A.) jukes-brownei* Vaughan (1945, p. 48) from the middle Eocene of Barbados.

P. (A.) jukes-brownei is so similar to *P. (A.) stephensoni* that it could be separated from it, if at all, only with difficulty. However, more specimens must be sectioned before this species can be analyzed fully.

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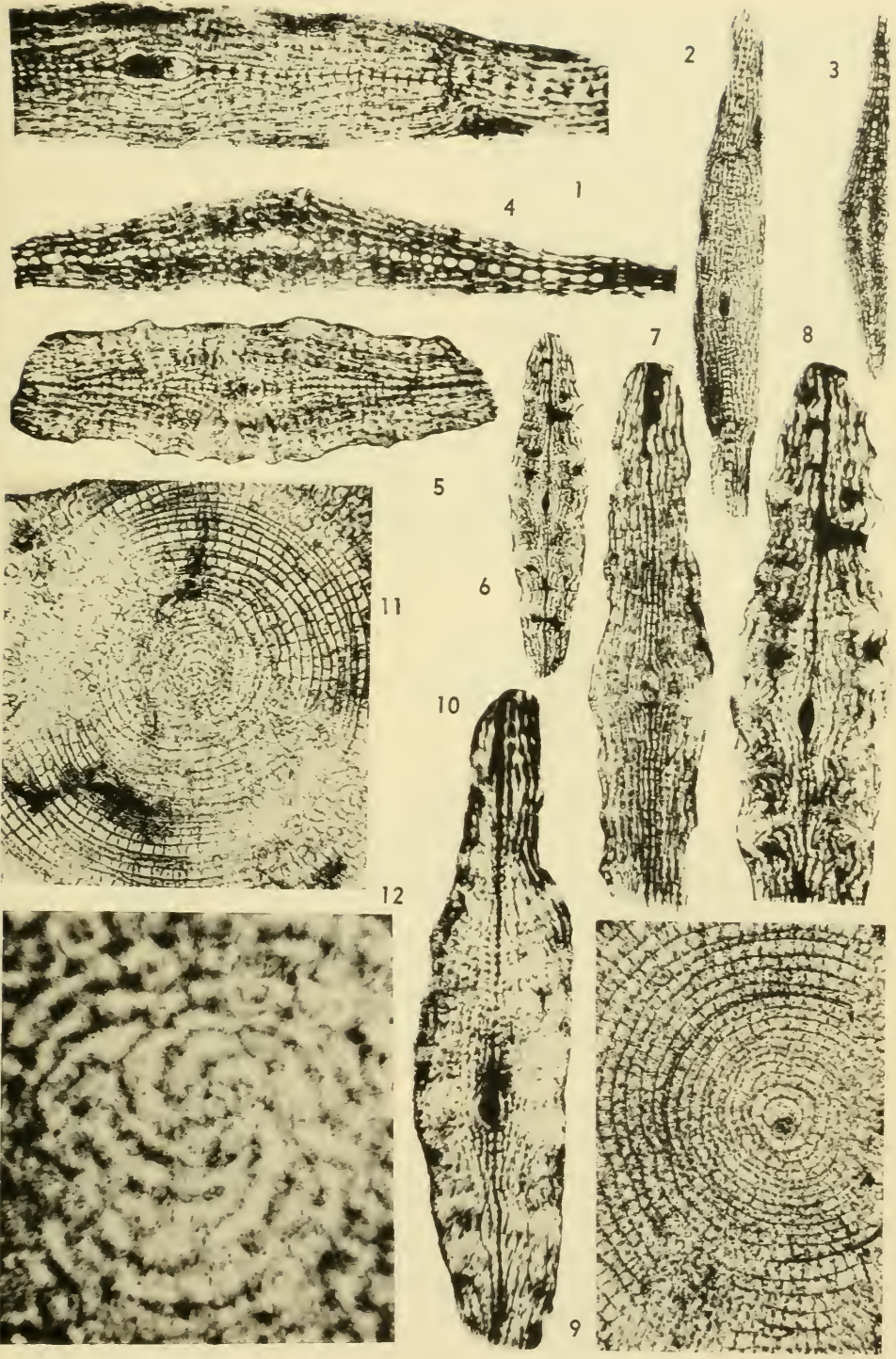
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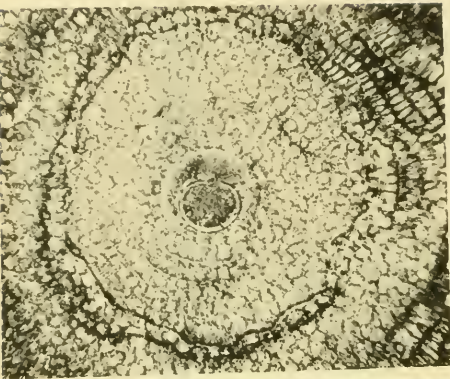
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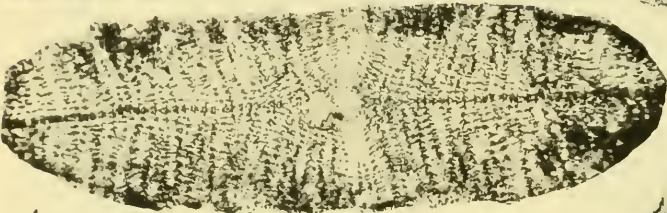
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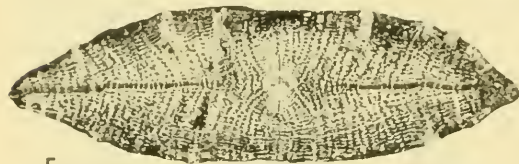
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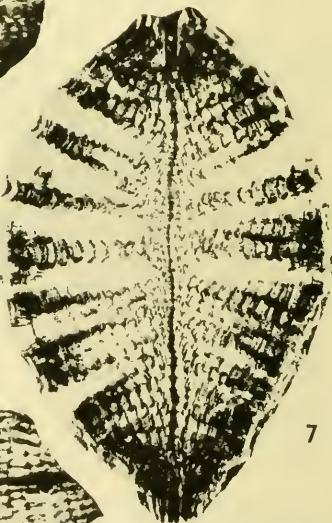
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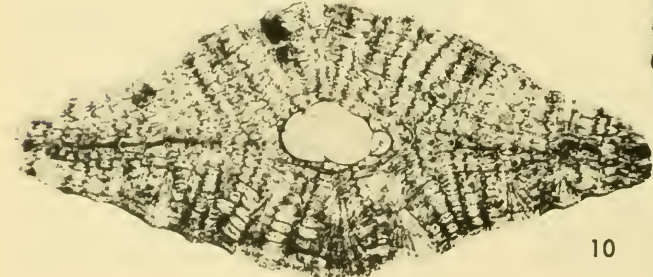
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**BULLETINS
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**PUERTO RICAN UPPER OLIGOCENE
LARGER FORAMINIFERA**

By

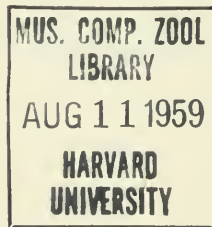
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PUERTO RICAN UPPER OLIGOCENE LARGER FORAMINIFERA*

K. N. SACHS, JR.
Cornell University

ABSTRACT

Nine species of larger Foraminifera from two localities from the San Sebastian formation of upper Oligocene age of Puerto Rico are discussed and illustrated. This fauna is similar to one described from the upper Oligocene part of the Caimito formation of Barro Colorado Island, Panama Canal Zone, and others from Texas, Cuba, and Trinidad. The intergradation of *Heterostegina israelskyi* with *H. antillea* is discussed, and a revised key to American Eocene and Oligocene heterosteginids is given.

INTRODUCTION

Through the kindness of E. A. Pessagno in the spring of 1956 two samples which had been collected by Peter Mattson of the U. S. Geological Survey from the San Sebastian formation of Puerto Rico were made available for study. As the fauna of these samples was well developed, and as comparatively little information has been published concerning Puerto Rican large Foraminifera, permission was requested from Dr. Mattson and kindly granted by him to record this fauna.

The two samples contained abundant, excellently preserved specimens of larger Foraminifera, the species of which are known from numerous localities of the Caribbean and Gulf Coast areas. Thus this part of the San Sebastian formation can be correlated with these areas.

The figured specimens are deposited in the Cole collection at Cornell University, and will be presented eventually to the U. S. National Museum.

The writer expresses his thanks to Mr. Pessagno and Dr. Mattson for the assistance which they gave so freely. Special thanks are expressed to Dr. W. Storrs Cole who made many helpful suggestions during this investigation.

SAN SEBASTIAN FORMATION

The San Sebastian formation represents the oldest of the Tertiary formations outcropping in an east-west belt on the north coastal plain of Puerto Rico. It rests unconformably on Cretaceous basement rocks and is composed of sands and gravels at the base which grade upward through siltstones and shales to calcareous shales and marls at the top.

Until about 1940, most workers in Puerto Rico assigned the San Sebastian formation to the middle Oligocene (Meyerhoff, 1933). However, little was known concerning the correlation of these sediments with deposits in other areas in the Caribbean and Gulf Coast region.

*The cost of the printed plates has been contributed by the William F. E. Gurley Foundation for paleontology of Cornell University.

Galloway and Heminway (1941, p. 285) correlated the San Sebastian formation with the middle Oligocene Byram marl on the basis of an intensive study of the smaller Foraminifera. In addition, they noted the presence of *Heterostegina antillea*, *Miogypsinoides complanata*, and *Lepidocyclina* cf. *parvula* (= *L. (Lepidocyclina) giraudi*).

Zapp and others (1948) considered the San Sebastian to be merely a facies equivalent of the supposedly overlying Lares limestone and Cibao marl. These units were placed collectively in the Río Guatemala group which was considered to include middle and upper Oligocene strata.

LOCALITIES

One sample (PR 2895) is an extremely fossiliferous marl which was obtained in a cut on a side road about 100 yards south from its juncture with the San Sebastian—Lares road (Rte. 111), 100 feet east of Km. 28.0. The other sample (PR 2897) is a fossiliferous marl which was obtained in a cut on the San Sebastian—Lares road (Rte. 111) where it crosses Quebrada Collazo at Km. 26.8.

FAUNA

The nine species of larger Foraminifera found are listed in Table 1. In addition, their relative abundance and occurrence elsewhere in the Caribbean and Gulf Coast region are given.

ZONATION AND CORRELATION

This fauna is similar to that reported by Cole (1957a, p. 314) from the Bohio and Caimito formations of Barro Colorado Island, Panama Canal Zone (see Table 1). Of nine species found in the San Sebastian formation, six are also present on Barro Colorado Island. In addition, two of the remaining species are found elsewhere in Panama in the Caimito formation. Four species present on Barro Colorado Island were not found in the Puerto Rican samples.

Four of the Puerto Rican species are known to occur in the *Lepidocyclina texana* horizon of the Gulf Coast (Gravell and Hanna, 1937). These are *Operculinoides ellisorae* and *O. howei* (= *Operculina dia*), *Lepidocyclina texana* (= *L. asterodisca*), *L. coleii* (= *L. giraudi*), and *Heterostegina israeli* and *H. texana* (= *H. antillea*).

Eight of the Oligocene species of larger Foraminifera reported from Trinidad by Vaughan and Cole (1941, p. 28) are also present in Puerto

TABLE 1

Distribution of Species of Larger Foraminifera from the San Sebastian Formation of Puerto Rico

	Puerto Rico		Barro Colorado Island, Panama, C.Z.		Cuba	Trinidad	Carriacou B.W.I.	Texas	Florida
	locality PR 2895	locality PR 2897	Bohio fm.	Caimito fm.					
<i>Operculina dia</i> (Cole and Ponton)	a	c			x	1	x	2	x
<i>Heterostegina antillea</i> Cushman	a	a	x		3	x	x	x	x
<i>Lepidocyclina (Lepidocyclina) asterodisca</i> Nuttall	c			x	x	x		4	
<i>caellei</i> Lemione and R. Douvillé	c	r	x		x	x			
<i>giraudi</i> R. Douvillé	c	r	x		x	x		5	x
<i>(Eulepidina) undosa</i> Cushman	c				x	x			x
<i>Miogypsina (Miogypsina) antillea</i> (Cushman)	r		x		6	7	x		8
<i>gunteri</i> Cole	r	r	x			x			x
<i>(Miolepidocyclina) panamensis</i> (Cushman)		c		x			x		x

a=abundant, c=common, r=rare, x=present, no quantitative significance.

1. as *O. bulbrooki* (Vaughan and Cole), *O. semmesi* (Vaughan and Cole),
2. as *O. antiguensis* (Vaughan and Cole)
3. as *O. ellisorae* (Gravell and Hanna), *O. bouei* (Gravell and Hanna)
4. as *L. texana* Gravell and Hanna
5. as *L. colei* Gravell and Hanna
6. as *M. intermediata* Drooger
7. as *M. baukinski* Hodson
8. as *M. cushmani* Vaughan

Rico (see Table 1). Vaughan and Cole (1941, p. 28) in referring to this fauna stated: "This is an upper rather than a lower Oligocene fauna".

In the Port St. Joe test well No. 3 in Gulf County, Florida (Cole, 1938), *Miogypsina gunteri* and *Heterostegina texana* (= *H. antillea*) were found in association at a depth of 996 to 1017 feet. At 1017 to 1035 feet, *H. texana* was found in association with *Lepidocyclina* (*Eulepidina*) *undosa* and *L. (L.) parvula* (= *L. (L.) giraudi*). In addition, *M. gunteri* was found at a depth of 890 to 911 feet, and *H. texana* (= *H. antillea*) at 859 to 890 feet.

Cole (1958a, p. 202) discussed the occurrence of *L. (L.) asterodisca*, *H. israelskyi* (= *H. antillea*), and *Operculina dia* at an upper Oligocene Cuban locality. In addition there are specimens of *O. dia*, *H. antillea*, *L. (L.) asterodisca*, *L. (L.) giraudi*, *L. (E.) undosa*, and *M. (Miogypsina) antillea* in the Cole collection at Cornell University which were collected by P. C. Hewitt (1958) from other upper Oligocene localities in Cuba.

Cole (1957b, 1958a) recently discussed the zonation of the Caribbean Oligocene on the basis of larger Foraminifera. An association of *Lepidocyclina* (*Lepidocyclina*) with *L. (Eulepidina)* characterizes the entire Oligocene. This *L. (Lepidocyclina)*—*L. (Eulepidina)* zone as defined by Cole is further subdivided into a lower zone marked by the absence of *Miogypsina* and an upper zone marked by the presence of *Miogypsina*.

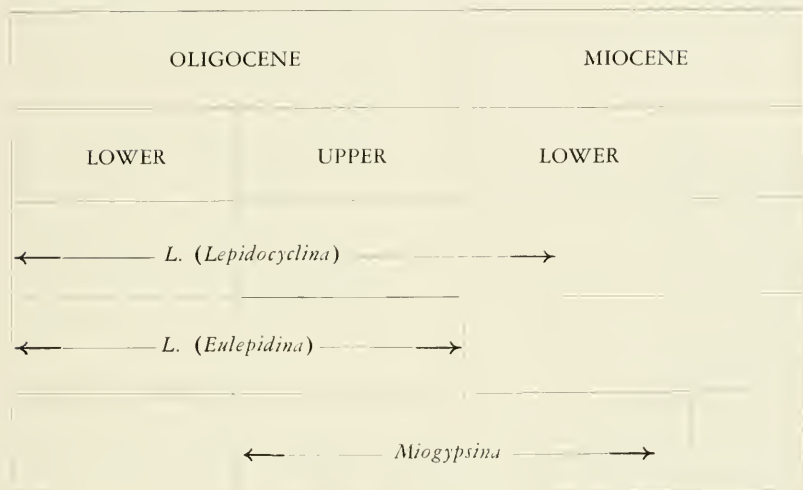
L. (Lepidocyclina) and *Miogypsina* have been reported from the Culebra formation of the Panama Canal Zone by Cole (1953, p. 332; 1957a, p. 321). As the Culebra formation is placed in the lower Miocene (Woodring, 1957, p. 38) *L. (Lepidocyclina)* and *Miogypsina* extend into the American lower Miocene, but *L. (Eulepidina)* and associated genera and subgenera do not (Cole, 1957b, p. 37).

The subjoined table summarizes the zonation of the Oligocene and lower Miocene which is followed here.

Sample PR 2895 contains *L. (Lepidocyclina)*, *L. (Eulepidina)*, and *Miogypsina*. The presence of these genera and subgenera clearly demonstrates that it should be referred to the upper or *Miogypsina* subzone of the more extensive *L. (Lepidocyclina)*—*L. (Eulepidina)* zone. Sample PR 2897 contains *L. (Lepidocyclina)* and *Miogypsina* but does not have *L. (Eulepidina)*. Although field evidence demonstrated that PR 2897 is stratigraphically higher than PR 2895, neither the absence of *L. (Eulepidina)* nor the apparent stratigraphic position of this sample is sufficient to outweigh the general aspect of its fauna. Of the six species found in this

TABLE 2

Stratigraphic Distribution of *L. (Lepidocyclina)*,
L. (Eulepidina), and *Miogypsina*



sample, only *L. (L.) giraudi* is known to occur in the *L. (Lepidocyclina)*—*Miogypsina* zone of the lower Miocene. The other five species have been reported only from the *L. (Lepidocyclina)*—*L. (Eulepidina)* zone. Therefore, both these samples are assigned to the upper Oligocene *Miogypsina* subzone of the *L. (Lepidocyclina)*—*L. (Eulepidina)* zone.

Drooger (1952, p. 25) reported *M. gunteri—tani* (= *M. (M.) antillea*) and *M. ecuadorensis* (= *M. (Miolepidocyclina) panamensis*) from a sample from the San Sebastian formation which he considered to be of middle Oligocene age. Although he did not list associated species, his locality is seemingly close to those under discussion, and is within the *Miogypsina* subzone of the *L. (Lepidocyclina)*—*L. (Eulepidina)* zone.

Later Drooger (1956) suggested a transatlantic correlation by means of Oligocene—Miocene planktonic Foraminifera and miogypsinids. As a result of this study he (1956, p. 187) transferred *M. ecuadorensis* (= *M. (Miolepidocyclina) panamensis*) from the middle Oligocene to the Aquitanian. In addition, the range of the miogypsinids as a group was considered to extend from upper Oligocene (*Miogypsinoides complanata*) to upper Helvetian (*M. (M.) antillea*).

The correlation between the European and American middle Tertiary as put forth by Drooger was expanded by Akers and Drooger (1957). On the basis of the presence of *M. cushmani* (= *M. (M.) antillea*) and *M. mexicana* (= *M. (Miolepidocyclina) staufferi*) in the subsurface Suwannee of Florida they placed the upper boundary of this formation in the Helvetian, and the overlying Tampa in the uppermost Helvetian and Tortonian.

In Panama and the Canal Zone Woodring (1957) correlated the Bohio formation with the Suwannee limestone, placed the fossiliferous part of the Caimito formation in the upper Oligocene, and correlated the Culebra formation with the Tampa limestone which he considered to be Aquitanian (1957, p. 37). Cole (1953, p. 332; 1957a, p. 321) reported *L. (L.) miraflorensis*, *L. (L.) waylandvaughani*, *L. (L.) yurnagumensis*, and *M. (M.) antillea* from the Culebra formation. Therefore, this seemingly belongs in the *L. (Lepidocyclina)*—*Miogypsina* zone of the lower Miocene.

The Tampa limestone of Florida is not known to have either *Lepidocyclina* or *Miogypsina*. If the Tampa limestone and the Culebra formation are Aquitanian, the underlying Suwannee must be largely Chattian inasmuch as the Suwannee contains *L. (Eulepidina)* which in the Americas is apparently restricted to the Oligocene.

DESCRIPTION OF SPECIES

Family Cameriniidae

Genus *Operculina* d'Orbigny, 1826

1959. *Operculinoides* Hanzawa, Cole, Bull. Amer. Paleont., v. 39, No. 181, p. 352.

Operculina dia (Cole and Ponton) Pl. 34, figs. 3, 4, 7, 12

1930. *Operculinella dia* Cole and Ponton, Florida Geol. Sur., Bull. 5, p. 37.

1958. *Operculinoides dia* (Cole and Ponton), Cole, Bull. Amer. Paleont., v. 38, No. 170, p. 198-200, pl. 22, figs. 1-3; pl. 24, fig. 5; pl. 25, figs. 3-13 (references).

Remarks.—As Cole (1959, p. 352) demonstrated recently that *Operculinoides* is a synonym of *Operculina*, all of the American species formerly referred to *Operculinoides* must be assigned to the genus *Operculina* d'Orbigny. Typical specimens of *O. dia* were abundant in both samples studied. The only species with which *O. dia* might be confused is *O. trinitatensis*. However, *O. dia* may be distinguished from this species by the sharp distal recurvature of the chamber walls as seen in median section (fig. 12, Pl. 34).

Occurrence in Puerto Rico.—Localities PR 2895, PR 2897.

Occurrence elsewhere.—Cuba, Mexico (as *O. semmesi*, *O. antiguensis*), Trinidad (as *O. bulbrooki*, *O. semmesi*, *O. antiguensis*), Antigua (as *O. antiguensis*), Carriacou, Texas (as *O. ellisora*, *O. howei*), Florida (as *O. dia*, *O. vicksburgensis*).

Genus **Heterostegina** d'Orbigny, 1826

Heterostegina antillea Cushman

Pl. 34, figs. 1, 10; Pl. 35, figs. 3-6, 10-12; Pl. 36, fig. 8

1919. *Heterostegina antillea* Cushman, Carnegie Inst. Washington, Publ. 291, p. 49, 50, pl. 2, fig. 1b; pl. 5, figs. 1, 2.

1957. *Heterostegina antillea* Cushman, Cole, Bull. Amer. Paleont., v. 37, No. 163, p. 327, pl. 25, figs. 3-5 (references).

1957. *Heterostegina israelskyi* Gravell and Hanna, Cole, *idem*, p. 327, 328, pl. 25, figs. 8, 9.

Remarks.—Gravell and Hanna (1937) erected two new species of *Heterostegina*. *H. israelskyi* was separated from other American heterostegines on the "thinner and more fragile character of the test", whereas *H. texana*, an umbonate type, was considered to differ from *H. antillea* which it closely resembled in that the thickened portion of the test occupied a greater proportion of the total diameter of the test.

Cole (1957a, p. 327) placed *H. texana* in the synonymy of *H. antillea*. However, he maintained *H. israelskyi* as a separate species and utilized the presence or absence of a distinct umbo as a distinguishing character between *H. antillea* and *H. israelskyi* in his key to the American species of *Heterostegina*.

The material from locality PR 2895 yielded numerous heterosteginids in an excellent state of preservation which at first were believed to represent both *H. israelskyi* and *H. antillea*. However, examination of a large number of these specimens showed a gradational series to exist, ranging from strongly umbonate individuals of the *H. antillea* type to thin, nonumbonate ones of the *H. israelskyi* type. This series is illustrated by figures 5, 12, 6, 11, 3, 4 and 10 of Plate 35 in that order. These should be compared with Cole's figures (1957a, pl. 25, figs. 4, 5, 6).

All the specimens have a single undivided operculine type of chamber following the embryonic apparatus. Cole (1952, p. 12) recorded that the next chamber is subdivided into three or more chamberlets. Gravell and Hanna's illustration (1937, pl. 62, fig. 3) of this first subdivided chamber does not show clearly, but there appear to be only two chamberlets present.

The specimens from Puerto Rico consistently have only two chamberlets present in the first subdivided chamber. However, this slight difference in subdivision does not apparently have any taxonomic significance.

Inasmuch as a complete gradation of forms without any significant break is present in specimens from a single population, *Heterostegina israelskyi* Gravell and Hanna is considered a synonym of *Heterostegina antillea* Cushman. A revised key to the American Eocene and Oligocene species of *Heterostegina* is given below.

Occurrence in Puerto Rico.—Localities PR 2895, PR 2897.

Occurrence elsewhere.—Panama Canal Zone (as *H. antillea*, *H. israelskyi*), Republic of Panama (as *H. antillea*, *H. israelskyi*), Cuba (as *H. israelskyi*), Trinidad, Antigua, Venezuela, Carriacou, Mexico, Texas (as *H. texana*, *H. israelskyi*), Florida.

Revised Key to the American Eocene and Oligocene Species of *Heterostegina*

- A. Test involute, evenly biconvex with pronounced axial plug.
 1. With one to four operculine chambers *H. panamensis* Gravell
- B. Test evolute, more or less compressed.
 1. With one operculine chamber *H. antillea* Cushman
 2. With two to fourteen operculine chambers *H. ocalana* Cushman

Family Orbitoididae

Genus *Lepidocyclina* Gümbel, 1870

Subgenus *Lepidocyclina* Gümbel, 1870

- Lepidocyclina* (*Lepidocyclina*) *asterodisca* Nuttall** Pl. 35, figs. 7, 9
 1932. *Lepidocyclina* (*Lepidocyclina*) *asterodisca* Nuttall, Jour. Paleont., v. 6, p. 34, 35, pl. 7, figs. 5, 8; pl. 9, fig. 10.
 1952. *Lepidocyclina* (*Lepidocyclina*) *asterodisca* Nuttall, Cole, U. S. Geol. Sur., Prof. Pap. 244, p. 17, 18, pl. 17, fig. 4 (references).
 1958. *Lepidocyclina* (*Lepidocyclina*) *asterodisca* Nuttall, Cole, Bull. Amer. Paleont., v. 38, No. 170, p. 201, 202, pl. 22, fig. 6; pl. 23; pl. 24, figs. 6, 7.

Remarks.—Typical four- and five-rayed specimens of *Lepidocyclina* (*L.*) *asterodisca* are common at locality PR 2895.

Occurrence in Puerto Rico.—Locality PR 2895.

Occurrence elsewhere.—Panama Canal Zone, Cuba, Trinidad, Texas (as *L. texana*), Venezuela, Mexico.

Lepidocyclina (Lepidocyclina) canellei Lemoine and R. Douvillé

Pl. 34, fig. 6; Pl. 35, fig. 8; Pl. 36, figs. 2, 7

1904. *Lepidocyclina canellei* Lemoine and R. Douvillé, Soc. Géol. France, Mem., v. 12, p. 20, pl. 1, fig. 1; pl. 3, fig. 5.

1952. *Lepidocyclina (Lepidocyclina) canellei* Lemoine and R. Douvillé, Cole, U. S. Geol. Sur., Prof. Pap. 244, p. 18-20, pl. 16, figs. 1-22; pl. 17, figs. 1-3 (references).

Remarks.—Abundant, well-preserved specimens of this distinctive and readily recognized species were present in the sample from locality PR 2895, and occurred rarely in the other sample. The equatorial section (Pl. 36, fig. 7) illustrates the arrangement of the perieubryonic chambers exceptionally well.

Occurrence in Puerto Rico.—Localities PR 2895, PR 2897.

Occurrence elsewhere.—Panama Canal Zone, Republic of Panama, Cuba, Trinidad, Jamaica, Venezuela, Antigua, Carriacou.

Lepidocyclina (Lepidocyclina) giraudi R. Douvillé

Pl. 35, figs. 1, 2

1907. *Lepidocyclina giraudi* R. Douvillé, Soc. Géol. France, Bull., ser. 4, v. 7, p. 305-311, pl. 10, figs. 9, 10, 15, 16.

1957. *Lepidocyclina (Lepidocyclina) giraudi* R. Douvillé, Cole, Bull. Amer. Paleont., v. 38, No. 166, p. 41, 42, pl. 4, fig. 3; pl. 5, figs. 1, 2; pl. 6, figs. 1, 2 (references).

Remarks.—Inasmuch as this abundant and well-known species has recently been discussed by Cole (1957*b*, p. 41), no further remarks will be given.

Occurrence in Puerto Rico.—Localities PR 2895, PR 2897.

Occurrence elsewhere.—Panama Canal Zone (as *L. parvula*, *L. giraudi*), Republic of Panama (as *L. parvula*, *L. giraudi*), Cuba (as *L. parvula*, *L. antiguensis*, *L. giraudi*), Trinidad (as *L. parvula*, *L. giraudi*), Antigua (as *L. parvula*, *L. antiguensis*), Jamaica (as *L. parvula*), Martinique, Carriacou, Texas (as *L. parvula*, *L. colei*), Florida (as *L. parvula*).

Subgenus **Eulepidina** H. Douvillé, 1911

Lepidocyclina (Eulepidina) undosa Cushman

Pl. 34, figs. 2, 5.

1919. *Lepidocyclina undosa* Cushman, Carnegie Inst. Washington, Publ. 291, p. 65, pl. 2, fig. 1a.

1945. *Lepidocyclina (Eulepidina) undosa* Cushman, Cole, Florida Geol. Sur., Bull. 28, p. 43, 44, pl. 1, figs. 14, 15; pl. 2, fig. 8; pl. 8, fig. 7; pl. 11, fig. 8 (references).

Remarks.—The vertical sections of *L. (Eulepidina) undosa* from locality PR 2895 are typical of the species. However, equatorial sections of the majority of the specimens examined show nephrolepidine arrangement of the embryonic apparatus.

Gradation between the nephrolepidine and eulepidine types of embryonic chambers has been recognized for some time, particularly in *L. (E.) undosa*. Vaughan (1924, pl. 34, figs. 5, 6) illustrated two topotypes of this species, one of which shows a nephrolepidine arrangement of the embryonic apparatus and the other eulepidine. Furthermore, he (1926, p. 394) remarked, "The embryonic chambers [of *L. undosa*] are large, thick-walled, and of the Nephrolepidine type. They grade into the Eulepidine type of chambers"

Inasmuch as numerous specimens referred to this species have the more advanced eulepidine type of embryonic chambers, most specialists have classified this species as *Eulepidina* rather than *Nephrolepidina*, although both subgeneric designations have been given it.

Occurrence in Puerto Rico.—Locality PR 2895.

Occurrence elsewhere.—Panama Canal Zone, Cuba, Trinidad, Antigua, Jamaica, Venezuela, Cayman Islands, Mexico, Alabama, Florida.

Family *Miogypsinidae*

Genus *Miogypsina* Sacco, 1893

Subgenus *Miogypsina* Sacco, 1893

- Miogypsina (Miogypsina) antillea* (Cushman) Pl. 34, fig. 8
 1919. *Heterosteginoides antillea* Cushman, Carnegie Inst. Washington, Publ. 291, p. 50, pl. 5, figs. 5, 6.
 1957. *Miogypsina (Miogypsina) antillea* (Cushman), Cole, Bull. Amer. Paleont., v. 37, No. 163, p. 320, 321, pl. 26, figs. 6, 7; pl. 28, figs. 1-9; pl. 29, figs. 1-9 (references).

Remarks.—Galloway and Heminway (1941, p. 444) described *Miogypsinoides complanata* from the San Sebastian formation of Puerto Rico. Drooger (1952, p. 23-26) restudied material from one of Galloway and Heminway's localities in the San Sebastian formation, and assigned the names *Miogypsina* ex. interc. *gunteri-tani* and *Miogypsina ecuadorensis* to the specimens he found. He considered that the specimens described by Galloway and Heminway were, at least in part, the same as his. Cole (1957a, p. 320) considered *M. ex. interc. gunteri-tani* a synonym of *M. antillea*, and *M. (Miolepidocyclina) ecuadorensis* a synonym of *M. (Miolepidocyclina) panamensis*.

Specimens examined from locality PR 2895 are of two types. The majority of the specimens are considered to be *M. antillea*. Comparison of fig. 8, Pl. 34 with fig. 4, pl. 28 of Cole (1957a) will show the close similarity of equatorial sections of this species from Puerto Rico and the

Panama Canal Zone. The remainder of the specimens from locality PR 2895 are considered to be *M. gunter*i, and are discussed under that species.

Occurrence in Puerto Rico.—Locality PR 2895.

Occurrence elsewhere.—Panama Canal Zone (as *M. antillea*, *M. intermedia*, *M. cushmani*), Republic of Panama, Cuba (as *M. antillea*, *M. irregularis*, *M. irregularis*—*intermedia*, *M. intermedia*, *M. intermedia*—*cushmani*), Trinidad (as *M. tani*), Jamaica, Venezuela, Costa Rica, Carriacou, Tintamarre (as *M. intermedia*—*cushmani*), Dominican Republic (as *M. antillea*, *M. tani*—*irregularis*), Florida (as *M. antillea*, *M. irregularis*, *M. irregularis*—*intermedia*, *M. intermedia*, *M. cushmani*).

Miogypsina (Miogypsina) gunteri Cole Pl. 34, figs. 9, 11; Pl. 36, figs. 1, 3, 4

1937. *Miogypsina (Miogypsina)* cf. *M. irregularis* (Michelotti), Barker and Grimsdale, Ann. Mag. Nat. Hist., ser. 10, v. 14, p. 163-166, pl. 5, figs. 4, 5, 7-10; pl. 7, figs. 2, 3.

1938. *Miogypsina (Miogypsina) gunter*i Cole, Florida Geol. Sur., Bull. 16, p. 42, 43, pl. 6, figs. 10-12, 14; pl. 8, figs. 1, 2, 4-9.

1957. *Miogypsina (Miogypsina) gunter*i Cole, Cole, Bull. Amer. Paleont., v. 37, No. 163, p. 321, 322, pl. 26, figs. 1-4, 8, 9; pl. 27, fig. 1 (references).

Remarks.—In addition to *M. (Miogypsina) antillea* a small number of specimens of *M. (Miogypsina) gunter*i were found in both samples. The Puerto Rican specimens of *M. gunter*i examined in thin-section are typical of the species as originally described and illustrated by Cole (1938, p. 42). Figures 9 and 11 of Plate 34 should be compared with Cole's figures (1938, pl. 8, figs. 1, 7).

Occurrence in Puerto Rico.—Localities PR 2895, PR 2897.

Occurrence elsewhere.—Panama Canal Zone, Trinidad (as *M. gunter*i, *M. basraensis*), Dominican Republic (as *M. gunter*i, *M. thalmani*), Costa Rica (as *M. gunter*i, *M. tani*), Mexico, Florida.

Subgenus **Miolepidocyclina** A. Silvestri, 1907

Miogypsina (Miolepidocyclina) panamensis (Cushman) Pl. 36, figs. 5, 6

1918. *Heterosteginoides panamensis* Cushman, U. S. Nat. Mus., Bull. 103, p. 97, pl. 43, figs. 3-8, not figs. 1, 2.

1957. *Miogypsina (Miolepidocyclina) panamensis* (Cushman), Cole, Bull. Amer. Paleont., v. 37, No. 163, p. 322, 323, pl. 26, fig. 5; pl. 27, figs. 2-8.

Remarks.—The material from locality PR 2897 contained a number of specimens of *M. (Miolepidocyclina) panamensis* which show the characteristic subcentral embryonic apparatus with a well-developed coil of peri-embryonic chambers. Figure 6 of Plate 36 should be compared with the illustrations given by Cole (1957a, pl. 27, figs. 2-8).

Occurrence in Puerto Rico.—Locality PR 2897.

Occurrence elsewhere.—Panama Canal Zone, Republic of Panama, Ecuador (as *M. ecuadorensis*), Carriacou, California (as *M. ecuadorensis*), Florida.

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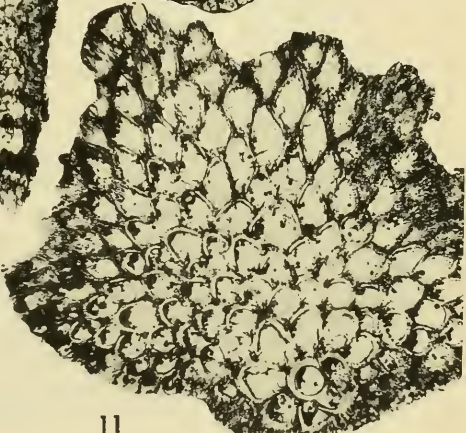
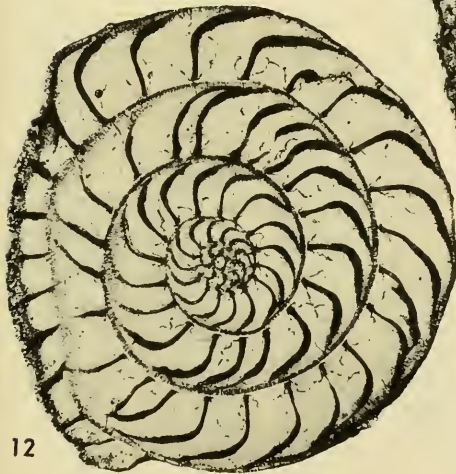
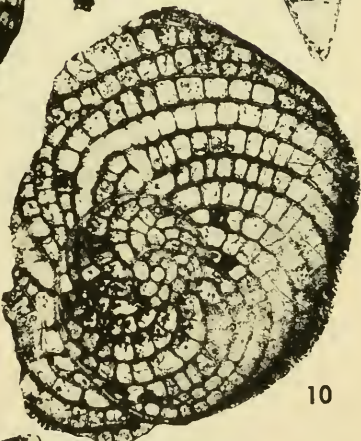
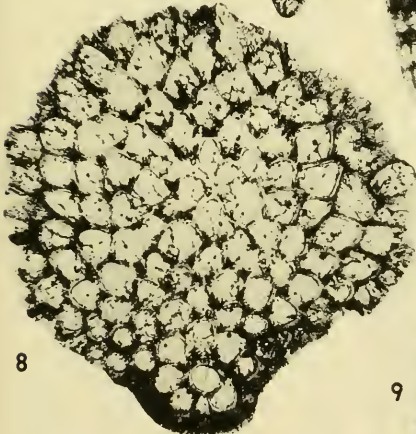
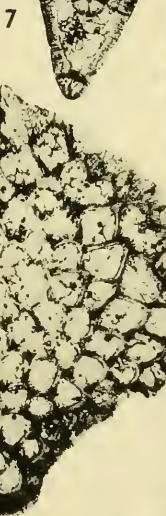
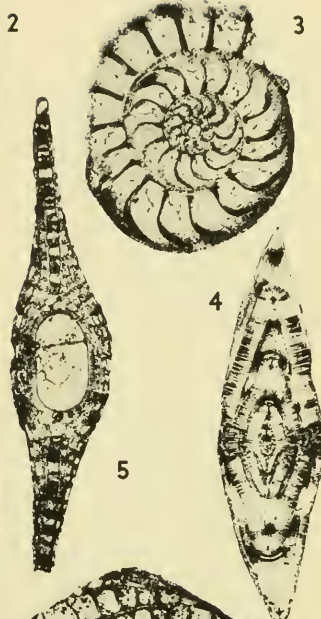
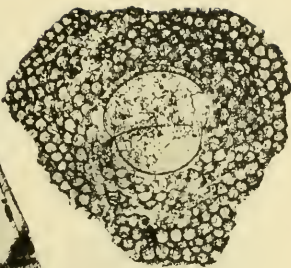
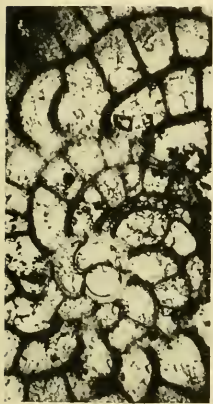
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PLATES

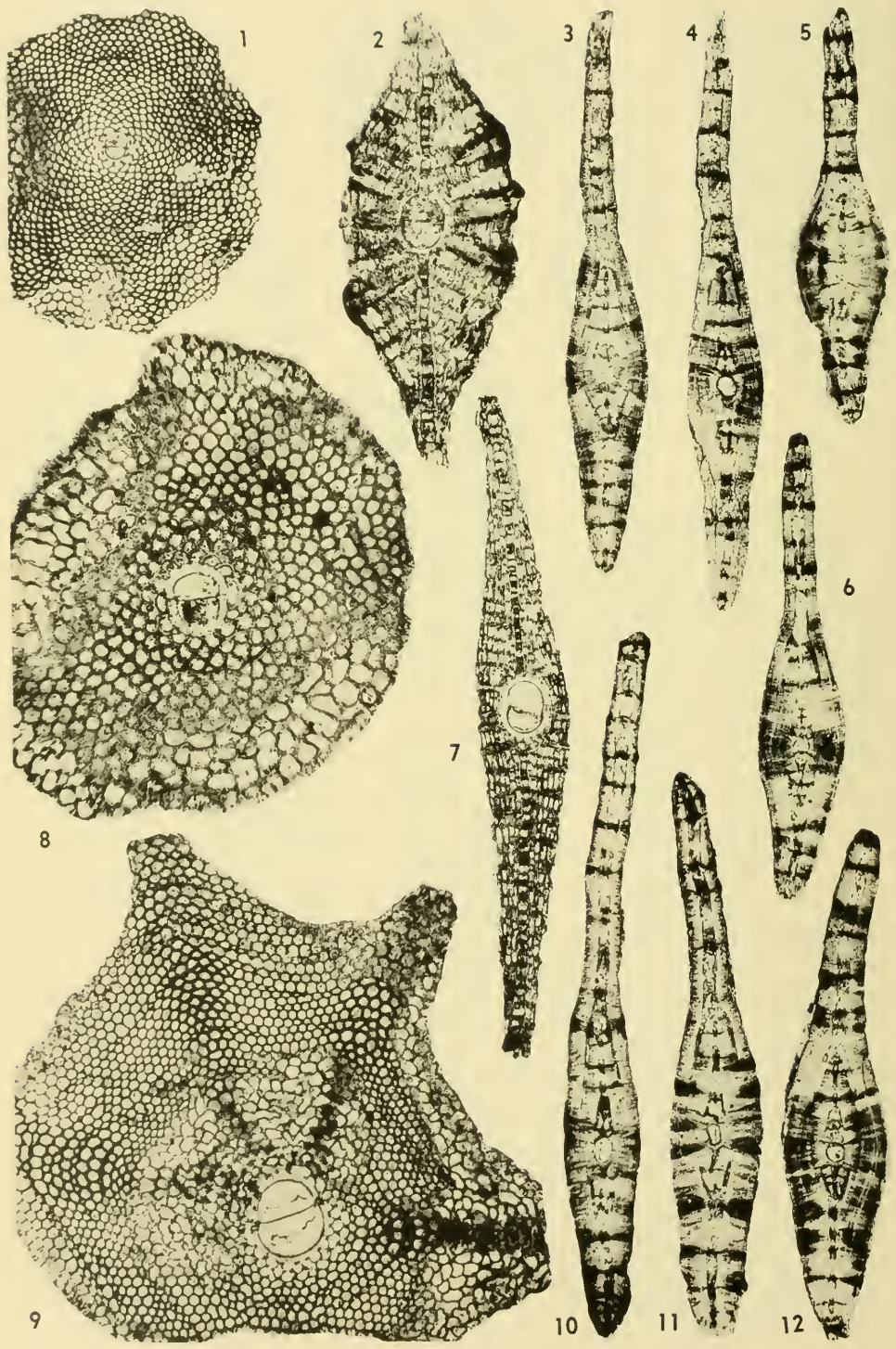
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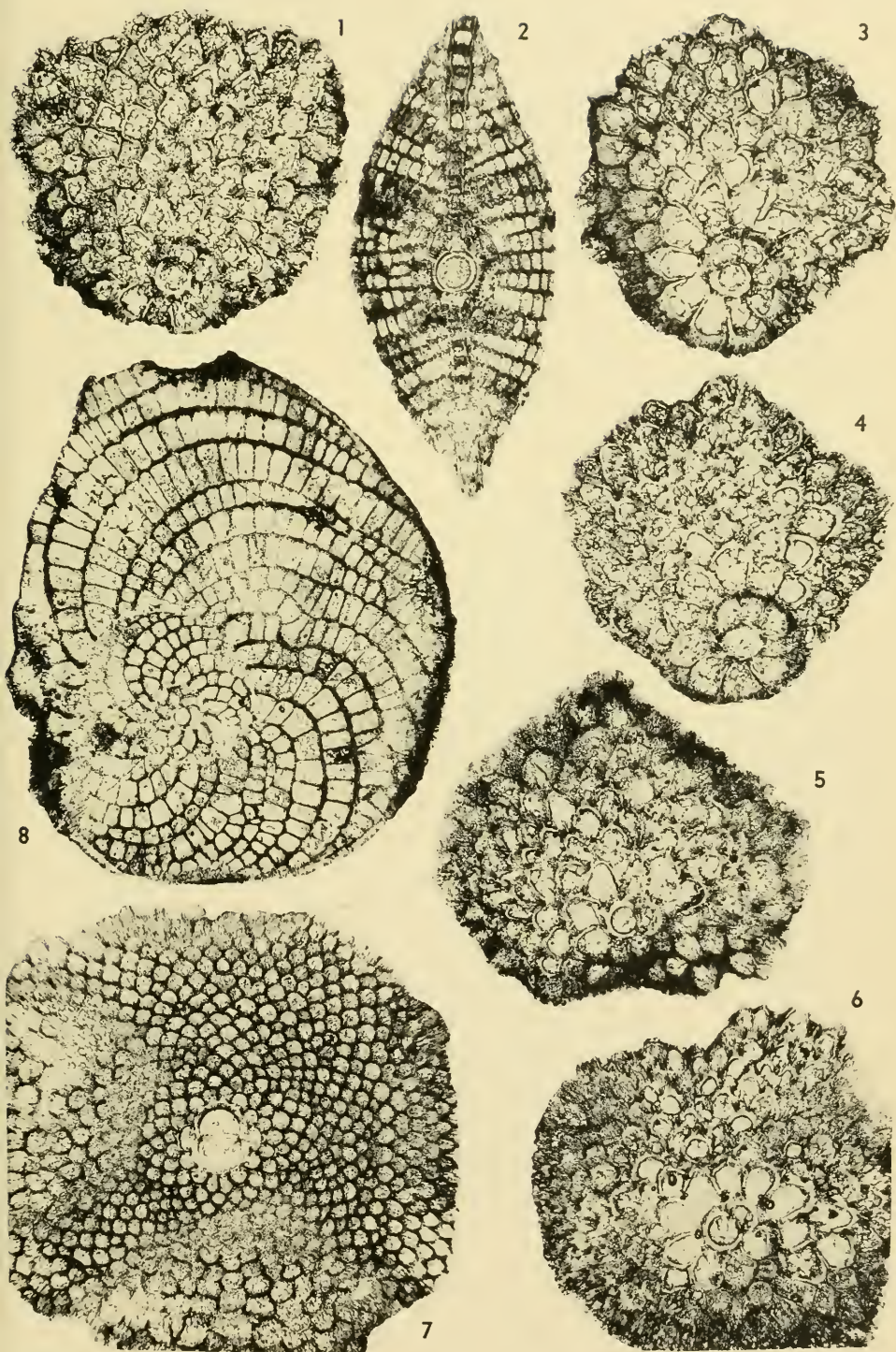


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