Zeitschrift: Eclogae Geologicae Helvetiae

Herausgeber: Schweizerische Geologische Gesellschaft

Band: 56 (1963)

Heft: 1

Artikel: Contribution to the geology and paleontology of the area of the city La Habana, Cuba, and its Surroundings

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DOI: https://doi.org/10.5169/seals-163038

Contribution to the Geology and Paleontology of the Area of the City of La Habana, Cuba, and its Surroundings

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With 75 figures and 26 plates (I–XXVI)

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ABSTRACT

In the area of the city of La Habana, Cuba, and its immediate surroundings two groups of formations are distinguished, viz. the Habana group of Turonian, possibly Cenomanian, to late Lower Eocene age and the Marianao group of late Lower Eocene to Pleistocene age. Serpentinites seem to be older than the Habana group sediments. The relationship with the serpentinites and with the Habana group of an isolated occurrence of early Lower Cretaceous limestones with *Nannoconus* near Santa María del Rosario could not be definitely established. The

Habana group sediments are essentially of flysch character reflecting orogenic movements in their source area. The Marianao group, on the other hand, is mainly a series of carbonates deposited under relatively quiet tectonic conditions. The post-Cojímar beds of the Marianao group, comprising the late Miocene to Pleistocene formations of the coastal areas are listed but not described in detail. Paleogeologic maps show extent and facies of the Oligo-Miocene Husillo and Cojímar formations. Structurally, the Habana area is the westward plunging end of an east–west trending uplift of intricately folded serpentinites and Habana group beds bordered by a relatively undisturbed rim-rock of Marianao group formations. It is suggested that the folding of the core of the Habana-Matanzas uplift was caused by northward directed gliding or plastic flowing movements which started in the Upper Cretaceous and terminated in the Lower Eocene. Correlations are proposed between the biostratigraphic zones established on planktonic Foraminifera, on discoasterids and on typical assemblages of larger benthonic Foraminifera.

The base of the Eocene epoch is defined by the advent of globorotaliids carrying keels formed by imperforate clear shell substance.

RÉSUMÉ

Deux groupes de formations ont été identifiés à La Havane et dans les environs immédiats. Il s'agit du *groupe Habana*, d'âge turonien (et peut-être cénomanien) à éocène inférieur, et du *groupe Marianao*, débutant à la fin de l'Eocène inférieur et se terminant avec le Pleistocène. Des serpentinites sont vraisemblablement plus anciennes que le groupe Habana. Les relations d'un affleurement isolé de calcaires à *Nannoconus* (Crétacé inférieur), près de Santa Maria del Rosario, avec les serpentinites et avec le groupe Habana n'ont pu être clairement définies.

Les sédiments du groupe Habana sont de type Flysch, et témoignent de mouvements orogéniques dans les régions d'où leurs éléments clastiques sont dérivés. Par contre, le groupe Marianao est avant tout formé de roches carbonatées déposées lors d'une période à tectonique relativement calme. Les sédiments du groupe Marianao postérieurs à la formation Cojímar, c'est-à-dire ceux d'âge miocène supérieur à pleistocène de la région côtière n'ont pas été étudiés en détail.

Structuralement, la région de La Havane forme l'extrémité, plongeant vers l'Ouest, d'un anticlinorium de direction Est-Ouest fait de plis complexes de serpentinites et de roches du groupe Habana, flanqués de roches du groupe Marianao peu tectonisées. Le plissement intense de la région axiale de l'anticlinorium Matanzas-Havane est considéré comme résultant d'un glissement ou d'un écoulement plastique vers le Nord, au Crétacé terminal et à l'Eocène inférieur.

Des zones biostratigraphiques ont été établies sur la base des Foraminifères planctoniques, des Discoastéridés et des grands Foraminifères benthiques. L'apparition des Globorotalidés à carènes imperforées a été choisie comme base de l'Eocène.

ABSTRACTO

En el área de la ciudad de la Habana, Cuba, y a sus alrededores se distinguen dos grupos de formaciones, a saber: el grupo Habana de edad turoniana, possiblemente cenomaniana a eocénica inferior y el grupo Marianao de edad eocénica inferior a pleistocénica. Las serpentinas parecen ser anteriores al grupo sedimentario Habana. No se ha podido establecer la relación que exista entre las serpentinas y el grupo Habana con un afloramiento aislado, cerca a Santa María del Rosario, de calizas con *Nannoconus* del Cretáceo Inferior. El carácter esencialmente de «flysch» de los sedimentos del grupo Habana refleja movimientos orogénicos en las áreas de origen. De otra parte el grupo Marianao consiste principalmente en una serie de carbonatos depositados en condiciones relativamente tranquilas. Se enumeran pero no se describen en detalle los depósitos post-Cojímar del grupo Marianao incluyendo las formaciones del Mioceno Inferior al Pleistoceno de las areas costeras. Se incluyen mapas paleogeológicos que presentan la extención y facies de las formaciones oligo-miocénicas Husillo y Cojímar. Estructuralmente el área de la Habana es el extremo que buza al Oeste de un macizo orientado en dirección Este-Oeste y formado por serpentinas y estratos del grupo Habana plegados en un intrincado sistema. Dicho macizo está rodeado por una faja de formaciones del grupo Marianao relativamente no disturbadas. Se sugiere que el plegamiento del núcleo del macizo Habana-Matanzas fué causado por movimientos plásticos en dirección norte que se iniciaron durante el Cretácico Superior y terminaron en el Eoceno Inferior. Se proponen correlaciones entre las diferentes zonas bioestratigráficas basadas en foraminíferos planktónicos, en discoastérides y en asociaciones típicas de foraminíferos bentónicos de gran tamaño. La base del Eoceno se define por la aparición de globorotálidos con quilla formada por la misma sustancia, clara e imperforada, del caparazón.

INTRODUCTION

The geological description of the area of the city of La Habana, Cuba, and its immediate surroundings covers an area more or less equivalent to that of the sheet La Habana, scale 1:50000, of the new topographic map of Cuba (Edition 1, 1956). Field and laboratory work was started by Brönnimann in 1952, but was done mainly by Rigassi and Brönnimann during the years 1957 to 1959. Relevant geological observations were contributed by Ch. Ducloz, who independently mapped certain parts of the Habana area in the years 1956 and 1957, and by J. P. Baughman and A. Sisson, who did extensive field work for Esso Standard (Cuba) Inc. east and west of the city of La Habana. Mapping was done on the 6 sheets of the new topographic map, scale 1:20000, into which the 1:50000 sheet La Habana is subdivided, and the results transferred as an interpretive geological map to the 1:50000 sheet (plate II). Some sections were surveyed on a scale of 1:10000, and many detail maps of type localities and other important outcrop areas were prepared on smaller scales. Aerial photographs of the scale 1:40000 were used to trace regional trends, faults and contacts. The sample stations are located on the new topographic map with reference to a system of rectangular coordinates with 1000 m spacing. The coordinates and the numerous detail maps and locality descriptions enable the reader to establish relatively accurately the geographic locations of the sample stations. The new topographic map with its system of coordinates is a major improvement on the unsatisfactory topography of the old Mapa Militar referred to by L. Rutten (1939, p. 493) as the factor limiting more than anything else the geological exploration of Cuba. A spot map has been compiled giving the geographic localities of all of the BRÖNNIMANN (BR) stations and of most of the type outcrops of the formations and members (plate IV). Certain samples collected by BAUGHMAN, SISSON, and DUCLOZ have been made available to us and, where they furnished pertinent information, included in our descriptions.

The Habana area is the steeply plunging western end of an east–west trending uplift which is generally called the Habana-Matanzas anticlinorium. Geomorphologically it shows inversion of relief, the actual uplift being breached and eroded in form of two elongate depressions separated from each other by a tectonic saddle at Hershey and bordered by rim-rocks. The topography is of relatively low relief. River valleys are drowned and erosion is at a minimum in many parts of the Habana area. Good natural outcrops are relatively scarce in comparison with the great number of artificial exposures such as road cuts, quarries, excavations for buildings, etc. The extraordinary construction activity during 1958, in particular road building, enabled us to study many otherwise unavailable exposures. The geologist visiting the Habana area in the future may discover that the here described outcrop pattern has changed at many places through construction work and that even type localities may have disappeared. Intrapolations between outcrops in the core of the anticlinorium where structures are often small and may change rapidly along strike may lead to wrong conclusions. Hence additional field control is required before a geological map can be drawn of the densely overbuilt old part of the city of La Habana, and of the suburbs of Cerro, Luyanó, Víbora, Jacomino, Lawton, etc. Many of the old quarries, in particular in the geologically important Marianao area, are today used as refuse dumps and difficult to investigate. Our work was further impeded by the tense political situation in the second half of 1958 and in 1959, which made it practically impossible to visit outcrops in the vicinity of railroads, bridges and water installations.

Emphasis is put on the stratigraphic description of the sedimentary section up to and including the Cojímar formation. We believe that the here presented stratigraphy will serve as a useful basis for future geological work in the Habana area and adjoining regions. The stratigraphy of the post-Cojímar beds was not studied in the same detail and referred to in a general way only in the chapter on the stratigraphic summary. The petrographic treatment of the igneous rocks is outside the scope of our work. It is our understanding that a comprehensive account of igneous and metamorphic rocks will be published in the near future by M. VUAGNAT, Geneva, who completed in the summer of 1959 an island-wide field investigation of igneous and metamorphic rocks, in particular of the serpentines. Only general remarks are made on the tectonics of the Habana area, because one of us (D.R.) is at present writing a paper on the tectonic features of Cuba and on the mechanics of the Cuban orogeny based on observations gathered not only in the Habana area but throughout the island.

The lithologic terminology of WILLIAMS, TURNER, and GILBERT (1955) was used in general, and the colors of the rocks were determined with the Rock-color Chart of the U.S. National Research Council (1948). The classification of the clastic calcareous sediments of the Habana group follows the generally accepted size-range subdivisions with the exception of the calcirudites in which, for practical reasons, average grain sizes of about 700 μ were already included.

The samples are consistently described by a brief megascopic lithologic characterization followed either by the enumeration of textural features and organic elements or by the listing of diagnostic fossils obtained from the washed residues. As this paper is essentially a geologic-stratigraphic study, no attempt was made to furnish complete lists of fossils, elements of which are arranged not alphabetically but rather in order of abundance and/or stratigraphic significance. However, particular attention is given to biostratigraphically significant microfossils on which the zonal subdivisions are based, such as planktonic Foraminifera and discoasterids. Reference is made to the description of some of the discoasterids of the Habana area by Brönnimann and Stradner (1960). Zones established on planktonic forms are correlated with assemblages of characteristic and in the field easily recognizable benthonic Foraminifera. With the exception of the echinoderms little is known of megafossils in our area. In future, considerable attention should be given to the collecting of megafossils which are absolutely necessary for the relative dating of the post-Cojímar formations.

For a brief review of the geological literature of the Habana area, the reader's attention is directed to the introductory chapters of the papers by R. H. Palmer (1934), and J. Brodermann (1940) and P. J. Bermúdez (1952).

DEPOSITORY OF MATERIAL

The microfaunal material from the BR (Brönnimann) and the here described Ducloz stations is deposited in the Museum of Natural History, Basle; that referring to Baughman and Sisson stations is in the collections of Esso Standard Oil, S. A. Megafossil collections and the illustrated planktonic Foraminifera are deposited in the United States National Museum, in Washington, D.C. A complete set of the lithologic samples is in the collections of Esso Standard Oil, S.A., and another one in the Museum of Natural History, Basle. H. Stradner, Klosterneuburg, Austria, has in his collection a set of Tertiary *Discoaster* samples.

ACKNOWLEDGMENTS

We are indebted to the Standard Oil Company (New Jersey) for the permission to publish this paper, and to the management of the exploration department of Esso Standard Oil, S.A., for the use of laboratory and drafting facilities. Much is owed to our colleagues J. P. Baughman, Ch. Ducloz, M. Kozary, A. Sisson, G. Stober and M. Vuagnat, who contributed field observations, material, ideas, and criticisms and were our companions on field trips. For the identification of fossils and petrographic descriptions of igneous rocks we are pleased to acknowledge the cooperation of G. C. Amstutz, La Rolla, U.S.A.; W. A. van den Bold, Baton Rouge, U.S.A.; J. P. Beckmann, Teheran, Iran; W. S. Cole, Ithaca, U.S.A.; C. W. Drooger, Utrecht, Holland; S. Hanzawa, Sendai, Japan; H. H. Hess, Princeton, U.S.A.; H. Puri, Tallahassee, U.S.A.; H. Stradner, Klosterneuburg bei Wien, Austria; and W. P. Woodring, Washington, D.C., U.S.A. Mrs. Maria Luisa Robles Ramos, Mexico City, Mexico, very kindly furnished material from Mexican type localities. We also included faunal assemblages from Cuban localities donated by the late W. H. Gravell. Special thanks are due to W. H. Bucher, New York, and H. YARBOROUGH, Houston, for comments on the structural aspects of the Habana area, and to G. A. COOPER, U.S. National Museum, Washington, D.C., for the drawing of diagnostic planktonic Foraminifera by the Museum's artist. Finally, we wish to thank J. F. DE ALBEAR, P. BORRO, J. BRODERMANN, M. L. JAUME, and M. SÁNCHEZ ROIG, all Habana, for having given us access to their libraries and collections and helped us in locating maps, publications and fossil material.

The publication of the paper was made possible through funds granted by the Schweizerischen Nationalfonds zur Förderung der wissenschaftlichen Forschung.

STRATIGRAPHY

Definition of Habana group and Marianao group

Several attempts have been made to establish a reliable stratigraphic sequence of the sediments of the Habana area. But because of the complicated tectonics and of the inadequate outcrop pattern in the core of the Habana-Matanzas uplift, the results were generally unsatisfactory. Even the stratigraphy of the better exposed and tectonically relatively simple rim-rock was not clearly understood, mainly because of the difficulty to recognize certain lithologic units in isolated outcrops, and also because of the rather poor correlation between field-stratigraphic and paleontological work.

Most of the geologists who studied this area, proposed on structural grounds a stratigraphic subdivision into a rim-rock of gently folded strata of Tertiary age and a core of highly disturbed Upper Cretaceous to Lower Eocene sediments and of igneous rocks. We also distinguished two structurally different stratigraphic series, the one forming the core of the uplift and the other restricted to the rim-rock extending in our area along the north coast from Jaimanitas to Cojímar and along the north flank of the Vento syncline. But moreover we were impressed by the lithologic differences between the two series. The older series of lithologies, here termed *Habana group*, overlies the ultramafics and consists mainly of clastics which range from bentonitic clays and shales and very fine graywacke silts and calcilutites to graywacke conglomerates and calcirudites. The maximum thickness does not exceed 1200 m.

The Neocomian limestones encountered at an isolated exposure west of Santa María del Rosario and for which no formation name is proposed, are lithologically not part of the Habana group.

The younger series of lithologies is here termed *Marianao group*. It overlies the Habana group and consists mostly of carbonates. Its total thickness does not exceed 250 m, or about one fifth of the estimated thickness of the Habana group.

The correlation chart, plate I, illustrates our concept of the stratigraphy of the Habana area. It is based on detailed and coordinated field and laboratory studies and in its essential elements believed to be well founded. In this chart, the base of the Eocene epoch is defined by the advent of the first globorotalias with true carina formed by clear imperforate shell substance. This moment in geological time can clearly be recognized. It represents as far as planktonic Foraminifera and discoasterids are concerned a major incision in the faunal evolution of the Paleogene and should be recognized as such.

Why the term Habana formation should no longer be used

Before summarizing the lithologic features of the formations of the Habana and Marianao groups a brief historic review is indicated to explain our decision to drop the term Habana formation as employed by R. H. PALMER and others. The name Havana or Habana was first introduced as a lithologic term by L. RUTTEN (1922) who proposed the "Older Habana formation" for Cretaceous deposits which he however placed in the Eocene, Oligocene and possibly "older Miocene" (PALMER, 1934, p. 128; L. RUTTEN, 1940, footnote on p. 545), and then by WHITNEY LEWIS (1932, p. 539) whose Cretaceous Havana shales refer to a vague lithologic unit below his Madruga chalk and above older Cretaceous rocks.

PALMER (1934, pp. 128–132, table I on p. 125) used the name Habana in a different sense from that originally given by RUTTEN. He defined the Habana formation as follows: "In the western half of the area under discussion (Habana area) the lower measures of the Habana formation are a thick series of light gray and brown, limy shales and marls. Wells within this terrain indicate that the unweathered shales are blue in color and contain much pyrite and organic material. Thus far they are known to contain but few fossils. These shales lie directly under a thick series of interbedded sandstones and shales that in private reports have been termed 'El Cano shales' from their occurrence near the town of that name. In the El Cano member thus far few fossils have been found. (El Cano was apparently first used by WHITNEY LEWIS (1932, p. 539) in his El Cano formation.)

From about the middle of the area and extending eastward to Matanzas the lower shales and the overlying hard sandstone change lithologically, assuming a more marine aspect, and break up into four fairly well recognized members. The lowest of these is a loosely consolidated gravel which is followed successively by a calcareous sandstone, a chalk, and is capped by a deposit that alternates between a limestone and a calcareous shale."

The following diagram attempts to show graphically PALMER's concept of the Habana formation of 1934. In this interpretation we have incorporated data from this author's stratigraphic chart (1934, p. 125), geological map (1934, fig. 1) and lithologic descriptions of the individual members of the eastern development of the Habana formation.

			Habana area		
			Western part	Middle part	Eastern part
Late Upper Cretaceous	Habana formation	Upper	Sandstones and shales (El Cano shales– El Cano member)	Brown shales ("Dirty shales")	Big Boulder Bed member
		Lower	Light gray and brown limy shales and marls	Chalk member (Jacomino) Cone sandstone member Lime gravel member	

Evidently, Palmer recognized at least two groups of lithologies in his Habana formation: a western group characterized by shales, sandstones and marls and a group in the middle to eastern part of the Habana area with predominantly clastic calcareous sediments. The brown shales occasionally referred to by PALMER as "Dirty shale" member of the Habana formation, were regarded as an intermediate facies between the western "El Cano" and the eastern "Big Boulder Bed" lithologies. The diagram explains further that the Habana formation is lithologically heterogeneous. It shows correlations between sediments of different environments and from different areas, which at the time they were proposed could not be supported by fossil evidence (PALMER, 1934, p. 131). In 1945, PALMER (p. 12) changed his idea of the Habana formation and recognized in its eastern development only 3 members by dropping the Chalk member. In this paper he did not mention any longer the "Dirty shale" equivalent of the Big Boulder Bed member.

Where subsequently the name Habana formation was mentioned, it never meant a well-defined formation with definite lithologic features but rocks of late Upper Cretaceous, mainly Maastrichtian age. PALMER (1942, p. 629) used Habana formation in exactly this age sense when he wrote: "The Maastrichtian in Cuba has been named the Habana formation from its well developed occurrences in Habana Province." He actually identifies the Maastrichtian stage with the Habana formation. The Habana formation therefore was regarded by PALMER, and later by some of the Dutch geologists as a time concept and not as a lithologic unit. THIADENS (1937) called Habana formation the shallow-water orbitoidal and rudistid limestones of Maastrichtian age of the Cienfuegos area, and VERMUNT (1937) applied the term Habana formation to the flysch-type deep-water sediments of Maastrichtian age of Pinar del Río Province.

Because the Habana formation is 1) a complex lithologic unit of wide stratigraphic and lithologic spread and 2) has been generally employed in a local stage sense, it is recommended to suppress it and to establish in its place 3 new lithologic units, viz. the pre-Vía Blanca beds of Cenomanian (?) to Turonian age, the Vía Blanca formation of Campanian to Lower Maastrichtian age, and the Peñalver formation of Upper Maastrichtian age. The name Habana, however, will still be used in the designation Habana group of formations. In our stratigraphic concept PALMER's El Cano shales are part of the Lower Eocene Capdevila formation.

Stratigraphic Summary

Habana group

As shown by the detail lithologic and environmental descriptions of its formations, the Habana group represents a flysch series (TERCIER, 1947; SUJKOWSKY, 1957) characterized by sedimentary features such as listed below:

1. Rapid alternation of sharply defined marine pelitic and psammitic layers. Psammitic layers are usually graded bedded, the coarser grains being at the bottom and the finer grains at the top of the bed.
2. Thick series of monotonous aspect.
3. Occasional intercalations of thin limestones and of conglomerates.
4. Penecontemporaneous folds and faults and erosional features caused by submarine slumping and turbidity currents reflecting unstable tectonic conditions in the source area.

5. Rapid vertical changes in faunal elements. Deep-water assemblages indicate the depositional environment. Shallow-water assemblages are accidental interlopers transported from the shelf.
6. Occurrence in calcilutaceous limestones of ichnocoenoses, and at the bottom surfaces of psammitic beds of infillings of animal tracks and of other erosional surface markings, such as the so-called hieroglyphs.

The Habana group ranges in age from early Upper Cretaceous to Lower Eocene and is subdivided from bottom to top as follows:

Pre-Vía Blanca beds—Maximum thickness about 20 m.

Probably unconformable on ultramafics. Olive gray, brownish and grayish silicified limestones, indurated siliceous shales, radiolarites and interbedded graywacke silts, tuffaceous and flow rocks. Ophicalcites at the base.

Age: Cenomanian (?) to Turonian.

—Major unconformity—

Gap of Coniacian to Santonian (Emscherian) age.

Vía Blanca formation—Maximum thickness about 500 m.

Unconformable on pre-Vía Blanca beds and probably locally also on ultramafics. Mostly reddish, brownish and greenish graywacke silts and sands, shales, and thin beds of white calcilutites. Thick lenticular intercalations (Bacuranao "limestone") of mainly fine-grained yellowish gray calcarenites and calcilutites with "clay" pebbles at base derived from underlying Vía Blanca beds. Lower part of Vía Blanca formation with grayish yellow tuffs, brownish and greenish bentonitic clays and some andesitic and porphyritic volcanics. Conglomerates with elements derived from intermediate igneous rocks, graywackes, radiolarites, limestones and marls occur at different stratigraphic levels within the Vía Blanca formation.

Age: Campanian, *Globotruncana linneiana* zone, to Lower Maastrichtian, *Rugotruncana gansseri* zone.

Peñalver formation—Thickness from 20 to 150 m.

Disconformable contact with Vía Blanca formation. Single graded cycle of mostly calcareous clastics. Overall color whitish when weathered, bluish gray when fresh. Basal portion generally with abundant subangular "clay" inclusions derived from the underlying Vía Blanca formation. Grain size at base from 5 mm to a few centimeters. Top hard calcilutite the clastic nature of which can only be recognized with the handlens or in thin sections. Geomorphologically forming dominant ridges. Exploited in numerous quarries. Common oil seeps.

Age: Upper Maastrichtian, *Rugotruncana mayaroensis* zone.

—Major disconformity—

Gap of Danian age.

Apolo formation—Maximum thickness about 100 m.

Transgressive on Peñalver formation. Reddish to brownish clays and graywacke silts and sands, and occasional igneous derived conglomerates.

Age: Lower Eocene, *Globorotalia angulata* zone.

Alkázar formation—Thickness about 10 to 40 m.

Transitional on Apolo formation. Greenish marls and chalks interbedded with hard, occasionally silicified well-cemented light-colored calcareous clastics and fragmental limestones. Geomorphologically forming minor ridges between the relatively softer Apolo and Capdevila beds.

Age: Lower Eocene, *Globorotalia velascoensis-Globorotalia membranacea* zone.

It seems that the Alkázar lithology can go locally as high as the *Globorotalia rex-Globorotalia formosa* zone.

Capdevila formation—Thickness from about 300 to 400 m.

Disconformable to transitional on Alkázar formation. Well-bedded brownish to orange shales and graywacke silts and sands. Subdivided into 4 lithologic parts. In the lower part, shales and graywacke silts better developed than graywacke sands; in the type part, the amount of finer sediments about equal to that of the coarser ones. The upper part of the formation characterized by greater development of the coarser beds and by some conglomerates. In this upper part, the graywacke sandstones contain large indurated concretions. The uppermost part of the formation consists of cream to brownish shales, graywacke silts and sands and some marly beds forming the lithologic transition to the carbonate facies of the Universidad formation, Marianao group.

Age: Lower Eocene.

Lower part or Unit I:	*Globorotalia rex-Globorotalia formosa* zone.
Type part or Unit II:	*Globorotalia broedermanni-Globorotalia pseudoscitula* zone.
Unit III:	No diagnostic microfossils.
Uppermost part or Unit IV:	*Globorotalia palmerae* zone.

Marianao group

The younger series of formations, the Marianao group, consists mainly of carbonates ranging in age from Lower Eocene to Pleistocene. Post-Cojímar formations, which are not distinguished in the interpretive geological map (plate II) are restricted to the coastal belt and to the Vento syncline. These young beds were not studied in the same detail, but certain new formation names and type localities will be proposed. The new formations are mentioned in the stratigraphic chart to show our opinion on age and correlation (plate I). This presentation is tentative and probably subject to changes after completion of mapping, lithologic studies and identification of megafossils.

The oldest formation of the Marianao group, the Universidad formation, is resting either transitionally or unconformably on the Habana group. Most of the carbonate formations are separated by unconformities or disconformities corresponding sometimes to considerable time gaps. They are often difficult to recognize in the field because of the similar overall lithologies of some of the formations. This difficulty is increased by the possibility to confound discordant formation boundaries with intraformational breaks. The unconformity between the Universidad formation and younger beds for instance, indicates one of the most pronounced sedimentary gaps of the Marianao group. A distinct unconformity occurs also between the Pleistocene and older beds. South of Playa de Guanabo, a small coastal town about 17 km east of Cojímar, Pleistocene calcarenites are resting with a strong angular unconformity on Vía Blanca beds.

The Marianao group consists of the following formations listed below from bottom to top:

Universidad formation—Maximum thickness about 50 m.

Transitional or transgressive on older beds. The formation is divided into two members. The lower, here called Toledo member, consists of white to greenish chalks and silicified limestones. The upper, here called Príncipe member, is a whitish to yellowish chalk.

Age: Lower Eocene, *Globorotalia palmerae* zone and *Globorotalia bullbrooki-Globorotalia aragonensis* zone, to Middle Eocene, *Hantkenina mexicana-Globorotalia aragonensis* zone and *Hantkenina dumblei-Globigerinatheka barri* zone.

—Unconformity—

Urría beds—Residual thickness 2 to 3 m.

Unconformably on older formations. Thin-bedded yellowish dolomitized limestones. Restricted to channel-like depressions.

Age: Probably Middle Eocene.

—Unconformity—

Punta Brava formation—Thickness 23 m.

Unconformable on Capdevila formation. Brownish calcareous silts and yellowish limestones. Toward the top whitish chalks.

Age: Upper Eocene. Upper part of *Globigerapsis semiinvoluta* zone.

—Unconformity—

Gap coincides with *Globorotalia cerroazulensis* zone.

Consuelo formation—Maximum thickness about 20 m.

Unconformable on older formations. Massive whitish to yellowish chalks with few thin shaley layers. Basal beds often slumped with reworked pre-Consuelo elements. Barite concretions.

Age: Oligocene, *Globigerina ampliapertura* zone to *Globigerina ciperoensis-Globorotalia opima* zone.

—Unconformity—

Husillo formation—Maximum thickness less than 25 m.

Unconformable on older formations. Whitish, massive and fragmental limestones, reefal and reefal derived limestones, yellowish chalky marls and chalky limestones. Locally conglomeratic, with igneous and sedimentary components.

Age: Oligo-Miocene, *Globigerina ciperoensis-Globorotalia opima* zone to *Globigerinatella insueta* zone.

Cojímar formation—Maximum thickness up to 50 m.

Unconformable or conformable on older beds. Yellowish whitish powdery chalks with irregularly constricted chalky limestone beds and algal limestones.

Age: Miocene, *Globorotalia fohsi* zone.

Post-Cojímar beds.

The following post-Cojímar beds are distinguished:

Güines formation: Type locality has not been established for the whitish to yellowish, massive, hard, crystalline, cavernous, dolomitic limestones which

are weathering to a lateritic soil. Pseudoölitic textures, algae, shallow-water megafossils and common peneroplids, often embedded in a clear calcite groundmass suggest restricted environments. Limestones of this type were encountered in the Vento syncline, where they rest unconformably on Husillo beds.
Age: post-Cojímar, Miocene or younger.

Rosario formation: Type locality is in the large quarry west of Santa María del Rosario, coordinates 359.00 N and 369.80 E. Whitish, conglomeratic marly chalks and yellowish to pale yellowish orange chalks. Common megafossils. Unconformably on Husillo beds (type locality) or on Capdevila beds (Arroyo Naranjo).
Age: Late Miocene, *Globorotalia menardii* zone.

Cangrejeras formation: Type locality in the large quarry east of Cangrejeras, a small village between Punta Brava and Sante Fé. Lower part whitish massive chalky limestones, upper part thin-bedded chalky limestones separated by very thin chalk layers. Solution cavities filled with limonitic clay. Megafossils. *Operculinoides cojimarensis* (D. K. PALMER) near Baracoa. Possibly transitional on Cojímar beds.
Age: post-Cojímar, Miocene or younger (pre-Pleistocene).

Vedado formation: Type locality at the Hotel Nacional, forming the northern cliff toward the Malecon. Whitish reefal limestones with large corals and other megafossils. Also reefal limestone of rubbly appearance. Weathering to lateritic soil.
Age: post-Cojímar, Miocene or younger (pre-Pleistocene).

Morro formation: Type locality in the western corner of the artificial basin made for the construction of the road tunnel under the Bahía de la Habana, on the north side of the entrance to the Bahía de La Habana, between Morro castle and the Fortaleza de la Cabaña. Yellowish to whitish indurated algal limestones and recrystallized chalks with calcite crusts. Common pelecypods. Resting transgressively on Cojímar beds. Dr. WOODRING (letter Jan. 4, 1961) reported *Lyropecten* (*Nodipecten*) aff. *L. colinensis* (F. and H. HODSON) from outcrops west of Casa Blanca and at foot of southern wall of the Fortaleza de la Cabaña. This pelecypod suggests a Pliocene age for the Morro formation.
Age: Probably Pliocene.

Jaimanitas formation: Type locality abandoned quarry near La Areca, Biltmore area, just north of the Biltmore Golf Club. Cotype locality lower calcarenite of road cut of the Habana–Mariel highway west of Santa Fé. Whitish to yellowish indurated calcarenite with abundant peneroplids and algal fragments. Thin-bedded, occasionally cross-bedded. Also shell beds, conglomerates and reefal deposits associated with calcarenites in the Jaimanitas–Biltmore–Miramar area, and coral formations forming the actual dog tooth-weathered beach terraces.
Age: Pleistocene, *Archaias angulatus* zone.

Santa Fé formation: Type locality upper calcarenite at the above mentioned road cut at the Habana–Mariel highway just west of Santa Fé. Whitish to

yellowish thin-bedded and cross-bedded calcarenite, separated from the underlying Jaimanitas calcarenite by a fossil soil horizon and calcite crusts indicating emersion period. Separated from recent lateritic soil by calcite crusts. Less indurated than the Jaimanitas calcarenite, with abundant algal fragments and peneroplids. Forming dune-like hills parallel to the shore.
Age: Pleistocene, *Archaias angulatus* zone.

Casa Blanca formation: Type locality at the post office of Casa Blanca, a small town on the north coast of the Bahía de la Habana, opposite the old part of La Habana. "Nodular" weathering whitish, chalky calcarenite with abundant peneroplids and megafossils, in particular echinids and pelecypods. The conglomeratic deposits with a reddish calcarenaceous matrix apparently resting unconformably on the Morro formation to the west of the type locality form part of the Casa Blanca formation.

Dr. WOODRING (letter Jan. 4, 1961) identified the following typically Pleistocene gastropods and pelecypods from the type locality of the Casa Blanca formation:

Modulus modulus (LINNÉ)
Strombus sp., fragment
Natica (Naticarius) canrena (LINNÉ)
Polinices lacteus (GUILDING)
Vasum muricatum (BORN), immature
Bulla occidentalis A. ADAMS ?
Pecten laurentii (GMELIN) ?
Aequipecten gibbus (LINNÉ)
Aequipecten gibbus nucleus (BORN)
Ostrea equestris SAY ?
Chama macerophylla GMELIN
Trachycardium muricatum (LINNÉ)
Trigoniocardia (Americardia) medium (LINNÉ)
Lirophora paphia (LINNÉ)
Age: Pleistocene, *Archaias angulatus* zone.

Serpentinites, diorites and associated igneous rocks

The only significant outcrops of serpentinites in the Habana area are along the east–west striking ridge from Regla, east of the Bahía de la Habana, to Guanabacoa and to Residencial Guanabacoa and extending farther east (plate II). Sections across this serpentinite body about 1 km west of Residencial Guanabacoa at the continuation of the Avenida Monumental are shown in fig. 1. Small east–west trending serpentinite bodies occur north of San Francisco de Paula and southwest of Santa María del Rosario. The main part of these rocks is formed by peridotite (harzburgite) which underwent medium to strong serpentinization which mostly affected the olivine. The bronzite and enstatite are usually fairly well preserved. The centers of many of the subangular to subrounded serpentinite "boulders", preformed through the original diaclasic fracture system of the peridotite mass, consist of peridotite. In good outcrops, 5 to 50 cm large "boulders" of relatively

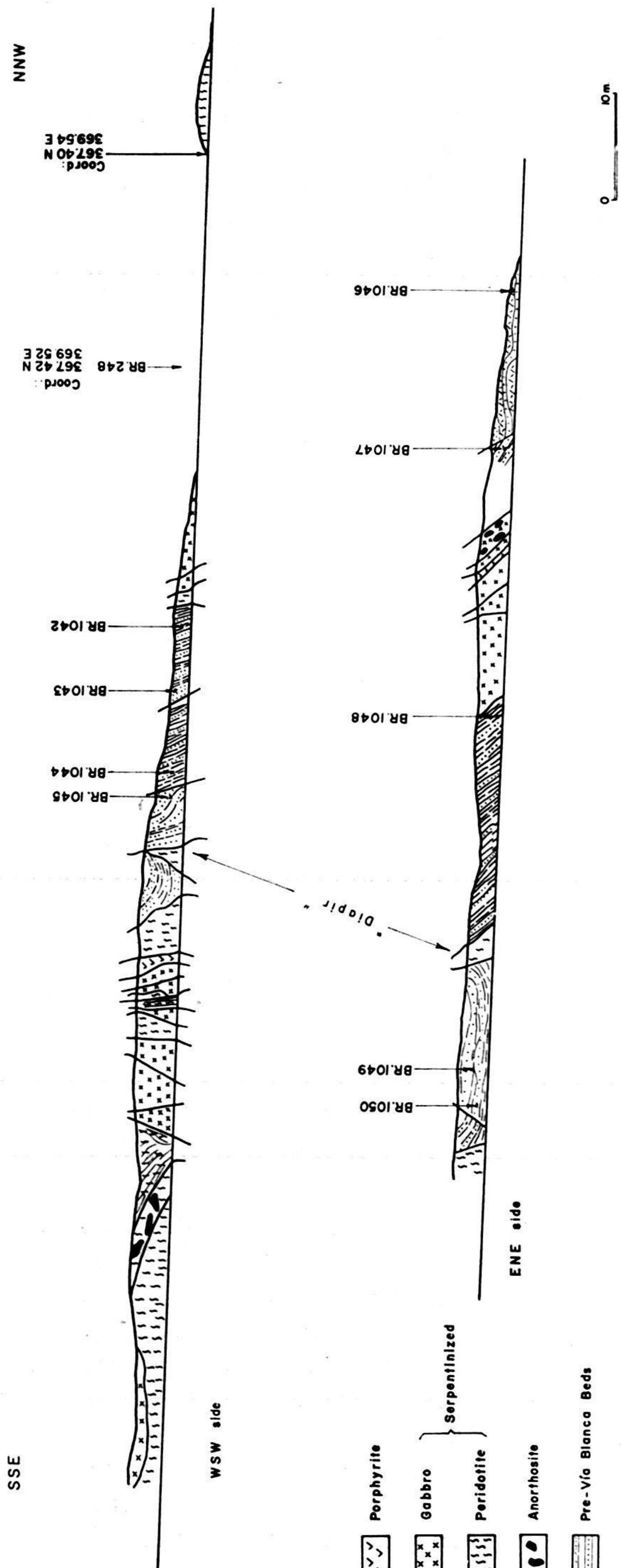


Fig. 1. Road cut at the continuation of the Avenida Monumental, across the serpentinite body of Guanabacoa.

fresh peridotite were observed to be surrounded by a completely serpentinized "matrix". The "boulders" show an increase of serpentinization from the center to the periphery. In a more advanced stage of hydration, the centers show serpentinized olivine and well-preserved pyroxene, while the peripheral zones have all their mineral components serpentinized. From these observations it is quite clear that the serpentinization is a secondary process (HESS, 1959, p. 13). There are also some finely crystallized apparently also serpentinized gabbros. Locally, there occur small slivers of rocks rich in feldspar, probably anorthosite. In general, it seems that the feldspar-bearing rocks are resting on the ultramafics. At many places in joints of these different igneous rocks opal was found. Cleavages and slickensides occur densely throughout these rocks, indicating tectonic movements. Asbestos was noted in tectonically stressed serpentinite in the outcrops of Reparto Muralla,

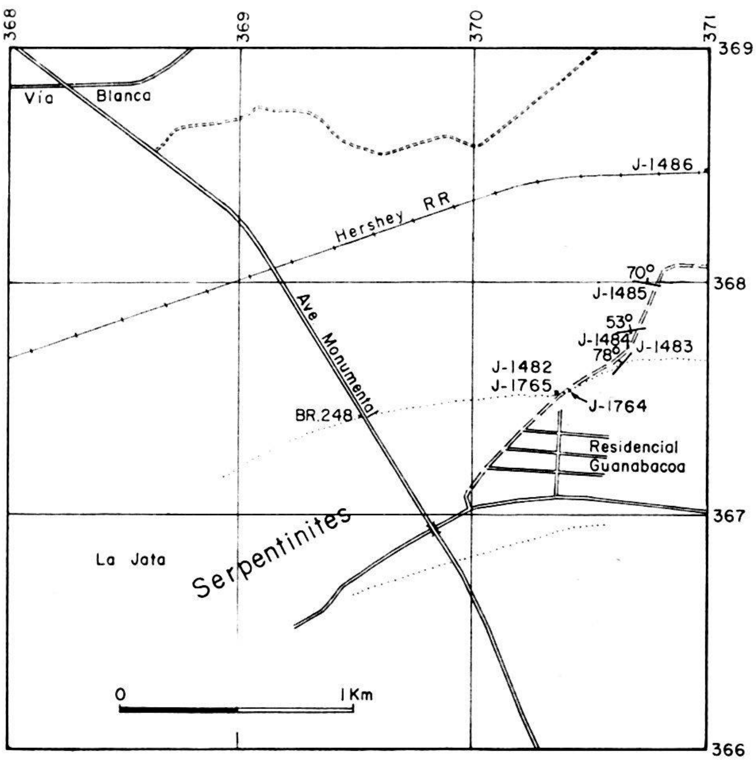


Fig. 2. Index map, Residencial Guanabacoa.

east of the Bahía de la Habana, just north of the Regla-Guanabacoa serpentinite mass. Talc has never been found in the Habana area and generally seems to be scarce in Cuba. We have seen this mineral only in northwestern Pinar del Río Province, in the Sierra de Escambray and in the Trinidad Mountains, Las Villas Province. In all these regions, serpentinite is in contact with schists and the talc is always localized along the schist-serpentinite contact. The main pattern of the cleavages and slickensides as well as the gabbro-peridotite contacts seem to be roughly parallel to the strikes observed in the nearby sediments. It thus appears that the igneous rocks are folded together with the sedimentary rocks. Some narrow serpentinite bodies piercing through the sediments look like diapirs and may be caused by increase of volume due to serpentinization. The large size of the olivine and pyroxene crystals in the peridotite indicates slow cooling. This excludes the possibility of the serpentines being flows interbedded in the Upper Cretaceous, except if such flows were very thick, as was postulated by DUBERTRET in the Near East.

Some of the closely studied contacts between serpentinites and pre-Vía Blanca beds appear to be of sedimentary nature. This would mean that the peridotite-serpentines of Regla-Guanabacoa are older than the pre-Vía Blanca beds, i.e. older than Cenomanian (?) to Turonian. They are also older than the intruding granodiorites reported by L. RUTTEN (1940, p. 542) from the Regla-Guanabacoa serpentinite body.

The discussion of the ultramafics of Cuba is not within the scope of the present study. But as these rocks form an important lithostratigraphic element of the area east of the Bahía de la Habana, a brief review of the controversial and as yet unsolved problem of the age of the serpentinites in Cuba and the neighboring islands Jamaica, Hispaniola, and Puerto Rico seems indicated.

In his worldwide review of serpentinite occurrences, HIESSLEITNER (1951–52, pp. 586 and 587) pointed out that there are two groups of peridotite-serpentines. One group for which the age of the intrusion is established by the actual observation of intrusive phenomena and which concerns virtually only pre-Mesozoic ultramafics, and another group, where the age of the emplacement is exclusively based on tectonic and stratigraphic observations, and therefore doubtful in many respects.

As far as could be ascertained from the literature, the Cuban serpentinites belong to this latter group, although according to TABER (1934) the serpentine massives of Cuba are associated with metamorphic schists and limestones of Paleozoic and older age (vide HIESSLEITNER, 1951–52, p. 585).

Isolated masses of metamorphic rocks are often found within the serpentinite bodies, as for instance in the serpentinites of Escambray, south of Santa Clara, Las Villas Province, or in the serpentinites of Camagüey (FLINT, DE ALBEAR and GUILD, 1948, pp. 43–45). But apparently nowhere in Cuba were intrusions observed of peridotite-serpentine in metamorphic rocks.

WHITNEY LEWIS (1932, pp. 543, 544) regarded it as probable that most of the serpentines were post-Cretaceous and intruded as narrow dikes and then spread "either as laccoliths and sills at some zone above the Cretaceous formations or as flows at the surface".

SCHÜRMANN (1935, pp. 340, 341) described the serpentines of central Cuba as syn-tectonic intrusions of the late Cretaceous (Laramid) orogeny. Those of western Cuba are according to SCHÜRMANN either intrusions of the Middle Eocene orogeny or they may represent masses tectonically displaced during this orogeny. The granodiorites, tectonically less involved than the serpentines, are regarded as younger, post-tectonic intrusions. According to M. G. RUTTEN (1936, p. 13) serpentine fragments were noted in the "Tuff formation" of central Cuba indicating that serpentine was formed prior to at least part of the tuffs. L. RUTTEN (1940, p. 542) in his note on the age of the serpentines in Cuba stated that on the "base of our [L. RUTTEN, M. G. RUTTEN, A. A. THIADENS, H. J. MAC GILLAVRY, and L. W. J. VERMUNT] field-observations, . . . all the serpentines are pre-eocene and very probably pre-upper-cretaceous", and discussing PALMER's descriptions of serpentine contacts east of Habana, he (1940, p. 545) finds proof that ". . . the serpentines which occur E. of Habana Bay, are pre-upper cretaceous." As can be inferred from L. RUTTEN's introductory statements about the observations made by himself and his students in Las Villas (former Santa Clara) and Camagüey provinces, "pre-upper-cretaceous" means pre-"Habana formation", that is pre-Campanian, perhaps pre-Cenomanian (?) to Turonian if the pre-Vía Blanca beds are included as in the Habana group of the present interpretation. L. RUTTEN (1940, pp. 545, 546) is moreover of the opinion that "there is no evidence for a different age of the serpentines of the provinces of Habana and Matanzas and those of Santa Clara, Camagüey and Oriente. It would, indeed, be very remarkable, if such rare and 'aberrant' rocks as serpentines had been formed in so small an area as Cuba in two different geological periods." The latter remark refers to R. H. PALMER's (1934, 1938, 1944, 1945) opinion on the age of the serpentinites, which he believed were emplaced at different times, most of them during the Upper Cretaceous. In western Oriente Province, PALMER reported serpentine fragments in the Upper Cretaceous, and in Las Villas Province, a serpentine dike cutting the Eocene, and in Matanzas Province serpentine marmorizing Güines limestones (L. RUTTEN, 1940, p. 544). PALMER (1945, p. 18) also mentioned that THAYER (personal communication) found serpentine fragments in the Lower Cretaceous "Aptychus beds" indicating the occurrence of pre-Lower Cretaceous serpentine. PALMER therefore recognized different serpentine intrusions from pre-Lower Cretaceous to late Tertiary, post-Güines time. L. RUTTEN (1940) visited some of PALMER's serpentine localities in the Habana-Matanzas area and found no evidence for a post-Upper Cretaceous age of the serpentines.

KEIJZER (1945, p. 19) encountered in the belt of large serpentine massives of the Sierra de Nipe, the Sierra del Cristal and the Sierra de Moa, Oriente Province, associated with the serpentines dark diabasic and gabbroidic rocks, which both were regarded as pre-Upper Cretaceous. Reference is made to KEIJZER's locality K. 234 where reportedly unmistakable inclusions occur of serpentines and diabasic rocks in Maastrichtian limestones with *Omphalocyclus, Lepidorbitoides, Vaughanina* and *Sulcoperculina dickersoni* (D. K. PALMER). The age of this assemblage is late Maastrichtian on the basis of *Omphalocyclus macroporus* (LAMARCK), and the serpentinites therefore would be pre-late Maastrichtian. In middle Oriente Province, DE VLETTER (1946, p. 33) found no convincing evidence for a pre-"Habana" age of the serpentinites and considered the possibility that they intruded during an "inter-Habana movement". According to VAN WESSEM (1943, p. 12), the contacts between serpentinites and "Aptychi" limestones of central Camagüey Province are all lacking contact metamorphism. They are apparently of tectonic nature. VAN WESSEM could say nothing about the age of the serpentinite emplacement in this area.

FLINT, DE ALBEAR, and GUILD (1948, pp. 43–45) found the ultramafics of the Camagüey district, Camagüey Province, to engulf schist and gneiss of unknown age and to be overlain by volcanics that appear to range from Early to Late Cretaceous, although the lower part of the volcanics is not dated. Based on this observation, WOODRING (1954, p. 722) placed with some reservation about the age of the lower volcanics, the intrusion of the Cuban ultramafics at an early date in Early Cretaceous time.

MITCHELL (1955) reviewed the opinions expressed on the West-Indian serpentinite occurrences and arrived at similar conclusions about the dates of their emplacements as did R. H. PALMER. LEWIS and STRACZEK (1955) found the ultrabasic rocks of the Sierra de Nipe and the Sierra de Cristal to be older than the "Habana formation" and at least as old as Campanian. This is practically in agreement with KEIJZER's (1945) concept on the age of the serpentinites of this area. WASSALL (1956) studied the extensive serpentinite bodies in Las Villas and Camagüey provinces and concluded that the serpentinite-gabbro mass differentiated from a primary peridotite magma, the serpentine being the lower layer of a serpentine gabbro sequence. The gabbro-peridotite body had originally a horizontal tabular shape and a total thickness of more than 5000 feet and, according to WASSALL, the medium to coarse crystallinity of the gabbro suggests slow cooling. In most areas studied, the serpentinites are overlain by volcanics of Lower Cretaceous or older age and the contacts between serpentinites and the volcanics appear to be fault contacts. Contact metamorphism is lacking. The underlying metamorphics are regarded by WASSALL to be of Upper Jurassic age because of their lithological similarity with dated Upper Jurassic metamorphics of Pinar del Río Province. The primary peridotite magma intruded according to this author along the contact of metamorphics and volcanics in the middle of the Upper Cretaceous post-volcanic and pre-clastic deposition. J. P. BAUGHMAN (private reports) comes to similar conclusions. He finds in the area of Bahía Honda, west of Habana, the serpentinites resting on the Neocomian limestones and overlain by the Cenomanian to Turonian pre-Vía Blanca beds.

BUCHER (1956, pp. 1307, 1308) described the serpentinites of Camagüey and Oriente provinces as large masses like sheets of lava which enclose unaltered blocks of limestone and other rocks. The internal structure is that of "mechanically deformed schists in which the attitude of the planes of schistosity varies unpredictably from one exposure to the next. Such a disordered structure is to be expected in a weak schistose material that spreads over the surface propelled by the flattening of the extruded mass piling up where it is forced out onto the surface from below. This interpretation solves the paradox of serpentine as a metamorphic rock that spreads like lava on the earth's surface. For weak rock bodies which spread under their own weight when forced out onto the surface by orogenic pressure, the writer proposes the term "flow-thrust sheet".

In Jamaica, the serpentinites, probably derived from peridotites, form together with apparently non-fossiliferous metamorphic rocks the basal complex of the Kingston district (MATLEY, 1929, 1951). The age of this series is pre-Mesozoic according to MATLEY, and the metamorphism probably caused by the Hercynian orogeny, and according to ZANS (1953) the age is Cretaceous, possibly Jurassic. MITCHELL (1955) puts the serpentinites between the Senonian and the Neogene. The basal complex is overlain by conglomerates, sandstones and shales of the Cenomanian to Coniacian *Inoceramus* series which correspond age-wise with the Provincial limestones of central Cuba (CHUBB, 1955, 1956) and with the pre-Vía Blanca beds of the Habana area. According to WILLIAMS (1959, p. 11) the Cenomanian to Turonian of the Central Inlier of Jamaica consists from bottom to top of the Basal conglomerate with andesitic and basic igneous pebbles, overlain by brown tuffaceous and calcareous shales of the *Inoceramus* beds, and the Lower Rudist limestone. A gap of Coniacian to probably Santonian age, corresponding to the similar gap in Cuba, separates the Cenomanian to Turonian from the ?Campanian Lower Tuffaceous series consisting of red weathering shales and conglomerates.

The age of the peridotite-serpentines of southwestern Puerto Rico is regarded by MEYERHOFF (1933) as Upper Cretaceous and intrusive into Upper Cretaceous rocks. MITCHELL (1955) placed the Puerto Rico peridotite intrusion in the interval Senonian to Danian, probably Campanian to Maastrichtian. MATTSON (1957, pp. 9–19) described the non-fossiliferous Bermeja complex of the Mayagüez area, southwest Puerto Rico, composed of serpentinized peridotite (serpentinite), silicified volcanics, cherts, spilites, amphibolites and grossularites, to be unconformably overlain by the early Upper Cretaceous Río Loco formation. The Bermeja complex is older than Santonian to Campanian, probably pre-Turonian. This age assignment corresponds with that of the serpentinites of the Habana area. The oldest Upper Cretaceous beds recognized by BERRYHILL, BRIGGS and GLOVER (1959, p. 23) in eastern Puerto Rico are of Turonian age. They overlie massive volcanic rocks whose age has not been determined.

The peridotites and serpentines of Santo Domingo occur in form of elongate masses in the crystalline central massive with the exception of 3 small bodies to the east which are associated with Cretaceous sediments. WEYL (1941, pp. 10–14) regarded the peridotites to be probably of an early Laramide age and the deformation and serpentinization of Laramide age, that is Late Upper Cretaceous. According to BUTTERLIN (1956, p. 107), the age of the rare peridotite occurrences of Haiti is indeterminate, probably Upper Cretaceous, and WOODRING et al. (1924) regarded them as Jurassic or older. One of us (D.R., 1961) has indicated reasons for considering the Cuban ultramafics as being older than any Cuban sediment and having been serpentinized during the late Upper Cretaceous or the early Eocene. The age of the ultramafics is regarded by RIGASSI as pre-Jurassic and probably even pre-Cambrian.

Diorites

There are only two outcrops of diorite near La Habana. A very small exposure occurs south of Guanabacoa, the other much larger is between Peñalver and Arango outside of the mapped area. R. H. PALMER (1934, p. 137, and geological map, text-fig. 1) mentions a small intrusion of serpentine and diorite near the south end of the Bahía de la Habana, west of Río Martín Pérez, which is probably identical with the amphibole diorite of Regla (L. RUTTEN, 1923; SCHÜRMANN, 1935, p. 341, footnote). Diorites are found in many other places in Cuba. They are well developed near Victoria de las Tunas, Oriente Province, and in the northern foothills of the Trinidad-Sancti Spiritus mountains of Central Cuba. These diorites range from gabbro diorite, as for instance at Holguín, Oriente Province, to quartz diorite. Marginal zones are often aplitic. The diorites are often intruding rocks of Upper Cretaceous age. One of the authors (D.R.) observed east of Sancti Spiritus, Las Villas Province, evidence of contact metamorphism in late Senonian sediments. On the other hand, diorite pebbles occur in Maastrichtian beds (="Habana formation" of previous authors), and it appears that the main intrusive phase took place during the late Senonian. It was not possible to ascertain whether or not in the Habana area the diorites intruded into the pre-Vía Blanca and/or the Vía Blanca formation.

Neocomian limestones

About 2 km due west of Santa María del Rosario, a small town in the east of the Habana area, a narrow east–west striking ridge is formed by vertical, strongly fractured and tectonically squeezed beds. The coordinates of a road cut across this ridge are 359.58 N and 369.06 E. The core of the ridge consists of a series of gray thin-bedded Neocomian limestones with black nodular chert. On both sides of this limestone, BR station 1118, there are gray and brown shales, some tuffaceous sandstones and thin beds of lighter colored limestones of Upper Cretaceous age.

From this road cut are the following random samples:

BR station 1118

(1) Lithology: Limestone, hard, dense, fractured, light gray to medium gray, with black nodular chert.
Texture: Cryptocrystalline groundmass with incipient dolomitization. Strongly fractured. Rock-forming *Nannoconus*.

Assemblage: *Nannoconus steinmanni* KAMPTNER (abundant)
Nannoconus globulus BRÖNNIMANN (rare)
Radiolaria (recrystallized)

(2) Lithology: Limestone as above.
Texture: Cryptocrystalline groundmass. Fractured. No *Nannoconus*.
Assemblage: Nondescript remains of planktonic Foraminifera, Radiolaria.

BR station 1119 (shale north of limestone ridge)
Lithology: Shale, soft, non-calcareous, dark yellowish brown, with calcite crusts. Barren.

BR station 1120 (light colored limestone south of the *Nannoconus* limestone)
Lithology: Limestone, hard, dense, fractured, very light gray to yellowish gray.
Texture: Cryptocrystalline groundmass, strongly fractured, with abundant recrystallized planktonic Foraminifera.

Assemblage: *Globotruncana fornicata* PLUMMER
Globotruncana cf. *linneiana* (D'ORBIGNY)
Globotruncana cf. *marginata* (REUSS)
Globotruncana stuarti (DE LAPPARENT)
"*Globigerina*" sp.
"*Globigerinella*" sp.
Heterohelix sp. or *Pseudoguembelina* sp.

This isolated outcrop is the only exposure in the Habana area of Neocomian limestones of the *Nannoconus steinmanni* zone. It is of deep-water facies and typical of the Neocomian limestones throughout Cuba. Its field-relationship with the younger sediments and with the serpentinites to the south are not known. It appears not to be in situ and may be either a slip mass within Vía Blanca beds or a tectonically dislocated mass, for which we did not introduce a new formational unit and name. Similar lithologies with *Nannoconus steinmanni* KAMPTNER were seen by us also in the uplift west of Habana, on the old road from Guanajay to Mariel, where they are likewise associated with Upper Cretaceous limestones and with serpentinites. Another occurrence of reworked Neocomian limestones close to the Habana area is represented by large subangular limestone blocks and pebbles with *Nannoconus steinmanni* KAMPTNER and Neocomian calpionellas in an arkosic conglomerate outcropping in a road cut of the Vía Blanca, 1.9 km northeast of the bridge over the Canasí river in northwestern Matanzas Province. Allochthonous specimens of *Nannoconus* were encountered in younger calcilutaceous sediments suggesting that Neocomian limestones were outcropping elsewhere in or close to the Habana area during the Upper Cretaceous.

The Neocomian limestones must have been deposited before the serpentinites were covered by the Cenomanian (?) to Turonian shales, radiolarites, silicified limestones and graywackes of the pre-Vía Blanca beds. The section described from the north flank of the Regla-Bacuranao uplift may be incomplete, and assuming that the ultramafics form the local basement, Neocomian limestones and perhaps older, possibly Jurassic beds, may still be found resting in structurally low areas on the serpentinites and overlain by the pre-Vía Blanca beds. The stratigraphic and structural problems posed by this singular exposure of Neocomian limestones cannot be solved in the Habana area.

Apart from the dark colored and thin-bedded Cenomanian (?) to Turonian shales of the pre-Vía Blanca series, and perhaps some shales of the Vía Blanca Formation, the Neocomian limestones are believed to be the only petroleum source rocks of the Habana area. The Neocomian limestones are dark-colored, fine-grained sediments of basinal environment to a large extent formed by the remains of planktonic organisms, and provided that reducing conditions prevailed during their deposition they may have generated hydrocarbons. These limestones or paleoecologically similar sediments of Cretaceous and Upper Jurassic age, such as the ammonite-bearing Oxfordian Jagua formation of Pinar del Río Province, are assumed to be the source of the petroleum produced today from the fracture systems of the serpentinite uplifts of northern Cuba, and seeping from the fractures of the Peñalver clastics and of spilitic flow rocks. They are probably also the source for the past submarine seepages which formed the accumulation of asphalt pebbles and the fracture fillings in the Universidad beds and in some of the younger beds (reworking from the Universidad formation ?) of the Marianao group of formations.

Pre-Vía Blanca Beds

Under the rather general term pre-Vía Blanca beds are here included the strata resting apparently unconformably on the serpentinites and which are overlain unconformably by the Vía Blanca formation. The pre-Vía Blanca beds are an heterogeneous group of lithologies consisting of indurated, in part siliceous shales, silicified limestones, radiolarites, opal, graywackes, tuffaceous beds, flow rocks and calcareous beds with serpentinite and other igneous fragments. Additional stratigraphic work needs to be done before one or more formation name(s) can be proposed for this series of lithologies. Fossil evidence suggests that they are, at least in part, of Turonian age. The pre-Vía Blanca graywackes and shales are thin-bedded and alternating and very similar lithologically to those of the younger Vía Blanca formation, so that it is usually not possible to distinguish shales and graywackes of the two units in the field. Moreover, in the Habana area the pre-Vía Blanca beds appear to be a thin unit, generally less than 20 m thick. For these reasons they are not differentiated in the interpretive geological map (plate II) and included in the Vía Blanca formation.

Pre-Vía Blanca beds are poorly exposed along the northern and southern flanks of the Regla-Guanabacoa serpentinite mass. Just east of the plant of the Concretera Nacional, coordinates 366.80 N and 365.34 E, pre-Vía Blanca beds are overlain, apparently unconformably by the Campanian Bahía conglomerate of the basal Vía Blanca formation. At this locality the pre-Vía Blanca graywackes and interbedded radiolarites show distinct slumping features. Silicified limestones occur and basal ophicalcites are well developed above the serpentinites. A questionable lithic tuff was noted. The faunas of the radiolarites and associated graywacke silts are diagnostic of Turonian, based on *Rotalipora* sp. affin to *Rotalipora turonica* (BROTZEN), *Praeglobotruncana* cf. *delrioensis* (PLUMMER) and 2-keeled *Globotruncana* spp. affin to *Globotruncana coronata* BOLLI. These forms were encountered in the stations described below.

BR station 866 and Sisson stations 319 and 320
Lithologies: Shale, silicified, laminated, fractured, medium light gray with olive green crusts. Interbedded with fine-grained graywacke sandstones.
Textures: Siliceous groundmass with abundant well-preserved Radiolaria. Microlamination through rhythmic accumulation of angular igneous grains. Common yellowish to dark brown minute inclusions suggesting organic material (kerogen ?).

Sisson stations 319 and 320, of mainly fine-grained graywacke texture, with radiolaria and planktonic Foraminifera.

Assemblage: Radiolaria
Sponge spicules
Meyenella meyeni DAVIS (as described by RIEDEL, 1953, p. 806, fig. 1)
Globotruncana sp. (2-keeled form affin to *Globotruncana coronata* BOLLI)
Praeglobotruncana cf. *delrioensis* (PLUMMER)
Rotalipora sp. (small form affin to *Rotalipora turonica* BROTZEN)
"*Globigerina*" cf. *subdigitata* CARMAN
Heterohelix sp. (finely striate form).

A better exposed outcrop of pre-Vía Blanca beds occurs in Reparto Muralla, west of the Vía Blanca highway, about 1.4 km northwest of the church of Guanabacoa. The coordinates of the outcrop are 367. 06 N and 364.92 E. At this point, massive highly slickensided and stressed serpentinites with rounded serpentinite "boulders" of up to 1 m diameter at the top of the serpentinite body, are overlain by about 6 m of ophicalcite, a barren, grayish yellow, friable calcareous material with abundant small angular serpentinite elements and larger elongate and rounded serpentinite stringers and inclusions. Sisson station 339 is from this outcrop. Associated with the serpentinite elements are tectonically stressed and fractured conglomeratic blocks of volcanic origin. The fractures of these blocks are filled with the above mentioned grayish yellow calcareous material. Stringers of calcitic material also penetrate into the main serpentinite body. The serpentinite elements are smaller and less common toward the top of the ophicalcite section, which is overlain apparently in normal sedimentary contact by about 1 m of cherty limestones. It is not known whether the ophicalcites represent a zone of weathering of the serpentinites or whether they were formed along a primary serpentinite-limestone contact. In the lower part, the cherty limestones are thin-bedded, broken-up and of rubbly appearance. There also occur interbedded calcareous layers with serpentinite elements. The cherty limestones are more massive in the upper part. The textures of thin sections show clearly that they were originally limestones, which later became fractured and silicified through silica-rich solutions. The cherty beds are followed by thin-bedded indurated and somewhat siliceous shales, graywacke siltstones and radiolarites. The top of these beds is not exposed at the Muralla outcrop. The siliceous shales and radiolarites from Sisson station 343, and BR stations 1355 and 1356 are rich in Radiolaria and *Meyenella meyeni* Davis. The latter exhibit a great variation in length and breadth of arms and in the development of the club-shaped tips. No *Nannoconus*, tintinnids or Foraminifera were found. The lack of diagnostic microfossils is disappointing because the outcrop clearly shows the sequence of beds, which rarely are as well exposed as at this locality. Similar Radiolaria and *Meyenella meyeni* Davis assemblages were also encountered in the first mentioned outcrop east of the plant of the Concretera Nacional and are suggestive of age equivalence of the two radiolarite occurrences.

Glaessner (1952, pp. 83, 84) discussed the genetic problem of the radiolarite zones of the folded belts of the Port Moresby Group, Papua. The depth of deposition is apparently unrelated to the silica enrichment, and there is no evidence that the bulk of the bedded chert of the Port Moresby Group is derived from the siliceous tests of Radiolaria or other siliceous organisms. Glaessner agrees with Davis (1918), who studied the Franciscan radiolarites of California in great detail, that the cherts were produced from solutions coming from pillow lavas and from submarine siliceous springs associated with that particular type of volcanic activity. This interpretation is here accepted to explain the silica-rich beds of the pre-Vía Blanca series. In the Habana area, the chert beds are not known to be accompanied by pillow lavas, but spilitic flows and tuffaceous rocks were observed elsewhere with radiolarites as in Mina Margot, west of Matanzas, and in the area of Bahía Honda, west of Habana (personal communication J. P. Baughman). A variolitic pillow lava occurs on the continuation of the Avenida Monumental about 5.9 km north of its intersection with the Carretera Central. The field relationship of these volcanic beds is not known, but they most probably form part of the pre-Via Blanca beds. One of the authors (D.R., 1961) has emphasized the significance of Upper Cretaceous siliceous solutions in the serpentinization of the Cuban ultramafics as well as in the formation of opal and the silicification of certain sediments.

The following stations described below are from bottom to top of the road cut in Reparto Muralla:

Sisson station 339
Lithology: Calcareous material, friable, grayish yellow, with angular to rounded fragments of serpentine and of conglomeratic igneous rocks. Barren.

BR station 1354 (Silicified limestone upper part)
Lithology: Limestone, siliceous, fractured, hard, medium light gray to pale yellowish brown.
Texture: Recrystallized calcite, interstices and fractures with dark brown substance, larger fractures filled with clear amorphous silica. Secondary silicification. Barren.

Sisson station 340 (Silicified limestone lower part)
Lithology: Limestone, grayish, and silica, brownish, irregularly interlaminated, vacuolar.
Texture: Recrystallized calcite, fractured, and laminated, with amorphous silica in layers and in fractures. Secondary silicification of limestone. Limestone and silica with dark brown substance, probably hydrocarbon, in interstices and along boundaries. Barren.

Sisson station 341 (Graywacke siltstone on top of silicified limestone)
Lithology: Siltstone, non-calcareous, pale yellowish to brown. Barren.

Sisson station 344 (Base of shale-radiolarite section on top of graywacke siltstone).
Lithology; Siltstone, non-calcareous, finely laminated, moderate yellowish brown. Barren.

Sisson stations 342 and 343 (Shale, siltstone and radiolarite)

(1) Lithology: Shale, non-calcareous, moderate to dark yellowish brown and shale, silty, calcareous, grayish yellow. Barren.
(2) Lithology: Radiolarite, bluish gray to medium gray.
Texture: Groundmass silicified, fractured and vacuolar, with dark brown substance, probably hydrocarbon, along fractures and in cavities and in form of globules. Abundant, in part well-preserved Radiolaria.
Assemblage: Radiolaria
Meyenella meyeni DAVIS (very variable forms).

BR station 1355 (Silicified shale)
Lithology: Shale, silicified, olive gray.
Texture: Siliceous groundmass, with recrystallized Radiolaria and with common mainly angular serpentine and other igneous fragments. Dark brown substance, probably hydrocarbon, in form of globules and specks.
Assemblage: Radiolaria.

BR station 1356 (Radiolarite interbedded in graywacke siltstones)
Lithology: Radiolarite, medium gray to medium bluish gray, with greenish yellowish crusts.
Texture: As Sisson station 343. Fractures filled with silica. Interbedded with layers showing fine-grained graywacke texture.

Assemblage: Radiolaria (abundant)
Meyenella meyeni DAVIS (abundant, with very variable shapes)

Another good outcrop of pre-Vía Blanca beds occurs north of Residencial Guanabacoa, coordinates 367.80 N and 370.68 E. The outcrop is about 1 km east of BR station 248, described later in this chapter. The geographic locations of the stations at this outcrop are explained in the index-map, text-fig. 2. The actual contact between the serpentinites and the adjoining sediments was not seen. Ophicalcites seem to be lacking. The pre-Vía Blanca beds, represented by Baughman stations 1482, 1483, 1764 and 1765, consist of thin-bedded siliceous shales, silty shales, radiolarites, and lenticular bodies of lithic tuffs embedded in the siliceous shales. The contact between these beds and the Vía Blanca formation of Baughman stations 1484 and 1486 is covered.

Baughman stations 1482 and 1765 (pre-Vía Blanca beds)
Lithologies: (1) Tuff, light yellowish gray, and
(2) Tuff, laminated, yellowish gray to gray, and
(3) Lithic tuff, greenish to pale yellow brown.
Texture: (1) Siliceous groundmass with abundant glass shards and Radiolaria. Globules of dark brown substance, possibly kerogen.
Assemblage: Radiolaria.
Texture: (2) Siliceous groundmass with abundant Radiolaria and some glass shards and angular igneous grains.
Assemblage: Radiolaria
Heterohelix sp. or *Pseudoguembelina* sp.
Texture: (3) H. H. HESS (letter, February 23, 1959) described this rock as a lithic tuff or possibly a flow breccia. It is composed of fragments largely of glass or decomposed glass with large fresh zoned plagioclases and fresh augites. The plagioclase is optically positive and has indices of refraction considerably higher than balsam so it probably is andesine or labradorite. There are a few pieces of fine-grained feldspar, with almost holocrystalline lava and some that are entirely glassy and vesiculated (pumice). This material is embedded in form of lenticular bodies in the siliceous Radiolaria-bearing beds described under (1) and (2). The sample from Baughman station 1765 is identical with this rock.
Assemblage: Radiolaria.

Baughman station 1483 (pre-Vía Blanca beds)
Lithology: Graywacke sandstone, shaley, non-calcareous, light brown to grayish orange. Barren.
Baughman station 1484 (Vía Blanca formation, Campanian)
Lithology: Graywacke sandstone, fine-grained, calcareous, grayish orange to pale yellowish brown.
Texture: Microcrystalline recrystallized calcite groundmass with rather densely packed angular igneous and limestone grains, fragments of mollusks, echinoderms and algae and some planktonic and benthonic Foraminifera. Diameter of average fragments ranges from about 50 to 250 μ.

Assemblage: *Globotruncana fornicata* PLUMMER
Pseudorbitoides sp. with single set of radial plates
Heterohelix cf. *pulchra* (BROTZEN)
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET.

Baughman station 1485 (Vía Blanca formation, *Rugotruncana gansseri* zone)
Lithology: Graywacke sandstone, calcareous, pale yellowish brown.
Texture: As Baughman station 1484, but unsorted and coarser. Diameters of average components range from about 100 to 3000μ.
Assemblage: *Vaughanina cubensis* D. K. PALMER
Orbitoides palmeri GRAVELL
Sulcoperculina spp.
Orbitocyclina sp.
Asterorbis sp.
Cosinella sp.
Kathina jamaicensis (CUSHMAN and JARVIS)
Coskinolina sp.
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET
Pseudotextularia elegans (RZEHAK)
Globotruncana stuarti (DE LAPPARENT)
Rugotruncana gansseri (BOLLI).

Vaughanina cubensis D. K. PALMER, 1934, is the morphologically most complex pseudorbitoid derived from *Sulcoperculina* THALMANN, 1938. Intermediate forms linking *Sulcoperculina* and *Vaughanina* have not been found. However, the early ontogenetic stages of *Vaughanina* clearly indicate a *Sulcoperculina* ancestor. *V. cubensis* always has been regarded as diagnostic of Maastrichtian (BRÖNNIMANN, 1952) and its frequent occurrence in Tertiary beds was generally believed to be allochthonous. However, we found *V. cubensis* in many old Tertiary samples to the exclusion of the usually associated reworked Upper Cretaceous benthonic Foraminifera such as *Omphalocyclus macroporus* LAMARCK, *Orbitoides palmeri* GRAVELL, *Asterorbis* spp. etc. suggesting an extension of the life range of the pseudorbitoid into the oldest Tertiary.

The ancestors of the bilaterally symmetric *Orbitoides* D'ORBIGNY, 1847, genotype *Orbitolites media* D'ARCHIAC, 1837, appear to be asymmetric *Acervulina*-like forms of great morphologic plasticity (BRÖNNIMANN, 1958, p. 175, 176). *Orbitoides* D'ORBIGNY is not related with *Pseudorbitoides* H. DOUVILLÉ nor with the group of *Orbitocyclina* VAUGHAN–*Lepidorbitoides* SILVESTRI. The latter forms may have evolved from *Pseudorbitoides* (BRÖNNIMANN, 1955).

Baughman station 1486
Lithology: Shale, non-calcareous, moderate yellowish brown. Washed residue with well-preserved Radiolaria.

One of the most impressive exposures of pre-Vía Blanca beds and underlying ultramafics is at the road cut on the continuation of the Avenida Monumental about 2 km southeast of the intersection with the Vía Blanca highway, south-

southeast of coordinates 367.40 N and 369.54 E. The contacts between the sediments and the serpentinized gabbro-peridotite uplift are well exposed, those between pre-Vía Blanca beds and Vía Blanca formation are covered. The pre-Vía Blanca beds consist of graywackes with interbedded bentonitic silty shales, radiolarites and grayish white and greenish yellow tuffs. Of particular interest is the occurrence in some beds of coarser graywackes of scattered quartz grains and of small fragments of serpentinite, the latter again suggesting stratigraphic contact with the serpentinites. As shown in the cross-sections, fig. 1, the structural conditions are extremely complicated and the contacts are tectonically squeezed and slickensided. Nowhere occurs contact metamorphism, an observation which agrees with those of L. RUTTEN (1940, p. 545) on the contacts between Guanabacoa serpentinite and Upper Cretaceous limestones, and of WASSALL (1956) on the contacts between serpentinites and volcanics in Las Villas Province. Also HILL (1958) described the contacts with the serpentinites of the Trinidad Mountains, serpentinized olivine gabbros of unknown age, to appear to be lacking indications of contact metamorphism. At the continuation of the Avenida Monumental, the pre-Vía Blanca beds are intricately associated with igneous rocks. Some of them carry an old Upper Cretaceous, Turonian or slightly older planktonic fauna with "*Globigerina*" *subdigitata* CARMAN, "*Globigerinella*" sp. and "*Globigerina*" sp. The stratigraphic positions of the below described stations are explained in the cross section, fig. 1.

BR station 248
Lithology: Shale, non-calcareous, moderate yellow brown.
Washed residue with

- "*Globigerina*" *subdigitata* CARMAN
- "*Globigerina*" sp. (5 to 6 chambers in the final whorl with finely spinose walls, and 5 to 8 chambered forms with smooth walls)
- "*Globigerinella*" sp. (practically identical with the form illustrated by CARMAN, 1929, p. 34, fig. 6)
- *Rotalipora* sp. or single-keeled *Globotruncana* sp. (casts)
- *Radiolaria* (large and well preserved specimens as described in BR stations 1047 to 1049).

BR station 1042
Lithology: Shale, calcareous, grayish orange.
Washed residue with

- *Globotruncana fornicata* PLUMMER
- *Globotruncana lapparenti* BROTZEN group
- *Globotruncana* cf. *linneiana* (D'ORBIGNY)
- *Globotruncana* cf. *marginata* (REUSS)
- *Globotruncana* cf. *sigali* REICHEL
- "*Globigerina*" sp. (5 to 6 chambered forms with finely spinose walls)
- "*Globigerinella*" cf. *escheri* (KAUFMANN)
- *Pseudoguembelina striata* (EHRENBERG)
- *Pseudoguembelina* cf. *excolata* (CUSHMAN)
- *Heterohelix globulosa* (EHRENBERG)
- Radiolaria.

BR station 1043

The assemblage is closely related to that from BR station 248.
Lithology: Limestone, hard, pale yellow brown.
Texture: Finely microcrystalline groundmass with planktonic microfossils and minute angular igneous grains.
Washed residue with

"*Globigerina*" cf. *subdigitata* CARMAN
"*Globigerina*" sp.
"*Globigerinella*" cf. *escheri* (KAUFMANN)
Heterohelix cf. *globulosa* (EHRENBERG).

BR station 1044
Lithology: Chalk, soft, very pale orange.
Washed residue with

Heterohelix cf. *globulosa* (EHRENBERG)
"*Globigerinella*" cf. *escheri* (KAUFMANN)
Radiolaria.

BR station 1045
Lithology: Limestone, hard, dense, pale greenish yellow (1), and graywacke sandstone, calcareous, pale brown (2).

(1) Texture: Cryptocrystalline argillaceous groundmass with planktonic microfossils.
Assemblage: "*Globigerinella*" *escheri clavata* BRÖNNIMANN
"*Globigerinella*" *escheri clavata* BRÖNNIMANN or "*Globigerina*" *subdigitata* CARMAN
"*Globigerina*" sp. (finely spinose, thin-walled and thick-walled forms)
Globotruncana sp.
Heterohelix cf. *globulosa* (EHRENBERG)
Schackoina sp. (complanate, aspect of chambers affin to *Schackoina cenomana* (SCHACKO))
Tubulospines of *Schackoina* sp.
Radiolaria
Coccoliths.

(2) Texture: Microcrystalline groundmass with densely packed angular to subangular fragments of brown and green igneous rocks and planktonic microfossils.
Assemblage: *Globotruncana* sp.

BR station 1046
Lithology: Tuff, pale greenish yellow.
Texture: Mainly glass shards and igneous grains arranged in layers.
Washed residue with Radiolaria and sponge spicules.

BR stations 1047, 1048 and 1049

The here listed samples are lithologically and faunally very similar and therefore described together.

Lithologies: Shale, non-calcareous, soft, grayish orange (1047), grayish yellow (1948), and silty, light brown (1049).
Washed residues with similar suites of large and well preserved Radiolaria.

BR station 1050
Lithology: Radiolarite, light olive gray.
Texture: Silicified groundmass with abundant Radiolaria. Alignment and shape of Radiolaria show stress.
Assemblage: *Meyenella meyeni* DAVIS
Radiolaria.

As in BR stations 866, 1356, and Sisson stations 319, 320 and 343 from the pre-Vía Blanca beds north of the Regla-Guanabacoa serpentinite body, the radiolarities contain abundant Radiolaria and *Meyenella meyeni* DAVIS.

Although in most instances no clear evidence for a stratigraphic contact of sediments on the serpentinites and associated rocks was found, we suggest that the contacts between the pre-Vía Blanca series and ultramafics were originally sedimentary contacts such as the one described from the road cut at Reparto Muralla, but that because of the later tectonic movements many of the contacts are now of distinctly tectonic aspect. SCHÜRMANN (1935, pp. 347–348) mentioned rolled fragments of serpentine in the transgressive Cretaceous of Habana. In respect to the contacts between sediments and larger serpentine bodies of Matanzas and Habana provinces, SCHÜRMANN noted that it is not always possible to prove that transgression of younger Cretaceous on an older erosional relic should be excluded and that the contacts are of tectonic nature.

DE VLETTER (1946, p. 24) considered the possibility that in Oriente Province "Habana formation" transgressed on the serpentinites. He noticed at the contacts frequently loose and partly rounded fragments of serpentine and gabbroidic rocks, which may belong to a basal conglomerate of the "Habana formation" suggesting a transgressive contact. The contacts however may be simply of tectonic nature, as also at clearly tectonic contacts occasionally loose gabbroidic blocks were observed. VAN RAADSHOVEN (in DE VLETTER, 1946, p. 25) found the serpentinites occasionally so intensely weathered that only blocks of serpentine and gabbro occurred without massive serpentinites suggesting weathering prior to transgressive contacts with the overlying sediments.

Quartz grains in some beds of the pre-Vía Blanca series indicate that quartz-bearing rocks, for instance granitic or gneissic rocks, were also exposed at the time of the pre-Vía Blanca transgression. The Cenomanian (?) to Turonian age of the pre-Vía Blanca beds corresponds closely with that of the "Tuff formation" and interbedded Provincial limestone of central Cuba, which on the basis of cephalopods and rudists is early Upper Cretaceous, probably Cenomanian to Coniacian (IMLAY, 1944, pp. 1011–1013). Lithologically the "Tuff formation" is clearly related with the pre-Vía Blanca beds. CHUBB (1956, pp. 10, 11) tentatively correlated the *Tepeyacia* rudist fauna of the Provincial limestone with *Caprinulinoides perfecta* PALMER, *Coalcomana ramosa* (BOEHM), *Sabinia* sp., *Ichthyosarcolites* sp., and *Tepeyacia corrugata* PALMER with the Cenomanian to Turonian *Inoceramus* series of Jamaica. The sedimentary gap between the pre-Vía Blanca beds and the

Vía Blanca formation can be explained either by non-deposition due to emersion, or by erosion due to submarine currents, or by lack of any sedimentation, or by erosion prior to the deposition of the Vía Blanca formation. The first possibility is regarded as improbable because no evidence for subaerial weathering of the pre-Vía Blanca beds was found, and the last explanation is likewise improbable because there are no components of post-Turonian to pre-Campanian age in the conglomerates of the Via Blanca formation. Non-deposition due to submarine currents is probably the correct explanation. It was previously noted that sediments of Emscherian age were found only at a few scattered outcrops and that the post-Turonian to pre-Campanian sedimentary gap is encountered almost throughout Cuba.

Vía Blanca Formation

Underlying the Peñalver formation and probably transgressive on pre-Campanian strata there is a series of Upper Cretaceous mainly clastic sediments, here called Vía Blanca formation, which shows striking lithologic similarities with the younger clastic formations of the Habana group. The name is derived from the Vía Blanca, the north coast highway connecting Habana with Varadero, which opens up good exposures of the formation along road cuts immediately east of the Bahía de la Habana. The Vía Blanca formation has a wide geographic distribution as it is also known in the area of Bahía Honda about 90 km west of Habana. The Vía Blanca beds are very strongly folded and cut by numerous minor faults and except for a few road cuts poorly exposed. There is no place in the Habana area where a continuous undisturbed section of over 50 m can be measured, and the here described isolated outcrops do not afford more than a tentative grouping of lithologies. The thickness of the formation is estimated at about 500 m. The Vía Blanca formation extends in age from the Campanian *Globotruncana linneiana* zone to the *Rugotruncana gansseri* zone of the Lower Maastrichtian.

The present notes are preliminary and restricted to the description and age evaluation of the different lithologic units here assigned to the Vía Blanca formation. Future work will show whether or not the Vía Blanca formation could be differentiated into two or more lithologic units of formation rank.

The discontinuity of the outcrops and the complicated structure of the beds do not allow the designation of a type section representing all the different lithologies here included in the Vía Blanca formation. For this reason we will describe several discrete outcrops, none of which alone would suffice to define the Vía Blanca formation. However, together they furnish a relatively good understanding of the Vía Blanca lithologies.

Outcrop pattern

The best exposures are along the Vía Blanca highway north and northeast of the town of Guanabacoa, and along the recently constructed road which is the continuation to the southeast of the Avenida Monumental, connecting the Vía Blanca highway and the Carretera Central near Cuatro Caminos. Other fair to good outcrops are in the areas east of Casa Blanca, and southeast of Habana between Santa María del Rosario, El Calvario and the Bahía de la Habana. West of the road from Habana to Calabazar, Vía Blanca beds were observed in a very few outcrops only, such as the greenish and yellowish gray tuffs, brownish tuffaceous Radiolaria-bearing graywacke sandstones, grayish yellow marls and green and brown bentonitic non-calcareous shales at the Plaza de la República, just at the foot of the Martí monument, coordinates 366.56 N and 357.86 E. BR stations 1008 to 1010 are from these beds which are typical of the lower part of the Vía Blanca formation. The fauna from station 1009 is of Campanian age. The texture of the tuff of BR station 1008 is very similar to that outcropping at the foot of Loma Urría described under Baughman stations 1789, coordinates 369.75 N and 366.40 E, and 1488, coordinates 369.64 N and 366.83 E. The geographic location of the latter two samples which are also of Campanian age, is explained in the geological map of the Casa Blanca–Cojímar area (plate III).

BR station 1008
Lithology: Tuff, porous, yellowish gray.
Texture: Glass shards and brownish igneous grains in argillaceous groundmass.
Washed residue with Radiolaria.

BR station 1009 (Campanian)
Lithology: Marl, grayish yellow.
Washed residue with

Globotruncana fornicata PLUMMER
Globotruncana stuarti (DE LAPPARENT)
"*Globigerinella*" *messinae messinae* BRÖNNIMANN
Pseudoguembelina striata (EHRENBERG)
Heterohelix sp. or *Pseudoguembelina* sp.

BR station 1010
Lithology: Shale, non-calcareous, grayish yellow to light brown.
Washed residue with Radiolaria.

Near the Martí monument, coordinates 366.13 N and 357.98 E, occurs also the westernmost extension within the Habana area of the late Maastrichtian Peñalver formation which forms the ridge on which the Palacio de Justicia is situated. Two samples from these late Maastrichtian calcarenites and calcilutites are described below.

BR station 1011 (Peñalver formation)
Lithology: Calcarenite, fine-grained, whitish.
Texture: Fragmental, poorly sorted. Components are angular to rounded fragments of sedimentary rocks, mollusks, echinoderms and benthonic Foraminifera. Rare igneous grains. Diameter of average components ranges from about 50 to 360 μ. Groundmass microcrystalline calcite.
Assemblage: *Sulcoperculina* sp. (strongly trochoid forms)
Vaughanina cubensis D. K. PALMER
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN)
Cuneolina bermúdezi D. K. PALMER
Globotruncana arca (CUSHMAN)
Globotruncana stuarti (DE LAPPARENT).

BR station 1012 (Peñalver formation)
Lithology: Calcilutite, coarse-grained, whitish.
Texture: As BR station 1011, but finer fragmental. Diameter of average components ranges from about 20 to 100 μ.
Assemblage: *Calcisphaerula innominata* BONET
Pithonella ovalis (KAUFMANN)
(These enigmatic forms are here virtually rock-forming).

The restricted areal distribution of the Vía Blanca and Peñalver formations to the west of the Habana area is due to the axial plunge of the structural units of the core of the Habana uplift to the west. The details of the structure of this area will be discussed in the chapter on the tectonics of the Habana area. As mentioned before, both the Vía Blanca and the Peñalver formations are again known farther to the west in the area of Bahía Honda.

Description of lithologic types

The lithologies of the Vía Blanca formation will be described in the following order, first the conglomerates, then the Bacuranao "limestone" intercalation of Campanian age, and finally 2 sets of samples from the typical flysch series. The one is from the Lower Maastrichtian *Rugotruncana gansseri* zone, collected along a road cut of the continuation of the Vía Monumental, and the other of Campanian to Maastrichtian age from the area east of Casa Blanca. Some notes will be added on igneous rocks.

The lithologies distinguished in the Vía Blanca beds are stratigraphically grouped as follows:

Lower Maastrichtian	Shales, Graywackes, Calcilutites, Vía Tunel and Schoolhouse Conglomerates
Campanian	Shales, Graywackes, Bacuranao "limestone", Tuffs, Flows, Bahía and Río Piedras Conglomerates.

Conglomerates of the Vía Blanca formation

The dominant lithologies of the Vía Blanca formation are well-bedded graywacke silts and shales in part bentonitic and usually graded-bedded coarser graywacke sandstones. The base of some of the coarser graywacke layers contains sometimes pebbles of igneous rocks of up to 2 cm in diameter. They also carry frequent "clay" pebbles. There occur further thin beds of very fine-grained clastic white limestone. These beds of an overall brownish occasionally somewhat greenish color are typically exposed along road cuts of the Vía Blanca highway and of the continuation of the Avenida Monumental. Conspicuous lithologic units within these dominant lithologies of the Vía Blanca formation are conglomerates composed either of mainly limestone elements or of mainly igneous elements. Of these conglomerates we have examined the following:

Bahía conglomerate Vía Tunel conglomerate	Both north of the Regla-Guanabacoa serpentinite mass.
Schoolhouse conglomerate Río Piedras conglomerate	Both south of the Regla-Guanabacoa serpentinite mass.

As based on a study of elements and matrix, the Campanian Bahía conglomerate seems to be the oldest conglomerate of the Vía Blanca formation. It is resting on pre-Vía Blanca beds and therefore interpreted as being a basal conglomerate, possibly of local significance, of the Vía Blanca formation. It is probably the oldest part of the Vía Blanca formation. Also of Campanian age, and apparently correlative with the Bahía conglomerate is the Río Piedras conglomerate, south of the Regla-Guanabacoa serpentinites, of which the stratigraphic position is not clearly known. The other two conglomerates, the Vía Tunel and the Schoolhouse conglomerates, are both of Maastrichtian age. These younger conglomerates may possibly cut down on older beds of the Vía Blanca formation or perhaps even on pre-Vía Blanca beds and the serpentinites. This question however can only then be answered when the areal distribution and stratigraphic position of the conglomerates are better known. It was noticed that the conglomerates contain apart from older elements usually also penecontemporaneous pebbles.

Bahía conglomerate

West of Guanabacoa, in the region of coordinates 367.00 N and 365.50 E, on the northern flank of the Regla-Guanabacoa serpentinite mass, there is a well-developed conglomerate, here called Bahía conglomerate, with Campanian and older Upper Cretaceous elements embedded in graywackes of medium to coarse grain size. The name is derived from the Reparto Residencial Bahía, just northwest of the town of Guanabacoa. The matrix samples, as represented by BR station 1353, are usually barren. Rarely they contain a poor Radiolaria assemblage as in Sisson station 236. The components can reach up to 1 m in diameter, but generally they are only 4 to 6 cm in diameter. Most of the elements are from andesitic and diabasic igneous rocks. Some of these were examined by H. H. Hess, Princeton, whose observations are included in the following descriptions of BR station 1351 (components 4, 6, 9, and 10) and Sisson stations 229, 231, and 235.

There occur also components of limestones, graywacke sandstones and siltstones, and radiolarites and some elements of apparently serpentinized peridotite and gabbro. Associated with the conglomeratic beds are thin-bedded reddish to brownish bentonitic shales and grayish whitish tuffs. Similar rocks crop out on the southern flank of this serpentinite uplift in the area of Habana Nueva, about 1 km south-southwest of the above described exposure. At coordinates 366.80 N and 365.34 E, just east of the plant of the Concretera Nacional, the Bahía conglomerate seems to be resting unconformably on the pre-Vía Blanca beds, which in their upper part show graywackes with slumping features reminiscent of those observed at the contact between Peñalver and Vía Blanca formations at the type locality of the Peñalver formation.

Samples from the grayish greenish radiolarites and siliceous shales of BR station 866 and Sisson stations 319 and 320, embedded in the slumped graywackes underlying the Bahía conglomerate, are described under pre-Vía Blanca beds. The age of these radiolarites is Turonian based on the occurrence of *Rotalipora* sp. affin to *Rotalipora turonica* (Brotzen), *Praeglobotruncana* cf. *delrioensis* (Plummer), and of *Globotruncana* sp. affin to *Globotruncana coronata* Bolli.

The following descriptions refer to components of the Bahía conglomerate.

BR station 867 (Probably Cenomanian to Turonian)
Lithology: Limestone, dense, yellowish gray.
Texture: Recrystallized microcrystalline calcite groundmass with glass shards, dark brown and green igneous grains and planktonic microfossils.
Assemblage: "*Globigerina*" sp. (thin-walled and finely spinose forms)
"*Globigerinella*" cf. *escheri* (Kaufmann)
Heterohelix sp.
Radiolaria.

BR station 868 (Campanian)
Lithology: Calcarenite, fine-grained, with igneous influence, very pale orange.
Texture: Microcrystalline calcite groundmass with angular to rounded fragments of mainly sedimentary rocks, mollusks, echinoderms, algae, and Foraminifera. Also dark brown and green igneous grains. Diameter of average components ranges from about 30 to 250 μ.
Assemblage: *Pseudorbitoides* cf. *rutteni* Brönnimann
Pseudorbitoides israelskyi Vaughan and Cole
Pseudorbitoides sp. (with single set of radial plates)
Sulcoperculina sp.
Globotruncana sp.
Heterohelix sp. or *Pseudoguembelina* sp.

BR station 1315A
Lithology: Limestone, fragmental, pale yellowish brown.
Texture: Microcrystalline clear calcite groundmass, with rounded to subangular fragments of sedimentary and igneous rocks, mollusks, echinoderms and algae.
Assemblage: *Quinqueloculina* sp.

BR station 1351
The numbers in parentheses refer to different components.

(1) Lithology: Limestone, dense, hard, pale yellowish brown.
Texture: Recrystallized microcrystalline groundmass with limonitic specks and remains of unidentifiable planktonic microfossils.

(2) Lithology: Limestone, somewhat fragmental, with slight igneous influence, grayish yellow.
Texture: Recrystallized calcite groundmass with dark brown and green angular igneous grains and planktonic microfossils.
Assemblage: Radiolaria
"*Globigerinids*"
Heterohelix sp.

(3) Lithology: Feldspathic lava with marked flow texture. Plagioclase microphenocrysts and plagioclase microlites in a partly glassy groundmass. Also microlites of a ferromagnesian mineral possibly hypersthene but probably amphibole (near parallel extinction slightly pleochroic colorless to green). Magnetite altered to limonite.

(4) Lithology: Lava similar to (3) but more glass, stronger flow structure and smaller phenocrysts.

(5) Lithology: Limestone, dense, yellowish gray.
Texture: Recrystallized calcite groundmass with glass shards and dark brown and green igneous grains and planktonic microfossils.
Assemblage: *Heterohelix* sp.
"*Globigerina*" sp.
Radiolaria.

(6) Lithology: Lava. Glassy rock with pronounced flow banding, plagioclase phenocrysts which are strongly zoned and microphenocrysts of magnetite.

(7) Lithology: Limestone, finely fragmental, slight igneous influence, yellowish gray.
Texture: Recrystallized calcite groundmass with angular brown and green igneous grains and some organic components.
Assemblage: *Robulus* sp.
Heterohelix sp.

(8) Lithology: Limestone, dense, hard, grayish yellow (Cenomanian to Turonian).
Texture: As (1) and discrete angular igneous grains.
Assemblage: *Heterohelix* sp.
"*Globigerina*" sp. (thin-walled and finely spinose forms)
"*Globigerinella*" *escheri* (KAUFMANN) group.

(9) Lithology: Lava. Plagioclase rich. Equidimensional plagioclase phenocrysts and microphenocrysts in a glassy groundmass. A few grains of nearly colorless ferromagnesian minerals (pale green) which have nearly parallel extinction (15°) and large negative optical angle (85°). Needle-like in shape. This is an amphibole. Cross sections of needles also indicate this.

(10) Lithology: Flow breccia or agglomerate. Fragments of glassy lavas and plagioclase crystals veined by quartz and fibrous minerals, possibly zeolites also red brown limonite (?) in veins. Lavas have a few serpentine pseudomorphs after hypersthene or olivine.

(11) Lithology: Limestone, algal, moderate yellowish brown.
Texture: Cryptocrystalline to microcrystalline groundmass with algae, encrusting Foraminifera, and discrete angular mollusk fragments. Also some igneous grains.
Assemblage: *Girvanella*-like forms
Nubecularia sp.
"*Globigerinia*" sp.
Acervulina sp.

BR station 1352
Lithology: Graywacke siltstone, friable, non-calcareous, moderate yellowish brown.
Washed residue with Radiolaria.

Sisson station 229
Lithology: Lava. Largely glass with clear plagioclase microlites and minute iron oxyde specks. A few small plagioclase phenocrysts indices of refraction considerably higher than the balsam used for mounting slide. Marked flow structures.

Sisson station 231
Lithology:

(1) Glomeroporphyritic clusters of plagioclase phenocrysts, cores apparently replaced by calcite. Similar to (3) but less biotite and its place taken by brown hornblende. Obviously a variant of (3).
(2) Fragments of lava in a calcite matrix. Fragments mostly same rock as (1) and (3).
(3) Quartzdacite lava or very shallow intrusive with calcite fracture fillings. Plagioclase and biotite phenocrysts in a groundmass of glass plagioclase microlites and irregular equidimensional quartz grains.

Sisson station 235
Lithology: Calcareous vitric tuff. Colorless glass shards in matrix probably calcite.

The following descriptions are from *matrix samples of the Bahía conglomerate:*

BR station 1353
Lithology: Graywacke sandstone, calcareous, pale yellowish brown. Barren.

Sisson station 236
Lithology: Graywacke sandstone, non-calcareous, light brown.
Washed residue with a few Radiolaria.

Vía Tunel conglomerate

Overturned, steeply northward dipping and about east-southeast striking conglomeratic beds of the late Vía Blanca formation crop out approximately 2.5 km east-northeast of the town of Casa Blanca situated opposite the old part of Habana on the northern coast of the Bahía de la Habana. The approximate coordinates of the best outcrops of this conglomerate, here called Vía Tunel conglomerate from the Reparto Vía Tunel south of Loma Urría, are 369.34 N and 365.35 E (plate III). The matrix of the conglomerate consists mainly of thin-bedded brownish shales, graded-bedded brownish graywacke sands and silts and hard fragmental limestones. The components are mainly fragments and casts of rudists and fragmental limestones. Igneous elements are scarce. The age of the conglomerate is Maastrichtian, but not late Maastrichtian as shown by the absence of *Omphalocyclus macroporus* (LAMARCK). Of particular significance is the common occurrence in some of the fragmental limestone components of *Historbitoides kozaryi* BRÖNNIMANN, a pseudorbitoid which was also found in elements of the Schoolhouse conglomerate outcropping along a road cut of the continuation of the Avenida Monumental, near coordinates 364.84 N and 371.41 E. *H. kozaryi* BRÖNNIMANN is usually accompanied by *Sulcoperculina angulata* BROWN and BRÖNNIMANN. The two conglomerates probably form a single unit, although the igneous elements are much more common in the Schoolhouse conglomerate than in the Vía Tunel conglomerate.

The following samples are from *components of the Vía Tunel conglomerate.* The youngest of these elements is of Lower Maastrichtian age, i.e. penecontemporaneous with the matrix of the conglomerate.

BR station 1374

The numbers in parentheses refer to different elements of the conglomerate.

(1, 2, 5, 6, 10, 11) Lithologies: Limestone, fragmental, grayish orange, usually filling of cavities of rudists (Lower Maastrichtian).

Textures: Fragmental, poorly sorted. Cryptocrystalline argillaceous and vacuolar groundmass usually with abundant densely packed angular fragments of mollusks, algae, echinoderms and encrusting Foraminifera. Diameters of average components from about 50 to 600 μ. Embedded in this fragmental matrix are larger fragments of mollusks and echinoderms of up to 3000 μ maximum diameter.

Assemblage: *Historbitoides kozaryi* Brönnimann
Calcisphaerula innominata Bonet
Pithonella ovalis (Kaufmann)
Acervulina cenomaniana (Seguenza).

(4, 13) Lithologies: Limestone, fragmental, grayish orange (Lower Maastrichtian).

Textures: Fragmental, poorly sorted. Cryptocrystalline argillaceous, in places microcrystalline recrystallized calcite groundmass with densely packed angular fragments of mollusks, echinoderms, algae and benthonic Foraminifera. Diameter of average components from about 60 to 600 μ. Rare larger fragments up to a maximum diameter of about 1000 μ.

Assemblages: *Historbitoides kozaryi* Brönnimann
Sulcoperculina angulata Brown and Brönnimann
Sulcoperculina spp.
Calcisphaerula innominata Bonet.

(12) Lithology: Chalk, indurated, dense, white (Campanian).

Texture: Microcrystalline groundmass with planktonic microfossils.

Assemblage: *Heterohelix* sp. or *Pseudoguembelina* sp. (strongly striate forms)
Globotruncana lapparenti Brotzen group
"*Globigerina*" sp.
Globotruncana stuarti (de Lapparent)
Globotruncana calcarata Cushman.

Baughman station 1762

(1) Lithology: Limestone, fragmental, with igneous influence, grayish orange (Lower Maastrichtian).

Texture: Recrystallized clear calcite groundmass with generally rolled fragments of limestones, mollusks, echinoderms, algae, and benthonic Foraminifera. Abundant pseudorbitoids, many of them coated with dark argillaceous material. Also some rounded igneous grains. Diameters of average components range from about 300 to 1000 μ.

Assemblage: *Orbitoides palmeri* Gravell
Historbitoides kozaryi Brönnimann
Pseudorbitoides cf. *rutteni* Brönnimann (?reworked)
Sulcoperculina spp.
Globotruncana lapparenti Brotzen group
Calcisphaerula innominata Bonet.

(2) Lithology: Limestone, fragmental, dark yellowish orange (Lower Maastrichtian).
Texture: Fragmental. Groundmass microcrystalline calcite, vacuolar. Components mainly planktonic microfossils, fragments of benthonic Foraminifera, algae, echinoderms and mollusks. Some angular brownish igneous grains. Diameter of average components ranges from about 100 to 350 μ.
Assemblage: *Vaughanina cubensis* D. K. PALMER
Pseudorbitoides sp. (with single set of radial plates)
Orbitoides palmeri GRAVELL (fragment)
Sulcoperculina sp.
Heterohelix sp. or *Pseudoguembelina* sp.
Globotruncana lapparenti BROTZEN group
Globotruncana stuarti (DE LAPPARENT)
Globotruncana linneiana (D'ORBIGNY)
Rugoglobigerina rugosa (PLUMMER)
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN)

(3) Lithology: Limestone, fragmental, very pale orange (Lower Maastrichtian).
Texture: Fragmental, poorly sorted. Mainly elongate mollusk fragments, and subangular to rounded fragments of sedimentary rocks, echinoderms and algae. Diameters of average components vary from about 60 to 1200 μ. Groundmass microcrystalline calcite.
Assemblages: *Vaughanina* cf. *cubensis* D. K. PALMER
Sulcoperculina spp.
Calcisphaerula innominata BONET.

(4) Lithology: Limestone, finely fragmental, pale yellowish brown (Campanian or Lower Maastrichtian).
Texture: Fragmental. Microcrystalline calcite groundmass with angular to rounded igneous grains. Large discrete mollusk and echinoderm fragments and common sulcoperculinas. Some planktonic microfossils.
Assemblage: *Sulcoperculina* cf. *dickersoni* (D. K. PALMER)
Sulcoperculina sp.
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN)
Globotruncana lapparenti BROTZEN group.

(5) Lithology: Limestone, fragmental, pale yellowish brown (Campanian or Lower Maastrichtian).
Texture: Fragmental. Microcrystalline calcite groundmass with small angular organic fragments. Diameters of average components range from about 25 to 150 μ. Embedded are isolated large mollusk and echinoderm fragments and sulcoperculinas. No igneous grains.
Assemblage: *Sulcoperculina* sp.
Sulcoperculina cf. *dickersoni* (D. K. PALMER)
Globotruncana lapparenti BROTZEN group
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

(6) Lithology: Limestone, dense, grayish orange (Campanian or Lower Maastrichtian).
Texture: Coral. Cavities filled with microcrystalline groundmass.
Assemblage: *Sulcoperculina* sp.
Globotruncana lapparenti BROTZEN group
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

(10) Lithology: Limestone, dense, very pale orange.
Texture: Microcrystalline calcite groundmass with specks of dark brown material. Barren.

(11) Lithology: Limestone, fragmental, grayish orange (filling of rudist cavity) (Lower Maastrichtian).
Texture: Fragmental, poorly sorted. Microcrystalline calcite groundmass with angular to subrounded fragments of sedimentary rocks, algae, mollusks, encrusting Foraminifera and echinoderms. Some larger Foraminifera. Diameters of average components from about 100 to 1500 μ. No igneous grains.
Assemblage: *Vaughanina cubensis* D. K. PALMER
Orbitoides cf. *palmeri* GRAVELL (small forms)
Sulcoperculina spp.
Placopsilina ex gr. *cenomana* D'ORBIGNY-*longa* TAPPAN.

(12) Lithology: Limestone, fragmental, grayish orange (filling of rudist cavity) (Lower Maastrichtian).
Texture: Fragmental, poorly sorted. Components angular to subrounded fragments of sedimentary rocks, mollusks, echinoderms, algae and benthonic Foraminifera. Diameters of average components range from about 50 to 700 μ. Groundmass microcrystalline calcite. Limonitic stains.
Assemblage: *Vaughanina cubensis* D. K. PALMER
Orbitoides palmeri GRAVELL
Sulcoperculina spp.
Calcisphaerula innominata BONET.

Baughman station 1769 (Lower Maastrichtian)
Lithology: Limestone, fragmental, vacuolar, grayish red.
Texture: Fragmental, poorly sorted. Angular fragments of mollusks, echinoderms, algae and benthonic Foraminifera in calcite groundmass. Interstices and vacuoles filled with black substance. Diameter of average components ranges from about 60 to 1000 μ.
Assemblage: *Vaughanina cubensis* D. K. PALMER
Orbitoides palmeri GRAVELL
Sulcoperculina spp.

Baughman station 1779
The numbers in parentheses refer to different components of the conglomerate.

(1) Lithology: Limestone, fragmental, very pale yellowish brown (Lower Maastrichtian).
Texture: Fragmental, poorly sorted. Microcrystalline calcite groundmass with angular to rounded fragments of mollusks, echinoderms, algae, sedimentary

rocks and benthonic Foraminifera. Diameter of average components ranges from about 90 to 1000 μ.

Assemblage: *Vaughanina cubensis* D. K. PALMER
Orbitoides palmeri GRAVELL
Sulcoperculina spp.
Placopsilina ex gr. *cenomana* D'ORBIGNY-*longa* TAPPAN
Calcisphaerula innominata BONET.

(2) Lithology: Limestone, fragmental, calcarenaceous with some igneous influence, dark yellowish orange (Campanian).
Texture: Fragmental, poorly sorted. As (1) but vacuolar, and some igneous grains.
Assemblage: *Sulcoperculina* spp.
Pseudorbitoides sp. (with single set of radial plates).

(3) Lithology: Calcarenite to calcirudite, with large discrete clay inclusions, light gray to yellowish gray.
Texture: Fragmental, unsorted. Same suite of components as in (1) and (2), but diameters of average fragments range from about 100 to 3000 μ.
Assemblage: *Pseudorbitoides* sp. (with single set of radial plates)
Historbitoides kozaryi BRÖNNIMANN
Sulcoperculina spp.

The following stations are from the Lower Maastrichtian *matrix of the Vía Tunel conglomerate.*

BR station 1375
Lithology: Shale, calcareous, pale yellowish brown.
Washed residue with

Globotruncana stuarti (DE LAPPARENT)
Globotruncana cf. *arca* (CUSHMAN)
Rugotruncana cf. *ellisi* BRÖNNIMANN and BROWN
Pseudoguembelina striata (EHRENBERG).

Baughman station 1761
Lithology: Graywacke siltstone, friable, marly, pale yellowish orange.
Washed residue with

Globotruncana arca (CUSHMAN)
Globotruncana contusa (CUSHMAN)
Globotruncana stuarti (DE LAPPARENT)
Planoglobulina glabrata (CUSHMAN)
Pseudotextularia elegans (RZEHAK)
Pseudoguembelina striata (EHRENBERG)
Pseudoguembelina excolata (CUSHMAN)
Sulcoperculina spp.

The following samples are from conglomerates of the Vía Blanca formation outcropping along the continuation of the Avenida Monumental from the Vía Blanca to the Carretera Central.

Schoolhouse conglomerate

A well-developed conglomerate occurs on the continuation of the Avenida Monumental along a cut of about 170 m length near to a point of coordinates 364.84 N and 371.41 E (see photograph of detail, fig. 3). The name of this conglomerate is derived from the rural schoolhouse No. 4 which is situated above the

Fig. 3. Detail view of the Schoolhouse conglomerate. The dark components are igneous rocks, the light colored components usually limestones. Scale 1:32.

eastern flank of the road cut. The matrix of the practically vertical conglomeratic beds consists mainly of brownish medium-grained graywacke sandstones and non-calcareous brownish shales of Maastrichtian age. Some of the beds are bearing almost exclusively well-rounded pebbles of andesitic and diabasic igneous rocks. Other beds carry mostly rudist fragments and subangular to angular boulders of white limestones rich in rudist fragments. The youngest of these boulders are of Maastrichtian age. On the western side of the road cut we observed a large allochthonous whitish limestone block of a volume of several cubic meters.

The following samples are from *components of the Schoolhouse conglomerate:*

BR station 655

The numbers in parentheses refer to different pebbles.

(1) Lithology: Limestone, fragmental, light gray (Campanian).

Texture: Cryptocrystalline to clear calcite groundmass with some grains of brown and green igneous rocks and abundant poorly sorted angular to subangular calcareous components derived from limestones, mollusks, echinoderms and algae (Corallinaceae and Dasycladaceae). Also benthonic and rare planktonic Foraminifera. Diameter of average grains from 150 to 1200 μ.

Assemblage: *Sulcoperculina* spp. (including very large almost planispiral forms with deep sulcus related to *Sulcoperculina dickersoni* (D. K. Palmer))

Meandropsina rutteni D. K. Palmer

Pseudorbitoides cf. *israelskyi* VAUGHAN and COLE
Pseudorbitoides sp. (with single set of radial plates)
Spiroloculina sp.
Calcisphaerula innominata BONET
Radiolaria.

(2) Lithology: Graywacke sandstone, calcareous, pale yellowish brown (Campanian).

Texture: As in (1), but stronger igneous influence and grain size from 100 to 1200 μ. Groundmass clear calcite.

Assemblage: *Sulcoperculina* spp.
Orbitoides sp. (primitive form, usually as rolled and coated fragments)
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET
Spiroloculina sp. (as in (1)).

(3) Lithology: Limestone, fragmental (Lower Maastrichtian).

Texture: Clear calcite groundmass with usually somewhat rolled and coated poorly sorted fragments of limestones, mollusks, echinoderms, algae, and benthonic Foraminifera and with some igneous grains. Common orbitoidal Foraminifera. The diameter of average fragments ranges from about 100 to 1200 μ.

Assemblage: *Orbitoides* cf. *palmeri* GRAVELL
Sulcoperculina sp.
Calcisphaerula innominata BONET
Vaughanina cubensis D. K. PALMER
Spiroloculina sp. (as in (1)).

(4) Lithology: Limestone, fragmental, grayish yellow (Campanian or Lower Maastrichtian).

Texture: Fragmental, unsorted. Cryptocrystalline groundmass with angular organic fragments, mainly algae and mollusks, and rare planktonic Foraminifera.

Assemblage: *Acervulina cenomaniana* (SEGUENZA)
Pseudorbitoides sp. (fragments only)
Globotruncana lapparenti BROTZEN group
Rugoglobigerina rugosa (PLUMMER)
Pseudotextularia elegans (RZEHAK)
Heterohelix sp. or *Pseudoguembelina* sp.
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET.

(5) Lithology: Limestone, fragmental, pale yellowish brown (Lower Maastrichtian).

Texture: As in (4), but groundmass microcrystalline and components smaller, ranging in diameter from about 100 to 350 μ.

Assemblage: *Historbitoides kozaryi* Brönnimann (this species is common in the components from the Vía Tunel conglomerate east of Casa Blanca)
Sulcoperculina angulata Brown and Brönnimann
Orbitoides palmeri Gravell
Vaughanina cubensis D. K. Palmer
Pithonella ovalis (Kaufmann)
Calcisphaerula innominata Bonet.

(6) Lithology: Limestone, fragmental, with large mollusk fragments, yellowish gray (Lower Maastrichtian).
Texture: Finely fragmental groundmass with discrete large rudist fragments.
Assemblage: *Orbitoides palmeri* Gravell (small form)
Vaughanina cubensis D. K. Palmer
Sulcoperculina sp.

(7) Lithology: Graywacke siltstone, calcareous, dark yellowish brown.
Texture: Fragmental. Densely packed angular to rounded fragments mainly of sedimentary and of brown and green igneous rocks. The diameter of average grains varies from about 70 to 350 μ. The matrix is recrystallized clear calcite.
Assemblage: *Globotruncana stuarti* (de Lapparent) group
Radiolaria.

(8) Lithology: Graywacke sandstone, yellowish gray (Maastrichtian).
Texture: As in (7), but poorly sorted, and diameter of average grains from about 300 to 2000 μ. Also some oölites.
Assemblage: *Vaughanina cubensis* D. K. Palmer
Calcisphaerula innominata Bonet.

Sisson station 242
Lithology: Limestone, fragmental, grayish orange (1), and limestone fragmental, with igneous grains, pale brown (2) (Maastrichtian).

(1) Texture: Fragmental, poorly sorted. The components are mainly angular fragments of mollusks in particular rudists, echinoderms and algae. Some orbitoidal Foraminifera were noticed. Diameter of average fragments ranges from about 100 to 300 μ. The matrix is microcrystalline to cryptocrystalline calcite.
Assemblage: *Sulcoperculina* sp.
Vaughanina cubensis D. K. Palmer
Acervulina cf. *cenomaniana* (Seguenza)
Globotruncana lapparenti Brotzen group
Calcisphaerula innominata Bonet
Pithonella ovalis (Kaufmann).

(2) Texture: Fragmental. The components are mainly small angular to rounded organic fragments and dark brown igneous grains. Diameter of average fragments ranges from about 20 to 100 μ. The matrix is microcrystalline. Embedded in the finely fragmental groundmass are isolated sulcoperculinas and larger mollusk and echinoderm fragments.

Assemblage: *Sulcoperculina* sp.
Calcisphaerula innominata BONET (common)
Pithonella ovalis (KAUFMANN) (common).

Sisson station 243
Lithology: Limestone, coralligen and algal, yellowish gray (1), and limestone, fragmental, yellowish gray (2) (Lower Maastrichtian).

(1) Texture: Cryptocrystalline groundmass with corals, encrusting algae and Foraminifera.
Assemblage: *Placopsilina* ex gr. *cenomana* D'ORBIGNY-*longa* TAPPAN.

(2) Texture: As Sisson station 242, but finer grained.
Assemblage: *Historbitoides kozaryi* BRÖNNIMANN
Fragments of orbitoidal Foraminifera
Pithonella ovalis (KAUFMANN).
Calcisphaerula innominata BONET

Sisson station 244
Lithology: Calcarenite to calcirudite, conglomeratic appearance with large clay pebbles, yellow gray (Lower Maastrichtian).
Texture: Fragmental, unsorted. The components are fragments of limestones, igneous rocks, mollusks, echinoderms and algae. Common vaughaninas and sulcoperculinas. The diameter of average components is from about 150 to 2500 μ. The groundmass is microcrystalline, vacuolar.
Assemblage: *Vaughanina cubensis* D. K. PALMER (common)
Orbitoides palmeri GRAVELL
Ctenorbitoides cardwelli BRÖNNIMANN (rare) (?reworked)
Sulcoperculina spp.
Orbitocyclina sp.
Pseudorbitoides sp. (with single set of radial plates) (coated)
Spiroloculina sp. (in fragment)
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

Sisson station 245 (Lower Maastrichtian)
This is from a component embedded as a reworked fragment in the conglomeratic sample described under Sisson station 244.
Lithology: Chalk, friable, powdery, white.
Washed residue with
Globotruncana fornicata PLUMMER
Intermediate forms between *Globotruncana fornicata* PLUMMER and *Globotruncana contusa* CUSHMAN
Globotruncana linneiana (D'ORBIGNY)
Globotruncana stuarti (DE LAPPARENT)
Globotruncana marginata (REUSS)
Pseudotextularia elegans (RZEHAK)
Rugoglobigerina rugosa rugosa (PLUMMER) group
Planoglobulina glabrata (CUSHMAN)

Heterohelix globulosa (Ehrenberg)
Pseudoguembelina striata (Ehrenberg).

The following samples are from the *matrix of the Schoolhouse conglomerate.*

BR station 656
Lithology: Clay, non-calcareous, pale yellowish brown.
Washed residue with a cast of *Heterohelix* sp.

Sisson station 246
Lithology: Clay, non-calcareous, dark yellowish brown, with white calcite inclusions.
Washed residue with

Vaughanina cubensis D. K. Palmer
Sulcoperculina dickersoni (D. K. Palmer)
Sulcoperculina sp.
Cosinella sp.

Río Piedras conglomerate

Conglomeratic beds with igneous and limestone components occur also along cuts on both sides of the continuation of the Avenida Monumental about 220 m south of its intersection with the road to Santa María del Rosario, and about 3.15 km E 8° S of the church of Santa María del Rosario. The outcrops are just south of the Río Piedras quarry of the Atlas Company, from which the name of the conglomerate is derived. The matrix is a graywacke sandstone. The youngest components and the matrix are of Campanian age. Of interest is the occurrence of common Cenomanian to Turonian components. Some of the components from this conglomerate are described below:

BR station 1152

The numbers in parentheses refer to components of the conglomerate.

(1) Lithology: Limestone, fragmental, light gray.
Texture: Fragmental. Subangular to rounded fragments of mollusks, echinoderms and algae embedded in microcrystalline calcite matrix. Some angular dark brown and green igneous grains. Diameter of average components ranges from about 50 to 1500 μ.
Assemblage: *Placopsilina* ex gr. *cenomana* d'Orbigny–*longa* Tappan
Calcisphaerula innominata Bonet.

(2) Lithology: Limestone, laminated, dense, yellowish gray (coccolithite).
Texture: Cryptocrystalline groundmass with abundant planktonic microfossils.
Assemblage: Coccoliths (rock-forming)
Radiolaria
"*Globigerina*" sp. (mainly very thin-walled smooth forms with deep umbilicus)
"*Globigerinella*" sp.

(3) Lithology: Limestone, fragmental, pale yellowish brown.

Texture: As (1), but diameter of average components ranges from about 70 to 600 μ. Matrix microcrystalline calcite.

Assemblage: *Pseudorbitoides* sp. (forms with a single set of radial plates)
Sulcoperculina sp.
Globotruncana lapparenti BROTZEN group
Heterohelix sp.

(4) Lithology: Calcilutite, dense, yellowish gray (coccolithite).
Texture: Argillaceous groundmass with minute angular organic derived fragments and angular igneous grains, ranging in size from about 2 to 20 μ. Manganese dendrites.

Assemblage: Coccoliths (rock-forming)
Radiolaria
"*Globigerina*" sp.

(5) Lithology: Graywacke sandstone, coarse-grained, non-calcareous, yellowish brown.
Texture: Cryptocrystalline to argillaceous groundmass with poorly sorted subangular to rounded igneous grains ranging in size from about 150 to 3500 μ.
Assemblage: Radiolaria
Heterohelix sp.
"*Globigerina*" sp. (as in (2))
Sulcoperculina sp. ?

(6) Lithology: Limestone, hard, dense, medium gray to gray (coccolithite).
Texture: Cryptocrystalline groundmass with subangular to angular igneous grains ranging in size from about 150 to 3500 μ.
Assemblage: Coccoliths (abundant)
Radiolaria
Heterohelix sp.
"*Globigerina*" sp. (thin-walled, smooth forms)
Schackoina cenomana (SCHACKO)
"*Globigerinella*" sp.

(7) Lithology: Limestone, fragmental, laminated, pale yellowish brown.
Texture: Fragmental, sorted, laminated. Components are subangular to rounded fragments of sedimentary and mainly dark green and brown igneous rocks, of mollusks, echinoderms, Foraminifera and algae. Diameter of average components in the fine-grained portion ranges from about 30 to 300 μ, in the coarse-grained portion from about 150 to 3500 μ. Groundmass clear calcite.
Assemblage: *Sulcoperculina* spp.
Pseudorbitoides sp. (with single set of vertical plates)
Heterohelix sp. or *Pseudoguembelina* sp.
"*Globigerina*" sp.
Calcisphaerula innominata BONET

(8) Lithology: Limestone, fragmental, pale yellowish brown.
Texture: Fragmental. Cryptocrystalline to microcrystalline groundmass with common angular to rounded mainly dark brown igneous grains, mollusks and echinoderm fragments. Abundant planktonic microfossils.

Assemblage: Radiolaria
Heterohelix sp. or *Pseudoguembelina* sp.
Globotruncana lapparenti BROTZEN group
"*Globigerina*" spp.

Sisson station 148
Lithology: Graywacke siltstone, non-calcareous, yellowish gray.
Washed residue with
"*Globigerina*" spp. (smooth thin-walled forms)
Radiolaria (common).

Sisson station 150
(1) Lithology: Calcilutite, pale yellowish brown (coccolithite).
Texture: Cryptocrystalline, brownish groundmass with minute angular organic derived fragments and abundant planktonic microfossils.
Assemblage: *Globotruncana* cf. *tricarinata* (QUEREAU)
Globotruncana linneiana (D'ORBIGNY)
Globotruncana cf. *fornicata* PLUMMER
Globotruncana stuarti (DE LAPPARENT)
Globotruncana lapparenti BROTZEN group
"*Globigerinella*" *messinae messinae* BRÖNNIMANN
"*Globigerinella*" *messinae carinata* BRÖNNIMANN
Rugoglobigerina rugosa (PLUMMER) group
Heterohelix sp. or *Pseudoguembelina* sp. (strongly striate forms),
Coccoliths (rock-forming).

(2, 3) Lithologies: Limestone, dense, light gray.
Textures: Cryptocrystalline calcite groundmass with abundant Radiolaria and planktonic Foraminifera.
Assemblage: "*Globigerina*" spp. (mainly thin-walled and finely spinose forms and forms in axial section affin to *Ticinella roberti* (GANDOLFI))
"*Globigerinella*" sp.
Schackoina cf. *jeanneti* REICHEL
Tubulospines of *Schackoina* sp.
Schackoina sp. (with spines and complanate coiling)
Radiolaria (abundant).

Sisson station 202
Lithology: Limestone, silty, pale yellowish to brown.
Texture: As Sisson station 150 (2).
Assemblage: "*Globigerina*" spp. (mainly thin-walled and in part finely spinose forms and forms in axial section affin to *Ticinella roberti* (GANDOLFI))
"*Globigerinella*" sp.
Hastigerinoides cf. *alexanderi* (CUSHMAN)
Tubulospines of *Schackoina* sp.
Radiolaria (abundant).

Sisson station 203
Lithology: Claystone, calcareous, pale brown.

Washed residue with

Globotruncana fornicata Plummer
Globotruncana linneiana (d'Orbigny)
Globotruncana cf. *marginata* (Reuss)
Globotruncana cf. *cretacea* (d'Orbigny)
Globotruncana stuarti (de Lapparent)
Rugoglobigerina rugosa rugosa (Plummer)
Pseudoguembelina excolata (Cushman)
Heterohelix globulosa (Ehrenberg)
Heterohelix pulchra (Brotzen).
"*Globigerina*" spp.
"*Globigerinella*" *messinae messinae* Brönnimann

The following descriptions refer to *matrix samples from the Río Piedras conglomerate*:

Sisson station 149
Lithology: Graywacke sandstone, non-calcareous, yellowish brown. Barren.

Sisson station 201
Lithology: Graywacke siltstone, calcareous, moderate yellowish brown.
Washed residue with

Globotruncana fornicata Plummer
Globotruncana stuarti (de Lapparent)
Globotruncana linneiana (d'Orbigny)
Globotruncana lapparenti Brotzen group
Rugoglobigerina rugosa rugosa (Plummer)
Pseudotextularia elegans (Rzehak)
?*Orbitocyclina minima* H. Douvillé (fragments).

Bacuranao "limestone"

Intercalations in the Vía Blanca graywackes and shales of graded-bedded calcareous clastics with numerous greenish pebble-sized "clay" inclusions in the lower beds are here called Bacuranao "limestone". The name is derived from the town of Bacuranao situated to the north of the main outcrops of the Bacuranao "limestone". The top of these intercalations is generally a very fine calcilutite composed mainly of coccoliths. The overall color is yellowish gray and the maximum thickness measured by us is about 20 m. They are almost identical in lithology with the fine-grained beds of the younger Peñalver formation, and would it not be for the occurrence of the characteristic basal loose calcirudites with conspicuous late Maastrichtian larger Foraminifera ("Lime Gravel" of Palmer), the Peñalver formation and these calcareous clastic intercalations of the Vía Blanca formation could not be distinguished in the field. Their main development is immediately south of the Regla-Guanabacoa uplift. The Bacuranao "limestone" occurs also farther to the east and perhaps could be regarded as a mappable unit. A single outcrop was found north of the Regla-Guanabacoa serpentinite mass near coordinates 368.13 N and 365.89 E, just southeast of the Esso Refinery Belot.

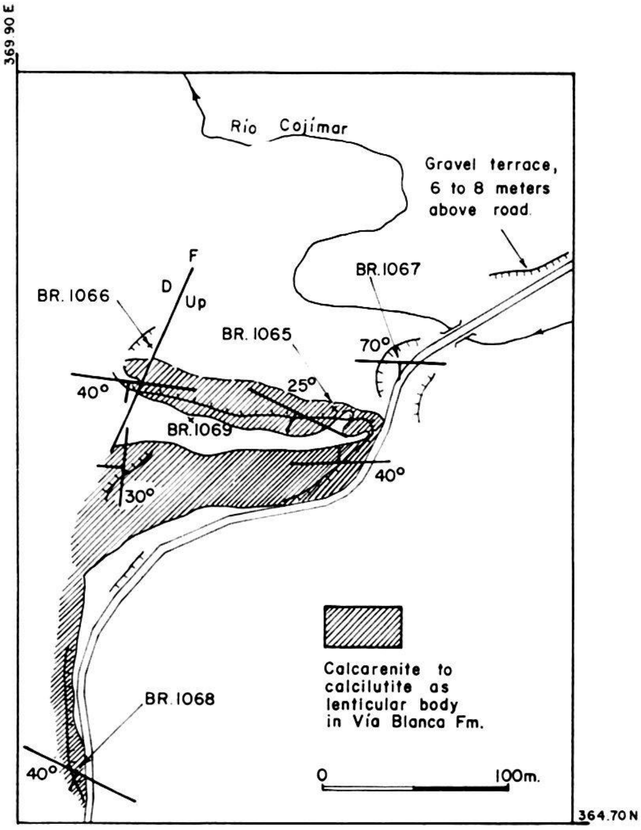


Fig. 4. Index map, Cantera San José.

The Bacuranao "limestone" seems to be enveloped in strongly contorted and squeezed Vía Blanca shales and graywackes. The intercalations are of Campanian age, and represent an earlier and apparently local development of Peñalver type lithology. In our area the intercalations appear to be lenticular as shown by the outcrops in the Cantera San José about 4 km east-southeast of Guanabacoa, coordinates 364.92 N and 370.00 E (see index map and cross sections figs. 4 and 5).

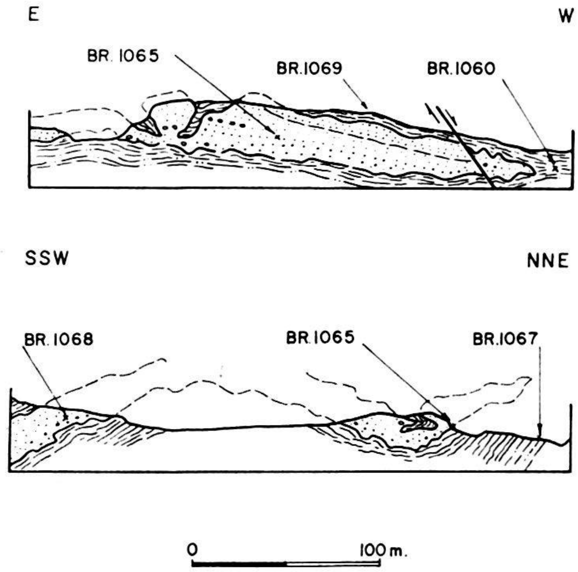


Fig. 5. Cross sections, Cantera San José.

Their lenticular nature is also reflected by the fact that they form discontinuous elliptical ridges, contrasting with the narrow, elongate and more continuous and more prominent crests of the younger Peñalver formation.

Good outcrops to study the calcarenaceous to calcilutaceous bodies are found in several quarries due east of Guanabacoa.

Cantera Río de Piedra

In the Cantera Río de Piedra, not to be confounded with the Cantera Río Piedras, at the continuation of the Avenida Monumental coordinates 366.16 N and 369.46 E, the attitude of the calcarenaceous intercalation cannot be seen, but

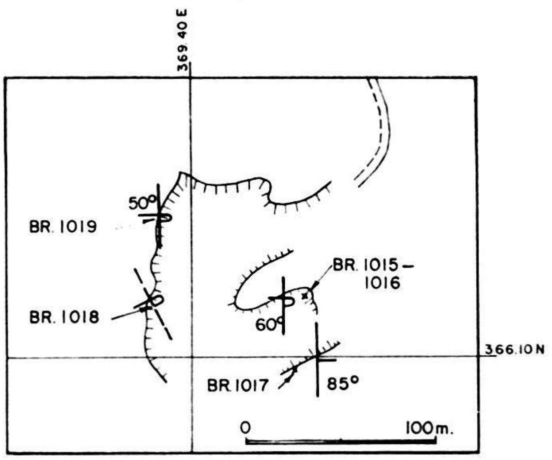


Fig. 6. Index map, Cantera Río de Piedra.

the Bacuranao lithologies are typically developed. The locations of the below described samples are explained in the index map (fig. 6):

BR stations 1015 and 1016

The samples from these stations are almost identical and therefore described together.

Lithology: Calcilutite, fine to coarse-grained, with minor igneous influence, yellowish gray.

Texture: Densely packed angular to rounded fragments derived from dark sediments, tuffs, and brownish to greenish igneous rocks. Also sponge spicules, Radiolaria, Foraminifera and algal fragments. Diameter of average grains from about 20 to 250 μ. Groundmass calcite.

Assemblage: *Globotruncana stuarti* (DE LAPPARENT) group
Heterohelix sp. or *Pseudoguembelina* sp. (striate forms)
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET
Pseudorbitoides sp. (fragment).

BR station 1017

Lithology: Calcilutite, fine-grained, with minor igneous influence, yellowish gray.

Texture: As in BR stations 1015 and 1016, but average grain size from about 5 to 60 μ. Groundmass clear microcrystalline calcite.

Assemblage: *Pithonella ovalis* (KAUFMANN)
Calcisphaerula innominata BONET

BR station 1018
Lithology: Chalk, soft, pale greenish yellow.
Washed residue with rare fragments of ostracodes.

BR station 1019
Lithology: Calcilutite, very fine-grained, with a few igneous grains, yellowish gray (coccolithite).

Texture: As in BR stations 1015 to 1017. Diameter of average grains from about 5 to 50 μ. Groundmass cryptocrystalline argillaceous calcite.

Assemblage: *Heterohelix* sp. or *Pseudoguembelina* sp. (striate forms)
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET
Coccoliths (abundant).

Abandoned quarry at coordinates 366.29 N and 369.40 E

The same lithologies can be seen in a nearby abandoned quarry at coordinates 366.29 N and 369. 40 E.

BR station 1020
Lithology: Calcilutite, coarse-grained, with a few igneous grains, yellowish gray.
Texture: As in BR stations 1015 to 1017, but diameter of average grains from about 60 to 250 μ. Groundmass clear microcrystalline calcite.

Assemblage: *Globotruncana lapparenti* BROTZEN group
Heterohelix sp. or *Pseudoguembelina* sp. (striate forms)
Sulcoperculina sp. (very small form with large umbilical plug)
Pseudorbitoides sp.
Cibicides sp.
Miliolids
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET.

BR station 1021
Lithology: Calcilutite, fine-grained, with a few igneous grains, yellowish gray.
Texture: As in BR stations 1015 to 1017 and 1020. Diameter of average grains from about 10 to 90 μ. Matrix microcrystalline to cryptocrystalline calcite.

Assemblage: *Sulcoperculina* sp.
Pseudorbitoides sp.
Heterohelix sp. or *Pseudoguembelina* sp. (striate forms)
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET

Washed residue with
Sulcoperculina sp. (very small form)
Calcisphaerula innominata BONET.

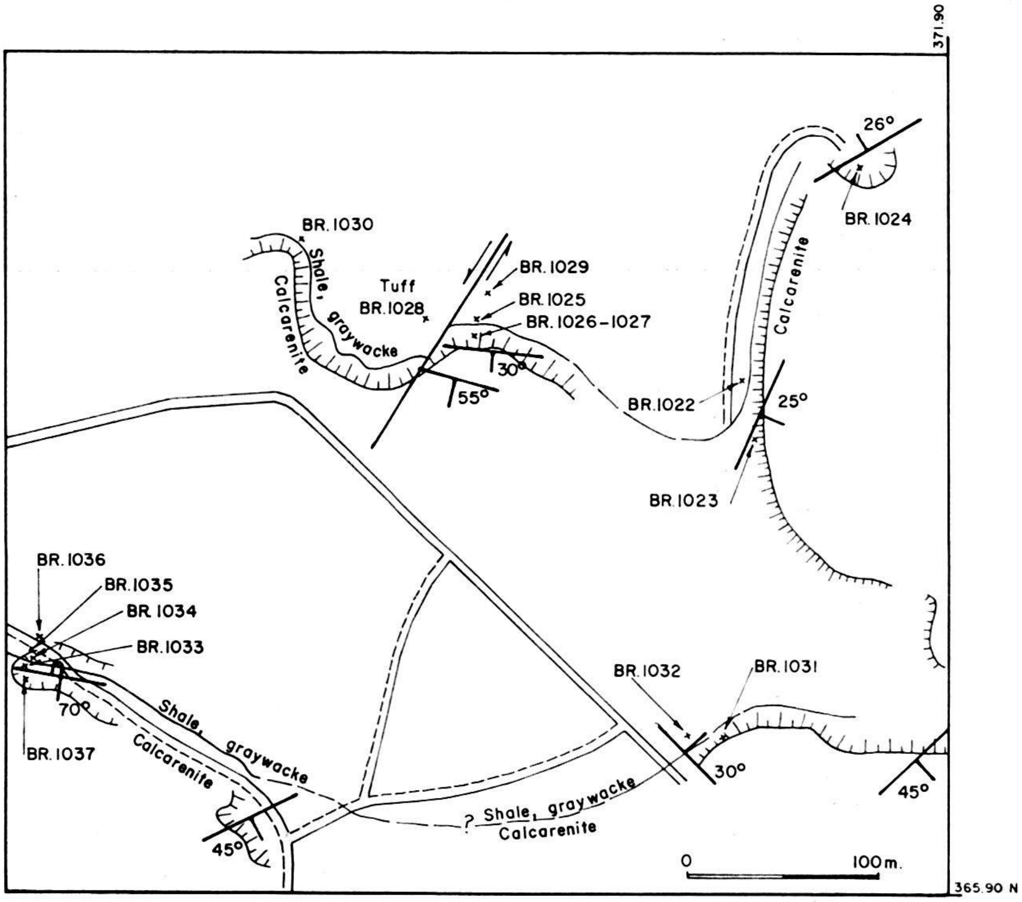


Fig.7. Index map, Cantera Santa María.

Cantera Santa María

In the Cantera Santa María, about 5 km east of Guanabacoa, two ridges of calcareous clastics are exposed (fig. 7). The ridge in the northern part of the quarry, north of grid latitude 366.05, is structurally normal and its contact toward the underlying Vía Blanca graywackes and shales shows submarine slumping. The other ridge in the southern part of the quarry is overturned and the contact toward the stratigraphically overlying graywacke shales and sandstones is well exposed.

BR station 1022

Lithology: Calcilutite, very fine-grained, yellowish gray.

Washed residue with

Heterohelix globulosa (Ehrenberg)
Pseudoguembelina cf. *striata* (Ehrenberg)
Bulimina reussi Morrow
Radiolaria.

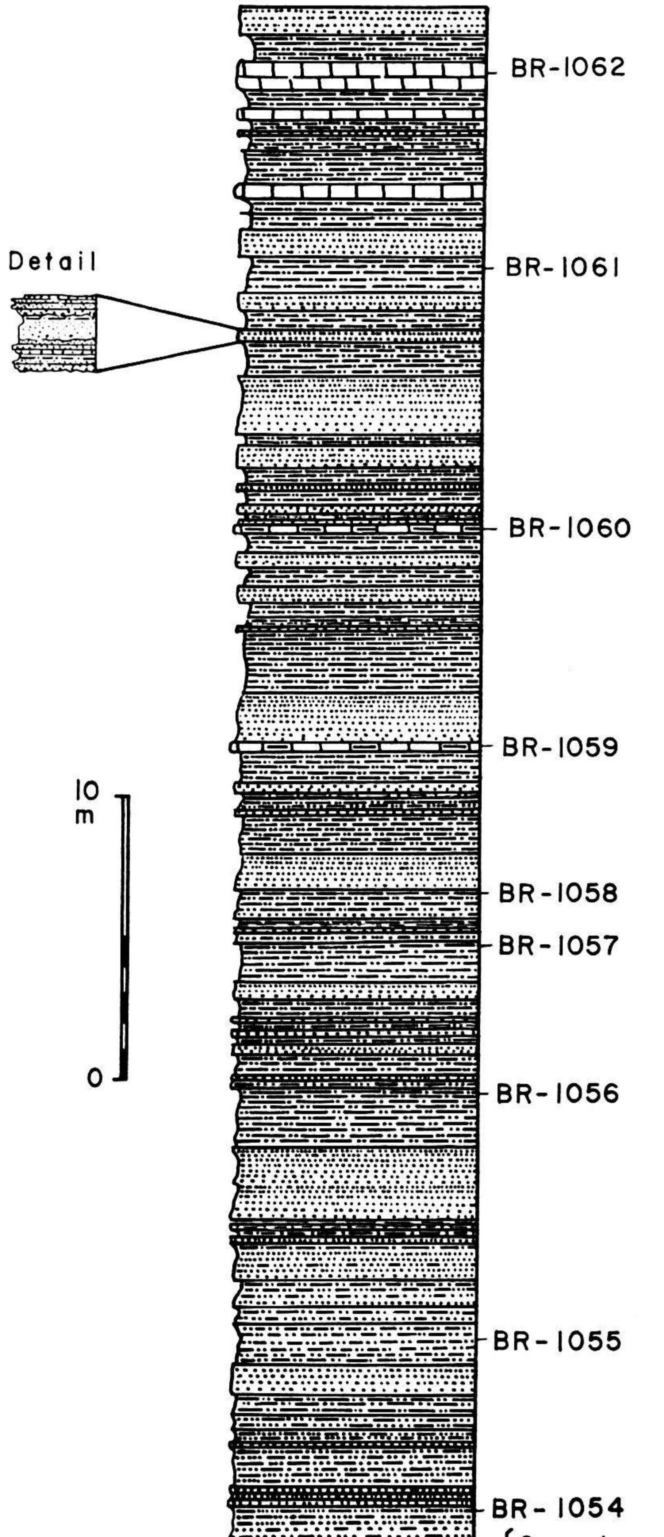
BR station 1023

Lithology: Calcilutite, fine-grained, with a few igneous grains, yellowish gray.

Texture: As in BR station 1021.

Assemblage: *Pithonella ovalis* (KAUFMANN)
Calcisphaerula innominata BONET.

BR stations 1024 and 1025 (Vía Blanca shales)
Lithologies: Shale, calcareous, yellowish gray and yellowish brown.



Washed residue with well-preserved Radiolaria.

BR station 1026
Lithology: Calcarenite, with minor amounts of igneous material, yellowish gray.
Texture: As in BR stations 1015, 1016, but diameter of average grains from about 60 to 750 μ.
Assemblage:
Globotruncana stuarti (DE LAPPARENT) group
Globotruncana lapparenti BROTZEN group
Pseudorbitoides sp.
Sulcoperculina spp.
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET.

BR station 1027
Lithology: Calcarenite, fine-grained, yellowish gray, with large greenish "clay" inclusions. This sample is from the base of a clastic calcareous Bacuranao intercalation in the Vía Blanca formation.
Washed residue with
Globotruncana stuarti (DE LAPPARENT)
Sulcoperculina sp. (small form)
Pseudotextularia elegans (RZEHAK)
Radiolaria.

Fig. 8. Columnar section of the upper part of the Vía Blanca formation, *Rugotruncana gansseri* zone.

BR stations 1028 and 1029

The samples from these stations are practically identical, and therefore described together.

Lithologies: Tuff, very pale orange, laminated.

Textures: Glass shards and argillaceous components densely packed in siliceous groundmass.

Assemblage: Radiolaria
Pithonella ovalis (KAUFMANN).

BR station 1030

Lithology: Shale, non-calcareous, gray brown. Barren.

BR stations 1031, 1033 and 1037

These samples are lithologically and faunally practically identical, and therefore described together.

Lithologies: Calcilutite, very fine-grained, with faint igneous influence, yellowish gray (coccolithite).

Textures: Densely packed angular to subangular fragments derived from organic material and from dark brown and green igneous rocks. Diameter of average components from about 3 to 20 μ. Matrix calcareous, somewhat argillaceous.

Assemblages: Coccoliths (abundant)
Calcisphaerula innominata BONET
fragments of planktonic Foraminifera.

Washed residue with
Radiolaria.

BR station 1032

Lithology: Clay, calcareous, conchoidal breaking, grayish orange, chalk, soft, pale yellowish brown.

Washed residue with
Globotruncana fornicata PLUMMER
Globotruncana stuarti (DE LAPPARENT)
Globotruncana linneiana (D'ORBIGNY)
Globotruncana inornata BOLLI
Heterohelix globulosa (EHRENBERG)
Sulcoperculina sp.
Radiolaria.

Cantera San José

In the Cantera San José, about 4 km east-southeast of Guanabacoa, just north of a point of coordinates 364.70 N and 369.90 E, a lenticular calcarenite interbedded in reddish brownish graywacke silts and shales is exposed along a cliff. As in the Cantera Santa María, the base of the Bacuranao "limestones" exhibits typical submarine slumping while the top shows a disconformity. The geographic location of the below described samples is shown in the index map, and cross sections figs. 4 and 5.

BR stations 1065, 1066 and 1068

These samples are lithologically and faunally very alike and therefore described together.

Lithologies: Calcarenite, fine-grained, with a few igneous grains, pale yellowish gray.

Texture: Densely packed angular to rounded components derived from mollusks, echinoderms, algae, larger Foraminifera, sedimentary and dark brown and green igneous rocks. Also planktonic microfossils. Diameter of average components ranges from about 10 to 300 μ. Groundmass microcrystalline calcite.

Assemblages:
Globotruncana lapparenti BROTZEN
Sulcoperculina spp. (very small forms with strong umbilical plugs)
Pseudorbitoides sp. (with single set of vertical plates)
Rhabdorbitoides hedbergi BRÖNNIMANN
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET.

Sections from the typical lithology of the upper part of the Vía Blanca formation

Continuation of the Avenida Monumental

In the upper part of the Vía Blanca formation, a good section of Lower Maastrichtian age is exposed along the continuation of the Avenida Monumental from a point near coordinates 363.93 N and 371.91 E to about 200 m farther to the southeast. The lithology is of flysch type. Of particular interest is here the occurrence of a few thin beds of coccoliths-bearing very fine-grained white calcilutites which carry chondrites exhibiting an extraordinary range of dimensions. Lithology and stratigraphic position of the samples are explained in the columnar section, fig. 8, and in the cross section, fig. 9. Figure 10 is a photograph of a small part of this section described below in some detail.

A typical yellowish brown graywacke silt and sand bed from above outcrop is about 1.1 m thick, graded, with average grain size of about 150 to 1300 μ at the base and of about 100 to 600 μ at the top. The bottom is sharply defined against dark brown, finely laminated fissile shale and shows on the bottom surface well-defined markings or hieroglyphs, which are the infillings of depressions on the surface of the underlying mud layer at the time of the silt deposition. These depressions were made by organisms and by wave action. Reference is made to the excellent photographs published by WEYL (1953, pp. 88–91) of the tracks of the snail *Rhinocoryne humboldti* (VALENCIENNES), of unidentified worms and of hermite crabs with different gastropod tests on the mud surface of the tidal plains near Rio Lempa, El Salvador. The sharpness of the contact and of the markings suggest that the silt was rapidly laid down on the shale surface. The top contact toward somewhat lighter brown fissile shale is less sharp, and in places one has the impression that it is transitional, suggesting a gradual settling-out of the sediment. At the top surface no hieroglyphic markings but flow structures were observed. The coarse-grained portion of the bed contains many specimens of *Vaughanina cubensis* D. K. PALMER and *Sulcoperculina dickersoni* (D. K. PALMER). These forms occur also but less frequently in the fine-grained top portion of the bed associated with *Rugotruncana gansseri* (Bolli), *Globotruncana arca* (Cushman), *Globotruncana stuarti* (de Lapparent), and *Globotruncanella havanensis* (Voorwijk). The graded graywacke silt bed usually consists of friable material. Occasionally the silt is indurated or contains one or more indurated layers of elongate "nodules" of 15 to 40 cm length and about 8 cm thickness. The nodules are probably of concretionary origin. Other graded graywacke beds exhibit essentially the same features as described above. The thickness of the graded beds ranges from considerably less than a meter to about 2 m. In the thickest of these beds at the described road cut of the continuation of the Avenida Monumental occur 3 layers of "nodular" concretions. Apart from these thicker graded graywackes occur thinner also friable graywacke silt and sand beds, which do not exhibit grading, at least not detectable with the hand lens. A typical ungraded graywacke silt bed is about 4 to 8 cm thick, with sharply defined bottom and top contacts against 2 to 5 cm thick layers of fissile shale. The bottom contacts of some of the thin graywacke beds show concave ripple mark-like structures, which appear to be the infillings of regular depressions on the shale bottom possibly caused by wave action. Typical ripple marks were not seen at this road cut but elsewhere in the Vía Blanca area, and always at the top of sandy-silty layers. Thick pelitic beds are usually less thick than the thick

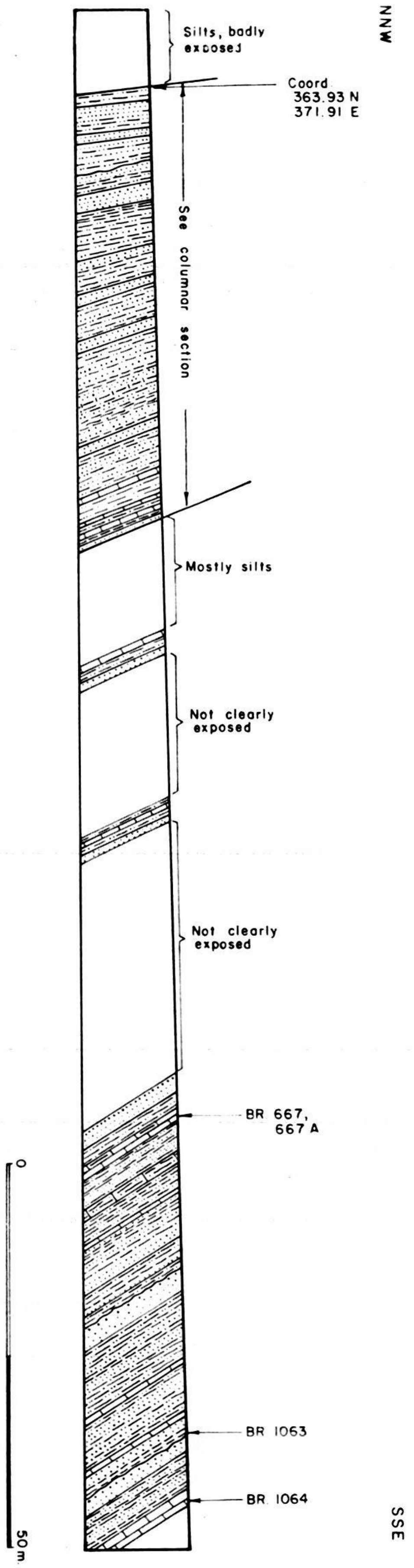


Fig. 9. Road cut at the continuation of the Avenida Monumental, across the upper part of the Vía Blanca formation, *Rugotruncana gansseri* zone.

Fig. 10. View of part of the Vía Blanca beds, *Rugotruncana gansseri* zone, Lower Maastrichtian. Road cut at the continuation of the Avenida Monumental south of a point of coordinates 363.93 N and 371.91 E.

psammitic beds. The thickness of the shale beds ranges from a few centimeters up to about 80 cm. A typical pale yellowish brown calcareous shale bed is about 30 cm thick, with well-defined bottom contact against a 4 cm thick bed of apparently ungraded lighter colored graywacke silt and equally sharp top contact against a 10 cm thick bed of whitish calcilutite (coccolithite), which is again overlain with well-defined contact by 10 cm of graywacke silt. The shales are normally finely laminated, fissile and occasionally they disintegrate into elongate nodular pieces. The calcilutites are whitish, and disintegrate either in form of nodular pieces or in form of very fine laminae. Calcilutites may contain chondrites and other ichnofossils. Some of the thinner beds of calcareous clastics exhibit grading from a fine calcarenite at the bottom with a grain size of about 20 to 180 μ to a calcilutite near the top, which is formed by a calcareous shale with a grain size of a few microns only. The calcilutaceous bed with the best chondrites seen at BR station 667 and 667A is about 1.2 m thick. Minor faults and typical slumping features were noted.

The planktonic assemblages are extremely rich and well preserved. *Rugotruncana gansseri* (Bolli), the diagnostic form of the lower Maastrichtian, occurs in BR stations 1055, 1056, and 1061.

The samples are here listed from bottom to top:

BR station 1054
Lithology: Shale, calcareous, very pale yellowish brown.
Washed residue with

Globotruncanella havanensis (Voorwijk)
Globotruncana mariei Banner and Blow
Globotruncana stuarti (de Lapparent)
Globotruncana cf. *tricarinata* (Quereau)
} very small specimens

"*Globigerinella*" *messinae messinae* BRÖNNIMANN
"*Globigerinella*" *messinae carinata* BRÖNNIMANN
Pseudotextularia elegans (RZEHAK) (forms with and without additional chambers)
Pseudoguembelina excolata (CUSHMAN)
Pseudoguembelina striata (EHRENBERG)
Rugoglobigerina rugosa rugosa (PLUMMER)
Rugoglobigerina macrocephala macrocephala BRÖNNIMANN
Heterohelix carinata CUSHMAN
Heterohelix globulosa (EHRENBERG)
Heterohelix pulchra (BROTZEN)
Schackoina multispinata (CUSHMAN and WICKENDEN).

BR station 1055
Lithology: Shale, calcareous, pale yellowish brown.
Washed residue with

Rugotruncana gansseri (BOLLI)
Globotruncana stuarti (DE LAPPARENT)
Globotruncana tricarinata (QUEREAU)
Globotruncana mariei BANNER and BLOW
Globotruncana arca (CUSHMAN)
Globotruncanella havanensis (VOORWIJK)
Intermediate forms between *Rugoglobigerina rugosa* (PLUMMER) and *Trinitella scotti* BRÖNNIMANN (last chamber slightly compressed, but not yet keeled)
Planoglobulina glabrata (CUSHMAN)
Rugoglobigerina rugosa rugosa (PLUMMER) group
Rugoglobigerina macrocephala macrocephala BRÖNNIMANN
Gublerina ornatissima (CUSHMAN and CHURCH)
Pseudotextularia elegans (RZEHAK) (forms with and without additional chambers)
Pseudoguembelina striata (EHRENBERG)
Pseudoguembelina excolata (CUSHMAN)
"*Globigerinella*" *messinae messinae* BRÖNNIMANN
"*Globigerinella*" *messinae carinata* BRÖNNIMANN
Heterohelix pulchra (BROTZEN)
Heterohelix globulosa (EHRENBERG)
Gublerina acuta robusta DE KLASZ
Heterohelix carinata CUSHMAN

BR station 1056
Lithology: Shale, calcareous, pale, yellowish brown.
Washed residue with

Rugotruncana gansseri (BOLLI)
Rugotruncana cf. *nothi* BRÖNNIMANN and BROWN
Globotruncana cf. *tricarinata* (QUEREAU)
Globotruncana stuarti (DE LAPPARENT)

Globotruncanella havanensis (VOORWIJK)
Globotruncana mariei BANNER and BLOW
Globotruncana arca (CUSHMAN)
Heterohelix globulosa (EHRENBERG)
"*Globigerinella*" *messinae messinae* BRÖNNIMANN
"*Globigerinella*" *messinae carinata* BRÖNNIMANN
Rugoglobigerina rugosa rugosa (PLUMMER) group
Heterohelix pulchra (BROTZEN)
Pseudotextularia elegans (RZEHAK) (forms with and without additional chambers)
Gublerina ornatissima (CUSHMAN and CHURCH)
Planoglobulina glabrata (CUSHMAN)
Pseudoguembelina striata (EHRENBERG)
Pseudoguembelina excolata (CUSHMAN)
Heterohelix carinata (CUSHMAN)
Intermediate forms between *Rugoglobigerina rugosa* (PLUMMER) and *Trinitella scotti* BRÖNNIMANN) (final chamber slightly compressed, but not yet keeled).

BR station 1057
Lithology: Shale, calcareous, nodular weathering, pale yellowish brown.
Washed residue with

Globotruncana mariei BANNER and BLOW
Globotruncanella havanensis (VOORWIJK)
Globotruncana stuarti (DE LAPPARENT)
Globotruncana tricarinata (QUEREAU)
Pseudoguembelina excolata (CUSHMAN)
Rugoglobigerina rugosa rugosa (PLUMMER)
"*Globigerinella*" *messinae messinae* BRÖNNIMANN
"*Globigerinella*" *messinae carinata* BRÖNNIMANN
Heterohelix carinata (CUSHMAN)
Heterohelix pulchra (BROTZEN)
Heterohelix globulosa (EHRENBERG)
Pseudoguembelina striata (EHRENBERG).

BR station 1058
Lithology: Marl, chalky, whitish.
Washed residue with

Pseudoguembelina striata (EHRENBERG)
Globotruncana cf. *mariei* BANNER and BLOW.

BR stations 1059, 1062 and 1064

These samples are lithologically and faunally practically identical and therefore reported together.

Lithologies: Calcilutite, dense, hard, manganese dendrites (1059); calcilutite, dense, hard, light yellowish gray (1062, 1064).

Textures: Cryptocrystalline groundmass with coccoliths in rock-forming quantities and minute angular organic fragments and igneous grains. Similar as texture of Brönnimann stations 667 and 667A.

Assemblages: "*Globigerina*" spp.
Heterohelix sp. or *Pseudoguembelina* sp. (with strong striae)
Pithonella ovalis (KAUFMANN)
Nannoconus steinmanni KAMPTNER } reworked
Nannoconus minutus BRÖNNIMANN } reworked

BR station 1060
Lithology: Calcilutite, grayish orange.
Washed residue with
Pseudoguembelina striata (EHRENBERG)
Globotruncana cf. *arca* CUSHMAN
Globotruncana stuarti (DE LAPPARENT)
Globotruncana mariei BANNER and BLOW
Pseudotextularia elegans (RZEHAK)

BR station 1061
Lithology: Shale, calcareous, nodular weathering, pale yellowish brown.
Washed residue with
"*Globigerinella*" *messinae carinata* BRÖNNIMANN
Rugotruncana gansseri (BOLLI)

BR stations 667 and 667A
Lithologies: Calcilutite, dense, hard, with chondrites, white to yellowish gray (coccolithite).
Textures: Cryptocrystalline groundmass with coccoliths in rock-forming quantities and minute, angular organic and igneous fragments. Limonitic spots. Diameter of average fragment ranges about 3 to 10 μ. With pockets of slightly coarser material.
Assemblage: *Heterohelix* sp. or *Pseudoguembelina* sp. (minute, striate forms)
Fragments of 2-keeled Globotruncanas
Globotruncanella havanensis (VOORWIJK)
Rugoglobigerina rugosa (PLUMMER)
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET

BR station 1063
Lithology: Shale, laminated, calcareous, pale yellowish brown.
Washed residue with
Pseudoguembelina striata (EHRENBERG)
Heterohelix globulosa (EHRENBERG)
"*Globigerina*" spp.

East of Casa Blanca

Another good section across the upper part of the Vía Blanca formation is exposed about 3 to 4 km east of Casa Blanca, in an area defined by grid longitudes 365.00 E and 367.00 E and by grid latitudes 369.00 N and 370.00 N. The geological situation of this traverse is explained in the map of the rim-rock and core area between Casa Blanca and Cojímar (plate III). Vía Blanca and Peñalver formations are here in a tight syncline with west-northwest under the rim-rock plunging axis. The northern flank of this syncline is steeply dipping and overturned. The oldest Vía Blanca beds are to the northeast, where they are overlapped by Alkázar, Universidad and Cojímar beds, and the youngest Vía Blanca beds are at the contact with the late Maastrichtian Peñalver formation which forms the center of the syncline. Construction of the roads of the Reparto Vía Tunel and of the Vía Monumental furnished a series of good artificial outcrops in the Vía Blanca beds. The main lithologies are shales, graded-bedded graywackes and fine-grained calcareous clastics, tuffs and conglomerates. The overall color is light brown. The beds are thin, well-defined and often contorted, probably due to slumping. Small-scale faults are common. In spite of these minor local disturbances, the Vía Blanca section gives the impression to be more or less continuous from the older beds of Campanian age to the northeast to the younger Maastrichtian beds in the southwest. The Vía Tunel conglomerate is from the upper part of this section close to the contact with the Peñalver clastics (BR stations 1374, 1375, Baughman stations 1761, 1762, 1769, 1779). The following succession from older to younger beds is shown: tuffs, tuffaceous non-calcareous shales, graywackes and calcareous shales along the Vía Monumental, and calcareous and non-calcareous shales and calcareous clastics including the Vía Tunel conglomerate toward the Peñalver–Vía Blanca contact. The samples from these Vía Blanca outcrops are described below from bottom to top. The relative stratigraphic position of the stations are indicated in the above mentioned geological detail map of the area between Casa Blanca and Cojímar.

Baughman station 1488
Lithology: Tuff, yellowish gray to pale olive.
Texture: Glass shards and igneous grains in dark argillaceous groundmass.
Assemblage: Radiolaria.

Baughman station 1489
Lithology: Graywacke, slightly calcareous, with large clay inclusions, pale yellowish brown.
Texture: Mainly angular igneous derived fragments in argillaceous groundmass. Some Foraminifera and mollusks remains.

Washed residue with poorly preserved
Heterohelix sp. or *Pseudoguembelina* sp.
"*Globigerina*" spp.
Radiolaria.

Baughman station 1788
Lithology: Shale, non-calcareous, tuffaceous, laminated, light olive gray.
Texture: Argillaceous groundmass with abundant glass shards, angular igneous grains and Radiolaria arranged in microlaminae through sorting of the fragments.
Assemblage: Radiolaria

Baughman station 1789
Lithology: Tuff, porous, pale greenish yellow to grayish yellow.

Texture: Glass shards in argillaceous groundmass. Some dark brown inclusions, probably igneous grains.
Assemblage: Radiolaria (scarce).

Baughman station 1790
Lithology: Shale, tuffaceous, non-calcareous, grayish yellow.
Washed residue with well-preserved Radiolaria.

Baughman station 1791
Lithology: Shale, calcareous, moderate yellowish brown.
Washed residue with

Radiolaria
Sulcoperculina sp.
Pseudorbitoides sp. ?
Reussella szajnochae (GRZYBOWSKY).

Baughman station 1721
Lithology: Shale, non-calcareous, grayish yellow.
Washed residue with

Globotruncana linneiana (D'ORBIGNY)
Globotruncana stuarti (DE LAPPARENT)
Globotruncana fornicata PLUMMER
Radiolaria

Baughman station 1760
Lithology: Shale, tuffaceous, non-calcareous, pale greenish yellow, limonitic weathering.
Washed residue with well-preserved Radiolaria, similar to those of Baughman station 1790.

Baughman station 1723

The samples from this station are components from a conglomerate which may occur at the base of the Cojímar formation or which may be a local development of the Vía Tunel conglomerate.

(1) Lithology: Calcarenite, friable, pale yellowish brown (Campanian).
Washed residue with

Globotruncana fornicata PLUMMER
Globotruncana stuarti (DE LAPPARENT)
Globotruncana linneiana (D'ORBIGNY)
Globotruncana tricarinata (QUEREAU)
Globotruncana cretacea (D'ORBIGNY)
Rugoglobigerina rugosa rugosa (PLUMMER)
Pseudorbitoides israelskyi VAUGHAN and COLE
Pseudorbitoides sp.
Sulcoperculina sp.

(2) Lithology: Limestone, fragmental, very pale orange (Lower Maastrichtian).
Texture: Fragmental, poorly sorted. Fragments of mollusks, echinoderms algae, benthonic Foraminifera and sedimentary rocks in a microcrystalline re-

crystallized calcite groundmass. Diameter of average components ranges from about 50 to 900 μ.

Assemblage: *Orbitoides palmeri* GRAVELL
Vaughanina cubensis D. K. PALMER
Placopsilina ex gr. *cenomana* D'ORBIGNY-*longa* TAPPAN.

Baughman station 1768
Lithology: Calcilutite, with manganese dendrites, grayish orange.
Texture: Cryptocrystalline, minutely fragmental groundmass with planktonic microfossils.

Assemblage: *Heterohelix* sp. or *Pseudoguembelina* sp.
"*Globigerina*" sp.
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN)
Radiolaria.

Baughman station 1724 (Lower Maastrichtian)
Lithology: Calcarenite, with igneous fragments, graded-bedded. The following description is from the coarse part of the bed.
Texture: Fragmental, poorly sorted. Microcrystalline groundmass with angular to rounded fragments of sedimentary and igneous rocks, mollusks, echinoderms, algae and benthonic Foraminifera, in particular pseudorbitoids and orbitoids. Diameter of average fragments ranges from about 100 to 2000μ.

Assemblage: *Vaughanina cubensis* D. K. PALMER
Sulcoperculina cf. *dickersoni* (D. K. PALMER)
Sulcoperculina spp.
Orbitoides palmeri GRAVELL
Asterorbis sp.
Orbitocyclina sp.
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

Baughman station 1727
Lithology: Calcilutite, finely laminated, grayish orange.
Texture: Minutely fragmental. Groundmass argillaceous with angular organic fragments and pseudoöolitic elements probably derived from sedimentary rocks. Also igneous grains. Diameters of average components from about 10 to 60 μ.

Assemblage: *Heterohelix* sp. or *Pseudoguembelina* sp.
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET
Nannoconus steinmanni KAMPTNER } reworked
Nannoconus globulus BRÖNNIMANN } reworked
Nannoconus wassalli BRÖNNIMANN } reworked
Coccoliths.

Baughman station 1726
Lithology: Calcilutite, grayish orange.
Texture: Fragmental, very fine-grained. Same suite of elements as listed in

Baughman station 1725(1). Diameter of average components ranges from about 10 to 100 μ.

Assemblage: *Calcisphaerula innominata* BONET
Pithonella ovalis (KAUFMANN)
Heterohelix sp. or *Pseudoguembelina* sp.

Baughman station 1725

The numbers in parentheses refer to different samples from graded bedded strata.

(1) Lithology: Calcarenite, fine-grained, with igneous grains, pale yellowish brown.

Texture: Fragmental, fine-grained. Groundmass microcrystalline calcite with angular to subrounded fragments of sedimentary and igneous rocks, mollusks, echinoderms, Foraminifera, and algae. Diameter of average fragments from about 30 to 300 μ.

Assemblage: *Vaughanina cubensis* D. K. PALMER
Heterohelix sp. or *Pseudoguembelina* spp.
Globotruncana lapparenti BROTZEN group
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

(2, 3, 4) Lithologies: Calcarenite to calcirudite, pale yellowish brown.

Textures: Fragmental, unsorted. Groundmass microcrystalline calcite, vacuolar, with angular to subrounded fragments of sedimentary rocks, mollusks, echinoderms, algae and benthonic Foraminifera. Discrete large mollusk fragments and larger Foraminifera. Diameter of average components ranges from about 30 to 600 μ. Large inclusions up to 2000 μ diameter.

Assemblages: *Orbitoides palmeri* GRAVELL
Sulcoperculina spp.
Vaughanina cubensis D. K. PALMER
Asterorbis sp. or *Orbitocyclina* sp.
Calcisphaerula innominata BONET.

The following samples of Campanian age appear to be of an intermediate stratigraphic position in respect to above traverse.

Baughman station 1781

Lithology: Limestone, fragmental, hard, pale yellowish brown.

Texture: Fragmental, laminated through sorting. Same suite of components as listed under Baughman station 1779, from about 20 to 60 μ in the fine-grained to about 90 to 450 μ in the coarse-grained portions. Groundmass recrystallized calcite.

Assemblage: "*Globigerina*" spp.
Globotruncana lapparenti BROTZEN group
Pseudorbitoides sp. (with single set of radial plates)
Pithonella ovalis (KAUFMANN)
Sulcoperculina sp.

Baughman stations 1782 and 1783

These samples are lithologically and faunally practically identical and therefore reported together.

Lithologies: Shale, calcareous, with clay inclusions, very pale orange (1782), and shale, calcareous, laminated, pale brown (1783).

Washed residue with

Globotruncana fornicata Plummer
Globotruncana stuarti (de Lapparent)
Globotruncana linneiana (d'Orbigny)
Pseudoguembelina cf. *excolata* (Cushman)
Planoglobulina glabrata (Cushman)
Reussella szajnochae (Grzybowski).

The samples from the Vía Tunel conglomerate were described in the chapter on the conglomerates of the Vía Blanca formation.

The Peñalver beds forming the center of the syncline, are represented by the following random stations:

Baughman station 1772 (Peñalver)
Lithology: Calcarenite, fine-grained, light grayish yellow.
Texture: Fragmental. Groundmass microcrystalline calcite, very porous, with angular to rounded fragments of sedimentary rocks, mollusks, echinoderms and Foraminifera. Some igneous grains. Diameter of average components ranges from about 25 to 150 μ.

Assemblage:
Globotruncana lapparenti Brotzen group
Heterohelix sp. or *Pseudoguembelina* sp.
Vaughanina cubensis D. K. Palmer (fragments)
Calcisphaerula innominata Bonet
Pithonella ovalis (Kaufmann).

Baughman station 1773 (Peñalver)
Lithology: Calcirudite, friable, moderate yellowish brown.
Washed residue with

Rugotruncana mayaroensis (Bolli)
Globotruncana stuarti (de Lapparent)
Globotruncana arca (Cushman)
Rugoglobigerina rugosa rugosa (Plummer)
Vaughanina cubensis D. K. Palmer
Sulcoperculina spp.

Baughman station 1777 (Peñalver)
Lithology: Calcirudite, friable, grayish orange to pale yellowish brown.
Washed residue with

Vaughanina cubensis D. K. Palmer
Omphalocyclus macroporus (Lamarck)
Cosinella sp.
Asterorbis cubensis D. K. Palmer
Sulcoperculina spp.
Radiolaria.

Baughman stations 1730, 1731 (Peñalver)
Lithologies: Calcarenite, pale yellowish brown.

Textures: Fragmental, medium-grained, poorly sorted. Groundmass microcrystalline to cryptocrystalline calcite, vacuolar, with angular to subrounded fragments of sedimentary rocks, mollusks, echinoderms, algae and benthonic microfossils. Some dark brown igneous grains. Diameter of average components ranges from about 60 to 750 μ.

Assemblages: *Vaughanina cubensis* D. K. PALMER
Sulcoperculina spp.
Asterorbis sp.
Asterorbis sp. or *Orbitocyclina* sp.
Orbitocyclina sp.
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

Baughman station 1733 (Peñalver)
Lithology: Calcarenite, fine-grained, grayish orange to pale yellowish brown.
Texture: Fragmental as Baughman stations 1730 and 1731, but finer grained. Diameter of average components ranges from about 30 to 250 μ.

Assemblage: *Vaughanina cubensis* D. K. PALMER
Sulcoperculina spp.
Asterorbis sp. or *Orbitocyclina* sp.
Asterorbis sp.
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

BR station 1136
Lithology: Calcirudite, friable, whitish to grayish yellow.
Washed residue with
Vaughanina cubensis D. K. PALMER
Asterorbis cubensis D. K. PALMER
Asterorbis macei D. K. PALMER
Omphalocyclus macroporus (LAMARCK)
Sulcoperculina cf. *dickersoni* (D. K. PALMER)
Sulcoperculina spp.
Cosinella sp.
Rugotruncana cf. *mayaroensis* (BOLLI)
Globotruncana arca (CUSHMAN)
Globotruncana stuarti (DE LAPPARENT)
Pseudoguembelina striata (EHRENBERG)
Trinitella scotti BRÖNNIMANN
Gublerina ornatissima (CUSHMAN and CHURCH)
Heterohelix globulosa (EHRENBERG)
Pseudotextularia elegans (RZEHAK).

BR station 1137
Lithology: Calcarenite, friable, whitish to yellowish gray.
Washed residue with
Globotruncana arca (CUSHMAN)
Globotruncana stuarti (DE LAPPARENT)

Globotruncana fornicata PLUMMER (reworked?)
Pseudotextularia elegans (RZEHAK) (forms with and without additional chambers)
Planoglobulina glabrata (CUSHMAN)
Pseudoguembelina excolata (CUSHMAN)
Pseudoguembelina striata (EHRENBERG)
Heterohelix globulosa (EHRENBERG)
Gublerina ornatissima (CUSHMAN and CHURCH)
Reussella szajnochae (GRZYBOWSKY)
Rugoglobigerina rugosa rugosa (PLUMMER).

Of special interest is the occurrence of *Rugotruncana mayaroensis* (BOLLI) with *Vaughanina cubensis* D. K. PALMER in the calcirudite of Baughman station 1773, which assigns the Peñalver beds to the late Maastrichtian *Rugotruncana mayaroensis* zone. *Omphalocyclus macroporus* (LAMARCK) was encountered in the nearby BR stations 1136 and 1137, both from the same calcirudite as Baughman station 1773.

Volcanic rocks

Elements of volcanic rocks are common in the conglomerates of the Vía Blanca formation. The following lithologic types were identified by H. H. HESS, Princeton:

Quartzdacite lava or very shallow intrusive
Feldspathic lava with marked flow texture
Flow breccia or agglomerate
Calcareous vitric tuff.

In a few isolated outcrops of the Vía Blanca formation andesitic rocks were found in situ. The most striking of these outcrops forms a geomorphologically prominent hill dominating to the northwest the town of Santa María del Rosario. Similar exposures of volcanic rocks as the one mentioned above are about 2.2 km west-northwest of Santa María del Rosario, coordinates 360.97 N and 369.18 E, and about 0.7 km southeast of Residencial Guanabacoa, coordinates 366.54 N and 371.25 E (BR station 1038). The igneous rocks are usually associated with brownish tuffs, but the relationship with other sediments can rarely be observed.

Environment and age

Representative of the overall lithology of the Vía Blanca formation is the series of graywacke silts and sands, calcareous and non-calcareous benthonitic shales, and finely clastic limestones from the continuation of the Avenida Monumental near coordinates 363.93 N and 371.91 E. Reference is made to the lithologic and faunal descriptions on page 247 to 249 of this paper and to the columnar section, fig.8. Similar lithologies can be found throughout the outcrop area of the Vía Blanca formation, but as a rule not as well-exposed and more disturbed. Bacuranao "limestone" intercalations, tuffs, flows and conglomerates are but local additions to this overall Vía Blanca lithology.

As mentioned before, this thick and monotonous series of sharply divided and relatively thin marine pelitic and psammitic layers reflects flysch sedimentation.

The normal environment of the flysch facies is deep water as indicated by the pelitic layers which carry rich planktonic assemblages suggesting after GRIMSDALE and VAN MORKHOVEN (1955) a depth deeper than 600 m with more than 50 % of the fauna composed of planktonic Foraminifera. According to VON KUENEN (1959, pp. 1020–1021), depths in flysch troughs tend to exceed 200 m and in some cases even surpass 2000 m. The psammitic layers with reefal derived fragments and orbitoidal Foraminifera are regarded as interlopers in a strange environment (SUJKOWSKI, 1957, p. 550). They are interpreted as local accidents probably caused by turbidity currents which interrupted the normal pelitic sedimentation and brought clastic foreign material from an outside source. The monotonous alternation of pelitic and psammitic layers is caused by unstable conditions in the source region of the psammitic material. The great amount of igneous grains in the clastic beds and even in the shaley beds of the Vía Blanca formation suggests that the source region was made up essentially of igneous material. As the entire Cretaceous section to the north of Cuba consists of carbonates, the source of the pyroclastics must have been to the south of the area under description. This interpretation agrees with WOODRING's (1954, pp. 723–725, fig. 1 on p. 724) representation of volcano-bearing lands to the south of Cuba during late Cretaceous times. Along these lands reefs developed which furnished the rich mollusk, especially rudist, algal, orbitoidal and echinoderm assemblages found in the psammitic layers and in the elements of the conglomerates of the flysch sequence.

Volcanic activity was pronounced during early Campanian time as witnessed by tuffs, tuffaceous shales and volcanic flows in the lower part of the Vía Blanca formation. It subsided toward the end of the Vía Blanca sedimentation and may have come to an end already in early Maastrichtian time. Elements from the Bahía, Vía Tunel, Río Piedras and Schoolhouse conglomerates suggest initiating of reefal deposition in Campanian time. As a corollary to the decline of volcanic activity, these reefs became more important as a source for the Vía Blanca clastics in early Maastrichtian time. During the late Maastrichtian Peñalver deposition, shallow shelf material and reefs were the dominant source of the clastics. As will be explained in the description of the Peñalver formation, these late Maastrichtian clastics are in part nothing but a final psammitic bed of the Vía Blanca formation. It was given formation rank for its widespread occurrence, different lithological features and its disconformable contact with the Vía Blanca formation.

The age of the Vía Blanca formation ranges from the Campanian *Globotruncana linneiana* zone to the Lower Maastrichtian *Rugotruncana gansseri* zone. The age of the matrix samples of the Bahía conglomerate, apparently the oldest unit of the Vía Blanca formation as far as can be inferred from the field stratigraphic relationship with the pre-Vía Blanca beds, is inconclusive, and the youngest components are of Campanian age with *Pseudorbitoides israelskyi* VAUGHAN and COLE, and *Pseudorbitoides* cf. *rutteni* BRÖNNIMANN. The conglomerate is therefore of Campanian or slightly younger age. Planktonics of definitely Campanian age with *Globotruncana fornicata* PLUMMER, *Globotruncana linneiana* (D'ORBIGNY) and *Globotruncana stuarti* (DE LAPPARENT) were found in calcareous shales interbedded with tuffs and tuffaceous shales near the Martí monument; east of Casa Blanca, in the Bacuranao "limestone"; in the matrix of the Río Piedras conglomerate; and in components of the Maastrichtian Vía Tunel and Schoolhouse conglomerates. *Rhabdorbitoides hedbergi* BRÖNNIMANN, a pseudorbitoid diagnostic of Campanian, was recorded in the basal calcirudaceous portion of the Bacuranao "limestone". *Pseudorbitoides israelskyi* VAUGHAN and COLE, another diagnostic form of Campanian age, was identified in a calcarenaceous boulder of the Bahía conglomerate associated with *Pseudorbitoides* cf. *rutteni* BRÖNNIMANN and sulcoperculinas; in a fragmental limestone component of the Schoolhouse conglomerate together with sulcoperculinas affin to *S. dickersoni* (D. K. PALMER), and with *Meandropsina rutteni* D. K. PALMER; and in a friable calcarenite from a conglomeratic outcrop east of Casa Blanca with the Campanian *Globotruncana fornicata* PLUMMER, *Globotruncana linneiana* (D'ORBIGNY), *Globotruncana stuarti* (DE LAPPARENT), *Globotruncana tricarinata* (QUEREAU), and *Globotruncana cretacea* (D'ORBIGNY). Other pseudorbitoids with a single set of vertical radial plates, such as *Pseudorbitoides rutteni* BRÖNNIMANN, apparently are also of Campanian age, because fragments of such forms were usually encountered with Campanian, or probable Campanian assemblages, or then reworked in Maastrichtian fragmental limestones. There is no reason at this time, to assume that the oldest Vía Blanca beds are of pre-Campanian age. That the Vía Blanca beds extend into the Lower Maastrichtian is proved by the occurrence of *Rugotruncana gansseri* (BOLLI) in the outcrops along the road cut of the continuation of the Avenida Monumental near coordinates 363.93 N and 371.91 E. This diagnostic form, however, was not found elsewhere in the Vía Blanca beds. But definitely Lower Maastrichtian Vía Blanca beds are also exposed east of Casa Blanca underlying the Peñalver formation with *Vaughanina cubensis* D. K. PALMER, *Omphalocyclus macroporus* (LAMARCK), *Asterorbis macei* D. K. PALMER, *Asterorbis cubensis* D. K. PALMER, *Orbitocyclina* sp., *Cosinella* sp. and a rich planktonic assemblage characterized by *Rugotruncana mayaroensis* (BOLLI), *Globotruncana arca* (CUSHMAN), *Trinitella scotti* BRÖNNIMANN. The underlying Lower Maastrichtian Vía Blanca beds contain *Vaughanina cubensis* D. K. PALMER, *Orbitoides palmeri* GRAVELL, and *Asterorbis* sp. In elements of the Vía Tunel conglomerate, which is from the upper part of the Lower Maastrichtian beds east of Casa Blanca, occur *Historbitoides kozaryi* BRÖNNIMANN, *Sulcoperculina angulata* BROWN and BRÖNNIMANN, *Orbitoides palmeri* GRAVELL and *Vaughanina cubensis* D. K. PALMER. Similar associations were encountered in elements of the likewise Lower Maastrichtian Schoolhouse conglomerate.

Discoasterids apparently do not occur or are extremely scarce in the Vía Blanca formation. Coccoliths, on the other hand, are the rock-forming elements of many of the calcilutites. Specimens of *Nannoconus* were occasionally seen in the very fine-grained lithologies, where they appear to be allochthonous. Megafossils, in particular rudists, were noted in the Vía Tunel and Schoolhouse conglomerates, but no collections have been made and described as yet from these localities or from any other locality of the Vía Blanca formation of the Habana area.

Peñalver Formation

The type locality of the Peñalver formation is situated on the continuation of the Avenida Monumental between the Vía Blanca and the Carretera Central, coordinates 362.85 N and 374.14 E (see location map, fig. 11). The name is derived from the small village of Peñalver about 1 km east of the type locality. The cotype locality of the Peñalver formation is the cut at the Carretera Central 0.5 to 0.8 km southeast of San Francisco de Paula, coordinates 359.56 N and 361.40 E. Part of the road cut is illustrated by fig. 16.

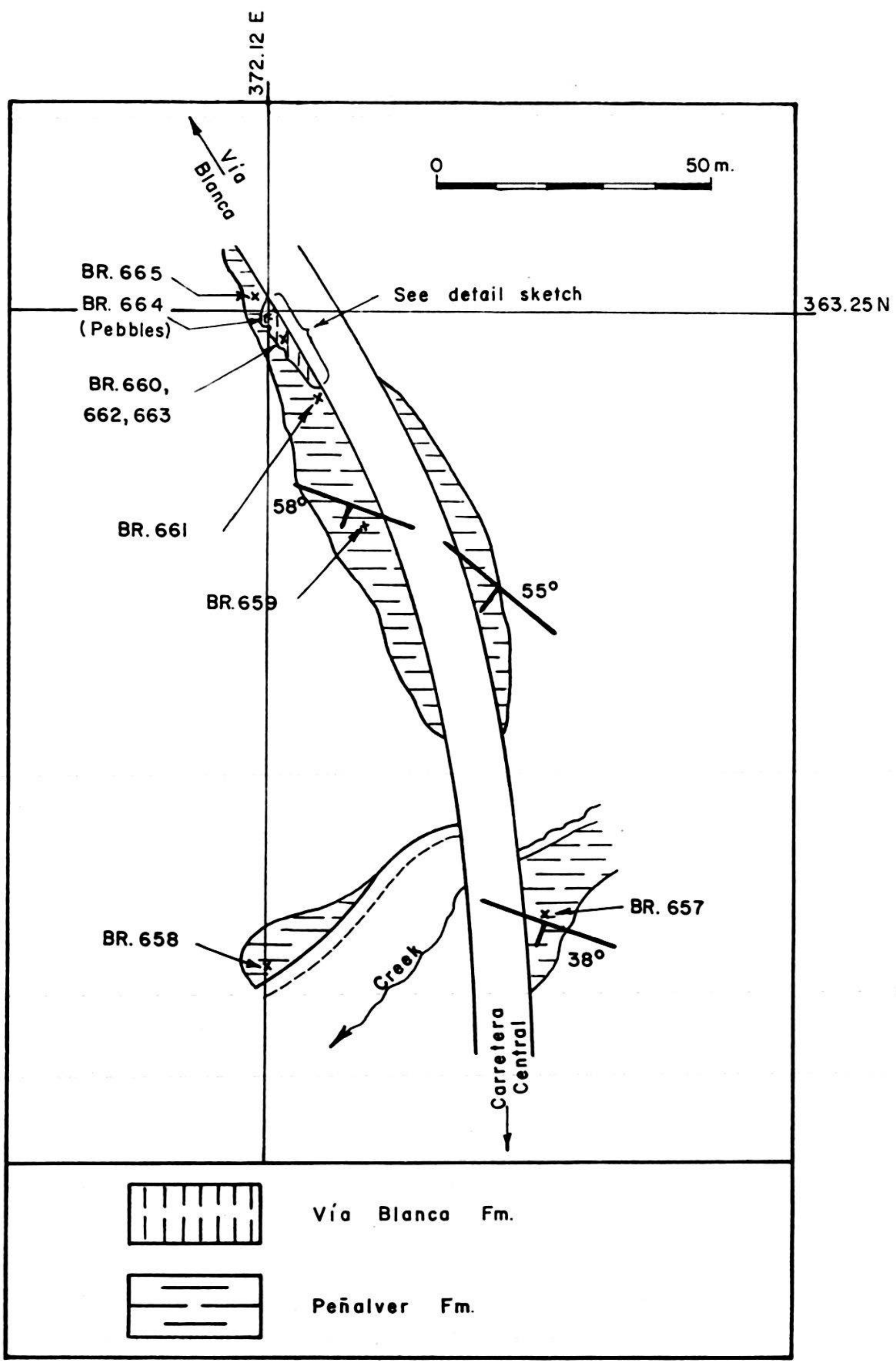


Fig. 11. Index map, type locality of the Peñalver formation.

As shown in the columnar section, fig. 12, the Peñalver formation is at the type locality about 60 m thick. It is composed of graded-bedded clastic material deposited during a single major sedimentary cycle. The basal portion of the Peñalver formation is coarse-grained with discrete larger fragments of about 1 cm, occasionally up to 3 cm in diameter, while the top of the formation consists of a chalky calcilutite, the grains of which can only be seen under the handlens. From base to top of the formation the grain size grades from coarse to fine. Measurements of average grains in thin sections of the type samples as represented by BR stations

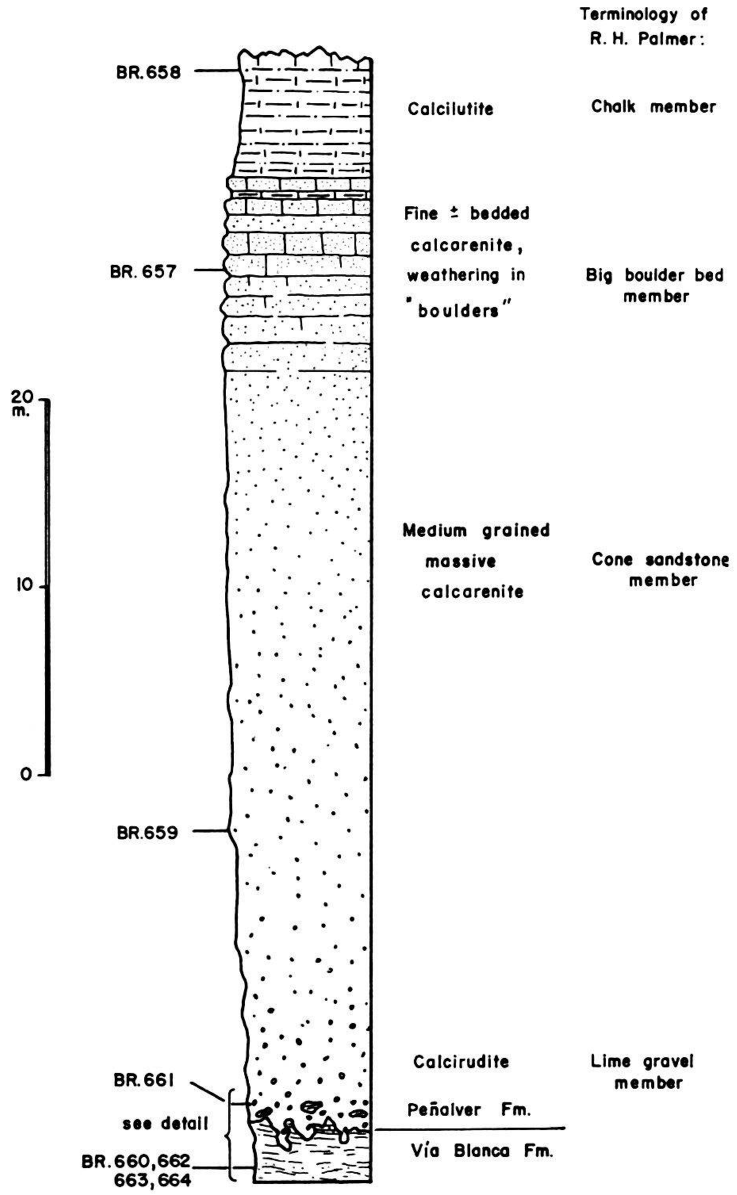


Fig. 12. Columnar section, type locality of the Peñalver formation.

657 to 659 and 661, show the following ranges of dimensions from the bottom to the top of the formation: coarse calcarenite to calcirudite 300 to 1000 μ: calcarenite 100 to 360 μ; 100 to 250 μ; and calcilutite 10 to 60 μ. There is no stratification except in the upper fine-grained calcilutaceous portion of the formation where some faint indications of bedding have been observed. Petrographically, the Peñalver formation is homogeneous throughout with the same suite of components in the coarse and in the fine portions. The elements are rounded to subangular fragments of Upper Cretaceous limestones and megafossils, in particular rudist and

echinoderm fragments, to which in the coarser, calcirudaceous lower portion also Maastrichtian larger Foraminifera are added. Other considerably less frequent components which occur also throughout the formation are fragments of green and dark brown igneous rocks. Angular to subangular dark brown "clay" pebbles or "clay" inclusions showing no or only little traces of transportation, and which are derived from the underlying brownish shales of the Vía Blanca and pre-Vía Blanca beds, and large rounded igneous pebbles are conspicuous elements of the coarser portions of the Peñalver formation. The diameters of the "clay" inclusions range from 20 to 40 cm. Smaller dark colored "clay" pebbles occur irregularly distributed higher in the Peñalver formation, like "small shot", as illustrated by the photograph from the road cut at the Carretera Central south of San Francisco de Paula (fig. 13). Thin sections of the basal calcirudite show angular to subangular fragments of mollusks, echinoderms, calcareous algae, limestones, angular black cherts and green and dark brown igneous rocks, and larger Foraminifera all em-

Fig. 13. Calcirudaceous lower part of the Peñalver formation with "small shot"-like angular to subangular dark "clay" inclusions. Cotype locality of the Peñalver formation at the northeastern side of the road cut of the Carretera Central, southeast of San Francisco de Paula.

bedded in a recrystallized microcrystalline to dark argillaceous groundmass. Thin sections of the chalky calcilutite at the top of the formation exhibit minute angular organic fragments, pseudoölites of dense cryptocrystalline limestones, minute inclusions of dark "clay", and of dark brown and green igneous rocks in an argillaceous to cryptocrystalline groundmass. Coccoliths are abundant in the calcilutites. The sample from BR station 658 could be called a coccolithite.

The overall color of the Peñalver formation is whitish to grayish white when weathered. Fresh outcrops are grayish to bluish. This relatively light color distinguishes in the field the Peñalver formation clearly from both the underlying and overlying brownish shaley and silty beds of the Vía Blanca and Apolo formations. On the other hand its color is very similar to that of the graded-bedded Bacuranao "limestones" intercalated in the lower part of the Vía Blanca formation and also to that of the clastic Lower Eocene Alkázar beds. Geomorphologically, the relatively hard Peñalver clastics form the highest ridges in the area southeast of La Habana.

Because of the lack of cement the lower coarse-grained portion of the formation is not as resistant to weathering as the fine to medium-grained, relatively well-cemented calcarenites of its middle to upper portion. When weathered, the lower portion forms a fine gravel of mostly limey pebbles and of larger Foraminifera, such as the easily recognizable *Omphalocyclus macroporus* (LAMARCK), *Orbitoides palmeri* GRAVELL, *Vaughanina cubensis* PALMER, *Asterorbis* spp. and *Sulcoperculina* spp. As explained in the introductory chapter to the stratigraphy, this fine calcareous gravel corresponds to PALMER's Lime Gravel member, the basal member of his "Habana formation" in its eastern development. In the somewhat harder and more resistant middle part of the formation occur perpendicular to the layering as indicated by the graded-bedding of the calcarenite, elongate cylindrical to

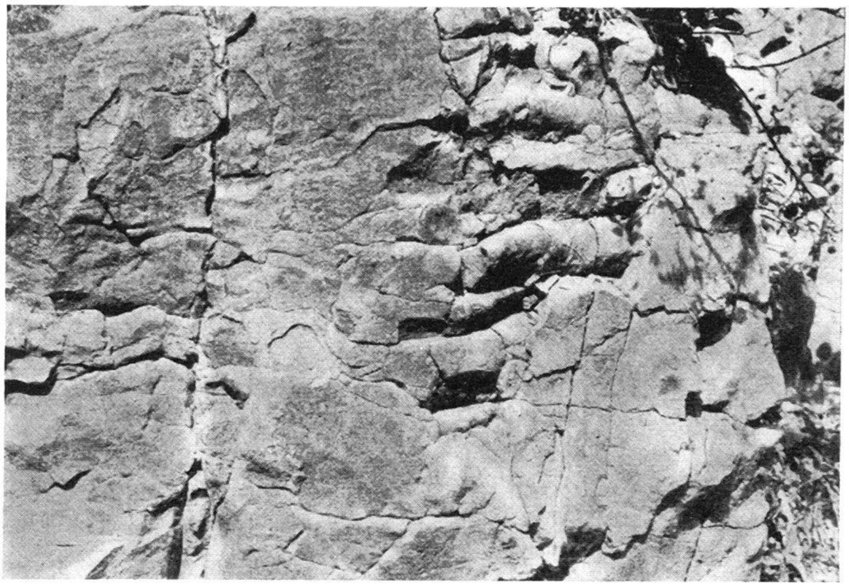


Fig. 14. Calcarenaceous middle part of the Peñalver formation with the elongate cylindrical structures ("cones" of R. H. PALMER). Cotype locality of the Peñalver formation at the southwestern side of the road cut of the Carretera Central, southeast of San Francisco de Paula. The bedding is vertical.

somewhat conical structures. They are illustrated by the photographs from the road cut at the Carretera Central southeast of San Francisco de Paula, the cotype locality of the Peñalver formation, and from the excellent Peñalver outcrop 2.4 km east-southeast of Arango (figs. 14, 15). These characteristic elongate structures may exhibit regular and shallow constrictions and may attain a maximum length of about 60 to 80 cm and a maximum thickness of about 10 cm. It was observed that the elongate structures may split dichotomously (J. P. BAUGHMAN, personal communication). Thin sections across 2 of these elongate calcarenaceous structures, one of 5 cm and the other of 10 cm diameter, collected in the above mentioned large Peñalver exposure 2.4 km east-southeast of Arango, do not show any oriented arrangement of the elements of the calcarenite which is composed of the same suite of fragments as the surrounding calcarenite. In particular, no textural differentiations were observed from the center to the periphery of the structures and there is no indurated shell. No remains of organisms or organic

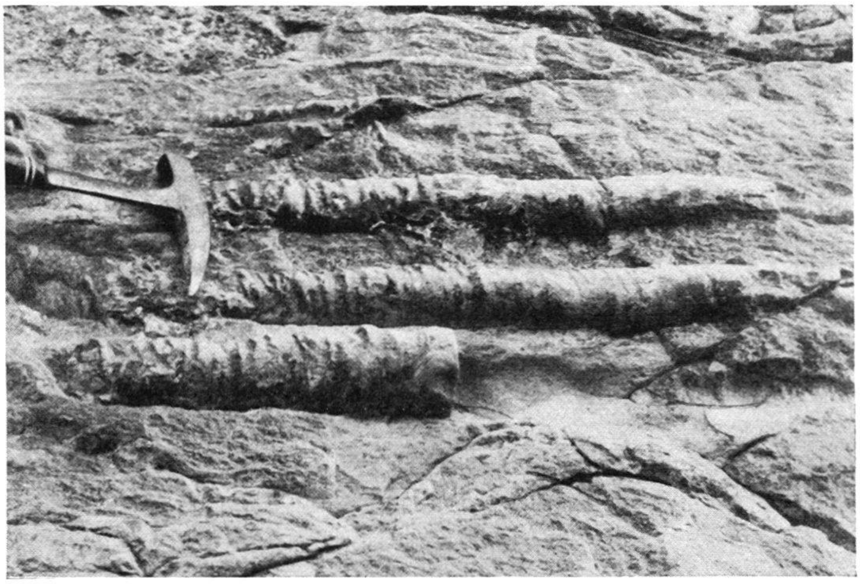


Fig. 15. Elongate cylindrical structures ("cones" of R. H. Palmer) from the middle part of the Peñalver formation at the road from Peñalver to Arango, about 2.4 km east-southeast of Arango. Bedding is vertical as in fig. 14.

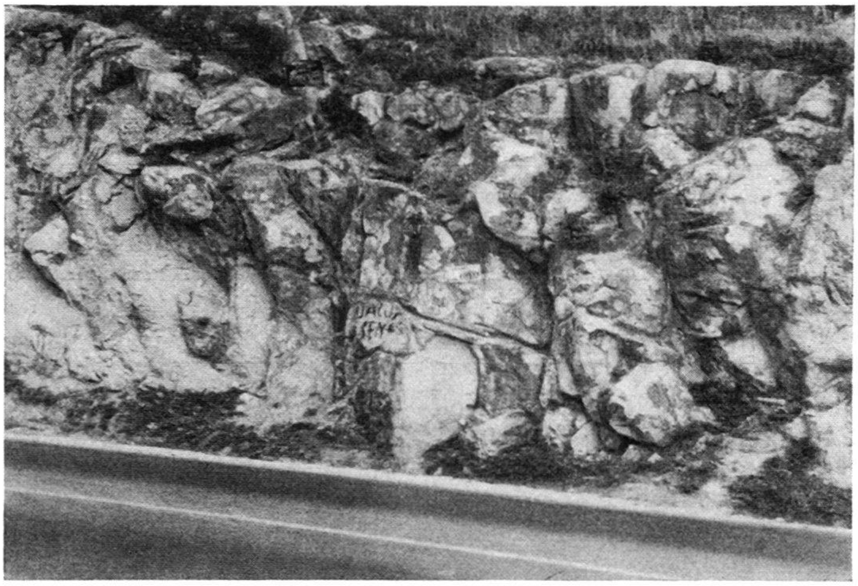


Fig. 16. Calcarenaceous lower middle part of the Peñalver formation with typical exfoliation weathering ("Big Boulders" of R. H. Palmer). Co-type locality of the Peñalver formation at the northeastern side of the road cut of the Carretera Central, southeast of San Francisco de Paula. Dip about 85° to the right (overturned).

material was found, and it appears that they are of anorganic origin. Interesting comments regarding the formation of such structures were made by Phoenix (1958, pp. 194–196), who described larger but similar cylindrical to cone-shaped and locally somewhat sinuous bodies of sandstone, 4 to 18 feet high and 1 to 6 feet in diameter, in fine-grained fluvial cross-bedded sandstones of the lower unit of the Middle and Late Jurassic Carmel formation, Coconino County, Arizona. These

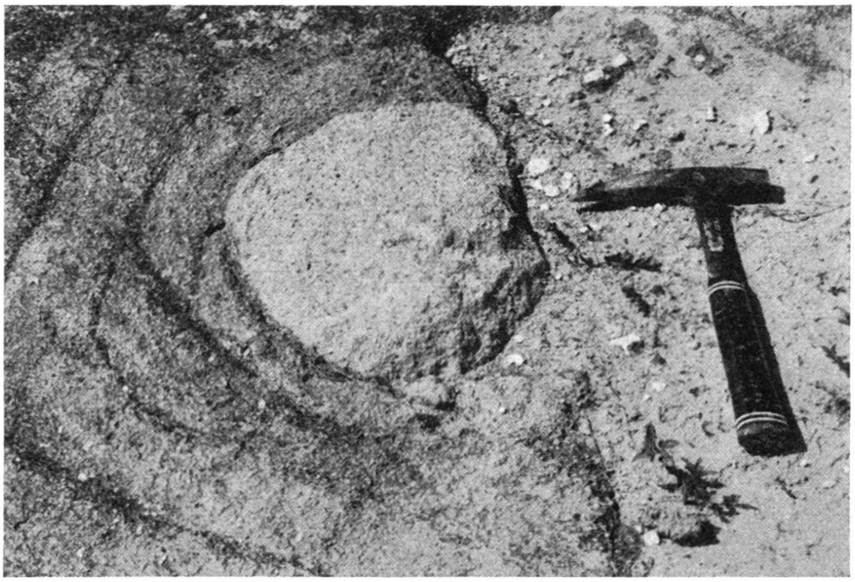


Fig. 17. Exfoliation weathering in the coarse calcarenaceous basal portion of the Peñalver formation on the road from Peñalver to Arango.

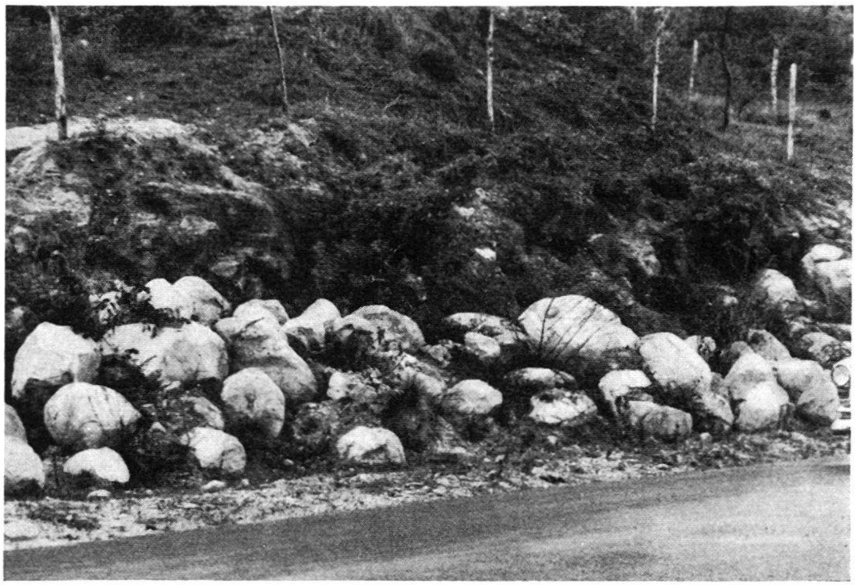


Fig. 18. Accumulation of exfoliation balls from Peñalver calcarenites, south of the type locality of the Peñalver formation on the continuation of the Avenida Monumental.

bodies usually penetrate a stratum of massive medium- to fine-grained sandstone, 10 to 15 feet thick. The sandstone within the cylinders is rarely bedded, but where it is, the bedding is horizontal. The cylinder material is like that in the host sandstone strata, but is less well sorted, and some cylinders are cemented to a greater degree than the surrounding rocks so that they stand in relief. These structures are regarded by PHOENIX to represent loci of release of hydrostatic pressure in the bed at the base of the cylinders. The release of pressure is believed to have been contemporaneous with deposition. The pressure needed to form the cylinders can be attributed partly to the load of overlying sediments and partly to a lateral pressure gradient in the ground water in the bed at the base of the cylinder. ALLEN (1941), who described the sandstone-plugged pipes in the Lower Old Red Sandstone of Shropshire, England, arrived at similar conclusions regarding their formation. Syngenetic formation of the much larger cylindrical structures of the early Paleozoic Potsdam sandstone which contain the same suite of components as the surrounding sediment was also suggested by DIETRICH (1952) and by HAWLEY and HART (1934, pp. 1017–34). Most probably the cylindrical structures from the middle part of the Peñalver formation are the "cones" which gave PALMER the name for the Cone Sandstone member of his "Habana formation". Toward the top of the section, the cylindrical structure-bearing calcarenites grade into harder and finer-grained calcarenites. There occur for the first time in the Peñalver formation indications of true bedding. Here jointing and weak bedding lead to a selective weathering process which in its last stages produces by exfoliation remarkably well-rounded large balls of up to 1 m diameter (figs. 16, 17, 18). A similar exfoliation process is well known from granitic rocks. CARL and AMSTUTZ (1958, pp. 1467, 1468) suggest that periodical exfoliation of the here described type may be caused by diffusion and periodic precipitation in a colloidal matrix of intergranular film as first described by LIESEGANG in 1896.

PALMER called the calcarenite which weathers in this peculiar fashion the Big Boulder Bed member of his "Habana formation". According to this author (1945, p. 12) the "boulders" are in part from conglomerates in the formation and in part from the disintegration of the limestone beds. We, however, did never observe any conglomerates with this size of components in the Peñalver formation, and it is possible that PALMER (1934, p. 131) confounded the exfoliation balls of the Peñalver formation with the large rounded graywacke sandstone concretions occasionally associated with rather coarse conglomerates of the Lower Eocene Capdevila formation. The early stages of the exfoliation process can also be observed in the lower calcirudaceous portion of the Peñalver formation, which however is not hard enough or well enough cemented to peel off in the form of concentric layers and to disintegrate into the well-rounded balls. Good outcrops of this type of weathering can be seen east of Arango and in the garden of Quinta Canaria.

The highest portion of the Peñalver formation is a fine whitish to grayish calcilutite of chalky aspect. It represents the Chalk member of PALMER's "Habana formation" as described by this author from Jacomino, a southeastern suburb of Habana on the Carretera Central to Matanzas. The relatively soft chalky calcilutite is usually not well exposed.

In the columnar section (fig. 12) we have indicated the corresponding PALMER units of the Peñalver formation. Although a lithological zonation into four subordinate units corresponding to the four "members" of PALMER is recognized, we do not believe that it is practical and useful to distinguish in the field for the purpose of mapping these four "members". Moreover, in the Habana area the

Peñalver formation is a relatively thin formation, only 60 m thick at the type locality, and the limits between the lithologic units are rather vague. It should be pointed out, however, that the Peñalver formation thickens toward the east and about 2.4 km east-southeast of Arango, 160 to 180 m of Peñalver formation have been measured (personal communication, J. P. BAUGHMAN). The comparison of our columnar section (fig. 12) with the stratigraphic table PALMER's (1934, table I on p. 125) demonstrates that our observations do not fully agree with those of PALMER. The sequence of PALMER's members differs from that shown in the present paper. PALMER puts the Big Boulder Bed member on top of the Chalk member whereas we mapped throughout the area the fine chalky calcilutite (=PALMER's Chalk member) to be overlying the somewhat coarser calcarenite which weathers by exfoliation.

At the type locality the contact of the Peñalver formation with the underlying Vía Blanca formation is well exposed. Figures 12 and 19 show the contact to be very irregular. The underlying brownish shales and silts are channeled, and the channels are filled with coarse sandy Peñalver material. Large blocks of the Vía Blanca formation have been separated and lie helter-skelter but with undisturbed bedding at the base of the Peñalver formation or are embedded as huge angular inclusions in the coarse basal portions of the Peñalver formation (see photograph,

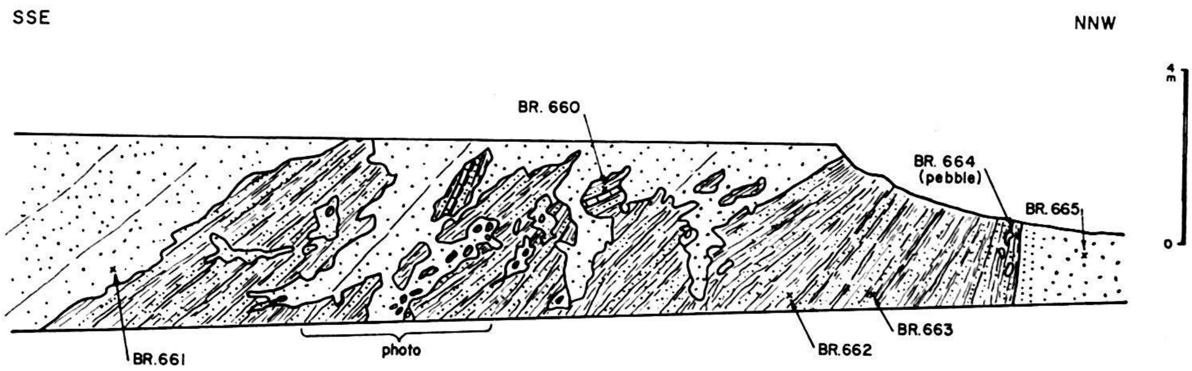


Fig. 19. Detail of the contact Vía Blanca formation (shales and graywackes) and Peñalver formation (calcareous clastics) at the type locality of the Peñalver formation.

fig. 20). This highly irregular contact suggests that the Peñalver formation was deposited as a heavy, sandy, turbid mass of calcareous detritus on top of not too well-consolidated Vía Blanca silts and shales. Conditions of sedimentation which could explain this irregular contact were recently described by HERSEY and RUTSTEIN (1958) from the Oriente Deep, a plain of 3 to 5 miles wide and 25 miles long at a depth of about 3900 fathoms south of the Sierra Maestra, eastern Cuba. The occurrence of reworked Cretaceous material seems to be characteristic of the chalky end-of-cycle calcilutite portion of the Peñalver formation. Of special interest is the re-deposition of the minute tests of *Nannoconus* species of Lower Cretaceous age, indicating that Lower Cretaceous limestones were exposed and eroded at the time of the Peñalver deposition. SÁNCHEZ ROIG (1949) described numerous species of echinids from the uppermost Cretaceous of Cuba, and according to BRODERMANN (1949, pp. 308–309) echinids are common in the coarse detrital

"Lime Gravel" (=lower portion of the Peñalver formation) and in the "Big Boulder Bed" (=middle portion of the Peñalver formation). The following genera of Maastrichtian echinids are mentioned from these beds: *Lanieria, Hemiaster, Procassidulus, Cardiaster, Conulus, Goniopygus, Linthia*, and *Pseudothopsis*. It is noteworthy that none of the Cretaceous echinid species recorded by SÁNCHEZ ROIG has been found in Tertiary sediments. The first Tertiary echinids reported are from the carbonate Lower Eocene Universidad formation where *Habanaster, Histocidaris, Leiopidina, Sanchezaster* etc. are common (BRODERMANN 1949, p. 309). Apart from fragments, no echinids are reported from the clastic Apolo, Alkázar and Capdevila formations.

The relative stratigraphic position of the type samples is given in the columnar section, fig. 12. They are here listed from bottom to top:

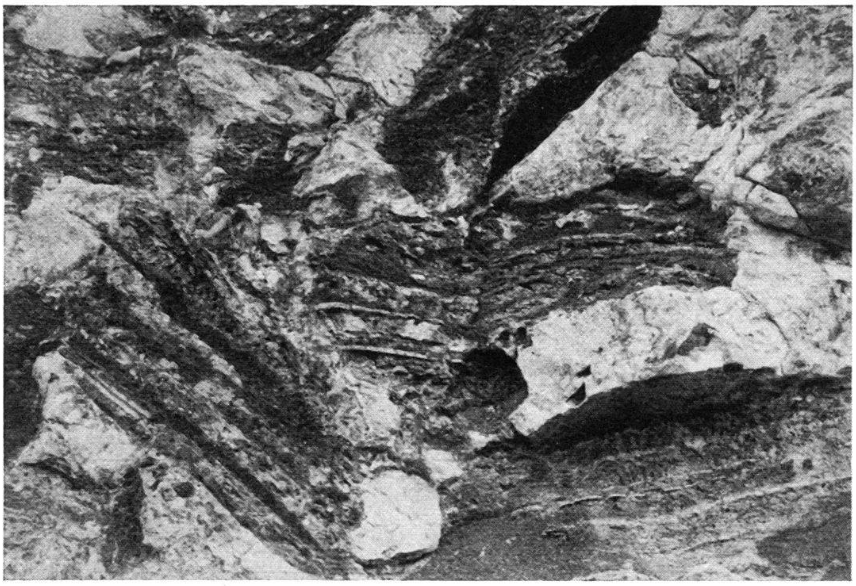


Fig. 20. Detail of the contact Vía Blanca formation and Peñalver formation. Blocks of Vía Blanca material are embedded in Peñalver clastics. Scale 1:20.

BR station 661

Lithology: Calcirudite, not well-cemented, friable, with abundant dark igneous grains, yellowish gray.

Texture: Coarse-fragmental, unsorted. Diameters of average components from 300 to 1000 μ. Components rather densely packed angular to subangular fragments of mollusks, mainly rudists, echinoderms, algae, larger Foraminifera and fragments of different limestones and of dark brown and green igneous rocks. Matrix microcrystalline calcite.

Assemblage: *Omphalocyclus macroporus* (LAMARCK)
Vaughanina cubensis D. K. PALMER
Orbitoides palmeri GRAVELL
Coskinolina n. sp.
Cosinella sp.
Sulcoperculina spp.
Kathina jamaicensis (CUSHMAN and JARVIS)

Siderolites skourensis (PFENDER)
Asterorbis sp.
Calcisphaerula innominata BONET

BR station 659
Lithology: Calcarenite, hard, with dark igneous grains, light olive gray.
Texture: Fairly coarse-fragmental, unsorted. Diameters of average components from 100 to 360 μ. Components densely packed angular to subangular fragments of mollusks, echinoderms, algae and larger Foraminifera. Fragments of dense microcrystalline limestone and of green and dark brown igneous rocks. Recrystallized microcrystalline groundmass.

Assemblage:
Globotruncana stuarti (DE LAPPARENT) group
Globotruncana lapparenti BROTZEN group
Heterohelix spp. or *Pseudoguembelina* spp.
Sulcoperculina sp.
Siderolites cf. *skourensis* (PFENDER)
Vaughanina cubensis D. K. PALMER
Fragments of pseudorbitoids
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET.

BR station 657
Lithology: Calcarenite, hard, with dark igneous grains, light olive gray.
Texture: Fairly coarse-fragmental, unsorted. Diameter of average components 100 to 250 μ. Components are densely packed angular to subangular fragments of aphanitic cryptocrystalline limestone, dark brown and green igneous rocks, fragments of mollusks, mainly rudists, echinoderms, calcareous algae and larger Foraminifera. Microcrystalline groundmass.

Assemblage:
Globotruncana contusa (CUSHMAN)
Globotruncana lapparenti BROTZEN group
Globotruncana stuarti (DE LAPPARENT) group
Globotruncana mariei BANNER and BLOW
Globotruncana arca (CUSHMAN)
Globotruncana linneiana (D'ORBIGNY) } reworked(?)
Globotruncana cf. *fornicata* PLUMMER } reworked(?)
Rugotruncana sp.
Heterohelix spp. or *Pseudoguembelina* spp.
"*Globigerina*" spp.
Pseudotextularia elegans (RZEHAK)
Siderolites cf. *skourensis* (PFENDER)
Sulcoperculina sp.
Vaughanina cubensis D. K. PALMER
Fragments of pseudorbitoids
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET.

BR station 658
Lithology: Calcilutite, hard, whitish to yellowish gray (coccolithite).

Texture: Microcrystalline to cryptocrystalline groundmass with small pseudoölites and with minute organic angular fragments of 10 to 60 μ average diameter and minute microfossils. Rare dark igneous fragments.

Assemblage:	Coccoliths (rock-forming)	
	Calcisphaerula innominata BONET	
	Fragments of planktonic microfossils	
	Nannoconus steinmanni KAMPTNER (rare)	reworked
	Nannoconus bermudezi BRÖNNIMANN (rare)	reworked
	Nannoconus wassalli BRÖNNIMANN (rare)	reworked

Other outcrops of the Peñalver formation

Quinta Canaria

Quinta Canaria is a private hospital located on the west side of the highway from Arroyo Apolo to Arroyo Naranjo, about 2.5 km north of Arroyo Naranjo, coordinates 359.56 N and 360.00 E. This locality has been mentioned by R. H. PALMER (1934, table I on p. 125, where it is named Quinta Canario) as a typical outcrop of the Lime Gravel member or Lime Gravels of his "Habana formation". In the area surrounding the hospital buildings the soil is formed by more or less weathered, whitish calcirudite which disintegrates into a fine calcareous gravel with grain sizes ranging from 2 to 5 mm. The attitude of the calcirudite cannot be exactly defined, but the dip seems to be rather flat toward the north. The relation neither toward younger nor older beds can be observed. A polygonal system of joints on the surface of the calcirudite indicates an early stage of exfoliation weathering. As the calcirudite is poorly cemented, the exfoliation process never properly develops and does not produce the big well-rounded balls described from the harder and finer calcarenites of other outcrops of the Peñalver formation. Subangular, barren inclusions of brownish orange and reddish silty shale up to 40 cm in diameter are frequent. The almost globular echinid *Lanieria lanieri* (COTTEAU) has been reported by SÁNCHEZ ROIG (1949, p. 62) from the "Lime Gravel" of Quinta Canaria.

The following are random samples from the outcrops at Quinta Canaria. The samples from BR stations 390, 391 and 1185 are "clay" inclusions in the calcirudite of the basal Peñalver formation. The sample from BR station 390A is from the friable calcirudite outcropping in the garden of Quinta Canaria.

BR station 390 ("clay" inclusion)
Lithology: Shale, non-calcareous, pale yellowish brown.
Washed residue barren.

BR station 391 ("clay" inclusion)
Lithology: Shale, calcareous, whitish to very pale orange.
Washed residue barren.

BR station 1185 ("clay" inclusion)
Lithology: Shale, non-calcareous, pale red.
Washed residue barren.

BR station 390A
Lithology: Calcirudite, soft, friable, whitish to yellowish gray.
Washed residue with

Globotruncana arca (CUSHMAN)
Globotruncana mariei BANNER and BLOW
Globotruncanella havanensis (VOORWIJK)
Rugoglobigerina rugosa rugosa (PLUMMER)
Rugoglobigerina macrocephala BRÖNNIMANN group
"*Globigerina*" spp.
Pseudoguembelina cf. *punctulata* (CUSHMAN)
Pseudotextularia elegans (CUSHMAN).

San Francisco de Paula

The here described outcrop was first mentioned by R. H. PALMER (1934, table I on p. 125) as characteristic of his Big Boulder Bed–Dirty Shales, and then of both the Lime Gravel and Cone Sandstone (1945, p. 12). In the explanations to the field trip from Matanzas to La Habana, PALMER (1938, no pagination) described from this road cut the Big Boulder Bed, the Cone Sandstone, Lime Gravel and Chalk, i.e. all the members of his "Habana formation" in its eastern development. The outcrop is situated along a road cut on the Carretera Central 0.5 to 0.8 km southeast of San Francisco de Paula, a village southeast of Habana, coordinates 359.56 N and 367.40 E. At this locality, the Carretera Central cuts the entire Peñalver formation with its four lithological zones. The calcareous clastics are striking about east and dipping either about 80° to the south in overturned position or are more or less vertical. At the southeastern end of the road cut occur calcirudites with large-sized components of up to 1 cm in diameter and with dark "clay" inclusions up to 10 cm in diameter. The top beds on the northwestern end of the road cut are fine-grained chalky calcarenites to very fine calcilutites. Between these extremes all the intermediate grain sizes are represented. In the middle part of the section elongate concretions, the cones of PALMER, are well developed (fig. 14). Slightly higher stratigraphically, typical exfoliation weathering can be observed (fig. 16). A few meters below the bottom of the formation on the southeastern side of the outcrop, brown graywacke silts and shales of the underlying Vía Blanca formation are exposed, but the contact between the two formations cannot be seen. Also the field relationship with the overlying beds cannot be observed.

The here listed samples are in stratigraphic order from bottom to top of the formation:

BR station 393
Lithology: Calcirudite, light olive gray to light olive brown, with angular inclusions of non-calcareous olive gray clay and of yellowish gray calcareous shale with maximum diameter up to 5 cm. This lithology is approximately from the calcarenite-calcirudite portion of the Peñalver formation as illustrated by the photograph fig. 13.
Texture: Coarse fragmental, unsorted. Diameter of average components from about 100 to 900 μ. Components are fragments of mollusks, especially rudists,

echinoderms, various types of limestones, dark brown and green igneous grains, and Foraminifera. Microcrystalline groundmass.

Assemblage: *Omphalocyclus macroporus* (LAMARCK)
Vaughanina cubensis D. K. PALMER (abundant)
Cosinella sp.
Siderolites skourensis (PFENDER)
Sulcoperculina spp.
Cuneolina bermudezi D. K. PALMER
Calcisphaerula innominata BONET

BR station 488
Lithology: Calcarenite, rather friable, with igneous grains, light olive gray.
Washed residue with
Omphalocyclus macroporus (LAMARCK)
Asterorbis macei D. K. PALMER
Asterorbis cubensis D. K. PALMER
Vaughanina cubensis D. K. PALMER
Sulcoperculina spp.
Pseudoguembelina cf. *palpebra* BRÖNNIMANN and BROWN
Rugoglobigerina macrocephala BRÖNNIMANN group

BR station 488A
Lithology: Calcilutite, chalky, conchoidal fracturing, light yellowish gray (coccolithite).
Texture: Cryptocrystalline-argillaceous groundmass with minute organic fragments of 5 to 10 μ average diameter, and planktonic microfossils. Some minute dark igneous grains.

Assemblage: Coccoliths (rock-forming)
Pseudoguembelina excolata (CUSHMAN)
Radiolaria.

Jacomino

At Jacomino, about 1 to 1.5 km south of the Bahía de la Habana, there are several quarries which are mentioned by R. H. PALMER (1934, table I on p. 125) as typical outcrops of the Chalk member of his "Habana formation". In a large quarry located near coordinates 362.06 N and 364.00 E, occurs in the lower part of the cliff a fine-grained hard grayish bluish calcarenite, which is sometimes brownish due to slight impregnation with oil. These beds are steeply dipping toward the south-southwest. The upper part of the cliff is formed by yellowish gray, hard conchoidal fracturing, thin-bedded, well-cemented and fine-grained calcilutites sharply separated from the underlying calcarenites by a break in lithology which may coincide with a possible minor tectonic dislocation. The upper beds, which correspond to PALMER's Chalk member, may have been thrust somewhat northward over the underlying coarser calcarenites. At this locality, the relationship to underlying and overlying formations cannot be seen.

The following samples are representative of the two lithologies of the Peñalver formation occurring in the Jacomino quarries:

BR station 481

Lithology: Calcarenite, hard, yellowish gray.

Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components ranges from 50 to 2000 μ. Components are fragments of mollusks, echinoderms, different types of limestone and dark igneous rocks. Rare angular ?quartz grains. Abundant planktonic Foraminifera. Groundmass microcrystalline. Texture and microassemblage are practically the same as in BR station 657.

Assemblage:
Globotruncana arca (Cushman)
Globotruncana stuarti (de Lapparent) group
Globotruncana mariei Banner and Blow
Globotruncana contusa (Cushman)
Globotruncana lapparenti Brotzen group
"*Globigerina*" spp.
Rugoglobigerina sp.
Heterohelix sp. or *Pseudoguembelina* sp.
Planoglobulina glabrata (Cushman)
Pseudotextularia elegans (Rzehak)
Siderolites skourensis (Pfender)
Vaughanina cubensis D. K. Palmer
Sulcoperculina sp.
Calcisphaerula innominata Bonet

BR station 482

Lithology: Calcilutite, hard, conchoidal fractioning, bluish white to yellowish gray (coccolithite).

Texture: Cryptocrystalline-argillaceous groundmass with abundant probably organic minute angular fragments of 5 to 15 μ diameter, and with discrete cryptocrystalline pseudoölites and angular fragments of dark brown shale up to 500 μ in diameter. In places dark brown to almost black through impregnation of oil.

Assemblage:
Globotruncanella havanensis (Voorwijk)
Trinitella scotti Brönnimann
Globotruncana mariei Banner and Blow
Globotruncana stuarti (de Lapparent) group
Globotruncana lapparenti Brotzen group
Rugoglobigerina sp.
Heterohelix spp. or *Pseudoguembelina* spp.
Gublerina sp.
"*Globigerinella*" sp.
"*Globigerina*" spp.
Pseudoguembelina excolata (Cushman)
Pithonella ovalis (Kaufmann)
Coccoliths (abundant)
Nannoconus steinmanni Kamptner (rare) } reworked
Nannoconus truitti Brönnimann (rare) } reworked
Nannoconus globulus Brönnimann (rare) } reworked

Washed residue with
Globotruncana lapparenti Brotzen group

Globotruncana arca (CUSHMAN)
Globotruncana stuarti (DE LAPPARENT)
Rugotruncana sp.
Trinitella scotti BRÖNNIMANN
Pseudotextularia elegans (RZEHAK)
Pseudoguembelina striata (EHRENBERG)

Reparto San Pedro

About 1.1 km south-southwest of San Francisco de Paula, near coordinates 359.2 N and 367.6 E, a cut along a secondary road of the Reparto San Pedro parallel to the Carretera Central, opens the complete sequence from the basal

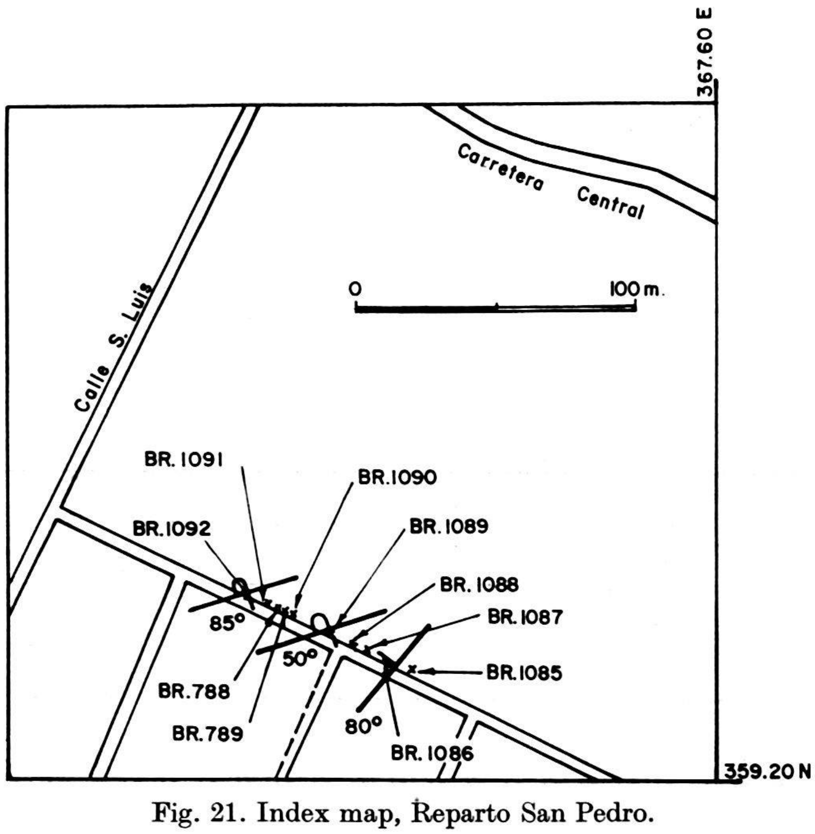


Fig. 21. Index map, Reparto San Pedro.

Apolo formation in the west-northwest to the Vía Blanca formation in the east-southeast (see index map and cross section, figs. 21, 22). The contact between the Apolo formation and the Peñalver formation, which is here overturned, is clearly disconformable. The top of the Peñalver formation is irregularly eroded and limonitic Apolo material fills all the irregularities in the surface of the Peñalver formation. The total thickness of the Peñalver formation is here 30 to 45 m. The finer-grained upper part of the Peñalver formation is about 20 m thick. The stratigraphically underlying calcarenite is less than 6 m thick, and the lower calcirudite is 6 to 9 m thick. It has, of course, to be expected that these figures do not correspond to the original thicknesses of the beds as the structural position of the section indicates that tectonic reductions may have taken place.

The following is a list of samples from this section. The stations are arranged from bottom to top. Samples 788, 1091 and 1092 are described under Apolo formation.

BR station 1085 (Vía Blanca formation)
Lithology: Chalk, pale yellowish orange.
Washed residue with
Globotruncana stuarti (DE LAPPARENT)
Pseudoguembelina cf. *costulata* (CUSHMAN)
Pseudoguembelina sp.
Calcisphaerula innominata BONET.

BR station 1086 (Peñalver formation)
Lithology: Calcirudite with fragments up to 5 mm, friable, grayish orange.
Washed residue with
Sulcoperculina sp.
Rugoglobigerina rugosa rugosa (PLUMMER)
Globotruncana lapparenti BROTZEN group
"*Globigerina*" spp.
"*Globigerinella*" spp.
Biglobigerinella sp. ?
Calcisphaerula innominata BONET.

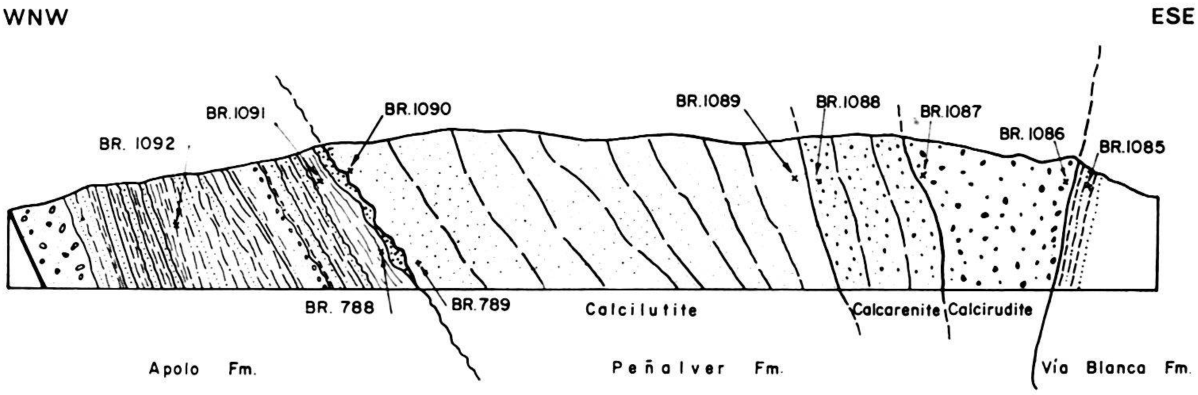


Fig. 22. Road cut at Reparto San Pedro. Scale about 1:600.

BR station 1087 (Peñalver formation)
Lithology: Calcarenite, fine-grained, somewhat friable, grayish yellow to pale orange.
Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components ranges from about 70 to 300 μ. Components are pseudoölites of dense dark limestone, rare oölites, common mollusk and echinoderm fragments and rare grains of dark igneous rocks. Abundant planktonic Foraminifera. Groundmass microcrystalline.
Assemblage: *Globotruncana lapparenti* BROTZEN group
Globotruncana mariei BANNER and BLOW
Rugoglobigerina rugosa rugosa (PLUMMER)
Pseudotextularia sp.

Vaughanina cubensis D. K. PALMER
Siderolites skourensis (PFENDER)
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

Washed residue with
Globotruncana spp. (badly preserved)
Gublerina ornatissima (CUSHMAN and CHURCH).

BR station 1088 (Peñalver formation)
Lithology: Calcarenite, fine-grained, friable, pale orange.
Texture: As BR station 1087. Diameter of average components ranges from about 35 to 180 μ.
Assemblage:
Globotruncana lapparenti BROTZEN group
Globotruncana stuarti (DE LAPPARENT)
Rugoglobigerina rugosa rugosa (PLUMMER)
Rugoglobigerina macrocephala BRÖNNIMANN
Rugotruncana cf. *mayaroensis* (BOLLI)
Rugotruncana sp.
Globotruncanella havanensis (VOORWIJK)
Globotruncana mariei BANNER and BLOW
Globotruncana cf. *fornicata* PLUMMER (reworked)
Globotruncana cf. *linneiana* (D'ORBIGNY) (reworked)
Heterohelix sp. or *Pseudoguembelina* sp.
Pseudotextularia sp.
Omphalocyclus macroporus (LAMARCK)
Siderolites skourensis (PFENDER)
Vaughanina cubensis D. K. PALMER
Sulcoperculina sp.
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN).

BR stations 1089, 1090 and 789 (Peñalver formation)

The material from these stations is lithologically and faunally very similar and therefore described together.

Lithologies: Calcilutite, rather coarse, hard, conchoidal fracturing, yellowish gray.
Textures: Cryptocrystalline-argillaceous groundmass with abundant angular, minute, organic fragments and with minute grains of dark igneous rocks. Diameter of average components ranges from about 10 to 150 μ. Abundant planktonic microfossils.
Assemblage:
Globotruncana lapparenti BROTZEN group
Globotruncana stuarti (DE LAPPARENT)
Globotruncana mariei BANNER and BLOW
Globotruncanella havanensis (VOORWIJK)
Rugoglobigerina rugosa rugosa (PLUMMER)
Rugoglobigerina macrocephala BRÖNNIMANN
Heterohelix sp. or *Pseudoguembelina* sp.

"*Globigerinella*" sp.
"*Globigerina*" sp.
Pseudotextularia sp.
Pithonella ovalis (Kaufmann)
Calcisphaerula innominata Bonet
Coccoliths
Nannoconus steinmanni Kamptner } reworked
Nannoconus colomi (de Lapparent) }

East of Casa Blanca

Immediately east of Casa Blanca, the Peñalver formation forms the center of a tight west-northwest plunging syncline. The geological situation of this area is explained in the detail-map of the rimrock area between Casa Blanca and Cojímar (plate III), and the samples from the Peñalver formation, i.e. BR stations 1136, 1137 and Baughman stations 1730, 1731, 1733, 1772, 1773, and 1777 were described under Vía Blanca formation (p. 257 to 258 of this paper). *Rugotruncana mayaroensis* (Bolli) was encountered in the calcirudite of Baughman station 1773.

Environment and age

The fragments of rudists, echinoderms and algae, and the abundant larger Foraminifera indicate a reefal source of the coarser clastics of the lower part of the Peñalver formation. The finer calcarenites and the calcilutites of the upper part of the Peñalver formation contain abundant planktonic microfossils. The association of planktonic and benthonic microfossils and megafossil debris suggests a basinal environment in front of a reefal complex. Fragments of dark brown and green igneous rocks occur throughout the samples but they are always a minor fraction of the Peñalver clastics. In contrast to the underlying Vía Blanca formation there are neither tuffaceous beds nor volcanic flows in the Peñalver formation. Igneous activity apparently was at a near stand-still during the Peñalver deposition or had completely subsided because also later in Tertiary times no signs of igneous activity are known in the Habana area. The Upper Cretaceous reefal complexes from which the Peñalver clastics originated were probably growing during the subsidence of a chain of volcanic islands to the south of the Habana area which followed the dying out of volcanic eruptions. In this respect it is of interest to note, that Chubb (1957, pp. 226–228) explained the origin of thick reefal deposits on certain volcanic islands of the Pacific by the gradual subsidence of the islands as a sequel to volcanic activity.

The lithology is that of flysch-type sedimentation. Characteristic of this mode of deposition are the irregular contact with the Vía Blanca formation, slumping features and the graded bedding from calcirudites at the base to calcilutites at the top of the formation. The graded-bedding and the homogeneous suite of components reflects a single major sedimentary cycle of apparently short duration. The relatively thin and widely distributed Peñalver formation was probably laid down as a sheet-like cover over the Vía Blanca beds. The irregular contact and the channeling in the top layers of the Vía Blanca formation appear to be caused by the rapid influx of the heavy calcirudaceous fraction of the basal Peñalver formation under turbulent conditions (turbidity currents). These turbulent conditions gradually subsided and were superseded by relatively quiet sedimentary conditions toward the calcilutaceous end-phase of the Peñalver cycle. The change may be gradual, as for instance at the type locality and at the road cut at San Francisco de Paula, or it may be rather abrupt as shown by the rapid change from calcarenite to calcilutite in the quarries at Jacomino.

The planktonic and benthonic microfossils of the type samples and of those from other outcrops indicate that the Peñalver formation is of Upper Maastrichtian age. Forms diagnostic of the Upper Maastrichtian *Rugotruncana mayaroensis* zone have been found in a few samples outside the type section. *Rugotruncana mayaroensis* (Bolli) was encountered with *Vaughanina cubensis* D. K. Palmer, *Sulcoperculina* sp., *Globotruncana arca* (Cushman), *Globotruncana stuarti* (de Lapparent) and *Rugoglobigerina rugosa* (Plummer) group in a typical Peñalver calcirudite outcropping east of Casa Blanca. *Rugotruncana gansseri* (Bolli), diagnostic of the Lower Maastrichtian, occurs commonly in certain beds of the upper Vía Blanca formation. Both *Rugotruncana gansseri* (Bolli) and *Rugotruncana mayaroensis* (Bolli) were also recorded in marls from isolated artificial outcrops east of Loma del Príncipe, along Avenida Carlos III and Avenida Simon Bolívar. Most of these assemblages, which are not described in the present paper, are allochthonous and consist of well-preserved Maastrichtian forms mixed with Lower Eocene keeled globorotalias and spinose globigerinas. The occurrence of the above mentioned diagnostic planktonic species demonstrates that beds representative of both zones of the Maastrichtian were deposited in the area of the city of La Habana, but may have been locally eroded in the post-Upper Cretaceous period of emergence which is witnessed by the local and partial truncation of the Peñalver clastics, by the absence of beds of Danian age and by the lithological features of the Apolo formation.

Discoasterids have not been encountered. Coccoliths, on the other hand, are common and occasionally they occur in rock-forming quantities as in the fine-grained Vía Blanca beds. No attempt was made to identify them, but it appears that the coccoliths suites of the Campanian and Maastrichtian differ from those of the Lower Tertiary. Echinids from the Peñalver formation reported by Sánchez Roig (1949) have been referred to in the introduction to the present chapter.

Apolo Formation

The Apolo formation is a new lithological unit between the Upper Maastrichtian Peñalver formation and the lower Eocene Alkázar formation. The type locality is situated about 1 km north of Arroyo Apolo, northeast of the eastern end of Avenida María Auxiliadora, Reparto Vibora Park, average coordinates 361.55 N and 361.40 E (see index map, fig. 23). The name is derived from Arroyo Apolo, a southern suburb of Habana at the junction of the highways from Managua and from Bejucal. The Apolo formation is a sequence of clays, silty shales, calcarenaceous graywackes, with some interbedded graded-bedded calcarenites with rare volcanic elements and nodular marls. The clays and silty shales are dark brown to reddish brown, the graywackes are brownish to grayish and greenish and the calcarenites and marls are whitish yellow to ochre. Some of the clastic beds, as represented by BR station 595, are distinctly calcirudaceous at the bottom with elements up to 2 cm in diameter, whereas their tops are very finely fragmental. Other clastic strata are not graded-bedded, but rhythmic deposition can be observed on a larger scale involving complete sequences from coarser-grained sandy or silty to clayey layers. Many of the components of the graywackes and calcarenites are derived from Upper Cretaceous neritic limestones and dark igneous rocks. Maastrichtian microfossils such as *Omphalocyclus macroporus* (LAMARCK), *Vaughanina cubensis* D. K. PALMER, *Orbitoides palmeri* GRAVELL and representatives of *Asterorbis* and *Sulcoperculina* occur allochthonously throughout the Apolo formation. Near the Apolo–Peñalver contact Maastrichtian microfossils may be so common that they more or less obliterate the Lower Eocene assemblages, as for instance in the basal beds of the type section of the Apolo formation. The Apolo lithology resembles in a general way the younger Lower Eocene Capdevila and the older Campanian to Maastrichtian Vía Blanca lithologies. It differs by the darker brown and reddish brown overall color and by the less pronounced upper delimita-

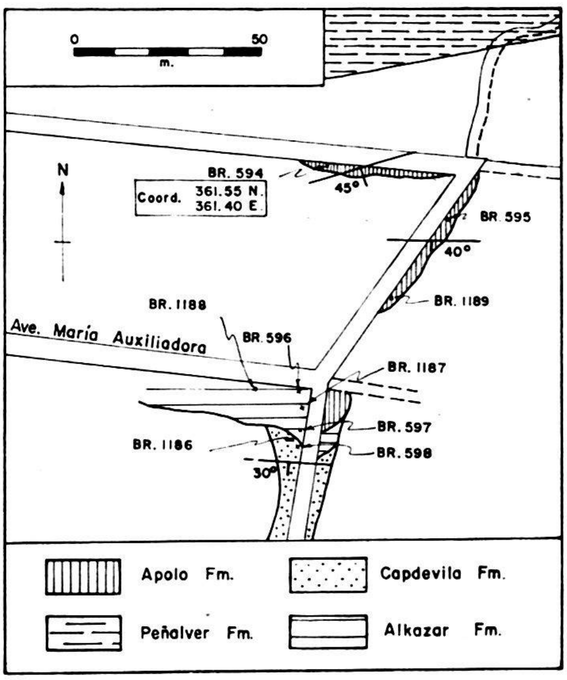


Fig. 23. Index map, type locality of the Apolo formation.

tion of its beds from the Capdevila formation and from the Vía Blanca silty graywackes. These differences, however, are rather vague and it is often difficult to decide whether an isolated outcrop of brownish or reddish brownish shales or graywacke silts or sands should be put in the Apolo, or in the Capdevila or in the Vía Blanca formation. In such cases paleontological evidence is needed. In the Habana area, Apolo and Alkázar formations appear to be distinct units. But the relationship between the two formations is close, although the respective lithologies are different, and on a regional basis they could perhaps be interpreted as a single lithologic unit.

At the type locality, the exposed thickness of the Apolo formation is about 40 m. As shown by the cross section, fig. 24, neither lower nor upper contacts with the adjoining formations can be seen. The shallow depression between the Peñalver and the Alkázar cuestas allows for about 75 m of softer beds, and we therefore estimate the thickness of the Apolo formation at about 75 m. The dips measured in the Apolo formation and in the overlying in general lighter colored Alkázar formation, represented by BR stations 1188, 596, 1187 and 597 described under Alkázar formation, are very similar, and the components of the coarser clastic beds and their faunal contents do not differ essentially in the two formations. The contact between the Apolo formation and the overlying Alkázar formation is therefore assumed to be transitional. At the Apolo type locality the dips of the beds are somewhat gentler than those of the underlying calcilutites and fine-grained calcarenites of the upper part of the Maastrichtian Peñalver formation, represented by BR stations 599 and 610, both described in the present chapter. But it cannot be decided whether the difference in dip is caused by structural steepening to the north or by an unconformity. The considerable amount of reworked Upper Cretaceous rock-fragments and fossils and the high content of limonitic material suggest that the Apolo formation transgressed over the Peñalver formation after a period of emergence in which lateritic material was formed. Typical Danian microfaunas, characterized by *Globigerina daubjergensis* BRÖNNI-

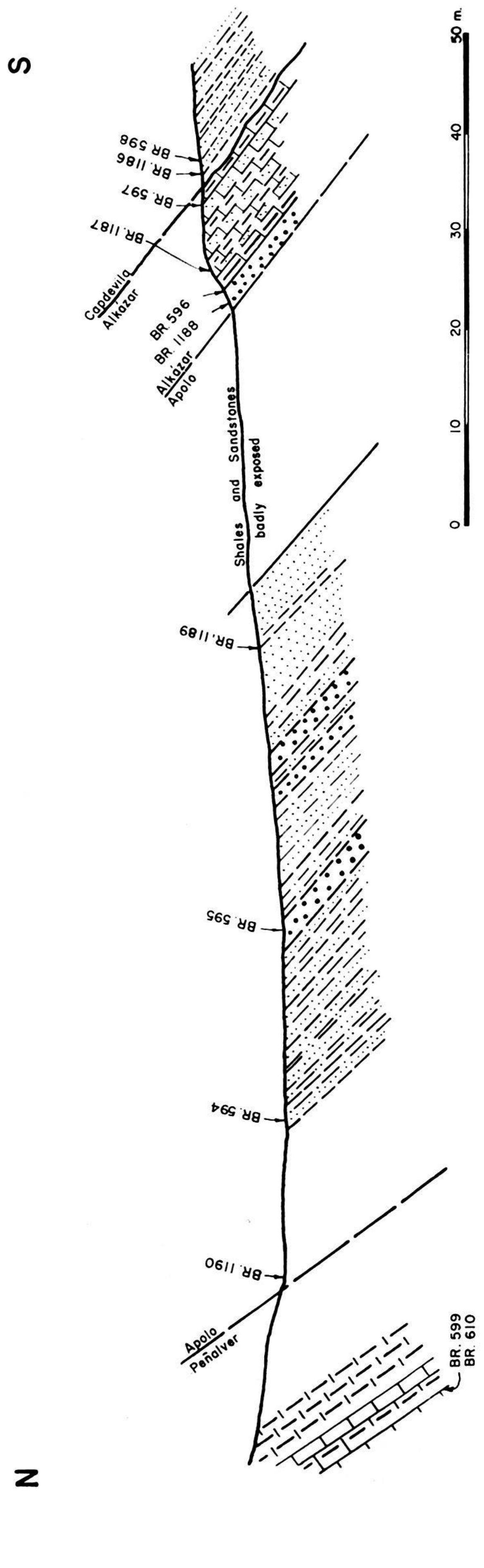


Fig. 24. Section across the type locality of the Apolo formation.

MANN, *Globigerina pseudobulloides* PLUMMER, *Globigerina triloculinoides* PLUMMER, and *Globorotalia compressa* (PLUMMER) and by the simultaneous absence of globotruncanas and keeled globorotalias, have to-date not been found in the Habana area. This negative faunal feature also suggests that the Habana area was emerged after deposition of the Peñalver formation at least for the duration of the Danian, and thus supports the proposed transgression of the Apolo formation on the Peñalver formation. The contact is, in any case, not transitional. Whether there is an angular unconformity still remains to be investigated. At other places, for instance at the road cut in the Reparto San Pedro, southeast of San Francisco de Paula, described previously under Peñalver formation, the contact between the Apolo and the Peñalver formations is well exposed and clearly disconformable.

The type section of the Apolo formation (fig. 24) is represented by 4 samples, which are listed below from bottom to top:

BR station 1190
Lithology: Clay, calcareous, moderate yellowish brown to dark brown.
Washed residue with rolled re-deposited Upper Cretaceous specimens of

Globotruncana linneiana (D'ORBIGNY)
Globotruncana arca (CUSHMAN)
Globotruncana stuarti (DE LAPPARENT) group
Globotruncanella havanensis (VOORWIJK)
Rugoglobigerina rugosa rugosa (PLUMMER)
"*Globigerinella*" cf. *messinae messinae* BRÖNNIMANN
Pseudotextularia elegans (RZEHAK) group
Trinitella scotti BRÖNNIMANN.

BR station 594
Lithology: Shale, non-calcareous, soft, pale brown.
Washed residue with Eocene spumellarias and nassellarias.

BR station 595
Lithology: Graywacke, calcirudaceous, friable, with strong igneous influence, yellowish brown.
Texture: Rather coarse-grained and poorly sorted. Diameter of average components ranging from about 400 to 3000 μ. Components are rounded to angular fragments of igneous rocks, limestones, algae, mollusks, echinoderms and larger Foraminifera. The igneous fraction is about equal to or greater than the calcareous fraction. Matrix microcrystalline calcite, limonitic.

Assemblage: *Braarudosphaera discula* BRAMLETTE and RIEDEL (one specimen)
Abundant fragments of encrusting forms of *Lithophyllum* (with typical conceptacles)

Vaughanina cubensis D. K. PALMER (common)
Orbitoides palmeri GRAVELL
Sulcoperculina spp.
Asterorbis sp. (fragment only)
} reworked from the Peñalver formation

BR station 1189
Lithology: Graywacke sandstone, calcareous, pale yellowish brown to moderate yellowish brown.

Texture: Fragmental to pseudoöolitic, unsorted. Diameter of average components ranging from about 30 to 250 μ. Components are rounded to angular fragments of mainly mollusks, coralline algae, cryptocrystalline limestones, and Foraminifera. Abundant dark brown and green igneous grains. Matrix microcrystalline.

Assemblage:
Globorotalia cf. *angulata* (WHITE)
Globorotalia spp. (keeled forms)
Globigerinas with spinose tests
Globotruncana linneiana (D'ORBIGNY) — reworked
Kathina jamaicensis (CUSHMAN and JARVIS) — reworked
Vaughanina cubensis D. K. PALMER — reworked
Calcisphaerula innominata BONET — reworked
Stomiosphaera sphaerica (KAUFMANN) — reworked

Washed residue with
Globigerina triloculinoides PLUMMER
Globigerina pseudobulloides PLUMMER
Globorotalia angulata (WHITE)
Globorotalia aequa CUSHMAN and RENZ
Pseudoguembelina cf. *excolata* (CUSHMAN) — reworked
Sulcoperculina sp. — reworked

In their paper on the Cuban globorotalias, CUSHMAN and BERMÚDEZ (1948) proposed three subgenera of *Globorotalia* CUSHMAN, 1927, *Truncorotalia*, subgenotype the Recent *Rotalia truncorotaloides* D'ORBIGNY, *Turborotalia*, subgenotype the Eocene *Globorotalia centralis* CUSHMAN and BERMÚDEZ, and *Globorotalia* s.s., subgenotype the Recent *Pulvinulina menardii* D'ORBIGNY var. *tumida* BRADY. These authors regarded the 3 subgenera of *Globorotalia* to be probably phylogenetically different, and defined them by the general shape of the test which is compressed and biconvex in *Globorotalia* s.s., planoconvex in *Truncorotalia*, and rounded, globular in *Turborotalia*. These definitions are based on differences of degree and resulted in a rather vague grouping of species. In 1958, BOLLI, LOEBLICH, and TAPPAN proposed a classification of the globorotalias in which a single morphologic character, the position of the aperture in respect to the umbilicus, was selected for the definition of the genera. BANNER and BLOW (1959, p. 1) correctly pointed out that the position of the aperture in relation to the umbilicus is only one of the morphologically significant features and alone inadequate to classify satisfactorily the globorotalias. The position of the aperture is not always clearly fixed and sometimes seems to vary within a species from form to form. Representatives of the *Globigerina pseudobulloides* PLUMMER group, for instance, would have to be assigned to *Globigerina* if the aperture is umbilical, and to *Turborotalia* if the aperture becomes extra-umbilical. BANNER and BLOW reinstated *Turborotalia*, giving it subgeneric rank, and restricted *Globorotalia* to those forms which carry a peripheral keel. *Turborotalia* and *Globorotalia*, in the sense of BANNER and BLOW, are both heterogeneous, polyphyletic groups composed of a number of lineages which sprang at different times from the plexus of globigerine ancestors. As demonstrated by figures of vertical centered sections (PESSAGNO, 1960, pl. 1, fig. 2 and pl. 2, fig. 2) the earliest portion of *Globorotalia menardii* (D'ORBIGNY) and of *Globorotalia tumida* (BRADY) invariably is a minute trochospiral globigerine. From this ancestral form turborotalias and globorotalias developed, and there is not the slightest reason to regard *Globorotalites* BROTZEN, 1942 as the ancestor of the Tertiary globorotalias (HOFKER, 1960). To distinguish morphologically between the iterative lineages grouped together in the polyphyletic *Turborotalia* and *Globorotalia* is at present not feasible. In view of these difficulties we have not proposed new generic names for the recognized lineages. BERMÚDEZ (1961), however, took a step in this direction and proposed the name *Pseudogloborotalia* HAQUE, 1956, genotype *P. ranikotensis* for the lineage of Lower Eocene truncate keeled globorotalias. From HAQUE's (1956, pp. 184, 185) description it is not clear whether this species in fact is representative of the Eocene truncate keeled globorotalias. The holotype of *P. ranikotensis* should be re-examined. REISS' (1957) generic names for the forms of this lineage, i.e. *Neotruncorotalia* and *Pseudotruncorotalia*, are according to BERMÚDEZ not valid because no genotypes were established (vide BERMÚDEZ, 1961, p. 1335).

Investigation of recent material by PARKER (1962, pp. 219–254) seems to indicate that the systematic position of *Globigerinita* BRÖNNIMANN is uncertain. Based on this we have, for the time being, accepted *Catapsydrax* BOLLI, LOEBLICH, and TAPPAN, 1958, genotype *Globigerina dissimilis* CUSHMAN and BERMÚDEZ, 1937, and have not put *Catapsydrax* into synonymy with *Globigerinita* as proposed by BERMÚDEZ (1961).

The following samples are from the Capdevila, Alkázar and Peñalver formations as exposed at the type locality of the Apolo formation. Samples from BR stations 1188 and 596, Alkázar formation, and from BR stations 1186 and 598, Capdevila formation, will be described later under Alkázar formation.

BR station 599 (Peñalver formation)
Lithology: Calcilutite, hard, conchoidal fracturing, yellowish gray.
Texture: Cryptocrystalline to argillaceous groundmass with minute angular organic fragments and fragments of planktonic microfossils. Diameter of average fragments from about 5 to 50 μ.

Assemblage: Fragments of Guembelinids
Nannoconus steinmanni (KAMPTNER) (reworked).

BR station 610 (Peñalver formation)
Lithology: Calcarenite, fine-grained, with discrete large angular shale inclusions, yellowish gray.
Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components from about 10 to 150 μ. Mainly fragments of mollusks, echinoderms, algae, limestones and shales. Also some dark brown and green igneous grains. Mixed planktonic and benthonic microfossils. Matrix microcrystalline.

Assemblage: *Globotruncana lapparenti* BROTZEN group
Globotruncana stuarti (DE LAPPARENT)
Globotruncana spp.
Pseudoguembelina cf. *excolata* (CUSHMAN)
Kathina cf. *jamaicensis* (CUSHMAN and JARVIS)

Siderolites skourensis (PFENDER)
Calcisphaerula innominata BONET (in globular clusters)
Pithonella ovalis (KAUFMANN)

Other outcrops of the Apolo formation

Reparto Alkázar

South of the Hospital Infantil Nacional, opposite the Sanatorio La Esperanza and directly north of the type locality of the overlying Alkázar formation, the reddish brownish silty shales and calcarenaceous graywackes of the Apolo formation are poorly exposed in the shallow depression between the Peñalver formation to the north and the Alkázar formation to the south. This locality is represented by BR stations 540 and 540B, approximate coordinates 359.94 E and 358.54 N (index map and cross section, figs. 27 and 28).

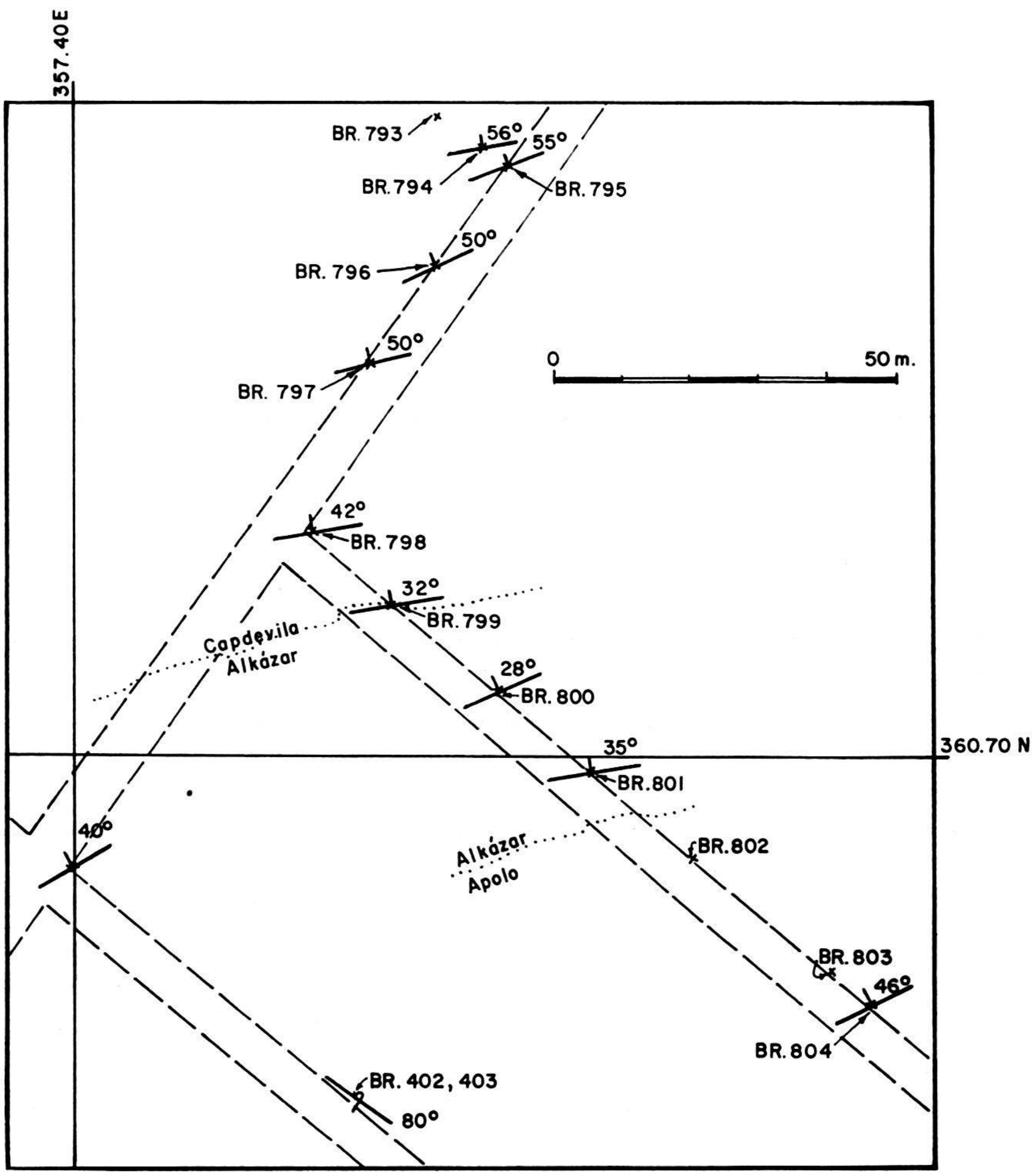


Fig. 25. Index map, Reparto Alta Habana.

BR station 540
Lithology: Calcarenite, soft, friable, thin-bedded, pale yellowish brown.
Washed residue with

Globorotalia angulata (WHITE)
Intermediate form between *Globorotalia angulata* (WHITE) and *Globorotalia uncinata* BOLLI (similar to the forms figured in LOEBLICH et al., 1958, pl. 17, figs. 10–12)
Globorotalia aequa CUSHMAN and RENZ
Globorotalia uncinata BOLLI
Globorotalia cf. *broedermanni* CUSHMAN and BERMÚDEZ
Globorotalia cf. *compressa* (PLUMMER)
Globorotalia cf. *tortiva* BOLLI
Globorotalia whitei WEISS
Globigerina triloculinoides PLUMMER
Globigerina pseudobulloides PLUMMER
Globigerina cf. *velascoensis* CUSHMAN
Globigerina triangularis WHITE
Chiloguembelina subtriangularis BECKMANN
Vaughanina cubensis D. K. PALMER (reworked).

BR station 540B
Lithology: Graywacke sandstone, hard, light olive gray.
Texture: Pseudoöolitic to fragmental, unsorted. Diameter of average components from about 25 to 250 μ. Components angular to rounded fragments of mainly mollusks and coralline algae. Abundant planktonic Foraminifera and dark brown to green igneous grains.

Assemblage:
Globorotalia spp. (truncate forms)
Globigerinas with spinose tests
Globotruncana stuarti (DE LAPPARENT) (reworked).

Washed residue with

Globigerina pseudobulloides PLUMMER
Globigerina triloculinoides PLUMMER
Globorotalia aequa CUSHMAN and RENZ
Globorotalia angulata (WHITE)
Rugotruncana gansseri (BOLLI) } reworked
Vaughanina cubensis D. K. PALMER } reworked
Planoglobulina glabrata (CUSHMAN) } reworked

Alta Habana

In the summer of 1958, the construction of the streets of a new reparto opened up a good section across the base of the Capdevila, the Alkázar and the top of the Apolo formations, about 600 m east-northeast of Reparto Alta Habana and about 100 m east of the Carretera de Vento, close to coordinates 360.70 N and 357.40 E (index map, fig. 25). The columnar section, fig. 26, shows about 90 m exposed section. The upper 45 m correspond to the base of the Capdevila formation which overlies 20 m of Alkázar formation. The base of the section is formed by about 25 m of poorly exposed Apolo beds.

The few outcrops of Apolo formation are reddish brownish silty shales, and grayish yellow calcarenites and fragmental limestones. The contact with the overlying whitish marls and limestones of the Alkázar formation is definitely transitional.

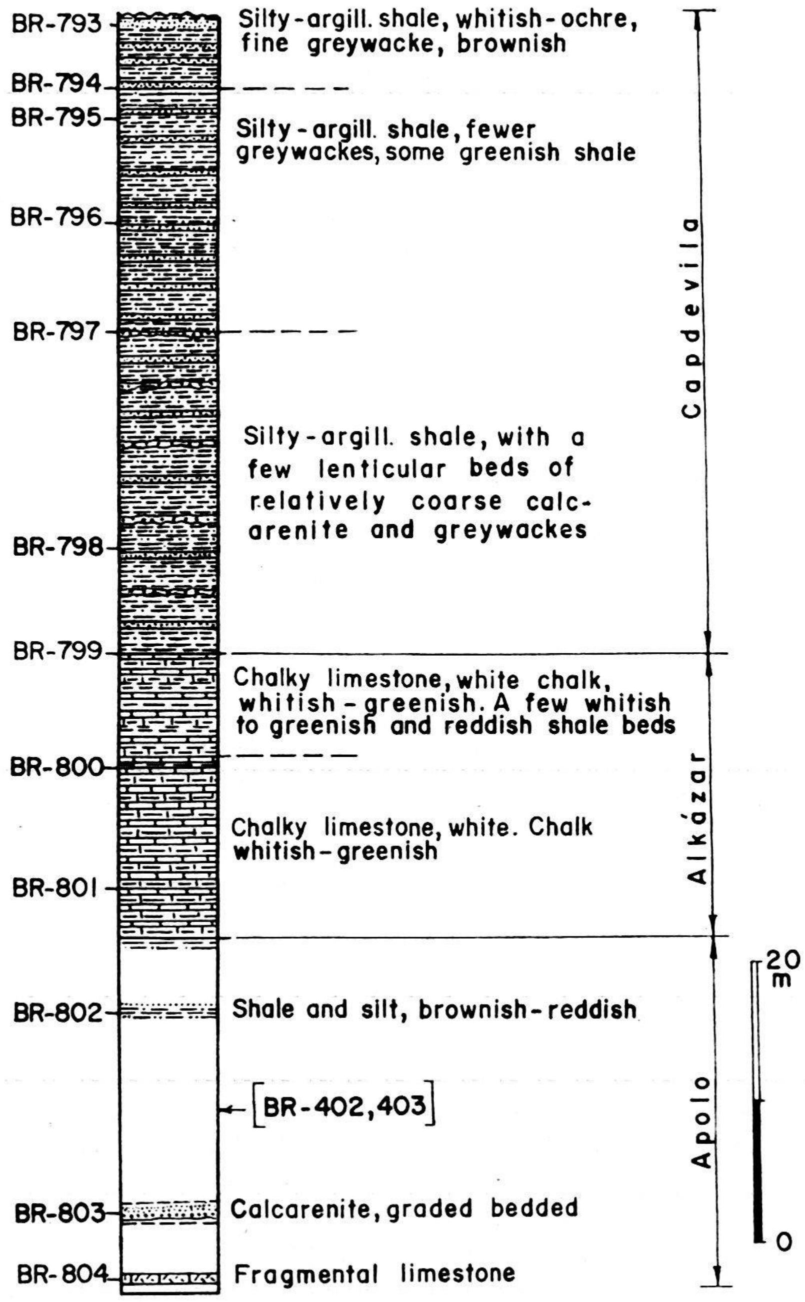


Fig. 26. Columnar section. Reparto Alta Habana.

The here listed samples are in stratigraphic order from bottom to top of the section:

BR station 804
Lithology: Calcirudite, hard, with angular inclusions of olive green shale fragments, light yellowish gray. Rare igneous grains.

Texture: Fragmental, coarse-grained, unsorted. Diameter of components from about 150 to 2800 μ. Components are pieces of dense limestone, olive green shale and of dark brown and greenish igneous rocks, but mainly larger Foraminifera and algal fragments. Matrix microcrystalline.

Assemblage:
- "*Operculina*" *catenula* CUSHMAN and JARVIS
- *Discocyclina barkeri* VAUGHAN and COLE
- *Discocyclina* cf. *crassa* CUSHMAN
- *Proporocyclina* cf. *cedarkeyensis* COLE
- *Pseudophragmina* sp. or *Proporocyclina* sp.
- New genus related with *Lockhartia–Kathina–Dictyoconoides* group with "lateral chambers" on umbilical side
- *Globorotalia* sp. (truncate form)
- *Globorotalia pseudomenardii* BOLLI group
- *Globigerina* sp. of spinose type
- *Distichoplax biserialis* (DIETRICH)
- *Lithoporella melobesioides* FOSLIE
- *Sulcoperculina* sp. } reworked
- *Vaughanina cubensis* D. K. PALMER } reworked

As indicated by the quotes, the generic name of "*Operculina*" *catenula* characterized by a pronounced marginal plexus and an operculinoid spiral is still under discussion. SACHS (1957, p. 107) listed as synonyms of *Operculina bermudezi* (D. K. PALMER), 1934, according to COLE (1959) a junior synonym of "*Operculina*" *catenula* CUSHMAN and JARVIS, 1932, the genera *Operculina, Pellatispirella, Camerina* [=*Nummulites*], *Miscellanea, Ranikothalia* and *Operculinoides.* COLE (1960) recognized only 2 valid nummulitid genera, i.e. *Camerina* and *Miscellanea.* It is here pointed out, that *Camerina* BRUGUIÈRE, 1792, has been invalidated by opinion 192 of the International Commission of Zoological Nomenclature and should no longer be used. It is replaced by *Nummulites* LAMARCK, 1801. *Miscellanea* PFENDER, 1934, lacks a marginal plexus and consequently should not be grouped with *Nummulites.* DROOGER (1960, p. 330), in his key to the genera of the rotaliids also separated *Miscellanea* from the nummulitids but derived both, which is improbable, from the same *Daviesina*-like ancestor. *Pellatispirella* HANZAWA, 1937, is according to COLE related with *Elphidium* and not with *Nummulites.* We concur with COLE that there are no valid grounds to retain *Ranikothalia* CAUDRI, genotype *Nummulites nuttalli* DAVIES, 1927, as suggested by NAGAPPA (1959) and later by DROOGER (1960). But it is still not clear whether the "nummulites cordelées" of DE CIZANCOURT (1948) as represented by "*O.*" *catenula* and reported from the old Tertiary of the Caribbean area, the southern United States and Mexico and from India and Africa, should be separated taxonomically from *Nummulites* LAMARCK. The only morphological difference between the "nummulites cordelées" and the true nummulites is in the marginal plexus which is much coarser and more prominent in respect to the test in the "nummulites cordelés". Conceivably the true nummulites evolved from the "nummulites cordelées" or from their direct ancestor by the refinement of the marginal plexus. Origin and evolution of the "nummulites cordelées" are still unkown. PURI (1957) derived some of the Tertiary nummulitids from the Upper Cretaceous *Sulcoperculina* THALMANN, 1938, genotype *Camerina* (?) *dickersoni* D. K. PALMER, 1934. The problem whether the old Tertiary "nummulites cordelées", of which "*O.*" *catenula* is the most typical representative, could have evolved from *Sulcoperculina* by developing a number of narrow sulci along the periphery and a bilaterally symmetric test should be further investigated. COLE (1953, p. 13) recognized the external similarity between "*O.*" *catenula* and *Operculinoides bermudezi* D. K. PALMER, 1934, and in one of his notes on names and variations in American nummulitids (1959) he puts the two forms into synonymy. In Mexico and the southern United States, "*O.*" *catenula* is regarded by COLE (1959, pp. 379–380) as diagnostic of the late Paleocene (Midway). In Cuba, we have recorded this species only in the basal Lower Eocene Apolo and Alkázar formations, correlative with the younger Midway of the Gulf Coast. The rare occurrence of "*O.*" *catenula* in certain samples of the younger Lower Eocene Capdevila formation may be due to reworking. It was never found in Upper Cretaceous beds (BERMÚDEZ, 1950, pp. 220–221).

Distichoplax biserialis (DIETRICH), an elongate, biserially cellular, calcareous microfossil of Lower Tertiary shallow-water deposits, shows in thin sections close analogy with the chitenous parts of the worm-like enteropneust *Rhabdopleura* (LEMOINE, 1960). *D. biserialis*, here regarded as an algae and not as an enteropneust (ELLIOTT, 1961, pp. 42, 43), was observed in most thin sections from the old Tertiary Apolo and Alkázar formations and in some thin sections from the Capdevila formation. It is usually associated with larger benthonic Foraminifera and with the thalli of *Lithoporella melobesioides* FOSLIE diagnostic of clear, warm, shallow water.

BR station 803
Lithology: Calcarenite, fine-grained, to calcilutite, pale greenish yellow to whitish.
Texture: Dense cryptocrystalline argillaceous matrix with abundant planktonic Foraminifera, fragments of algae and of discocyclinids. Rare igneous grains.

Assemblage:
- *Globorotalia angulata* (WHITE)
- *Globorotalia* cf. *aequa* CUSHMAN and RENZ
- Globigerinas with spinose tests
- *Globorotalia pseudomenardii* BOLLI group
- *Pseudophragmina* sp. or *Proporocyclina* sp.
- "*Amphistegina*" *lopeztrigoi* D. K. PALMER
- *Discocyclina anconensis* BARKER
- *Distichoplax biserialis* (DIETRICH)
- *Lithoporella melobesioides* FOSLIE

BR station 802
Lithology: Shale, non-calcareous, grayish orange.
Washed residue with
- *Globorotalia aequa* CUSHMAN and RENZ
- *Globorotalia* cf. *angulata* (WHITE)
- *Globigerina primitiva* FINLAY
- *Globigerina pseudobulloides* PLUMMER
- *Globigerina triloculinoides* PLUMMER

Globigerina cf. *prolata* BOLLI
Eocene nassellarias and spumellarias (abundant)

Additional samples stratigraphically between BR stations 803 and 802 but about 55 m to the west-southwest of these stations are:

BR station 402
Lithology: Chalk, shaley, grayish yellow.
Washed residue with

Globorotalia cf. *aequa* CUSHMAN and RENZ (strongly spinose forms similar to those illustrated by LOEBLICH et al., 1958, pl. 50, figs. 6 a–c, from the Hornerstown formation)
Globorotalia cf. *whitei* WEISS
Globigerina cf. *pseudobulloides* PLUMMER
Globigerina cf. *linaperta* FINLAY
Eocene nassellarias and spumellarias.

BR station 403
Lithology: Calcarenite, rather coarse-grained, light yellowish gray.
Texture: Fragmental to pseudoöolitic, unsorted. Diameter of average components from about 100 to 1500 μ. Components mainly larger Foraminifera and algal fragments. Also some echinoderm and mollusk fragments. Very rare igneous grains. Matrix microcrystalline.
Assemblage: "*Amphistegina*" *lopeztrigoi* D. K. PALMER
"*Operculina*" *catenula* CUSHMAN and JARVIS
Discocyclina barkeri VAUGHAN and COLE
Discocyclina anconensis BARKER
Pseudophragmina sp. or *Proporocyclina* sp.
Globorotalia spp. (truncate forms)
Globorotalia pseudomenardii BOLLI group
Globigerinas of spinose type
Lithoporella melobesioides FOSLIE
Distichoplax biserialis (DIETRICH)
Vaughanina cubensis D. K. PALMER (reworked).

"*Amphistegina*" *lopeztrigoi* D. K. PALMER, 1934, is a massive, pustulate, shallow-water rotaliid of the Cuban Middle Eocene. BARKER and GRIMSDALE (1936) regarded it as the ancestor of the lepidocyclinids. Both external and internal features show affinity with *Tremastegina senni* (CUSHMAN), 1945, from the Middle Eocene Scotland formation of Barbados, W. I. *Tremastegina* BRÖNNIMANN differs from *Amphistegina* D'ORBIGNY by rows of basal pores through the ventral septa and by alternating arcuate chambers on the ventral side of the test. By the latter feature it is allied with *Eoconuloides* COLE and BERMÚDEZ, 1944, originally described from the Cuban Paleocene and Lower Eocene, and HANZAWA in his recent revision is strongly inclined to put *Tremastegina* in synonymy with *Eoconuloides* (1962, p. 140). A morphologic revision of these forms is indicated. We have seen numerous thin sections of "*A.*" *lopeztrigoi* in the Cuban material but, probably because of the generally poor preservation through recrystallization, we were unable to clearly detect the ventral pores characteristic of *Tremastegina*. Consequently, we did not assign this form to *Tremastegina*. BECKMANN (1959, p. 419) found "*A.*" *lopeztrigoi* to range from the *Globorotalia velascoensis–Globorotalia pseudomenardii* zone or slightly older to the Lower Middle Eocene.

Reparto San Pedro

A good section is exposed from the Vía Blanca formation across the steeply dipping Peñalver formation to the Apolo formation in Reparto San Pedro, southeast of San Francisco de Paula (index map and cross sections, figs. 21 and 22).

At this locality, the Apolo formation consists of 16 to 17 m of brownish graywacke silts and shales with interbedded graywacke sands and conglomerates. The beds are slightly overturned toward the north. At the lower surfaces of some of the coarser graywacke beds hieroglyphs are well developed. The conglomerates are of particular interest because they were not found at the Apolo type section. But similar conglomerates have also been observed at other Apolo localities such as immediately north-northwest of Santa María del Rosario, coordinates 360.02 N and 370.91 E. From the conglomerates of the Vía Blanca formation these beds can be distinguished by the almost complete absence of sedimentary pebbles and by the high degree of roundness of the igneous pebbles. The contact between Apolo formation and Peñalver formation is disconformable.

BR station 788
Lithology: Shale, non-calcareous, yellowish brown to dark yellowish orange (1), graywacke sand, slightly calcareous, friable, moderate yellowish brown (2).

Washed residues with

Eocene nassellarias and spumellarias
Sulcoperculina sp. (reworked)
Casts of Upper Cretaceous globigerinas and guembelinids (reworked)
Nannofossils absent.

Environment and age

As explained in the introduction to the stratigraphic chapter, the sedimentary features and faunal associations of the Apolo formation reflect flysch-type sedimentation in a fore-reefal to basinal environment. Characteristic is the overall dark brownish to reddish brownish color caused by the great amount of limonitic and igneous material derived from emerged and weathered Upper Cretaceous land areas. Reworked Upper Cretaceous microfossils are common to abundant in the basal brown calcareous clays and graywackes of the Apolo formation. Discoasterids were seen in only a single sample, BR station 595, where a specimen of *Braarudosphaera discula* BRAMLETTE and RIEDEL occurs. But abundant coccoliths have been noticed in the fine-grained matrix of graywackes. Non-calcareous shales may yield abundant nassellarias and spumellarias.

The benthonic Foraminifera of the type samples are mainly re-deposited Maastrichtian larger Foraminifera. Other Apolo outcrops contain "*Operculina*" *catenula* CUSHMAN and JARVIS, "*Amphistegina*" *lopeztrigoi* D. K. PALMER, *Disco-*

cyclina barkeri VAUGHAN and COLE, *Discocyclina anconensis* BARKER, and usually other discocyclinas, pseudophragminas and proporocyclinas. This association is closely related with that from the younger Alkázar formation. The planktonic Foraminifera of the Apolo formation, on the other hand, are different from those of the Alkázar beds. The diagnostic planktonic form of the type samples is *Globorotalia angulata* (WHITE). *Globorotalia velascoensis* (CUSHMAN) and the keeled forms of the *Globorotalia pseudomenardii* BOLLI group are absent.

It follows that the Apolo formation falls in the Lower Eocene *Globorotalia angulata* zone, which underlies the *Globorotalia velascoensis–Globorotalia pseudomenardii* zone and overlies the Danian *Globigerina daubjergensis–Globorotalia compressa* zone.

Alkázar Formation

The Alkázar formation is a new lithologic unit of Lower Eocene age overlying the Apolo formation and underlying the Capdevila formation. The name is derived from Reparto Alkázar (correct spelling Alcázar), situated on the western side of the road from Arroyo Apolo to Arroyo Naranjo, about 1.5 km northeast of Arroyo Naranjo. The average coordinates of the outcrop area are 358.45 N and 360.10 E.

Before describing the outcrops of the Alkázar formation, we will briefly review the status of the old Tertiary Madruga, Luyano and Lucero beds. BERMÚDEZ (1950, p. 222) suggested that the Madruga Chalk introduced by LEWIS (1932, p. 539) may be the same as the Luyano Marl of DEGOLYER (1918, p. 141). Madruga Chalk and Luyano Marl, however, were both vaguely defined by their authors, and although they may mean the same it would be difficult to prove that they are identical with or equivalents of the Alkázar formation. Most probably, the Alkázar formation is only a part of, and therefore included in DeGolyer's and Lewis' lithologic units. Based on Lewis' description we can assume that the Madruga Chalk contains any whitish chalky and marly beds between the late Upper Cretaceous Vía Blanca formation, which is an approximate equivalent of Lewis' Havana shales, and the Capdevila formation, which is the same as his El Cano formation. BERMÚDEZ (1950, p. 219) re-defined the Madruga formation and selected as type locality the road cut under the bridge over the Carretera Central near San Antonio, Madruga, Habana Province, about 60 km east-southeast of La Habana. There are exposed brownish to yellowish graywacke silts and sandstones wthr large pebbles, sometimes up to 30 cm in diameter, mostly derived from Uppie Cretaceous limestones but also from volcanic rocks and from tuffaceous sandstones. The relationship of these beds to other formations is not known. R. H. PALMER's locality 1214, the type locality of the Maastrichtian index fossil *Vaughanina cubensis* D. K. PALMER, apparently is from the Madruga formation exposed in the cut of the railroad to Central Hershey, 1 km west of Central San Antonio. R. H. PALMER (1948, p. 72) found at this locality "abundant Foraminifera and one *Lanieria* in a conglomerate boulder and matrix". BRÖNNIMANN (1952, p. 93) re-sampled PALMER's station 1214 and found Lower Eocene planktonics associated with Upper Cretaceous larger Foraminifera. Although the Madruga formation in the sense of BERMÚDEZ may be a valid lithologic unit in the Madruga area, we propose to suppress it in the Habana area for the following reasons: 1) Lewis did

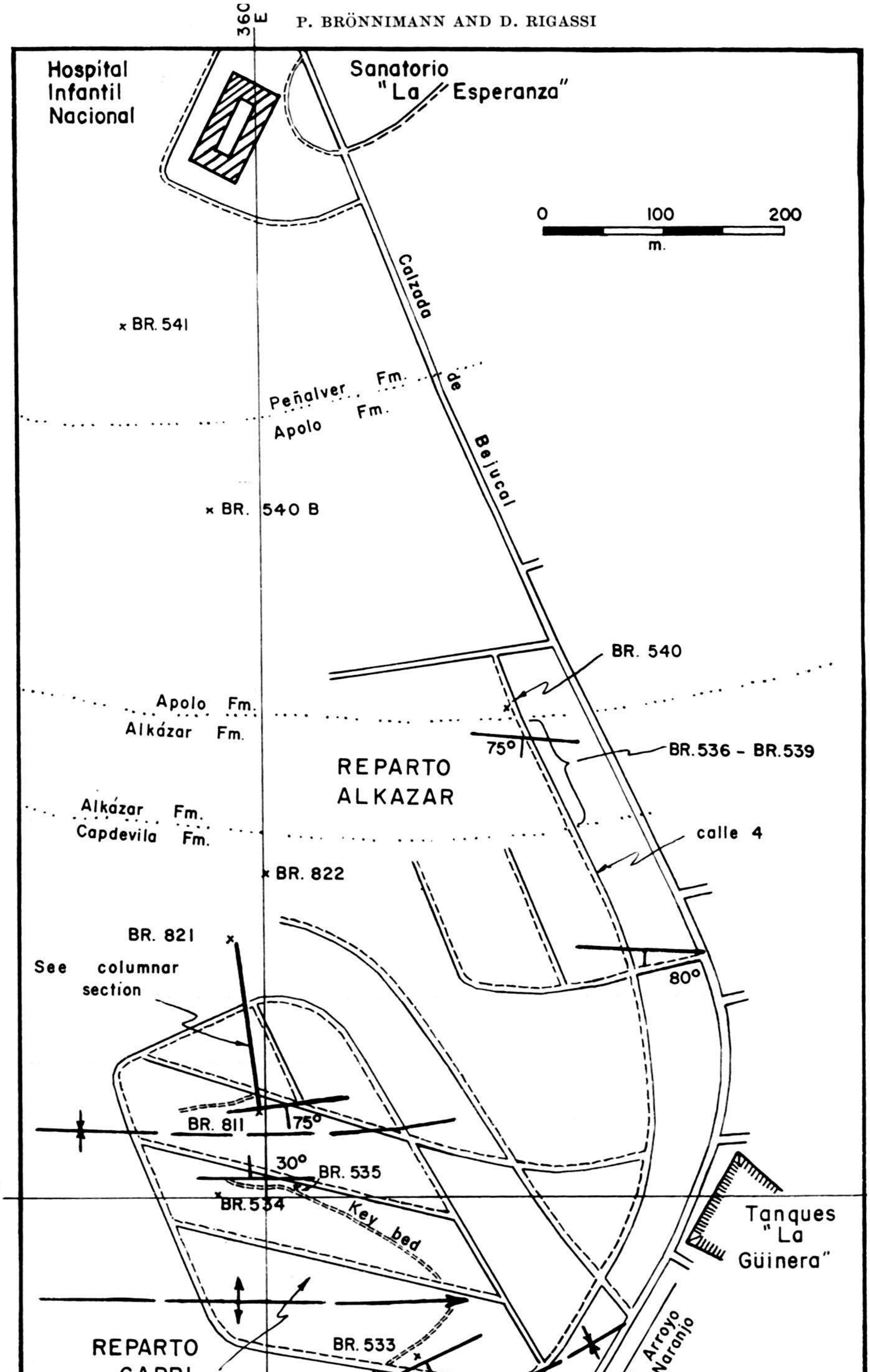


Fig. 27. Index map of the type locality of the Alkázar formation.

not explicitely define a type locality of his Madruga Chalk nor did he record its faunal content, 2) the lithology of BERMÚDEZ' type locality differs from the lithology reported by Lewis for his Madruga Chalk, and 3) in the Habana area proper, the lowermost Eocene does not contain any beds similar to those described by BERMÚDEZ from the type locality of his Madruga formation.

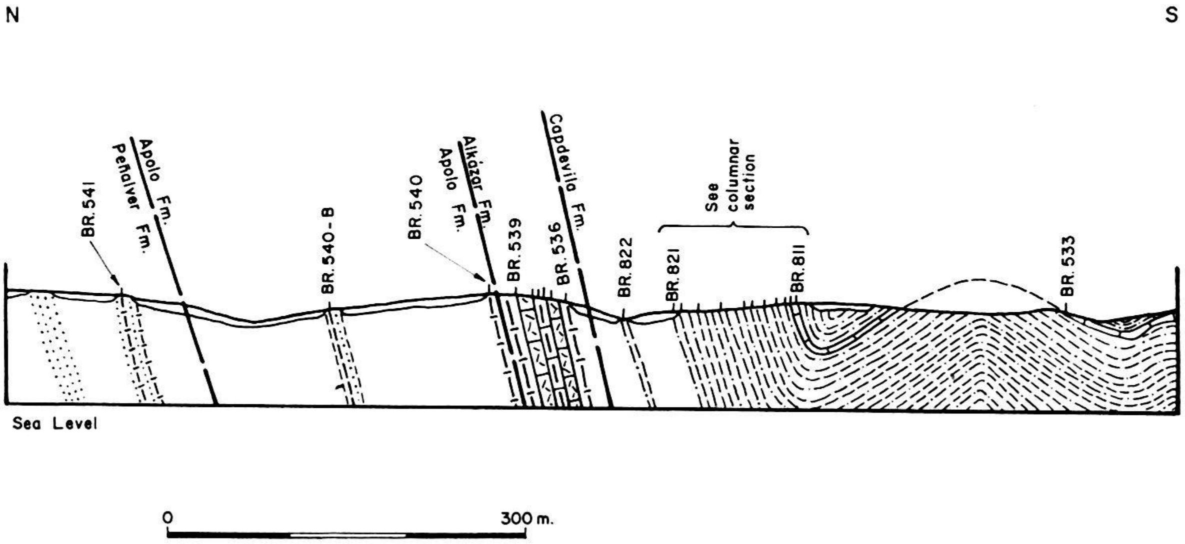


Fig. 28. Cross section type locality of the Alkázar formation.

To judge from lithology and microfauna, the Lucero formation of BRODERMANN (1943, p. 121) is most probably the same as or part of the Alkázar formation. Although the name Lucero was preoccupied by the Lucero beds of DEGOLYER (1918, p. 142), BRODERMANN used it again for a formation of ". . . arenisca fina rica en *Vaughanina cubensis* PALMER, intercalada entre arcilla grisacea con buena fauna microscopica en la que predominan *Globorotalia velascoensis* (CUSHMAN) y *G. membranacea* (EHRENBERG) [= *G. pseudomenardii* BOLLI]. . . . La fauna fina de la arcilla gris contiene abundante radiolaria. . . ." He regarded the Lucero formation as the upper beds of the Cretaceous or perhaps as Paleocene.

Relationship of Alkázar and Apolo formations

In the best-exposed Lower Eocene sections, the Alkázar formation always overlies transitionally the Apolo formation. At their type localities, the two formations appear to be lithologically well-defined units. As remarked previously under Apolo formation there are, however, indications that on a more regional scale Alkázar and Apolo formations could be regarded as a single formation rather than two different formations. In the Jaruco area, about 1.5 km west of Jaruco on the road to Campo Florido, for instance, there are at least 2 zones of Alkázar lithologies interbedded in the upper part of a series of Apolo-type beds. We also observed that in many Alkázar outcrops thin, reddish and brownish graywacke silts and sands of Apolo aspect are interbedded in the Alkázar formation, and that in Apolo outcrops occasionally occur thin intercalations of white chalks and fragmental Alkázar-type limestones.

Description of the type locality of the Alkázar formation

The type section of the Alkázar formation are the outcrops on the secondary road, Calle 4 of Reparto Alkázar, running about 50 m west of and parallel with the road from Arroyo Apolo to Arroyo Naranjo (index map, fig. 27). At this locality, about 25 m of Alkázar formation were exposed during the summer of 1958, but neither bottom nor top could be directly observed (cross section, fig. 28). The relatively hard Alkázar beds form a minor ridge between the relatively softer Capdevila and Apolo formations. The latter occurs in a shallow depression to the north and contains in BR stations 540 and 540B a Lower Eocene fauna with *Globorotalia angulata* (WHITE) and reworked Upper Cretaceous Foraminifera. The Alkázar formation underlies the Capdevila formation which is well exposed to the south of the type section; the contact however was covered. When the type locality was again visited in December 1958, it was found to be completely built over by a settlement and only isolated outcrops and floats of Alkázar chalks and calcarenites were seen.

The Alkázar formation consists of whitish, greenish and grayish, rarely light brown shales and chalks with interbeds of mostly whitish to yellowish gray, well-cemented, hard, fragmental limestones, calcarenites and calcirudites with angular "clay" inclusions. The chalks and shales differ from the whitish chalky calcilutites of the upper part of the Peñalver formation by the absence or scarcity of exotic igneous fragments. The components of the hard calcarenites and the clastic limestones are predominantly fragments of calcareous algae and other organic detritus and Foraminifera.

The relative stratigraphic position of the Alkázar type samples is given in the cross section, fig. 28. They are from bottom to top:

BR station 539

Lithology: Shale, slightly calcareous, hard, conchoidal fracturing, whitish to very pale orange and yellowish gray (coccolithite).

Texture: Argillaceous to cryptocrystalline groundmass with minute fragments.

Assemblage: *Coccolithus grandis* BRAMLETTE and RIEDEL and other coccoliths, mainly placoliths (rock-forming)
Discoaster multiradiatus BRAMLETTE and RIEDEL (common)
a) typical form of about 11 to 16 μ diameter, with central knob and with about 20 radii
b) very small form of about 5 to 7 μ diameter with central knob and with 14 to 15 distally bluntly pointed radii
Discoaster cf. *barbadiensis* TAN
Discoaster bebalaini TAN
Discoaster hilli TAN
Discoaster ornatus STRADNER
Thoracosphaera spp. (very small globular and ellipsoid bodies).

BR station 538A

Lithology: Calcarenite, fine-grained, hard, yellowish gray.

Texture: Fragmental to pseudoölitic, unsorted, similar to BR station 537, but somewhat coarser. Diameter of average components ranging from about 50 to

650 μ. Rare rounded to subangular, brown to brown green igneous grains. Abundant fragments of Corallinaceae and Foraminifera.

Assemblage: *Globorotalia pseudomenardii* BOLLI group
Globorotalia spp. (truncate forms)
Chiloguembelina sp.
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
"*Operculina*" *catenula* CUSHMAN and JARVIS
Discocyclina barkeri VAUGHAN and COLE
Pseudophragmina sp. or *Proporocyclina* sp.
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE
Discoaster hilli TAN (rare)
Vaughanina cubensis D. K. PALMER (reworked).

BR station 538
Lithology: Shale, hard, slightly calcareous, pale grayish to pale greenish yellow (coccolithite–radiolarite).

Texture: Argillaceous to cryptocrystalline groundmass with abundant Radiolaria and diatoms (*Triceratium* sp.).

Assemblage: *Coccolithus grandis* BRAMLETTE and RIEDEL
Coccoliths, mainly placoliths (rock-forming)
Discoaster bebalaini TAN
Discoaster hilli TAN
Discoaster cf. *ornatus* STRADNER
Discoaster multiradiatus BRAMLETTE and RIEDEL (typical and minute forms)
Marthasterites cf. *tribrachiatus* (BRAMLETTE and RIEDEL) (Maximum diameter from tip to tip of radii about 11 μ. Lengths of radii from 5 to 7 μ. Thickness of radii 1.5 to 2 μ)
Marthasterites bramlettei BRÖNNIMANN and STRADNER (Diameter about 12.5 μ)
Marthasterites riedeli BRÖNNIMANN and STRADNER
Nannoturbella moriformis BRÖNNIMANN and STRADNER
Thoracosphaera spp. (minute globular and ellipsoid bodies).

BR station 537
Lithology: Calcarenite, fine-grained, hard, very pale orange to grayish orange pink.

Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components ranging from about 35 to 350 μ. Angular to subrounded fragments derived from shells, algae, and limestones. Also dark brown and green igneous fragments. Abundant planktonic microfossils and some fragments of discocyclinas. Groundmass microcrystalline.

Assemblage: *Globorotalia pseudomenardii* BOLLI group
Globorotalia spp. (truncate forms)
Globigerinas with spinose tests
Chiloguembelina sp.

Discocyclina spp. (fragments with ± square equatorial chambers as seen in horizontal section)
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Coccoliths (rare)
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE
Vaughanina cubensis D. K. PALMER (reworked).

BR station 536
Lithology: Chalk, whitish to yellowish gray (coccolithite).
Texture: Cryptocrystalline to argillaceous groundmass with abundant coccoliths and discoasterids. Also Radiolaria.
Assemblage: Radiolaria
Coccoliths, mainly placoliths (rock-forming)
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Discoaster bebalaini TAN
Discoaster hilli TAN
Discoaster multiradiatus BRAMLETTE and RIEDEL (typical and minute forms)
Marthasterites contortus (STRADNER)
Marthasterites cf. *tribrachiatus* (BRAMLETTE and RIEDEL) (Very thick three-armed forms with truncate and indentated tips. Maximum diameter from tip to tip from about 10 to 20 μ. Diameter of radii from 3.75 to 5 μ. Peripheral indentation about 2.5 μ deep. This form differs from those here referred to *M. tribrachiatus* and may represent a new species)
Thoracosphaera spp. (minute globular and ellipsoid bodies)

Washed residue with Eocene spumellarias and nassellarias.

Other outcrops of the Alkázar formation

We examined many outcrops of Alkázar formation, but rarely we could see the contacts with other formations.

Alta Habana

At Alta Habana, a locality described previously under Apolo formation, the entire Alkázar formation is exposed (index map and columnar sections, figs. 25 and 26). It is a 20 m thick sequence of alternating, well-bedded, whitish to greenish chalks and whitish chalky limestones, which are practically identical with those described from the type locality. In the upper 7 m there are a few thin intercalations of whitish to greenish and reddish shales which were not found at the type locality. The boundaries toward the Capdevila and Apolo formations are transitional. This would suggest that the irregular Capdevila–Alkázar contact as observed at the type locality of the Apolo formation near Arroyo Apolo is disconformable rather than unconformable.

The following stations are from this section. They are here arranged from bottom to top:

BR station 801

Lithology: Shale, somewhat calcareous, indurated, white (coccolithite–radiolarite).

Texture: Cryptocrystalline to argillaceous groundmass with rock-forming coccoliths and Radiolaria.

Assemblage:
- Coccoliths (rock-forming)
- *Discoaster* cf. *barbadiensis* TAN
- *Discoaster hilli* TAN
- *Discoaster multiradiatus* BRAMLETTE and RIEDEL (typical and minute forms (common))
- *Discoaster ornatus* STRADNER
- *Marthasterites bramlettei* BRÖNNIMANN and STRADNER
- *Nannoturbella moriformis* BRÖNNIMANN and STRADNER
- *Thoracosphaera* spp. (globular and ellipsoid bodies of 19 to 25 μ diameter)
- Radiolaria (common).

BR station 800

Lithology: Shale, chalky, calcareous, somewhat indurated, white to pale greenish yellow (coccolithite–radiolarite).

Texture: Cryptocrystalline to argillaceous groundmass with rock-forming coccoliths and with abundant planktonic Foraminifera and with Radiolaria.

Assemblage:
- *Globorotalia pseudomenardii* BOLLI group (small and high-spired forms)
- *Globorotalia* spp. (truncate forms)
- Globigerinas with spinose tests
- Coccoliths, mainly placoliths (rock-forming)
- *Discoaster bebalaini* TAN
- *Discoaster hilli* TAN (common)
- *Discoaster multiradiatus* BRAMLETTE and RIEDEL (typical and minute forms)
- *Discoaster ornatus* STRADNER
- *Marthasterites contortus* (STRADNER)
- *Marthasterites* cf. *tribrachiatus* (BRAMLETTE and RIEDEL)
- *Nannoturbella moriformis* BRÖNNIMANN and STRADNER
- *Thoracosphaera* spp. (very small globular to ellipsoid bodies)
- Radiolaria.

BR station 799

Lithology: Shale, practically non-calcareous, indurated, white to pale greenish yellow (coccolithite–radiolarite).

Texture: Cryptocrystalline to argillaceous groundmass with rock-forming coccoliths and Radiolaria, diatoms (*Triceratium* sp.), rare planktonic Foraminifera and sponge spicules.

Assemblage:
- *Globorotalia* spp. (truncate forms)
- *Globigerina* spp. with spinose walls
- Radiolaria (abundant)
- Coccoliths (abundant)

Coccolithus grandis BRAMLETTE and RIEDEL (abundant)
Discoaster multiradiatus BRAMLETTE and RIEDEL
Marthasterites contortus (STRADNER)
Marthasterites cf. *tribrachiatus* (BRAMLETTE and RIEDEL)
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL) var. *robustus* (STRADNER)
Braarudosphaera bigelowi (GRAN and BRAARUD)
Thoracosphaera sp. (minute ellipsoid and globular bodies)
Nannoconus steinmanni KAMPTNER (reworked).

Cerro

Alkázar beds are poorly exposed in a small and isolated road cut at Avenida de la Independencia, 300 m northeast of its intersection with the Calzada del Cerro, between Calle Talleres and Calle Santa Ana, Reparto Ensanche del Vedado, coordinates 365.20 N and 357.49 E. This outcrop was previously described by BERMÚDEZ (1950, p. 221) as his station 530 and referred to the Madruga Chalk. It consists of steeply dipping, soft whitish chalky limestones, olive grayish siliceous shales and harder layers of indurated yellowish gray calcarenites and fragmental limestones. The contacts with other formations are not exposed.

The following are descriptions of random samples from this locality:

BR station 331
Lithology: Shale, non-calcareous, indurated, in part silicified, whitish to pale yellowish gray (coccolithite–radiolarite), and chalk, marly, whitish.
Texture: Cryptocrystalline to argillaceous with abundant minute angular fragments derived from organic material and dark igneous rocks. Planktonic microfossils, especially coccoliths and Radiolaria, diatoms (*Triceratium* sp.), and sponge spicules.

Assemblage:
Radiolaria (abundant)
Coccoliths, mainly placoliths (abundant)
Marthasterites cf. *tribrachiatus* (BRAMLETTE and RIEDEL)
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL) var. *robustus* (STRADNER)
Discoaster brouweri TAN (one specimen) (Six-armed specimen of about 25 μ maximum diameter from tip to tip of opposite radii. Radii very slender, about 2.5 μ thick, only very slightly tapering toward the tips. Central portion of test shows spiral arrangement of radii. No central knob.)
Discoaster multiradiatus BRAMLETTE and RIEDEL (typical and minute forms)
Braarudosphaera cf. *discula* BRAMLETTE and RIEDEL
Thoracosphaera spp. (minute ellipsoid and globular bodies)
Nannoconus steinmanni KAMPTNER
Nannoconus bermudezi BRÖNNIMANN
Nannoconus truitti BRÖNNIMANN
Nannoconus colomi (DE LAPPARENT)
} reworked

Washed residue with

Globorotalia cf. *aequa* CUSHMAN and RENZ
Globorotalia velascoensis (CUSHMAN)
Globigerina velascoensis CUSHMAN
Globorotalia pseudomenardii BOLLI (identical to the forms illustrated by SUBBOTINA, pl. 16, figs. 12-13, 1953)
Globorotalia aff. *elongata* GLAESSNER
Globigerina cf. *pseudobulloides* PLUMMER (large specimen)
Globigerina triangularis WHITE
Discocyclina sp. (very small and strongly pitted forms)
Radiolaria.

BR station 1197
Lithology: Calcarenite, whitish to yellowish gray (1–4). Shale, non-calcareous, silicified, yellowish gray to pale olive (5).

Thin sections 1–4

Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components ranges from about 150 to 700 μ. Components are mainly fragments of coralline algae, mollusks and echinoderms, and larger Foraminifera. Very rare dark brown and green igneous grains. Matrix microcrystalline calcite.

Assemblage: "*Operculina*" *catenula* CUSHMAN and JARVIS
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Discocyclina barkeri VAUGHAN and COLE
Pseudophragmina sp. or *Proporocyclina* sp.
Pseudophragmina sp.
Globigerinas with spinose tests
Globorotalia spp. (truncate forms)
Coccoliths
Lithoporella melobesioides FOSLIE
Cosinella sp. } reworked
Vaughanina cubensis D. K. PALMER } reworked

Thin section 5

Texture: Cryptocrystalline to argillaceous, silicified groundmass with abundant Radiolaria and sponge spicules.

Assemblage: Radiolaria
Coccoliths.

BERMÚDEZ (1950, p. 221) mentioned the following planktonic Foraminifera from this outcrop: *Globigerina triloculinoides* PLUMMER, *Globorotalia albeari* CUSHMAN and BERMÚDEZ, *Globorotalia membranacea* (EHRENBERG) [= *Globorotalia pseudomenardii* BOLLI] and *Globorotalia* cf. *velascoensis* (CUSHMAN).

Arroyo Apolo

The field relationship between Alkázar and Capdevila formations can be seen along the southern flank of the east–west striking ridge formed by the late Maastrichtian Peñalver formation about 500 to 600 m north of Arroyo Apolo. The contact at the corner of Avenida Lourdes and Avenida María Auxiliadora, Reparto Vibora Park, Arroyo Apolo, coordinates 361.55 N and 361.40 E is irregular (index map, fig. 23). But there appears to be not an unconformity but only a local disconformity between the two formations, because 250 m to the east of this outcrop the top Alkázar formation and the base Capdevila formation are perfectly conformable (cross section of the Apolo formation, fig. 24). The contact with the underlying Apolo formation was not exposed at this locality and we believe that it is transitional for reasons explained in the description of the Apolo formation.

BR stations 1188 and 596 are from the bottom, 1187 from the middle and 597 from the top of the Alkázar formation. BR stations 1186 and 598 are from the basal beds of the overlying Capdevila formation. BR station 1188 is from the first whitish calcarenaceous bed at the transition from Apolo to Alkázar formation, indicating the base of the Alkázar formation.

BR station 1188 (basal bed of Alkázar formation)
Lithology: Calcarenite, hard, with rare igneous grains, whitish to yellowish gray (1), and shale, calcareous, pale yellowish brown (2).

Thin section (1)

Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components ranges from about 100 to 700 μ. Components are mainly fragments of coralline algae, mollusks, echinoderms and larger Foraminifera. Planktonic microfossils are common. Rare dark brown and green rounded igneous grains. Matrix microcrystalline calcite.

Assemblage:
"*Operculina*" *catenula* CUSHMAN and JARVIS
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Discocyclina barkeri VAUGHAN and COLE
Pseudophragmina sp. or *Proporocyclina* sp.
Proporocyclina sp.
Globorotalia spp. (truncate forms)
Globigerinas with spinose tests
Globorotalia pseudomenardii BOLLI group
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE

Washed residue (2) with
Globorotalia aequa CUSHMAN and RENZ
Globorotalia velascoensis (CUSHMAN)
Globorotalia wilcoxensis CUSHMAN and PONTON
Globorotalia pseudomenardii BOLLI group
Globigerina linaperta FINLAY
Globigerina primitiva FINLAY
Globigerina soldadoensis BRÖNNIMANN group
Globigerina triangularis WHITE
Discocyclina sp. (small and strongly pitted form)
Eocene spumellarias and nassellarias.

BR station 596

Lithology: Calcarenite, yellowish gray to very light gray, with many dark igneous grains.

Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components varying from 70 to 700 μ. Fragments are from shells, algae, limestones, and dark brown and greenish igneous rocks. Foraminifera are common. Matrix microcrystalline.

Assemblage:
"*Operculina*" *catenula* CUSHMAN and JARVIS
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Discocyclina barkeri VAUGHAN and COLE
Pseudophragmina sp.
Globorotalia spp. (truncate forms)
Globigerinas with spinose tests
Globorotalia pseudomenardii BOLLI group
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE
Vaughanina cubensis D. K. PALMER (reworked).

BR station 1187

Lithology: Calcarenite, coarse-grained, hard, with igneous influence, very pale orange (1) and shale, chalky, calcareous, white to pale greenish yellow (coccolithite) (2).

Texture:

Thin section 1: Fragmental to pseudoölitic, unsorted. Diameter of average components from about 100 to 1500 μ. Components are from limestones, mollusks, echinoderms, coralline algae, larger Foraminifera, and dark igneous rocks. Matrix microcrystalline.

Thin section 2: Cryptocrystalline to argillaceous groundmass with rock-forming coccoliths and discoasterids and abundant planktonic Foraminifera.

Assemblage:

Thin section 1:
"*Operculina*" *catenula* CUSHMAN and JARVIS
Eoconuloides wellsi COLE
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Discocyclina cf. *barkeri* VAUGHAN and COLE
Proporocyclina sp.
Pseudophagmina sp. or *Proporocyclina* sp.
Globigerina spp. with spinose walls
Globorotalia spp. (truncate forms)
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE
Vaughanina cubensis D. K. PALMER (reworked).

Thin section 2
Coccoliths (abundant)
Discoaster multiradiatus BRAMLETTE and RIEDEL (abundant) (typical and minute forms)
Discoaster bebalaini TAN (common)
Discoaster hilli TAN

Thoracosphaera sp. (globular and ellipsoid bodies)
Globorotalia pseudomenardii Bolli group
Globorotalia spp. (truncate forms)
Globigerinas with spinose walls.

Washed residue (1) with
Globorotalia aequa Cushman and Renz
Globorotalia cf. *velascoensis* (Cushman)
Globigerina primitiva Finlay
Eocene spumellarias.

BR station 597
Lithology: Limestone, shaley, whitish to yellowish gray.
Assemblage: *Globorotalia* cf. *aequa* Cushman and Renz
Globorotalia velascoensis (Cushman)
Globigerina spp. (deformed specimens).

BR station 1186
Lithology: Calcarenite, fine-grained, friable, dark yellowish orange.
Washed residue with
Globorotalia aequa Cushman and Renz
Globorotalia cf. *broedermanni* Cushman and Bermúdez
Globigerina intermedia (Subbotina)
Globigerina linaperta Finlay
Globigerina soldadoensis Brönnimann group
Globigerina triangularis White
Tertiary spumellarias.

BR station 598
Lithology: Shale, non-calcareous, pale yellowish brown.
Washed residue with Eocene spumellarias and nassellarias.

San Francisco de Paula

At coordinates 360.45 N and 368.30 E, about 1.4 km east to east-northeast from San Francisco de Paula, a village on the Carretera Central east of La Habana, typical Alkázar beds occur in a northward overturned tight anticline. On the northeastern flank of the anticline, the Alkázar formation is bordered by steeply south dipping overturned Capdevila beds. BR stations 484 to 487 are from graded-bedded, white to yellowish gray fragmental limestones and yellow gray shaley chalks. Some of the reworked limestone fragments contain planktonic assemblages derived from older or penecontemporaneous Lower Eocene beds.

BR station 484
Lithology: Chalk, shaley, soft, yellowish gray.
Assemblage: Tertiary spumellaria and nassellaria and sponge spicules.

BR station 485
Lithology: Shale, calcareous, indurated, yellowish gray (coccolithite).
Texture: Cryptocrystalline to argillaceous groundmass with minute planktonic microfossils.

Assemblage: Coccoliths (abundant)
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Braarudosphaera discula BRAMLETTE and RIEDEL
Discoaster multiradiatus BRAMLETTE and RIEDEL (abundant) (typical and minute forms)
Discoaster sp.
Thoracosphaera sp. (small globular and ellipsoid bodies).

BR station 486

Lithology: Calcarenite, with abundant igneous grains, of salt and pepper aspect, yellowish gray.

Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components from about 100 to 550 μ. Components densely packed fragments of algae, different types of limestones and igneous rocks, shells and abundant Foraminifera. Matrix microcrystalline calcite.

Assemblage: "*Amphistegina*" *lopeztrigoi* D. K. PALMER
"*Operculina*" *catenula* CUSHMAN and JARVIS
Discocyclina spp.
Globorotalia pseudomenardii BOLLI group
Globorotalia spp. (truncate forms)
Globigerinas with spinose tests
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE.

BR station 487

Lithology: Calcarenite, coarse-grained, hard, rounded igneous grains, whitish to grayish yellow.

Texture: Fragmental to pseudoölitic with little recrystallized microcrystalline groundmass. Diameter of average elements from about 100 to 1500 μ. Components are fragments of algae, limestones of different origin, echinoderms, mollusks and igneous rocks. Larger Foraminifera are abundant.

Assemblage: "*Amphistegina*" *lopeztrigoi* D. K. PALMER
"*Operculina*" *catenula* CUSHMAN and JARVIS
Discocyclina barkeri VAUGHAN and COLE
Discocyclina spp. (among these forms are small discocyclinas with hexagonal equatorial chambers)
Pseudophragmina sp. or *Proporocyclina* sp.
Fabularia sp.
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE.

A large allochthonous angular limestone fragment with planktonic microfauna contains apart from reworked *Vaughanina cubensis* D. K. PALMER and *Sulcoperculina* sp.

Globorotalia spp. (truncate forms)
Globorotalia pseudomenardii BOLLI group
Globigerinas with spinose tests.

Road from Guanabacoa to Cojímar

The type beds of the Cojímar formation overlie unconformably grayish yellow marly, nodular graywackes, siliceous shales and calcarenites of the Lower Eocene Alkázar formation (?) which in type of bedding and lithology display affinity to the Capdevila formation. The contact between Alkázar (?) and Cojímar beds is exposed at the bottom of the quarry, which opens up the basal portion of the Cojímar chalks, and immediately north of Avenida Río (index map of the Cojímar type locality, fig. 73). The unconformity between the Alkázar (?) and the Cojímar formations is illustrated by the photographs, figs. 29 and 30. The planktonic assemblage of BR station 1378, which is from a marly chalk just below the Cojímar beds at Avenida Río, contains *Globorotalia* cf. *rex* MARTIN, indicating a younger Lower Eocene age than that of the Alkázar beds west of the Bahía de La Habana.

The top beds of the Alkázar formation (?) are represented by the following samples here listed from bottom to top:

Outcrop in bottom of quarry

BR station 930
Lithology: Calcarenite, with rare igneous grains, yellowish gray.
Texture: Fragmental to pseudoöolitic, unsorted. Diameter of average components from about 50 to 550 μ. Components are mainly rounded to subrounded fragments of coralline algae, mollusks, echinoderms and larger Foraminifera. Some rounded dark brown and green igneous grains. Planktonic Foraminifera are common. Matrix recrystallized calcite.
Assemblage: "*Amphistegina*" *lopeztrigoi* D. K. PALMER (common)
Pseudophragmina sp. or *Proporocyclina* sp.
Discocyclina sp.
Discocyclina cf. *anconensis* BARKER
"*Operculina*" *catenula* CUSHMAN and JARVIS
Globorotalia spp. (truncate forms)
Globigerinas with spinose tests
Lithoporella melobesioides FOSLIE
Distichoplax biserialis (DIETRICH)
Vaughanina cubensis D. K. PALMER (reworked).

BR station 931
Lithology: Limestone, chalky, hard, white to grayish yellow (coccolithite).
Texture: Cryptocrystalline to argillaceous, with abundant Radiolaria, planktonic Foraminifera and nannoplankton.
Assemblage: Coccoliths, mainly placoliths (abundant)
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Radiolaria (abundant)
Globorotalia spp. (truncate forms)
Globigerinas with spinose tests
Discoasters multiradiatus BRAMLETTE and RIEDEL (typical and minute forms)
Discoaster bebalaini TAN (rare)

Braarudosphaera cf. *discula* BRAMLETTE and RIEDEL (rare)
Thoracosphaera spp. (globular and ellipsoid bodies).

Outcrops north of Avenida Río immediately below contact with Cojímar beds

BR station 959

Lithology: Chalk, shaley, soft, grayish yellow.
Washed residue with Tertiary spumellarias and nassellarias mixed with Cojímar globigerinas (contaminated).

Road from the Vía Blanca to the Carretera Central (Continuation of Avenida Monumental)

About 4.5 km north of the intersection of the continuation of the Avenida Monumental with the Carretera Central, a section is exposed of about 20 m of brownish to whitish shales and chalks with interbedded conglomeratic layers. It is immediately south of a ridge of spillitic variolitic pillow lavas and possibly overlies them unconformably. Most of the pebbles are of sedimentary origin. Igneous components are andesites, serpentinites and tuffs, but no spillites have been found as yet. Although the color of the beds and the white chalks and fragmental limestones are very similar to other Alkázar beds, the conglomerates with mainly sedimentary pebbles are strongly reminiscent of the conglomeratic beds in the cut of the Carretera Central near Central San Antonio which have been redefined as type locality of the Madruga formation by BERMÚDEZ (1950). The exposure at the continuation of the Avenida Monumental and the Madruga outcrop are about in the same strike. The conglomeratic lenses are scattered throughout the Madruga formation, which is probably contemporaneous with the Apolo–Alkázar beds. The Avenida Monumental outcrop apparently is but a local facies of these early Eocene deposits which seem to be restricted to an area along the southern rim-rock of the Habana anticlinorium.

BR station 489
Lithology: Chalk, shaley, whitish to pale greenish yellow.
Washed residue with

Globorotalia velascoensis (CUSHMAN)
Globorotalia cf. *aequa* CUSHMAN and RENZ
Globorotalia pseudomenardii BOLLI
Globorotalia elongata GLAESSNER
Globigerina velascoensis CUSHMAN
Globigerina triangularis WHITE.

BR station 490
Lithology: Shale, indurated, somewhat calcareous, white to very pale orange (coccolithite).
Texture: Cryptocrystalline to argillaceous groundmass with abundant coccoliths, sponge spicules and some planktonic Foraminifera.
Assemblage: Coccoliths, mainly placoliths (abundant)
Tremalithus eopelagicus BRAMLETTE and RIEDEL

Discoaster multiradiatus BRAMLETTE and RIEDEL (typical and minute forms)
Discoaster sp. indet.
Thoracosphaera spp. (globular and ellipsoidal bodies)
Radiolaria
Globorotalia spp. (truncate forms)
Globigerinas with spinose walls
Chiloguembelina spp.

Washed residue with
Globorotalia velascoensis (CUSHMAN)
Globigerina spp.
Tertiary spumellarias.

Environment and age

The rapid alternation of relatively thin layers of graded clastics derived from reefal complexes containing apart from benthonic also planktonic microfossils with shaley and chalky layers in which planktonic microfossils, in particular coccoliths and discoasterids, prevail, indicates that the depositional environment of the Alkázar formation is fore-reefal to basinal and that the sedimentation is of flysch-type. The clastics show relatively little igneous influence, and the overall light color of the Alkázar formation suggests that not much lateritic material, which gave the strong brownish color to the basal Apolo beds, was eroded during the deposition of the Alkázar beds. Reworked Upper Cretaceous microfossils are no longer as common as in the Apolo beds, although *Vaughanina cubensis* D. K. PALMER still occurs in most of the thin sections of the clastic limestones. Allochthonous representatives of the Lower Cretaceous *Nannoconus* KAMPTNER have occasionally been encountered in the very fine-grained rocks.

We were unable to isolate planktonic Foraminifera from the hard type samples of the Alkázar formation. Random cuts of planktonics in thin sections show that truncate keeled globorotalias close to *G. velascoensis* (CUSHMAN), globigerinas and globorotalias ex gr. *G. pseudomenardii* BOLLI are common. Important nannoplanktonic elements of the chalks and calcareous shales of the Alkázar type samples affording identification of species in thin sections, are the often rock-forming discoasterids and the coccoliths.

In the Habana area, discoasterids occur for the first time in a sample of the Apolo formation, BR station 595, where a specimen of *Braarudosphaera discula* BRAMLETTE and RIEDEL was recorded. None were observed in the Upper Cretaceous, and the advent of common discoasterids in the Alkázar beds is regarded as a biostratigraphically important event. Coccoliths, on the other hand, occur in both the Upper Cretaceous and the Tertiary of the Habana area. The following suite of discoasterids was recorded:

Braarudosphaera cf. *discula* BRAMLETTE and RIEDEL (rare)
Braarudosphaera bigelowi (GRAN and BRAARUD) (rare)
Discoaster cf. *barbadiensis* TAN (rare)
Discoaster bebalaini TAN (common)
Discoaster brouweri TAN (a single specimen)

Discoaster hilli TAN (common)
Discoaster multiradiatus BRAMLETTE and RIEDEL (common) (typical and minute forms)
Discoaster ornatus STRADNER
Discoaster sp. indet.
Marthasterites bramlettei BRÖNNIMANN and STRADNER
Marthasterites contortus (STRADNER)
Marthasterites riedeli BRÖNNIMANN and STRADNER
Marthasterites cf. *tribachiatus* (BRAMLETTE and RIEDEL)
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL) var. *robustus* (STRADNER) (common)

Associated minute microfossils are coccoliths, which occur rock-forming, and of which *Coccolithus grandis* BRAMLETTE and RIEDEL and *Tremalithus eopelagicus* BRAMLETTE and RIEDEL could be identified. These two forms are conspicuous because of their relatively large size.

Other minute microfossils are:

Thoracosphaera spp.
Nannoturbella moriformis BRÖNNIMANN and STRADNER.

Outside of the type section, most of the listed discoasterids are associated with *Globorotalia velascoensis* (CUSHMAN), *Globorotalia aequa* CUSHMAN and RENZ, and *Globorotalia pseudomenardii* BOLLI group, to name only the most significant planktonic Foraminifera. *Globorotalia* cf. *rex* MARTIN was encountered in the Alkázar (?) beds unconformably underlying the Cojímar formation.

Radiolaria, i.e. spumellarias and nassellarias, are common in some of the non-calcareous shales and soft chalks. They are often well preserved and would deserve a more detailed investigation. Diatoms (*Triceratium* sp.) were also noticed.

The benthonic Alkázar assemblages are virtually identical with those reported from the Apolo formation. Characteristic benthonic Foraminifera are "*Operculina*" *catenula* CUSHMAN and JARVIS, "*Amphistegina*" *lopeztrigoi* D. K. PALMER, *Discocyclina barkeri* VAUGHAN and COLE, and *Discocyclina* cf. *anconensis* BARKER. Pseudophragminas and proporocyclinas are present throughout the formation. *Eoconuloides wellsi* COLE and BERMÚDEZ, a conical form related with "*Amphistegina*" *lopeztrigoi*, on the other hand, was encountered only in BR station 1194 from the top of the Alkázar beds in Reparto Veracruz. *Boreloides cubensis* COLE and BERMÚDEZ and *Helicostegina gyralis* BARKER and GRIMSDALE, both reported by BERMÚDEZ (1952, p. 230) from his "Lucero member" of the Capdevila formation where they are associated with *E. wellsi*, were not found in the Alkázar beds. According to BECKMANN (1959, p. 417), *B. cubensis* appears for the first time in the *Globorotalia rex* zone of his biostratigraphic subdivision, and the first helicosteginas are recorded only slightly later than *B. cubensis*.

Based on planktonic Foraminifera, the Alkázar beds are of *Globorotalia velascoensis*–*Globorotalia pseudomenardii* group age. In terms of a discoasterids zonation, the Alkázar formation would fall in the *Discoaster multiradiatus*–*Marthasterites bramlettei*–*Marthasterites contortus* zone.

Capdevila Formation

R. H. PALMER (1934, p. 132; fig. 2 on p. 131) derived the concept of a new formation consisting of "brown shales and sandstones that differ from the Dirty shales [of his "Habana formation"] principally in the higher percentage of sandy material" from outcrops on Rancho Boyeros highway between Capdevila and Vento, south of La Habana. From field relation and lithology PALMER believed these brown shales and sandstones to be Upper Cretaceous and to conclude the "Dirty shale" deposition. He mentioned, however, that they carry a meager fauna considered Lower Eocene by some paleontologists. From the presence of

Fig. 29. Unconformable contact of the Alkázar formation (?), below, and Cojímar formation, above, at Avenida Río, west of Río Cojímar.

ripple marks and coarse material scattered throughout the beds he inferred that they have been deposited under shore conditions, an opinion which today no longer can be upheld. In the chapter "Return from Batabanó" of the explanations to field trips in Cuba (R. H. PALMER, 1938, no pagination), for the first time the term Capdevila formation appears to have been used in print. In this paper of 1938, conglomerates are added to the lithological inventory of 1934, and reference is made to the "intensely folded, overturned and overthrust" appearance of the Capdevila formation along the Rancho Boyeros highway.

PALMER (1934, 1938, 1945) did not explicitly designate a type locality for the Capdevila formation which forms the terrain around the village of Capdevila, situated about 10 km south of La Habana at the intersection of the Rancho Boyeros (formerly General Machado) highway and the secondary road to Arroyo Naranjo, at coordinates 358.72 N and 356.13 E. Later BRODERMANN (1940, p. 27) mentioned as typical localities of the Capdevila formation: 1) the outcrops in the Tejar Capdevila north of Vento, 2) the road cuts along the highway from Habana to Rancho Boyeros, and 3) outcrops at El Cano, 0.8 km east of the Carretera Central south of Arroyo Arenas. From these localities, BERMÚDEZ (1950, p. 227) selected as type locality the outcrops at Capdevila represented by his station 207 from which he reported a poor foraminiferal assemblage with *Globorotalia capdevilensis* CUSHMAN and BERMÚDEZ, a junior synonym of *Globorotalia pseudoscitula* GLAESSNER. Better preserved and richer faunas are listed by BERMÚDEZ (1950, pp. 227–229) from his stations 205 at Tejar Retiro north of Capdevila, with *G. capdevilensis*, *G. wilcoxensis* CUSHMAN and PONTON, and *Nonion micrus* COLE, and 235C at Tejar Cuba near Arroyo Naranjo with the above listed species and *Globorotalia palmerae* CUSHMAN and BERMÚDEZ and some globigerinas. BERMÚDEZ stated (1950, p. 229) that the Capdevila formation is lower Eocene in age and that

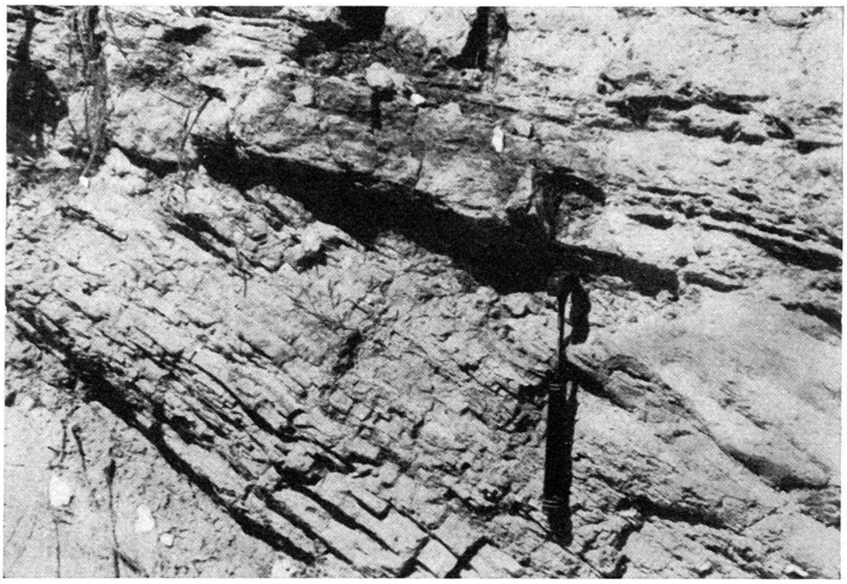


Fig. 30. Detail of the unconformity between Alkázar formation (?), below, and Cojímar formation, above, at Avenida Río, west of Río Cojímar.

it underlies the Lower Eocene Universidad formation and overlies the Paleocene Madruga formation, without describing the nature of the contacts between these units. He further correlated the Capdevila formation with the Wilcox formation of the Gulf Coast. For the outcrops at El Cano, referred by Brodermann to the Capdevila formation, LEWIS (1932, p. 539) earlier proposed the El Cano formation which he described as "thin-bedded clay shales, sandy shales, micaceous sandstones, sandstones and conglomerates with occasional thin limestone members, yellow to ochre in color and friable". As was already noted by BERMÚDEZ (1950, p. 229), the El Cano formation of Lewis is synonymous with PALMER's Capdevila formation. PALMER's (1934, pp. 129, 131) El Cano shales or El Cano member of the "Habana formation", regarded by this author as a western equivalent of his Big Boulder Bed–Dirty shale member of the "Habana formation", is a synonym of the Capdevila formation. This is evident from PALMER's geological map of the Habana area (1934, fig. 1). Although the Capdevila formation is a junior synonym of the El Cano formation of Lewis, the former name is in general use today and we are following, though somewhat reluctantly, BERMÚDEZ by suppressing El Cano formation and retaining Capdevila formation as a stratigraphic nomen conservandum. The Lucero beds of DEGOLYER (1918, p. 142), which were regarded as a synonym of the El Cano formation by LEWIS (1932, p. 539), most probably include among other lithologic units also the Capdevila formation. But the Lucero beds of DEGOLYER are a general term representative of all the predominantly clastic lithologies overlying the serpentine and underlying the predominantly non-clastic carbonate Eocene and younger Bejucal limestones and therefore so vaguely defined that they have no standing in modern stratigraphic work. BRODERMANN (1943, p. 121) again used the name Lucero and regarded his likewise vaguely defined Lucero formation as the upper beds of the Cretaceous or perhaps as Paleocene. They are most probably the same as or part of the Alkázar formation.

In his later and more comprehensive paper on the geology of Cuba, R. H. PALMER (1945, table 1 on p. 5, and pp. 16, 30) described the Capdevila formation as "... a thick series of shales, sandstones and a few conglomerates which is rather widely distributed in western Habana and eastern Pinar del Río provinces. It weathers to an ochreous brown soil.... Its scanty fauna is confined to Foraminifera and Radiolaria. Some of the Foraminifera are Midway Eocene in age. ... It is well exposed at Capdevila, 10 kilometers south of Habana." This author believed (1945, p. 30) that the "very siliceous content of the Cayetano formation furnished the sands and shales of the Paleocene Capdevila formation". In the same paragraph, Palmer stated that there is no unconformity between the "Habana formation" and the Capdevila formation.

As shown in the following stratigraphic table on page 321, we distinguish the lithologic units I to IV within the Capdevila formation. We were unable to definitely establish member or formation rank and no names will be introduced for the individual lithologic units. BERMÚDEZ (1950, p. 230), on the other hand, proposed for conglomerates composed of small calcareous pebbles which in places grade into friable sand and which are interbedded in the shales of the Capdevila formation, the name Lucero member of the Capdevila formation. This name was previously used in a different sense by DEGOLYER (1918, p. 142) and by BRODERMANN (1943, p. 121). According to BERMÚDEZ the Lucero beds are characterized by a suite of Lower Eocene larger Foraminifera such as *Eoconuloides wellsi* COLE and BERMÚDEZ, *Boreloides cubensis* COLE and BERMÚDEZ, *Cymbalopora cushmani* COLE and BERMÚDEZ [=*Eofabiania cushmani* (COLE and BERMÚDEZ)], *Discocyclina havanensis* COLE and BERMÚDEZ, *Discocyclina barkeri* VAUGHAN and COLE, *Miscellanea antillea* (HANZAWA) [="*Operculina*" *catenula* CUSHMAN and JARVIS], *Pseudophragmina cedarkeysensis* COLE. This lithologic and faunal description may correspond to the conglomeratic Unit III underlying the marly and sandy beds with *Globorotalia palmerae* CUSHMAN and BERMÚDEZ described in this paper as the youngest beds or Unit IV of the Capdevila formation, or it may also be a loose term for the designation of the coarser clastic beds in general of the Capdevila formation. In the stratigraphic chart dated February 24, 1948, BERMÚDEZ (1950) regarded the Lucero member as a lateral, lithologically different time equivalent of the Capdevila formation. This usage of the lithostratigraphic term member is not permissible. Concluding, it can be stated that the Lucero member of BERMÚDEZ does not seem to have a definite stratigraphic meaning and therefore is suppressed in the present paper.

Description of the type locality of the Capdevila formation

The type locality of the Capdevila formation is situated at the intersection of the highway from La Habana to Rancho Boyeros with the road to Arroyo Naranjo, 5.6 km south of the Palacio de los Deportes, coordinates 358.72 N and 356.13 E (index map, fig. 31). We studied and measured the type section in February 1958, when the building site of the factory of "Aceite El Cocinero" exposed the formation

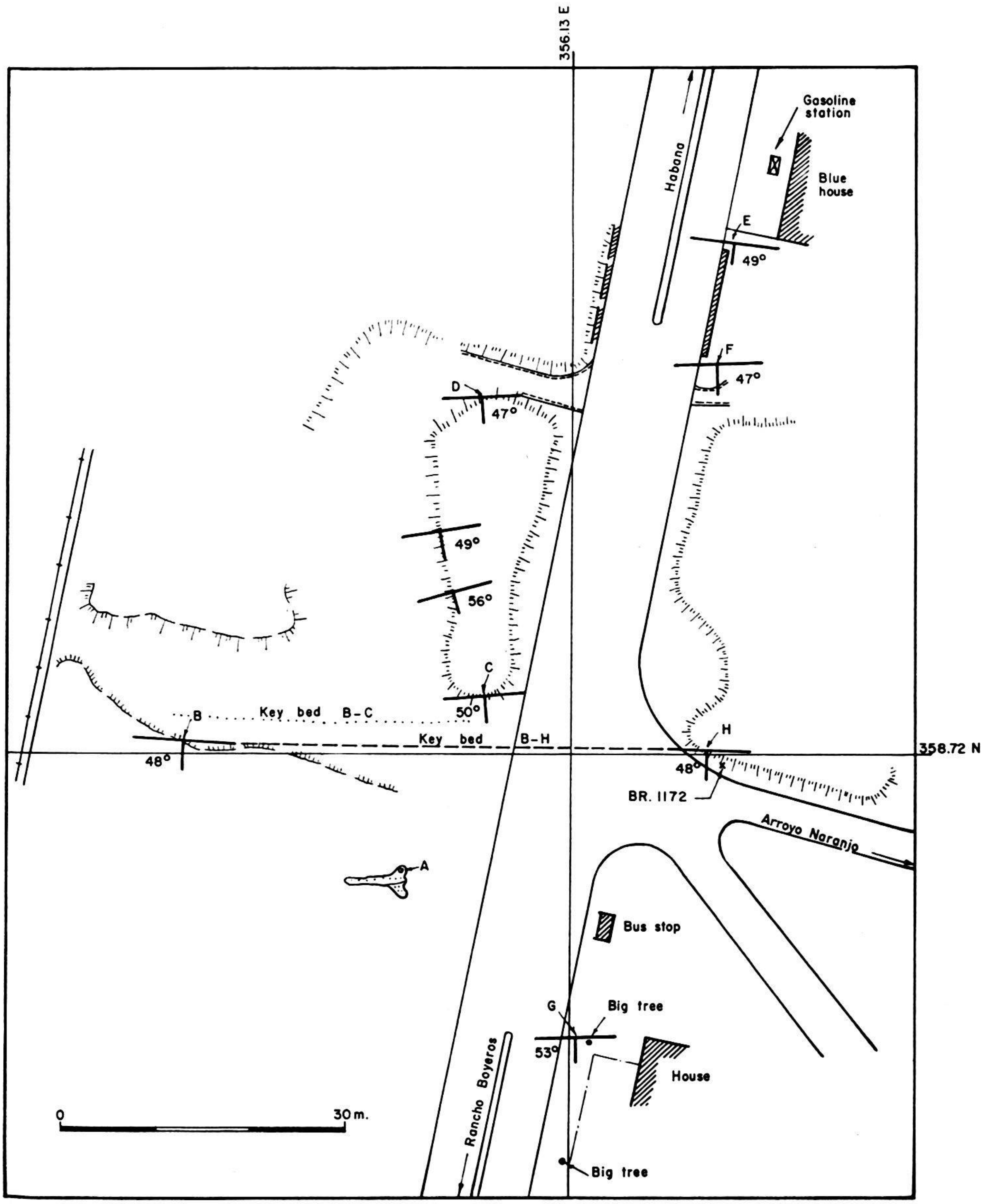


Fig. 31. Index map of the type locality of the Capdevila formation.

on the west side of the highway to Rancho Boyeros. As shown by the index map, the Capdevila formation is also outcropping on the eastern side of the highway. Presumably, the type locality will be partially concealed by the new factory buildings, but good outcrops of the Capdevila formation will always be found along fresh road cuts and at building sites in the vicinity of the type locality.

In the stratigraphic chart of the Capdevila formation (p. 321 of this paper), the type beds are designated as lithologic Unit II. They are represented by about 70 m of clastic sediments of which 55 % were exposed in 1958. The columnar section, fig. 32, illustrates a 38 m thick series of beds which are about 90 % outcropping. The cross section, fig. 34, shows the relationship of the total exposed section to the columnar section. The lithologies of the clastic beds range from very fine silty graywacke shales and silts to coarse graywacke sandstones and calcarenites and conglomerates with igneous derived components. The dominant color of fresh outcrops is brownish. Some of the beds are dark brown to reddish brown or orange, others are ochre to grayish and greenish. The silty shales are thin and soft, unctuous, occasionally calcareous. The "sandstone" may range from a calcarenite with few volcanic fragments to a typical non-calcareous graywacke, composed mainly of fragments derived from dark igneous rocks. The volcanic fragments are either green or weathered orange ferruginous minerals. The matrix of the graywackes is usually non-calcareous. However, some of the

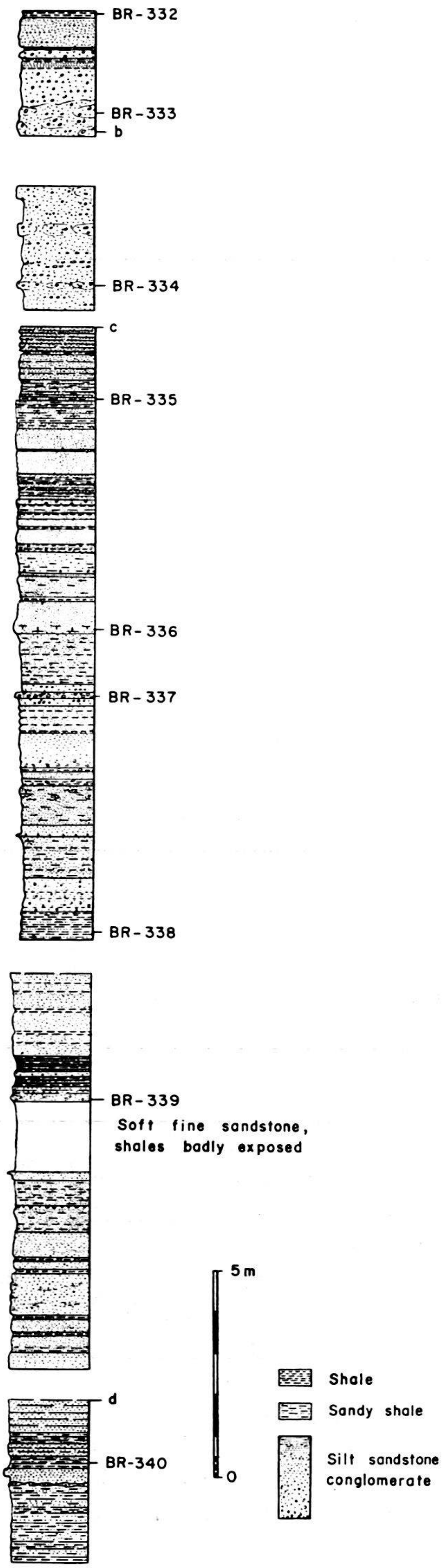


Fig. 32. Columnar section of the type locality of the Capdevila formation (lithologic Unit II).

harder beds and some of the nodules or concretions have a limey cement. The color of these limey "sandstone" inclusions is grayish-blue when unweathered. Microconglomerates with component size of 2 to 6 mm have also been observed. Some beds of coarse graywacke contain large pebbles in irregular lenticular accumulations (fig. 34). In the upper part of the type section as illustrated by the

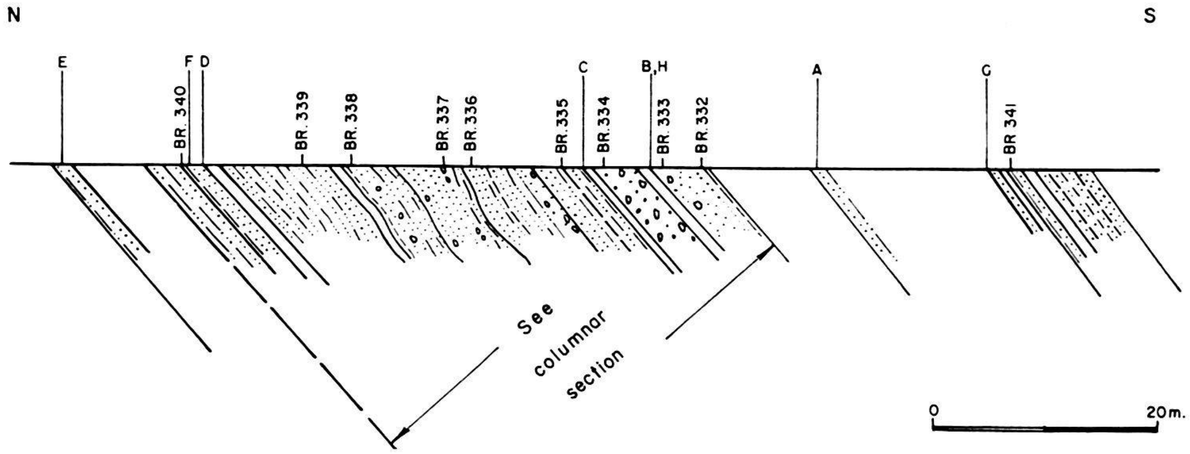


Fig. 33. Section across the type locality fo the Capdevila formation (lithologic Unit II).

columnar section, fig. 32, occur ellipsoid "sandstone" concretions which however are much smaller than those from the overlying conglomeratic part of the formation or lithologic Unit III.

In the conglomerates we distinguished the following types of pebbles:

a) Pebbles of brownish shaley to finely silty material ("galets mous", "clay" pebbles) which are derived from the immediately underlying silty and shaley Capdevila beds. They range in size from a few mm to 20 cm.

b) Pebbles of whitish, yellow or greenish hard dense limestone, not well-rounded, with diameters up to 10 cm. Texture and micro assemblages of these pebbles are described under BR stations 333, 334 and 337.

c) Pebbles of greenish well-rounded volcanic material, usually less than 1 cm in diameter.

The difference in roundness between the limestone and igneous pebbles may suggest that the igneous pebbles were subjected to a longer transport than the limestone components or that they were reworked from older conglomerates consisting of igneous pebbles. Thin sections, however, show the opposite picture with usually angular igneous fragments and rounded limestone components.

Apart from the pebbles, there occur in the Capdevila formation and in other shaley beds, especially in the late Upper Cretaceous Vía Blanca formation, small, white, soft, calcareous pebble-like concretions considered to be of Recent origin and apparently caused by weathering. The same white material is also found in joints and veins of these formations. A related Recent formation is the so-called calcite mesh, a weathering phenomenon occurring along the contacts of serpentinites and limestones. In Las Villas Province, drilling has shown that the calcite mesh is a superficial formation (WASSALL, 1956, p. 10).

In graded beds of the Capdevila type section, the sequence can be: fine to coarse, or coarse to fine, or fine to coarse to fine, or coarse to fine to coarse. These irregularities indicate that the type beds of the Capdevila formation were deposited by irregular submarine currents, which sometimes were strong enough to transport pebbles of 10 cm diameter and to erode shaley beds, and sometimes barely able to move particles of a diameter of 0.1 mm.

The relative stratigraphic position of the samples from the type locality described below is indicated in the columnar section, fig. 32, and in the cross section, fig. 33. The stations are here listed from bottom to top:

BR station 340
Lithology: Shale, silty, friable, non-calcareous, moderately yellow brown.
Washed residue barren.

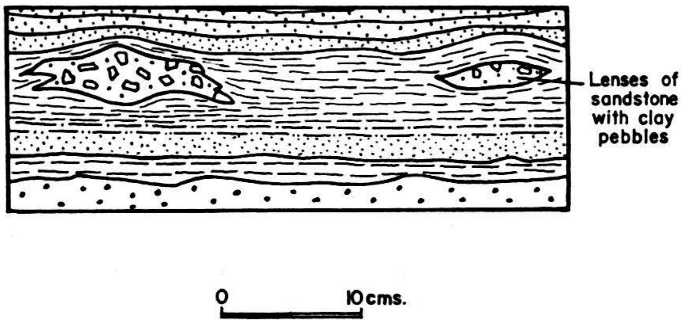


Fig. 34. Lithologic detail of the type locality of the Capdevila formation.

BR station 339
Lithology: Graywacke sandstone–siltstone, calcareous, laminated pale yellow brown.

Texture: Fragmental to pseudoölitic. Components are angular to subangular dark igneous grains, limestone pseudoölites and organic fragments. Each group makes up about 50 % of the components. Matrix fairly coarsely recrystallized calcite. Rare planktonic Foraminifera.

Assemblage: *Globorotalia* sp. (truncate form)
Globigerina sp. with spinose test
Chiloguembelina sp.

BR station 338
Lithology: Shale, silty, friable, non-calcareous, dark yellow orange.
Washed residue barren.

BR station 337

Thin section 1

Lithology: Shale, silty, calcareous, rather soft, grayish orange. This shale is from a pebble enclosed in a coarse graywacke sandstone as described from BR station 339.

Texture: Cryptocrystalline to argillaceous groundmass with minute angular quartz grains and dark igneous grains. Microlamination through linear arrangement of these grains. Matrix fairly coarsely recrystallized calcite.

Assemblage: *Globorotalia broedermanni* CUSHMAN and BERMÚDEZ
Globigerina spp. with thick spinose walls
Coccoliths (common)
Discoaster lodoensis BRAMLETTE and RIEDEL (rare)
Thoracosphaera sp. (rare).

Thin section 2

Lithology: Graywacke sandstone, fairly coarse-fragmental, calcareous, grayish orange.
Texture: Mainly angular to subangular dark igneous grains. Also rounded to subangular limestone, shale and organic fragments. Diameter of average components from about 60 to 600 μ. Matrix fairly coarsely recrystallized calcite.

Assemblage: a) Shale component as described in thin section 1 of BR station 337
Globorotalia broedermanni CUSHMAN and BERMÚDEZ
Globigerina spp. with thick spinose walls
Coccoliths (common)
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Discoaster lodoensis BRAMLETTE and RIEDEL (rare)
b) Limestone component, pseudoölitic. Barren.
c) Limestone component, dense argillaceous. Barren.

BR station 336
Lithology: Graywacke siltstone, calcareous, light brown.
Texture: Fragmental to pseudoölitic, unsorted. Angular to subangular igneous and rounded limestone components, rare algal fragments and planktonic and a few benthonic Foraminifera. Diameter of average component ranges from about 30 to 180 μ. Matrix recrystallized calcite. As a whole similar to the texture of thin sections from BR station 339.

Assemblage: *Globorotalia* ex gr. *G. pseudoscitula* GLAESSNER
Globorotalia broedermanni CUSHMAN and BERMÚDEZ
Globigerina spp. with coarse perforations
Chiloguembelina sp.
Sponge spicules.

BR station 335
Lithology: Shale, silty, friable, calcareous, moderately yellow brown.

Washed residue with
Globorotalia aequa CUSHMAN and RENZ
Globorotalia aff. *conicotruncata* SUBBOTINA (see SUBBOTINA, 1953, pl. 20, figs. 11 a–c)
Globorotalia aff. *planoconica* SUBBOTINA
Globorotalia broedermanni CUSHMAN and BERMÚDEZ
Globorotalia aff. *convexa* (SUBBOTINA)
Globorotalia pseudoscitula GLAESSNER

Globorotalia imitata Subbotina
Globigerina prolata Bolli
Globigerina soldadoensis Brönnimann group
Pseudohastigerina micra (Cole).

BR station 334
Lithology: Shale, hard, somewhat silty, calcareous, pale yellow brown. This is a pebble in coarse graywacke sandstone.
Texture: Microcrystalline to argillaceous groundmass with minute angular dark brown and green igneous grains.
Assemblage: *Globorotalia* ex gr. *G. pseudoscitula* Glaessner.

BR station 333
Lithology: Shale, calcareous, greenish gray (thin section 2), embedded in sandstone (thin section 1). The shale is from a pebble in graywacke sandstone as described from thin section 2 of BR station 337.

Thin section 1
Texture: As BR station 337, thin section 2.
Assemblage: Limestone component:
Globigerina spp. with coarse perforations
Discoasterids (rare), poorly preserved, of the group of *Marthasterites tribrachiatus* (Bramlette and Riedel)
Vaughanina cubensis D. K. Palmer (reworked)

Thin section 2
Texture: Microcrystalline to argillaceous groundmass with some small angular quartz grains and dark igneous grains. Abundant planktonic Foraminifera. This texture is from the shale pebble embedded in the graywacke sandstone.
Assemblage: *Globorotalia broedermanni* Cushman and Bermúdez
Globorotalia ex gr. *G. pseudoscitula* Glaessner
Globigerina spp. with thick walls and coarse perforations
Discoaster cf. *lodoensis* Bramlette and Riedel
Thoracosphaera sp.

BR station 332
Lithology: Shale, silty, friable, calcareous, dark yellow orange to moderately yellow brown.
Washed residue with
Globorotalia aequa Cushman and Renz
Globorotalia wilcoxensis Cushman and Ponton
Globorotalia pseudoscitula Glaessner (common)
Globorotalia planoconica Subbotina (see Subbotina, 1953, pl. 17, figs. 4, 5)
Globorotalia elongata Glaessner
Globorotalia cf. *perclara* Loeblich and Tappan
Globigerina soldadoensis Brönnimann group
Globigerina linaperta Finlay

Globigerina taroubaensis Brönnimann
Globigerina prolata Bolli
Globigerina triangularis White
Pseudohastigerina micra (Cole) (common).

BR station 341
Lithology: Shale, silty, calcareous, pale yellow brown to moderately yellow brown. Washed residue with

Globorotalia cf. *aragonensis* Nuttall (not clearly keeled forms)
Globorotalia aequa Cushman and Renz
Globorotalia aff. *spinuloinflata* (Bandy)
Globorotalia elongata Glaessner
Globorotalia pseudoscitula Glaessner
Globorotalia broedermanni Cushman and Bermúdez (common)
Globigerina soldadoensis Brönnimann group
Globigerina linaperta Finlay
Globigerina prolata Bolli
Pseudohastigerina micra (Cole).

BR station 1172 is from the key bed k–h of the Capdevila type locality exposed at the corner formed by the highway to Rancho Boyeros with the road to Arroyo Naranjo (index map, fig. 31).

BR station 1172
Lithology: Graywacke sandstone, calcareous, pale yellowish brown, with larger inclusions of pale yellowish orange shale.
Texture: Fragmental to pseudoölitic, unsorted. Components are loosely packed mainly angular to subangular fragments of sedimentary and dark igneous rocks. Also some larger Foraminifera and mollusk and algal fragments. Diameter of average components from about 100 to 600 μ. Matrix clear calcite, unfossiliferous.
Assemblage: *Discocyclina* sp.
Globigerinas with spinose tests
Globorotalia sp. (truncate form)
Lithoporella melobesioides Foslie
Distichoplax biserialis (Dietrich)

A reworked fragment of a coccolithite possibly of Alkázar origin contains:
Discoaster multiradiatus Bramlette and Riedel
Discoaster bebalaini Tan
Tremalithus eopelagicus Bramlette and Riedel
Thoracosphaera sp.

BR stations 1173 and 1174 are from a well exposed and easily accessible outcrop of graywacke silts and sandstones at the main entrance to Central Toledo, north of Capdevila on the western side of the Rancho Boyeros highway, coordinates 357.85 N and 355.95 E. This outcrop is here correlated faunally and lithologically with the graywacke silts and sandstones of the type section of the Capdevila formation (lithologic Unit II).

BR station 1173
Lithology: Graywacke siltstone, calcareous, friable, light brown.
Washed residue with

Globorotalia pseudoscitula GLAESSNER
Globorotalia imitata SUBBOTINA
Globorotalia aff. *conicotruncata* SUBBOTINA
Globorotalia broedermanni CUSHMAN and BERMÚDEZ
Globorotalia elongata GLAESSNER
Globigerina cf. *taroubaensis* BRÖNNIMANN
Globigerina triangularis WHITE
Globigerina soldadoensis BRÖNNIMANN group
Globigerina prolata BOLLI
Globigerina linaperta FINLAY.

BR station 1174
Lithology: Graywacke siltstone, calcareous, showing lamination and truncation of laminae suggesting intraformational erosion, pale yellowish brown.
Texture: Fragmental to pseudoölitic. Diameter of average components from about 50 to 150 μ. Components are angular fragments of mainly dark brown and green igneous rocks. Some cryptocrystalline sedimentary fragments and common planktonic microfossils. Matrix recrystallized calcite.
Assemblage: Globigerinas with spinose tests
Globorotalias with distinct keel ex gr. *G. pseudoscitula* GLAESSNER
Coccoliths (rare).

Other outcrops of the Capdevila formation

Before entering on the description of other outcrops, we will briefly discuss the various lithologic units distinguished in the Capdevila formation, their microfaunal assemblages and their stratigraphic sequence.

As shown in the following stratigraphic table, we subdivide the Capdevila formation from bottom to top into the lithologic Units I to IV. Some or each one of these units may be of member or possibly even of formation rank. But because the contacts were not well exposed and the outcrop pattern was inadequate, we were unable to establish definite relationships between them. From the contacts with the underlying Alkázar formation and the overlying Universidad formation however, the lithologies of the basal Unit I and of the top Unit IV could be recognized and stratigraphically defined in respect to the underlying and overlying formations. The type section of the Capdevila formation is representative lithologically of Unit II, which according to our observations is faunally younger than the basal Unit I and older than the transitional Unit IV. Based on field observations, the graywacke "sandstones" with the large Capdevila concretions and the pebble- to boulder-sized igneous and limestone conglomerates of Unit III were tentatively placed above the lithologically somewhat related but finer clastic type locality Unit II. The beds of Unit III lack diagnostic microfaunas and from the faunal aspect alone they could also be put between the basal unit and the type locality lithologies.

Stratigraphic table, showing the subdivisions of the Capdevila formation into lithogloic units, their typical outcrops and diagnostic Foraminifera.

Units	Lithologies and diagnostic Foraminifera	Typical localities
IV	Chalks and chalky shales and silts. Overall color: white to yellow to orange brown. *Globorotalia palmerae* CUSHMAN and BERMÚDEZ *Globorotalia pseudoscitula* GLAESSNER *Globorotalia aragonensis* NUTTALL	Autopista del Mediodía. Tejar Consuelo.
III	Graywacke sandstones and pebble to boulder sized conglomerates. Large concretions. Overall color: orange brown to brown. No diagnostic microfauna.	Road cut about 2.2 km southeast of Capdevila on road from Capdevila to Arroyo Naranjo.
II	Graywacke siltstones, sandstones and silty shales. Microconglomerates. Small concretions. Overall color: yellow brown to orange brown. *Globorotalia broedermanni* CUSHMAN and BERMÚDEZ *Globorotalia pseudoscitula* GLAESSNER *Globorotalia aragonensis* NUTTALL (ancestral forms).	Type locality of Capdevila formation at Capdevila. Entrance to Central Toledo. Corner Calle 26 and highway to Rancho Boyeros.
I	Graywacke siltstones and sandstones, silty shales and shaley marls. White intercalations of radiolarites-coccolithites and calcilutites with *Chondrites*. Overall color: light yellow to brown. *Globorotalia rex* MARTIN *Globorotalia formosa* BOLLI *Globorotalia wilcoxensis* CUSHMAN and PONTON *Globorotalia quetra* BOLLI *Eoconuloides wellsi* COLE and BERMÚDEZ *Dictyoconus cookei* MOBERG *Eofabiania cushmani* (COLE and BERMÚDEZ)	San Juan de Dios Hospital. Repartos Alta Habana, Capri and Veracruz.

The Capdevila formation is the end-phase of the clastic flysch-type sedimentation of the Habana group. By nature of its usually transitional contact with the Universidad formation of the carbonate Marianao group it combines features of both types of sedimentation. Lithologic units I, II and III consist of clastic sediments, including the *Chondrites*-bearing "limestones" and the radiolarite–coccolithite intercalations of Unit I which are very fine-grained calcilutites. The chalks and chalky shales of Unit IV, on the other hand, are already closely allied with the quiet carbonate sedimentation of the Marianao group.

Faunally, the lithologic units are also different. Unit I, which overlies the Lower Eocene *Globorotalia velascoensis–Globorotalia pseudomenardii* zone of the Alkázar formation is characterized by *Globorotalia rex* MARTIN, *Globorotalia formosa* BOLLI group, *Globorotalia wilcoxensis* CUSHMAN and PONTON, and *Globorotalia quetra* BOLLI. The larger benthonic forms *Eoconuloides wellsi* COLE and BERMÚDEZ, *Eofabiania cushmani* (COLE and BERMÚDEZ) and *Dictyoconus cookei* MOBERG appear in this zone for the first time. This assemblage of planktonic and benthonic species is representative of the Lower Eocene *Globorotalia rex–Globorotalia formosa* zone. The beds of Unit II yield a strongly differing assemblage with the diagnostic *Globorotalia broedermanni* CUSHMAN and BERMÚDEZ, *Globorotalia* *pseudoscitula* GLAESSNER and the first ancestral forms of *Globorotalia aragonensis* NUTTALL. The specimens of Unit II are generally much smaller and more delicate than those from the other lithologic groups. We refer the type locality assemblage to the lower Eocene *Globorotalia broedermanni–Globorotalia pseudoscitula* zone, which overlies the *Globorotalia rex–Globorotalia formosa* zone. No diagnostic microfauna was recorded from Unit III. The transitional Unit IV contains the spinose *Globorotalia palmerae* CUSHMAN and BERMÚDEZ, *Globorotalia pseudoscitula* GLAESSNER, and well developed specimens of *Globorotalia aragonensis* NUTTALL. The fauna of Unit IV is here assigned to the Lower Eocene *Globorotalia palmerae* zone which overlies the *Globorotalia broedermanni–Globorotalia pseudoscitula* zone and underlies the late Lower Eocene *Globorotalia aragonensis–Globorotalia bullbrooki* zone of the basal Universidad formation.

Outcrops of lithologic Unit I

Toward its base, the Capdevila formation is generally more shaley than the type locality beds of the lithologic Unit II. Between graywacke sands and silts and shales occur intercalations of thin, white to yellowish brown calcilutites and chalky shales with *Chondrites* and rather hard, white to yellowish conchoidal fracturing shaley calcilutaceous radiolarites–coccolithites. As can be observed in the outcrop area of Reparto Capri, some of the thicker sandy beds are graded and other beds show no grading at all. At the base of coarser sand beds we observed micro-conglomerates with angular to subangular "clay" pebbles. Occasionally we noticed larger "clay" pebbles of up to 10 cm diameter. The sedimentation is cyclic. The cycle starts with sands or silts and ends with bentonitic shales or with white to yellowish calcilutaceous radiolarites–coccolithites.

Sanatorio San Juan de Dios

The shaley basal part of the Capdevila formation crops out typically east of the Sanatorio San Juan de Dios, about 1.5 km northwest of Arroyo Naranjo, coordinates 357.98 N and 358.80 E. Here the Capdevila formation appears to be in transitional or perhaps disconformable contact with the underlying Alkázar formation. The following is a random sample from this locality:

BR station 400

Lithology: Calcilutite, shaley, slightly calcareous, hard, conchoidal fracturing, laminated, white to yellowish gray (coccolithite–radiolarite).

Texture: Cryptocrystalline to argillaceous groundmass, with microlamination through sorting and linear accumulation of dark argillaceous material. Very small irregularly distributed angular igneous particles. Abundant planktonic microfossils, mainly Radiolaria, discoasterids and coccoliths.

Assemblage:
- Radiolaria (common)
- Coccoliths, mainly placoliths (abundant)
- *Thoracosphaera* spp. (minute globular and ellipsoid bodies of about 20 to 30 μ diameter (abundant)
- *Tremalithus eopelagicus* BRAMLETTE and RIEDEL

Discoaster aster BRAMLETTE and RIEDEL
Marthasterites tribrachiatus BRAMLETTE and RIEDEL
Marthasterites sp.
Discoaster sp. affin to minute forms of *D. multiradiatus* BRAMLETTE and RIEDEL
Small discs of about 5 to 7 μ diameter, with central knob and 14 to 16 distally pointed radii as in BR station 539, Alkázar formation.
Discoaster cf. *woodringi* BRAMLETTE and RIEDEL
Forms intermediate between *D. aster* and *D. woodringi* BRAMLETTE and RIEDEL.
Discoaster lodoensis BRAMLETTE and RIEDEL
Specimens usually somewhat corroded.
Discoaster sp. close to *D. barbadiensis* TAN, but without central knob
Test with 11 more or less sharply pointed arms, which are spirally arranged in center of disc. Diameter 12 to 15 μ.
Discoaster barbadiensis TAN
Braarudosphaera discula BRAMLETTE and RIEDEL
Braarudosphaera bigelowi (GRAN and BRAARUD)
Globigerina spp. } minute forms
Chiloguembelina spp. }
Nannoconus truitti BRÖNNIMANN } reworked
Nannoconus steinmanni KAMPTNER }

Reparto Capri

South of the type locality of the Alkázar formation, the basal beds of the Capdevila formation are well exposed (index map, fig. 27). The contact with the underlying Alkázar formation, however, was masked when the discontinuous section of about 110 m was measured (columnar section, fig. 35). About 60 to 70 % of the section consist of whitish to light brown shales. Interbedded are 10 to 25 cm thick beds of fine-grained, brownish graywackes. In intervals of 6 to 15 m there occur 0.8 to 2.5 m thick beds of coarse calcarenaceous graywacke, which sometimes are conglomeratic with mainly shaley elements up to 1 cm in diameter. Near the top of the section there is a whitish, faintly limey, minutely clastic Radiolaria-bearing bed. This bed, the key bed in diagrams, BR station 535, is continuous and shows clearly the folding of the Capdevila formation. We followed it over some distance whereas the graywacke beds as a rule pinch out rapidly as shown by the detail of the columnar section, fig. 36.

The relative stratigraphic position of the samples collected at Reparto Capri is shown in the columnar section, fig. 35, of which the location is shown on the map, fig. 27; the structure of the area is explained by the cross-section, fig. 28. They are here listed from bottom to top:

BR station 822
Lithology: Marl, shaley, white.
Washed residue with Eocene spumellarias and nassellarias.

BR stations 814, 816, 819, and 821

These stations are lithologically and faunally very similar and here summarized to avoid repetition. Stratigraphically they are listed from top to bottom in numerical order.

Lithologies: Graywacke sandstone, slightly calcareous, with large, irregularly distributed "clay" pebbles, dark yellowish orange.

Textures: Fragmental to pseudoölitic unsorted. Diameter of average components from about 150 to 700 μ, some large discrete inclusions of shale up to 1800 μ in diameter. Components are subangular to angular dark brown and green igneous grains and subrounded fragments of mollusks, algae, sedimentary rocks, and larger Foraminifera. Matrix recrystallized calcite.

Assemblages: *Dictyoconus cookei* MOBERG (a single, somewhat doubtful oblique section)
Eoconuloides wellsi COLE and BERMÚDEZ
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Globorotalia sp. (truncate form) (in reworked fragment)
Vaughanina cubensis D. K. PALMER (reworked).

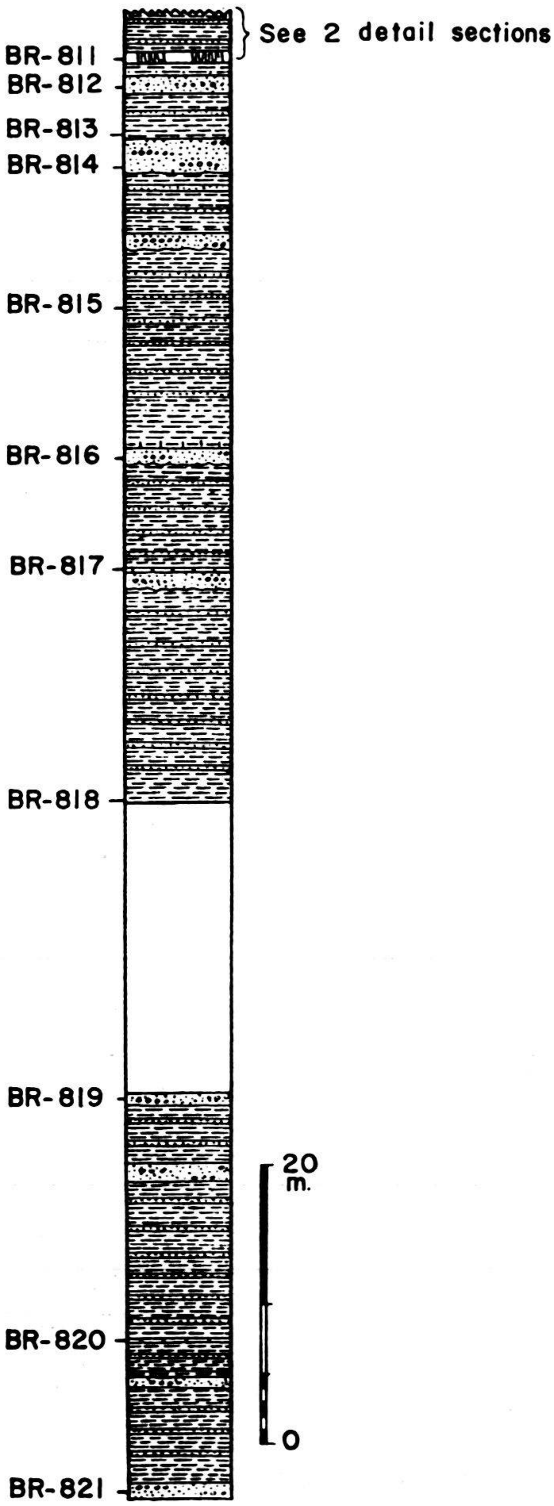


Fig. 35. Columnar section, Reparto Capri.

BR station 820

Lithology: Calcilutite, shaley, hard, conchoidal fracturing, very pale orange to pale yellowish orange (coccolithite).

Texture: Cryptocrystalline to argillaceous groundmass, with abundant minute angular fragments and planktonic microfossils.

Assemblage: Coccoliths (common)
Discoaster sp. close to *D. barbadiensis* TAN, but without central knob
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL)
Thoracosphaera sp.

Chiloguembelina spp. } minute forms
Globigerina spp. }

BR station 818

Lithology: Marl, shaley, grayish orange.

Washed residue with

Globorotalia formosa BOLLI group
Globorotalia cf. *whitei* (WEISS)
Globorotalia cf. *conicotruncata* SUBBOTINA
Globorotalia wilcoxensis CUSHMAN and PONTON
Globorotalia pseudomenardii BOLLI group
Globigerina soldadoensis BRÖNNIMANN group
Globigerina prolata BOLLI
Globigerina linaperta FINLAY
Globigerina cf. *taroubaensis* BRÖNNIMANN
Pseudohastigerina micra (COLE)
Eocene spumellarias and nassellarias.

BR station 817

Lithology: Calcilutite, shaley, hard, conchoidal fracturing, with manganese dendrites, pale yellowish orange (coccolithite).

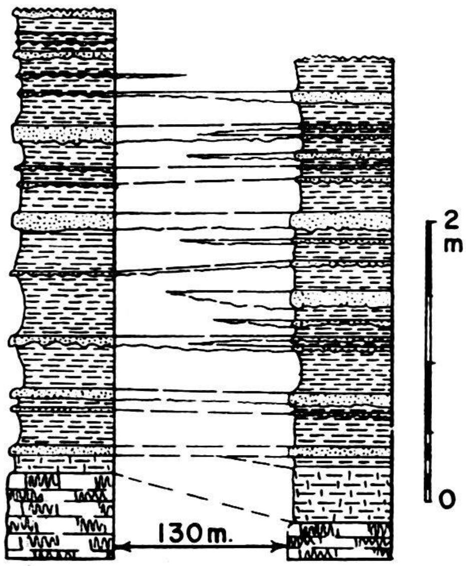


Fig. 36. Detail of the columnar section, Reparto Capri.

Texture: Same as BR station 820.

Assemblage: Coccoliths (common)
Discoaster sp. close to *D. barbadiensis* TAN, but without central knob
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL)
Thoracosphaera sp. (common).

BR station 815

Lithology: Calcilutite, marly, grayish, yellow.

Washed residue with

Globorotalia cf. *rex* MARTIN (small specimen)
Globigerina linaperta FINLAY
Globigerina soldadoensis BRÖNNIMANN group
Globigerina cf. *taroubaensis* BRÖNNIMANN
Pseudohastigerina micra (COLE)
Eocene spumellarias and nassellarias.

BR station 813
Lithology: Marl, shaley, moderate yellowish brown to grayish orange.
Washed residue with

Globorotalia pseudomenardii BOLLI group
Globigerina prolata BOLLI
Pseudohastigerina micra (COLE)
Eocene spumellarias and nassellarias.

BR station 812
Lithology: Graywacke sandstone, calcareous, with layers of larger "clay" pebbles, moderate yellowish brown to grayish orange.
Texture: Same as BR station 814.
Assemblage:

Globorotalia spp. (truncate forms)
Globigerinas with thick and coarsely perforate walls
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Discocyclina sp.
Eofabiania cushmani (COLE and BERMÚDEZ)
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE.

BR station 811
Lithology: Calcilutite, shaley, somewhat silicified, hard, conchoidal fracturing, white to yellowish gray (radiolarite).
Texture: Cryptocrystalline to argillaceous groundmass with abundant Radiolaria, coccoliths and discoasterids.
Assemblage:

Radiolaria
Coccoliths, mainly placoliths
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN
Discoaster sp. close to *D. barbadiensis* TAN, but without central knob
Discoaster lodoensis BRAMLETTE and RIEDEL
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL) with wide variation in thickness and length of arms
Marthasterites sp.
Braarudosphaera bigelowi (GRAN and BRAARUD)
Thoracosphaera sp.
Chiloguembelina spp. } minute forms
Globigerina spp. }

The following stations are situated south of above section. BR station 534 is from below and BR station 533 from above the key bed, which is represented by BR station 535, thin section 2, and BR station 811:

BR station 534

Lithology: Graywacke sandstone, coarse-grained, slightly calcareous, pale yellowish brown.

Texture: As thin section of BR station 533, but larger fragments. Diameter of average components from about 70 to 500 μ. Igneous material is dominant. Limestone pseudoölites are larger and more common than in BR station 533. Also fragments of coralline algae.

Assemblage: *Globigerina soldadoensis* Brönnimann group
Globigerina spp. with thick walls and coarse perforations
Vaughanina cubensis D. K. Palmer (reworked)
Lithoporella melobesioides Foslie.

BR station 535

Thin section 1

Lithology: Calcarenite, rather coarse-grained, yellowish gray.

Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components ranges from about 150 to 700 μ. Components mainly angular to rounded fragments of algae, mollusks, echinoderms, larger Foraminifera, and of cryptocrystalline sediments. Rare igneous grains. Matrix recrystallized calcite.

Assemblage: "*Operculina*" *catenula* Cushman and Jarvis
"*Amphistegina*" *lopeztrigoi* D. K. Palmer
Globigerinas with spinose tests
Globorotalia spp. (truncate forms)
Pseudophragmina sp. or *Proporocyclina* sp.
Discocyclina barkeri Vaughan and Cole
Discocyclina sp.
Lithoporella melobesioides Foslie
Vaughanina cubensis D. K. Palmer (reworked).

Thin section 2

Lithology: Calcilutite, hard, slightly siliceous, with manganese dendrites, very pale orange (radiolarite–coccolithite).

Texture: Cryptocrystalline to argillaceous groundmass with abundant Radiolaria, discoasterids, coccoliths and planktonic Foraminifera.

Assemblage: Radiolaria
Coccoliths
Marthasterites tribrachiatus (Bramlette and Riedel) (Forms with thick arms and bluntly pointed not indentated tips)
Discoaster sp. *close* to *D. barbadiensis* Tan, but without central knob. Partly with longer and more pointed arms than the specimen illustrated by Bramlette and Riedel (1959, pl. 39, fig. 5a) (corroded specimens of *D. lodoensis* ?)

Discoaster lodoensis BRAMLETTE and RIEDEL
Discoaster cf. *aster* BRAMLETTE and RIEDEL
Braarudosphaera discula BRAMLETTE and RIEDEL
Thoracosphaera spp. (minute ellipsoid to globular bodies)
Globorotalia broedermanni CUSHMAN and BERMÚDEZ
Globorotalia pseudoscitula GLAESSNER group
Chiloguembelina sp. (minute forms)
Globigerinas with spinose tests.

Thin section 3

Lithology: Graywacke sandstone, non-calcareous, light brown to dark yellowish orange.

Texture: Predominantly angular to subangular, unsorted, dark igneous grains and quartz grains. Some pseudoölitic limestone and algal components. Diameter of average components from about 100 to 500 μ. Groundmass coarsely recrystallized.

Assemblage: "*Amphistegina*" *lopeztrigoi* D. K. PALMER
Eofabiania cushmani (COLE and BERMÚDEZ)
Proporocyclina sp. or *Pseudophragmina* sp. (fragments only)
Discocyclina sp. (fragments only)
Globigerina spp. with coarse perforations
Radiolaria
Lithoporella melobesioides FOSLIE
Sulcoperculina sp. (reworked).

BR station 533

Lithology: Graywacke siltstone, shaley, slightly calcareous, yellowish gray.

Texture: Abundant small angular dark igneous grains and quartz grains and rare pseudoölitic limestone fragments in microcrystalline groundmass. Diameter of average components ranging from about 10 to 100 μ.

Assemblage: *Globorotalia aequa* CUSHMAN and RENZ
Globigerina sp. with spinose test
Radiolaria (common).

Washed residue with
Globigerina prolata BOLLI (as illustrated in LOEBLICH et al., 1958, pl. 35, figs. 7a, b)
Pseudohastigerina micra (COLE)
Eocene spumellarias and nassellarias.

Alta Habana

Another outcrop of the basal unit of the Capdevila formation is about 600 m north of the Reparto Alta Habana on the highway to Rancho Boyeros, coordinates 361.12 N and 356.77 E. This locality is described under Apolo formation (index map, fig. 25). The dominantly shaley base of the Capdevila formation is well exposed above the underlying Alkázar formation. A section of about 45 m was measured. It is composed of silty shales in beds of 50 cm to 1 m thickness, interbedded graywacke sandstones and more or less calcarenaceous graywackes. The shales are here mainly of whitish to ochre color which contrasts with the mainly brownish color of the type locality beds. In the lower 20 to 25 m of the section there are a few irregular intercalations of relatively coarse calcarenaceous graywacke. Higher in the section, the clastics are fine, brownish graywackes in regular 10 to 20 cm thick beds. The percentage of graywackes increases toward the top of the exposed section where the shaley beds are only 20 to 50 cm thick. The relative stratigraphic position of the samples is indicated in the columnar section (fig. 26). They are here listed from bottom to top:

BR station 798
Lithology: Shale, silty, pale greenish yellow.
Washed residue with large and well-preserved Eocene spumellarias and nassellarias.

BR station 797
Lithology: Graywacke-calcarenite, yellowish gray.
Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components from about 150 to 700 μ. Components are dark brown and green igneous grains and fragments of mollusks, echinoderms, algae, sedimentary rocks and larger Foraminifera. Matrix recrystallized calcite.

Assemblage:
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Eoconuloides wellsi COLE and BERMÚDEZ
Pseudophragmina sp.
Pseudophragmina sp. or *Proporocyclina* sp.
Asterocyclina sp.
Discocyclina sp.
Globorotalia spp. (truncate forms)
Globigerina spp. with spinose walls and coarse perforations
Lithoporella melobesioides FOSLIE
Distichoplax biserialis (DIETRICH).

BR station 796
Lithology: Graywacke siltstone, calcareous, yellowish gray.
Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components from about 30 to 100 μ. Components are angular dark brown and green igneous fragments and cryptocrystalline, subangular to rounded fragments of sedimentary rocks, algae and mollusks. Common planktonic Foraminifera. Matrix cryptocrystalline to microcrystalline calcite.

Assemblage:
Globorotalia spp. (truncate forms)
Globigerina spp. with spinose tests
Tremalithus eopelagicus BRAMLETTE and RIEDEL and other coccoliths.

Washed residue with
Globorotalia aequa CUSHMAN and RENZ
Globorotalia pseudomenardii BOLLI group
Globigerina soldadoensis BRÖNNIMANN group
Globigerina cf. *velascoensis* CUSHMAN

Globigerina triangularis WHITE
Globigerina linaperta FINLAY
Eocene spumellarias and nassellarias.

BR station 795
Lithology: Graywacke siltstone, calcareous, grayish yellow.
Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components ranging from about 50 to 120 μ. Components angular mainly dark brown and green igneous grains and rounded fragments of cryptocrystalline sedimentary rocks. Also some algal, echinoderm and mollusk fragments. Matrix recrystallized calcite. Nannoplankton absent.

Assemblage: Globigerinas with spinose walls
Globorotalia spp. (truncate forms)
Lithoporella melobesioides FOSLIE

Washed residue with
Globorotalia rex MARTIN
Globorotalia wilcoxensis CUSHMAN and PONTON
Globorotalia aff. *whitei* (WEISS)
Globigerina soldadoensis BRÖNNIMANN group
Globigerina primitiva FINLAY
Eocene spumellarias and nassellarias (large specimens as in BR station 793).

BR station 794
Lithology: Marl, shaley, pale greenish yellow to yellowish gray.

Washed residue with
Globorotalia aff. *imitata* SUBBOTINA
Eocene spumellarias and nassellarias.

BR station 793
Lithology: Marl, shaley, grayish yellow.
Washed residue with large and well-preserved Eocene spumellarias and nassellarias.

Area between the Avenida de los Presidentes and the Escuela Quimica de la Universidad

As shown in the index map, fig. 49, and in the columnar section, fig. 51, the Príncipe member of the Universidad formation is overlying at the corner of Avenida de los Presidentes and Avenida de la Universidad apparently unconformably about 2 m of irregularly bedded, reddish brownish to brown gypsum-bearing graywacke silts and shales with abundant Radiolaria. Capdevila and Universidad beds of this outcrop are illustrated by the photograph fig. 37. These graywackes are here correlated on lithologic and faunal grounds with Unit I of the Capdevila formation although the contact with the presumably underlying Alkázar formation is not exposed. BR station 346 is from the bottom and BR station 347 from the top of these beds.

BR station 346
Lithology: Shale, silty, moderate brown.
Washed residue with Eocene spumellarias and nassellarias.

BR station 347
Lithology: Shale, silty, pale brown to moderate brown.
Washed residue with Eocene spumellarias and nassellarias, contaminated with Universidad globigerinas.

Near the Escuela de Filosofía y Letras and the Escuela Quimica of the University of Habana, between Calle Zapata and Avenida de la Universidad, Radiolaria-bearing, alternating reddish to brownish and grayish brown shales, and graywacke silts and sands underlie the Capdevila beds referred to above. Some of the sandy beds are graded from coarse to fine, other beds do not show, at least not macroscopically, any grading at all. The individual beds are relatively thin, clearly delimited and change abruptly. The sedimentary cycles start with sandy or silty

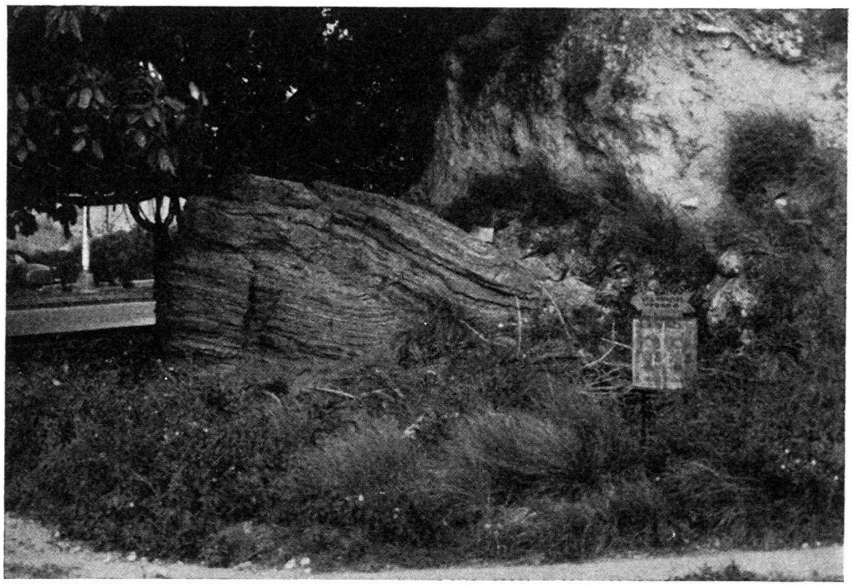


Fig. 37. Capdevila formation overlain by Toledo beds, Universidad formation, at the corner of Avenida de los Presidentes and Avenida de la Universidad.

beds and end with bentonitic shales. The samples listed below are from bottom to top of this outcrop:

BR stations 11 (bottom) to 15 (top)

Lithologies and faunas from these stations are very similar and here summarized to avoid repetition.
Lithologies: Shales, silty, non-calcareous, moderate yellowish brown to dark yellowish orange.
Washed residues with Eocene spumellarias and nassellarias, partly contaminated with Universidad globigerinas.

BR station 1003
Lithology: Shale, calcareous, grayish brown to moderate brown.
Washed residue with

Globorotalia rex Martin
Globorotalia quetra Bolli
Globorotalia wilcoxensis Cushman and Renz

Globigerina soldadoensis BRÖNNIMANN group
Globigerina linaperta FINLAY
Eoconuloides wellsi COLE and BERMÚDEZ
Vaughanina cubensis D. K. PALMER (reworked).

BR station 1004
Lithology: Shale, silty non-calcareous, dark yellowish orange.
Washed residue with Eocene spumellarias and nassellarias.

Additional samples with rich planktonic assemblages collected at a later time and which could not exactly be located with reference to above traverse, but which are from beds younger than BR station 15 and more or less equivalent stratigraphically with the samples from BR station 1003 and 1004, are represented by the following stations listed from bottom to top. BR station 1204 is about 1 m below the contact with the Universidad beds.

BR station 1200
Lithology: Siltstone, calcareous, with igneous influence, pale yellowish brown.
Washed residue with

Globorotalia aequa CUSHMAN and RENZ
Globorotalia rex MARTIN
Globorotalia formosa BOLLI group
Globorotalia aragonensis NUTTALL
Globorotalia wilcoxensis CUSHMAN and PONTON
Globorotalia whitei (WEISS)
Globorotalia quetra BOLLI
Globigerina linaperta FINLAY
Globigerina soldadoensis BRÖNNIMANN group
Globigerina prolata BOLLI
Globigerina primitiva FINLAY
Globigerina cf. *taroubaensis* BRÖNNIMANN
Globigerina triangularis WHITE
Rotalia capdevilensis CUSHMAN and BERMÚDEZ
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Eoconuloides wellsi COLE and BERMÚDEZ
Discocyclina sp.
Nassellarias and spumellarias (abundant)
Vaughanina cubensis D. K. PALMER (reworked).

BR station 1201
Lithology: Siltstone, calcareous, with igneous influence, pale yellowish brown.
Texture: Microcrystalline groundmass with igneous grains and pseudoölitic pellets of cryptocrystalline dense limestone. Abundant planktonic Foraminifera and some fragments of algae and of larger Foraminifera.

Assemblage: *Globorotalia* spp. (truncate forms)
Globigerinas with thick and coarsely perforated walls
Eoconuloides wellsi COLE and BERMÚDEZ
"*Amphistegina*" *lopeztrigoi* D. K. PALMER

Proporocyclina sp. or *Pseudophragmina* sp.
Discocyclina sp.
Lithoporella melobesioides FOSLIE.

Washed residue as BR station 1200.

BR station 1202
Lithology: Shale, slightly calcareous, with manganese dendrites, pale yellowish brown. Barren.

BR station 1203
Lithology: Shale, non-calcareous, silty, friable, moderate yellowish brown to dark yellowish orange.
Washed residue with large and well-preserved Eocene spumellarias and nassellarias.

BR station 1204
Lithology: Siltstone, non-calcareous, friable, moderate yellowish brown.
Washed residue with Eocene spumellarias and nassellarias.

Calle Zapata

A road cut at Calle Zapata, at the south flank of Loma del Príncipe, 150 m to the east of the intersection of Calle Zapata and Calle C, Vedado, coordinates 367.16 N and 357.90 E, exposes brownish graywacke sandstones and shales of the basal part of the Capdevila formation. These beds are in strike with the outcrops described above and overlain by siliceous Toledo beds at the corner of Calle Zapata and Calle C. BR station 348 is from the top and BR station 349 from the base of this Capdevila outcrop.

BR station 349
Lithology: Shale, non-calcareous, dark yellowish brown.
Washed residue with large and well-preserved Eocene spumellarias and nassellarias.

BR station 348
Lithology: Graywacke sandstone, hard, calcareous, grayish orange.
Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components from about 40 to 350 μ. Components are mainly subangular to angular igneous grains and subrounded to rounded fragments of algae, mollusks and echinoderms. Also large benthonic and a few planktonic Foraminifera. Matrix recrystallized calcite.

Assemblage: *Discocyclina* cf. *barkeri* VAUGHAN and COLE
Pseudophragmina sp. or *Proporocyclina* sp.
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Eofabiania cushmani (COLE and BERMÚDEZ)
Globorotalia sp. (truncate form)
Globigerinas with thick and coarsely perforate walls
Distichoplax biserialis (DIETRICH)
Lithoporella melobesioides FOSLIE
Sulcoperculina sp. (reworked)
Vaughanina cubensis D. K. PALMER (reworked).

Punta Brava

BR station 388 is from the brownish Capdevila graywacke shales and sandstones underlying the Upper Eocene Punta Brava formation at the quarry east of Punta Brava (index map, fig. 64), here referred to the basal part of the Capdevila formation.

BR station 388
Lithology: Graywacke sandstone, friable, dark yellowish orange to light brown.
Washed residue with

Discocyclina barkeri Vaughan and Cole
"*Amphistegina*" *lopeztrigoi* D. K. Palmer
Valvulineria extensa Cushman and Bermúdez
Vaginulina midwayana Fox and Ross
Boldia cf. *madrugaensis* Cushman and Bermúdez
Vaughanina cubensis D. K. Palmer (reworked)
Asterorbis macei D. K. Palmer (reworked)

Outcrops of Unit II

The lithology of Unit II has been described under the type locality of the Capdevila formation.

Outcrops of Unit III

The part of the Capdevila formation apparently overlying the type beds is more clastic, in places conglomeratic with igneous, sandstone, siltstone and predominantly limestone components. Volcanic rocks furnish maximum 30 to 50% of the total pebbly material. The limestone components are subangular to poorly rounded whereas the igneous components are well-rounded and smaller in size. This may suggest long transport or reworking of the igneous pebbles from older igneous conglomerates. A characteristic exposure of the conglomeratic part of the Capdevila formation is on the road from Capdevila to Arroyo Naranjo at about 2.2 km southeast of Capdevila close to Finca La Chata of former President Carlos Prio Socarras. The top of the outcropping section corresponds to coordinates 357.20 N and 357.95 E. At this locality, represented by BR stations 389 and 389A, the pebbles are predominantly sedimentary in origin and representative of Maastrichtian *Vaughanina cubensis* D. K. Palmer assemblages (pebble 9), and fore-reef assemblages (pebbles 1–6), which may be only slightly older or perhaps penecontemporaneous with the Capdevila beds. The columnar section, fig. 38, has been measured on the east-northeastern side of the road, where about 50 m of continuous Capdevila beds are exposed. With the exception of two very thin beds of silty shales, the section is made up of medium to coarse graywacke sandstones and of conglomerates (BR stations 805 to 810). The color of the beds is brownish throughout. Embedded in graywacke beds are large irregularly ellipsoidal concretions which attain here diameters of up to 40 cm. They are much harder than the surrounding material, in fresh cuts bluish, and occur either isolated or joined together forming nodular beds. The clastic material of which they consist does not differ from that in which they are embedded. Apparently they were formed by

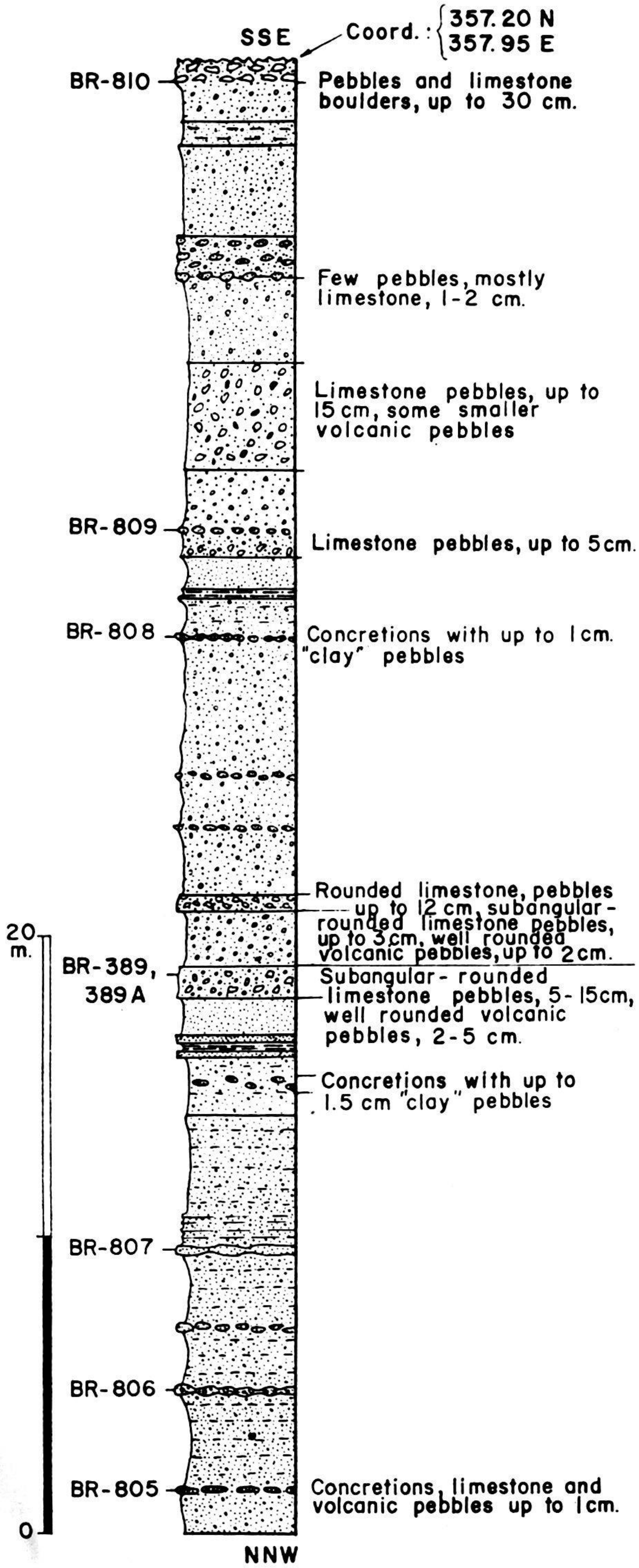


Fig. 38. Columnar section of the lithologic Unit III of the Capdevila formation at the road from Capdevila to Arroyo Naranjo.

concentration of calcite. One of the characteristics of this part of the Capdevila formation is the poor sorting of the various clastic elements. The finer graywacke sandstones are composed of elements ranging from 1 to 2 mm in diameter, and dispersed throughout the rock are isolated larger pebbles of up to 10 mm in size. The conglomeratic graywackes, on the other hand, are formed by a matrix of 2 to 5 mm large elements and embedded in it are larger isolated pebbles or boulders of up to 15 cm in size, occasionally even reaching 30 cm in diameter. It was noticed that no graded bedding occurs.

The following descriptions refer to pebbles found at BR station 389:

Pebble 1
Lithology: Limestone, hard, fragmental to pseudoölitic, yellowish gray.
Texture: Fragments of algae, echinoderms and mollusks in form of large irregularly rounded pseudoölites in recrystallized calcite matrix. Typical back-reef environment.

Assemblage: Tertiary Corallinaceae and other algae
Encrusting Foraminifera
Thick-walled *Quinqueloculina* spp.

Pebble 2
Lithology: Limestone, hard, pseudoölitic, yellowish gray.
Texture: Fragments of algae, echinoderms and mollusks in cryptocrystalline to argillaceous matrix. Rare green igneous grains.
Assemblage: Tertiary Corallinaceae and other algae
Encrusting Foraminifera
Proporocyclina sp.
Amphistegina sp.
Boldia sp.
Globigerina sp.
Miliolids.

Pebble 3
Lithology: Shale, calcareous, pale grayish yellow.
Texture: Planktonic microfossils in microcrystalline calcite matrix, arranged in microlaminae. Also some small angular dark igneous grains.
Assemblage: *Globigerina* spp.
Radiolaria.

Pebble 4
Lithology: Limestone, finely pseudoölitic to fragmental, pinkish gray.
Texture: Fragments of algae, echinoderms, mollusks and some Foraminifera in microcrystalline matrix.
Assemblage: Tertiary Corallinaceae
Encrusting Foraminifera
Globorotalia spp. (truncate forms)
Globorotalia ex gr. *G. pseudomenardii* BOLLI
Globigerina spp. with coarse perforations.

This assemblage appears to be related with those described from the Lower Eocene Alkázar formation.

Pebble 5
Lithology: Limestone, finely fragmental to pseudoölitic, yellowish gray.
Texture: Pseudoölites of algae, igneous fragments and planktonic microfossils in microcrystalline matrix.
Assemblage: Tertiary Corallinaceae
Globorotalia broedermanni CUSHMAN and BERMÚDEZ
Globorotalia spp. (truncate forms)
Vaughanina cubensis D. K. PALMER (reworked).

Pebble 6
Lithology: Limestone, finely fragmental to pseudoölitic, yellowish gray.
Texture: Fragments of algae, echinoderms and mollusks, and Foraminifera in cryptocrystalline to microcrystalline groundmass.

Assemblage: Tertiary Corallinaceae
"Operculina" catenula CUSHMAN and JARVIS
Discocyclina barkeri VAUGHAN and COLE
Amphistegina sp. (same form as recorded in pebble 2)
Encrusting Foraminifera
Nondescript rotaliids
Miliolids.

Pebble 9
Lithology: Limestone, finely fragmental, pale yellowish brown.
Texture: Abundant Foraminifera and igneous grains in microcrystalline matrix.

Assemblage: *Vaughanina cubensis* D. K. PALMER (abundant)
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN)
Heterohelix sp. or *Pseudoguembelina* sp. (coarsely striate forms)
Dasycladaceae.

BR station 805, 806, 808 and 809

These stations are lithologically and faunally very similar and therefore here summarized, although they are from different stratigraphic horizons as indicated in the columnar section, fig. 38.
Lithologies: Graywacke sandstone, coarse-grained, with large pebbles, calcareous, pale to dark yellowish brown.

Textures: Fragmental, unsorted. Diameter of average components ranges from about 100 to 800 μ, with some larger inclusions of mainly igneous rocks up to 3500 μ. Components are mainly angular to rounded dark brown and green igneous fragments, also some fragments of sedimentary rocks and a few Foraminifera and shell fragments. Matrix coarsely recrystallized calcite.

Assemblages: *Discocyclina* sp.
Eofabiania cushmani (COLE and BERMÚDEZ)
"Amphistegina" lopeztrigoi D. K. PALMER
"Operculina" catenula CUSHMAN and JARVIS (possibly reworked)
Large fragments of reworked Upper Cretaceous limestone with coccoliths and
Calcisphaerula innominata BONET
Pithonella ovalis (KAUFMANN)
Sulcoperculina sp. (reworked)
Pseudorbitoid sp. (reworked).

BR station 807
Lithology: Graywacke sandstone, fine-grained, calcareous, grayish orange to light brown.

Texture: As BR stations 805, 806 but finer, with diameter of average components from about 70 to 350 μ, and without larger inclusions.

Assemblage: *Globigerina* sp. with thick and coarsely perforate walls
Lithoporella melobesioides FOSLIE.

BR station 810
Lithology: Calcarenite to calcirudite, with slight igneous influence and with larger greenish "clay" pebbles, grayish orange to moderate yellowish brown.
Texture: Fragmental to pseudoölitic, unsorted. Diameter of average components ranges from about 100 to 1500 μ. Components mainly fragments of algae, bryozoas, echinoderms and sedimentary rocks. Also common larger Foraminifera. Rare igneous grains. Matrix coarsely recrystallized calcite.
Assemblage: *Globorotalia* sp. (truncate form)
Globigerinas with thick and coarsely perforate walls
"*Operculina*" *catenula* CUSHMAN and JARVIS (possibly reworked)
"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Discocyclina barkeri VAUGHAN and COLE
Discocyclina cf. *mestieri* VAUGHAN
Discocyclina spp.
Lithoporella melobesioides FOSLIE
Vaughanina cubensis D. K. PALMER (reworked).

A striking feature of the conglomeratic part of the Capdevila formation is the occurrence, embedded in graywacke sandstones, of large indurated, irregularly ellipsoid, brownish sandstone concretions. They may be up to 1 m in diameter and sometimes occur in accumulations in the brownish top soil. They have also been found outside the conglomeratic part and are a good indication for the Capdevila formation. Farmers use them in demarcation lines. Indurated concretions have also been found near the top of the type section of the Capdevila formation (columnar section, fig. 32). They are however much smaller than those from Unit III. Typical exposures of the sandy concretions are at the above mentioned road cut about 1.2 km west of Arroyo Naranjo, and at a cut exposing thin-bedded brownish sands, shales and silts probably of type locality age immediately south of Plaza del Mediodía on the road toward Guatao, coordinates 356.50 N and 349.02 E (photograph, fig. 39). Accumulations of concretions can be seen in the fields east of El Cano and north of the Rovers Club, southeast of Capdevila.

Outcrops of Unit IV

The top unit of the Capdevila formation is characterized by thin and well-bedded chalks, chalky limestones, marly clays, and graywacke sands, silts and shales of generally light yellow to orange brown color. As observed at Autopista del Mediodía, the sedimentary cycle usually starts with a fine sand or silt bed which occasionally shows graded bedding, and ends with a soft powdery chalk or chalky limestone bed. The beds change abruptly and their limits are well-defined. In some of the sandy beds there are small lenticular nests of somewhat coarser reddish material.

Autopista del Mediodía

A typical outcrop of the top beds of the Capdevila formation, where it is in perfect transitional contact with the Toledo member of the Universidad formation, is exposed at the road cut south of the intersection of the Autopista del Mediodía

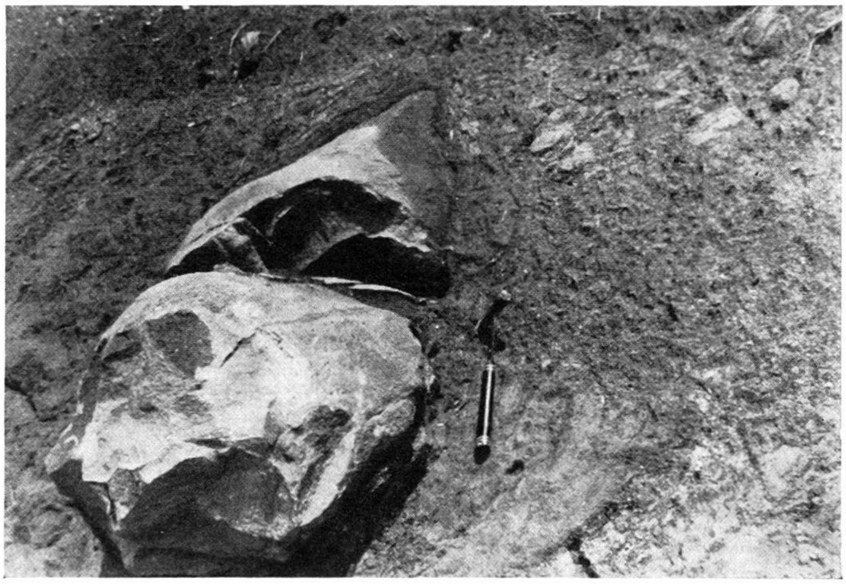


Fig. 39. Sandy concretion in the Capdevila formation southwest of Plaza del Mediodía, at the road to Guatao.

with the secondary road to Arroyo Arenas, coordinates 357.80 N and 348.50 E (index map, fig. 45).

The top of the Capdevila formation is arbitrarily fixed by the highest graywacke sands and silt, which are interbedded with chalks containing rich foraminiferal faunas. BR stations 426 (bottom) and 428 (top) are of particular interest because they contain numerous *Globorotalia palmerae* CUSHMAN and BERMÚDEZ. This delicately spinose form has not been found in the older Capdevila units. A form similar to *G. palmerae* occurring in Unit I, but heavier and coarser spined, is *Rotalia capdevilensis* CUSHMAN and BERMÚDEZ. *G. palmerae* as well as *Globorotalia elongata* GLAESSNER are related with *Globorotalia pseudoscitula* GLAESSNER.

BR station 426
Lithology: Chalk, very powdery, white to pale greenish yellow.
Washed residue with

Globorotalia palmerae CUSHMAN and BERMÚDEZ (common)
Globorotalia pseudoscitula GLAESSNER
Globorotalia elongata GLAESSNER
Globigerina cf. *linaperta* FINLAY
Globigerina soldadoensis BRÖNNIMANN group
Pseudohastigerina micra (COLE) (common)
Eocene spumellarias and nassellarias.

BR station 427
Lithology: Chalk, grayish yellow.
Washed residue with

Globorotalia pseudoscitula GLAESSNER
Pseudohastigerina micra (COLE)
Eocene spumellarias and nassellarias.

BR station 428
Lithology: Chalk, very powdery, white to pale greenish yellow.

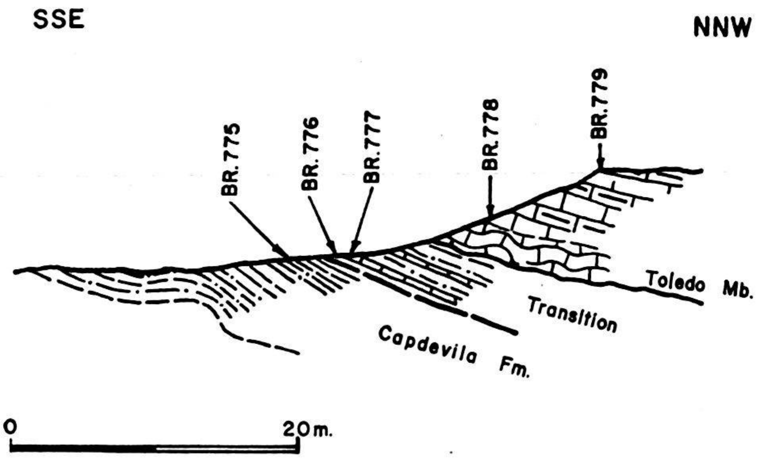


Fig. 40. Contact Capdevila–Universidad formations at Tejar Consuelo.

Washed residue with

Globorotalia palmerae Cushman and Bermúdez
Globorotalia pseudoscitula Glaessner
Globigerina cf. *linaperta* Finlay
Pseudohastigerina micra (Cole)
Eocene spumellarias and nassellarias.

Tejar Consuelo

Thin-bedded whitish to orange Capdevila graywacke shales and silts and chalks of the lithologic Unit IV are exposed in disconformable or unconformable contact with the Toledo member of the Lower to Middle Eocene Universidad formation in the eastern part of Tejar Consuelo (index map, fig. 59). The top Capdevila beds are strongly limonitic suggesting an erosional gap between Capdevila and Universidad formations. Chalk and limestone samples from this contact zone are listed below from bottom to top as shown in the cross section, fig. 40:

BR station 775 (Capdevila)
Lithology: Shale, chalky, pale to dark yellowish orange.
Washed residue with Eocene spumellarias and nassellarias.

BR station 776 (Capdevila–Toledo contact zone)
Lithology: Chalk, powdery, whitish to pale yellowish orange.

Washed residue with

Globorotalia palmerae Cushman and Bermúdez
Globigerina prolata Bolli
Globigerina soldadoensis Brönnimann
Globigerina linaperta Finlay
Pseudohastigerina micra (Cole)
Eocene spumellarias and nassellarias.

BR station 777 (Capdevila–Toledo contact zone)
Lithology: Limestone, silicified, with manganese films and dendrites, pale yellowish orange.
Texture: Microcrystalline groundmass.
Assemblage: Radiolaria.

BR station 778 (Toledo)
Lithology: Chalk, hard, conchoidal fracturing, white to grayish yellow.
Abundant asphalt pebbles.
Washed residue with
Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia planoconica SUBBOTINA
Globorotalia convexa SUBBOTINA
Pseudohastigerina micra (COLE)
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Globigerina aff. *turgida* FINLAY
Eocene spumellarias and nassellarias.

BR station 779 (Príncipe)
Lithology: Limestone, white to grayish yellow.
Texture: Microcrystalline groundmass with planktonic microfossils.
Assemblage: *Globorotalia* sp. (truncate form)
Globigerinas with thick and coarsely perforate walls
Hantkenina sp.
Thoracosphaera sp.

Just west of this Capdevila–Universidad section of the eastern part of Tejar Consuelo, a small tightly folded anticline shows in its core thin-bedded, chalky, silty and sandy yellowish orange Capdevila–Toledo contact beds and at the flanks thick beds of silicified and strongly fractured limestones of the Toledo member. This anticline is illustrated by fig. 41, which also indicates the stratigraphic position of the stations described below:

BR station 783 (Core of anticline)
Lithology: Shale, non-calcareous, dusky yellow.
Washed residue with well-preserved Eocene spumellarias and nassellarias.

BR station 782
Lithology: Chalk, silty, dark yellowish orange.
Washed residue with
Globorotalia aragonensis NUTTALL
Globigerina soldadoensis BRÖNNIMANN group
Globigerina cf. *triangularis* WHITE
Globigerina cf. *turgida* FINLAY
Globigerina senni (BECKMANN)
Abundant Eocene spumellarias and nassellarias.

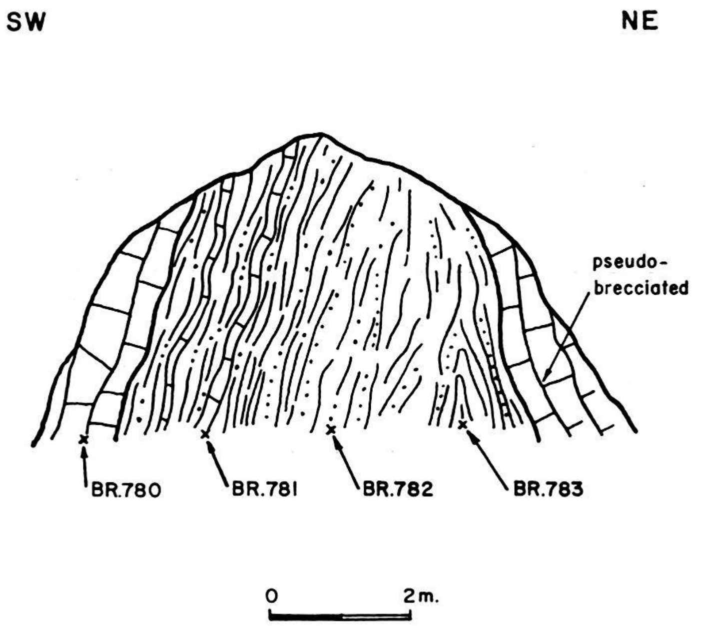


Fig. 41. Anticline with Capdevila beds in the core and Toledo beds at the flanks, eastern part of quarry at Tejar Consuelo.

BR Station 781
Lithology: Chalk, silty, pale yellowish orange.

Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globigerina senni (BECKMANN)
Pseudohastigerina micra (COLE)
Eocene spumellarias and nassellarias.

BR station 780 (First silicified bed of the Toledo member)
Lithology: Limestone, silicified, strongly fractured, very pale orange to pale greenish yellow.
Texture: Microcrystalline calcite groundmass, in part silicified.
Assemblage: Radiolaria.

Environment and age

The Capdevila formation consists mainly of unsorted to poorly sorted graywacke conglomerates, sands, silts and silty shales, i.e. clastic rocks with 30 % or more dark igneous detritus. Other less common rocks are calcarenites, calcilutites, very fine-fragmental calcilutaceous radiolarite-coccolithites. Some bentonitic shales and chalks occur in the transitional zone linking Unit IV of the Capdevila formation with the Toledo member of the Universidad formation. The predominance of graywackes and the overall brownish color distinguish the Capdevila formation from the underlying lighter colored and mainly calcarenaceous to calcilutaceous Alkázar formation. The Capdevila formation is genetically related with the Upper Cretaceous Vía Blanca formation and to some degree also with the Lower Eocene Apolo and Alkázar formations. Reworked Upper Cretaceous microfossils are no longer common. Only rare specimens of *Vaughanina cubensis* D. K. PALMER, *Asterorbis macei* D. K. PALMER, and *Sulcoperculina* spp., all of Upper Cretaceous age, and of *Nannoconus* spp. of Lower Cretaceous age were recorded.

The individual Capdevila beds are generally relatively thin, with well-delimited tops and bottoms and continuous. Psammitic and pelitic beds follow each other in rapid alternation. Sedimentary cycles involving complete sequences from coarser beds at the base to finer beds at the top are frequent in the lithologic Units I and IV. The upper beds of these cycles are usually light colored calcilutites, minutely clastic radiolarite-coccolithites and chalks. The lithologic Unit IV shows transitional features leading from the clastic sedimentation of the Habana group to the carbonate sedimentation of the Marianao group. Macroscopically, many of the psammitic beds appear to be ungraded, others are distinctly graded from coarse at the base to fine at the top, and still others are irregularly graded, from fine to coarse, or from coarse to fine to coarse, or from fine to coarse to fine. The ungraded sandy and silty beds were deposited very rapidly, whereas regular grading from coarse to fine suggests relatively slow settling of the clastic material. Irregular grading, in particular, was noticed in the type locality beds of the Capdevila formation. They are believed to reflect sedimentation by irregular submarine currents which were sometimes strong enough to transport coarser material up to conglomeratic size, to form accumulations of microconglomerates and to truncate shaley beds, and sometimes barely able to transport shale particles. Intraformational erosion was noticed throughout the Capdevila formation, but especially in Units I and II. Turbidity currents which probably caused the disturbed Vía Blanca–Peñalver contact as described on p. 269 of this paper, were apparently not active during Capdevila time. Submarine slumping as illustrated in fig. 42, however, was observed. Hieroglyphic markings occur often at the base of sandy beds, and chondrites were found in the light colored end-of-cycle calcilutites of Unit I outcropping in Reparto Veracruz, about 2 km northwest of San Francisco de Paula, immediately southwest of the Carretera Central. The average coordinates of the outcrop area are 361.5 N and 364.8 E. The finer clastic beds contain planktonic microfossils, and the coarser clastic beds yield larger benthonic Foraminifera, and larger fragments of mainly algae, mollusks and echinoderms with an admixture of planktonic microfossils. All of the above mentioned features point to a flysch-type sedimentation in a fore-reefal to basinal area in front of an extensive igneous complex with a probably poorly developed reefal cover. Toward the end of the Capdevila sedimentation positive movements subsided and large scale influx of clastic material stopped. The last igneous clastics were noticed in some beds of the Upper Eocene Punta Brava formation and in the basal conglomerate of the Husillo formation in its western development (Punta Brava Quarry).

Discoasters and associated microfossils are a conspicuous element of the fine-grained Capdevila beds. The following discoasterids were identified in thin sections:

Braarudosphaera bigelowi (GRAN and BRAARUD)
Braarudosphaera discula BRAMLETTE and RIEDEL (rare to common)
Discoaster aster BRAMLETTE and RIEDEL (rare)

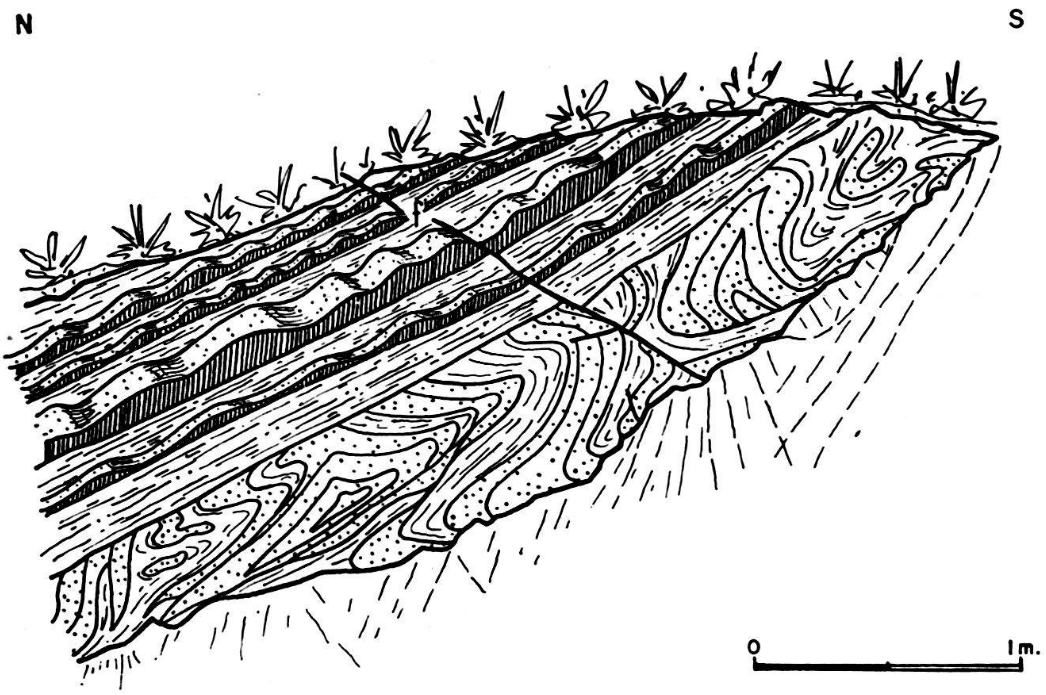


Fig. 42. Slumping in Capdevila beds.

Discoaster sp. *close* to *D. barbadiensis* TAN (rare to common)
Discoaster lodoensis BRAMLETTE and RIEDEL (common)
Discoaster sp. *similar* to minute forms of *Discoaster multiradiatus* BRAMLETTE and RIEDEL (common)
Discoaster woodringi BRAMLETTE and RIEDEL (rare)
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL) (common)

Associated nannofossils are:

Coccoliths, mainly placoliths, which occur rock-forming, and of which *Tremalithus eopelagicus* BRAMLETTE and RIEDEL was identified
Thoracosphaera spp. (common).

Discoaster lodoensis BRAMLETTE and RIEDEL, *Marthasterites tribrachiatus* and *Discoaster woodringi* BRAMLETTE and RIEDEL are new in the Capdevila formation. The typical large tests of *Discoaster multiradiatus* BRAMLETTE and RIEDEL appear to be restricted to the Alkázar formation.

Radiolaria, i.e. spumellarias and nassellarias are common in many beds of the Capdevila formation, in particular in the lithologic Units I, II and IV. They are usually well preserved and some assemblages contain rather large specimens.

The most significant larger benthonic Foraminifera recorded in the Capdevila formation are:

"*Amphistegina*" *lopeztrigoi* D. K. PALMER
Asterocyclina sp.
Dictyoconus cookei MOBERG
Discocyclina cf. *barkeri* VAUGHAN and COLE

Eofabiania cushmani (COLE and BERMÚDEZ)
Eoconuloides wellsi COLE and BERMÚDEZ
Proporocyclina sp. or *Pseudophragmina* sp.
Pseudophragmina sp.
Rotalia capdevilensis CUSHMAN and BERMÚDEZ.

The Capdevila assemblage of larger benthonic Foraminifera differs from that of the underlying Alkázar formation by the advent of *Eoconuloides wellsi* COLE and BERMÚDEZ, *Eofabiania cushmani* (COLE and BERMÚDEZ). *Dictyoconus cookei* MOBERG is represented by a single doubtful specimen. Also *Asterocyclina* seems to occur for the first time in the Capdevila beds. *Rotalia capdevilensis* CUSHMAN and BERMÚDEZ, a diagnostic form of lithologic Unit I, is here mentioned because of its similarity with *Globorotalia palmerae* CUSHMAN and BERMÚDEZ of lithologic Unit IV, with which it might be confounded. With the exception of a heterogeneous sample from the finca "La Coronela" at the highway to Rancho Boyeros (BERMÚDEZ station 1266), we were unable to find in our material *Boreloides cubensis* COLE and BERMÚDEZ and *Helicostegina gyralis* BARKER and GRIMSDALE, which both were mentioned by BERMÚDEZ (1952, p. 230) from his "Lucero member" of the Capdevila formation. These two interesting species, however, are quite common in Lower Eocene fore-reefal deposits of Oriente Province. According to our observations, *"Operculina" catenula* CUSHMAN and JARVIS, one of the most characteristic larger benthonic species of the Apolo and Alkázar formations, apparently does not extend into the Capdevila beds. This is in contrast with the findings of BECKMANN (1959, p. 417, fig. 2) who recorded *"Operculina" bermudezi* (=*"Operculina" catenula*) throughout our Capdevila zones excepting the *Globorotalia palmerae* zone of Unit IV.

The sequence of planktonic Foraminifera recorded in the four lithologic units of the Capdevila formation shows the following Lower Eocene biostratigraphic zones from bottom to top:

a) *Globorotalia rex–Globorotalia formosa* zone
b) *Globorotalia broedermanni–Globorotalia pseudoscitula* zone
c) *Globorotalia palmerae* zone.

In terms of the discoasterid zonation, the Capdevila formation is part of the *Marthasterites tribrachiatus–Discoaster lodoensis* zone.

Universidad Formation

The Universidad formation was introduced by BERMÚDEZ (1937, p. 163) for massive beds of white to yellowish fine-grained, chalky limestones outcropping in the area from the Castillo del Príncipe to the campus of the University of Habana. As type locality he designated the outcrop in the northeastern corner of "Jardín de los Laureles" beneath the old library building of the University of Habana. This locality is represented by BERMÚDEZ station 257, today covered by University buildings and no longer accessible. Other typical outcrops of the Universidad formation listed by BERMÚDEZ (1950, p. 235) are the road cuts of the Avenida de los Presidentes, the Avenida de la Universidad and the Calle Zapata, all at Loma del Príncipe. The best exposures are the cuts on both sides of the Avenida de los Presidentes between the monument of J. M. Gómez and its intersection with the

Avenida de la Universidad. The cut on the western side of Avenida de los Presidentes is illustrated by the photograph, fig. 50. Foraminifera from various localities of the Universidad formation were compiled by BERMÚDEZ (1950, pp. 231–233), who mentioned the following planktonic species: *Globorotalia aragonensis* NUTTALL, *Globorotalia crassata* CUSHMAN, *Globorotalia spinulosa* CUSHMAN, *Globigerina topilensis* CUSHMAN, *Globigerina orbiformis* COLE, *Globigerina* cf. *apertura* CUSHMAN, *Globigerina* cf. *cretacea* D'ORBIGNY and *Nonion micrus* COLE. The road cut at Avenida de los Presidentes was previously described by R. H. PALMER (1934, pp. 132, 133, and fig. 2 on p. 133) as a characteristic locality of his Príncipe formation which at first was believed to be Upper Eocene. Subsequent faunal analysis by BERMÚDEZ, GRIMSDALE, KEIJZER, and Mrs. PALMER (BERMÚDEZ 1950, p. 233), however, established a late Lower Eocene age for this lithologic unit and demonstrated affinities with the foraminiferal faunas of the underlying Capdevila formation. BERMÚDEZ also substituted the name Príncipe formation by Universidad formation. The name Príncipe formation, on the other hand, was used by BERMÚDEZ (1937, p. 163) for Upper Eocene beds which were supposed to be overlying the Lower Eocene Universidad formation at Loma del Príncipe. In the stratigraphic chart of February 24, 1948 (BERMÚDEZ, 1950), the Príncipe formation is no longer listed and superseded by the Consuelo formation.

Princípe formation is a better name than Universidad formation and although PALMER omitted to formally designate a type locality, the formation was unambiguously defined by his reference to the road cut at Loma del Príncipe. In our opinion, the name Príncipe formation was well chosen by PALMER and it would have been given preference over Universidad formation if it would have been retained by BERMÚDEZ in its original meaning (1950, p. 234). However, as in the case of the Capdevila formation, we will continue to use Universidad formation as a stratigraphic nomen conservandum. For the chalky upper member of the Universidad formation, the name Príncipe will be retained, because these beds are typically exposed at Loma del Príncipe. The here proposed nomenclatorial procedure seems to agree best with PALMER's original intention and description of his Príncipe formation in which the silicified lower beds of the Universidad formation are not included.

The silicified lower member of the Universidad formation is here named Toledo member. It was interpreted by BERMÚDEZ (1950, p. 236) as a silicified time equivalent of the Universidad formation. We have discussed a similar incorrect application of the term member in the chapter on the Capdevila formation. The Zapata formation or Toledo formation of BRODERMANN (1940, p. 8) is synonymous with the Toledo member as defined in this paper.

The Universidad formation is well developed along the northern rim-rock. As witnessed by many outcrops in Pinar del Río, Matanzas, Las Villas, Camagüey and Oriente provinces, the Universidad formation was laid down apparently uniformly over most of Cuba. We did not find any Universidad beds along the southern rim-rock of the area investigated except in a large quarry about 1.5 km west-southwest of Santa María del Rosario, coordinates 359.00 N and 369.80 E. The important outcrops of Toledo beds at the west entrance to Jaruco, about 45 km east-southeast of the Bahía de la Habana, and Toledo and Alkázar pebbles in conglomeratic Rosario marls of post-Cojímar age outcropping southeast of San Francisco de Paula, coordinates 359.04 N and 368.06 E, demonstrate that at least Toledo beds existed also in this area and that they were partially removed in pre-Rosario time.

Toledo member

The Toledo member is a siliceous facies of the lower Universidad formation. The silicification varies locally, and it can affect a more or less thick portion of the lower Universidad formation. At Avenida de los Presidentes, where the member is transgressive on Capdevila clastics, the Toledo beds are poorly silicified and only about 4 m thick. At the corner of Calle Zapata and Calle C, Vedado, a few meters of typical, siliceous Toledo beds have been observed. In the quarry east of Río Almendares, Nuevo Vedado, where the bottom of the member is not exposed, we measured about 21 m of Toledo member. The average thickness of the Toledo member appears to be 10 to 12 m as on the east side of the road cut at Autopista del Mediodía, where the contacts with both the underlying Capdevila formation and the overlying Príncipe member are transitional.

The base of the Toledo beds is arbitrarily defined at the top of the highest clastic bed of Capdevila lithology. The character of the contact of the Universidad formation with the Capdevila formation changes locally. As mentioned above, it is transitional at the Autopista del Mediodía, disconformable or unconformable at Tejar Consuelo, and distinctly unconformable at Avenida de los Presidentes. The contact between Toledo and Príncipe members is throughout the area transitional, the top of the Toledo member being chosen arbitrarily where the highest silicified bed occurs.

Description of the type locality of the Toledo member

The type locality of the Toledo member is in the quarry of Tejar Toledo, west of the road from Marianao to Central Toledo, about 1.3 km south of the Carretera Central, coordinates 354.00 E and 360.00 N (index map, fig. 43). In this quarry crop out 10 to 15 m of whitish to slightly grayish or greenish more or less shaley and powdery limestone or chalk interbedded with flint nodule-bearing beds and silicified white to yellowish limestones, which are occasionally completely silicified into amber chert. Most of the joints are black due to accumulation of manganese oxide. The average thickness of the individual silicified bed is about 20 to 40 cm. Small asphalt pebbles have been found irregularly dispersed in the chalky limestones above BR station 368 and below BR station 370. At the type locality, top and bottom of the Toledo member are not exposed.

The relative stratigraphic position of the Toledo type samples is indicated in the columnar section, fig. 44. They are listed here from bottom to top:

BR station 369
Lithology: Chalk, soft, powdery, white, with asphalt pebbles.
Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI

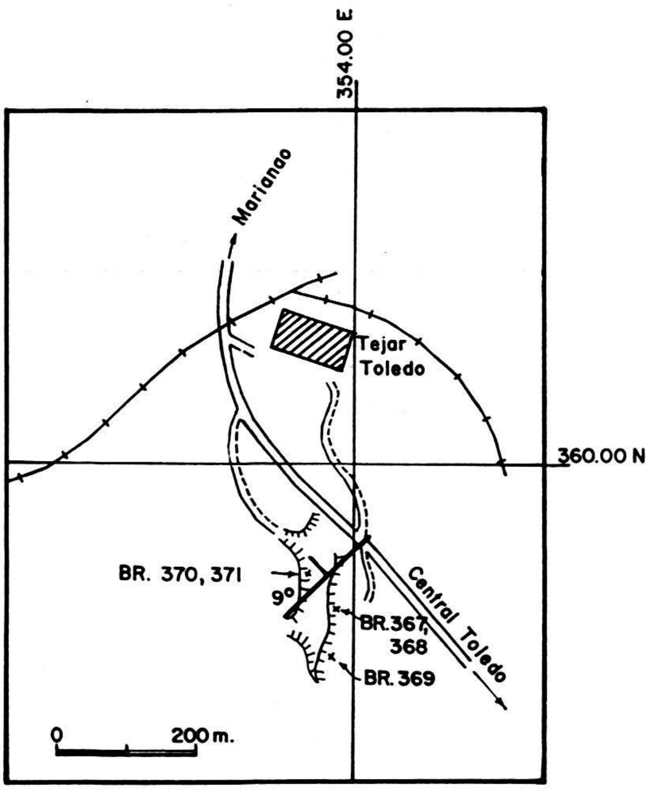


Fig. 43. Index map of Tejar Toledo.

Globigerina bolivariana Petters
Globigerina boweri Bolli
Globigerina prolata Bolli
Globigerina soldadoensis Brönnimann group
Globigerina aff. *turgida* Finlay
Globorotalia convexa Subbotina group
Globorotalia aff. *planoconica* Subbotina
Globorotalia aff. *pseudoscitula* Glaessner
Catapsydrax unicavus Bolli, Loeblich, and Tappan
Eocene spumellarias and nassellarias.

BR station 367
Lithology: Chalk, soft, powdery, white, with asphalt pebbles.

Washed residue with

Globorotalia aragonensis Nuttall
Globorotalia bullbrooki Bolli
Globorotalia convexa Subbotina group
Globorotalia aff. *planoconica* Subbotina
Globigerina boweri Bolli
Globigerina soldadoensis Brönnimann
Catapsydrax unicavus Bolli, Loeblich, and Tappan
Eocene nassellarias and spumellarias.

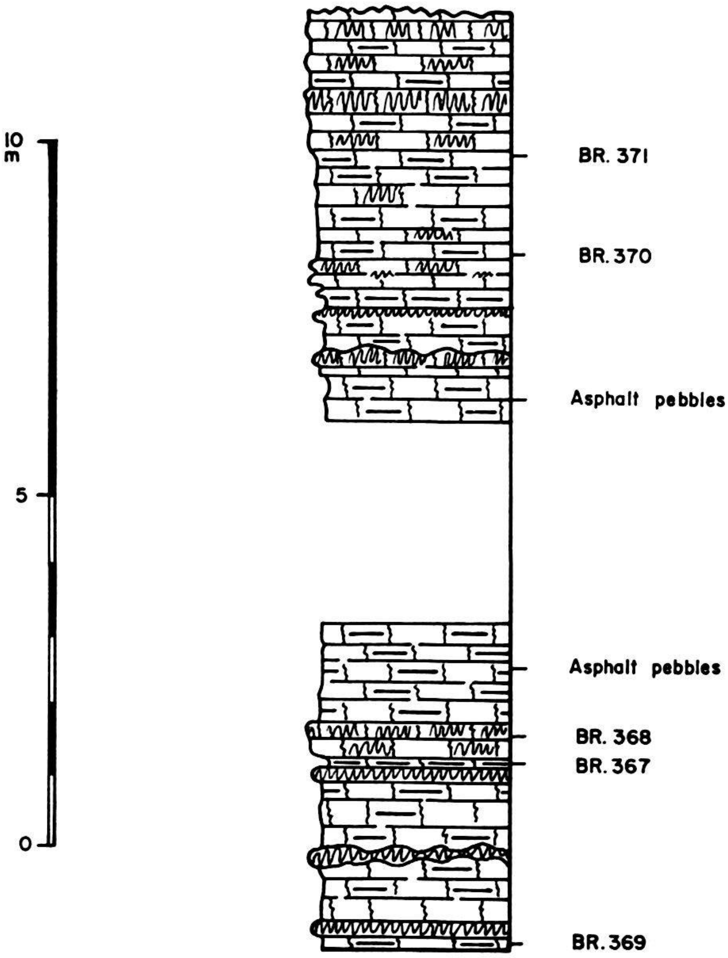


Fig. 44. Columnar section of the Toledo member of the Universidad formation, Tejar Toledo.

BR station 368

Lithology: Limestone, silicified, slightly calcareous, with asphalt pebbles, white to pale greenish yellow (coccolithite-radiolarite).

Texture: Silicified cryptocrystalline groundmass with abundant planktonic microfossils.

Assemblage:
Globorotalia bullbrooki BOLLI group
Globigerina spp.
Radiolaria (abundant)
Coccoliths, mainly placoliths (abundant)
Thoracosphaera sp.
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL)
Marthasterites sp.
Discoaster aecus BRÖNNIMANN and STRADNER
Discoaster barbadiensis TAN
a) Typical forms
b) Small forms of 8 to 9 μ diameter with 6 to 7 diamond-shaped and pointed arms
Discoaster geometricus BRÖNNIMANN and STRADNER

Discoaster cf. *woodringi* BRAMLETTE and RIEDEL, small form with 6 blunt arms of 7 μ diameter
Braarudosphaera bigelowi (GRAN and BRAARUD)
Braarudosphaera discula BRAMLETTE and RIEDEL.

BR station 370
Lithology: Chalk, soft powdery, white to yellowish white, with asphalt pebbles.
Washed residue with
Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia convexa SUBBOTINA group
Globorotalia aff. *planoconica* SUBBOTINA
Globigerina soldadoensis BRÖNNIMANN group
Globigerina boweri BOLLI
Globigerina senni (BECKMANN)
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Eocene nassellarias and spumellarias.

BR station 371
Lithology: Chalk, powdery, white to very pale yellow.
Texture: Cryptocrystalline groundmass with abundant planktonic microfossils.
Assemblage: *Globorotalia* spp. (truncate forms)
Globigerina spp.
Coccoliths, mainly placoliths (abundant)
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Thoracosphaera spp. (globular to ellipsoid bodies)
Discoaster aecus BRÖNNIMANN and STRADNER
Discoaster cf. *aster* BRAMLETTE and RIEDEL, small forms of about 12 μ diameter with 6 short rays with blunt to slightly pointed tips, intermediate between *D. aster* and *D. woodringi*.
Discoaster barbadiensis TAN (common)
Discoaster cf. *molengraaffi* TAN
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL)
Braarudosphaera bigelowi (GRAN and BRAARUD)
Braarudosphaera discula BRAMLETTE and RIEDEL (abundant) Diameter from about 5 to 15 μ
Nannotetraster swasticoides (MARTINI)

Other outcrops of the Toledo member

The silicified beds of the Toledo member are known from numerous good outcrops in the Habana area. The most important ones are described below.

Autopista del Mediodía

The Toledo member is well exposed along a road cut at the Autopista del Mediodía just north of its intersection with the secondary road to Arroyo Arenas, coordinates 357.90 N and 348.48 E (index map, fig. 45). It forms a prominent scarp at the base of which the mentioned secondary road leads from the Autopista del Mediodía to Arroyo Arenas. The church of Arroyo Arenas is located on this scarp cut there by the Carretera Central. The excellent exposure at the church was recently covered with a coat of concrete. At the road cut at the Autopista del Mediodía, the Toledo member is in transitional contact with the underlying

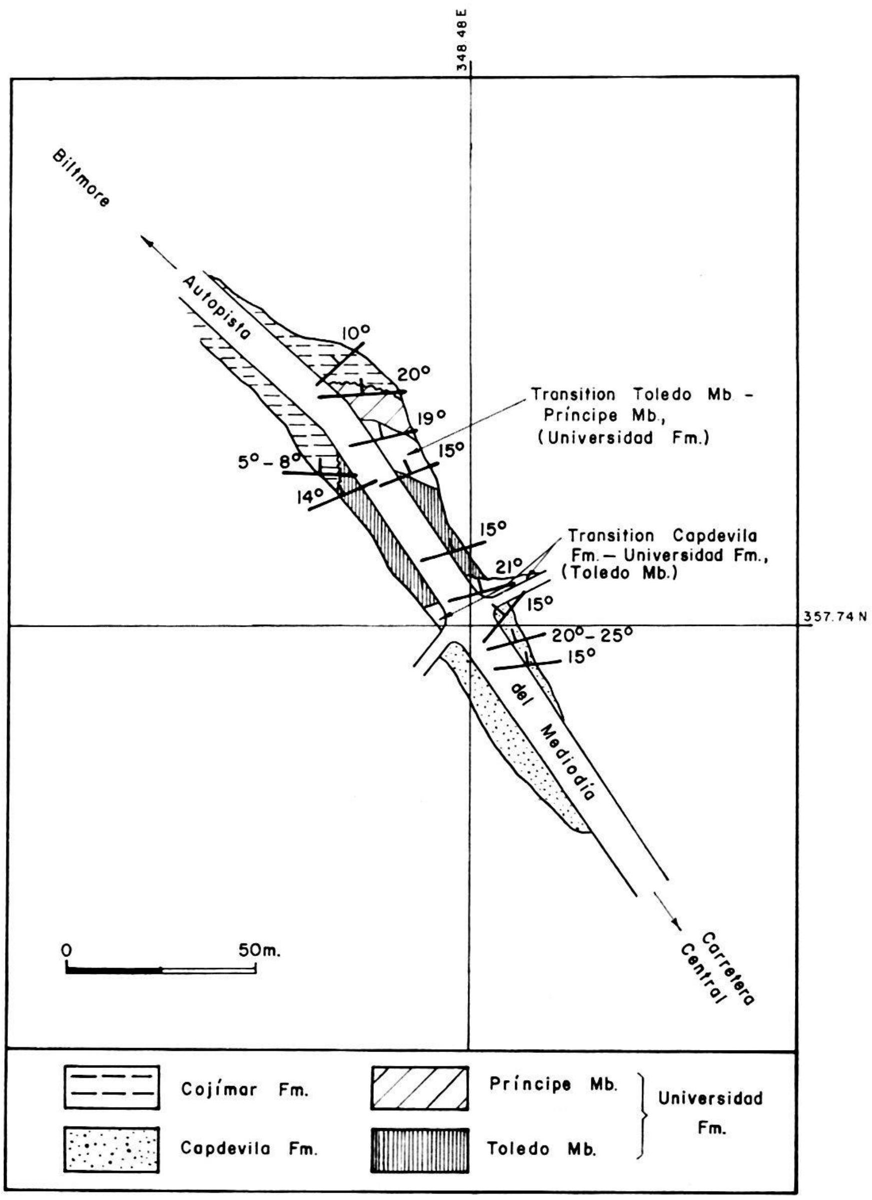


Fig. 45. Index map of the road cut at Autopista del Mediodía.

Globorotalia palmerae-bearing beds of the Capdevila formation (columnar section, fig. 46). The lower boundary of the Toledo beds is arbitrarily determined by the highest graywacke sands and silts of the Capdevila formation. BR station 415, on the western side of the road cut, is from the about 4 m thick transitional zone between the Toledo and the Capdevila beds as illustrated by the cross section, fig. 48. BR stations 416 to 418 are from the siliceous shales and chalks and interbedded siliceous limestones of the Toledo member proper. The samples are described below in stratigraphic order from bottom to top:

BR station 415

Lithology: Chalk, soft, white to grayish yellow.

Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia cf. *aspensis* (COLOM)
Globorotalia palmerae CUSHMAN and BERMÚDEZ
Globorotalia convexa SUBBOTINA group
Globorotalia broedermanni CUSHMAN and BERMÚDEZ
Globorotalia planoconica SUBBOTINA
Globorotalia imitata SUBBOTINA
Globorotalia pseudoscitula GLAESSNER
Globorotalia cf. *pseudomayeri* BOLLI
Globigerina aff. *yeguaensis* WEINZIERL and APPLIN
Globigerina bolivariana PETTERS
Globigerina soldadoensis BRÖNNIMANN group
Pseudohastigerina micra (COLE)
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Catapsydrax echinatus BOLLI
Eocene spumellarias and nassellarias.

BR station 416

Lithology: Chalk, soft, white to grayish yellow, and limestone, silicified, hard, conchoidal fracturing, white to grayish yellow.

Texture: Cryptocrystalline, silicified groundmass with abundant Radiolaria.

Assemblage: Radiolaria
Coccoliths, mainly placoliths
Discoaster lodoensis BRAMLETTE and RIEDEL (common)
Discoaster aecus BRÖNNIMANN and STRADNER
Discoaster geometricus BRÖNNIMANN and STRADNER
Discoaster sp., close to *D. barbadiensis* TAN, but without central knob
Discoaster barbadiensis TAN
Braarudosphaera discula BRAMLETTE and RIEDEL
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL) (rare)
Thoracosphaera sp.
Globigerina spp. (minute forms)

Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia imitata SUBBOTINA
Globorotalia palmerae CUSHMAN and BERMÚDEZ
Globorotalia pseudoscitula GLAESSNER
Globorotalia broedermanni CUSHMAN and BERMÚDEZ
Globorotalia convexa SUBBOTINA
Globigerina soldadoensis BRÖNNIMANN group

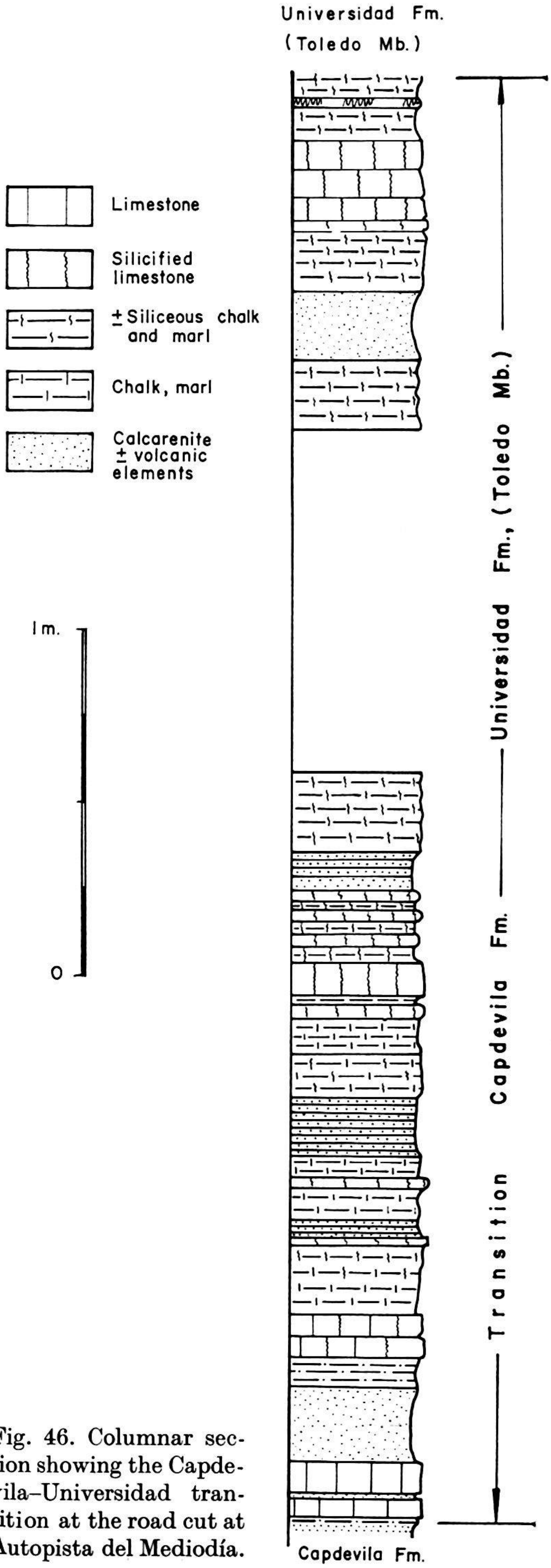


Fig. 46. Columnar section showing the Capdevila–Universidad transition at the road cut at Autopista del Mediodía.

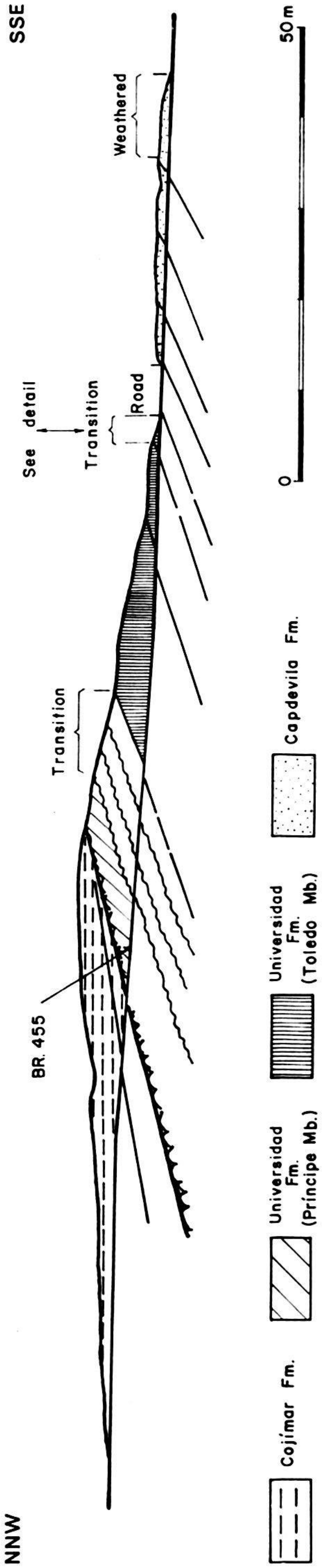


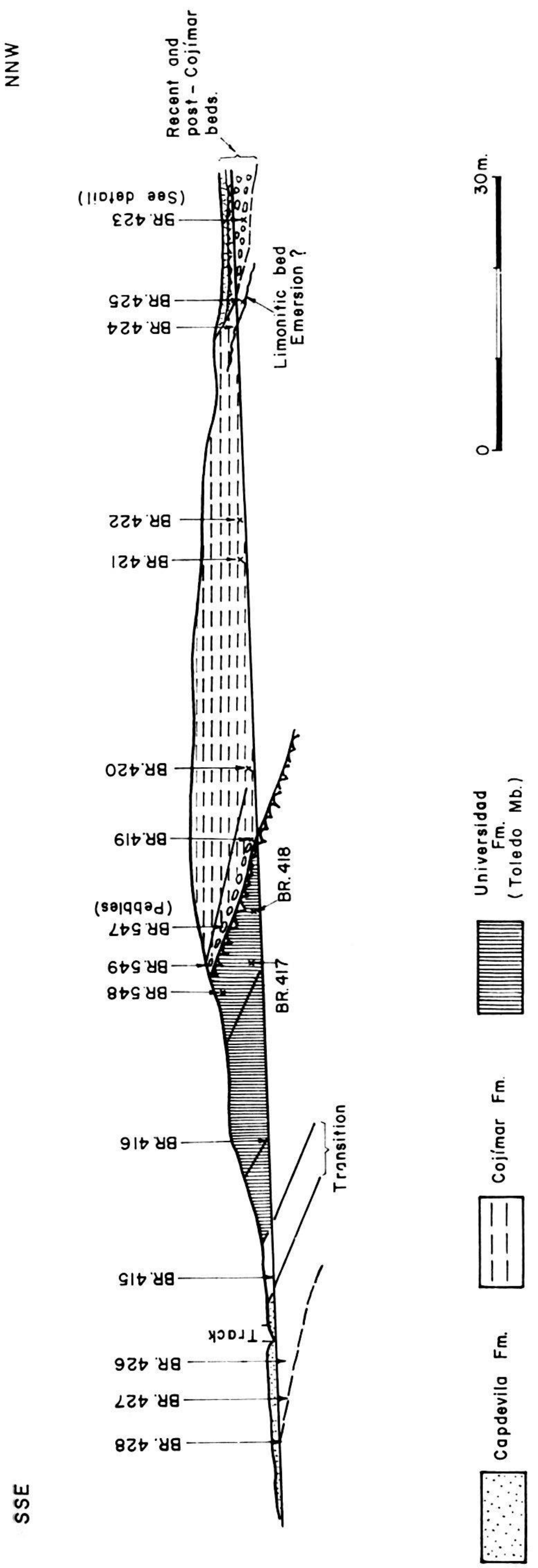
Fig. 47. Eastern side of the road cut at Autopista del Mediodía.

Globigerina bolivariana Petters
Globigerina cf. *boweri* Bolli
Globigerina collactea (Finlay)
Catapsydrax unicavus Bolli, Loeblich, and Tappan
Pseudohastigerina micra (Cole).

BR station 417
Lithology: Chalk, soft, white, and limestone, silicified white to yellowish.
Texture: As BR station 416.
Assemblage: Radiolaria
Coccoliths
Tremalithus eopelagicus Bramlette and Riedel
Discoaster lodoensis Bramlette and Riedel
Discoaster barbadiensis Tan
Discoaster sp. close to *D. barbadiensis* but without central knob
Thoracosphaera sp.
Globigerinas with coarsely perforate thick walls.

Washed residue with
Globorotalia aragonensis Nuttall
Globorotalia bullbrooki Bolli
Globorotalia palmerae Cushman and Bermúdez
Globorotalia pseudoscitula Glaessner
Globorotalia convexa Subbotina
Globorotalia imitata Subbotina
Globigerina soldadoensis Brönnimann group
Globigerina collactea (Finlay)
Globigerina yeguaensis Weinzierl and Applin
Pseudohastigerina micra (Cole)
Catapsydrax unicavus Bolli, Loeblich, and Tappan
Eocene spumellarias and nassellarias.

BR station 418
Lithology: Shale, silicified, irregularly laminated, grayish yellow to moderate yellow with asphalt pebbles (coccolithite-radiolarite).
Texture: As BR stations 416 and 417.
Assemblage: Radiolaria (abundant)
Coccoliths (abundant), mainly placoliths
Discoaster lodoensis Bramlette and Riedel (abundant)
a) typical forms
b) forms with stellate central knob
Discoaster barbadiensis Tan
Discoaster cf. *aster* Bramlette and Riedel
Discoaster aecus Brönnimann and Stradner
Discoaster geometricus Brönnimann and Stradner
Discoaster currens Stradner
Marthasterites tribrachiatus (Bramlette and Riedel) (rare)
Thoracosphaera sp.
Globigerinas with thick and coarsely perforate walls.



About 20 m of Universidad formation are exposed on the east side of the road cut at the Autopista del Mediodía (cross section, fig. 47). The lower 12 m, approximately, are Toledo member and the upper 8 m are the lower part of the transitionally overlying Príncipe member. The Príncipe member is here overlain by transgressive and slightly unconformable Cojímar formation of *Globorotalia fohsi* age. The details of this contact will be described later under Príncipe member. On the west side of the road cut, the transgressive Cojímar formation cuts deeper and overlies the Toledo member as shown in the cross section of the road cut, fig. 48. The unconformity is characterized by bore holes in Toledo limestones filled with Cojímar material and by the occurrence of siliceous pebbles of the Toledo member at the base of the Cojímar formation. BR station 549 is from the bed with bore holes, and BR station 547 from the base of the Cojímar formation. On the eastern side, the about 5 m thick transitional zone between the Toledo and Príncipe members shows the progressive disappearance of the siliceous limestones. There, the Toledo member is composed of thin beds of cream to tan and grayish silicified limestones, marls, chalky limestones and more or less silicified chalky limestones. Small, irregularly distributed asphalt pebbles have been encountered throughout

Fig. 48. Western side of the road cut at Autopista del Mediodía.

the Universidad formation and in the basal beds of the Cojímar formation where they are probably reworked from the Universidad formation. The stratigraphic positions of the samples from the Toledo–Cojímar contact on the western side of this road cut are indicated in the cross section, fig. 48. They are listed from bottom to top.

BR station 548 (Universidad formation, Toledo member)
Lithology: Chalk, soft, powdery, whitish to very pale orange.

Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globigerina soldadoensis BRÖNNIMANN group
Globigerina senni (BECKMANN)
Globigerina aff. *prolata* BOLLI.

BR station 549

This sample is from the zone with bore holes below the unconformity surface. Material from bore hole fillings has been washed (a) and hard limestone from the Toledo beds in which the bore holes are sunk has been sectioned (b).

(a) Washed residue of very pale orange to grayish orange Cojímar chalk from bore hole fillings with

Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia fohsi lobata BERMÚDEZ
Globorotalia mayeri CUSHMAN and ELLISOR
Sphaeroidinella grimsdalei (KEIJZER)
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globorotalia bullbrooki BOLLI (reworked from Toledo member)

(b) Thin section from very pale orange to grayish orange Toledo limestone (coccolithite-radiolarite).

Assemblage: *Globorotalia bullbrooki* BOLLI
Globigerina spp.
Pseudohastigerina micra (COLE)
Radiolaria
Coccoliths (rock-forming)
Discoaster barbadiensis TAN (typical and minute forms)
Discoaster aster BRAMLETTE and RIEDEL
Discoaster lodoensis BRAMLETTE and RIEDEL.

BR station 547

This is a siliceous pebble from the conglomerate at the base of the Cojímar chalks which yields mixed Toledo and Cojímar faunas.
Lithology: Cryptocrystalline groundmass with planktonic microfossils.

Assemblage: *Globorotalia* spp. (truncate forms)
Globigerina spp. with thick and coarsely perforate walls
Coccoliths (rock-forming), mainly placoliths
Discoaster aster BRAMLETTE and RIEDEL

Discoaster sp. close to *D. barbadiensis* TAN, but without central knob
Discoaster barbadiensis
Discoaster cf. *molengraaffi* TAN
Braarudosphaera discula BRAMLETTE and RIEDEL (abundant)
Micrantholithus sp. (not as strongly incised as *M.* cf. *vesper* DEFLANDRE illustrated by BRAMLETTE and RIEDEL, 1958, pl. 38, fig. 8)
Nannotetraster swasticoides (MARTINI)
Thoracosphaera sp.

BR station 546 (Cojímar)
Lithology: Chalk, soft, very pale yellowish orange.
Assemblage: *Globorotalia fohsi fohsi* CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Orbulina suturalis BRÖNNIMANN
Sphaeroidinella grimsdalei (KEIJZER).

Tejar Consuelo

Tejar Consuelo is located about 400 m southwest of the intersection of Avenida 26 and Calzada de Puentes Grandes, Cerro. The coordinates of the southern building of the brick factory are 364.50 N and 356.58 E (location map, fig. 59). For details on the geology of the quarry at Tejar Consuelo see the description under Consuelo formation. The Toledo member forms the lower portion of the southwestern cliff of the quarry, where it is overlain transitionally by the Príncipe member of the Universidad formation. Toledo beds are not exposed at the northeastern cliff of the quarry, but they occur either disconformably or slightly unconformably on the Capdevila beds in the eastern part of the quarry where Calle Santa María reaches the quarry area. The individual Toledo beds are here much thicker than in the quarry at Tejar Toledo. They consist of about 7 to 8 m of whitish to grayish greenish chalky and marly limestones with thin interbeds of silicified limestone and of siliceous nodules. Asphalt pebbles occur throughout the Universidad formation but mainly in the Príncipe beds. The Oligocene Consuelo formation overlies at Tejar Consuelo the Príncipe member with a slight but distinct angular unconformity (photographs, figs. 56, 57 and columnar sections, fig. 60). The Toledo member is here less silicified than at the type locality at Tejar Toledo.

The relative stratigraphic position of the Toledo samples is indicated in the columnar section, fig. 60. They are listed from bottom to top:

BR station 359
Lithology: Chalk, soft, powdery, pale to dark yellowish orange, with asphalt pebbles.

Washed residue with
Globorotalia spinuloinflata (BANDY)
Globigerina senni (BECKMANN).

BR station 358
Lithology: Chalk, hard, powdery, pale yellowish orange with asphalt pebbles.
Washed residue with

Globorotalia bullbrooki Bolli
Globorotalia aff. *planoconica* Subbotina
Globorotalia convexa Subbotina
Globigerina soldadoensis Brönnimann group
Globigerina cf. *turgida* Finlay
Globigerina cf. *senni* (Beckmann)
Pseudohastigerina micra (Cole)
Eocene spumellarias and nassellarias.

BR station 357
Lithology: Limestone, silicified, hard, slightly calcareous, finely laminated, with minute asphalt pebbles, very pale orange to grayish orange (coccolithite-radiolarite).
Texture: Silicified cryptocrystalline groundmass with abundant planktonic microfossils, in particular well-preserved coccoliths and discoasterids.
Assemblage: *Globorotalia bullbrooki* Bolli group
Globigerina spp. with thick and coarsely perforate walls
Chiloguembelina sp.
Pseudohastigerina micra (Cole)
Coccoliths, mainly placoliths (rock-forming)
Discoaster lodoensis Bramlette and Riedel up to 35 μ maximum diameter (abundant)
Discoaster woodringi Bramlette and Riedel
Discoaster barbadiensis Tan (common)
Discoaster aster Bramlette and Riedel (common)
Discoaster aecus Brönnimann and Stradner
Discoaster binodosus Martini
Zygolithus dubius Deflandre
Heliorthus fallax Brönnimann and Stradner
Braarudosphaera discula Bramlette and Riedel
Thoracosphaera spp.
Radiolaria (abundant).

Quarry east of Río Almendares, Nuevo Vedado

The entrance to this quarry is at the intersection of Avenida Antonio Soto with Calle 38 of Reparto Nuevo Vedado, coordinates 365.22 N and 356.08 E. About 29 m of Universidad formation are outcropping below the Vedado (?) formation, which is deposited on a very irregular channeled unconformity surface. Possibly there is Urría formation between the Vedado (?) formation and the Toledo member of the Universidad formation represented by 21 m of whitish to greenish gray, more or less shaley and chalky limestone with thin layers and nodules of silicified limestone. Asphalt pebbles are very conspicuous. The silicified beds are rather thin compared with those of the outcrops at Tejar Consuelo and separated by thicker chalky beds. The bottom of the member is not exposed. BR stations 680 and 680A are lithologically and faunally very similar random samples from the base of the Toledo member outcropping in this quarry:

BR stations 680 and 680 A
Lithologies: Chalk, powdery, white to grayish yellow.
Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia aff. *convexa* SUBBOTINA
Globigerina senni (BECKMANN)
Globigerina boweri BOLLI
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Pseudohastigerina micra (COLE)
Eocene spumellarias and nassellarias.

Avenida de los Presidentes

The two members of the Universidad formation are cut by Avenida de los Presidentes between the monument of J. M. Gómez and the intersection with Avenida de la Universidad, coordinates 367.41 N and 358.26 E (index map, fig. 49). The total thickness of the Universidad formation is about 20 m. The Toledo member consists of only 4 to 5 m of white to yellowish chalky limestones with irregular beds and nodules of more or less silicified fractured limestones. As shown by the columnar section, fig. 51, the Toledo member is here considerably less silicified than in the quarry at Tejar Toledo. It overlies unconformably the brownish, thin and irregularly bedded gypsum-bearing graywacke sands, silts and shales of the basal unit of the Capdevila formation. The lowermost beds of the Toledo member, represented by BR station 1005, are somewhat brownish and shaley which is probably caused by reworking of Capdevila lithologies. Southwest of the Castillo del Príncipe at the corner of Calle C and Calle Zapata, just at the entrance to the Hospital de Nuestra Señora de las Mercedes, the silicified Toledo member is exposed in a low cliff where BR station 687 has been collected.

The stratigraphic position of the following samples is shown in the index map, fig. 49 and in the columnar section, fig. 51. They are from bottom to top:

BR station 1005 (Universidad formation, Toledo member, base)
Lithology: Shale, calcareous, moderate yellowish brown, associated with leached silicified limestone, pale yellowish brown to very pale orange.
Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia aspensis (COLOM)
Globorotalia bullbrooki BOLLI
Globorotalia convexa SUBBOTINA
Globorotalia palmerae CUSHMAN and BERMÚDEZ
Globorotalia pseudoscitula GLAESSNER
Globigerina aff. *collactea* (FINLAY)
Globigerina aff. *prolata* BOLLI
Pseudohastigerina micra (COLE).

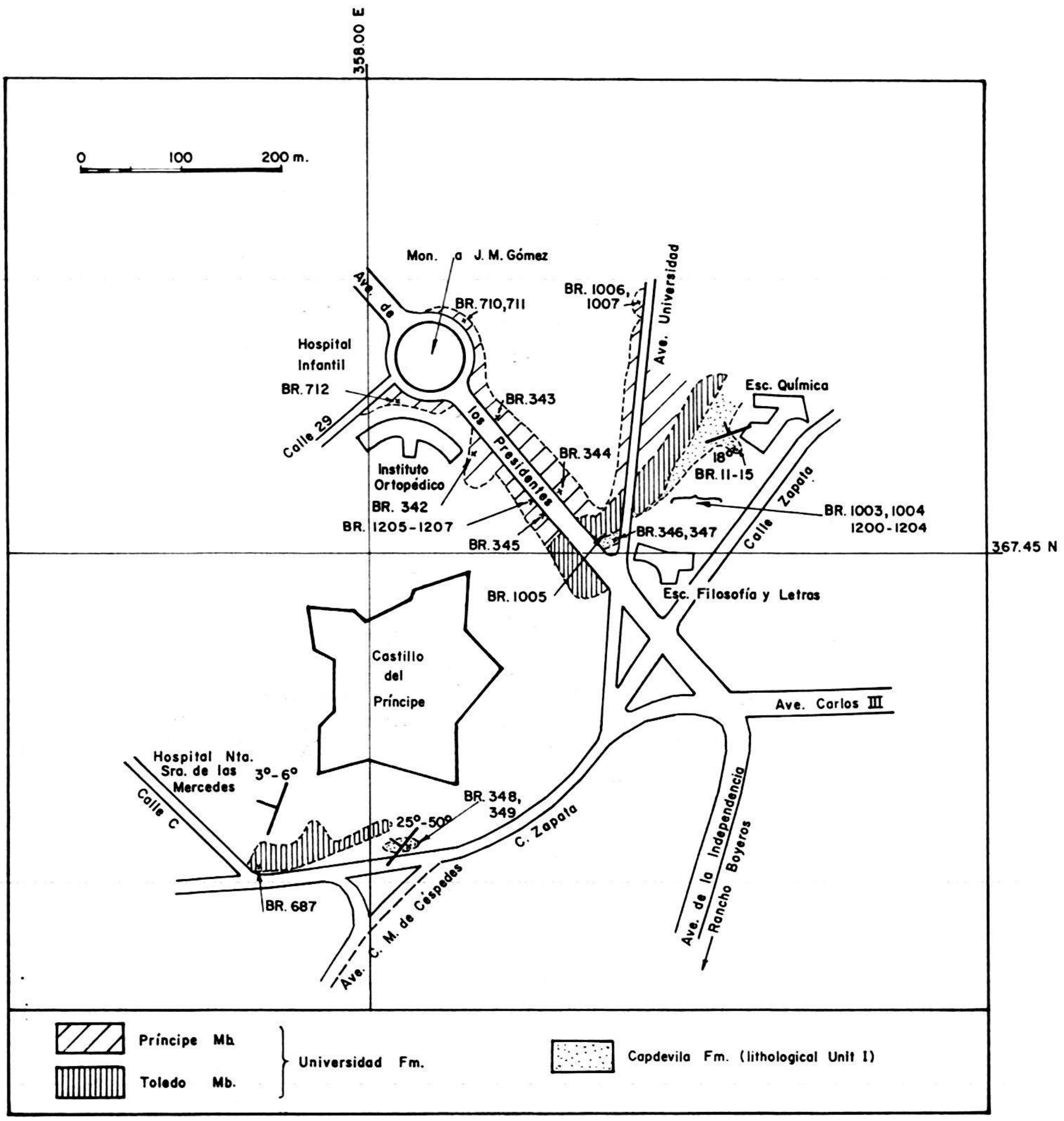


Fig. 49. Index map of the area at Castillo del Príncipe.

The outcrop at the corner of Calle C and Calle Zapata is documented by BR station 687:

Lithology: Limestone, silicified, hard, with asphalt pebbles, very pale orange (coccolithite).

Texture: Microcrystalline, silicified groundmass with abundant planktonic microfossils.

Assemblage: *Globorotalia* spp. (truncate forms)
Globigerina spp. with thick and coarsely perforate walls
Pseudohastigerina micra (COLE)
Coccoliths, mainly placoliths (rock-forming)
Discoaster sp. close to *D. barbadiensis* TAN but without central knob

Discoaster barbadiensis Tan (abundant)
Discoaster cf. *lodoensis* Bramlette and Riedel (small forms with short thin needle-like radii)
Discoaster lodoensis Bramlette and Riedel (corroded specimens are common)
Thoracosphaera spp.

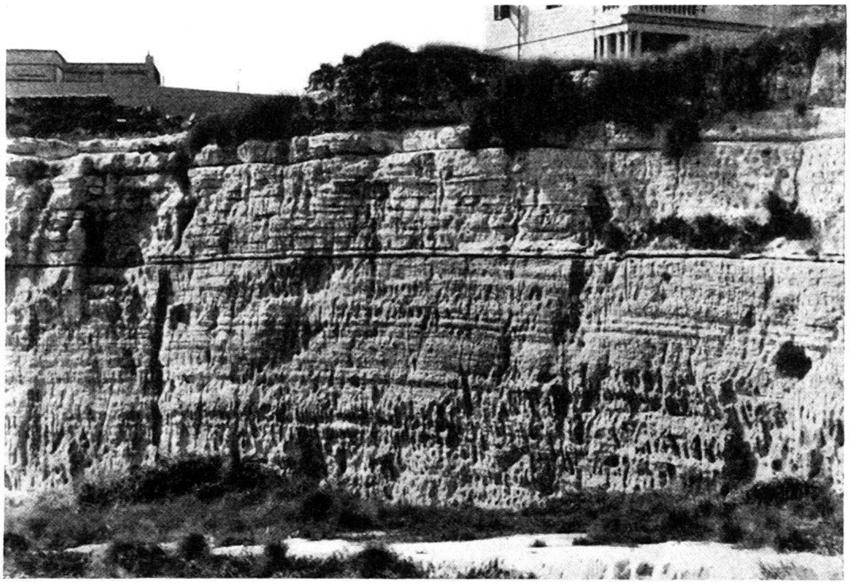


Fig. 50. View of the western side of the road cut at Avenida de los Presidentes just below the Instituto Ortopédico, showing the Príncipe member of the Universidad formation.

Príncipe member

The contact between Príncipe and Toledo members is transitional throughout the area studied. The true top of the Príncipe member is not known because it is everywhere unconformably overlain by younger rocks. The younger beds of the Príncipe member are of Middle Eocene age with *Hantkenina mexicana* Cushman, *Hantkenina dumblei* Weinzierl and Applin, *Globorotalia spinulosa* Cushman, *Globorotalia lehneri* Cushman and Jarvis, *Globorotalia aragonensis* Nuttall, *Truncorotaloides rohri* Brönnimann and Bermúdez, *Truncorotaloides topilensis* (Cushman), *Globigerapsis index* (Finlay), *Globigerina boweri* Bolli and the first representatives of *Globorotalia centralis* Cushman and Bermúdez. Some of these forms are characteristic of the early Middle Eocene *Hantkenina mexicana–Globorotalia aragonensis* zone, which overlies the *Globorotalia aragonensis–Globorotalia bullbrooki* zone of late Lower Eocene age and others of the late Middle Eocene *Hantkenina dumblei–Globigerinatheka barri* zone or common to both zones.

The unconformable upper boundary of the Universidad formation points toward post-Príncipe movements. In the quarry east of Punta Brava, the Universidad formation has been completely eroded before Upper Eocene time, allowing the transgression of the Upper Eocene Punta Brava formation on the Lower Eocene Capdevila formation. In other places, the Basal Oligocene Consuelo formation (Tejar Consuelo and Husillo quarry), or the Husillo formation (Tejar Andrade), or the Cojímar formation (co-type locality Cojímar formation, Tejar Andrade), or the Rosario formation (quarry 1.5 km west-southwest of Santa María del Rosario) overlie unconformably the Príncipe beds.

Description of the type locality of the Príncipe member

The type locality of the Príncipe member is situated along the road cut at Avenida de los Presidentes between the monument of J. M. Gómez and the intersection with Avenida de la Universidad, coordinates 367.41 N and 358.26 E (index map, fig. 49). The road cut is illustrated by the photograph, fig. 50. The Príncipe member is about 16 m thick and formed by massive, white to yellowish and orange fine-grained chalks and chalky limestones (columnar section, fig. 51). The chalk is generally hard and locally shows, evidenced by darker and lighter colors, crossbedding probably caused by submarine currents. There are a few thin and softer shaley breaks. BR station 712 is from the less massive top beds of the Príncipe member on the west-northwest side of the road cut close to the Instituto Ortopédico of the University of Habana. They bear tubular organisms and small pebbles probably of intraformational origin. Asphalt pebbles have been noticed throughout the Príncipe beds. The contact with the underlying poorly silicified Toledo beds is transitional.

At the base of the western cliff of the road cut, about 100 m northeast of the intersection of Avenida de los Presidentes and Avenida de la Universidad, occurs an irregularly contoured recrystallized silicified limestone body of nodular appearance, which is embedded in Príncipe chalks. Recrystallization apparently was caused by waters which raised along a minor fault. The irregular top of this mass could be taken for an unconformity. Oil impregnation, probably also fault

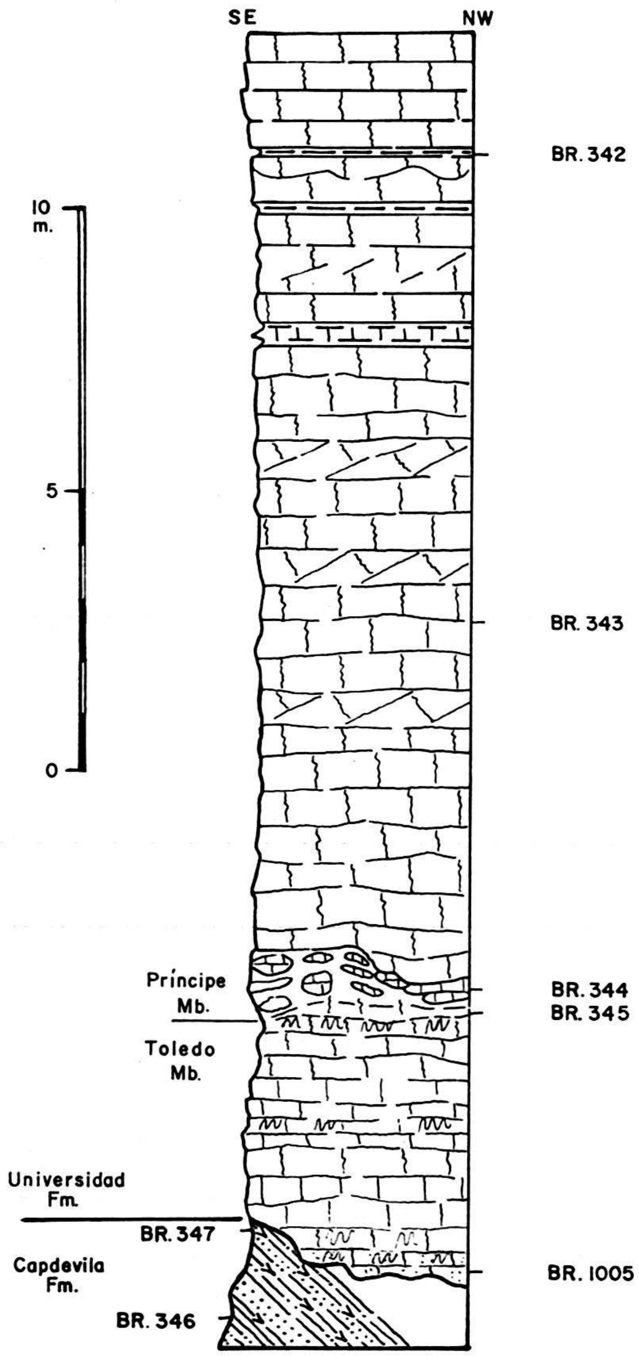


Fig. 51. Columnar section of Capdevila beds and Universidad formation, Avenida de los Presidentes.

controlled, was noticed in the chalk immediately overlying the silicified mass. Another secondary alteration was seen at the top of the Príncipe beds just beneath the buildings of the Hospital Calixto García at Avenida de la Universidad, where the overlying Miocene limestones have been changed by surface waters into a hard recrystallized, cavernous mass. Bore holes made by lithophagic organisms were noticed and thin sections from BR stations 1006 and 1007 exhibit numerous *Palaxius habanensis* BRÖNNIMANN and NORTON, a crab coprolite with 2 groups of 5 comma-shaped canals (BRÖNNIMANN and NORTON, 1961).

The relative stratigraphic position of the Príncipe type samples is shown in the index map and in the columnar section (figs. 49, 51). They are listed below from bottom to top:

BR station 1207
Lithology: Limestone, hard, light yellowish gray.
Texture: Microcrystalline groundmass with abundant planktonic Foraminifera. Asphalt inclusions.

Assemblage:
- *Globorotalia* spp. (truncate forms)
- *Globigerina senni* (BECKMANN)
- *Globigerina* spp. with thick and coarsely perforate walls
- Coccoliths } rare
- *Thoracosphaera* spp. } rare

BR station 1205
Lithology: Shale, calcareous, pale yellowish brown to light olive gray.
Washed residue with
- *Globorotalia aspensis* (COLOM)
- *Globorotalia spinuloinflata* (BANDY)
- *Truncorotaloides rohri* BRÖNNIMANN and BERMÚDEZ
- *Globigerina boweri* BOLLI
- *Globigerina senni* (BECKMANN)
- *Globigerina* aff. *yeguaensis* WEINZIERL and APPLIN
- *Catapsydrax unicavus* BOLLI, LOEBLICH, and TAPPAN
- *Pseudohastigerina micra* (COLE).

BR station 1206
Lithology: Chalk, soft, powdery, pale yellowish orange, with asphalt pebbles.
Washed residue with
- *Globorotalia aragonensis* NUTTALL
- *Globorotalia aspensis* (COLOM)
- *Globorotalia convexa* SUBBOTINA
- *Globorotalia spinuloinflata* (BANDY)
- *Truncorotaloides* aff. *topilensis* (CUSHMAN)
- *Globigerapsis index* (FINLAY)
- *Catapsydrax unicavus* BOLLI, LOEBLICH, and TAPPAN
- *Globigerina* aff. *collactea* (FINLAY)
- *Globigerina senni* (BECKMANN)
- *Globigerina soldadoensis* BRÖNNIMANN group

Globigerina turgida FINLAY
Globigerina cf. *yeguaensis* WEINZIERL and APPLIN
"*Globigerinoides*" *higginsi* BOLLI.

BR 345 (Universidad formation, Príncipe member, base)
Lithology: Chalk, soft, powdery, grayish orange to dark yellowish orange.
Washed residue with
Globorotalia aspensis (COLOM)
Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globigerina prolata BOLLI
Globigerina soldadoensis BRÖNNIMANN group
Globigerina aff. *turgida* FINLAY
Globigerina aff. *yeguaensis* WEINZIERL and APPLIN.

BR station 344
Lithology: Limestone, silicified, hard, with asphalt pebbles, very pale orange.
Texture: Microcrystalline groundmass with abundant planktonic microfossils.
Assemblage: *Globorotalia* spp. (truncate forms)
Globigerina with thick and coarsely perforate walls
Pseudohastigerina micra (COLE)
Coccoliths
Discoaster barbadiensis TAN
Thoracosphaera sp.

BR station 343
Lithology: Chalk, soft, white to light grayish yellow with algal pebbles.
Washed residue with
Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia cf. *spinulosa* CUSHMAN
Globigerina senni (BECKMANN)
Globigerina soldadoensis BRÖNNIMANN group
Globigerina aff. *yeguaensis* WEINZIERL and APPLIN
Globigerina sp.
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Pseudohastigerina sp. close to *P. micra* (COLE), but with compressed test.

BR station 342
Lithology: Chalk, soft, white.
Washed residue with
Globorotalia aragonensis NUTTALL
Globorotalia aspensis (COLOM) group
Globorotalia bullbrooki BOLLI
Globigerina boweri BOLLI
Globigerina senni (BECKMANN)
Globigerina aff. *yeguaensis* WEINZIERL and APPLIN.

BR station 710 and 711
Lithology: Chalk, soft, powdery, white to yellowish, with asphalt pebbles.
Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia aff. *spinuloinflata* (BANDY)
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Globigerina boweri BOLLI
Globigerina yeguaensis WEINZIERL and APPLIN.

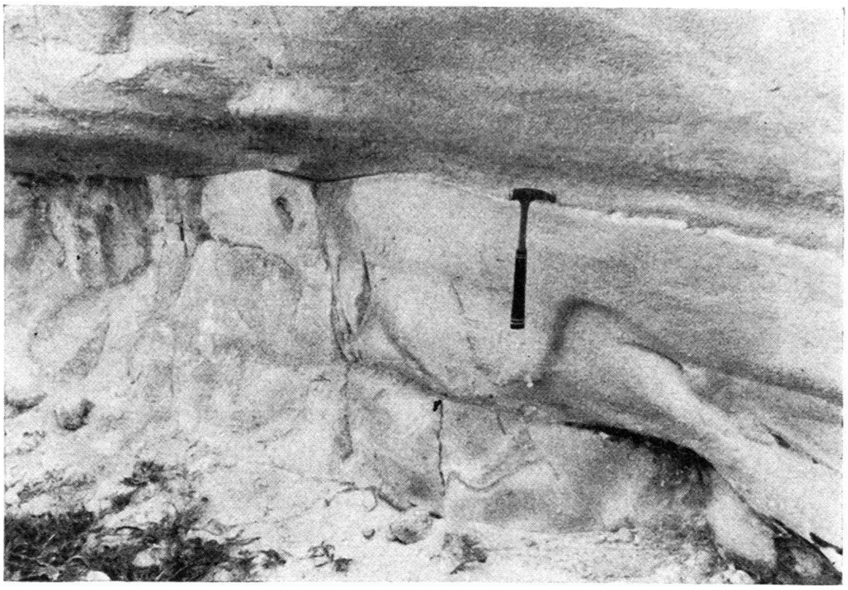


Fig. 52. Intraformational unconformity in the Universidad formation, quarry east of Río Almendares.

BR station 712
Lithology: Chalk, soft, powdery, white.
Washed residue with

Hantkenina dumblei WEINZIERL and APPLIN
Hantkenina mexicana CUSHMAN
Globorotalia aragonensis NUTTALL
Globorotalia cf. *bullbrooki* BOLLI
Globorotalia spinulosa CUSHMAN
Truncorotaloides topilensis (CUSHMAN)
Globigerina boweri BOLLI
Globigerina aff. *linaperta* FINLAY
Globigerina yeguaensis WEINZIERL and APPLIN
"*Globigerinoides*" *higginsi* BOLLI.

BR stations 1006 and 1007 are two random samples from the recrystallized chalk at Hospital Calixto García, just at the Eocene–Miocene unconformity:
Lithology: Limestone, hard, vacuolar, yellowish to yellowish gray.

Texture: Cryptocrystalline, dense, in places recrystallized clear calcite, with abundant planktonic microfossils and some benthonic Foraminifera and *Palaxius habanensis* Brönnimann and Norton (crab coprolites) in fillings of bore holes.

Assemblage: *Globorotalia* cf. *lehneri* Cushman and Jarvis
Globorotalia spp. (truncate forms)
Truncorotaloides topilensis (Cushman)
Globigerina senni (Beckmann)
Coccoliths
Discoaster barbadiensis Tan
Braarudosphaera discula Bramlette and Riedel.

Other outcrops of the Príncipe member

Autopista del Mediodía

In the description of the Toledo member we have mentioned that the contact between the Príncipe and the Toledo members on the eastern side of the road cut is transitional (index map, fig. 45, and columnar section, fig. 46). The massive, more or less chalky, whitish and yellowish limestones of the Príncipe formation show at this locality a gradual increase of limonitic material toward the top. Several irregular limonitic surfaces are suggestive of intraformational disconformities. The top beds are recrystallized, strongly limonitic and the unconformity surface is characterized by bore holes filled with material of the transgressively overlying *Globorotalia fohsi*-bearing Cojímar formation. On the western side of the road cut, the Príncipe member had been eroded in pre-Cojímar time and is found only in the form of limonitic limestone pebbles at the base of the Cojímar formation (cross section, fig. 48). Asphalt pebbles occur throughout the Príncipe beds.

The only sample investigated from the eastern side of the road cut is just from the uppermost bed of the Príncipe member:

BR station 455

Lithology: Limestone, hard, with asphalt pebbles, very pale orange.

Texture: Cryptocrystalline to microcrystalline groundmass with limonitic specks and abundant planktonic microfossils.

Assemblage: *Globorotalia* spp. (truncate forms)
Globigerina spp. with thick and coarsely perforate walls
Pseudohastigerina micra (Cole)
Coccoliths, mainly placoliths (abundant)
Braarudosphaera cf. *bigelowi* (Gran and Braarud)
Braarudosphaera discula Bramlette and Riedel (abundant)
Discoaster sp. close to *D. barbadiensis* Tan, but without central knob
Discoaster barbadiensis Tan
Discoaster cf. *molengraaffi* Tan
Discoaster cf. *lodoensis* Bramlette and Riedel
a) forms close to the typical ones
b) forms with slightly indentated radii
Thoracosphaera sp.

Tejar Consuelo

The Príncipe member is at Tejar Consuelo in transitional contact with the silicified Toledo member (index map, fig. 59). It consists of about 15 m of more or less well-bedded, whitish to yellowish chalks and marls. Numerous asphalt pebbles are irregularly dispersed throughout the Príncipe beds. There are local accumulations of chalk pebbles of intraformational origin, particularly in the eastern cliff of the quarry. The Príncipe member is cut unconformably by the lithologically very similar transgressive Oligocene Consuelo chalks of the *Globigerina ampliapertura* zone (photographs, fig. 56, 57, and columnar sections, fig. 60). In its basal beds the latter show slumping phenomena. The unconformity between Universidad and Consuelo formations is evidenced by different dips, but features suggestive of emergence such as bore holes or limonitic crusts do not occur in the cliff. On the eastern side of the quarry, however, a good contact with bore holes and Universidad pebbles can be observed on top of the Príncipe beds. Here, the unconformity surface is very irregular and channeled as in the quarry east of Río Almendares. BR station 708 is from intraformational pebbles of the Príncipe beds, and BR station 703 from the top of the Príncipe beds.

The stratigraphic position of the following samples from the western cliff of the quarry can be seen in the columnar sections (fig. 60). They are here listed from bottom to top:

BR station 356
Lithology: Limestone (radiolarite-coccolithite), hard, with asphalt pebbles, laminated, pale greenish yellow (1) and chalk, hard, whitish yellow (2).
Texture: Cryptocrystalline groundmass with abundant planktonic microfossils (1).
Assemblages: *Globorotalia* spp. (truncate forms)
Globigerina spp. with thick and coarsely perforate walls
Coccoliths, mainly placoliths (rock-forming)
Radiolaria (abundant)
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN (abundant)
a) typical forms
b) minute forms of about 6μ diameter with large central knob of 2 to 2.5 μ diameter. In these specimens, the radii appear to be better separated than in *D. barbadiensis.*
Discoaster lodoensis BRAMLETTE and RIEDEL (common)
Discoaster colleti PARÉJAS
Discoaster hilli TAN
Discoaster gemmeus STRADNER
Discoaster geometricus BRÖNNIMANN and STRADNER
Nannotetraster swasticoides (MARTINI)
Marthasterites sp.
Thoracosphaera spp.

Washed residue (2) with
Globorotalia aragonensis NUTTALL
Globorotalia aspensis (COLOM) group

Globorotalia bullbrooki Bolli
Globigerina cf. *senni* (Beckmann)
Globigerina soldadoensis Brönnimann group
Eocene spumellarias and nassellarias.

BR station 353A
Lithology: Chalk, powdery, grayish yellow, with asphalt pebbles.
Washed residue with
Globorotalia aragonensis Nuttall
Globorotalia aspensis (Colom)
Globorotalia bullbrooki Bolli
Globorotalia convexa Subbotina
Globorotalia spinuloinflata (Bandy)
Globigerina cf. *prolata* Bolli
Globigerina senni (Beckmann)
Globigerina soldadoensis Brönnimann group (abundant)
Globigerina cf. *turgida* Finlay
Catapsydrax unicavus Bolli, Loeblich, and Tappan
Pseudohastigerina micra (Cole).

BR stations 354 and 355
Lithology: Chalk, nodular, fairly hard, whitish to grayish yellow (354), and chalk, powdery, whitish yellow (355).
Washed residues with
Globorotalia aragonensis Nuttall
Globorotalia aspensis (Colom)
Globorotalia bullbrooki Bolli
Globigerina senni (Beckmann)
Globigerina soldadoensis Brönnimann group
Globigerina aff. *yeguaensis* Weinzierl and Applin
Catapsydrax cf. *unicavus* Bolli, Loeblich, and Tappan.

The following samples are from the Príncipe member of the northeastern cliff of the quarry. Their stratigraphic position is shown in the index map of the Consuelo area, fig. 59:

BR station 708 (intraformational pebbles or concretions in the Príncipe beds)
Pebble 1
Lithology: Chalk, indurated, grayish yellow, with asphalt inclusions.
Texture: Microcrystalline, with asphalt inclusions and recrystallized remains of planktonic microfossils. Recrystallization destroyed discoasterids, coccoliths, etc.

Pebble 2
Lithology: Chalk, indurated, blotchy, grayish yellow, with asphalt inclusions.
Texture: As pebble 1.

Pebble 3
Lithology: Chalk, indurated, whitish to grayish yellow, with limonitic film.
Texture: As pebbles 1 and 2.

Assemblage: *Thoracosphaera* sp.
Discoaster barbadiensis TAN.

BR station 703

Lithology: Chalk, indurated, powdery, grayish yellow, with abundant asphalt fragments.

Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia convexa SUBBOTINA.
Globorotalia spinuloinflata (BANDY)
Globigerina senni (BECKMANN)
Globigerina soldadoensis BRÖNNIMANN group
Globigerina turgida FINLAY
Globigerina yeguaensis WEINZIERL and APPLIN
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN

Quarry east of Río Almendares

The location of this quarry is described under Toledo member. The Príncipe member is here a rather massive whitish yellow chalk with some thin marly layers. The preserved thickness below the transgressive coralligen Vedado (?) formation is about 4 to 10 m. Asphalt pebbles are abundant. A low-angle intraformational unconformity has been observed within the Príncipe member at the northwest side of the quarry as shown by the photograph, fig. 52. The unconformity surface on top of the Príncipe member is very irregularly channeled. We were not able to obtain samples from the somewhat darker top beds underlying the Vedado (?) formation nor from the latter. Although the darker beds are believed to be Universidad formation, a faunistic study is needed to exclude the possibility of their being part of the Consuelo formation.

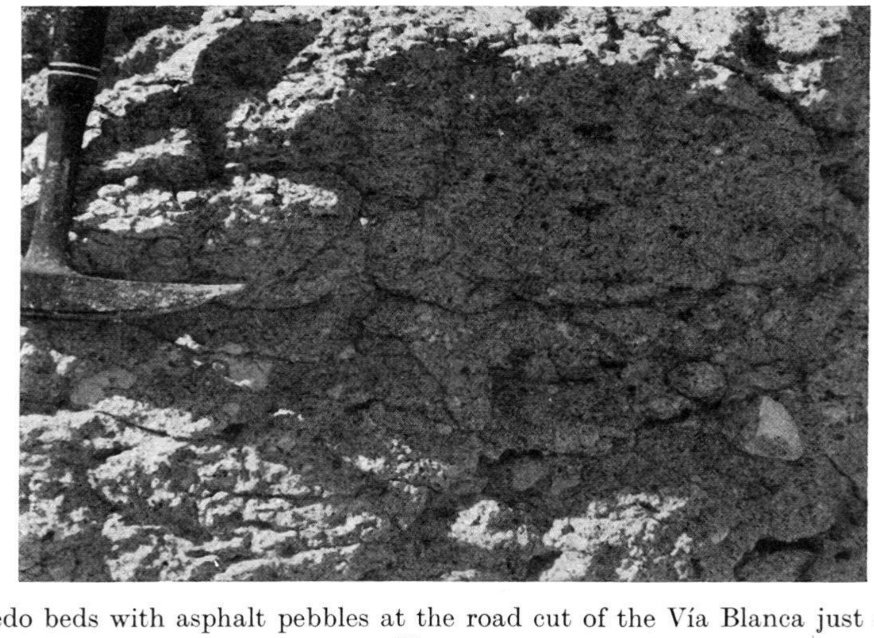


Fig. 53. Toledo beds with asphalt pebbles at the road cut of the Vía Blanca just east of Playa Jibacoa.

Fig. 54. Toledo beds with asphalt veins at the road cut of the Vía Blanca just east of Playa Jibacoa.

Many excellent outcrops of Universidad beds occur along the rim-rock of the Marianao area. Of these only two will be mentioned, i.e. Cantera Husillo and Tejar Andrade.

Cantera Husillo

The Príncipe member of the Universidad formation is well exposed in the southeastern part of Cantera Husillo, Marianao, which is described in detail under Husillo formation (index map, fig. 67). The beds dip 6° toward W 10° N. The following Príncipe samples have been collected in this quarry:

BR stations 845 and 846

BR station 846 is about 3 m stratigraphically below station 845, which comes from a bed showing slumping features. The samples from these stations are lithologically and faunally very similar and are described together to avoid repetition.
Lithologies: Chalk, indurated, whitish to very pale orange (845), chalk, whitish with asphalt inclusions (846).
Textures: Cryptocrystalline to microcrystalline groundmass with planktonic microfossils.
Assemblages:
- *Globorotalia* spp. (truncate forms)
- *Globigerina senni* (BECKMANN)
- Coccoliths spp., mainly placoliths
- *Tremalithus eopelagicus* BRAMLETTE and RIEDEL (large specimens)
- *Braarudosphaera discula* BRAMLETTE and RIEDEL (common to abundant)
- *Discoaster aster* BRAMLETTE and RIEDEL
- *Discoaster barbadiensis* TAN
- *Discoaster* cf. *lodoensis* BRAMLETTE and RIEDEL

Discoaster cf. *woodringi* BRAMLETTE and RIEDEL
Micrantolithus cf. *vesper* DEFLANDRE
Thoracosphaera spp. (globular and ellipsoid bodies).

Fig. 55. Typical thin-bedded siliceous Toledo beds at the road cut of the Vía Blanca just east of Playa Jibacoa.

Washed residue with

Globorotalia cf. *aragonensis* NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia cf. *spinuloinflata* (BANDY)
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ
Truncorotaloides topilensis (CUSHMAN)
Globorotalia convexa SUBBOTINA
Globigerinatheka barri BRÖNNIMANN
Globigerina boweri BOLLI
Globigerina senni (BECKMANN)
Globigerina yeguaensis WEINZIERL and APPLIN
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Chiloguembelina martini (PIJPERS).

Tejar Andrade

Tejar Andrade is situated east of La Lisa, a suburb of Marianao, about 500 m southwest of the Autodromo of Marianao. Coordinates of the factory building are 359.20 N and 353.00 E. In the northeastern part of Tejar Andrade, Husillo bioherms and chalky limestones rest unconformably on Príncipe beds. The Toledo member is represented by BR station 856 and the Príncipe member by BR station 858. The location of these two samples can be seen in the sketch, fig. 72.

BR station 856 (Universidad formation, Toledo member)
Lithology: Limestone, laminated, siliceous, white to grayish yellow.

Texture: Cryptocrystalline silicified groundmass with abundant planktonic microfossils and asphalt inclusions.

Assemblage: *Globorotalia* spp. (truncate forms)
Globigerina spp.
Radiolaria (common)
Coccoliths, mainly placoliths
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN
Discoaster woodringi BRAMLETTE and RIEDEL
Braarudosphaera bigelowi (GRAN and BRAARUD) (up to 23 μ diameter)
Braarudosphaera discula BRAMLETTE and RIEDEL
Marthasterites sp.
Thoracosphaera sp.

BR station 858 (Universidad formation, Príncipe member)
Lithology: Chalk, hard, powdery, white.
Texture: Microcrystalline to cryptocrystalline with abundant planktonic microfossils.

Assemblage: *Globorotalia* spp. (truncate forms)
Globigerina spp.
Chiloguembelina spp.
Coccoliths, mainly placoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Braarudosphaera bigelowi (GRAN and BRAARUD) (common)
Braarudosphaera discula BRAMLETTE and RIEDEL (common)
Braarudosphaera undata STRADNER
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN
Discoaster lodoensis BRAMLETTE and RIEDEL
Discoaster woodringi BRAMLETTE and RIEDEL
Discoaster aecus BRÖNNIMANN and STRADNER
Discoaster cf. *molengraaffi* TAN
Marthasterites sp.
Thoracosphaera sp.

BR station 858 (Universidad formation, Príncipe member)
Lithology: Chalk, hard, powdery, white.
Texture: Microcrystalline to cryptocrystalline with abundant planktonic microfossils.

Assemblage: *Globorotalia* spp. (truncate form)
Globigerina spp.
Chiloguembelina spp.
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)

Braarudosphaera bigelowi (GRAN and BRAARUD)
Braarudosphaera discula BRAMLETTE and RIEDEL
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN
Discoaster lodoensis BRAMLETTE and RIEDEL
Discoaster woodringi BRAMLETTE and RIEDEL
Marthasterites sp.

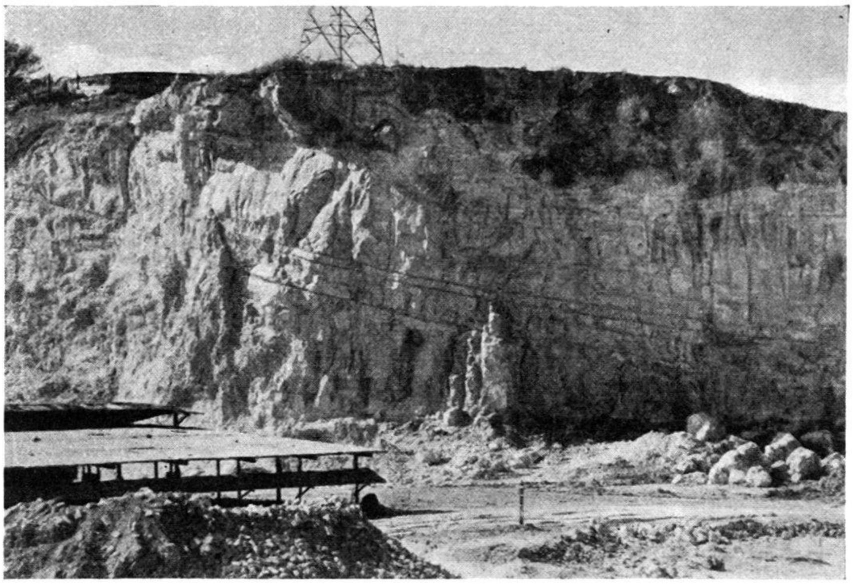


Fig. 56. General view of the southeastern cliff at Tejar Consuelo.

Washed residue with
Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia convexa SUBBOTINA
Globigerina boweri BOLLI
Globigerina turgida FINLAY
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN.

As pointed out in the introduction to this chapter, there is only a single exposure of Universidad formation at the southern rim-rock, in a large quarry near Santa María del Rosario.

Santa María del Rosario

About 1.5 km west-southwest of Santa María del Rosario is a large quarry, coordinates 359.00 N and 369.80 E, in which the Príncipe member apparently transgresses on Alkázar formation. The contact is not exposed. The Príncipe beds consist of about 15 to 20 m of hard, massive white orange chalks on top of which there are a few intercalations of a fine-grained hard, yellowish limestone. Samples from the white chalk are BR stations 1115 and 1116, and the limestone is represented by BR stations 1117 and 1149. In the eastern part of the quarry, the Príncipe member is unconformably overlain by Husillo reefal limestones of the *Lepido-*

cyclina–Miogypsina zone, where BR station 1150 is located. In the southern part of the quarry, the Universidad formation is covered by gently dipping transgressive conglomeratic chalks and marls of the Rosario formation (BR stations 1112 and 1148).

Fig. 57. Detail of the angular unconformity between the Consuelo formation, above, and the Universidad formation, Príncipe member, below, southwestern cliff at Tejar Consuelo.

BR station 1115
Lithology: Chalk, hard, powdery, very pale orange.
Texture: Cryptocrystalline groundmass with abundant planktonic microfossils.

Assemblage:
Globorotalia bullbrooki Bolli group
Globorotalia spp. (truncate forms)
Chiloguembelina martini (Pijpers)
Truncorotaloides cf. *topilensis* (Cushman)
Globigerina senni (Beckmann)
Pseudohastigerina micra (Cole)
Discoaster barbadiensis Tan
Braarudosphaera discula Bramlette and Riedel
Thoracosphaera spp.

Washed residue with
Globorotalia aff. *spinuloinflata* (Bandy)
Globigerina senni (Beckmann).

BR station 1116
Lithology: Chalk, hard, powdery, white.
Texture: Cryptocrystalline groundmass with abundant planktonic microfossils.

Assemblage:
Hantkenina cf. *mexicana* Cushman
Globorotalia lehneri Cushman and Jarvis
Globorotalia spp. (truncate forms)
Globigerina senni (Beckmann)

Coccoliths
Discoaster barbadiensis TAN
Braarudosphaera discula BRAMLETTE and RIEDEL
Thoracosphaera spp.

Washed residue with
Hantkenina dumblei WEINZIERL and APPLIN
Hantkenina mexicana CUSHMAN
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globigerina senni (BECKMANN)
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ
Globigerapsis index (FINLAY).

BR station 1117
Lithology: Limestone, very pale orange.
Texture: Cryptocrystalline groundmass with abundant planktonic microfossils.
Assemblage: *Globorotalia* spp. (truncate forms)
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ
Truncorotaloides topilensis (CUSHMAN)
Globigerina senni (BECKMANN)
Discoaster barbadiensis TAN
Braarudosphaera bigelowi (GRAN and BRAARUD)
Braarudosphaera discula BRAMLETTE and RIEDEL
Thoracosphaera spp.

BR station 1149
Lithology: Limestone, very pale orange.
Texture: Microcrystalline to cryptocrystalline groundmass with recrystallized planktonic Foraminifera.
Assemblage: *Globorotalia* ex gr. *lehneri* CUSHMAN and JARVIS
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ
Truncorotaloides topilensis (CUSHMAN)
Globigerina senni (BECKMANN)
Braarudosphaera discula BRAMLETTE and RIEDEL
Thoracosphaera spp.

BR station 1150 (Husillo formation)
Lithology: Limestone, hard, white to very pale orange.
Texture: Cryptocrystalline groundmass, in places recrystallized, with abundant organic detritus. Larger Foraminifera are common.
Assemblage: *Lepidocyclina* spp. with spatulate equatorial chambers
Operculinoides sp.
Miogypsina sp.
Gypsina globulus (REUSS)
Amphistegina sp.

Associated with the white orbitoidal Husillo limestone as described above occurs a grayish orange pseudoölitic to oölitic shallow-water limestone composed of subcircular to elongate elements of a dense cryptocrystalline groundmass containing larger angular, organic fragments, embedded in a recrystallized clear calcite groundmass. The pseudoölites appear to be crab coprolites. The oölites were originally pseudoölites around which one or more thin secondary layers were deposited. Composite pseudoölites were also noticed.

BR stations 1112 and 1148 (Rosario formation)

The samples from these stations are lithologically and faunally very similar and therefore described together.

Lithology: Chalk, marly, conglomeratic, white (1112) and chalk, yellowish to pale yellowish orange (1148).

Washed residue with

Discorbis floridensis Cushman
Elphidium poeyanum (d'Orbigny)
Elphidium puertoricense Galloway and Hemingway
Clavulina tricarinata d'Orbigny
Valvulina oviedoiana d'Orbigny
"*Streblus*" *beccarii* (Linné)
Amphistegina angulata (Cushman)
Globigerinoides trilobus (Reuss)
Globorotalia menardii (d'Orbigny)
Planorbulina cf. *dominicana* Bermúdez
Meandropsina cf. *matleyi* (Vaughan)
Peneroplis proteus d'Orbigny
Archaias cf. *angulatus* (Fichtel and Moll)
Reworked miogypsinas and Universidad globigerinas.

H. S. Puri (letter February 9, 1959) identified the following ostracodes from these stations:

Actinocythereis exanthemata (Ulrich and Bassler)
Bairdoppilata triangulata Edwards
Orionina vaughani (Ulrich and Bassler)
Mutilus confragosa (Edwards)
Aurila conradi (Howe and McGuirt)
Paracytheridea chipolensis Puri
Cytheropteron sp.
Loxoconcha sp.

and noted that *Bairdoppilata triangulata, Mutilus confragosa* and *Aurila conradi* are confined to the Choctawhatchee Miocene in Florida, and that *Orionina vaughani* and *Actinocythereis exanthemata* range from the Chipola Miocene to the Recent. *Paracytheridea chipolensis* is restricted to the Chipola, but as only a single specimen of this form was found Puri prefers not to put too much weight on this species, and regards the assemblage as probably of Choctawhatchee age.

Environment and age

The Universidad formation consists mainly of well-bedded, light colored chalks and limestones with generally cryptocrystalline to microcrystalline microtextures. Asphalt grains and pebbles are dispersed throughout the formation. Veins and veinlets of asphalt cutting the thin-bedded Toledo member were observed at the bottom of the road cut at the Vía Blanca just east of Playa Jibacoa about 20 km east of the Bahía de la Habana. The asphalt fragments are syngenetic. The veins and veinlets, on the other hand, are post-Universidad. The asphalt was probably derived during and after Universidad time from large seepages formed on the structures of the pre-Universidad orogeny. Toledo beds from this outcrop with

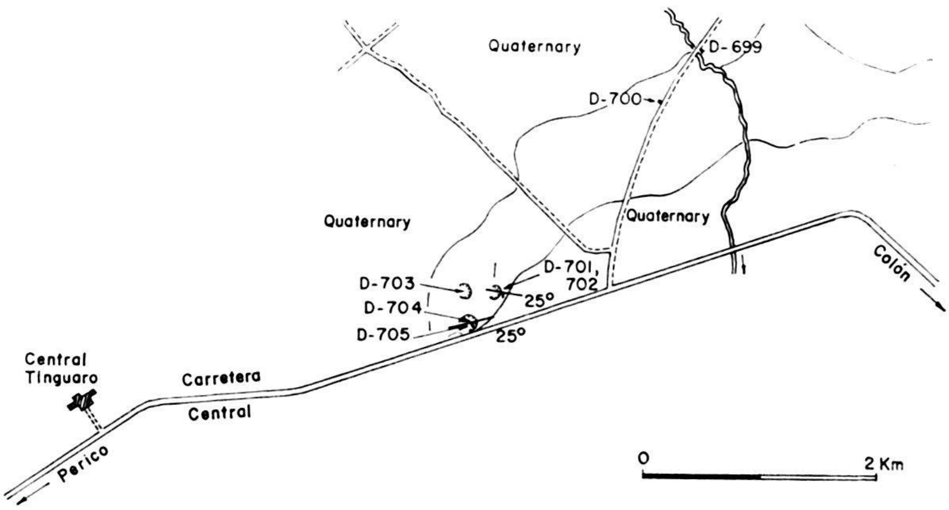


Fig. 58. Index map of the area near Central Tinguaro.

asphalt pebbles are illustrated by the photograph, fig. 53, and with asphalt veins by the photograph, fig. 54. The absence or scarcity of asphalt elements in the lithologically very similar Consuelo formation aids in distinguishing the Universidad from the overlying Consuelo beds. We noticed that asphalt pebbles are not restricted to the Universidad formation, but that they appear locally also in the Cojímar chalks. The fine-grained sediments and the large amount of planktonic microfossils, of which coccoliths, discoasterids and Radiolaria occur occasionally in rock-forming quantities, are good evidence for a basinal environment of the Universidad formation. This opinion, however, is not shared by all students of Cuban geology. Sánchez Roig (1949) reported from the Lower and Middle Eocene of Tejar Consuelo rare specimens or only fragments of *Sanchezaster habanensis* Lambert, *Habanaster sanchezi* Lambert, *Histocidaris sanchezi* Lambert (fragments of test and spines), *Cidaris cubensis* Lambert (only spines), *Centrostephanus habanensis* Lambert (only spines), *Leiopedina cienaguensis* Sánchez Roig, *Gauthieria sanchezi* Lambert, *Cyclaster jacksoni* Lambert and *Victoriaster lamberti* Sánchez Roig, and from the Toledo member of Tejar Toledo *Goniocidaris habanensis* Sánchez Roig (known only by its characteristic spines). The beds from which the echinids from the Consuelo quarry originate are not described and there is some doubt regarding their actual provenance. Possibly, some or all of them may come from the Consuelo chalks. Brodermann (1949, p. 309) inferred from the occurrence of echinids in the Lower to Middle Eocene Universidad formation that it was deposited in a shallow sea. But for the overall lithology and wide-spread distribution of the Universidad beds, the microfaunas, the microtextures, the occurrence of manganese oxide films, we do not agree with BRODERMANN. The light tests of echinids were capable of floating after death, similar to those of cephalopods, and thus could be transported from their original shallow-water habitat into the open sea.

Estimates of the ratio of planktonic and benthonic microfossils suggest that the depth of the Universidad sea was from about 600 to 1200 m (GRIMSDALE and VAN MORKHOVEN, 1955). These depth figures agree in a general way with a depth estimate of 500 to 1500 m, probably 800 to 1000 m, for the ecologically related Eo-Oligocene Oceanic sea of Barbados by BECKMANN (1954), based on the assumed depth distribution of fossil benthonic Foraminifera as derived from that of related

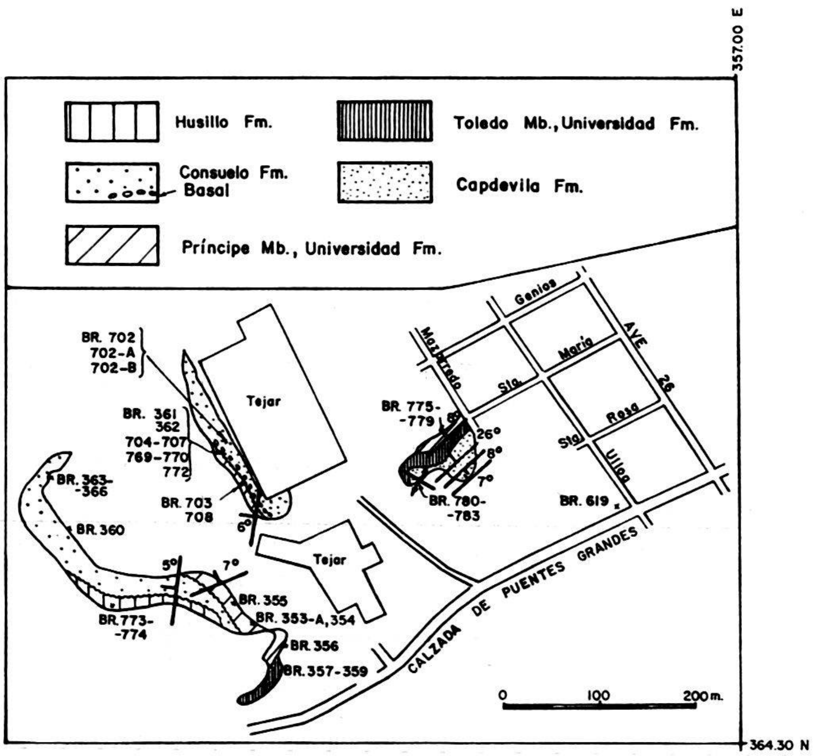


Fig. 59. Index map of Tejar Consuelo.

Recent forms. STAINFORTH (1945, 1948) suggested a depth of 400 to 500 m for the ecologically likewise related Oligo-Miocene Cipero sea of Trinidad, although the high percentage of planktonic specimens, more than 90 % according to STAINFORTH, would indicate a depth of about 1200 m, if we apply the results obtained from the depth distribution of Recent faunas of the Gulf of Mexico by GRIMSDALE and VAN MORKHOVEN (1955, p. 484).

Conspicuous sedimentary features of the Universidad formation are local intraformational unconformities, cross-bedding and slumping caused by currents and possibly by unstable bottom conditions (photograph, fig. 52). Frequently noticed were also structureless rounded pebbles from a few millimeters diameter to fist-size, composed of the same material in which they are embedded and which appear to be concretions formed contemporaneous with deposition.

Discoasters, coccoliths and associated nannofossils are common and conspicuous elements of the Universidad chalks and limestones. In silicified Toledo limestones they are often perfectly preserved. The following discoasterids were recorded:

Braarudosphaera bigelowi (Gran and Braarud) (rare)
Braarudosphaera discula Bramlette and Riedel (common to abundant)
Braarudosphaera undata Stradner
Discoaster aecus Brönnimann and Stradner
Discoaster aster Bramlette and Riedel (rare)
Discoaster barbadiensis Tan (common)
Discoaster binodosus Martini
Discoaster colleti Paréjas
Discoaster currens Stradner
Discoaster gemmeus Stradner
Discoaster geometricus Brönnimann and Stradner
Discoaster hilli Tan
Discoaster lodoensis Bramlette and Riedel (common to abundant)
Discoaster cf. *molengraaffi* Tan
Discoaster woodringi Bramlette and Riedel (rare)
Marthasterites tribrachiatus (Bramlette and Riedel) (rare)
Marthasterites spp.
Nannotetraster swasticoides (Martini).

Associated nannofossils are:

Coccoliths, mainly placoliths, which occur in rock-forming quantities, with large specimens of *Tremalithus eopelagicus* Bramlette and Riedel
Heliorthus fallax Brönnimann and Stradner
Micrantholithus sp. (rare)
Thoracosphaera spp. (common to abundant)
Zygolithus dubius Deflandre.

The Lower to Middle Eocene Universidad formation is subdivided into a lower part which belongs to the *Discoaster lodoensis-Marthasterites tribrachiatus* zone and an upper part assigned to the *Discoaster lodoensis* zone. The discoaster assemblages of the lower part which correspond to the *Globorotalia palmerae* and the *Globorotalia bullbrooki–Globorotalia aragonensis* zones are therefore identical to those of the Capdevila formation as far as the diagnostic forms are concerned.

As in the Alkázar and Capdevila formation, Radiolaria, i.e. spumellarias and nassellarias, are common in certain beds, in particular of the Toledo member.

Larger benthonic Foraminifera such as discocyclinas, asterocyclinas, *Dictyoconus* etc., and algal fragments are absent in the relatively deep-water sediments of the Universidad formation. In the thin sections and washed residues studied no reworked pre-Universidad in particular no Upper Cretaceous material was encountered.

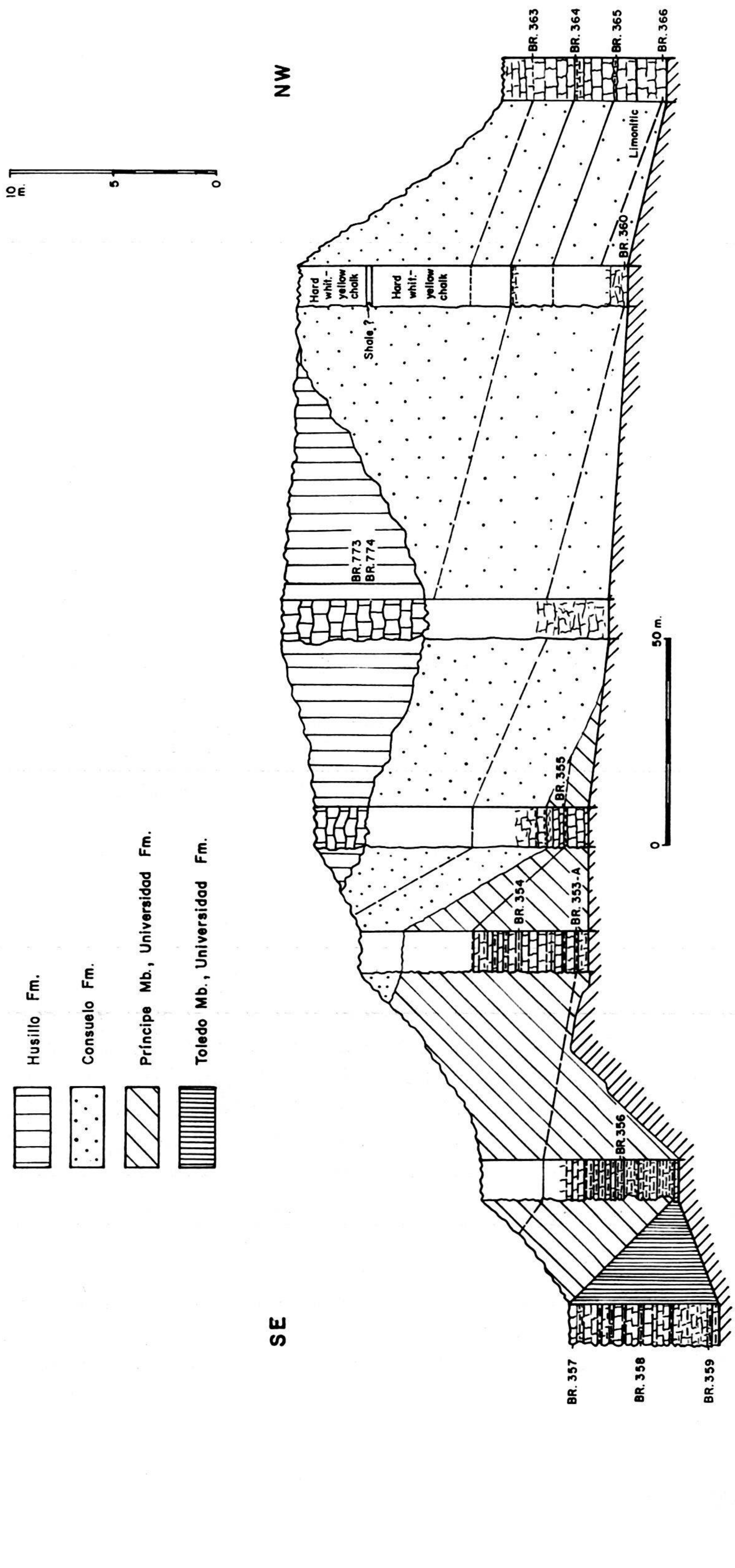


Fig. 60. Columnar section, southwestern cliff at Tejar Consuelo.

In terms of planktonic Foraminifera, the Universidad formation is zoned as follows:

d) *Hantkenina dumblei–Globigerinatheka barri* Zone	Príncipe Member	Universidad formation	Eocene	Middle
c) *Hantkenina mexicana–Globorotalia aragonensis* Zone				
b) *Globorotalia bullbrooki–Globorotalia aragonensis* Zone	Príncipe Member / Toledo Member			Lower
a) *Globorotalia palmerae* Zone	Toledo Member			

During the *Globorotalia palmerae* zone, the transition took place from the clastic flysch-type sedimentation of the Capdevila formation to the carbonate-type sedimentation of the Universidad formation. The *Globorotalia palmerae* zone therefore includes Capdevila and Universidad beds. It is of interest to note, that BOLLI

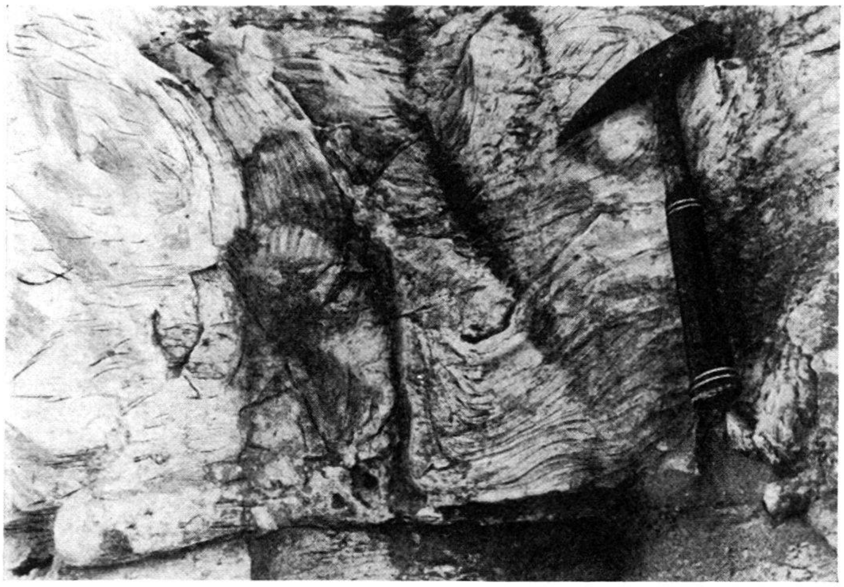


Fig. 61. Unconformity between Universidad formation, Príncipe member, below, and slumped and contorted Consuelo beds, above, Tejar Consuelo.

(1958, in LOEBLICH et al., p. 158) recognized in Trinidad a planktonic assemblage apparently intermediate between those of the *Globorotalia palmerae* and of the *Hantkenina aragonensis* [=*H. mexicana* CUSHMAN] zones in which *Globorotalia palmerae* is no longer present and *Hantkenina mexicana* has not yet appeared. This intermediate assemblage is characteristic of our late Lower Eocene *Globorotalia bullbrooki–Globorotalia aragonensis* zone. The *Hantkenina dumblei–Globigerinatheka barri* zone is only locally preserved in the Habana area. It is representative of the 4 Middle Eocene zones proposed in Trinidad, B.W.I., between the *Hantkenina mexicana–Globorotalia aragonensis* zone and the Upper Eocene *Globigerapsis semiinvoluta* zone, which in our area appear to be of minor stratigraphic significance and, if present, probably only detectable by very close-spaced sampling. Forms diagnostic of this zone were found allochthonous in Consuelo beds.

Urría Beds

A new lithologic unit of the Habana area is a recrystallized in part dolomitized limestone of post-Toledo and pre-Husillo age, here called Urría beds. It is of minor significance in the stratigraphic sequence and therefore not given formation rank. The type locality, BR station 791, is from exposures at the Avenida Monumental, at the south flank of Loma de Urría, about 1.4 km south-southwest of the coastal town of Cojímar, coordinates 369.94 N and 366.22 E. It is indicated on the detail geological map of the rim rock area between Morro and Cojímar, plate III. There the Urría beds consist of thin and regularly bedded layers of yellowish gray to grayish orange dolomitized limestone filling the 2 to 3 m deep narrow channels scoured into the Toledo member of the Universidad formation, probably by post-Toledo submarine erosion (photographs, figs. 62, 63). The disposition of the beds is paralic suggesting deposition confined to the channels. The overlying transgressive Cojímar chalks, BR stations 963 and 964, cut both the Toledo and the post-Toledo Urría beds.

BR station 791 (Urría beds)
Lithology: Limestone, hard, somewhat granular, yellowish gray.
Texture: Microcrystalline calcite, vacuolar. Barren.

BR stations 963 and 964 (Cojímar formation)

The samples from these stations are lithologically and faunally very similar and here described together.
Lithologies: Limestone, fragmental, hard, white (963), and chalky, white to very pale orange (964).
Textures: Cryptocrystalline to microcrystalline groundmass with fragments of algae, encrusting Foraminifera, echinoderms, bryozoas and mollusks. Common amphisteginas. Some planktonic Foraminifera.

Assemblages:
Amphistegina spp.
Acervulina inhaerens SCHULTZE
Acervulina sp.
Sporadotrema sp.
Orbulina cf. *suturalis* BRÖNNIMANN
Globigerina spp.
Globorotalia fohsi barisanensis LEROY.

Other outcrops of the Urría beds

Outside of the Habana area as defined in this study, on the road from Barreras to the Vía Blanca, about 1.7 km northeast of Barreras, a small town southwest of Santa María del Mar, coordinates 370.28 N and 376.99 E, another dolomitic channel filling was observed. There, the channels are in brownish, largely igneous derived shales and silts, either of the Lower Eocene Apolo or Alkázar formation. Both the Lower Eocene beds and the dolomitized limestones are transgressively overlain by *Miogypsina*-bearing fragmental reefal limestones of the Husillo formation. The dolomitized limestones are here regarded as the equivalent of the Urría beds of the Vía Monumental. The stations from this outcrop are listed below in stratigraphical order from bottom to top:

BR station 887 (Apolo or Alkázar formation)

This sample is stratigraphically about 4 m below the Urría-Apolo or Alkázar contact.

Lithology: Graywacke siltstone, calcareous, friable, grayish orange.

Washed residue with abundant nassellarias and spumellarias and a fragment of *Globorotalia* sp. (truncate form).

BR station 888 (Urría beds)

Lithology: Limestone, hard, pale yellowish orange to grayish orange.

Texture: Microcrystalline calcite, dolomitized, vacuolar.

Assemblage: Radiolaria of Tertiary aspect.

BR station 889 (Husillo formation)

Lithology: Limestone, fragmental, hard, in part vacuolar, white to grayish orange.

Texture: Cryptocrystalline to microcrystalline groundmass, in part vacuolar, with fragments of corals, algae, encrusting Foraminifera, bryozoas, echinoderms and mollusks. Common miogypsinas and heterosteginas. Some globigerinas.

Assemblage:
- *Miogypsina bracuensis* VAUGHAN
- *Heterostegina antillea* CUSHMAN
- *Operculinoides* cf. *dius* (COLE and PONTON)
- *Amphistegina* spp.
- *Carpenteria* sp.
- *Sporadotrema* sp.
- *Planorbulinella larvata* (PARKER and JONES)
- *Planorbulina mediterranensis* D'ORBIGNY
- *Acervulina inhaerens* SCHULTZE
- *Gypsina globulus* REUSS
- *Archaias* cf. *operculiniformis* HENSON
- *Meandropsina* sp.
- *Lepidocyclina* (*Lepidocyclina*) sp.
- *Orbitocyclina* sp. (fragment, reworked).

Urría beds of similar lithology were also seen about 1.6 km east-southeast of the Cojímar type locality, south of Loma San Pedro, in channels of the Alkázar formation. Some of the post-Toledo strata in the large quarry east of the Río Almendares at the intersection of Avenida Antonio Soto and Calle 38, Reparto Nuevo Vedado, may possibly represent Urría beds.

Environment and age

The dolomite rhomboeders of the Urría beds are of secondary nature, and the abundant Tertiary Radiolaria in the outcrop at the Barreras–Vía Blanca road suggest an open-marine origin for the Urría beds. It is evident that their age is not only pre-Cojímar, as concluded from the type locality, but even pre-Husillo. They were deposited after the deep-water Lower Eocene Toledo beds and prior to the reefal Husillo limestones with *Miogypsina* and *Heterostegina antillea* CUSHMAN. In the Habana area this age range is represented by the following sedimentary sequence from bottom to top:

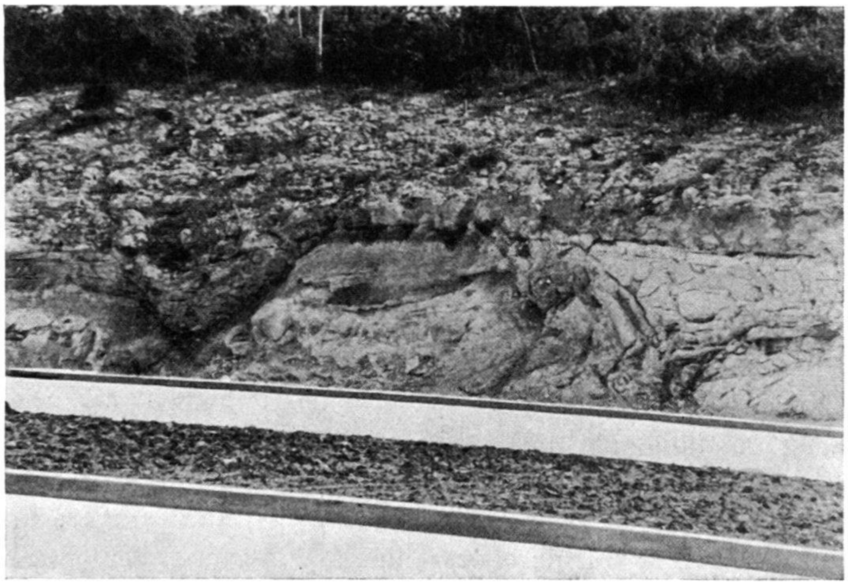


Fig. 62. View of the Urría type locality at the road cut of the Avenida Monumental, south of Loma Urría, showing the channeled Toledo beds, the Urría channel filling and the unconformably overlying Cojímar formation.

Príncipe member of the Universidad formation—Lower to Middle Eocene, but not late Middle Eocene, except BR station 455.
Punta Brava formation—Early Upper Eocene.
Consuelo formation—Oligocene.
Lepidocyclina-bearing conglomerates at Punta Brava—Oligocene—pre-type Husillo with *Miogypsinas* and *Heterostegina antillea*—Miocene.

None of these units is lithologically reminiscent of the Urría beds which therefore are tentatively regarded as relics of a formation laid down during one of the gaps in above succession. Radiolaria are common in the Lower to Middle

Fig. 63. Detail of the Toledo channel and the Urría filling as shown in fig. 62.

Eocene, and their occurrence in the outcrop of the Barreras–Vía Blanca road may indicate a Middle Eocene post-Universidad age for the Urría beds.

Punta Brava Formation

For Upper Eocene yellowish to orange hard limestones, chalky limestones, and fine-grained calcarenites we introduce a new lithologic unit, the Punta Brava formation. It is known only from outcrops near Punta Brava, a small village on the Carretera Central toward Pinar del Río in the south-western corner of the Habana area as defined in this paper. The Punta Brava formation differs from both the Upper Eocene Jabaco formation and Jicotea member defined by BERMÚDEZ from outcrops outside the Habana area. Before describing the new formation, the status of these units will be briefly discussed.

The type locality of the Upper Eocene Jabaco formation is at a cut of the road from Guanajay to El Mariel, 4.5 km west-northwest of Guanajay, Pinar del Río Province (BERMÚDEZ, 1950, p. 247). The lithology is a series of yellowish irregularly bedded, marly limestones. Layers of intraformational reworked rock fragments and fossils are a conspicuous element of this formation. In certain beds larger benthonic Foraminifera are abundant. Many perfectly preserved discocyclinas, asterocyclinas and lepidocyclinas were noticed as well as *Dictyoconus cookei* MOBERG and *Fabiania cassis* SILVESTRI of which *F. cubensis* (COLE and BERMÚDEZ) is a junior synonym. As will be seen from the planktonic species cited below, the type samples of the Jabaco beds are from the late Upper Eocene *Globorotalia cerroazulensis* zone, not early Upper Eocene as stated by BERMÚDEZ (1950, p. 247). The following samples listed from bottom to top are from the type locality of the Jabaco formation:

BR station 497 (Base of outcrop)
Lithology: Marl, chalky, grayish yellow.
Washed residue with

Cribrohantkenina bermudezi THALMANN
Hantkenina alabamensis CUSHMAN
Hantkenina suprasuturalis BRÖNNIMANN
Globorotalia cerroazulensis (COLE)
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerina ampliapertura BOLLI
Globigerina rohri BOLLI group
Globoquadrina venezuelana (HEDBERG) group
Globorotaloides suteri BOLLI
Globigerinatheka barri BRÖNNIMANN
Chiloguembelina cubensis (PALMER) and reworked Universidad forms

BR station 498 (1 m stratigraphically above 497)
Lithology: Marl, chalky, grayish yellow.
Washed residue with

Hantkenina alabamensis CUSHMAN
Hantkenina suprasuturalis BRÖNNIMANN
Globorotaloides suteri BOLLI

Globigerina ampliapertura BOLLI
Globigerina parva BOLLI
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Pseudohastigerina micra (COLE)
Chiloguembelina cubensis (PALMER) and reworked Universidad forms

BR station 499 (1.5 m stratigraphically above 497)
Lithology: Limestone, hard, orbitoidal, very pale orange to pale yellowish orange.
Texture: Cryptocrystalline groundmass with many discocyclinas, lepidocyclinas, *Operculinoides*, Rupertiidae and algal fragments. Also planktonic Foraminifera.

Assemblage of planktonic microfossils with
Hantkenina alabamensis CUSHMAN-*suprasuturalis* BRÖNNIMANN group
Globorotalia cerroazulensis (COLE)
Globigerina spp.
Chiloguembelina cubensis (PALMER)
Braarudosphaera bigelowi (GRAN and BRAARUD)
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN
Discoaster cf. *deflandrei* BRAMLETTE and RIEDEL (rare)
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Thoracosphaera sp.

BR station 500 (4 m stratigraphically above 497)
Lithology: Marl, shaley, grayish yellow to pale yellowish orange.
Texture: Cryptocrystalline groundmass with planktonic microfossils and rare orbitoidal Foraminifera (coccolithite).

Assemblage: *Globigerina* spp.
Pseudohastigerina micra (COLE)
Braarudosphaera bigelowi (GRAN and BRAARUD)
Discoaster aster BRAMLETTE and RIEDEL (common)
Coccoliths (abundant)
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Thoracosphaera sp. (common).

Washed residue with
Hantkenina alabamensis CUSHMAN
Hantkenina suprasuturalis BRÖNNIMANN
Globorotalia cerroazulensis (COLE)
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globorotaloides suteri BOLLI
Globigerina ampliapertura BOLLI
Globigerina parva BOLLI
Globigerina rohri BOLLI group
Globoquadrina venezuelana (HEDBERG) group
Chiloguembelina cubensis (PALMER).

BR station 501 (6 m stratigraphically above 497)
Lithology: Limestone, hard, grayish yellow to very pale orange.
Texture: Cryptocrystalline groundmass with common planktonic and benthonic Foraminifera. Also mollusk, echinoderm, orbitoidal and algal fragments. Rare igneous grains.

Assemblage: *Globigerina* spp.
Pseudohastigerina micra (Cole)
Chiloguembelina cubensis (Palmer)
Braarudosphaera bigelowi (Gran and Braarud)
Coccoliths
Tremalithus eopelagicus Bramlette and Riedel (large specimens)
Thoracosphaera sp.

In the Habana area there are no Upper Eocene rocks of similar lithology. The name Jabaco formation therefore cannot be applied to Upper Eocene beds outcropping at Punta Brava. Under the name Jicotea member of the Jabaco formation, Bermúdez (1950, pp. 249 and 250) described yellowish marls with fine limey sand from a road cut on the Carretera Central, 1 km east of Jicotea, Las Villas Province. From this locality, which was not sampled by us, Bermúdez (1950) listed the following planktonic Foraminifera: *Globigerina mexicana* Cushman [=*Porticulasphaera mexicana* (Cushman)], *Globigerina* cf. *conglobata* H. B. Brady, *Globorotalia centralis* Cushman and Bermúdez, *Hantkenina alabamensis* Cushman, *Hantkenina longispina* Cushman and *Nonion micrus* Cole [=*Pseudohastigerina micra* (Cole)]. The outcrop is isolated and neither top nor bottom of the Jicotea beds can be seen. Apparently there were never more than a few meters of whitish chalk exposed. An inspection of this locality in the summer of 1958 showed the

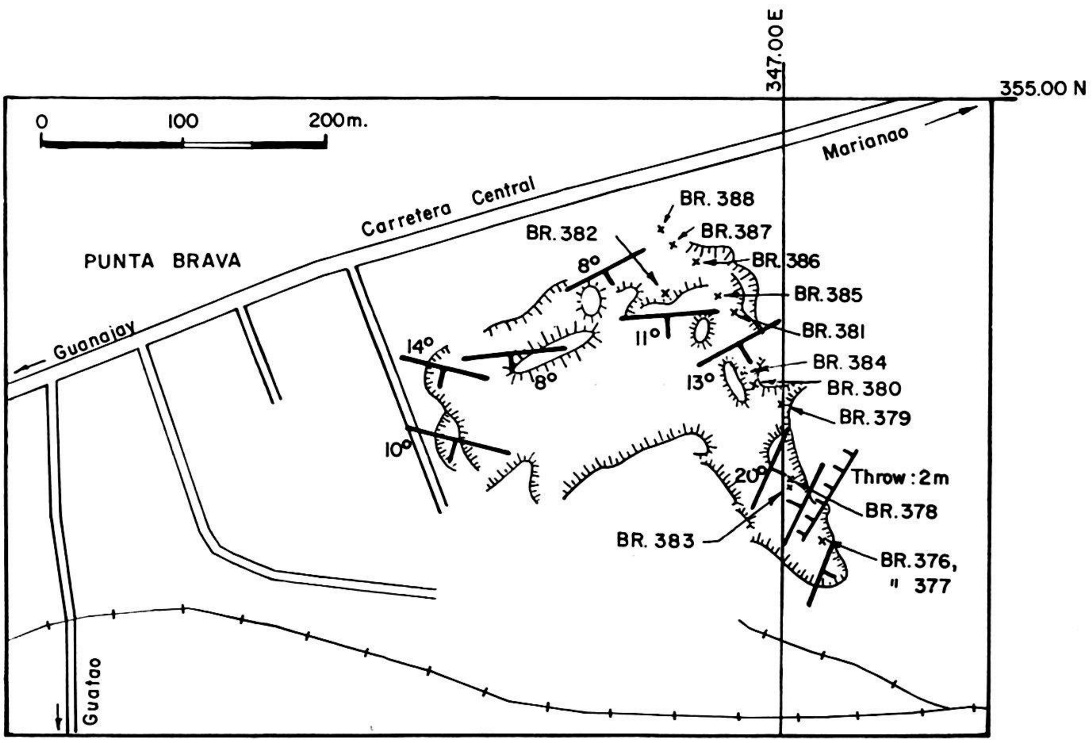


Fig. 64. Index map of the quarry east of Punta Brava.

Jicotea beds to be under heavy grass and soil cover, and lithologies reminiscent of the Punta Brava formation could not be found. In view of these observations it is our opinion that also the name Jicotea should not be used for Upper Eocene beds in the Habana area.

Description of the type locality of the Punta Brava formation

The type locality of the Punta Brava formation was completely exposed in the summer of 1958 in the abandoned quarry east of Punta Brava, a village on the Carretera Central about 3 km southwest of the Plaza del Mediodía. The coordinates of the quarry area are 354.80 N and 347.00 E (index map, fig. 64). The Punta Brava formation consists of about 23 m of well-bedded, hard, whitish to yellowish orange limestones and chalky limestones and orange to grayish more or less shaley, very fine-grained, graded-bedded calcarenites with dark igneous grains. As shown in the columnar section, fig. 65, each sedimentary cycle is closed by shaley beds. Toward the top of the formation, the bedding is less distinct and in the uppermost 5 m there are no more clastic beds. An irregular surface, probably corresponding to a local intraformational disconformity, was observed about 6 m above the base of the formation. The formation rests unconformably on much steeper dipping brownish sandy

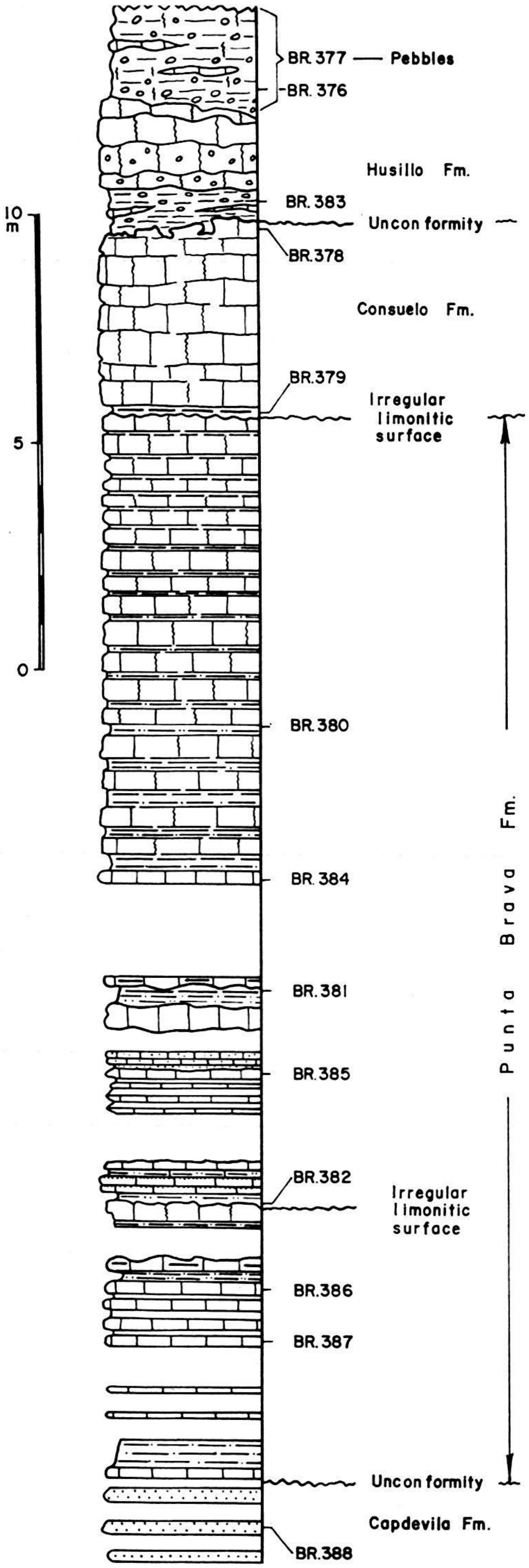


Fig. 65. Columnar section of the Punta Brava, Consuelo and Husillo formations, quarry east of Punta Brava.

Lower Eocene Capdevila beds, represented by BR station 388, described under Capdevila formation. The white to yellowish massive chalks of the Oligocene Consuelo formation overlie disconformably or with slight angular unconformity the Punta Brava formation. This disconformity or unconformity is marked by an irregular, limonitic surface suggesting emersion. The overlying Consuelo beds of the *Globigerina ciperoensis–Globorotalia opima* zone contain re-deposited Upper Eocene and Lower to Middle Eocene planktonic Foraminifera. Unconformably on top of the Consuelo beds follow conglomeratic chalks and chalky limestones with

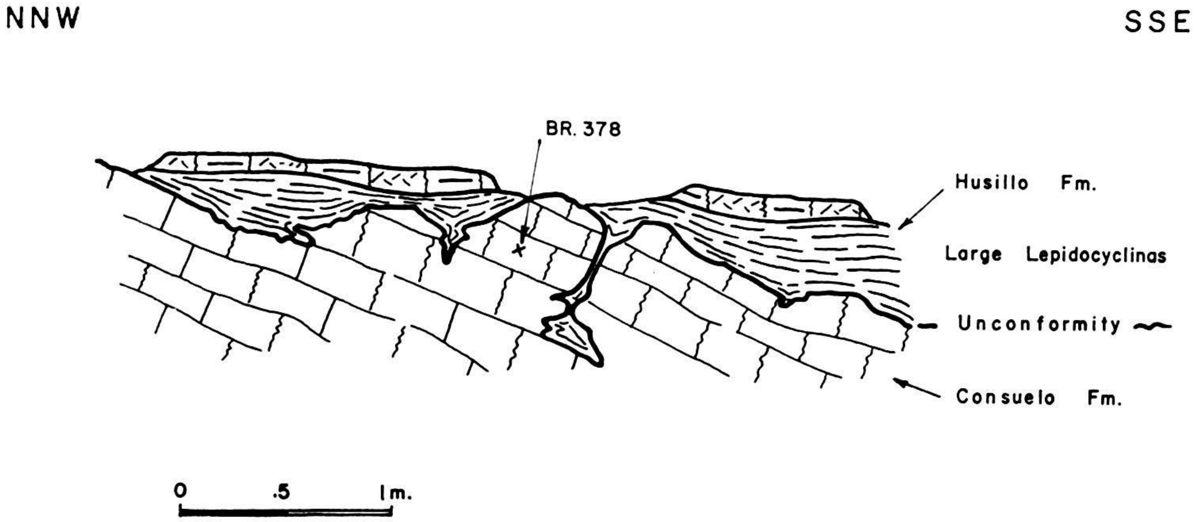


Fig. 66. Detail of the unconformable contact between the Consuelo and Husillo formations, quarry east of Punta Brava.

numerous lepidocyclinas and *Operculinoides* which we tentatively assigned to the Husillo formation. Although the unconformity is distinctly angular and irregular as expressed by the sketch of the contact zone, fig. 66, there is practically no time break between the Consuelo and the Husillo beds, both of which seem to form part of the *Globigerina ciperoensis–Globorotalia opima* zone.

W. M. van den Bold (letter March 21, 1963) identified in BR station 383 the following ostracodes:

Aurila deformis (Reuss) ?
Bairdia sp.
Cytherella sp.

and in BR 376, which is stratigraphically about 2.8 m higher,

Aurila deformis (Reuss)
Bairdia sp.
Jugosocythereis vicksburgensis (Howe)
Krithe sp.

At a later visit, in December 1958, the quarry in which the type section was measured was found to be filled up and levelled. However, at the remaining eastern cliff, the Punta Brava beds and adjoining formations were still accessible.

The stratigraphic position of the Punta Brava type samples is shown in the columnar section (fig. 65). They are from bottom to top:

BR station 387
Lithology: Limestone, hard, whitish to very pale orange.
Texture: Microcrystalline groundmass with planktonic microfossils. Recrystallization destroyed most of the discoasterids and coccoliths.

Assemblage:
Discoaster barbadiensis TAN (common)
Discoaster cf. *woodringi* BRAMLETTE and RIEDEL (rare)
Braarudosphaera bigelowi (GRAN and BRAARUD)
Braarudosphaera discula BRAMLETTE and RIEDEL (common)
Coccoliths (rare)
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Thoracosphaera spp. (ellipsoid and spherical bodies).

BR station 386
Lithology: Limestone, chalky, very pale orange.
Texture: Microcrystalline groundmass with planktonic microfossils.

Assemblage:
Globigerina spp. with coarse perforations
Discoaster aster BRAMLETTE and RIEDEL (rare)
Discoaster barbadiensis TAN (rare)
Braarudosphaera bigelowi (GRAN and BRAARUD) (common)
Braarudosphaera discula BRAMLETTE and RIEDEL
Coccoliths (rare)
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Thoracosphaera spp. (ellipsoid and spherical bodies).

BR station 382
Lithology: Calcarenite, very fine-grained, friable, with a few igneous grains, dark yellowish orange.

Washed residue with
Hantkenina alabamensis CUSHMAN
Hantkenina thalmanni BRÖNNIMANN
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globigerapsis index (FINLAY)
Globigerapsis semiinvoluta (KEIJZER)
Globoquadrina venezuelana (HEDBERG) group
Globigerina aff. *rohri* BOLLI group
Globigerina ampliapertura BOLLI
Globigerina linaperta FINLAY
Chiloguembelina cubensis (PALMER).

BR station 385
Lithology: Limestone, grayish orange.
Texture: Microcrystalline groundmass with planktonic microfossils.

Assemblage:
Hantkenina alabamensis CUSHMAN
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globoquadrina venezuelana (HEDBERG) group

Globigerina cf. *ampliapertura* BOLLI
Globigerina rohri BOLLI group
Globigerapsis semiinvoluta (KEIJZER)
Discoaster barbadiensis TAN
Braarudosphaera bigelowi (GRAN and BRAARUD)
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimen)
Thoracosphaera sp. (globular bodies).

BR station 381
Lithology: Calcarenite, very fine-grained, friable, with a few igneous grains, grayish orange to dark yellowish.
Washed residue with
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globoquadrina venezuelana (HEDBERG) group
Globigerina ampliapertura BOLLI
Globigerina rohri BOLLI group
Globigerina aff. *senni* (BECKMANN)
Globigerapsis index (FINLAY).

BR station 384
Lithology: Limestone, very pale orange.
Texture: Microcrystalline to cryptocrystalline groundmass with abundant planktonic microfossils and few angular igneous grains in layers.
Assemblage: *Globigerapsis index* (FINLAY)
Globigerapsis semiinvoluta (KEIJZER)
Globorotalia centralis CUSHMAN and BERMÚDEZ
Braarudosphaera bigelowi (GRAN and BRAARUD)
Discoaster barbadiensis TAN
Coccoliths (rare)
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimen)
Thoracosphaera sp. (globular bodies).

BR station 380
Lithology: Calcarenite, very fine-grained, friable, with a few igneous grains, dark yellowish orange.
Washed residue with
Hantkenina alabamensis CUSHMAN
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globoquadrina venezuelana (HEDBERG) group
Globigerina aff. *ampliapertura* BOLLI
Globigerina rohri BOLLI group
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerapsis semiinvoluta (KEIJZER)
Chiloguembelina cubensis (PALMER).

The samples from BR stations 378 and 379 are from the Oligocene Consuelo formation and those from BR stations 383, 376, 377 and 1013 from beds tentatively referred to the Oligo-Miocene Husillo formation. Their stratigraphic position is indicated in the columnar section, fig. 65. They will be described under Consuelo formation.

Environment and age

The type section of the Punta Brava formation consists in its lower half of clastic, dark orange, very fine-grained calcarenites or calcareous siltstones with dark igneous fragments, and in its upper half of whitish to orange hard limestones and chalky limestones of cryptocrystalline texture with interbedded shales. The upper beds contain abundant microfossils of which some groups such as coccoliths and discoasterids may occur in rock-forming quantities. From a rough estimate of the ratio of planktonic and benthonic Foraminifera it can be inferred that the type beds were formed under basinal conditions, similar to those under which the limestones and chalks of the Universidad formation were laid down (GRIMSDALE and VAN MORKHOVEN, 1955). The associated fine-grained clastics also yield abundant planktonic Foraminifera indicating that they too were deposited under deep-water conditions. Larger benthonic Foraminifera, in particular discocyclinas, asterocyclinas and lepidocyclinas, conspicuous in the type beds of the Jabaco formation, are absent. Minute clastic fragments, usually angular dark igneous grains, were noticed to be arranged in microlaminae in otherwise non-clastic deeper water limestones, suggesting that the source of the clastic material was probably not too close to the Punta Brava locality. The recurrence of clastic sedimentation in the Upper Eocene and the fore-reefal faunal association of the Jabaco beds are suggestive of a post-Universidad pre-Consuelo period of apparently minor uplift movements in the Habana area. This would explain the flysch-type graded-bedding of the Punta Brava clastics reflecting rapid influx and settling of the detrital material in a trough in front of an unstable area. Late Middle Eocene rocks were only rarely encountered in the Habana area and Upper Eocene beds are missing, excepting in Punta Brava and perhaps at Tejar Consuelo (slumped beds). The late Middle and Upper Eocene planktonic Foraminifera in the basal slumped zone at Tejar Consuelo may however imply that late Middle to Upper Eocene basinal sediments were originally laid down over all or part of the Habana area, but were then removed prior to Consuelo time as a sequel to the mentioned uplift movements.

The discoasterids of the Punta Brava beds are poorer in species than those of the Lower to Middle Eocene Universidad formation. The following species were recorded in the type samples:

Braarudosphaera bigelowi (GRAN and BRAARUD) (rare)
Braarudosphaera discula BRAMLETTE and RIEDEL (common)
Discoaster aster BRAMLETTE and RIEDEL (rare)
Discoaster barbadiensis TAN (common)
Discoaster cf. *woodringi* BRAMLETTE and RIEDEL (rare).

The other nannofossils associated with the discoasterids continue as in the Lower to Middle Eocene beds:

Coccoliths, with large specimens of *Tremalithus eopelagicus* BRAMLETTE and RIEDEL
Thoracosphaera spp. (globular and ellipsoid bodies).

Discoasterids, coccoliths and *Thoracosphaera* occur in all the thin sections studied, but their number often appeared reduced through recrystallization. Radiolaria are virtually absent in the Punta Brava beds.

The following diagnostic Universidad discoasterids do not extend into or perhaps occur only rarely in the Punta Brava formation:

Discoaster lodoensis BRAMLETTE and RIEDEL
Marthasterites tribrachiatus (BRAMLETTE and RIEDEL)
Marthasterites sp.

The extinction of *D. lodoensis* and of *M. tribrachiatus*, the two most characteristic Universidad forms, creates a distinct faunal break between the Universidad and the Punta Brava beds. The latter are here referred to the *Discoaster barbadiensis* zone.

The planktonic Foraminifera of the Punta Brava formation are diagnostic for Upper Eocene, but not for the late Upper Eocene *Globorotalia cerroazulensis* zone, as represented at Jabaco. A lithologic gap, indicated in the field by an irregular, limonitic disconformity separates the Punta Brava formation and the *Globigerina ciperoensis–Globorotalia opima* zone of the Oligocene Consuelo formation. At Tejar Consuelo the Consuelo formation extends from the *Globigerina ampliapertura* zone into the *Globigerina ciperoensis–Globorotalia opima* zone. Based on the absence of *Globorotalia cerroazulensis* and on the occurrence of highly evolved representatives of *Globorotalia centralis* and *Globigerapsis semiinvoluta*, the Punta Brava beds are here placed at the top of the early Upper Eocene *Globigerapsis semiinvoluta* zone.

Consuelo Formation

Chalky beds of the older part of the Marianao group assigned by R. H. PALMER and later by BERMÚDEZ to formations of Upper Eocene age, turned out later to be either older or younger than Upper Eocene. The Consuelo formation proposed by BERMÚDEZ (1950) is a case in point, and a review appears indicated to explain the present nomenclatorial usage and age assignment of the beds erroneously regarded at one time or another as Upper Eocene.

PALMER (1934, p. 125, table I, pp. 132 and 133) included in his supposedly Upper Eocene Príncipe formation, or "upper phase of the Eocene", the soft whitish sediments above the Capdevila formation or "lower phase of the Eocene", and below the Oligo–Miocene overlap. In 1937, BERMÚDEZ (pp. 153–169) sampled the typical exposures of the Príncipe formation along the road cuts across Loma del Príncipe and on the campus of the University of Habana, and found certain but not all of the faunas to be Lower Eocene (index map, fig. 49). Based on this he believed to deal with an older lithologic unit different from PALMER's Príncipe formation which he called Universidad formation. But in fact BERMÚDEZ did not find a new formation. What he showed was simply that part of PALMER's Príncipe formation is of Lower Eocene age. PALMER in his paper of 1945 (table I on p. 6) accepted BERMÚDEZ' Universidad formation. Later, BERMÚDEZ (1950, p. 258) restudied the outcrops at Loma del Príncipe and found them all to be Lower Eocene, i.e. belonging to the Universidad formation. At this point of the investigation, the nomenclatorially correct procedure would have been to re-define the age range and the type locality of PALMER's Príncipe formation and to drop the synonymous Universidad formation, which was proposed much later than Príncipe formation. This was, however, not done and as we explained in the introduction to the Universidad formation, reluctantly and only for reasons of tradition we accepted the name Universidad formation but used Príncipe to name its upper non-silicified member.

For apparently Upper Eocene beds, which BERMÚDEZ (1950, p. 258) found in the quarry at Tejar Consuelo, he chose the new name Consuelo formation. They are separated at Tejar Consuelo from the lithologically very similar underlying Lower Eocene Universidad beds by a distinct unconformity as shown by the photographs, figs. 56, 57 and 61. In the paper of 1950, BERMÚDEZ dropped the name Príncipe formation, and Consuelo formation instead of Príncipe formation was then used by this author for rocks of the Habana area believed to be of Upper Eocene age. For the beds unconformably overlying at Tejar Consuelo the Universidad formation, we will continue to use BERMÚDEZ' name Consuelo formation. But it will be necessary to define the type of this formation lithologically and geographically more accurately and to change its age assignment from Upper Eocene to Oligocene.

But before describing the type locality of the Consuelo formation, we will briefly comment on two formations most probably identical with the Consuelo formation, i.e. the Guatao formation of BRODERMANN (1943, p. 127) and the Tinguaro formation of R. H. PALMER (1945, p. 17). Although the Consuelo formation was later proposed than both Guatao and Tinguaro formations, it is considered advisable to drop the latter in favor of Consuelo formation.

Remarks on the Guatao formation

The type locality of the Guatao formation is a water well in the garden of the Finca Nuestra Señora de Lourdes of the Colegio de la Salle, Guatao, about 1.5 km due south of Punta Brava, on the Carretera Central, a locality referred to previously under Punta Brava formation. The lithology is described by BRODERMANN (1943, p. 127) as a "marga amarillenta" with a mixed assemblage of Upper Eocene and Lower Oligocene Foraminifera. This description also fits that of the slumped basal beds of the Consuelo formation at the southeastern cliff of the quarry at Tejar Consuelo. We were unable to study the lithology and the fauna from the Guatao type locality, because the samples referred to by BRODERMANN and by BERMÚDEZ could not be located in the collections of the Comisión del Mapa Geologico de Cuba. However, through the courtesy of Ing. J. BRODERMANN we received a microfauna from a surface exposure assigned by this author to the Guatao formation. It is from an outcrop south of the Habana area, on the Autopista del Mediodía, 4.9 km south of its intersection with the Carretera Central and 1.2 km north of the crossing with the road to El Chico. The fauna appears to be from a yellowish chalk. The more important planktonic Foraminifera are:

Globigerina ciperoensis angulisuturalis BOLLI (common)
Globigerina ciperoensis angustiumbilicata BOLLI (abundant)
Globigerina ciperoensis ciperoensis BOLLI (abundant)
Globoquadrina venezuelana (HEDBERG) group
Globigerina euapertura JENKINS
Globigerina rohri BOLLI group
Globorotalia opima opima BOLLI
Globorotaloides suteri BOLLI
Chiloguembelina cubensis (D. K. PALMER)
Pseudohastigerina micra (COLE) } (reworked)
Globorotalia lehneri CUSHMAN and JARVIS } (reworked)

This heterogeneous microfauna is from the *Globigerina ciperoensis–Globorotalia opima* zone. At the type locality of the Consuelo formation, the younger Consuelo beds extend into this zone and there is not much doubt that the above described sample comes from a bed of the Consuelo formation. A good outcrop of the Guatao formation within the Habana area, mentioned by BRODERMANN, occurs in the Bosque de la Habana, just north of Tejar Consuelo, but was not investigated by us. As the type locality of the Guatao formation is not readily accessible, and as the type samples are not available it is recommended to drop this name.

Remarks on the Tinguaro formation

R. H. PALMER (1945, p. 17) mentioned outcrops of marls on the lands of the Tinguaro sugar mill, west of Colón, Province of Matanzas, about 150 km east-southeast of La Habana as good exposures of his Tinguaro formation. He correlated the "soft, buff marl" from a shallow water well at Finca Adelina, approximately 9.5 km east of Colón and 0.5 km north of the Carretera Central, with the Tinguaro formation. The rich foraminiferal fauna from Finca Adelina was analyzed by D. K. PALMER and P. BERMÚDEZ (1936), and without using the name Tinguaro formation these authors reported (1936, p. 233) that similar assemblages were found at Central Tinguaro, 16 km to the west of Finca Adelina, at Central Alava, 5 km to the north, and at Finca Aguedita, 7 km to the southeast. Although the fauna is dominated by planktonic Foraminifera, PALMER and BERMÚDEZ recorded only three globigerinas, viz. *Globigerina* cf. *G. bulloides* D'ORBIGNY, *Globigerina conglobata* BRADY, var., and *Globigerina* cf. *G. inflata* D'ORBIGNY. Also mentioned are *Guembelina cubensis* D. K. PALMER and *Sphaeroidina bulloides* D'ORBIGNY. The planktonics from this material, which was also referred to by BERMÚDEZ (1950, pp. 268–270), need to be revised and brought up to date nomenclatorially. A rich and well-preserved microfauna from the Finca Adelina locality received from the late D. W. GRAVELL (station 5609) contains:

Globoquadrina venezuelana (HEDBERG) group (abundant)
Globigerina bradyi WIESNER (rare)
Globigerina ciperoensis angulisuturalis BOLLI (rare)
Globigerina ciperoensis angustiumbilicata BOLLI (rare)
Globigerina ciperoensis ciperoensis BOLLI (abundant)
Globigerina euapertura JENKINS (common)

Globigerina parva BOLLI (rare)
Globigerina rohri BOLLI group (common)
Globigerina cf. *trilocularis* D'ORBIGNY (common)
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ) (one specimen)
Globorotalia opima nana BOLLI (rare)
Globorotalia opima opima BOLLI (common)
Cassigerinella chipolensis (CUSHMAN and PONTON) (one specimen)
Pseudohastigerina micra (COLE) (one specimen)
Chiloguembelina cubensis (D. K. PALMER) (rare)
Globoquadrina altispira altispira (CUSHMAN and JARVIS) (common)
Globoquadrina altispira globosa BOLLI (one specimen).

This assemblage is composed of the forms generally recorded in Cuba from the *Globigerina ciperoensis–Globorotalia opima* Zone, and of two representatives of the genus *Globoquadrina* FINLAY, i.e. *Globoquadrina altispira altispira* (CUSHMAN and JARVIS) and *Globoquadrina altispira globosa* BOLLI (one typical specimen). According to the stratigraphic distribution established for the Tertiary planktonics in Trinidad, B.W.I., *Globoquadrina* occurs for the first time in the *Catapsydrax dissimilis* Zone with *Globoquadrina altispira globosa. Globoquadrina altispira altispira* evolved from *Globoquadrina venezuelana* (HEDBERG) which seems to be a typical "Durchläufer", by developing a higher spiral and stronger apertural flaps, but in other respects, especially in the number of chambers of the final whorl, it is very close to *Globoquadrina venezuelana.* The delicate apertural flaps being the diagnostic feature, it is very much a matter of preservation whether a primitive form of the *venezuelana–altispira* group can be recognized as a *Globoquadrina. Globigerina euapertura* JENKINS is not related with *Globoquadrina venezuelana* as assumed by JENKINS (1960), but with *Globigerina ampliapertura* BOLLI. *Globigerina rohri* BOLLI most probably is a *Globoquadrina.*

The association of primitive globoquadrinas with *Globigerina ciperoensis ciperoensis* BOLLI and *Globorotalia opima opima* BOLLI indicates that the advent of *Globoquadrina* FINLAY takes place in Cuba already in the *Globigerina ciperoensis–Globorotalia opima* zone.

W. A. VAN DEN BOLD (letter March 21, 1963) identified from GRAVELL station 5609 the below listed ostracodes regarded as about Vicksburg in age:

Krithe hiwanneensis HOWE and LEA
Brachycythere russelli HOWE and LAW
Costa maquayensis VAN DEN BOLD
Ambocythere reticulata VAN DEN BOLD
Pterygocythereis ivani (HOWE)
Trachyleberidea cubensis mammidentata (VAN DEN BOLD)

The beds of the Finca Adelina water well would then fall in the *Globigerina ciperoensis–Globorotalia opima* zone, which is represented by the youngest beds of the Consuelo type section at Tejar Consuelo, and by the conglomeratic *Lepidocyclina*-bearing basal Husillo (?) beds at Punta Brava.

R. H. PALMER (1945, p. 17) regarded the Tinguaro formation in part as the deeper water equivalent of the zone of larger lepidocyclinas with *Lepidocyclina* *undosa* Cushman and *Lepidocyclina favosa* Cushman that occurs directly above the Eocene in many widely separated localities in Cuba and which we tentatively put at the base of the Husillo formation.

From supposedly shallow-water developments of the Tinguaro formation, Bermúdez (1950) reported, without giving localities, the following larger Foraminifera:

Lepidocyclina dilatata Michelotti
Lepidocyclina formosa Schlumberger
Lepidocyclina fragilis Cushman
Lepidocyclina parvula Cushman
Lepidocyclina piedraensis Vaughan
Lepidocyclina yurnagunensis Cushman
Lepidocyclina yurnagunensis Cushman var. *morganopsis* Vaughan
Operculinoides vicksburgensis Vaughan and Cole.

The type area of the Tinguaro formation near Central Tinguaro, Matanzas Province, was visited by us in the summer of 1958 and again by Ducloz in 1959. East of the Central we observed poorly outcropping chalk reminiscent of the Consuelo lithologies. The yellowish, indurated and powdery chalk of Ducloz station 699 as described below is representative of this lithology. At Central Tinguaro proper there are no outcrops, the terrain being under heavy soil cover. The following samples collected in March 1959 by Ducloz and kindly put at our disposal are from the outcrops east of Central Tinguaro. Their geographic locations are given in the index map, fig. 58. Of particular significance are the Consuelo-like chalk from Ducloz station 699 which yields a rich homogeneous microfauna of the *Globigerina ciperoensis–Globorotalia opima* zone, and the occurrence of abundant specimens of *Heterostegina israelskyi* Gravell and Hanna in the overlying limestones of Ducloz station 703 about 2.8 km southwest of Ducloz station 699. This species was not found in the Husillo samples of the Habana area, where certain beds carry abundant *Heterostegina antillea* Cushman, and possibly suggests a horizon stratigraphically different from the *Miogypsina* spp.–*Heterostegina antillea* horizon of the Husillo formation. Ducloz stations 700 to 702, 704 and 705, are from whitish and yellowish calcarenites and limestones with benthonic Foraminifera reminiscent of the Husillo and Cojímar lithologies. These beds are all younger than the chalk outcropping at Ducloz station 699. Miogypsinas are absent and only a single fragment of a *Lepidocyclina* sp. was encountered in a thin section from Ducloz station 702.

Ducloz station 699
Lithology: Chalk, indurated, powdery, whitish to pale yellowish orange.

Washed residue with

Globigerina ciperoensis angulisuturalis Bolli (common)
Globigerina ciperoensis angustiumbilicata Bolli (abundant)
Globigerina ciperoensis ciperoensis Bolli (abundant)
Globigerina parva Bolli
Globigerina rohri Bolli group
Globigerina cf. *trilocularis* d'Orbigny

Globoquadrina venezuelana (HEDBERG) group
Globorotalia opima nana BOLLI
Globorotalia opima opima BOLLI (common)
Globorotaloides suteri BOLLI.

Ducloz station 700
Lithology: Calcarenite, fine-grained, whitish to grayish yellow.
Texture: Fragmental to pseudoölitic, somewhat vacuolar, in part recrystallized groundmass. Components are fragments of algae, mollusks and echinoderms. Common benthonic Foraminifera and ostracodes. Diameter of average component from about 30 to 150 μ. Texture and generic composition of the microfauna are very similar to that of the Pleistocene calcarenites.
Assemblage: *Archaias* cf. *operculiniformis* HENSON
Acervulina inhaerens SCHULTZE
Amphistegina sp.
Meandropsina sp.
Peneroplis sp.
Miliolids.

Ducloz station 701
Lithology: Limestone, hard, yellowish orange.
Texture: Completely recrystallized groundmass. Microfossils destroyed.

Ducloz station 702
Lithology: Limestone, calcarenaceous, hard, whitish.
Texture: As Ducloz station 700.
Assemblage: *Sporadotrema cylindricum* (CARTER)
Meandropsina sp.
Gypsina sp.
Archaias cf. *operculiniformis* HENSON
Amphistegina sp.
Lepidocyclina sp. (only fragment).

Ducloz station 703
Lithology: Limestone, granular, grayish yellow, with abundant oriented larger Foraminifera.
Texture: Microcrystalline groundmass with abundant heterosteginas.
Assemblage: *Heterostegina israelskyi* GRAVELL and HANNA (rock-forming).

Ducloz station 704
Lithology: Limestone, granular, laminated, grayish yellow.
Texture: Microcrystalline groundmass with abundant densely packed planktonic microfossils. Minute forms destroyed through recrystallization.
Assemblage: *Globigerina* spp.

Ducloz station 705
Lithology: Limestone, hard, whitish.
Texture: Fragmental to pseudoölitic, recrystallized groundmass. Components

fragments of mollusks, echinoderms, algae and benthonic Foraminifera. Large discrete inclusions of dense, light brown barren argillaceous material.

Assemblage: Miliolids
Peneroplis sp.
Sorites sp.
Meandropsina sp.
Amphistegina sp.
Archaias sp.

In our opinion there is no question that the Tinguaro formation, as represented by Ducloz station 699 and by the Finca Adelina beds, is a time equivalent of the Consuelo formation. Moreover Tinguaro formation has priority over Consuelo formation. However, R. H. PALMER did not define a type locality and the isolated outcrops near Central Tinguaro do not afford a clear understanding of the lithologic sequence which, as shown by the above listed samples, is referable to different formations. Further, it is impossible to determine the thickness of the Tinguaro formation and its attitude toward adjoining units. For these reasons it is suggested to discard the name Tinguaro formation at least for the Habana area and to use in its stead Consuelo formation.

Description of the type locality of the Consuelo formation

The type locality of the Consuelo formation is in the quarry at Tejar Consuelo situated in the Reparto Cerro, La Ciénaga, on the northern side of the Calzada de Puentes Grandes about 400 m west-southwest of its intersection with Avenida 26, and about 1 km east of Río Almendares (BERMÚDEZ, 1950, p. 260). The coordinates of the southern building of the brick factory are 364.50 N and 356.58 E (index map, fig. 59).

The geology of the quarry is rather complicated and its significance as a central and easily accessible outcrop area where Capdevila, Universidad, Consuelo and Husillo formations are exposed warrants a more detailed description of the geological situation. In the smaller eastern part of the quarry, brownish beds of the Capdevila formation are in transitional contact with the Toledo member of the Universidad formation. This outcrop has been previously described under Capdevila formation (pp. 340 to 342, of this paper). In 1958 and 1959 the main part of the quarry, southeast of the factory buildings was flanked by two steep cliffs. The northeastern cliff, directly under the factory buildings, trends in northwestern direction and shows a continuous exposure over a distance of about 200 m and with a height ranging from 6 to 10 m. Along the southeastern base of this cliff grayish yellow chalky limestones with asphalt pebbles of the Príncipe member of the Universidad formation are exposed. As shown in the index map, fig. 59, BR stations 703 and 708 are from the basal part of the cliff. They have been described in the chapter on the Universidad formation. The Príncipe chalks are unconformably overlain by the likewise chalky, whitish to grayish yellow Consuelo formation. The lithologic similarity between the Consuelo formation and the Príncipe member of the Universidad formation is reflected by the fact that the brick factory uses indiscriminately material from both the Universidad and the Consuelo formation in the manufacture of the bricks. Slight lithologic differences between the Príncipe member and the Consuelo formation are 1) the Universidad formation contains abundant asphalt pebbles which are virtually absent in the Consuelo formation, and 2) the Universidad formation is more regularly and thinner bedded than the Consuelo formation. These differences are rather tenuous, and in an isolated outcrop the two formations can be distinguished by their faunal contents only. The higher southwestern cliff is about 350 m long and up to 16 m high. The base of its eastern part is formed by both Toledo and Príncipe member of the Universidad formation on which transgress the type Consuelo beds as defined in this paper. On top of the central part of this cliff occur unconformably overlying the Consuelo formation a few meters of *Miogypsina*-bearing white to yellowish, hard, cavernous and limonitic weathering reefal Husillo limestones. BR stations 773 and 774, which will be described in the chapter on the Husillo formation, are from this limestone. At the northwestern half of the larger cliff the maximum thickness of the Consuelo formation is about 19 m. At other places only about 8 m of Consuelo formation are preserved between the Universidad formation and the transgressive Husillo formation (columnar sections, fig. 60).

The Consuelo formation is a series of whitish to grayish yellow, massive chalky limestones, with a few thin layers of greenish grayish soft calcareous shale. In places there occur very thin limonitic layers.

At the southwestern cliff, the type Consuelo formation rests unconformably on the Universidad formation (index map and columnar sections, figs. 59, 60, and photographs of cliff and contact, figs. 56, 57, 61). This angular unconformity, already mentioned by BERMÚDEZ (1950, p. 258), is here clearly recognizable, but in an isolated outcrop the contact could appear to be almost transitional. In such cases the only evidences of an unconformity would be the abrupt change in faunas and the occurrence of numerous limonitic spots in the basal beds of the Consuelo formation. Such an accumulation of limonitic spots could be regarded as the expression of an emergence.

At the lower northeastern cliff of the quarry matters are more complicated. There the basal beds of the Consuelo formation are formed by a 2 to 5 m thick zone of hard whitish chalk, which is lighter in color than both the underlying Príncipe member and the overlying typical Consuelo formation. This peculiar Consuelo chalk is characterized by very irregular and contorted bedding apparently caused by submarine slumping (photograph of contact, fig. 61). Dispersed throughout this zone are small pebbles up to fist-size derived from the underlying Universidad formation. The unconformable character of the contact between Consuelo and Universidad formations is here demonstrated not alone by the fact that the underlying Universidad beds are truncated, but also by the occurrence in the Universidad beds of bore holes made by lithophagic organisms. Moreover, the unconformity surface shows irregular channel-like depressions filled by the slumped, hard, whitish, pebble-bearing Consuelo chalk. Faunal analysis of the samples from BR stations 361, 769, 770, 772, 704 to 707, shows that the slumped material is derived from Lower, Middle and Upper Eocene beds, with Late Middle and Upper Eocene planktonics predominant. The occurrence of Upper Eocene planktonic Foraminifera suggests that strata of this age and of deep-water origin were once deposited in the Habana area but removed in pre-Consuelo erosional periods. The slumped material is interpreted to represent the filling, at the time of the Consuelo transgression, of channels scoured by post-Universidad erosion. These channels are reminiscent of those at the south flank of Loma de Urría in which the dolomitic Urría beds are deposited. Simultaneous reworking of Universidad material took place and pebbles were formed, which then were dispersed throughout the slumped zone. The typical Consuelo beds of the *Globigerina ampliapertura* zone (BR station 702B) overlying this whitish zone, do not exhibit evidence of slumping. From this can be inferred that the sedimentation gradually became quiet. However, heterogeneous faunas from BR stations 702 and 702A of these depositionally more quiet beds are proof that reworking of older material continued for some time. The contact between the slumped beds and the regularly bedded Consuelo chalks is transitional. The age of the slumped zone is either Upper Eocene or Oligocene. The age cannot be definitely established because *Globigerina ampliapertura*, the youngest diagnostic form occurring in these beds, is not restricted to the Oligocene but occurs according to LOEBLICH et al. (1958) already in the Upper Eocene, *Globorotalia cerroazulensis* zone. However, more for lithologic and general geological considerations than for faunistic reasons, we are placing tentatively the slumped beds in the *Globigerina ampliapertura* zone of the basal Consuelo formation. Similar heterogeneous assemblages were found by us only in the Oligocene *Globigerina ciperoensis–Globorotalia opima* zone of the Consuelo formation outcropping at Punta Brava, and in a sample of the same age referred by BRODERMANN to his Guatao fauna.

Southwestern cliff

The southwestern cliff as described above is herewith designated the type locality of the Consuelo formation. As shown in the columnar sections, fig. 60, the type samples are from BR stations 360 and 363 to 366. BERMÚDEZ (1950, pp. 259 and 260) mentioned as type locality of the Consuelo formation the "parte superior" or "capas superiores" of the quarry at Tejar Consuelo. In view of the rather complicated geology of this quarry this designation is not adequate to locate Bermúdez' type station 36, in which this author recorded the following planktonic species:

- *Globigerina apertura* CUSHMAN [=*Globigerina ampliapertura* BOLLI]
- *Globorotalia cerroazulensis* (COLE)
- *Gümbelina cubensis* D. K. PALMER [=*Chiloguembelina cubensis* (D. K. PALMER)]
- *Gümbelina goodwini* CUSHMAN and JARVIS [=*Chiloguembelina martini* (PIJPERS)]
- *Hantkenina alabamensis* CUSHMAN
- *Hantkenina brevispina* CUSHMAN
- *Hantkenina longispina* CUSHMAN
- *Nonion micrus* COLE [=*Pseudohastigerina micra* (COLE)]

This may be a homogeneous fauna of Upper Eocene age, or a basal Consuelo assemblage with reworked Upper Eocene forms. It is probably from the slumped basal Consuelo beds of the southeastern cliff. The microfauna listed by BERMÚDEZ as another typical Consuelo fauna from his station 18, Cantera Kohly, Bosque de la Habana, about 1 km northwest of Tejar Consuelo, is clearly heterogeneous. It contains the above listed Upper Eocene planktonics and the Middle Eocene *Globigerina mexicana* CUSHMAN [=*Porticulasphaera mexicana* (CUSHMAN)]. We were unable to find this sample in the collections of the Comisión del Mapa Geologico de Cuba. It is probably also from the slumped basal Consuelo beds.

The type samples described below are listed from bottom to top. BR stations 360 and 364 to 366 are from the *Globigerina ampliapertura* zone and the stratigraphically youngest sample, BR station 363, is from the *Globigerina ciperoensis–Globorotalia opima* zone. Most of the assemblages contain reworked Lower to Middle (?Upper) Eocene species. The ostracodes from BR stations 360, 363 to 366 have been identified generically by W. A. VAN DEN BOLD (letter March 21, 1963).

BR station 360
Lithology: Chalk, powdery, light grayish yellow.
Washed residue with

Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ) (one specimen)
Globigerina ampliapertura BOLLI (common)
Globigerina ciperoensis angustiumbilicata BOLLI
Globigerina parva BOLLI (abundant)
Globigerina rohri BOLLI group (common)
Globigerina cf. *trilocularis* D'ORBIGNY
Globoquadrina venezuelana (HEDBERG) group
Pseudohastigerina micra (COLE)
Chiloguembelina cubensis (D. K. PALMER) (abundant)
Globorotalia centralis CUSHMAN and BERMÚDEZ } reworked
Globorotalia sp. (truncate form). }

Macrocypris sp.
Bairdia sp.
Krithe sp.
Pseudocythere sp.

BR station 366
Lithology: Chalk, fairly indurated, powdery, grayish yellow.
Washed residue with

Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globorotalia opima nana BOLLI
Globigerina ampliapertura BOLLI (common)
Globigerina ciperoensis angustiumbilicata BOLLI (common)
Globigerina euapertura JENKINS
Globigerina parva BOLLI (abundant)
Globigerina rohri BOLLI group
Globoquadrina venezuelana (HEDBERG) group
Globorotaloides suteri BOLLI
Chiloguembelina cubensis (D. K. PALMER) (abundant)
Cassigerinella chipolensis (CUSHMAN and PONTON)

Pseudohastigerina micra (COLE)
Globigerina soldadoensis BRÖNNIMANN group } reworked
Globigerina linaperta (FINLAY)

Macrocypris sp.
Bairdia sp.
Argilloecia sp.

BR station 365
Lithology: Chalk, powdery, grayish yellow.
Washed residue with

Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globorotalia opima nana BOLLI
Globigerina ampliapertura BOLLI (common)
Globigerina ciperoensis angustiumbilicata BOLLI (abundant)
Globigerina parva BOLLI (abundant)
Globigerina rohri BOLLI group
Globoquadrina venezuelana (HEDBERG) group
Chiloguembelina cubensis (D. K. PALMER) (abundant)
Cassigerinella chipolensis (CUSHMAN and PONTON)

Cytherella sp.
Bairdia sp.
Bythocypris sp.
Krithe sp.

BR station 364
Lithology: Chalk, fairly indurated, powdery, light yellowish to grayish yellow.
Washed residue with

Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerina ampliapertura BOLLI (common)
Globigerina ciperoensis angustiumbilicata BOLLI
Globigerina euapertura JENKINS
Globigerina parva BOLLI (abundant)
Globigerina rohri BOLLI group
Globigerina cf. *trilocularis* D'ORBIGNY
Globoquadrina venezuelana (HEDBERG) group
Chiloguembelina cubensis (D. K. PALMER) (abundant)
Globorotalia spinuloinflata (BANDY) (reworked).

Bairdia sp.
Bradleya sp.
Macrocypris sp.
"*Krausella*" sp.
Krithe sp.

BR station 363
Lithology: Chalk, powdery, white to grayish yellow, with limonitic streaks and concretions.

Washed residue with

Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerina ampliapertura BOLLI (rare)
Globigerina ciperoensis angulisuturalia BOLLI
Globigerina ciperoensis angustiumbilicata BOLLI
Globigerina ciperoensis ciperoensis BOLLI
Globigerina euapertura JENKINS
Globigerina parva BOLLI (abundant)
Globigerina rohri BOLLI group
Globoquadrina venezuelana (HEDBERG) group
Globorotalia opima nana BOLLI
Globorotalia opima opima BOLLI group (common) (first large and well-developed specimen)
Globorotaloides suteri BOLLI
Chiloguembelina cubensis (D. K. PALMER) (abundant).

Bradleya aff. *dictyon* (BRADY)
Bairdia sp.
Bythocypris sp.
Cytherella sp.

Northeastern cliff

The slumped beds, here about 3.9 m thick, were closely and carefully sampled in order to establish beyond doubt the heterogeneous composition of the faunas. The relative positions of the samples are shown in the index map of the Consuelo quarry, fig. 59. BR stations 361 and 362 are random samples from the slumped beds. BR station 704 is from the base of the slumped zone, 705 is 1.2 m stratigraphically above 704, and 706 is 1.5 m stratigraphically above 705. BR station 706 is still within the slumped beds which at this level are without pebbles.

BR station 361

Lithology: Chalk, indurated, grayish yellow, with asphalt inclusions.

Washed residue heterogeneous with

Hantkenina alabamensis CUSHMAN
Hantkenina cf. *dumblei* WEINZIERL and APPLIN
Hantkenina longispina CUSHMAN
Hantkenina suprasuturalis BRÖNNIMANN
Globigerina ampliapertura BOLLI
Globigerina boweri BOLLI
Globigerina parva BOLLI
Globigerina prolata BOLLI
Globigerina senni (BECKMANN)
Globigerina soldadoensis BRÖNNIMANN group
Globigerina cf. *yeguaensis* WEINZIERL and APPLIN
Globorotalia cerroazulensis (COLE)
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globigerapsis kugleri BOLLI

Globorotalia aequa Cushman and Renz
Globorotalia aragonensis Nuttall
Globorotalia cf. *aspensis* (Colom)
Globorotalia lehneri Cushman and Jarvis
Globorotalia spinuloinflata (Bandy)
Pseudohastigerina micra (Cole)
Truncorotaloides rohri Brönnimann and Bermúdez
Globigerinatheka barri Brönnimann
Catapsydrax dissimilis (Cushman and Bermúdez).

BR station 362
Lithology: Chalk, indurated, powdery, whitish to pale greenish yellow.
Texture: Cryptocrystalline to microcrystalline groundmass with planktonic microfossils (a) and with irregular shaped inclusions of the same texture of up to about 3000 μ diameter (b).

Assemblage: a) Groundmass
Globigerina spp.
Discoaster aster Bramlette and Riedel
Discoaster barbadiensis Tan
Braarudosphaera bigelowi (Gran and Braarud)
Braarudosphaera discula Bramlette and Riedel
Coccoliths
Tremalithus eopelagicus Bramlette and Riedel
Thoracosphaera spp.

b) Inclusions
Globigerina spp.
Coccoliths.

Washed residue heterogeneous with
Hantkenina alabamensis Cushman
Hantkenina suprasuturalis Brönnimann
Cribohantkenina bermudezi (Thalmann)
Globorotalia centralis Cushman and Bermúdez
Globigerapsis index (Finlay)
Globigerapsis semiinvoluta (Keijzer)
Catapsydrax dissimilis (Cushman and Bermúdez)
Globigerina ampliapertura Bolli
Globigerina parva Bolli
Globigerina rohri Bolli group
Pseudohastigerina micra (Cole)
Globorotalia aragonensis Nuttall
Globorotalia bullbrooki Bolli
Truncorotaloides cf. *topilensis* (Cushman)
Porticulasphaera mexicana (Cushman)
Chiloguembelina martini (Pijpers)
Globigerinatheka barri Brönnimann.

BR station 704

This sample is from the base of the slumped zone.

Lithology: Chalk, indurated, whitish to grayish yellow.

Washed residue heterogeneous with

Globorotalia cf. *aequa* CUSHMAN and RENZ
Globorotalia cf. *aspensis* (COLOM)
Globorotalia cf. *bullbrooki* BOLLI
Globorotalia spinulosa CUSHMAN
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globigerinatheka barri BRÖNNIMANN
Globigerapsis index (FINLAY)
Globigerapsis kugleri BOLLI
Globigerapsis semiinvoluta (KEIJZER)
Globigerina ampliapertura BOLLI
Globigerina senni (BECKMANN)
Globigerina cf. *yeguaensis* WEINZIERL and APPLIN
Pseudohastigerina micra (COLE)
Chiloguembelina martini (PIJPERS)

BR station 705

Lithology: Chalk, indurated, powdery, whitish to grayish yellow, with limonitic inclusions.

Washed residue heterogeneous with

Hantkenina longispina CUSHMAN
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globorotalia lehneri CUSHMAN and JARVIS
Globigerina ampliapertura BOLLI
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerinatheka barri BRÖNNIMANN
Globigerapsis index (FINLAY)
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ.

BR station 706

Lithology: Chalk, indurated, powdery, whitish to grayish yellow.

Washed residue heterogeneous with

Hantkenina alabamensis CUSHMAN
Hantkenina suprasuturalis BRÖNNIMANN
Globorotalia cerroazulensis (COLE)
Globorotalia lehneri CUSHMAN and JARVIS
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerina ampliapertura BOLLI
Truncorotaloides topilensis (CUSHMAN)
Pseudohastigerina micra (COLE)
Chiloguembelina cubensis (D. K. PALMER).

BR station 707

The following descriptions refer to two indurated chalk pebbles from the basal layer of the slumped bed.

Lithology: Chalk, indurated, whitish to grayish yellow, with asphalt inclusions, (1) and (2).

Pebble 1
Texture: Cryptocrystalline to microcrystalline groundmass with planktonic microfossils. Asphalt inclusions and limonitic stains.
Assemblage: *Globorotalia* spp. (truncate forms)
Globigerina senni (BECKMANN)
Globigerina spp.
Coccoliths
Braarudosphaera bigelowi (GRAN and BRAARUD) (common)
Discoaster barbadiensis TAN
Thoracosphaera spp. (globular and ellipsoid bodies).

Pebble 2
Texture: As Pebble 1.
Assemblage: *Globorotalia centralis* CUSHMAN and BERMÚDEZ
Globigerina spp.
Pseudohastigerina micra (COLE)
Coccoliths
Discoaster barbadiensis TAN (abundant)
Braarudosphaera discula BRAMLETTE and RIEDEL
Braarudosphaera bigelowi (GRAN and BRAARUD)
Thoracosphaera spp. (globular and ellipsoid bodies).

The following three samples are from additional BR stations located in the slumped bed. They are arranged in stratigraphic sequence from bottom to top. BR stations 769 and 770 are from the pebbly basal layer and 772 is just from below the environmentally more quiet beds on top of the slumped zone.

BR station 769
Lithology: Chalk, indurated, whitish, with reworked asphalt inclusions.
Washed residue heterogeneous with
Hantkenina alabamensis CUSHMAN
Hantkenina suprasuturalis BRÖNNIMANN
Cribohantkenina bermudezi (THALMANN)
Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globorotalia spinuloinflata (BANDY)
Globorotalia cerroazulensis (COLE)
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globigerina ampliapertura BOLLI
Globigerina parva BOLLI
Globigerina senni (BECKMANN)
Truncorotaloides topilensis (CUSHMAN)
Pseudohastigerina micra (COLE).

BR station 770
Lithology: Chalk, indurated, powdery, grayish yellow. With abundant asphalt fragments.

Washed residue heterogeneous with
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerina cf. *ampliapertura* BOLLI
Globigerina parva BOLLI
Globigerapsis index (FINLAY)
Globorotalia centralis CUSHMAN and BERMÚDEZ
Pseudohastigerina micra (COLE)
Globigerinatheka barri BRÖNNIMANN
Globorotalia sp. (truncate form).

BR station 772
Lithology: Chalk, indurated, powdery, finely laminated, whitish to grayish yellow.

Washed residue heterogeneous with
Hantkenina cf. *alabamensis* CUSHMAN
Globigerina ampliapertura BOLLI
Globigerina parva BOLLI
Globigerina rohri BOLLI group
Globigerina senni (BECKMANN)
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Pseudohastigerina micra (COLE)
Globorotalia spinuloinflata (BANDY)
Chiloguembelina cubensis (D. K. PALMER).

The following samples are from the typical, undisturbed Consuelo beds transitionally overlying the slumped zone. They still show reworking with the exception of the fauna from BR station 702B.

BR station 702
Lithology: Chalk, indurated, powdery, grayish yellow, with reworked asphalt fragments.
Washed residue heterogeneous with
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globoquadrina venezuelana (HEDBERG) group
Globigerina ampliapertura BOLLI
Globigerina parva BOLLI
Globigerina rohri BOLLI group
Globigerina cf. *ciperoensis ciperoensis* BOLLI
Chiloguembelina cubensis (D. K. PALMER)
Globorotaloides suteri BOLLI
Pseudohastigerina micra (COLE)
Globorotalia spinuloinflata (BANDY)
Globorotalia spinulosa CUSHMAN
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ
Globigerapsis index (FINLAY)

BR station 702A
Lithology: Chalk, indurated, powdery, grayish yellow, with abundant reworked asphalt fragments.

Washed residue heterogeneous with

Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Pseudohastigerina micra (COLE)
Globigerina ciperoensis angustiumbilicata BOLLI
Globigerina parva BOLLI
Globigerina rohri BOLLI group
Globigerina senni (BECKMANN) (reworked)
Globoquadrina venezuelana (HEDBERG) group
Globorotaloides suteri BOLLI
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globorotalia cerroazulensis (COLE)
Globorotalia rex MARTIN
Globorotalia spinulosa CUSHMAN
Globorotalia spinuloinflata (BANDY)
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ
Truncorotaloides topilensis (CUSHMAN)

BR station 702B

This is the first Consuelo sample, *Globigerina ampliapertura* zone, without reworked older Foraminifera.
Lithology: Chalk, indurated, powdery, grayish yellow, with reworked asphalt particles.
Washed residue with

Globigerina ampliapertura BOLLI (abundant)
Globigerina ciperoensis angustiumbilicata BOLLI
Globigerina parva BOLLI
Globigerina rohri BOLLI group
Globoquadrina venezuelana (HEDBERG) group
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Chiloguembelina cubensis (D. K. PALMER).

Other outcrops of the Consuelo formation

Reparto Alturas del Vedado

About 300 m northwest of Tejar Consuelo and south of Reparto Alturas del Vedado, the Consuelo formation is exposed along the slope of Avenida Antonio Soto, approximate coordinates 365.22 N and 356.10 E. Lithologically, the Consuelo beds are similar to those of the nearby type locality, excepting the occurrence of numerous well-preserved echinid spines probably of *Rhabdocidaris sanchezi* LAMBERT, and of conspicuous, heavy, egg-shaped concretions, which H. H. HESS determined as barytes (letter dated June 2, 1958). Along this slope we observed limonitic layers.

The following samples are from bottom to top of the outcrop:

BR station 685
Lithology: Chalk, indurated, powdery, whitish to grayish yellow.

Washed residue with

Globigerina ampliapertura BOLLI
Globigerina rohri BOLLI group
Globoquadrina venezuelana (HEDBERG) group
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globorotalia cf. *opima nana* BOLLI
Chiloguembelina cubensis (D. K. PALMER).

BR stations 682 and 683

The samples from these stations are very similar faunally and lithologically and therefore reported together.

Lithologies: Chalk, indurated, powdery, whitish to grayish yellow.

Textures: Cryptocrystalline to microcrystalline groundmass with abundant planktonic microfossils.

Assemblages: *Globigerina* spp.
Chiloguembelina cubensis (D. K. Palmer)
Coccoliths, mainly placoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN (common)
Discoaster woodringi BRAMLETTE and RIEDEL (common)
Discoaster cf. *molengraaffi* TAN
Discoaster sp. indet.
Marthasterites sp.
Braarudosphaera bigelowi (GRAN and BRAARUD)
Microantholithus flos DEFLANDRE
Thoracosphaera sp.

Washed residue with

Globigerina ampliapertura BOLLI
Globigerina rohri BOLLI group
Globorotaloides suteri BOLLI
Chiloguembelina cubensis (D. K. PALMER).

Quarry east of Punta Brava

The location of this quarry has been described under Punta Brava formation (index map, fig. 64). In the summer of 1958, 4 to 5 m of whitish massive Consuelo chalks were exposed overlying the Upper Eocene Punta Brava beds. The lowermost bed of the Consuelo formation is a 5 to 10 cm thick shaley layer which rests on a limonitic and irregularly eroded solution surface on top of the early Upper Eocene Punta Brava formation. This suggests emergence, but no evidence of an angular unconformity between the Punta Brava and the Consuelo beds was seen because of the poor bedding near the contact between the two formations. The top of the Consuelo formation, on the other hand, is truncated by definitely transgressive and unconformable conglomeratic beds characterized by large discoid and sellate lepidocyclinas and here tentatively placed in the Husillo formation. The stratigraphic position of the Consuelo and Husillo samples, BR stations 376 to 378, and 383, from this outcrop is shown in the columnar section, fig. 65.

The planktonic microfauna from BR station 379 is heterogeneous with Lower and Upper Eocene forms re-deposited in a *Globigerina ciperoensis–Globorotalia opima* assemblage. It is reminiscent of the heterogeneous faunas reported from the slumped Consuelo beds of Tejar Consuelo and of BRODERMANN's Guatao fauna. The fauna of BR station 378 is homogeneous. The numerous large and in part sellate lepidocyclinas from BR stations 376 and 383 are long-ranging forms. According to W. STORRS COLE they may suggest correlation with the Meson formation of Mexico which at many horizons yields great quantities of *Lepidocyclina (Eulepidina) undosa* CUSHMAN. *Globigerina ciperoensis ciperoensis* BOLLI, *Globigerina ciperoensis angustiumbilicata* BOLLI, *Globigerina ciperoensis angulisuturalis* BOLLI, *Catapsydrax dissimilis* (CUSHMAN and BERMÚDEZ), *Globorotalia opima* BOLLI and *Globigerina euapertura* JENKINS, associated at Punta Brava with the large lepidocyclinas, are diagnostic of the *Globigerina ciperoensis–Globorotalia opima* zone. The planktonic Foraminifera encountered in a sample from the type locality of the Meson formation in a road cut at 24.8 km of the Tuxpan road, Tampico, Mexico, kindly donated by Mrs. Maria Luisa Robles Ramos, chief paleontologist of Petroleos Mexicanos, Mexico City, are essentially *Globigerina ciperoensis ciperoensis, Globigerina ciperoensis angustiumbilicata*, and *Globigerina* cf. *trilocularis*. The absence of *Globigerina ampliapertura* and of *Globorotalia opima* suggests that this fauna falls in the younger part of the *Globigerina ciperoensis–Globorotalia opima* zone. This is only very slightly younger than the age of our *Lepidocyclina*-bearing samples from the Punta Brava quarry as described in the following and in the chapter on the Husillo formation. Although the *Lepidocyclina* beds are younger than the underlying Consuelo chalks, the age difference is not measurable in terms of planktonic Foraminifera, which in both horizons are diagnostic of the *Globigerina ciperoensis–Globorotalia opima* zone. In the type locality of the Consuelo formation, the youngest Consuelo beds extend into this zone. It is possible that the rich planktonic assemblages of the *Lepidocyclina* beds are, at least in part, re-deposited. The faunas, however, appear homogeneous and reworking cannot be detected.

BR station 379 (Consuelo formation)
Lithology: Chalk, powdery, with reworked asphalt fragments, whitish yellow to grayish orange.
Washed residue heterogeneous with

Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerina euapertura JENKINS
Globigerina ciperoensis angulisuturalis BOLLI
Globigerina ciperoensis angustiumbilicata BOLLI
Globigerina ciperoensis ciperoensis BOLLI
Globigerina parva BOLLI
Globigerina rohri BOLLI group
Globigerina senni (BECKMANN)
Globigerina soldadoensis BRÖNNIMANN group
Globoquadrina venezuelana (HEDBERG) group
Globorotaloides suteri BOLLI
Globorotaloides cf. *suteri* BOLLI (as illustrated in LOEBLICH et al., 1958, pl. 27, figs. 14 a–c)

Globorotalia brodermanni CUSHMAN and BERMÚDEZ
Globorotalia centralis CUSHMAN and BERMÚDEZ
Globorotalia opima opima BOLLI
Cassigerinella chipolensis (CUSHMAN and PONTON)
Reworked Punta Brava and older hantkeninas, globigerinas, and truncate keeled globorotalias as listed below
Hantkenina alabamensis CUSHMAN
Hantkenina suprasuturalis BRÖNNIMANN
Globorotalia aequa CUSHMAN and RENZ
Globorotalia bullbrooki BOLLI
Globorotalia cf. *formosa* BOLLI
Globigerapsis index (FINLAY)
Truncorotaloides rohri BRÖNNIMANN and BERMÚDEZ
Pseudohastigerina micra (COLE).

BR station 378 (Consuelo formation)
Lithology: Chalk, powdery, white (coccolithite).
Texture: Microcrystalline to cryptocrystalline with abundant planktonic microfossils.

Assemblage:
Chiloguembelina cubensis (D. K. PALMER)
Globigerina spp.
Discoaster deflandrei BRAMLETTE and RIEDEL (common)
Typical specimens as illustrated by BRAMLETTE and RIEDEL (1954, p. 399, figs. 1 a–c). Maximum diameter 10 to 12 μ.
Coccoliths (abundant)
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Thoracosphaera spp.

Washed residue with
Globigerina euapertura JENKINS
Globigerina ciperoensis angustiumbilicata BOLLI
Globigerina rohri BOLLI group
Globorotalia opima BOLLI group
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Pseudohastigerina micra (COLE).

BR station 383 (Husillo formation)
Lithology: Chalk, powdery, yellowish to pale yellowish orange, with lepidocyclinas (smaller specimens than in station 376) and *Operculinoides*.

Washed residue with
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globorotalia opima nana BOLLI (common)
Globorotalia opima opima BOLLI (common)
Globigerina euapertura JENKINS (common)
Globigerina ciperoensis angustiumbilicata BOLLI (abundant)
Globigerina parva BOLLI
Globigerina rohri BOLLI group
Globigerina cf. *trilocularis* D'ORBIGNY

Globoquadrina venezuelana (HEDBERG) group
Globorotaloides suteri BOLLI
Chiloguembelina cubensis (D. K. PALMER)
W. STORRS COLE (letter, March 3, 1959) identified from this station
Lepidocyclina gigas CUSHMAN
Lepidocyclina (Lepidocyclina) giraudi R. DOUVILLÉ
Lepidocyclina (Eulepidina) undosa CUSHMAN
W. A. VAN DEN BOLD (letter March 26, 1963) listed the following ostracodes
Aurila deformis (REUSS) ?
Bairdia sp.
Cytherella sp.

BR station 376 (Husillo formation)
Lithology: Chalk, rather hard, whitish to grayish yellow, with large and sellate lepidocyclinas up to 4 cm diameter.
Washed residue with
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globorotalia opima nana BOLLI (abundant)
Globorotalia opima opima BOLLI (abundant)
Globorotaloides suteri BOLLI
Globigerina euapertura JENKINS (common)
Globigerina ciperoensis angulisuturalis BOLLI (common)
Globigerina ciperoensis angustiumbilicata BOLLI (abundant)
Globigerina ciperoensis ciperoensis BOLLI (abundant)
Globigerina parva BOLLI
Globigerina rohri BOLLI group
Globigerina cf. *trilocularis* D'ORBIGNY
Globoquadrina venezuelana (HEDBERG) group
Chiloguembelina cubensis (D. K. PALMER)
Cassigerinella chipolensis (CUSHMAN and PONTON)
Porticulasphaera mexicana (CUSHMAN) (reworked)
W. STORRS COLE (letter March 3, 1959) identified from this station
Lepidocyclina gigas CUSHMAN
Lepidocyclina (Eulepidina) undosa CUSHMAN,
and W. A. VAN DEN BOLD (letter March 21, 1963)
Aurila deformis (REUSS)
Jugosocythereis vicksburgensis (HOWE)
Krithe sp.
Bairdia sp.

BR station 377
Described below are thin sections (1–14) from pebbles of sedimentary origin collected in a heterogeneous basal conglomerate tentatively assigned to the Husillo formation overlying the Consuelo beds in the quarry east of Punta Brava. As

shown in the columnar section, fig. 65, BR station 383 is situated at the base of the interval from which the pebbles have been collected. Apart from sedimentary pebbles occur also usually well-rounded gabbro, basalt, serpentinite and granodiorite components (personal communication, J. P. BAUGHMAN). North and west of Guanajay this conglomerate can be found on serpentine and on Upper Cretaceous to Upper Eocene formations. The well-roundedness of the igneous elements may be suggestive of derivation from older Cretaceous igneous conglomerates. The here listed sedimentary pebbles are from the late Dogger and older Cayetano (?) formation, from Neocomian *Nannoconus* limestones and from Tertiary limestones.

Thin section 1 (Universidad formation)
Lithology: Limestone, hard, somewhat siliceous.
Texture: Cryptocrystalline groundmass with planktonic microfossils, whitish to grayish yellow.
Assemblage: *Globorotalia centralis* CUSHMAN and BERMÚDEZ
Globigerina senni (BECKMANN)
Truncorotaloides cf. *topilensis* (CUSHMAN)
Braarudosphaera bigelowi (GRAN and BRAARUD)
Thoracosphaera sp.
Radiolaria (common).

Thin section 2
Lithology: Limestone, grayish orange.
Texture: Mainly fragments of algae, echinoderms and mollusks embedded in clear calcite groundmass. Also benthonic Foraminifera.
Assemblage: *Amphistegina* sp.
Cibicides sp.
?*Eofabiania cushmani* (COLE and BERMÚDEZ)
Lithoporella melobesioides FOSLIE.

Thin section 3
Lithology: Limestone, grayish orange.
Texture: Fragmental. Components mainly fragments of coralline algae, echinoderms and mollusks. Also many benthonic Foraminifera. Groundmass calcite.
Assemblage: *Pararotalia mexicana mecatepecensis* (NUTTALL)
Amphistegina sp.
Lepidocyclina sp. (fragments)
Lithoporella melobesioides FOSLIE.

Thin section 4 (Cayetano formation)
Lithology: Quartz sandstone, fine-grained, yellowish gray. Barren.

Thin sections 5, 9, 11 (*Nannoconus* limestones)
Lithology: Limestone, pale yellowish brown (5), light gray (9), (11).
Texture: Cryptocrystalline to microcrystalline groundmass, pseudoölitic in places, with abundant Radiolaria. Incipient dolomitization.
Assemblage: Radiolaria
Nannoconus globulus BRÖNNIMANN
Nannoconus kamptneri BRÖNNIMANN.

Thin sections 6, 7, 8
Lithology: Limestone, light gray.
Texture: Microcrystalline. Barren.

Thin section 10
Lithology: Limestone, pale yellowish brown.
Texture: Cryptocrystalline groundmass with incipient dolomitization. Barren.

Thin section 12
Lithology: Chert, dark gray, slightly calcareous.
Texture: Silicified; originally probably pseudoölitic, dolomitic groundmass. Barren.

Thin section 13
Lithology: Chalk, whitish to grayish yellow.
Texture: Microcrystalline groundmass with planktonic microfossils.
Assemblage: *Globigerina* spp. (abundant)
Discoaster cf. *aster* BRAMLETTE and RIEDEL (common)
Discoaster barbadiensis TAN
Braarudosphaera bigelowi (GRAN and BRAARUD)
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Thoracosphaera spp.

Thin section 14
Lithology: Chalk, whitish to grayish yellow.
Texture: Microcrystalline groundmass with planktonic microfossils (coccolithite).
Assemblage: *Globigerina* spp.
Chiloguembelina cubensis (D. K. PALMER)
Discoaster barbadiensis TAN
Discoaster deflandrei BRAMLETTE and RIEDEL (common)
Coccoliths (abundant)
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Thoracosphaera spp.

Cantera Husillo

The location of the Husillo quarry will be explained under Husillo formation (index map, fig. 67). In the southern part of the quarry, the Consuelo beds rest on the Príncipe member of the Universidad formation. BR stations 845 and 846 are from the *Hantkenina dumblei–Globigerinatheka barri* zone of the late Middle Eocene Príncipe chalks outcropping in the southeastern part of the quarry. These chalks exhibit submarine slumping. In its northwestern part, where the type section of the Husillo formation is exposed, the Consuelo beds form the bottom part of the cliff as illustrated by the photograph, fig. 69. The unweathered Consuelo chalks are grayish, as at BR station 849, and the overlying weathered Consuelo beds are grayish yellow and partly affected by submarine slumping as at BR stations 850 and 851. Both PALMER (1945, p. 17) and BERMÚDEZ (1950, p. 264), observed that also the Tinguaro beds outcropping in the Colón anticline of Matanzas Province, probably identical with the Oligocene Consuelo formation, are bluish

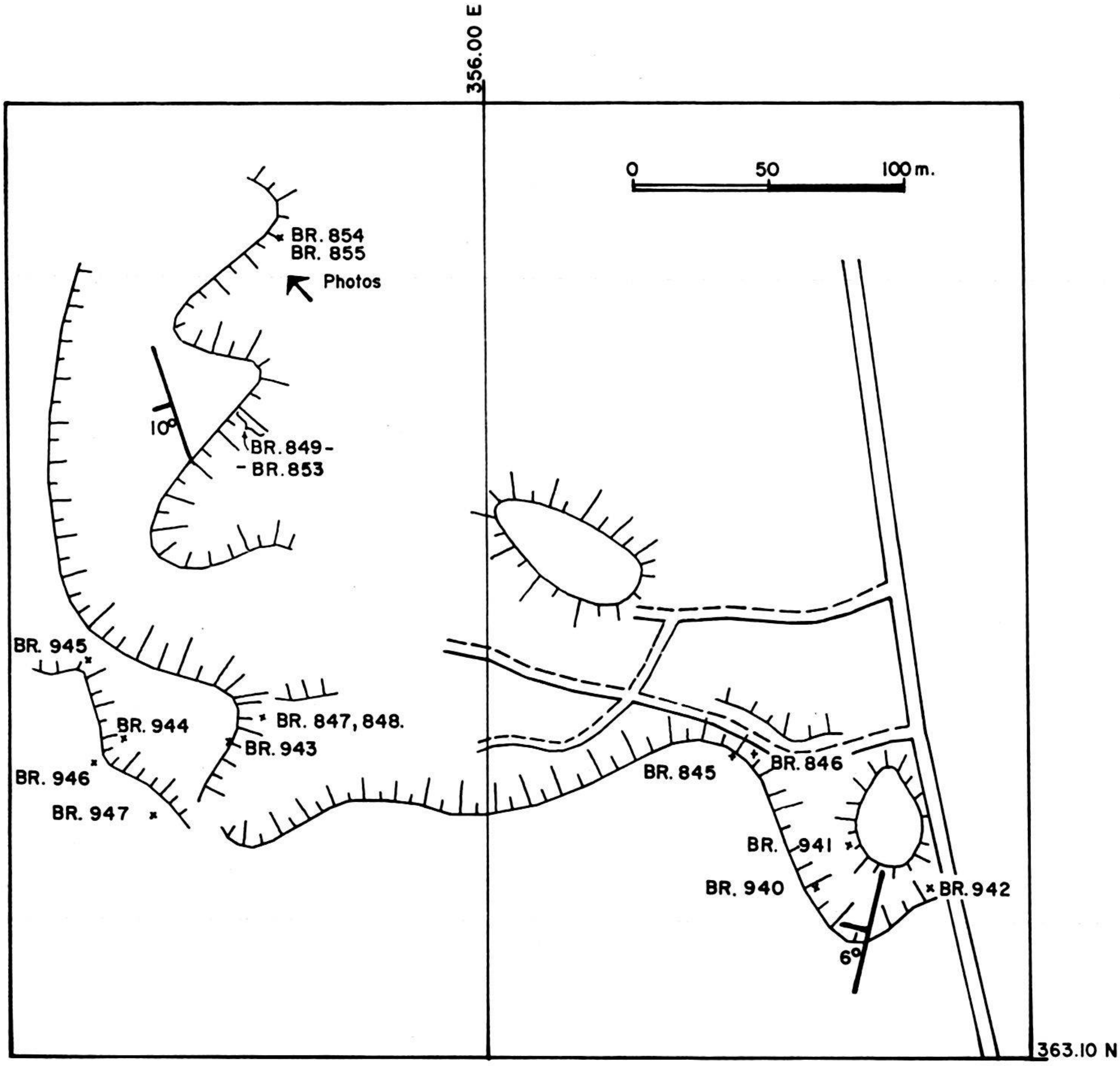


Fig. 67. Index map of Cantera Husillo.

gray unweathered and yellowish weathered. The stratigraphic positions of BR stations 849 to 851, listed below from bottom to top, are given in the columnar section, fig. 68:

BR stations 849 and 850 (Consuelo formation)

BR station 849 is from the unweathered Consuelo chalk immediately underlying the weathered grayish yellow Consuelo chalk of BR station 850. In order to avoid repetition the two samples are here reported together. They are both from the *Globigerina ampliapertura* zone.

Lithologies: Chalk, very light gray (849); chalk, powdery, grayish yellow, weathered (850).

Washed residues with

Globigerina ampliapertura Bolli
Globigerina parva Bolli (abundant)
Globigerina rohri Bolli group

Globorotalia opima nana BOLLI
Globorotaloides suteri BOLLI
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Chiloguembelina cubensis (D. K. PALMER).

BR station 851 (Consuelo formation)

This station is from a chalky bed exhibiting distinct intraformational slumping features. The planktonic microfauna is homogeneous and representative of the *Globigerina ampliapertura* zone.

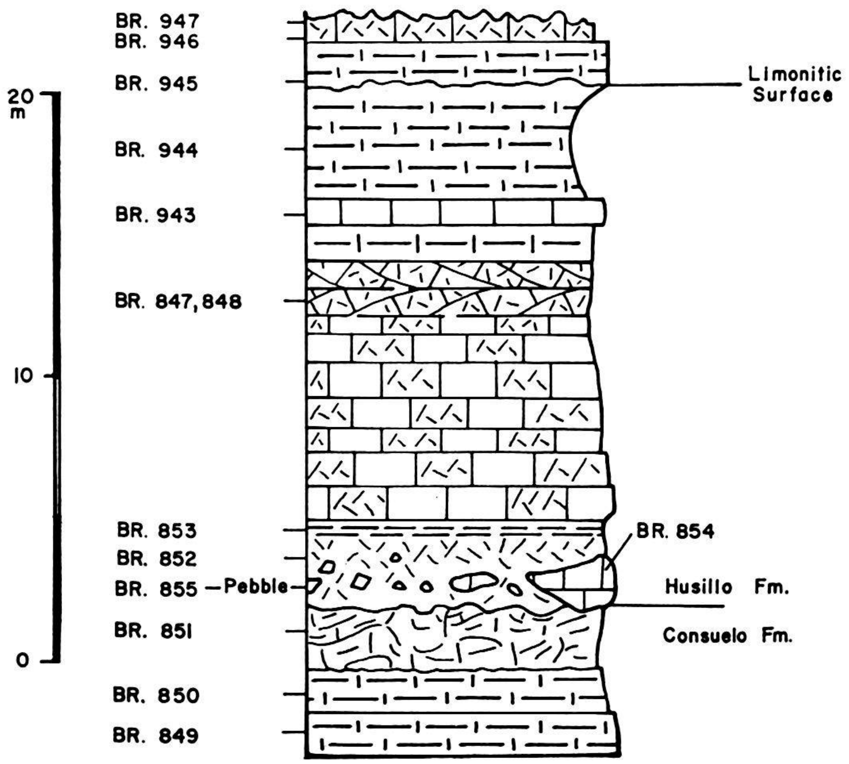


Fig. 68. Columnar section of the Husillo formation.

Lithology: Chalk, whitish to grayish yellow.
Texture: Cryptocrystalline to microcrystalline groundmass with abundant planktonic microfossils.

Assemblage:
Globigerina spp.
Chiloguembelina cubensis (PALMER)
Coccoliths (abundant)
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN
Discoaster woodringi BRAMLETTE and RIEDEL
Braarudosphaera bigelowi (GRAN and BRAARUD)
Thoracosphaera spp. (globular and ellipsoid bodies).

Washed residue with
Globigerina ampliapertura BOLLI (common)
Globigerina euapertura JENKINS

Globigerina parva BOLLI
Globigerina rohri BOLLI group
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globoquadrina venezuelana (HEDBERG) group
Chiloguembelina cubensis (D. K. PALMER).

Environment and age

The Consuelo formation is lithologically so close to the Príncipe member of the Universidad formation that in an isolated outcrop the two units can hardly be distinguished. Only the absence or scarcity of asphalt inclusions in the undisturbed Consuelo beds may aid to separate them from the Universidad chalks. Intraformational unconformities, disconformities and slumping suggesting unstable bottom conditions are features common to both the Consuelo and Universidad formations. The cryptocrystalline to microcrystalline textures as seen in thin sections and the abundance of planktonic microfossils of which the minute discoasterids and coccoliths may occur in rock-forming quantities, point toward a basinal environment of the Consuelo formation. Planktonic Foraminifera predominate, and although no counts were made, the estimated ratio between planktonic and benthonic species appears to be rather high, suggesting after GRIMSDALE and VAN MORKHOVEN (1955) a depth range of about 600 to 1200 m for the Consuelo sea. Detailed counts might narrow this depth interval down, but it is believed that the order of magnitude for the estimated depth range would remain unchanged. The depth range of the Consuelo sea is the same as that inferred for the ecologically related Universidad and Punta Brava seas of Cuba. The late Cojímar and the Husillo faunas, on the other hand, show a lower ratio between planktonic and benthonic species than the Consuelo faunas suggesting a sea considerably shallower than 600 m. D. K. PALMER and BERMÚDEZ (1936, pp. 223–239) arrived at a depth range of about 180 to 900 m for the foraminiferal fauna from the water well at Finca Adelina [=Tinguaro beds of R. H. PALMER] by comparing the depth distributions of the fossil species with those compiled by NORTON (1930) and by THORP (1931) for Recent species of the Caribbean area. The Finca Adelina fauna is dominated by abundant globigerinas. According to NORTON, in the Recent deposits of the Caribbean seas globigerinas are usually common to abundant below 900 m. The restrictive remark of PALMER and BERMÚDEZ (1936, p. 239) that probably the depth distribution of the Finca Adelina fauna tends toward the shallower limits of above range therefore does not seem to be justified. From the abundance of globigerinas it appears to be more probable that the actual depth range tends more toward 900 m than toward 180 m. This would essentially be in agreement with the depth estimate arrived at by us.

Megafossils and larger benthonic Foraminifera are not reported from the Consuelo chalks, although fragments of echinids were noticed in the outcrops of Avenida Antonio Soto, north of Tejar Consuelo. As mentioned earlier it may be possible that some or most of the echinids listed by SÁNCHEZ ROIG from the quarry at Tejar Consuelo originate from the Consuelo and not from the Universidad beds as stated by SÁNCHEZ ROIG (1949). The conglomeratic beds with the large discoid and sellate lepidocyclinas, interpreted by D. K. PALMER and also by

BERMÚDEZ as shallow-water equivalents of the Consuelo formation, are here regarded as a new lithologic unit tentatively assigned to the Husillo formation. Redeposited Lower to Upper Eocene planktonic Foraminifera are common in the slumped and disturbed basal Consuelo beds. Radiolaria appear to be absent.

The discoasterids and associated nannofossils of the type locality samples were not studied, but thin sections from the somewhat more indurated Consuelo chalks outcropping close to the type locality along Avenida Antonio Soto, about 300 m northwest of Tejar Consuelo, contain the following species:

Braarudosphaera bigelowi (GRAN and BRAARUD) (common)
Coccoliths (common), mainly placoliths, with large specimens of *Tremalithus eopelagicus* BRAMLETTE and RIEDEL
Discoaster aster BRAMLETTE and RIEDEL (rare to common)
Discoaster barbadiensis TAN (common)
Discoaster cf. *molengraaffi* TAN
Discoaster woodringi BRAMLETTE and RIEDEL (common)
Discoaster cf. *woodringi* BRAMLETTE and RIEDEL (common)
Discoaster sp. indet.
Marthasterites sp.
Micrantholithus flos DEFLANDRE
Thoracosphaera spp. (globular and ellipsoid bodies).

This assemblage is closely related with that of the Upper Eocene Punta Brava formation. *Discoaster woodringi* BRAMLETTE and RIEDEL, only rarely or doubtfully encountered in the Universidad and Punta Brava samples is one of the dominant discoasters of the Consuelo formation which is here assigned to the *Discoaster woodringi* zone of Oligocene age. Thoracosphaeras and coccoliths continue seemingly unchanged from the Eocene beds.

In terms of planktonic Foraminifera, the Consuelo formation extends from the *Globigerina ampliapertura* zone into the overlying *Globigerina ciperoensis–Globorotalia opima* zone.

Husillo formation

For rocks between the Lower Oligocene Tinguaro formation [=Consuelo formation] and the Upper Oligocene Cojímar formation, BERMÚDEZ (1950, p. 270) proposed the Jaruco formation. This Middle Oligocene formation was described to contain either abundant lepidocyclinas and miogypsinas or rich *Globigerina* faunas. In both ecologic types reportedly occurs as diagnostic species the compressed rotaliid *Kelyphistoma* [=*Almaena*] *alavensis* (D. K. PALMER). Mrs. PALMER ascribed in her manuscripts to the Jaruco formation a local stage sense, that is the Cuban Middle Oligocene (vide BERMÚDEZ). BRODERMANN's (1943, pp. 128 and 145) lithologic units Colon, or *Heterostegina* zone, Middle Oligocene, Jaruco and Tarará, both Upper Oligocene, were put by BERMÚDEZ (1950, p. 272) into synonymy with his Middle Oligocene Jaruco formation. BERMÚDEZ' Middle Oligocene Jaruco formation thus differs from the Jaruco formation of BRODERMANN, who already in 1943 (pp. 129, 130 and 145) introduced this name for an Upper Oligocene unit

underlying the Tarará formation. Clearly, his name has priority over BERMÚDEZ' Jaruco formation. From the stratigraphic table on p. 145 it is evident, however, that the type locality of BRODERMANN's Jaruco formation is most probably the same as that of the Jaruco formation of BERMÚDEZ. We are therefore referring in the following to the more informative type locality report of BERMÚDEZ (1950, p. 270), who described the Jaruco formation as "una marga blanca amarillenta con mucha arena calcarea y gruesas capas de conglomerados costeros". The type locality, represented by Bermúdez station 614, is reported to be situated in the cut of the Central Hershey railroad near the town of Jaruco where ". . . las margas tienen la tendencia a consolidarse, formando una caliza grosera". We visited the type area and did not find any outcrops along the railroad of Central Hershey. The only outcrops were in the cuts of the railroad of the Ferrocarriles Unidos de la Habana close to the intersection with the railroad of Central Hershey where neither marls nor conglomerates were seen, the lithology being hard, whitish limestones with miogypsinas. BR station 886, described below, is from this locality.
Lithology: Limestone, fragmental, hard, in places vacuolar, white.
Texture: Microcrystalline groundmass, vacuolar, with densely packed fragments of mainly coralline algae, echinoderms, mollusks, and corals and encrusting Foraminifera. Common miogypsinas and amphisteginas. Rare planktonic Foraminifera. Texture similar to that of the hard fragmental Husillo limestones.

Assemblage: *Miogypsina* spp. (common)
Lepidocyclina sp. (fragment only)
Amphistegina cf. *angulata* CUSHMAN (common)
Archaias cf. *operculiniformis* HENSON
Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Sporadotrema sp.
Globigerina spp.

The top of the *Miogypsina*-bearing limestones and the contact with the underlying Toledo member of the Universidad formation are covered. The latter crops out in a small quarry north of the road from Campo Florido to Jaruco, just at the west entrance to Jaruco. The Universidad beds, documented by BR station 884, are of late Lower Eocene age, *Globorotalia bullbrooki–Globorotalia aragonensis* zone.

BR station 884
Lithology: Limestone, silicified, hard, white to pale greenish yellow.
Texture: Cryptocrystalline, silicified groundmass with abundant planktonic microfossils.

Assemblage: *Globigerina senni* (BECKMANN)
Globorotalia sp. (truncate forms)
Chiloguembelina sp.
Radiolaria
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Discoaster aster BRAMLETTE and RIEDEL (rare)
Discoaster barbadiensis TAN (common)

Braarudosphaera discula BRAMLETTE and RIEDEL (common)
Thoracosphaera spp. (globular and ellipsoid bodies) (common).
Meyenella-like bodies (as described by RIEDEL, 1953) (rare)

Washed residue with

Globorotalia aragonensis NUTTALL
Globorotalia bullbrooki BOLLI
Globigerina senni (BECKMANN)
Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN
Radiolaria.

The Jaruco formation is poorly defined lithologically and geographically. For this reason we prefer not to use Jaruco formation in the Habana area, and to introduce the Husillo formation for the mainly shallow-water beds between the deeper water Consuelo and Cojímar formations.

Description of the type locality of the Husillo formation

The type locality of the Husillo formation is situated in the Cantera Husillo 1.5 km east of the Colegio de Belén, Marianao, a western suburb of La Habana. The approximate coordinates of the type locality are 363.20 N and 356.00 E (index map, fig. 67). The low hill of about 60 m height called Loma del Husillo, a few hundred meters east of the type locality, is formed by Universidad beds which are also exposed in the easternmost part of the Husillo quarry. BR stations 845, 846, 940, 941, and 942, previously described under Universidad formation, are from the Príncipe member of this quarry. In the central part of the quarry, these beds are overlain unconformably by typical Oligocene Consuelo chalks which show strongly contorted bedding, evidence of submarine slumping. In the western part of the quarry the Consuelo beds are overlain unconformably by a series of beds, about 20 m thick, here designated the type section of the Husillo formation (columnar section, fig. 68 and photograph, fig. 69). The type Husillo consists of fine- to medium-grained, generally not well cemented reefal detritus of dominantly whitish color with a few intercalations of more shaley and chalky beds, and of pene-contemporaneous conglomerates and of bioherms. BR station 852 is from the basal bed of the formation which is a chalky calcirudite formed by reefal derived, loosely cemented material. This bed also contains angular boulders, BR station 855, and rounded isolated bioherms, BR station 854, built mostly by corals, coralline algae and benthonic Foraminifera, in particular encrusting forms and miogypsinas (photograph, fig. 70). The thickness of this bed is variable because of its transgressive character and its mode of deposition. On the average we measured about 2 m. On this basal bed follows a thin whitish to yellowish chalk represented by BR station 853. Then follow about 9 m of hard grayish reefal derived limestones, BR station 847, and white, chalky calcarenites, BR station 848, which in their top portion exhibit indications of cross-bedding, reminiscent of that observed in the dunes of the Pleistocene Santa Fé formation. This bed is overlain by 7 to 8 m of softer, more shaley and granular, whitish to yellowish gray chalks and chalky limestones where BR stations 944, 945, and 946 are located. It includes close to its base a 1 m thick, hard, reefal derived, yellowish gray calcirudaceous limestone, BR station 943. Just below BR station 945, about 1.5 m from the top of this section, occurs a distinct irregular limonitic intercalation which, in view of the micropaleontological information and of the identical lithology above and below it, must be interpreted as an intraformational break probably caused by a brief period of

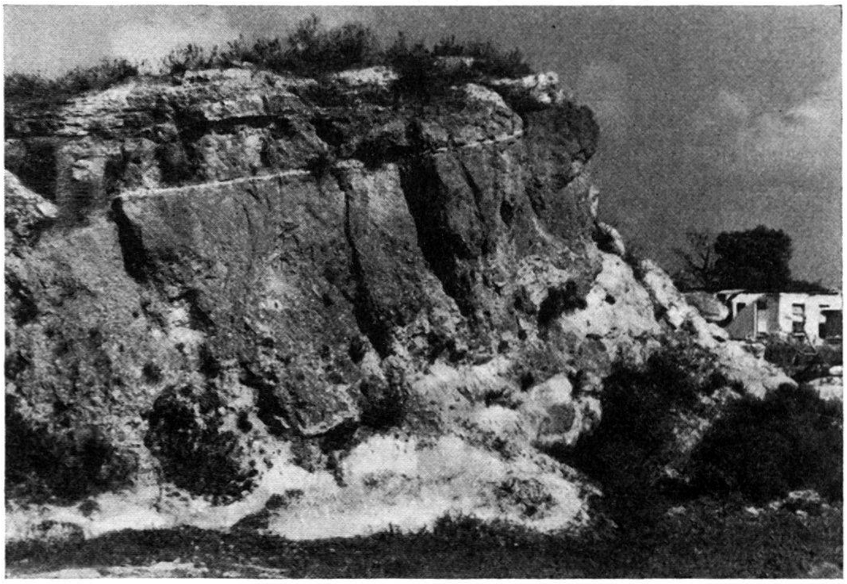


Fig. 69. Type section of the Husillo formation, eastern part of Cantera Husillo.

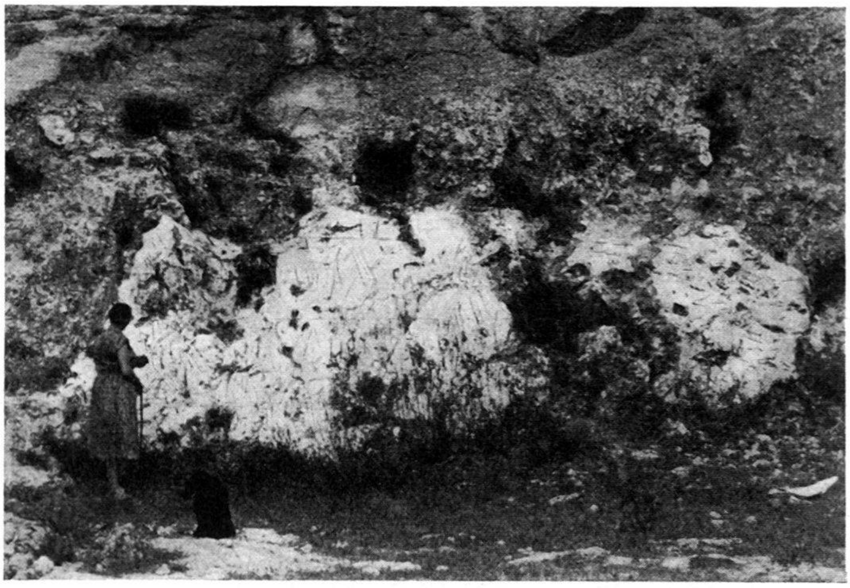


Fig. 70. Bioherms in the basal bed of the Husillo formation, cliff eastern part of Cantera Husillo.

emergence. It was noticed that the lithology of the chalky portion is similar to that of the type Cojímar, and close to that of BR station 1013A at Punta Brava, and to that of the Cacahual lithology outcropping east of the road from Santiago de las Vegas to Cacahual. On top of this chalky section there is again a 1 m thick reefal derived, calcirudaceous white limestone, where BR station 947 is located. The contact with the Cojímar formation forming the final cliff toward Marianao, is not exposed. However, it is believed that the dip-slope to the west-southwest of the top Husillo limestone bed represents actually an important lithologic boundary. From field evidence it is not clear whether the contact with the overlying Cojímar formation is disconformable or transitional. There is virtually no time gap, the Husillo beds being here in the *Globigerinatella insueta* zone and the Cojímar beds in the *Globorotalia fohsi* zone, and for paleontological reasons a pronounced unconformity is unlikely to exist.

The stratigraphic position of the type samples is given in the columnar section, fig. 68. They are from bottom to top:

BR station 852 (basal bed of the formation)
Lithology: Calcirudite, chalky, loosely cemented, white.
Texture: Cryptocrystalline to microcrystalline groundmass, vacuolar, with fragments of Corallinaceae and Dasycladaceae (*Halimeda* sp.), corals, echinoderms and bryozoas. Also common benthonic and rare planktonic Foraminifera.

Assemblage:
- *Miogypsina* sp. (fragments)
- *Lepidocyclina* sp. (spatulate equatorial chambers)
- *Operculinoides* sp.
- *Amphistegina* cf. *angulata* CUSHMAN (common)
- *Quinqueloculina* spp.
- *Gypsina globulus* REUSS
- *Planorbulina mediterranensis* D'ORBIGNY
- *Planorbulinella larvata* (PARKER and JONES)
- *Archaias* cf. *operculiniformis* HENSON
- *Meandropsina* sp.
- *Sporadotrema cylindricum* (PARKER)
- *Acervulina inhaerens* SCHULTZE
- *Globigerina* spp.

Washed residue with
- *Globigerinatella insueta* CUSHMAN and STAINFORTH (rare)
- *Globoquadrina altispira* (CUSHMAN and JARVIS) group
- *Globoquadrina dehiscens* (CHAPMAN, PARR, and COLLINS)
- *Globoquadrina venezuelana* (HEDBERG) group
- *Globigerinoides subquadratus* BRÖNNIMANN
- *Globorotalia fohsi barisanensis* LEROY
- *Globorotalia mayeri* CUSHMAN and ELLISOR.

BR station 854 (Bioherm)
Lithology: Limestone, fragmental, hard, dense, white.
Texture: Cryptocrystalline to microcrystalline groundmass with fragments of corals, algae, echinoderms and encrusting Foraminifera. Rare planktonic Foraminifera. Also fecal pellets without internal structures.

Assemblage:
- *Amphistegina* cf. *angulata* CUSHMAN
- *Planorbulinella larvata* (PARKER and JONES)
- *Acervulina inhaerens* SCHULTZE
- *Archaias* cf. *operculiniformis* HENSON
- *Dendritina* sp.

Gypsina globulus Reuss
Gypsina vesicularis (Parker and Jones) *discus* Goës
Globigerina spp.

BR station 855 (Pebble)
Lithology: Limestone, fragmental, hard, white.
Texture: Cryptocrystalline dense groundmass with fragments of echinoderms, mollusks, algae and larger benthonic Foraminifera.
Assemblage: *Miogypsina* sp.
Lepidocyclina sp. (fragment)
Archaias cf. *operculiniformis* Henson
Gypsina globulus Reuss
Heterostegina cf. *antillea* Cushman (fragment)
Amphistegina cf. *angulata* Cushman
Acervulina inhaerens Schultze
Globigerina spp.

BR station 853
Lithology: Chalk, marly, powdery, whitish to yellowish.
Washed residue with
Globigerinatella insueta Cushman and Stainforth (rare)
Globorotalia mayeri Cushman and Ellisor
Globoquadrina altispira (Cushman and Jarvis) group
Globoquadrina dehiscens (Chapman, Parr, and Collins)
Globoquadrina venezuelana (Hedberg) group.

BR station 847
Lithology: Limestone, fragmental, hard, pinkish gray to yellowish gray.
Texture: Cryptocrystalline to microcrystalline groundmass with fragments of algae, echinoderms and mollusks.
Assemblage: *Amphistegina* cf. *angulata* Cushman
Acervulina sp.
Globigerina spp.

BR station 848
Lithology: Calcarenite, somewhat chalky, white.
Texture: Cryptocrystalline groundmass, in part vacuolar, with fragments of algae, echinoderms, mollusks, bryozoas and larger benthonic Foraminifera. Also structureless fecal pellets.
Assemblage: *Miogypsina* sp.
Heterostegina antillea Cushman
Amphistegina cf. *angulata* Cushman
Acervulina inhaerens Schultze
Sporadotrema sp.
Carpenteria proteiformis Goës
Gypsina globulus Reuss
Archaias cf. *operculiniformis* Henson
Meandropsina sp. (small forms)
Globigerina spp.

Washed residue with

Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia fohsi barisanensis LEROY
Globigerinoides bisphericus TODD
Globigerinoides trilobus (REUSS) group
Globoquadrina altispira (CUSHMAN and JARVIS) group
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globoquadrina venezuelana (HEDBERG) group
Chiloguembelina cubensis (D. K. PALMER)
Globorotalia cf. *spinuloinflata* (BANDY) } reworked
Globigerapsis index (FINLAY) } reworked

BR station 943

Lithology: Calcirudite, hard, vacuolar, yellowish gray.
Texture: Clear calcite groundmass with pseudoölitic and fragmental components derived mainly from Corallinaceae and Dasycladaceae (*Halimeda* sp.), echinoderms, mollusks and benthonic Foraminifera. Also rounded fragments of limestones with globigerinids. Diameter of average components from about 300 to 1200 μ.

Assemblage:
Amphistegina cf. *angulata* CUSHMAN
Heterostegina antillea CUSHMAN
Sporadotrema cylindricum (CARTER)
Planorbulinella larvata (PARKER and JONES)
Acervulina inhaerens SCHULTZE
Archaias cf. *operculiniformis* HENSON (common)
Dendritina sp.
Meandropsina sp.
Peneroplis sp.
Miliolids
Gypsina globulus REUSS
Globigerina spp.

BR station 944

Lithology: Chalk, powdery, granular, indurated, whitish to yellowish.

Washed residue with

Globigerinoides bisphericus TODD
Globigerinoides trilobus (REUSS) group
Globigerina foliata BOLLI
"*Globigerina*" *juvenilis* BOLLI
Globoquadrina altispira (CUSHMAN and JARVIS) group
Sphaeroïdinella grimsdalei (KEIJZER)
Globorotalia fohsi barisanensis LEROY
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia cf. *scitula* (BRADY).

BR station 945

Lithology: Chalk, powdery, granular, indurated, whitish to grayish yellow.

Washed residue with

Globigerinoides bisphericus TODD
Globigerinoides sacculifer (BRADY)
Globigerinoides subquadratus BRÖNNIMANN
Globigerinoides trilobus (REUSS) group
"*Globigerina*" *juvenilis* BOLLI
Globoquadrina altispira (CUSHMAN and JARVIS) group
Globorotalia fohsi barisanensis LEROY
Globorotalia mayeri CUSHMAN and ELLISOR
Cassigerinella chipolensis (CUSHMAN and PONTON).

W. A. VAN DEN BOLD (letter 21. 3. 1963) identified from this station and from BR station 944 the following ostracodes:

Aurila deformis (REUSS)
Bairdia sp.
Jugosocythereis ? *vicksburgensis* (HOWE)
Loxoconcha cubensis V. D. BOLD
Perissocytheridea sp.
Quadracythere antillea (V. D. BOLD)
This assemblage is regarded by VAN DEN BOLD as about "Güines" in age.

BR station 946
Lithology: Limestone, chalky, granular, grayish yellow.
Texture: Cryptocrystalline to microcrystalline groundmass with abundant planktonic Foraminifera. As a rule the minute microfossils are destroyed through recrystallization.
Assemblage:

Globorotalia fohsi barisanensis LEROY
Globigerinoides sp.
Globoquadrina sp.
Coccoliths (rare)
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Discoaster cf. *woodringi* BRAMLETTE and RIEDEL (rare)
Braarudosphaera discula BRAMLETTE and RIEDEL (rare)
Braarudosphaera bigelowi (GRAN and BRAARUD) (rare)
Thoracosphaera sp. (globular bodies)
Gypsina globulus REUSS.

Washed residue with

Miogypsina sp.
Amphistegina cf. *angulata* CUSHMAN
Globigerinatella insueta CUSHMAN and STAINFORTH (rare)
Globoquadrina altispira (CUSHMAN and JARVIS) group
Globigerinoides trilobus (REUSS) group.

BR station 947
Lithology: Calcirudite, hard, white.
Texture: Fragmental to pseudoöolitic, unsorted. Components angular to rounded fragments of algae, mainly Corallinacea, bryozoas and echinoderms. Also larger

benthonic Foraminifera. Diameter of average components from about 100 to 2500 μ. Also rounded fragments of limestones. Matrix clear calcite or cryptocrystalline. Aspect of texture and faunal composition very similar to that of the Pleistocene calcarenites.

Assemblage: *Amphistegina* cf. *angulata* CUSHMAN
Archaias cf. *operculiniformis* HENSON
Meandropsina sp.
Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Sporadotrema sp.

Other outcrops of the Husillo formation

Tejar Consuelo and vicinity

On top of the western cliff of Tejar Consuelo, a hard, cavernous reefal limestone with miogypsinas of maximum 7 m thickness fills the erosional channels in the highest beds of the Consuelo formation. This limestone is separated from the light colored Consuelo chalks by a red, limonitic layer suggesting emergence prior to its deposition. BR stations 773 and 774 are random samples from the *Miogypsina* limestone. Reference is made to the index map of Tejar Consuelo, fig. 59, and to the columnar sections, fig. 60.

BR stations 773 and 774

These samples are very similar lithologically and faunally and therefore described together.
Lithologies: Limestone, hard, vacuolar, fragmental, whitish to grayish yellow.
Textures: Cryptocrystalline groundmass with fragments of Corallinaceae and Dasycladaceae (*Halimeda* sp.), echinoderms, corals, bryozoas and encrusting Foraminifera. Common miogypsinas and amphisteginas.

Assemblages: *Miogypsina* spp.
Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Sporadotrema cylindricum (CARTER)
Amphistegina cf. *angulata* CUSHMAN
Meandropsina sp.
Archaias cf. *operculiniformis* HENSON
Globigerina spp.

West-southwest of Tejar Consuelo along Calle San Antonio, Reparto Bosque de La Habana, coordinates 365.13 N and 356.32 E, the same fragmental limestone, represented by BR station 843, can be seen with the same relationship toward the Consuelo beds documented by BR station 844.

BR station 843 (Husillo formation)
Lithology: Limestone, coralligen, hard, grayish yellow.
Texture: Cross section of coral. Cavities filled with cryptocrystalline minutely fragmental groundmass.

Assemblage: *Amphistegina* cf. *angulata* CUSHMAN
Acervulina inhaerens SCHULTZE

BR station 844 (Consuelo formation)
Lithology: Chalk, granular, powdery, very pale orange.
Washed residue with
Globigerina ampliapertura BOLLI
Globigerina rohri BOLLI group
Chiloguembelina cubensis (D. K. PALMER)

Cantera de Vento

In the easternmost of the 3 quarries called Cantera de Vento, coordinates 356.09 N and 356.30 E, about 2.5 km south of Capdevila on the western side of the highway to Rancho Boyeros, a few decimeters of fragmental Husillo beds with miogypsinas overlie in the northern part of the quarry unconformably Lower Eocene Capdevila graywacke silts and shales. BR station 583 is from the *Miogypsina* limestone which is separated from the Capdevila beds by a thin calcite crust. In the western and southern part of this quarry occur about 10 m of hard

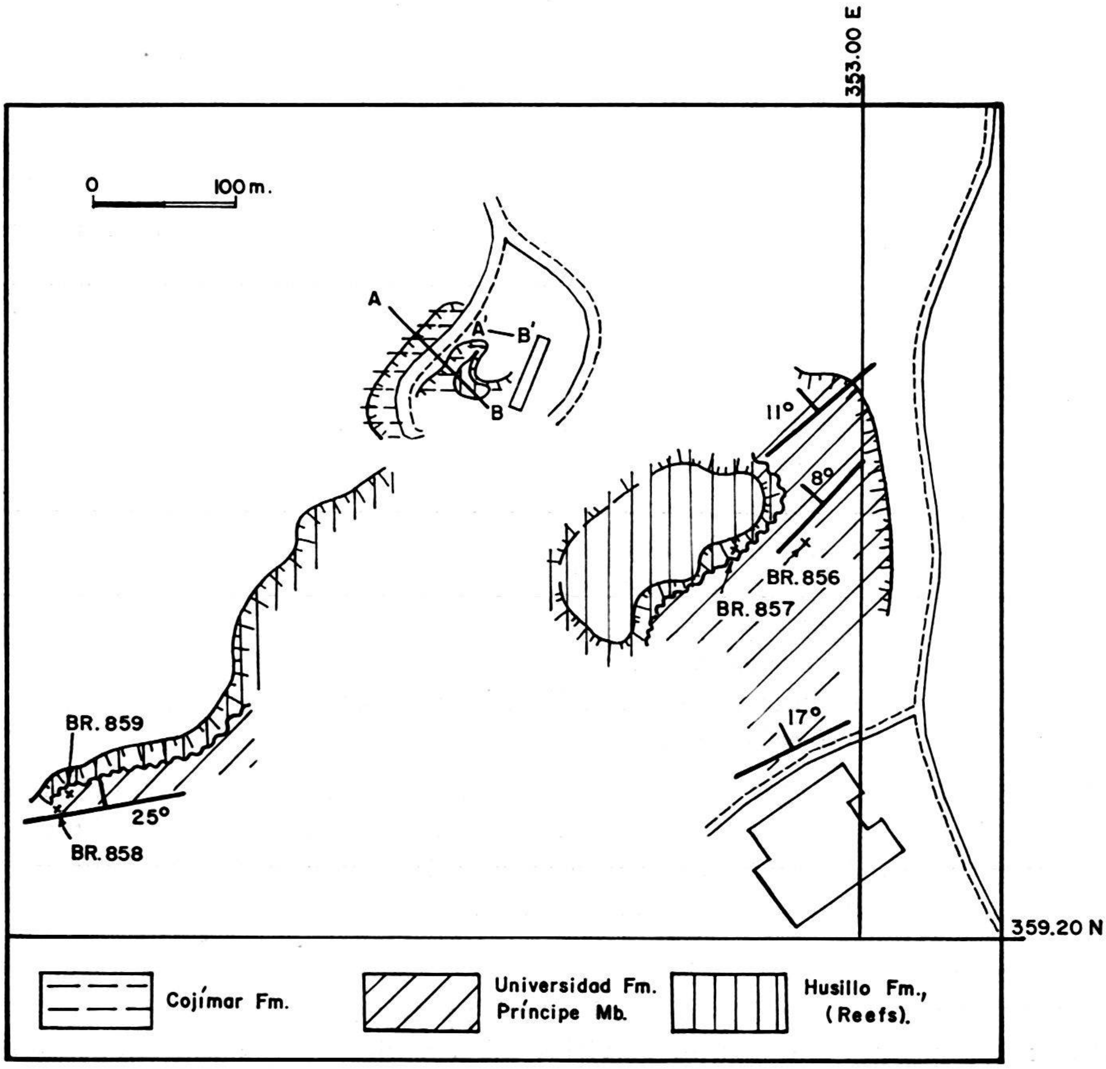


Fig. 71. Index map of the area at Tejar Andrade.

massive Husillo and Capdevila beds cut by a minor east striking fault. BR stations 584 and 606 are from the hard massive limestone which is lithologically and texturally similar to that found in the Pogolotti Quarry, Marianao area.

BR stations 583 and 606

Lithologies and faunas from these stations are practically identical and therefore reported together.

Lithologies: Calcirudite, not well-cemented, with large yellowish orange "clay" inclusions, yellowish gray to grayish yellow (583), calcirudite, well-cemented, grayish orange (606).

Textures: Microcrystalline groundmass with abundant miogypsinas, lepidocyclinas and other larger benthonic Foraminifera, fragments of echinoderms, algae and mollusks. Some planktonic Foraminifera. Also angular fragments of limestones.

Assemblages:
Miogypsina spp.
Miogypsinoides sp. ?
Lepidocyclina sp. with spatulate equatorial chambers
Lepidocyclina (*Lepidocyclina*) sp.
Amphistegina cf. *angulata* CUSHMAN
Sporadotrema cylindricum (CARTER)
Operculinoides sp.
Acervulina inhaerens SCHULTZE
Carpenteria sp.
Gypsina globulus REUSS
Archaias cf. *operculiniformis* HENSON
Globigerina spp.

BR station 584

Lithology: Limestone, fragmental, hard, whitish to very pale orange.

Texture: Cryptocrystalline to microcrystalline groundmass with fragments of algae, bryozoas, echinoderms and mollusks. Some benthonic and planktonic Foraminifera.

Assemblage:
Miogypsina sp.
Amphistegina cf. *angulata* CUSHMAN
Operculinoides sp.
Lepidocyclina sp. with spatulate equatorial chambers
Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Planorbulinella larvata (PARKER and JONES)
Globigerina spp.

Tejar Andrade

In Tejar Andrade, perfectly preserved bioherms of the Husillo formation are overlain, apparently disconformably, by the deeper water Cojímar chalks of the *Globorotalia fohsi* zone. The location of the following random samples from these bioherms is shown in the location map, fig. 72 and in the cross sections, fig. 73.

BR station 857

Lithology: Limestone, hard, fragmental, vacuolar, white.

Texture: Cryptocrystalline groundmass, vacuolar in places, with fragments of

Corallinacea and Dasycladaceae (*Halimeda* sp.), encrusting Foraminifera, echinoderms, bryozoas, and mollusks. Common amphisteginas.

Assemblage: *Amphistegina* cf. *angulata* CUSHMAN
Meandropsina sp.
Acervulina inhaerens SCHULTZE.

BR stations 859 and 862

These samples are lithologically and faunally very similar and here described together.

Lithologies: Limestone, hard, fragmental, with abundant Dasycladaceae, somewhat vacuolar, white to yellowish gray.

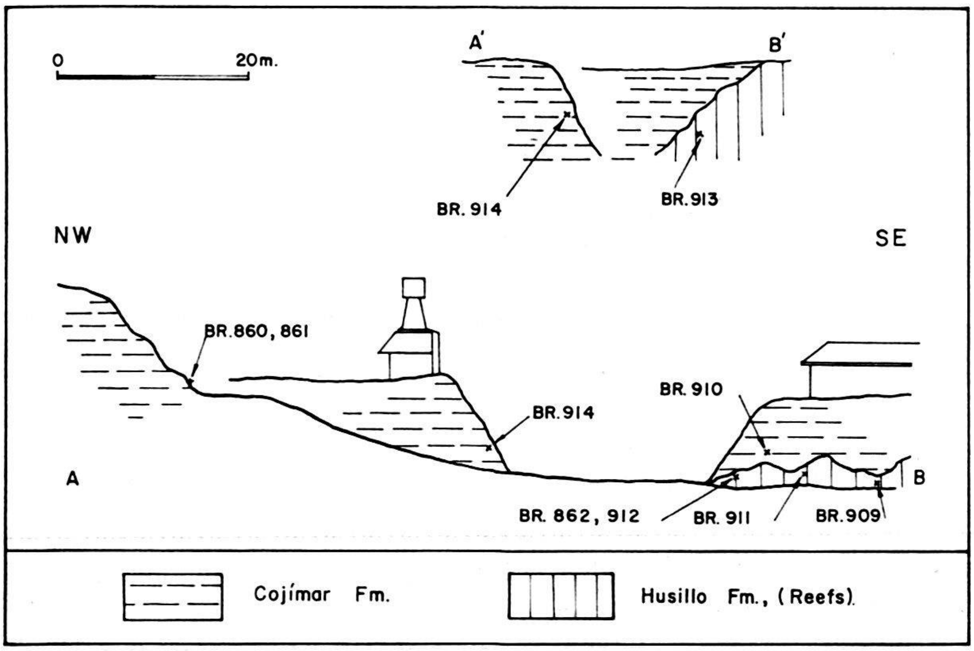


Fig. 72. Cross sections at Tejar Andrade.

Textures: Cryptocrystalline groundmass, recrystallized in places, with fragments of Corallinaceae, Dasycladaceae (*Halimeda* sp.), corals, encrusting Foraminifera, echinoderms, mollusks. Common amphisteginas and some globigerinas.

Assemblages: *Amphistegina* cf. *angulata* CUSHMAN
Archaias cf. *operculiniformis* HENSON
Meandropsina sp.
Sporadotrema sp.
Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Globigerina spp.

BR station 909 A

Lithology: Limestone, hard, fragmental, white to yellowish gray.

Texture: Cryptocrystalline to microcrystalline groundmass, in places vacuolar, with fragments of Corallinaceae, Dasycladaceae, bryozoas, echinoderms, encrusting Foraminifera, corals and mollusks. Common heterosteginas and some globigerinas.

Assemblage: *Amphistegina* cf. *angulata* CUSHMAN
Heterostegina antillea CUSHMAN
Sporadotrema sp.
Planorbulina mediterranea D'ORBIGNY
Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Archaias cf. *operculiniformis* HENSON
Meandropsina sp.
Globigerina spp.

BR station 911
Lithology: Limestone, chalky, fragmental, white to grayish yellow.
Texture: As BR station 909A.

Assemblage: *Heterostegina antillea* CUSHMAN
Amphistegina cf. *angulata* CUSHMAN
Meandropsina sp.
Archaias cf. *operculiniformis* HENSON
Peneroplis sp.
Acervulina inhaerens SCHULTZE
Sporadotrema sp.
Globigerinoides cf. *bisphericus* TODD
Globigerina spp.

BR station 913
Lithology: Limestone, hard, fragmental, whitish.
Texture: As BR stations 909A and 913.

Assemblage: *Amphistegina* cf. *angulata* CUSHMAN
Acervulina inhaerens SCHULTZE
Planorbulinella larvata (PARKER and JONES)
Gypsina globulus REUSS
Archaias cf. *operculiniformis* HENSON
Sporadotrema sp.

Pogolotti Quarry

About 10 m of rather flat-lying Husillo limestones are exposed in the Pogolotti quarry, Marianao, coordinates 361.45 N and 355.54 E. Random samples from the hard, whitish biohermal, in part fragmental to conglomeratic limestones are BR stations 976 and 977. The conglomeratic limestone contains large pebbles of Cacahual-type chalky limestone as described under BR station 978.

BR stations 976 and 977

The samples from these stations are very similar and therefore described together.

Lithologies: Limestone, algal, finely fragmental, white to yellowish gray (976), very light gray (977).

Textures: Microcrystalline groundmass of clear calcite with abundant fragments of Corallinaceae, Dasycladaceae (*Halimeda* sp.), echinoderms, bryozoas, mollusks and encrusting Foraminifera.

Assemblages: *Miogypsina* sp.
Heterostegina antillea CUSHMAN
Amphistegina cf. *angulata* CUSHMAN
Sporadotrema sp.
Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Archaias cf. *operculiniformis* HENSON
Meandropsina sp.
Globigerina spp.

BR station 978 (Pebbles of Cacahual-type limestone embedded in the reefal detrital limestone of BR stations 976 and 977).
Lithology: Limestone, hard, grayish orange to dark yellowish orange (pebbles), and limestone, hard, medium light gray (matrix).
Texture of pebbles: Cryptocrystalline groundmass with abundant planktonic Foraminifera.

Assemblage of pebbles:
Chiloguembelina cubensis (D. K. PALMER)
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globorotalia cf. *praemenardii* CUSHMAN and STAINFORTH
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL? (large specimen)
Braarudosphaera bigelowi (GRAN and BRAARUD)
Discoaster cf. *aster* BRAMLETTE and RIEDEL
Discoaster deflanderi BRAMLETTE and RIEDEL
Discoaster woodringi BRAMLETTE and RIEDEL
Transitional forms between *D. woodringi* BRAMLETTE and RIEDEL and *D. deflandrei* BRAMLETTE and RIEDEL
Thoracosphaera sp. (globular bodies).

Quarry north of Cacahual

Described below are random samples collected in the large abandoned quarry north of Cacahual on the eastern side of the road from Santiago de las Vegas to Cacahual, about 800 m south of Santiago de las Vegas. About 10 to 15 m of fine-grained limestones here generally referred to as Cacahual limestones, are exposed. The *Discoaster* assemblage of these samples is identical with that reported above from the pebbles in the detrital limestone collected in the large quarry near Pogolotti.

BR stations 64–66, 933, 934

These random samples are lithologically and faunally virtually identical and here summarized in order to avoid repetition.
Lithologies: Limestone, chalky, granular through accumulation of tests of planktonic Foraminifera, friable, grayish orange.
Textures: Cryptocrystalline to microcrystalline groundmass with abundant planktonic microfossils.

Assemblages: *Globigerina* spp.
Globigerinoides spp.
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL ?
Discoaster aster BRAMLETTE and RIEDEL (common)
Discoaster barbadiensis TAN (rare)
Discoaster deflandrei BRAMLETTE and RIEDEL (common)
Discoaster woodringi BRAMLETTE and RIEDEL (common)
Braarudosphaera bigelowi (GRAN and BRAARUD) (rare)
Transitional forms between *D. woodringi* BRAMLETTE and RIEDEL and *D. deflandrei* BRAMLETTE and RIEDEL (common)
Thoracosphaera spp. (common).

Washed residue with
Globigerinatella insueta CUSHMAN and STAINFORTH (rare)
Porticulasphaera transitoria (BLOW)
Globoquadrina altispira (CUSHMAN and JARVIS) group
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globigerinoides bisphericus TODD
Globigerinoides subquadratus BRÖNNIMANN
Globigerinoides trilobus (REUSS)
"*Globigerina*" *juvenilis* BOLLI
Globigerina rohri BOLLI group
Globigerina cf. *trilocularis* D'ORBIGNY
Globorotalia fohsi barisanensis LEROY
Globorotalia mayeri CUSHMAN and ELLISOR.

Cantera Cuyuji

Cantera Cuyuji is situated about 600 m east-northeast of the Cantera de Vento, approximate coordinates 356.40 N and 356.80 E. The relation of the Husillo limestones toward the Capdevila clastics is the same as in the Cantera de Vento. The main cliff of the quarry is broken by a number of minor east–west striking faults. The Husillo limestone, here about 15 m thick, is folded into a gentle anticline of the same east–west strike. The lithology is a porous, fragmental, whitish limestone. In places the beds follow the irregular surfaces of perfectly preserved harder and cavernous coral bioherms. Attitude and lithology of the beds and bioherms give the Husillo formation an irregular aspect which was also noticed at the type section at Tejar Husillo. BR station 607 is from the bottom of the quarry, BR station 608 is from its northern cliff.

BR station 607
Lithology: Limestone, chalky, fragmental, whitish to very pale orange.
Texture: Cryptocrystalline to microcrystalline vacuolar groundmass with abundant miogypsinas and other benthonic and some planktonic Foraminifera and with fragments of algae, bryozoas, echinoderms and mollusks.

Assemblage: *Miogypsina* spp.
Sporadotrema cylindricum (CARTER)

Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Amphistegina cf. *angulata* CUSHMAN
Archaias cf. *operculiniformis* HENSON
Globigerina spp.

BR station 608
Lithology: Limestone, chalky, powdery, fragmental, finely vacuolar, whitish.
Texture: Cryptocrystalline to microcrystalline in part vacuolar groundmass with abundant fragments of algae, mollusks, corals, echinoderms and bryozoas. Common miogypsinas and other benthonic Foraminifera. Some globigerinas.

Assemblage: *Miogypsina* spp.
Lepidocyclina sp. with spatulate equatorial chambers
Lepidocyclina (*Lepidocyclina*) sp.
Operculinoides sp.
Amphistegina cf. *angulata* CUSHMAN
Gypsina globulus REUSS
Acervulina inhaerens SCHULTZE
Archaias cf. *operculiniformis* HENSON
Sporadotrema sp.
Planorbulinella larvata (PARKER and JONES)
Globigerina spp.

Outcrop on the road from Barreras to the Vía Blanca, south of Playa Tarará

An outcrop of massive *Miogypsina* limestones outside of the Habana area proper, here referred to as the Husillo formation, can be seen in a small abandoned quarry on the northwestern side of the road from Barreras to the Vía Blanca, just southwest of the Reparto Alturas de Boca Ciega, coordinates 370.28 N and 376.99 E. The orbitoidal Husillo limestones of BR station 889 described under Urría beds, rest unconformably on Urría dolomite or Lower Eocene beds. The actual thickness of the Husillo formation is not known and its relationship to younger formations was not studied in detail. BERMÚDEZ (1950, p. 271) mentioned *Miogypsina*-bearing marls about 2 km south of Playa Tarará at his stations 594 to 597 and assigned them to the Jaruco formation. The outcrop referred to by BERMÚDEZ is very likely the same as the one described here.

On the west of the road immediately north of the abandoned quarry described above, coordinates 370.37 N and 376.89 E, a white friable chalk is interbedded in harder Husillo limestones. The fauna from this chalk, Sisson station 31, contains apart from miogypsinas and *Almaena alavensis* (D. K. PALMER), a well preserved planktonic assemblage with

Globigerina rohri BOLLI (group)
Globoquadrina altispira (CUSHMAN and JARVIS)
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globoquadrina venezuelana (HEDBERG)
Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ) (common)

which refers it to the *Catapsydrax dissimilis* zone.

Quarry East of Punta Brava

The location of this quarry has been explained in the chapter on the Upper Eocene Punta Brava formation. Unconformably on the whitish to yellowish Consuelo beds there were exposed in the early summer of 1958 about 5 m of yellowish to orange conglomeratic chalky marls and chalky limestones. Details of the contact between the truncated Consuelo formation and the younger beds as it was observed at that time are illustrated in fig. 66. The conglomeratic beds carry abundant discoid and sellate lepidocyclinas, pelecypods, echinoderms, corals. Microfaunas from 2 horizons within the conglomeratic beds, represented by BR stations 376 and 383, were previously described in the explanations to the columnar section of the Punta Brava formation (fig. 65). The top of these beds was not exposed when the stratigraphic succession was first studied. In the course of the late summer of 1958, the Punta Brava quarry was completely filled up. South of the southeastern part of the former quarry new excavations exposed about 5 to 10 m of yellowish orange and yellowish gray chalks and fragmental limestones overlying the conglomeratic beds with lepidocyclinas. The thickness is estimated because the gentle dip cannot be exactly determined. The top of these limestones is formed by a fragmental limestone with scattered pebbles similar to those collected from the underlying *Lepidocyclina* horizon of the *Globigerina ciperoensis–Globorotalia opima* zone. With the exception of these pebbles, the fragmental limestone is lithologically virtually identical with the fragmental Husillo limestones of the Husillo–Pogolotti–Andrade outcrops of the Marianao area. The relationship with the conglomeratic and fragmental limestones of the Pogolotti quarry is striking. The lower and thicker part of these upper beds, however, is a finely granular yellowish to dark orange, chalky limestone with abundant planktonic microfossils. It is lithologically identical with the Cacahual limestone and contains *Globigerinoides bisphericus* TODD, *Globigerinoides subquadratus* BRÖNNIMANN and *Globigerinatella insueta* CUSHMAN and STAINFORTH. The fact that no lithologic break can be seen between the *Lepidocyclina*-bearing conglomeratic beds of the *Globigerina ciperoensis–Globorotalia opima* zone and the younger chalks of Cacahual type of the *Globigerinatella insueta* zone suggests that the conglomerates and the chalks are probably separated by a disconformity rather than by a significant unconformity.

BR station 1014 (conglomeratic beds with lepidocyclinas)

See also descriptions of BR stations 383 and 376.

Lithology: Chalk, friable, powdery, pale to dark yellowish orange.

Washed residue with

Catapsydrax dissimilis (CUSHMAN and BERMÚDEZ)
Globigerina euapertura JENKINS
Globigerina ciperoensis angulisuturalis BOLLI
Globigerina ciperoensis angustiumbilicata BOLLI (abundant)
Globigerina ciperoensis ciperoensis BOLLI (abundant)
Globigerina rohri BOLLI (group)
Globigerina cf. *trilocularis* D'ORBIGNY
Globoquadrina venezuelana (HEDBERG)
Globorotalia opima nana BOLLI

Globorotalia opima opima BOLLI
Globorotaloides suteri BOLLI
Chiloguembelina cubensis (D. K. PALMER)
Pseudohastigerina micra (COLE).

W. S. COLE (letter, Feb. 23, 1959) identified from this sample
Operculinoides dius (COLE and PONTON)
Lepidocyclina (Lepidocyclina) giraudi R. DOUVILLÉ
Lepidocyclina (Lepidocyclina) wayland-vaughani COLE
Lepidocyclina (Lepidocyclina) yurnagunensis CUSHMAN
Lepidocyclina (Eulepidina) undosa CUSHMAN.

COLE places this assemblage in the *Lepidocyclina (Lepidocyclina)–Lepidocyclina (Eulepidina)* zone, which he proposed as the lower zone of the Oligocene, and correlates it approximately with the Suwannee limestone of Florida. He does not regard it as forming the basal part of his lower zone. This opinion is supported by the planktonic Foraminifera diagnostic of the *Globigerina ciperoensis–Globorotalia opima* zone, which overlies the basal Oligocene *Globigerina ampliapertura* zone.

BR station 1013A (Cacahual lithology)
Lithology: Limestone, hard, granular, pale yellow orange.
Texture: Cryptocrystalline groundmass with abundant planktonic microfossils and rare fragments of lepidocyclinas and algae.

Assemblage: *Globigerina* spp. (abundant)
Chiloguembelina cubensis (D. K. PALMER)
Lepidocyclina sp.
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL (large specimens)
Discoaster woodringi BRAMLETTE and RIEDEL
Braarudosphaera bigelowi (GRAN and BRAARUD)
Thoracosphaera sp.

BR station 1013 (Husillo-type fragmental and conglomeratic limestones and Cacahual-type chalk, limestone)
Lithologies: Chalk, indurated, yellowish to yellowish gray (1), calcarenite to calcirudite, hard, pale yellowish orange (2) and (3), calcirudite, conglomeratic, yellowish gray (4).

(1) Texture: as BR station 1013A.
Assemblage: As BR station 1013A.
(2), (3) and (4) Textures: Microcrystalline groundmass with fragments of algae, mollusks, echinoderms, bryozoas, and benthonic Foraminifera, and larger rounded inclusions of cryptocrystalline material. Lepidocyclinas and large rotalias are common. Diameter of average components from about 150 to 1500 μ.

Assemblages: *Pararotalia mexicana mecatepecensis* (NUTTALL)
Lepidocyclina spp.
Amphistegina cf. *angulata* CUSHMAN
Operculinoides sp.
Globigerina spp.

Gypsina globulus Reuss
Carpenteria sp.
Sporadotrema sp.
Planorbulina mediterranensis d'Orbigny
Discoaster deflandrei Bramlette and Riedel } in reworked
Thoracosphaera sp. } component

Whether the conglomeratic *Lepidocyclina* beds of BR stations 376, 377, 383 and 1014 are a local transgressive facies of the basal Husillo formation or whether they are a new lithologic unit between the deep-water Consuelo formation and the generally shallow-water Husillo formation sensu stricto, cannot be answered from the isolated outcrop at Punta Brava alone. Although we tentatively and for convenience sake assigned the *Lepidocyclina* beds to the Husillo formation, we prefer to leave this problem open. In our opinion it can only be resolved by further field studies south and west of Punta Brava. Brodermann (1943, stratigraphic table, p. 145) distinguished in his stratigraphic succession beds with large lepidocyclinas underlying those described from the water well near Finca Adelina and overlying his Guatao formation. From the localities mentioned by Brodermann it appears that the beds with large lepidocyclinas represent a stratigraphic horizon which can be followed over a wide area. At Punta Brava they are separated from the Consuelo formation by a distinct unconformity and for this reason they are not regarded as a shallow-water facies of the Consuelo formation [=Tinguaro formation of Bermúdez and Palmer] although both belong to the *Globigerina ciperoensis–Globorotalia opima* zone.

The age of the transgressive Husillo beds seems to change from area to area. At the Husillo type locality, they form part of the *Globigerinatella insueta* zone, BR station 852, and near the quarry north of Barreras on the road to Tarará, a planktonic microfauna diagnostic of the *Catapsydrax dissimilis* zone occurs in chalks interbedded in typical Husillo limestones with *Miogypsina* and *Heterostegina antillea*, Sisson station 31. In the Punta Brava area, the transgressive beds with large *Lepidocyclina* carry the planktonics of the *Globigerina ciperoensis–Globorotalia opima* zone. The Husillo formation thus would range from the *Globigerina ciperoensis–Globorotalia opima* zone to the *Globigerinatella insueta* zone. The *Globorotalia kugleri* zone which is within this interval, was not found in the Habana area. This may be explained by the transgressive nature, in the rim-rock area, of the Husillo beds. Southward of the mainly shallow-water reefal complex Husillo beds may be replaced by deeper water deposits of the Cacahual-type and it is expected that in this facies the complete planktonic zonal sequence will be present. This facies change is clearly indicated by the occurrence of a thin Cacahual-type layer between reefal limestones in the Husillo quarry and by the thicker Cacahual-type limestones southward at Punta Brava.

Environment and age

The type section of the Husillo formation is composed of the following principal lithologies:

a) Calcarenites and calcirudites.

Loosely or firmly cemented with calcite, porous. Groundmass in thin section generally vacuolar, cryptocrystalline to microcrystalline, occasionally of clear calcite, with more or less densely packed transported fragments of rocks of types (b), (c) and (d) and comminuted fragments of mollusks, corals, echinoderms, bryozoas, encrusting and other benthonic Foraminifera, and of algae, mainly Corallinaceae and Dasycladaceae (*Halimeda* sp.). Orbitoidal and planktonic Foraminifera usually occur in the groundmass between the above listed components but rarely in great numbers. Structureless fecal pellets were occasionally noticed. Environment: Reefal complex.

b) Fragmental limestones.
Dense, cryptocrystalline to microcrystalline groundmass which contains in form of discrete inclusions essentially the same suite of components as the rocks described under (a). Environment: Reefal complex.

c) Chalky limestones.
Cryptocrystalline to microcrystalline groundmass containing abundant planktonic microfossils. Environment: Relatively deep water.

d) Chalks.
Generally friable, powdery, with abundant planktonic microfossils. Environment: Relatively deep water.

Isolated, in places interconnected, irregularly rounded bioherms with large corals characterize the basal transgressive bed of the type section of the Husillo formation, demonstrating that this bed is from the reefal area sensu stricto. We do not know whether there was a continuous fringing reef landwards of these isolated or semi-isolated bioherms or whether they are representative of the open-shoal type of reef as defined by HENSON (1950, p. 23). The bioherms are buried by or associated with comminuted organic material derived from reefs by wave action and later consolidated into a porous, loosely or firmly cemented calcareous sand. Comminuted reefal derived material and occasional fragments of older limestones form the younger detrital beds of the type section. Bioherms, however, were not found in these younger beds, which for reasons explained below were probably deposited in the fore-reefal area.

The lithologies described under (a) and (b) were laid down in the area of the reef complex in the sense of Henson. The environmental types of the reef complex can best be determined by groups of fossils with living representatives of which the ecology is known. Orbitoidal Foraminifera such as lepidocyclinas and miogypsinas therefore can only be indirectly considered for paleoecologic conclusions. On the other hand, the environmental significance of peneroplids, amphisteginids, heterosteginas, *Operculinoides* and certain Dasycladaceae, all forms which occur throughout the Husillo samples, will be examined below in some detail.

It is significant that miliolids, frequent in the back-reef areas, are scarce in the Husillo type samples. Whole tests and fragments of peneroplids, represented by *Archaias* cf. *operculiniformis* HENSON, *Meandropsina* n. sp. (small form), *Peneroplis* sp., *Dendritina* sp. and *Sorites* cf. *orbiculus* (FORSKÅL) occur in most samples but are generally scarce. A noteworthy exception is BR station 943, which is from a hard porous calcirudite with a clear calcite groundmass where *Archaias* cf. *operculiniformis* HENSON is common. The peneroplids are one of the biostratigraphically more important groups of the post-Husillo strata, in particular of the relatively shallow-water Güines to Recent beds. According to NORTON (1930), MYERS (1942, 1943), and HENSON (1950, pp. 22–24), living peneroplids prefer clear, shallow water of temperatures ranging from 18.9°C to 31.4°C. They are particularly abundant down to 5 fathoms depth, rarely occur below 60 fathoms, and apparently do not flourish on mud bottoms. HENSON noted further that most peneroplids are rare in the actual reef rocks, and where the latter form a distinct fringing reef, the back-reef "Miliolid–Peneroplid biofacies" may be quite sharply limited from the fore-reef "Nummulitic–Orbitoid biofacies". In areas of patchy bioherms, however, this boundary may not be as clearly developed and the peneroplids and miliolids are often scattered through the surrounding calcareous sands derived from reef erosion. Reviewing the environments in which fossil peneroplids occur, HENSON finds that they are not necessarily restricted to the back-reef areas but also inhabit the reef limestones proper and may extend into the fore-reef areas, but doubts if they actually lived there. According to MOORE (1947, pp. 732 and 734), Peneroplidae, i.e. *Peneroplis pertusus*, *Sorites*, *Archaias*, occur in the Florida Keys mainly in the back-reef environment and also, but rarely, in the shallow fore-reef area down to a depth of 102 feet. Peneroplidae and Amphisteginidae, the latter with *Amphistegina* cf. *angulata* CUSHMAN also very frequent in our material, are the dominant Foraminifera in the sediments of the reefal area, and reach their peak abundance on the outer reef patches, that is in the shallow fore-reef area. The great abundance of peneroplids in the shallow-water Florida Bay, where no live forms were found, is interpreted by MOORE as accumulations through sorting or as accumulations from previous geologic time when the environment was such that peneroplids could live in this area. The ecologic results of MOORE are particularly significant because they refer to an area close to Cuba, and as the environments of fossil peneroplids are according to HENSON (1950, p. 21) closely analogous to those favored by Recent species, it may be inferred that the environments of the biohermal and reefal detrital beds of the Husillo formation were probably very similar to those of the Recent reefal and shallow fore-reefal areas along the east coast of Florida, but perhaps with stronger fore-reef influence as indicated by the occasionally abundant lepidocyclinas, miogypsinas, *Heterostegina antillea* CUSHMAN, *Operculinoides* and by the consistent but never dominant occurrence of planktonic microfossils.

Heterostegina, another important genus represented in the Husillo beds, is flourishing in temperatures from about 22°C to 27°C and in depths down to perhaps 40 fathoms (NORTON, 1930, p. 347). COLE (1958, p. 750) found *Heterostegina suborbicularis* D'ORBIGNY in the vicinity of Bikini and the Philippine islands at an average depth of 25 to 52 fathoms. This author (1958, p. 751) comes to the conclusion that "The sediments which contain *Heterostegina*, *Lepidocyclina*, and similar genera probably accumulated at shallower depth [than 70 fathoms]". The best estimate for depth of accumulation of such sediments would be around 25–40 fathoms. This depth interval partly lies within the deeper fore-reef area of the northern Florida Keys.

Operculinoides, a genus recently put by COLE (1959) into synonymy with *Operculina*, occurs virtually throughout the Husillo samples, but is never abundant.

It also occurs with *Operculinoides cojimarensis* (D. K. PALMER) in the Cojímar beds. *Operculina* was found in the vicinity of the Philippine Islands and Bikini from 10 to 1105 fathoms (CUSHMAN, 1921) and from 10 to 410 fathoms (CUSHMAN, TODD, and POST, 1954). The average depth at which *Operculina* was frequent or common is 25 fathoms (Bikini) and 70 fathoms (Philippines). *Operculina* is common in slightly greater average depth than *Heterostegina* and the peneroplids.

Restricted environments are also represented but appear to be the exception for the Husillo formation. A singular oölitic limestone with crab coprolites encountered in the large quarry 1.5 km west-southwest of Santa María del Rosario, is here regarded as deposited under lagoonal bank-type conditions. The fragments of calcareous algae, in particular of *Halimeda* LAMOUROUX, 1812, a tropical Dasycladacea, known from 0 to 80 m depth, which is abundant, occasionally rock-forming in some of the detrital Husillo beds from Tejar Andrade, the Husillo quarry and the quarry near Pogolotti, is suggestive of lagoonal and reefal environments or nearness to these environments. Green algae such as *Caulerpa* and *Halimeda* are according to WELLS (1957, pp. 618 and 623), common on the undersides of overhangs of coral colonies growing in the coral–algal zone, limiting the reefal flat from the seaward slope, and on lagoon reef structures, and TAYLOR (1957, p. 701) reported chiefly *Caulerpa* and *Halimeda* from the deeper water of the lagoons of 4 atolls of the Marshall Islands. TAYLOR described the surface sediment of the lagoon floors to be formed mainly by the segments of *Halimeda*. Abundant segments of *Halimeda opuntia* LAMOUROUX were seen by BRÖNNIMANN in the back-reef area of Boocoo reef, Tobago, British West Indies (BRÖNNIMANN, 1949, p. 182).

The detrital Matansa and Tagpochau limestones from Saipan, Tinian, and Rota referred by HANZAWA (1957, pp. 6, 32 and 33) to biohermal, lagoonal and fore-reefal detrital facies of coral reefs and to shallow submarine banks are lithologically and faunally comparable with our lithologic types (a) and (b). TODD, CLOUD, LOW, and SCHMIDT (1954, p. 677) suggested that the Tagpochau limestone was deposited in water of about 100 m depth. HANZAWA (1957, pp. 54, 55) listed from the Tagpochau limestone *Archaias angulatus* (FICHTEL and MOLL) ?, *Sorites martini* (VERBEEK) and *Marginopora vertebralis* BLAINVILLE. In the Mariana and younger limestones, usually elevated fringing reefs, HANZAWA recorded *Sorites marginalis* (LAMARCK) [=*Sorites orbiculus* (FORSKÅL)] and *Marginopora vertebralis* BLAINVILLE.

As witnessed by the cryptocrystalline to microcrystalline texture in thin sections and the abundant planktonic microfossils, the chalky limestones and chalks of the lithologic types (c) and (d) were deposited under deeper water conditions similar to those which prevailed during Consuelo or Universidad time. The relatively high ratio of planktonic to benthonic Foraminifera suggests a depth range of 500 to 1200 m for these deposits.

From the paleoecological point of view the most striking feature of the type beds of the Husillo formation is the rapid change in space and time from relatively shallow-water, reefal complex to relatively deeper water deposits. These facies changes and the occurrence of conglomeratic beds with angular limestone boulders derived from bioherms, of irregularly shaped isolated or nearly isolated bioherms, and of cross-bedded calcarenites give this formation a lithologically unstable and intricate aspect. It is to be expected that toward the uplift area, the Husillo formation is made up mainly of back-reefal or even littoral deposits, and that in basinal direction it assumes a deeper water character, as for instance in the Cacahual area. Husillo strata may show locally considerable reworking of older elements. This is explained by their transgressive character.

Although megafossils such as corals, mollusks and fragments of echinoderms were seen by the writers in the Husillo beds, apparently none have been described in the literature. It is possible, however, that some of the echinids reported by JACKSON (1922) and by VAUGHAN (1922, p. 112) from Cuban localities, and some of the forms of assumed Oligocene age mentioned by SÁNCHEZ ROIG (1949) may originate from the Husillo formation. Only two Middle Oligocene species, *Clypeaster parvus* MICHELIN and *Clypeaster lanceolatus* COTTEAU have been described by JACKSON (1922, p. 42) from Habana and its vicinity. SÁNCHEZ ROIG (1949, p. 71) refers *Clypeaster lanceolatus* COTTEAU to the Lower Miocene.

Larger benthonic Foraminifera are common. In the conglomeratic Husillo beds of the *Globigerina ciperoensis–Globorotalia opima* zone outcropping near Punta Brava occur *Operculinoides dius* (COLE and PONTON), *Lepidocyclina (Lepidocyclina) giraudi* R. DOUVILLÉ, *Lepidocyclina (Lepidocyclina) waylandvaughani* COLE, *Lepidocyclina (Lepidocyclina) yurnagunensis* CUSHMAN, *Lepidocyclina (Eulepidina) undosa* CUSHMAN, and *Pararotalia mexicana mecatepecensis* (NUTTALL). This assemblage is from COLE's *Lepidocyclina (Lepidocyclina)–Lepidocyclina (Eulepidina)* zone. In the Husillo strata of the *Catapsydrax dissimilis* zone, exposed at the abandoned quarry on the west side of the road from Barreras to Tarará, *Miogypsina bracuensis* VAUGHAN, *Lepidocyclina (Lepidocyclina)* sp., *Heterostegina antillea* CUSHMAN and *Operculinoides* cf. *dius* (COLE and PONTON) were recorded. This assemblage would fall into COLE's *Lepidocyclina (Lepidocyclina)–Miogypsina* zone, which overlies the *Lepidocyclina (Lepidocyclina)–Lepidocyclina (Eulepidina)* zone referred to above. In thin sections from the type Husillo beds, which are biostratigraphically part of the *Globigerinatella insueta* zone, random sections of the following larger Foraminifera were identified (miogypsinas by HANZAWA). The stations are listed from bottom to top:

BR station 852	*Miogypsina* sp.
	Operculinoides sp.
	Lepidocyclina sp. (single fragment only).
BR station 855	*Miogypsina bracuensis* VAUGHAN ?
	Lepidocyclina sp. (single fragment only)
	Heterostegina cf. *antillea* CUSHMAN.
BR station 848	*Miogypsina* sp.
	Heterostegina antillea CUSHMAN.
BR station 943	*Heterostegina antillea* CUSHMAN.
BR station 946	*Miogypsina* sp.

Well preserved assemblages of larger Foraminifera were further encountered in thin sections from the following stations, outside of the Husillo type section:

BR station 583	*Miogypsina hawkinsi* HODSON ? or *Miogypsina bramlettei* ?
	Miogypsina hawkinsi HODSON ?

Miogypsina antillea CUSHMAN
Miogypsina bracuensis VAUGHAN
Miogypsinoides ?
Lepidocyclina (Lepidocyclina) sp.
Operculinoides sp.

BR station 588 *Miogypsina hawkinsi* HODSON ?
Lepidocyclina (Lepidocyclina) sp.
Operculinoides sp.

BR station 606 *Miogypsina bracuensis* VAUGHAN or *Miogypsina antillea* CUSHMAN
Miogypsina antillea CUSHMAN ?
Lepidocyclina (Lepidocyclina) sp.
Operculinoides sp.

BR station 607 *Miogypsina bracuensis* VAUGHAN ?
Miogypsina antillea CUSHMAN ?

BR station 608 *Miogypsina hawkinsi* HODSON ?
Miogypsina antillea CUSHMAN ?
Miogypsina bracuensis VAUGHAN ?
Lepidocyclina (Lepidocyclina) sp.

BR station 778 *Miogypsina* sp.

BR station 889 *Miogypsina bracuensis* VAUGHAN ?
Heterostegina antillea CUSHMAN
Operculinoides sp.

In terms of orbitoidal Foraminifera, the *Miogypsina* assemblages with rare fragments of lepidocyclinas may be from the upper part of COLE's *Lepidocyclina (Lepidocyclina)*–*Miogypsina* zone or from the *Miogypsina* zone considering the possibility of reworking of *Lepidocyclina* fragments, and the assemblages from BR stations 607, 778, 848, 889, 943, and 946 without *Lepidocyclina* may represent the *Miogypsina* zone. *Miogypsina* apparently became extinct at the end of the *Globigerinatella insueta* zone. A few miogypsinas were encountered in the Cojímar formation, but regarded as re-deposited from the Husillo beds, which in places are unconformably overlapped by Cojímar chalks and chalky limestones.

Heterostegina antillea CUSHMAN occurs in most *Miogypsina* assemblages, and the term *Heterostegina* zone, as applied in the Gulf Coast (AKERS and DROOGER, 1957) could also be used in Cuba to designate the interval from the *Lepidocyclina (Lepidocyclina)*–*Miogypsina* zone to the *Miogypsina* zone, or in terms of planktonic Foraminifera, the interval from the *Catapsydrax dissimilis* zone, or perhaps from the *Globorotalia kugleri* zone, to the *Globigerinatella insueta* zone. The range of *Heterostegina israelskyi* GRAVELL and HANNA, which was not encountered in the Husillo strata of the Habana area, but occurs in shallow-water deposits near Central Tinguaro, is not known. The term *Heterostegina* zone as used above therefore refers only to *Heterostegina antillea* CUSHMAN. SACHS (1959, pp. 405–406) arrived from a study of *H. antillea* CUSHMAN from Puerto Rico at the conclusion that *H. israelskyi* GRAVELL and HANNA is a junior synonym of *H. antillea*. From the Cuban material, we had the impression that the two forms can be distinguished in thin sections.

The minute planktonic microfossils are usually destroyed through recrystallization. In the chalky limestone from BR station 946 rare discoasters, thoracospheres and coccoliths were recorded. In the chalky limestones from Cacahual and in the pebbles of Cacahual-type limestone, embedded in the conglomeratic Husillo beds outcropping in Pogolotti quarry, rich discoaster and coccolith assemblages were encountered with the following dominant species

Braarudosphaera bigelowi (GRAN and BRAARUD) (rare)
Coccoliths (common)
Discoaster aster BRAMLETTE and RIEDEL (common)
Discoaster barbadiensis TAN (rare)
Discoaster deflandrei BRAMLETTE and RIEDEL (common)
Discoaster woodringi BRAMLETTE and RIEDEL (common)
Transitional forms between *D. woodringi* BRAMLETTE and RIEDEL and *D. deflandrei* BRAMLETTE and RIEDEL (common)
Thoracosphaera spp. (common).

These assemblages differ from those of the Consuelo formation only by the common occurrence of *Discoaster deflandrei* BRAMLETTE and RIEDEL. The *Globigerinatella insueta*-bearing beds of the Husillo formation are here referred to the *Discoaster deflandrei* zone. BRAMLETTE (in WOODRING, 1958, p. 21) identified the following discoasters and coccolithophores from the Caimito formation of Barro Colorado Island, Canal Zone, Woodring station 54n, which is from the *Globorotalia kugleri* zone:

Discoaster aff. *D. challengeri* BRAMLETTE and RIEDEL (few)
Discoaster deflandrei BRAMLETTE and RIEDEL (common)
Discoaster aff. *D. deflandrei* BRAMLETTE and RIEDEL (some characters intermediate between those of *D. deflandrei* and *D. woodringi*) (common)
Discoaster perplexus BRAMLETTE and RIEDEL (few)
Discoaster woodringi BRAMLETTE and RIEDEL (common)
Thoracosphaera imperforata KAMPTNER (few)
Sphenolithus abies DEFLANDRE (few)
Sphenolithus ? sp. (common)
Coccolithus sp. (common)
Coccolithus cf. *C. leptoporus* (MURRAY and BLACKMAN) (rare)
Coccolithus cf. *C. pelagicus* (WALLICH) (common)
Discolithus sp. (few)
Helicosphaera aff. *H. carteri* KAMPTNER (common)
Rhabdosphaera cf. *R. claviger* (MURRAY and BLACKMAN) (rare)
Unidentified coccoliths, including many having a diameter of 2 to 3 μ.

The discoasters common in this assemblage are the same as in the Cacahual chalky limestone of the *Globigerinatella insueta* zone. It therefore appears that the *Discoaster deflandrei* zone, as proposed above, covers the interval from the *Globo-*

rotalia kugleri to the *Globigerinatella insueta* zone. The larger Foraminifera from the Caimito zone, identified by COLE (in WOODRING, 1958, p. 24) are *Heterostegina antillea* CUSHMAN, *Heterostegina israelskyi* GRAVELL and HANNA, *Operculinoides panamensis* (CUSHMAN), *Lepidocyclina* (*Lepidocyclina*) *canellei* LEMOINE and R. DOUVILLÉ, *Lepidocyclina* (*Lepidocyclina*) *giraudi* R. DOUVILLÉ, *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* CUSHMAN, *Lepidocyclina morganopsis* VAUGHAN, *Lepidocyclina* (*Nephrolepidina*) *vaughani* CUSHMAN, *Miogypsina* (*Miogypsina*) *antillea* (CUSHMAN) and *Miogypsina* (*Miolepidocyclina*) *panamensis* (CUSHMAN). This assemblage would be referrable to COLE's *Lepidocyclina* (*Lepidocyclina*)–*Miogypsina* zone which according to the associated planktonic Foraminifera from Woodring station 54n would also include the *Globorotalia kugleri* zone. It is of interest, that *Heterostegina antillea* CUSHMAN and *Heterostegina israelskyi* GRAVELL and HANNA are associated in the assemblage from WOODRING station 54f, whereas in the Cuban material examined by us, the two forms do not seem to occur together.

The following table shows the tentative correlation between the zones established on discoasters and on planktonic Foraminifera and Cole's zones of orbitoidal Foraminifera, based on the Cuban and Panamanian associations. The *Operculinoides* zone is proposed for the assemblages of larger Foraminifera without miogypsinids overlying the *Miogypsina* zone. It probably can be extended to cover the interval from the *Globorotalia fohsi* zone to the end of the Miocene.

The Husillo formation extends from the *Globigerina ciperoensis–Globorotalia opima* zone, Oligocene, to the *Globigerinatella insueta* zone, Miocene; in terms of

<table>
<tr><th></th><th>Discoasters</th><th>Planktonic Foraminifera</th><th colspan="2">Larger Foraminifera</th><th>Formation</th></tr>
<tr><td rowspan="4">Miocene</td><td>————</td><td>Globorotalia fohsi zone</td><td colspan="2">Operculinoides zone</td><td>Cojímar format.</td></tr>
<tr><td rowspan="3">Discoaster deflandrei zone</td><td>Globigerinatella insueta zone</td><td>Miogypsina zone</td><td rowspan="3">Heterostegina antillea zone</td><td rowspan="3">Husillo formation</td></tr>
<tr><td>Catapsydrax dissimilis zone</td><td rowspan="2">Lepidocyclina (Lepidocyclina)–Miogypsina zone</td></tr>
<tr><td>Globorotalia kugleri zone</td></tr>
<tr><td rowspan="2">Oligocene</td><td rowspan="2">Discoaster woodringi zone</td><td>Globigerina ciperoensis–Globorotalia opima zone</td><td rowspan="2" colspan="2">Lepidocyclina (Lepidocyclina)–Lepidocyclina (Eulepidina) zone</td><td rowspan="2">////////
Consuelo formation</td></tr>
<tr><td>Globigerina ampliapertura zone</td></tr>
</table>

larger Foraminifera from the *Lepidocyclina* (*Lepidocyclina*)–*Lepidocyclina* (*Eulepidina*) to the *Miogypsina* zone; and in terms of discoasters from the *Discoaster woodringi* to the *Discoaster deflandrei* zone.

Cojímar formation

The Cojímar formation is one of the best known lithostratigraphic units of the Habana area. It was proposed by R. H. PALMER (1934, p. 134) for a series of Oligocene (? Miocene) "soft white and tan marls" outcropping at different localities

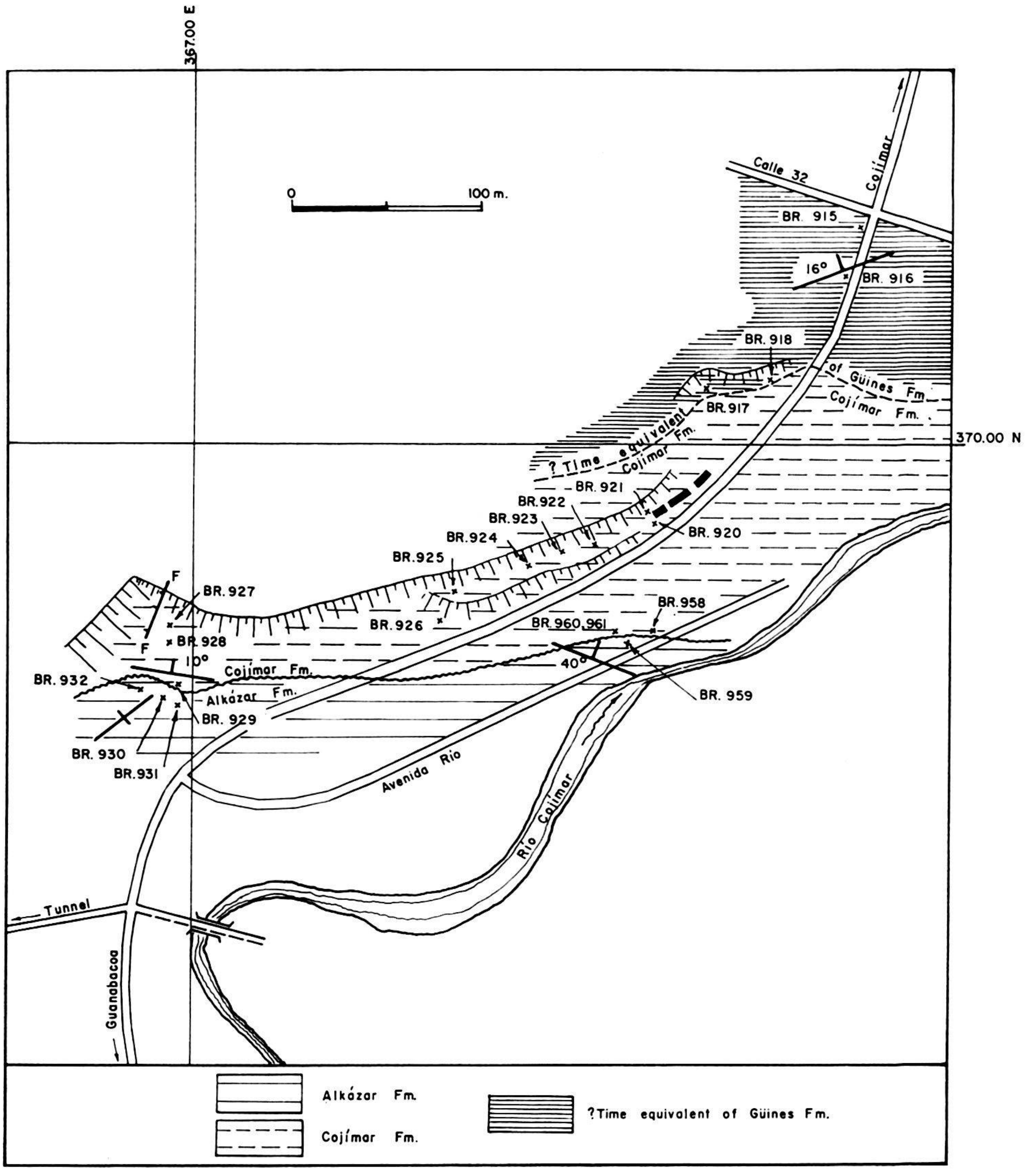


Fig. 73. Index map of the type locality of the Cojímar formation at the road from Guanabacoa to Cojímar.

along the northern rim-rock, especially at the south slope of the hill that extends from Morro Castle at the entrance to the Bahía de la Habana eastward toward the coastal town of Cojímar and beyond. The name of the formation is derived from the Cojímar river which cuts a gorge south of Cojímar between Loma de Urría in the west and Loma San Pedro in the east. In this general area, R. H. PALMER noticed that the Cojímar formation overlies unconformably Upper Cretaceous beds and underlies with transitional contact beds which he assigned to the Güines formation. No figures were given for the thickness of the Cojímar formation. Mrs. D. K. PALMER (1940, p. 19) described the lithology as a soft, light gray to cream marl, and defined as type locality the exposures along the west side of the road from Guanabacoa to Cojímar in the gorge of the Cojímar river, at the south edge of Cojímar about 6.5 km east of La Habana. After a careful analysis of the microfauna, Mrs. PALMER (1940–1941) assigned the Cojímar formation to the Upper Oligocene. The beds were reported to be tectonically so broken that no satisfactory information on thickness and attitude could be obtained. Three kilometers west of the type locality and approximately east of Casa Blanca, Mrs. PALMER found that the Cojímar formation is resting unconformably on the Lower Eocene Universidad formation, and that toward the top it is grading into the assumed Miocene Güines limestone, and is reaching a thickness of 550 feet. There, just east of the Hospital Naval, the Cojímar formation is exposed in a deep road cut. This outcrop is here designated cotype locality of the Cojímar formation.

In the following, revised descriptions are presented of the Cojímar formation as it could be studied at the type locality in the summers of 1958 and 1959 (index map, fig. 73). We did not find it difficult to distinguish the Cojímar lithologies from those of the Universidad and the Consuelo formations, although we admit that this problem might arise in small isolated outcrops (D. K. PALMER, 1940, p. 25). The base of the formation is exposed in the west–southwestern corner of the type section. Here the Cojímar beds are dipping 10° to the N 10° E and are unconformable on almost vertical southwest striking beds of the locally somewhat siliceous Alkázar formation. In the top beds of the Lower Eocene occur bore holes made by lithophagic organisms filled with limonitic granular Cojímar material. Above this distinct angular unconformity are about 30 to 35 m of typical Cojímar beds. They consist of alternating harder and softer chalky beds, predominantly yellowish orange and yellowish gray to whitish, occasionally with fine irregular limonitic striae, which were noticed also in other outcrops of the Cojímar formation and therefore seem to be one of its characteristic features. There are also some calcarenites and fragmental, porous and chalky limestones. The stratification is poor and in general no distinct bedding planes exist. The beds are somewhat thinner and better defined in the lower half of the formation. The boundaries between harder and softer beds are nowhere clearly defined. The harder beds often show a thinning–thickening aspect probably caused by differential compaction during diagenesis. Certain chalky beds have a granular surface due to the abundance of fragments of pelecypods, echinoderms, algae and Foraminifera, especially tests of globigerinids. Toward the top of the type section, the beds appear to be less fossiliferous than at the bottom. The planktonic microfossils are generally badly preserved and coated with country rock. For this reason, *Orbulina suturalis* BRÖNNIMANN and *Orbulina*

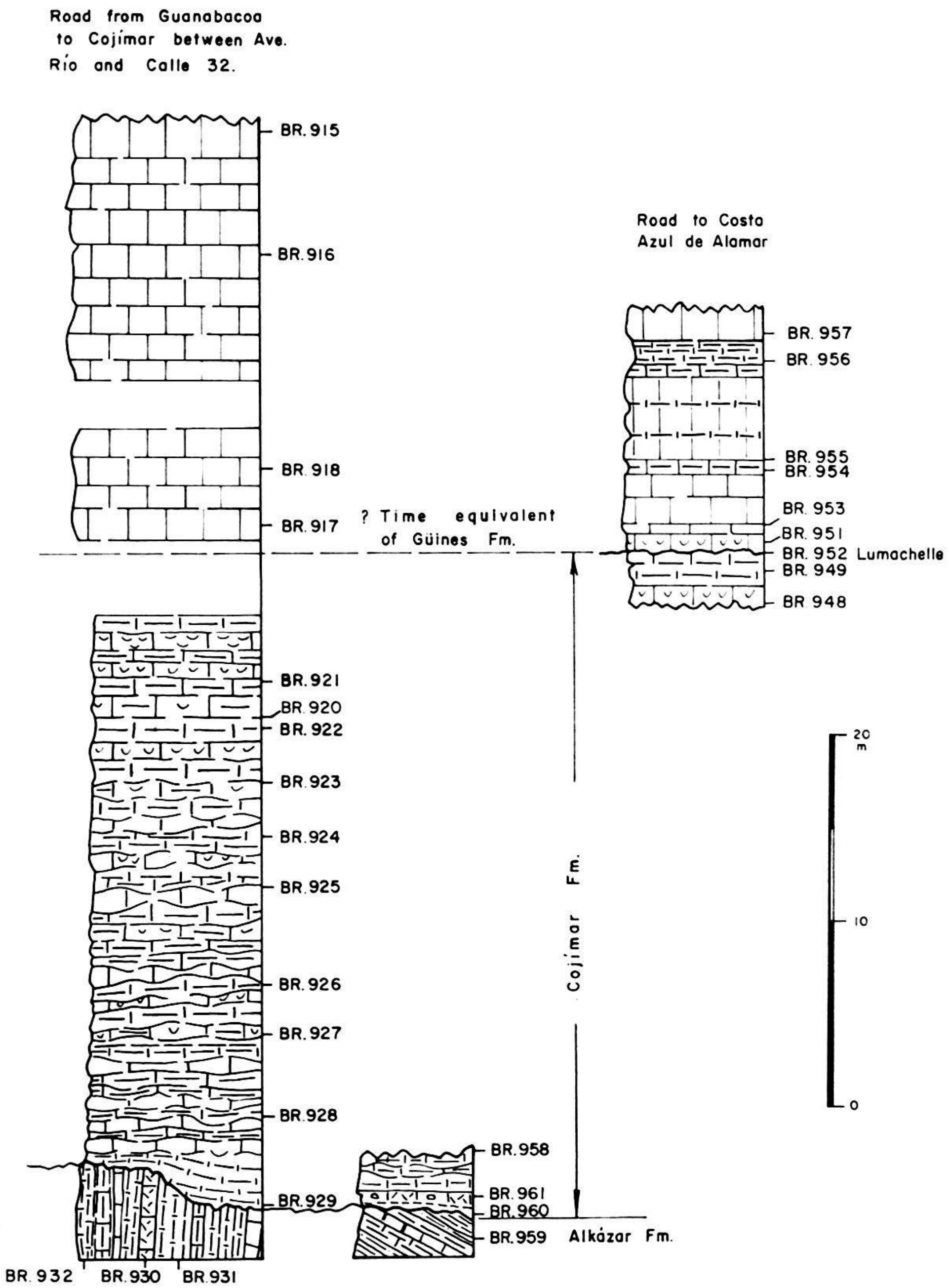


Fig. 74. Columnar sections of the type Cojímar formation, and of the contact Cojímar formation— ?equivalent of Güines formation at the road to Costa Azul de Alamar.

universa D'ORBIGNY could occasionally not be distinguished. The beds on top of the type section, where BR stations 915 to 918 are located, are formed by hard massive crystalline limestones which lack softer intercalations, and which either belong already to a new formation possibly a time equivalent of the Güines formation, or are the top beds of the Cojímar formation altered through accumulation of calcite and subsequent recrystallization. The contact between these upper beds and the typical Cojímar beds is not exposed at the type section. At other places it is of distinctly transitional nature. In the upper portion of the type section, the quality of the outcrops is poor and the country rock is masked locally by small patches of light gray Quaternary terrace material of the Cojímar river as represented by BR station 919.

The stratigraphic sequence of the type samples is explained in the columnar section, fig. 74. They are listed from bottom to top from BR stations 920 to 929:

BR stations 930, 931
Described under Alkázar formation.

BR station 929
Lithology: Chalk, indurated, granular, pale yellowish orange.
Washed residue heterogeneous and similar to BR station 961 with

Globoquadrina dehiscens (Chapman, Parr, and Collins)
Globorotalia fohsi barisanensis LeRoy
Globorotalia fohsi fohsi Cushman and Ellisor
Globorotalia mayeri Cushman and Ellisor
Globorotalia scitula (Brady)
Globigerinoides subquadratus Brönnimann
Globigerinoides trilobus (Reuss) group
Globorotaloides variabilis Bolli
Globorotalia obesa Bolli
"*Globigerina*" *juvenilis* Bolli
Orbulina suturalis Brönnimann
Operculinoides cojimarensis Palmer (common)
Globorotalia aequa (Cushman and Renz) } reworked
Pseudohastigerina micra (Cole) } reworked
Pseudoguembelina excolata (Cushman) } reworked

BR station 928
Lithology: Chalk, indurated, powdery, whitish to light grayish yellow.
Washed residue heterogeneous with

Globorotalia fohsi barisanensis LeRoy
Globorotalia fohsi fohsi Cushman and Ellisor
Globorotalia mayeri Cushman and Ellisor
Globorotalia obesa Bolli
Globorotalia praemenardii Cushman and Stainforth
Globorotalia scitula (Brady)
Globigerina foliata Bolli
"*Globigerina*" *juvenilis* Bolli
Globoquadrina dehiscens (Chapman, Parr, and Collins)
Globigerinoides subquadratus Brönnimann
Globigerinoides trilobus (Reuss) group
Orbulina suturalis Brönnimann
Globorotaloides variabilis Bolli
Pseudoguembelina excolata (Cushman) (reworked).

BR station 927
Lithology: Chalk, indurated, powdery, light grayish yellow.

Washed residue with

Orbulina suturalis BRÖNNIMANN
Globorotaloides variabilis BOLLI
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia obesa BOLLI
Globorotalia praemenardii CUSHMAN and STAINFORTH
Globigerinoides trilobus (REUSS) group
Globigerina foliata BLOLI
"*Globigerina*" *juvenilis* BOLLI

BR station 926

Lithology: Chalk, friable, powdery, whitish to light grayish yellow.

Washed residue slightly heterogeneous with

Globigerina foliata BOLLI
"*Globigerina*" *juvenilis* BOLLI
Globigerinoides trilobus (REUSS) group
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia obesa BOLLI
Globorotalia praemenardii CUSHMAN and STAINFORTH
Orbulina bilobata (D'ORBIGNY)
Orbulina suturalis BRÖNNIMANN
Globorotaloides variabilis BOLLI
Upper Cretaceous guembelinids (reworked).

BR station 925

Lithology: Limestone, chalky, friable, light grayish yellow.

Washed residue heterogeneous with

Orbulina suturalis BRÖNNIMANN
Globigerinoides trilobus (REUSS) group
Globorotalia fohsi barisanensis LEROY
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia obesa BOLLI
Globorotalia praemenardii CUSHMAN and STAINFORTH
Globoquadrina altispira (CUSHMAN and JARVIS) group
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globoquadrina venezuelana (HEDBERG)
Globigerina foliata BOLLI
"*Globigerina*" *juvenilis* BOLLI
Globorotaloides variabilis BOLLI
Operculinoides cojimarensis (D. K. PALMER)
Globotruncana stuarti (DE LAPPARENT) (reworked).

BR stations 922, 923 and 924

Lithologies: Chalk, friable, powdery, grayish yellow to yellowish orange, (922, 924); limestone, chalky, whitish to grayish yellow (923).

Washed residues with

Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia obesa BOLLI
Globorotalia praemenardii CUSHMAN and STAINFORTH
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globigerina foliata BOLLI
"*Globigerina*" *juvenilis* BOLLI
Globorotaloides variabilis BOLLI
Globigerinoides trilobus (REUSS) group
Orbulina suturalis BRÖNNIMANN
Sphaeroidinella grimsdalei (KEIJZER).

From BR station 922 W. A. VAN DEN BOLD (letter 21. 3. 1963) identified the following ostracodes of about "Güines" age:

Aurila deformis (REUSS)
Bairdia sp.
Echinocythereis ? *jacksonensis* (HOWE and PYEATT)
Hermanites hutchisoni V. D. BOLD
Loxoconcha antillea V. D. BOLD
Pterygocythereis n. sp.
Quadracythere antillea (V. D. BOLD)

BR stations 920 and 921

Lithologies: Limestone, fragmental, porous, very pale orange.

Textures: Microcrystalline vacuolar groundmass with fragments of algae, mollusks, echinoderms and bryozoas. Common amphisteginas and globigerinas. Nannoplankton destroyed through recrystallization.

Assemblages: *Orbulina suturalis* BRÖNNIMANN
Globigerina spp.
Amphistegina spp.
Meandropsina sp.
Archaias cf. *operculiniformis* HENSON
Acervulina inhaerens SCHULTZE.

The following samples are from the questionable time equivalent of the Güines beds on top of the Cojímar type section. They probably represent a new formation different from the Güines formation.

BR station 918

Lithology: Limestone, hard, yellowish gray.

Texture: Microcrystalline groundmass with some fragments of echinoderms, algae and mollusks. Most microfossils destroyed through recrystallization.

BR stations 916 and 917
Lithologies: Limestone, hard, porous, whitish to yellowish gray, in part limonitic (916), chalky, porous, white (917).
Textures: Cryptocrystalline to microcrystalline groundmass, in part vacuolar, with abundant and rather large fragments of algae, echinoderms, encrusting Foraminifera, bryozoas, and mollusks. Common amphisteginas and some globigerinas.

Assemblages:
- *Orbulina suturalis* Brönnimann
- *Globigerina* spp.
- *Acervulina inhaerens* Schultze
- *Gypsina globulus* Reuss
- *Sporadotrema cylindricum* (Carter)
- *Amphistegina* spp.
- *Meandropsina* sp.
- *Planorbulina mediterranensis* d'Orbigny.

BR station 915
Lithology: Limestone, hard, porous, whitish to light yellowish gray.
Texture: Cryptocrystalline to microcrystalline groundmass, in part vacuolar, with fragments of algae, mollusks, encrusting Foraminifera, bryozoas and echinoderms. Common amphisteginas and globigerinas. The minute planktonic forms destroyed through recrystallization.

Assemblage:
- *Orbulina suturalis* Brönnimann
- *Globigerina* spp.
- *Amphistegina* spp.
- *Acervulina inhaerens* Schultze
- *Planorbulina mediterranensis* d'Orbigny
- *Sporadotrema* sp.

BR station 919 (Quaternary terrace)
Lithology: Limestone, in places vacuolar, light gray.
Texture: Recrystallized calcite. Barren.

The pronounced angular unconformity between Cojímar and Lower Eocene beds is perfectly exposed at the bottom of the western flank of the Cojímar gorge along Avenida Río (index map, fig. 73; photographs of contact, figs. 29, 30). There, the yellowish in places silicified arenaceous Lower Eocene beds, BR station 959, are truncated by Cojímar beds. The basal Cojímar bed is an indurated calcarenaceous layer composed of organic fragments (BR station 960). It contains some igneous grains and is directly overlain by a softer sandy and conglomeratic chalk with some angular to subangular chert pebbles with reworked faunal elements of Lower Eocene and Upper Cretaceous age, BR station 961, and this by a thin, shaley lumachelle formed by fragments of pelecypods. Pectens, similar to *Lyropecten* (*Nodipecten*) *articulosus* (Cooke) were noticed in this bed. Mrs. Palmer (1940, p. 23) reported *Miogypsina* sp. from the basal strata of the Cojímar formation about 1 km east of Casa Blanca, and well preserved specimens of *Globotruncana* from 9 different localities of the Cojímar formation. These forms are unquestionably allochthonous (D. K. Palmer, 1940–1941, pp. 288–291). We also recorded globotruncanas and guembelinids in addition to keeled, truncate globorotalias in the type samples of the Cojímar formation, which in this general area transgresses on the Vía Blanca, Alkázar, Universidad and Husillo formations. Then follow the typical Cojímar lithologies as described above with abundant small rounded and irregular knolls of encrusting algae and fragments of pelecypods. BR station 958 is from this algal bed, about 3.5 m above the unconformity.

BR station 959 (Alkázar formation)

Lithology: Chalk, indurated, powdery, granular appearance, yellowish orange.
Washed residue heterogeneous with abundant Lower Eocene Radiolaria mixed by contamination from the overlying Cojímar beds with

Orbulina suturalis BRÖNNIMANN
Globoquadrina altispira (CUSHMAN and JARVIS)
Globoquadrina venezuelana (HEDBERG)
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Sphaeroidinella grimsdalei (KEIJZER)
Globotruncana cf. *arca* (CUSHMAN) (reworked).

BR station 960

Lithology: Calcarenite, whitish to yellowish gray, with rare igneous grains.
Texture: Microcrystalline vacuolar groundmass with rather densely packed fragments of algae, echinoderms, bryozoas, encrusting Foraminifera, and mollusks. Abundant benthonic Foraminifera, in particular amphisteginas. Also some globigerinids.

Assemblage:
Amphistegina spp.
Gypsina globulus REUSS
Acervulina inhaerens SCHULTZE
Archaias sp. (fragments only)
Planorbulina mediterranensis D'ORBIGNY
Globotruncana lapparenti BROTZEN group (reworked)
Globorotalia sp. (truncate form) (reworked)
Lepidocyclina sp. (fragment) (reworked)

BR station 961

This assemblage shows strong reworking of Upper Cretaceous planktonic Foraminifera.

Lithology: Calcarenite, friable, pale yellowish orange.

Washed residue heterogeneous with

Globorotalia fohsi barisanensis LEROY
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globigerinoides trilobus (REUSS) group
Orbulina universa D'ORBIGNY
Globoquadrina altispira (CUSHMAN and JARVIS)
Sphaeroidinella grimsdalei (KEIJZER)
Globorotaloides variabilis BOLLI

Globorotalia spinuloinflata (BANDY)
Globorotalia sp. (truncate form)
Catapsydrax stainforthi BOLLI, Loeblich, and TAPPAN
Globotruncanella havanensis (VOORWIJK)
Globotruncana linneiana (D'ORBIGNY)
Pseudotextularia elegans (RZEHAK)
} reworked

BR station 958
Lithology: Limestone, fragmental, porous, with large algal remains, pale yellowish orange.
Texture: Cryptocrystalline to microcrystalline vacuolar groundmass with fragments of algae, encrusting Foraminifera, echinoderms, bryozoas and mollusks, common amphisteginas and some globigerinas. Algae and encrusting Foraminifera make up about 50 % of the area of the thin section.

Assemblage: *Sporadotrema* sp.
Amphistegina cf. *angulata* CUSHMAN
Acervulina inhaerens SCHULTZE
Globigerina spp.

Washed residue heterogeneous with
Orbulina suturalis BRÖNNIMANN
Globoquadrina altispira (CUSHMAN and JARVIS)
Globorotaloides variabilis BOLLI
Globorotalia fohsi barisanensis LEROY
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia obesa BOLLI
Globorotalia mayeri CUSHMAN and ELLISOR
Globigerinoides trilobus (REUSS) group
Chiloguembelina cubensis (D. K. PALMER)
Globigerina ciperoensis angustiumbilicata BOLLI
Globorotalia cf. *wilcoxensis* CUSHMAN and PONTON
Globorotalia aequa CUSHMAN and RENZ
Rugoglobigerina rugosa (PLUMMER)
} reworked

Contact Cojímar formation—(?)time equivalent of the Güines formation in the Cojímar–Alamar area

Typical Cojímar beds are exposed at cuts of the road from Avenida Monumental along the southern slope of the gorge of Río Cojímar on the north flank of Loma San Pedro toward the Reparto Costa Azul de Alamar. The younger part of the section which crops out along the culminating portion of the road is formed by massive, hard, cavernous limestone which may be either altered Cojímar chalk or a new formation, ?time equivalent of the Güines formation as exposed in the Vento syncline and in the Güines area. The older part of the section is in typical Cojímar beds directly corresponding with those of the type locality. In these beds we collected large pectens identified by W. P. WOODRING (letter of October 7, 1959) as *Lyropecten* (*Nodipecten*) *articulosus* (COOKE). WOODRING remarks "that the type lot of this species was collected at the "quarry near asylum, near Guajay (Wajay), 15 miles southwest of Habana" (COOKE, 1919, p. 136, pl. 7, figs. 7, 8). *Lyropecten* (*Nodipecten*) *articulosus* is closely related to *L. condylomatus* (DALL) from the late Miocene Chipola formation of Florida. The earliest species of *Lyropecten* appear according to WOODRING "in strata of late Oligocene age in the Canal Zone and in Trinidad. *L. articulosus*, however, is more closely related to *L. condylomatus* than to the late Oligocene forms. On the basis of this one species, it is more probable that the strata near Guajay and near Cojímar are of early Miocene age than that they are late Oligocene. . . ." Near the top of the typical Cojímar lithologies, represented by BR stations 948 and 949, occurs a 1 to 4 cm thick layer of greenish and limonitic clay with abundant flattened tests of pectens and other lamellibranchs. This bed is regarded as a beach lumachelle formed during a brief emergence. It is cutting the underlying beds somewhat irregularly and apparently disconformably. BR station 952 is from this lumachelle. The overlying beds where BR station 951 was taken, may be already the ?time equivalent of the Güines formation. It is a 1 m thick porous light yellowish or orange limestone with numerous mollusk remains, in general very similar to the top Cojímar beds, but somewhat harder. The conspicuous tests of *Operculinoides cojimarensis* (D. K. PALMER) were seen below and above the lumachelle. Above the questionable Güines time equivalent, the formation is a massive, hard crystalline limestone with a few thin interbeds of hard calcareous shale. This contact zone is illustrated by the columnar section, fig. 74, which explains the relative stratigraphic positions of the samples described below.

BR station 957
Lithology: Limestone, fragmental, hard, porous, whitish to grayish yellow.
Texture: As BR stations 951, 953–955.
Assemblage:
Planorbulina mediterranensis D'ORBIGNY
Amphistegina spp.
Sporadotrema cylindricum (CARTER)
Acervulina inhaerens SCHULTZE
Archaias sp.
Meandropsina sp.
Orbulina universa D'ORBIGNY
Globigerina spp.
Miogypsina sp. (reworked).

BR station 956
Lithology: Chalk, friable, powdery, whitish.
Washed residue with
Orbulina universa D'ORBIGNY
Globigerina spp., and
reworked Upper Cretaceous Foraminifera.

BR stations 953, 954, 955

These samples are lithologically and faunally very similar and are therefore summarized in a single description.

Lithologies: Limestone, fragmental, hard (953, 955), chalky (954), whitish to grayish yellow.
Textures: As station 951.
Assemblages: *Planorbulina mediterranensis* D'ORBIGNY
Amphistegina spp.
Acervulina inhaerens SCHULTZE
Operculinoides cojimarensis (D. K. PALMER) (only in 953)
Archaias sp.
Meandropsina sp.
Gypsina globulus REUSS
Orbulina suturalis BRÖNNIMANN
Orbulina universa D'ORBIGNY
Globigerina spp.
Sporadotrema cylindricum (CARTER).

BR station 951
Lithology: Limestone, fragmental, chalky, whitish to light pale yellowish orange.
Texture: Microcrystalline groundmass with minute fragments of mollusks and echinoderms and with larger discrete fragments of algae, corals, bryozoas, encrusting Foraminifera, echinoderms and mollusks. Common amphisteginas and globigerinids.
Assemblage: *Acervulina inhaerens* SCHULTZE
Amphistegina sp.
Orbulina suturalis BRÖNNIMANN
Orbulina universa D'ORBIGNY
Archaias sp.
Meandropsina sp.
Globigerina spp.

BR station 952 (Lumachelle)
Lithology: Chalk, clayey with abundant mollusk fragments, whitish to greenish.
Washed residue with
Globorotalia obesa BOLLI
Globorotalia mayeri CUSHMAN and ELLISOR
Orbulina suturalis BRÖNNIMANN
Globigerina foliata BOLLI
"*Globigerina*" *juvenilis* BOLLI
Globorotaloides variabilis BOLLI
Sphaeroidinella grimsdalei (KEIJZER)
Globigerinoides trilobus (REUSS) group.

BR stations 949 and 950
These two samples are lithologically and faunally almost identical and therefore described together.
Lithologies: Chalk, indurated, powdery, light yellowish orange.
Washed residue with
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR

Orbulina bilobata (D'ORBIGNY)
Orbulina suturalis BRÖNNIMANN
Orbulina universa D'ORBIGNY
Globigerinoides trilobus (REUSS) group
Globorotaloides variabilis BOLLI
Globorotalia obesa BOLLI
Globorotalia praemenardii CUSHMAN and STAINFORTH
Globigerina foliata BOLLI
Globoquadrina altispira (CUSHMAN and JARVIS)
Operculinoides cojimarensis (D. K. PALMER).

BR station 948
Lithology: Chalk, indurated, granular, pale yellowish orange.
Washed residue with
Globorotalia obesa BOLLI
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotaloides variabilis BOLLI
Orbulina universa D'ORBIGNY
Orbulina suturalis BRÖNNIMANN
Globigerinoides trilobus (REUSS) group
Operculinoides cojimarensis (D. K. PALMER).

At Avenida Monumental, just immediately west of the Urría type locality, coordinates 369.94 N and 366.22 E, about 5 m of the questionable time equivalent of the Güines formation are exposed. These strata, represented by BR stations 964 and 965, show the same lithology as at the culmination of the road toward Reparto Costa Azul de Alamar. The actual contact with the underlying Cojímar formation is masked by talus. At this locality, the Cojímar formation is only about 8 m thick, against 30 to 35 m at the type section, and overlies unconformably the Toledo member of the Universidad formation. As at Avenida Río, the basal 2 m of the Cojímar formation contain numerous isolated "nodules" of encrusting algae, BR station 963. The top of the algal bed is a thin pecten lumachelle with a clayey and limonitic matrix indicating a brief period of intraformational emergence.

BR station 963 (Cojímar formation)
Lithology: Limestone, hard, fragmental, granular in appearance, porous, white.
Texture: Cryptocrystalline to microcrystalline groundmass, vacuolar, with abundant small angular fragments of organic origin, in which are embedded discrete large fragments of algae (*Lithophyllum* sp.), encrusting Foraminifera, bryozoas, echinoderms and mollusks. Common amphisteginas and globigerinids and large arenaceous Foraminifera.
Assemblage: *Amphistegina* spp.
Sporadotrema sp.
Acervulina inhaerens SCHULTZE
Orbulina suturalis BRÖNNIMANN
Orbulina universa D'ORBIGNY
Globigerina spp.

BR station 964
Lithology: Limestone, hard, chalky, whitish.
Texture: As BR station 963, but without large algal fragments and with only a few globigerinids.

Assemblage: *Amphistegina* sp.
Acervulina inhaerens SCHULTZE
Sporadotrema sp.
Globigerina spp.

BR station 965
Lithology: Limestone, hard, dense, whitish to yellowish gray, limonitic.
Texture: Microcrystalline groundmass with traces of microfossils.

Other outcrops of the Cojímar formation

Autopista del Mediodía

On the western side of the road cut at the Autopista del Mediodia we measured about 15 to 17 m of Cojímar formation (index map, fig. 45). The unconformable contact between the Toledo member of the Universidad formation and the Cojímar formation has already been described under Universidad formation (see p. 355 of this paper). The Cojímar lithology does not differ essentially from that of the type Cojímar but it lacks the coarser organic fragments which give a granular aspect to some beds and it also lacks the harder shell-bearing beds. As a whole, the color of the formation is lighter than that of the type beds. The very top of the formation is not exposed. In February 1958, a trench showed a conglomerate composed of large angular blocks of Cojímar material, BR station 423B, in a white powdery chalk matrix, BR station 423A, separated only by a small covered gap from the underlying Cojímar formation. The matrix of this conglomerate appears to be already of post-*Globorotalia fohsi* age. The actual contact may be unconformable. The section along the eastern side of the road cut at the Autopista del Mediodía differs from that of the western side by the preservation of the 5 lowest meters of Príncipe member below the Cojímar formation. This contact has previously been described in the chapter on the Universidad formation. Neither the top of the Cojímar formation nor the younger beds can be seen at this locality.

BR station 423A (matrix of conglomerate)
Lithology: Chalk, friable, powdery, white.

Washed residue with
Globigerinoides trilobus (REUSS) group
Orbulina bilobata (D'ORBIGNY)
Orbulina suturalis BRÖNNIMANN
Globigerina foliata BOLLI
Globorotalia mayeri CUSHMAN and ELLISOR.

BR station 423B (components of conglomerate)
Lithology: Chalk, indurated, powdery, white.
Texture: Cryptocrystalline to microcrystalline with planktonic microfossils. Minute microfossils generally destroyed through recrystallization.

Assemblage: *Globigerina* spp.
Orbulina suturalis BRÖNNIMANN
Coccoliths.

Washed residue with
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globigerinoides trilobus (REUSS).

BR station 419
Lithologies: Chalk, grayish yellow.

Washed residues heterogeneous with reworked Lower Eocene Radiolaria and with
Globigerinoides trilobus (REUSS) group
"*Globigerina*" *juvenilis* BOLLI
Globoquadrina altispira (CUSHMAN and JARVIS)
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia obesa BOLLI
Globorotalia mayeri CUSHMAN and ELLISOR
Globigerina soldadoensis BRÖNNIMANN (reworked).

Pebbles of Toledo limestone at the base of the Cojímar chalks collected in BR station 419:
Lithology: Limestone, silicified, laminated, light yellowish brown to yellowish orange.
Texture: Silicified groundmass with abundant Radiolaria.

Assemblage: Radiolaria
Discoaster lodoensis BRAMLETTE and RIEDEL (common)
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN
Thoracosphaera sp.
Coccoliths.

BR stations 420, 421 and 422

Lithologies and microfaunas from these stations are practically identical and therefore reported in a single description.
Lithologies: Limestone, chalky, white.
Textures: Microcrystalline groundmass with planktonic microfossils. The minute components of the planktonic assemblages are destroyed through recrystallization.

Assemblages: *Orbulina bilobata* (D'ORBIGNY)
Orbulina suturalis BRÖNNIMANN
Orbulina universa (D'ORBIGNY)
Globigerina spp.

Washed residue with
Globigerinoides subquadratus BRÖNNIMANN
Globigerinoides trilobus (REUSS) group
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia obesa BOLLI

Globorotalia praemenardii CUSHMAN and STAINFORTH
Globigerina foliata BOLLI
Orbulina suturalis BRÖNNIMANN
Orbulina universa D'ORBIGNY
Globoquadrina altispira (CUSHMAN and JARVIS).

BR station 546
Lithology: Chalk, friable, pale yellowish orange.
Washed residue with
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globigerinoides trilobus (REUSS) group
Orbulina suturalis BRÖNNIMANN
Sphaeroidinella grimsdalei (KEIJZER).

BR stations 547 and 549 (basal Cojímar, western cut)
Lithologies: Limestone, silicified, dark yellowish orange (547 pebble from Toledo member), chalk, friable, light grayish yellow (549).
Texture: Cryptocrystalline to microcrystalline limonitic groundmass with abundant planktonic microfossils (547).
Assemblages: *Globorotalia* spp. (truncate forms)
Globigerina senni (BECKMANN)
Coccoliths (abundant)
Braarudosphaera bigelowi (GRAN and BRAARUD)
Braarudosphaera discula BRAMLETTE and RIEDEL (common)
Discoaster aster BRAMLETTE and RIEDEL
Discoaster barbadiensis TAN
Discoaster lodoensis BRAMLETTE and RIEDEL
Forms intermediate between *D. barbadiensis* and *D. aster*
Thoracosphaera spp.
Washed residue of BR station 549 with
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia fohsi lobata BERMÚDEZ
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia praemenardii CUSHMAN and STAINFORTH
Globorotalia obesa BOLLI
Globigerinoides trilobus (REUSS) group
Orbulina universa D'ORBIGNY
Orbulina bilobata (D'ORBIGNY)
Sphaeroidinella grimsdalei (KEIJZER)
Globoquadrina altispira (CUSHMAN and JARVIS)
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS).

BR station 455 (top Universidad, eastern cut)
Lithology: Limestone, hard, pale yellowish orange.
Texture: Cryptocrystalline to microcrystalline groundmass with abundant planktonic microfossils.

Assemblage: *Globigerinatheka barri* BRÖNNIMANN
Truncorotaloides topilensis (CUSHMAN)
Globigerapsis sp.
Globigerina senni (BECKMANN)
Coccoliths
Tremalithus eopelagicus BRAMLETTE and RIEDEL
Braarudosphaera discula BRAMLETTE and RIEDEL (abundant)
Discoaster barbadiensis TAN (common)
Micrantholithus cf. *M. vesper* DEFLANDRE (rare)
Thoracosphaera sp.
Intermediate forms between *D. aster* and *D. barbadiensis*.

The absence of *D. lodoensis* suggests a late Middle Eocene age for this assemblage.

New reparto in former quarry northwest of Pogolotti, Marianao

Between Calzada Real and coordinates 362.52 N and 355.20 E, the Cojímar formation is exposed over a distance of more than 200 m along a northwest trending cliff. The beds dip from 8° to 16° to the northwest. The total thickness is 40 to 45 m. The basal beds are more indurated than the younger ones, which show the typical Cojímar lithology, in particular the fine irregular orange striae. But, as at the cut at the Autopista del Mediodia, the coarser granular beds are lacking. The contacts with the underlying Husillo formation and the overlying (?)time equivalent of the Güines formation are not exposed. The samples from the cliffs listed below are from bottom to top:

Northeastern portion of cliff

BR stations 904 (bottom) and 905

The samples from these stations are lithologically and faunally virtually identical and therefore recorded in a single description.

Lithologies: Limestone, fragmental to calcarenaceous, pale yellowish orange to yellowish gray.

Textures: Cryptocrystalline to microcrystalline groundmass, dense to vacuolar, with fragments of mollusks, echinoderms, algae, encrusting Foraminifera and bryozoas. Common amphisteginas and globigerinids.

Assemblages: *Orbulina suturalis* BRÖNNIMANN
Orbulina universa D'ORBIGNY
Globoquadrina cf. *dehiscens* (CHAPMAN, PARR, and COLLINS)
Globigerina spp.
Amphistegina spp.
Operculinoides cojimarensis (D. K. PALMER)
Archaias sp.
Meandropsina sp.
Acervulina inhaerens SCHULTZE
Gypsina globulus REUSS
Planorbulina mediterranensis D'ORBIGNY
Miogypsina sp. (fragment, reworked)
Sporadotrema sp.

Washed residue (905) with

Globigerinoides trilobus (Reuss) group
Orbulina suturalis Brönnimann
Orbulina universa d'Orbigny
Globoquadrina altispira (Cushman and Jarvis)
Globorotalia obesa Bolli
Amphistegina spp.
Operculinoides cojimarensis (D. K. Palmer).

BR station 906
Lithology: Limestone, fragmental to calcarenaceous, yellowish gray.
Texture: Microcrystalline groundmass, vacuolar, with densely packed minute fragments of mainly echinoderms, mollusks and algae. Also larger fragments of echinoderms, and algae. Common amphisteginas, and some globigerinids.

Assemblage:
Amphistegina spp.
Archaias sp.
Acervulina inhaerens Schultze
Orbulina universa d'Orbigny
Sporadotrema sp.
Globigerina spp.

Southwestern portion of cliff

BR station 909
Lithology: Chalk, indurated, with yellowish orange striae. Whitish, to very pale orange overall color.
Washed residue with

Globorotalia fohsi fohsi Cushman and Ellisor
Globorotalia fohsi barisanensis LeRoy
Globorotalia mayeri Cushman and Ellisor
Globorotalia obesa Bolli
Globorotalia scitula (Brady)
Globigerinoides trilobus (Reuss) group
Orbulina suturalis Brönnimann
Orbulina universa d'Orbigny

BR stations 907 (top) and 908

These samples are lithologically and faunally similar and therefore described together.
Lithologies: Limestone, chalky, whitish (907), chalk, friable, powdery (908).
Textures: Microcrystalline, extremely vacuolar groundmass with irregularly distributed organic derived minute fragments and planktonic Foraminifera.

Assemblages:
Orbulina suturalis Brönnimann
Orbulina universa d'Orbigny
Globigerina spp.

Washed residues with

Orbulina bilobata (d'Orbigny)
Orbulina suturalis Brönnimann

Orbulina universa D'ORBIGNY
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia fohsi lobata BERMÚDEZ
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia obesa BOLLI
Globorotaloides variabilis BOLLI
Globigerina foliata BOLLI
"*Globigerina*" *juvenilis* BOLLI
Globoquadrina altispira (CUSHMAN and JARVIS)
Globoquadrina dehiscens (CHAPMAN, PARR, and COLLINS)
Globigerinoides subquadratus BRÖNNIMANN
Globigerinoides trilobus (REUSS) group
Globigerinoides mitra TODD
Sphaeroidinella grimsdalei (KEIJZER)

Tejar Andrade

The geographic location of Tejar Andrade, Marianao, has been explained under Husillo formation. Reference is made to the index map, fig. 71, and to the cross sections, fig. 72. The quarry is divided in two sections by Arroyo Bañabuey. In the southeastern section, only pre-Cojímar formations are exposed. In the northwestern section of the quarry, reduced outcrops of the Príncipe member of the Universidad formation are found (BR station 858). Reefal limestones of the Husillo formation overlie also at this locality unconformably the Universidad formation (BR station 859). Husillo bioherms form the central part of this portion of the quarry. In the northeastern section of the quarry, very hard, massive reefal limestones, documented by BR stations 862, 909A, 911, 913, are at the base of the exposed section which is normally overlain by typical Cojímar beds (BR stations 860, 861, 910, 912, 914). The surface on top of the reefs is smooth and hard and apparently represents the original surface. The reefal limestones are also here attributed to the Husillo formation. The contact between the Husillo reefs and the Cojímar formation is very irregular. Apparently the growth of the reefs was interrupted by a sudden subsidence which initiated over this area the relatively deeper water conditions of Cojímar time. This interpretation of the contact is supported by the lack of limonitic residues at the top of the bioherms. The Cojímar formation is typically developed but, as at the Autopista del Mediodía and the Reparto northwest of Pogolotti, Marianao, it lacks the granular beds.

The following samples from the Cojímar formation were taken at random:

BR stations 860 and 861

They are lithologically and faunally very similar and therefore described together.

Lithologies: Chalk, friable, powdery, granular, very pale orange to pale yellowish orange (860), chalk, white (861).

Washed residues with

Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia obesa BOLLI

Globorotalia praemenardii CUSHMAN and STAINFORTH
Orbulina bilobata (D'ORBIGNY)
Orbulina suturalis BRÖNNIMANN
Orbulina universa D'ORBIGNY
Globigerinoides trilobus (REUSS) group.

BR stations 910 and 912

These samples are faunally and lithologically practically identical and therefore reported together.

Lithologies: Chalk, friable, powdery, whitish.

Washed residue with

Operculinoides cojimarensis (D. K. PALMER)
Globoquadrina altispira (CUSHMAN and JARVIS)
Globigerinoides trilobus (REUSS) group
Globorotalia fohsi fohsi CUSHMAN and ELLISOR
Globorotalia mayeri CUSHMAN and ELLISOR
Globorotalia obesa BOLLI
Orbulina suturalis BRÖNNIMANN
Orbulina universa D'ORBIGNY
Globigerina foliata BOLLI.

BR station 914

Lithology: Chalk, friable, powdery, white.

Washed residue with

Globorotalia mayeri CUSHMAN and ELLISOR
Globigerinoides trilobus (REUSS) group
Orbulina sp.
Globorotalia fohsi fohsi CUSHMAN and ELLISOR.

Environment and age

At the type section of the Cojímar formation and at Loma Urría and Loma San Pedro, we observed the following principal lithologies, arranged below in order of significance.

a) Chalks and chalky limestones

Thin sections of the indurated chalks or chalky limestones show a microcrystalline groundmass with common to abundant planktonic Foraminifera. The minute planktonic microfossils such as discoasters and coccoliths are usually destroyed through recrystallization. The friable powdery chalks contain rich *Globigerina–Globorotalia* faunas. Associated with the planktonic assemblages we encountered occasionally *Operculinoides cojimarensis* (D. K. PALMER).

Environment: Relatively deep water.

b) Fragmental limestones

The next common lithology of the Cojímar type section are fragmental limestones. They appear mainly toward the top of the formation. In thin sections, the groundmass of these limestones is cryptocrystalline to microcrystalline with

abundant and usually rather densely packed minute subangular to angular, organic derived fragments. The minute fragments and the cryptocrystalline to microcrystalline groundmass are so finely mixed that a secondary groundmass is formed in which are embedded larger and isolated fragments of algae, encrusting and other benthonic Foraminifera, echinoderms, mollusks and bryozoas and whole tests of benthonic Foraminifera, in particular amphisteginas. Planktonic Foraminifera are common. The nannoplankton seems to be destroyed through recrystallization.
Environment: Intermediate between reefal complex and deeper water.

c) Calcarenites

Calcarenites are a minor lithologic constituent of the basal portion of the type section. Exceptionally they also occur interbedded with the above described fragmental limestones of type (b). The groundmass of the calcarenites is microcrystalline, vacuolar, with more or less densely packed comminuted fragments of algae, echinoderms, bryozoas, mollusks and encrusting and other benthonic Foraminifera. Algae and encrusting Foraminifera are occasionally the dominant components. Whole tests of amphisteginas and other rotaliids are common. *Operculinoides cojimarensis* (D. K. PALMER) was noticed. Peneroplids such as *Archaias* cf. *operculiniformis* HENSON and *Meandropsina* sp. are usually present as fragments. Planktonic Foraminifera are scarce. As in the chalks and chalky limestones of type (a) the minute planktonic microfossils, if originally present, appear to be destroyed through recrystallization.
Environment: Reefal complex.

Two of the above described lithologic types, i.e. chalks and chalky limestones (a) and calcarenites (c), are very similar to those reported from the Husillo formation and suggest similar depositional environments. The calcarenites of the Cojímar formation are derived from a reef and probably were deposited in the fore-reefal area. No isolated bioherms were encountered in the Cojímar beds. The fragmental limestones of lithologic type (b) with the abundant minute organic components and the larger discrete organic inclusions, occasionally with many planktonic Foraminifera, are believed to have been formed in an intermediate area between deeper water and reefal complex. These limestones differ from the fragmental limestones of the Husillo formation, which are, at least in part, of biohermal origin. The limestones following on top of the Cojímar type section and referred to the questionable time equivalent of the Güines formation are fragmental limestones of the type (b). They are well developed in the Alamar section, from BR station 951 at the base to BR station 957 at the top, and they differ considerably from the Güines formation as developed in the south of the Habana area which is clearly a back-reef deposit. They contain *Operculinoides cojimarensis* (D. K. PALMER) and *Cuneolinella cojimarensis* (D. K. PALMER, 1940–1941, pp. 26, 122). The lumachelle at BR station 952 is interpreted as having been formed during a brief emergence. The chalks and chalky limestones with the common to abundant planktonic Foraminifera of the lithologic type (a) were laid down under relatively deeper water conditions, similar to the chalks interbedded in the Husillo type section. In the washed residues from the chalky beds of the Cojímar type section, it was found that the ratio of planktonic and benthonic Foraminifera decreases from the bottom to the top of the section from about 50 to 90 % in BR stations 929 and 961, to about 50 % in BR stations 924, 928, and to about 40 % and less in BR stations 920 to 922. Applying the results of GRIMSDALE and VAN MORKHOVEN (1955), the estimated depth of the chalky sediments of the Cojímar beds is interpreted to decrease during geological time from about 600 to 1200 m for BR stations 929 and 961, near the base of the formation, to about 600 m for the stations with an approximate ratio of planktonic and benthonic forms of about 50 %, and to about 100 to 600 m, or less, for the stations near the top of the formation. The fragmental limestones and the lumachelle referred to the questionable time equivalent of the Güines formation, overlying in the Cojímar–Alamar area the Cojímar formation, would also be relatively shallow-water deposits, close to a reefal complex as indicated by the combination of planktonic and benthonic microfossils and reefal derived material. In contrast to the Husillo beds as exposed in the Husillo quarry, the facies of the Cojímar formation does not change rapidly from deeper to shallow-water conditions and back to deeper water, but gradually from deeper to shallower water. The older Cojímar chalks are the last deep water deposits in the stratigraphic sequence of the Habana area, and as such comparable with the chalks of the Universidad and Punta Brava formations. The post-Cojímar beds of the Habana area, represented by the questionable time equivalent of the Güines limestones in the Cojímar–Alamar area, by the restricted shallow-water limestones and dolomites of the Güines formation sensu stricto, by the marls of the Rosario formation with oysters and peneroplids of late Miocene age, by the reefal Vedado and Morro formations, by the Pleistocene Biltmore shell bed, and finally by the cross-bedded calcarenites of the Pleistocene Casa Blanca, Jaimanitas and Santa Fé formations, all indicate distinctly very shallow marine environments.

Mrs. PALMER (1940–1941, pp. 22–27) published a table with the percentages of species of each foraminiferal family found in the Cojímar formation and compared them with those compiled by NORTON (1930) for the Recent foraminiferal fauna of the Caribbean sea. Although the percentages of the Cojímar fauna correspond fairly well with Norton's zone from 500 to 825 fathoms, Mrs. PALMER concluded after a discussion of the depth ranges of *Gypsina discus* (GOËS), *Gypsina globulus* REUSS, *Orbulina bilobata* (D'ORBIGNY), *Amphistegina*, *Sporadotrema* and *Sorites* that the probable depth of the Cojímar sea was approximately 200 fathoms. In order of magnitude this result does not conflict strongly with our depth estimate of about 600 m for the middle and major portion of the type section based on the method developed by GRIMSDALE and VAN MORKHOVEN.

Reworking of older faunal and lithologic elements is conspicuous in the lower Cojímar beds. Usually one finds Upper Cretaceous and Eocene planktonic Foraminifera and occasionally even some igneous grains, probably derived from the clastics of the Habana group. This is explained by the overlap of the Cojímar beds in the type area on the Upper Cretaceous Vía Blanca formation and on the Lower Eocene Alkázar and Universidad formations.

Not much has been published on the megafossils of the Cojímar formation, although well-preserved specimens of lamellibranchs, corals, echinids and algae were noticed in the type Cojímar beds.

The following echinids were described by SÁNCHEZ ROIG (1949) from beds outcropping in the Cojímar and Marianao areas and assigned by this author to the Upper Oligocene. Only those forms are here listed, which in our opinion are most probably from the Cojímar formation. Of 17 species cited 14 are from Finca La Noria, located on the south side of the Loma San Pedro which is wholly in Cojímar beds. Those indicated by * are indigenous to Cuba.

Antillaster elegans JACKSON, Finca La Noria, Cojímar
**Amblypneustes corrali* LAMBERT and SÁNCHEZ ROIG, Finca La Noria, Cojímar
**Aplolampas* sp., Finca La Noria, Cojímar
Agassizia clevei COTTEAU, Finca La Noria, Cojímar
**Neopasagus sanchezi* (LAMBERT), Finca La Noria, Cojímar
Brissoma antillarum COTTEAU, Finca La Noria, Cojímar
**Brissoma habanensis* SÁNCHEZ ROIG, Río Cojímar and quarries at the entrance of Cojímar
**Echinolampas cojimarensis* SÁNCHEZ ROIG, Finca La Noria, Cojímar
Echinolampas anguillae COTTEAU, Finca La Noria, Cojímar
**Hebertia jacksoni* LAMBERT, Finca La Noria, Cojímar
**Leiocidaris cojimarensis* LAMBERT and SÁNCHEZ ROIG, Finca La Noria, Cojímar
**Pericosmus roigi* LAMBERT, Estación de Ceiba, F. C. de Marianao
**Progonolampas sanchezi* LAMBERT, Finca La Noria, Cojímar
**Schizaster habanensis* SÁNCHEZ ROIG, Asilo Nacional de Ancianos, Casa Blanca
**Schizaster cojimarensis* SÁNCHEZ ROIG, Finca La Noria, Cojímar
Schizobrisus antillarum COTTEAU, Finca La Noria, Cojímar
Schizobrisus clevei COTTEAU, Finca La Noria, Cojímar

We do not know of any other records of megafossils from the Cojímar formation of the Habana area. The large pecten identified by WOODRING as *Lyropecten (Nodipecten) articulosus* (COOKE) is from the Cojímar beds of the north cliff of Loma San Pedro. The type of this species was collected by BARNUM BROWN and is from disintegrated limestones encountered in a quarry near "asylum near Guajay [=Wajay], 15 miles southwest of Habana." There are many quarries in the general area between the highway to Rancho Boyeros and the village of Wajay and it is almost impossible to locate Barnum Brown's outcrop with any degree of certainty. The same is true with the other fossil localities listed by COOKE (1919, p. 109) in the vicinity of Habana as:

Vento, Province of Habana, with *Cyprea* sp., *Pecten ventonensis* COOKE n. sp., *Teredo* sp., *Panope* sp., *Metis trinitaria* DALL, and *Lucina* sp.

Calabazar, Province of Habana, with *Scaphander* sp., *Cassidea sulcifera* (SOWERBY) ?, *Cypracea* sp., *Lucania* sp.

Near E.C.A. ?, Cuba (within 10 miles of Habana) with *Malea camura* GUPPY and *Lucina* sp.

Quarry near asylum near Guajay, 15 miles southwest of Habana, with *Ostrea haitensis* SOWERBY, *Pecten decorus* COOKE, n. sp. and *Pecten articulosus* COOKE, n. sp. COOKE regarded the small collections from Calabazar and Wajay to be probably of Oligocene age, and the one from "Near E.C.A." may be somewhat younger than the others, although the evidence is inconclusive. SÁNCHEZ ROIG (1949, p. 246) recorded *Ostrea haitensis* SOWERBY from a cut at the railroad from Habana to Marianao, Estación de Ceiba. This is the same locality from which this author described *Pericosmus roigi* LAMBERT.

As pointed out earlier, discoasters and coccoliths so common in the older Tertiary appear to be destroyed through recrystallization in all of the Cojímar samples examined by us. The planktonic Foraminifera, however, indicate that the Cojímar formation is part of the *Globorotalia fohsi* zone which overlies the *Globigerinatella insueta* zone and underlies the *Globorotalia mayeri* zone. Not all of the subzones of the *Globorotalia fohsi* zone were recognized. The type section of the Cojímar formation is within the *Globorotalia fohsi fohsi* subzone, and only three samples, one from the Cojímar beds at the road cut at the Autopista del Mediodía, BR station 549, and the others from the Marianao area, BR stations 907 and 908, are from the younger *Globorotalia fohsi lobata* subzone. The *Globorotalia fohsi robusta* subzone, the youngest of the subzones of the *Globorotalia fohsi* zone was not recognized, either because it is not represented, or because, and from the field evidence this seems to be more probable, a distinct facies change occurs from the chalky deeper water beds to the hard fragmental limestones of relatively shallow-water character from which globorotalias either could not be isolated or where they are practically absent. In terms of larger Foraminifera, the Cojímar formation is part of the *Operculinoides* zone, which is extended from the *Globorotalia fohsi* zone to the end of the Miocene.

TECTONICS OF THE HABANA AREA

The over 80 km long east–west trending Habana–Matanzas uplift or anticlinorium plunges near Matanzas axially eastward into the sea. Southwest of Habana it sharply turns toward the west-southwest and also shows a distinct axial plunge. Pre-Capdevila beds are not exposed between the highway from Habana to Rancho Boyeros and the Guanajay–Mariel uplift immediately to the west of the mapped area. Approximately halfway between Habana and Matanzas, in the vicinity of Central Hershey, a northwest trending saddle filled with Oligocene and younger sediments covers the steeply folded and broken core of the anticlinorium. This saddle is possibly caused by a fault trend in older sediments.

To the south of the Habana anticlinorium lies the also east–west trending relatively flat Vento syncline with beds of Miocene and ?younger age. Farther south follows the Bejucal uplift with a core of steeply folded Lower Eocene beds, probably Apolo, Alkàzar and Capdevila formations. Between the Bejucal uplift and the Caribbean sea to the south, the Miocene to younger beds are gently dipping southward. The flattening of the dips in the southernmost exposures of this area is suggestive of a third apparently less pronounced east–west trending uplift located off-shore.

The northern rim-rock od the Habana anticlinorium

The entrance to the Bahía de la Habana is dividing the northern rim-rock into two segments. The west-southwestern segment, made up mainly of post-Capdevila beds, dips throughout Vedado and Marianao toward the northwest, and toward the north-northwest in the vicinity of Arroyo Arenas and Punta Brava. The dips range from 5° to 25° with average values of 10° to 11°. There is only one major tectonic feature disturbing the western segment of the northern rim-rock, that is the about N 10° E trending fault which is followed in part by the Río Almendares. This fault is probably of the wrench type, with a relative displacement of the eastern side toward the north-northeast. Very likely the fault was active during different geological periods. The segment of the northern rim-rock east of the entrance to the Bahía de la Habana is dipping in general to the north, with dips ranging from 5° to 34°. The average value of the dips is about 18°. Formations of post-Vía Blanca and pre-Cojímar age are only locally preserved. Some minor tectonic accidents occurred in the eastern segment such as the small east-southeast trending anticline cut by the road just east of the Hospital Naval, where the cotype locality of the Cojímar formation is exposed.

As suggested by R. H. PALMER (1934), it seems very probable that the steep cliff along the northeast side of the entrance to the Bahía de la Habana corresponds to a northwest trending fault. Morphologic expressions of a fault were encountered during the construction of the tunnel across the Bahía de la Habana (personal communication by Ing. J. F. DE ALBEAR). Such a fault would explain the differences of both stratigraphic and structural character between the western and the eastern side of the entrance to the Bahía de la Habana.

The southern rim-rock of the Habana anticlinorium

From Punta Brava to the highway from Habana to Rancho Boyeros, the southern rim-rock is dipping 5° to 12° toward the south. Farther east between Arroyo Naranjo and the Carretera Central, the inclinations of the dips are similar, their azimuths however are directed toward the south-southeast. South of Santa María del Rosario, the dips are virtually identical with those between Punta Brava and the highway from Habana to Rancho Boyeros. The post-Capdevila to pre-Güines beds are by far not as well preserved as in the northern rim-rock. The Universidad formation is known to us only by a single outcrop in the quarry about 1.5 km west-southwest of Santa María del Rosario. The Cojímar formation is missing. The Husillo formation, on the other hand, is rather well but not continuously developed along the southern rim-rock.

The core of the Habana anticlinorium

As shown by the interpretive geological map (plate II) and the cross sections I to IV (fig. 75), the core of the Habana anticlinorium is sharply contrasting with the rim-rock by its steep and often overturned beds and by its numerous faults. The strikes of most of the beds are in east–west direction.

The axial plunge of the anticlinorium toward the west is reflected by the successive disappearance in that direction of the serpentinites, which within the studied area do not outcrop west of the Bahía de la Habana, and of the pre-Vía Blanca, Vía Blanca, Peñalver, Apolo and Alkázar formations. West of Alta Habana–Los Pinos, the oldest exposed beds belong to the Capdevila formation. A few kilometres west of the here described area, the anticlinorium is higher again as witnessed by the occurrence of Upper Cretaceous beds, probably pertaining to the Peñalver and Vía Blanca formations. Because of the scarcity of good outcrops not much can be said about the actual tectonic conditions below the Capdevila formation. Water wells drilled in 1913 on the grounds of Cervecería La Tropical, Puentes Grandes, Marianao, coordinates 364.60 N and 355.30 E, are reported to have reached "serpentinite" at the shallow depth of about 60 feet (DEGOLYER, 1918, p. 138). In a general way it appears safe to state that the tectonic pattern of the covered core must be very similar to that of the deeper exposed core east of La Habana. The structurally highest portion of the anticlinorium is the Regla–Guanabacoa–Bacuranao serpentinite body. South of the Regla–Guanabacoa–Bacuranao uplift, the folds have generally vertical or overturned northern flanks. The dips at the south flanks of the folds range from about 50° to 60°. North of the uplift, the southern flanks of the folds are steeper than to the south and often overturned as can be seen in the detailed geological map of the rim-rock between Casa Blanca and Cojímar (plate III).

The core of the Habana–Matanzas anticlinorium is characterized by a sequence of very incompetent beds. It displays similarities with many areas of flow tectonics as for instance with the Préalpes Médianes Plastiques and the Ubaye–Embrunnais nappes of the Swiss and French Alps, and with the Basle–Argovian Jura of northern Switzerland. In all these regions we are dealing with a sedimentary sequence folded and displaced on some very plastic layers, as for instance the shales and evaporites of Triassic age on which the Jura Mountains were folded, and which are resting in their turn on a relatively undisturbed substratum. In the Habana area, where the displacement through a gliding or plastic flow mechanism was directed to the north, no evidence was found for low-angle thrusts with large horizontal displacement. According to W. H. BUCHER (personal communication) the mode of folding as expressed by the Peñalver formation (fig. 75) implies that a major gliding plane must exist at a depth of approximately 500 m deeper than the bases of the synclinal folds of the Peñalver formation. One of the writers (D. R., 1961) has expressed the opinion that this gliding plane is separating highly disturbed sediments and serpentinites from non-disturbed peridotites of the mantle. Some authors suggested that the central Cuban structure is the result of the superposition of several low-angle thrust sheets, at the base of which serpentinites are found (BRÖNNIMANN and PARDO, 1956; WASSALL, 1956). In our opinion, however, the only regions of Cuba where large-scale low-angle thrust sheets are clearly developed are the Organos Mountains of Pinar del Río Province, southwest of a line connecting La Palma and San Diego de Los Baños, with Jurassic to Lowermost Eocene rocks forming magnificent thrust sheets displaced to the north or northwest, and the Trinidad–Sancti Spiritus mountains, where metamorphics of yet unknown age are folded into large, probably northward displaced nappes (RIGASSI, 1961, pp. 3–7). For such movements as those which produced the steep folds of the core of the Habana anticlinorium, the term "rheogenetic movements" has been proposed.

Age of deformation

In the Habana area, the lower and upper time limits of the gliding or plastic flow phase can be traced as follows:

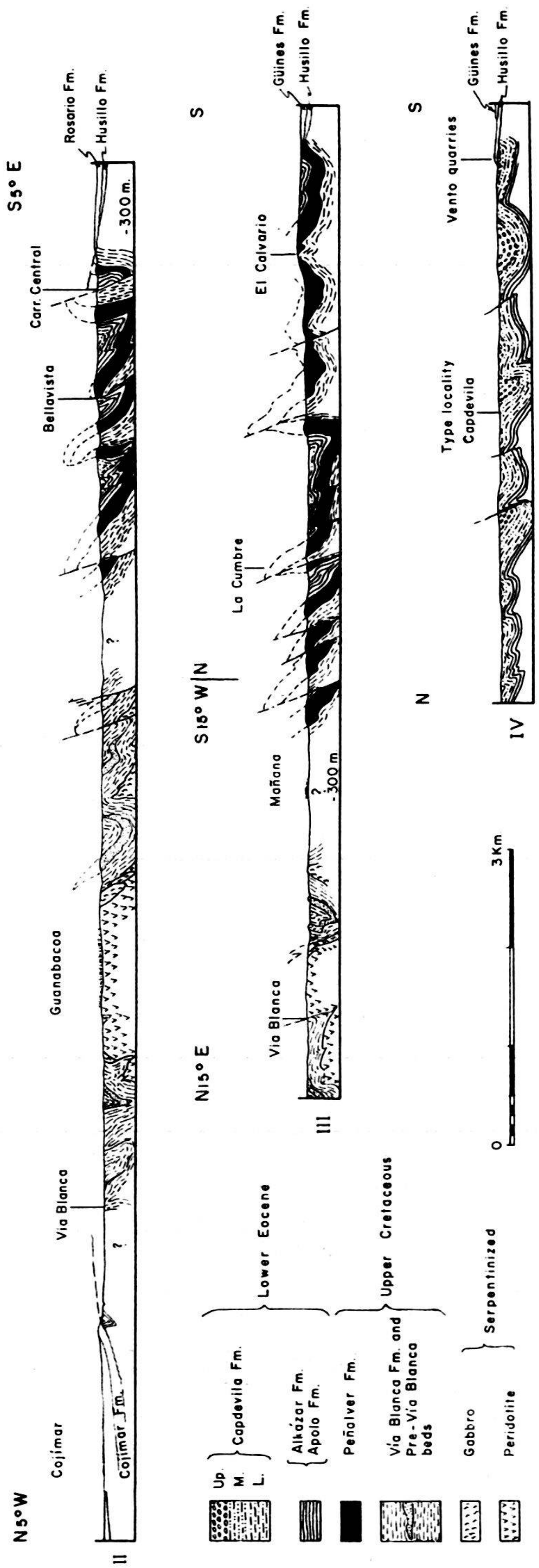


Fig. 75. Cross sections I to IV, Habana area.

The beginning of the flysch-type deposition represents also the beginning of tectonical instability in the source areas. The pre-Vía Blanca beds are not yet adequately known in order to decide whether or not they have all the characteristics of a flysch series. The Vía Blanca sedimentation, on the other hand, is definitely of flysch-type. The age of the oldest Vía Blanca beds is Campanian and their clastics were probably mostly of southern origin. The Universidad formation, the base of which is late Lower Eocene, was not affected by gliding movements. It is true that some instability persisted throughout the Tertiary as witnessed by slumped beds and numerous disconformities and unconformities, but it appears that the regional tectonical expression of this instability is restricted to gentle folds with dips usually not exceeding 20°. The gliding or rheogenetic movements in the Habana area are thus of mid-Laramid age, with their paroxysmal phase during the late Upper Cretaceous and the early Tertiary (Campanian to Lower Eocene).

Faults

The north-northeast striking faults west of the highway from Habana to Rancho Boyeros are believed to be the attenuated surface expression in beds of Capdevila and younger age of an important wrench fault trend with a relative displacement of the eastern side toward the north-northeast. It is pointed out that this interpretation is based on regional considerations rather than on actual field observations. Physical evidence of faults is rarely seen in this area. Several faults have been clearly identified on aerial photographs in the region between Central Toledo and the highway to Rancho Boyeros, but could not be investigated in the field because of the political situation at the time of our survey. The fault followed by the Río Almendares, east of Marianao, is still seen in post-Cojímar beds. Its last displacement was of late Miocene or younger age. As expressed by the paleogeological map of the Cojímar formation (plate VI), an important movement occurred in post-Cojímar time. The paleogeological study of the Husillo formation (plate V) indicates that there was already in Husillo time a depression along the present fault line. In the vicinity of Loma Príncipe, the dips in the Capdevila formation at the moment of the Universidad transgression were 12° to 19° toward the west-northwest. This could be interpreted as a very early indication of the north-northeast trending wrench faults. Wrench movements apparently occurred over a very long period of time with alternating phases of relative tectonic quietness and of activity. This is the case for many of the wrench faults with which the authors are familiar, such as those in California, the Jura Mountains, the Appennin, and the Near East (Red Sea–Dead Sea–Hatay fault trend).

N 10° W to N 35° W trending faults east of the highway from Habana to Rancho Boyeros are regarded as old faults, because none can be followed into the southern rim-rock, and because the two lips are definitely disymmetric. A good example of this type of fault occurs between coordinates 360.7 N and 368.4 E and coordinates 359.1 N and 368.85 E. These faults must have been active before the end of the mid-Laramid folding, i.e. before late Lower Eocene time. Better exposed faults of similar direction in other Cuban regions, in particular those in the Coliseo area, Matanzas Province, must have originated during the Lower Eocene. They underwent, however, reactivation in younger geological periods.

A third fault trend is directed toward the northwest and the west-northwest. Representative of this fault group are those in the area of Vieja Linda, Los Pinos and Arroyo Apolo, and the hypothetical fault at the entrance of the Bahía de la Habana. These fractures are possibly antithetical faults caused by the north-northeast trending wrench faults.

The folding of the rim-rock

The basal unit of the rim-rock proper, the Universidad formation, is either transgressive on beds ranging in age from the Vía Blanca formation to the Capdevila formation or it is transitional on the Capdevila beds. It never shows the steep dips affecting older formations. The Punta Brava and Consuelo formations are so restricted geographically that they cannot furnish any general idea on the diastrophism which occurred during the time interval from the Universidad formation to the Husillo formation. At the moment of the Consuelo transgression, the dip of the underlying Universidad beds was at Tejar Consuelo, Reparto Cerro, La Cienaga, about 7° toward the south-southwest. The dip in the Punta Brava beds, in the quarry east of Punta Brava was probably 14° to 15° toward the northwest. The paleogeological map of the Husillo formation shows that there was a very weak reactivation of some east–west trending folds after the deposition of the Universidad beds and before the Husillo transgression. The scant information available from the paleogeological map of the Cojímar formation does not afford any significant conclusions on movements during its time of deposition.

Post-Cojímar sediments are of two types, i.e. sediments transgressive on Cojímar beds and involved in later movements, such as the Morro formation, and marine terraces, both above and below sea level, and not visibly affected by later movements. During late Neogene time, the area was gently uplifted and folded in what constitutes the Habana anticline proper of former authors. Possibly compression due to meridian forces reactivated the folds of the core but did not affect the rim-rocks of massive carbonates of the Marianao group. During the Quaternary, there were apparently no measurable tectonic movements in the Habana area, because the above mentioned marine terraces are not tilted and their elevations are continuous. Hence it seems that the occurrence of different levels of marine terraces which may be found on any formation from the Vía Blanca upwards, must be attributed to the effects of the glacial period and not to epeirogenetic movements. These observations are in contrast with those made in other Cuban areas, especially in southern Oriente Province and in the Trinidad Mountains, where the terrace pattern suggests rather strong Recent uplift movements (L. RUTTEN, 1941; DEL CORRAL, 1944). The slumped masses of Peñalver clastics found for instance near coordinates 363.7 N and 371.6 E are believed to have occurred in Recent time.

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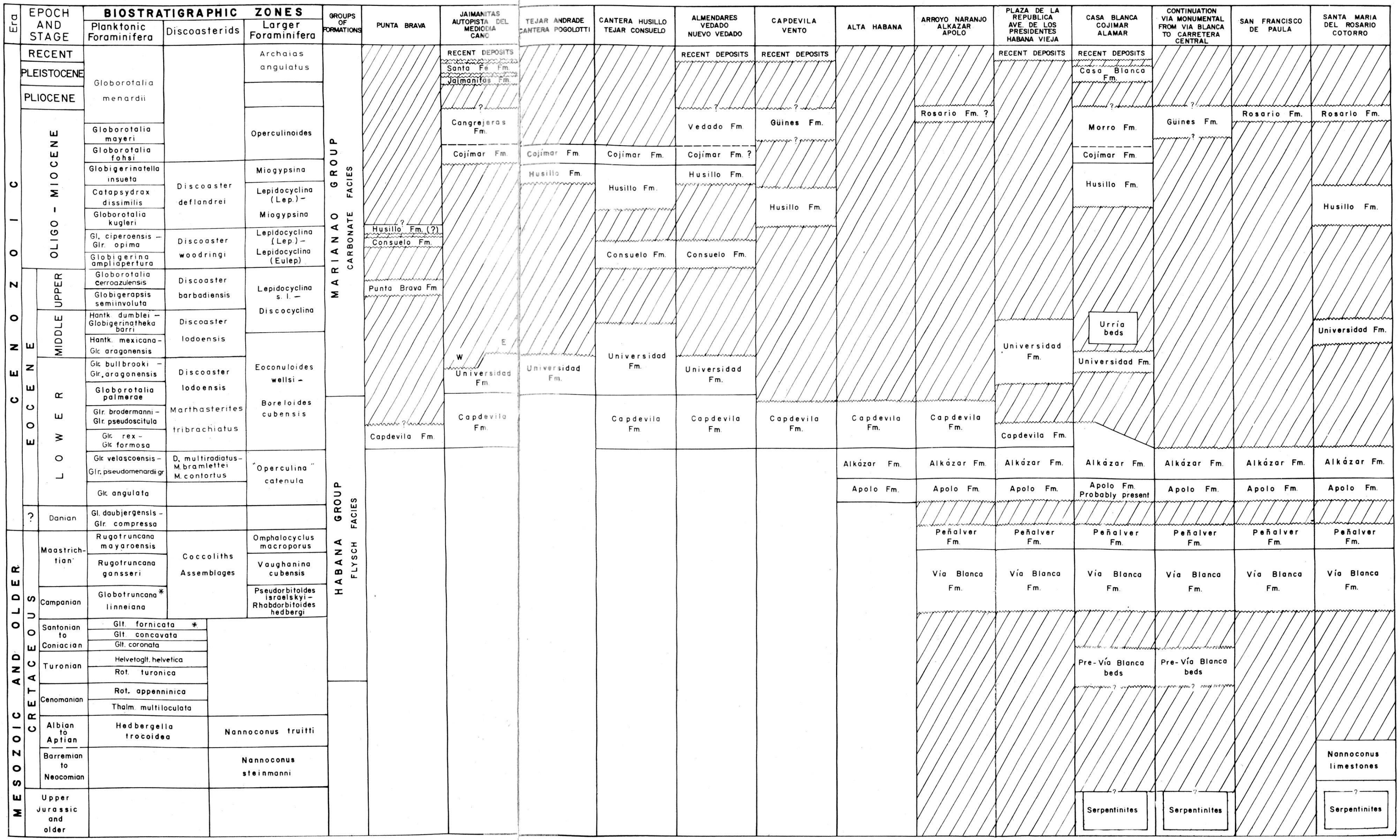
Manuscript received October 30, 1961

Eclogae geologicae Helvetiae,
Vol. 56/1 (1963)

CORRELATION CHART HABANA AREA

P. BRØNNIMANN and D. RIGASSI: Contribution to the Geology and Paleontology of the Area of the City of La Habana, Cuba, and its Surroundings. PLATE I



* Zonation not definitely established

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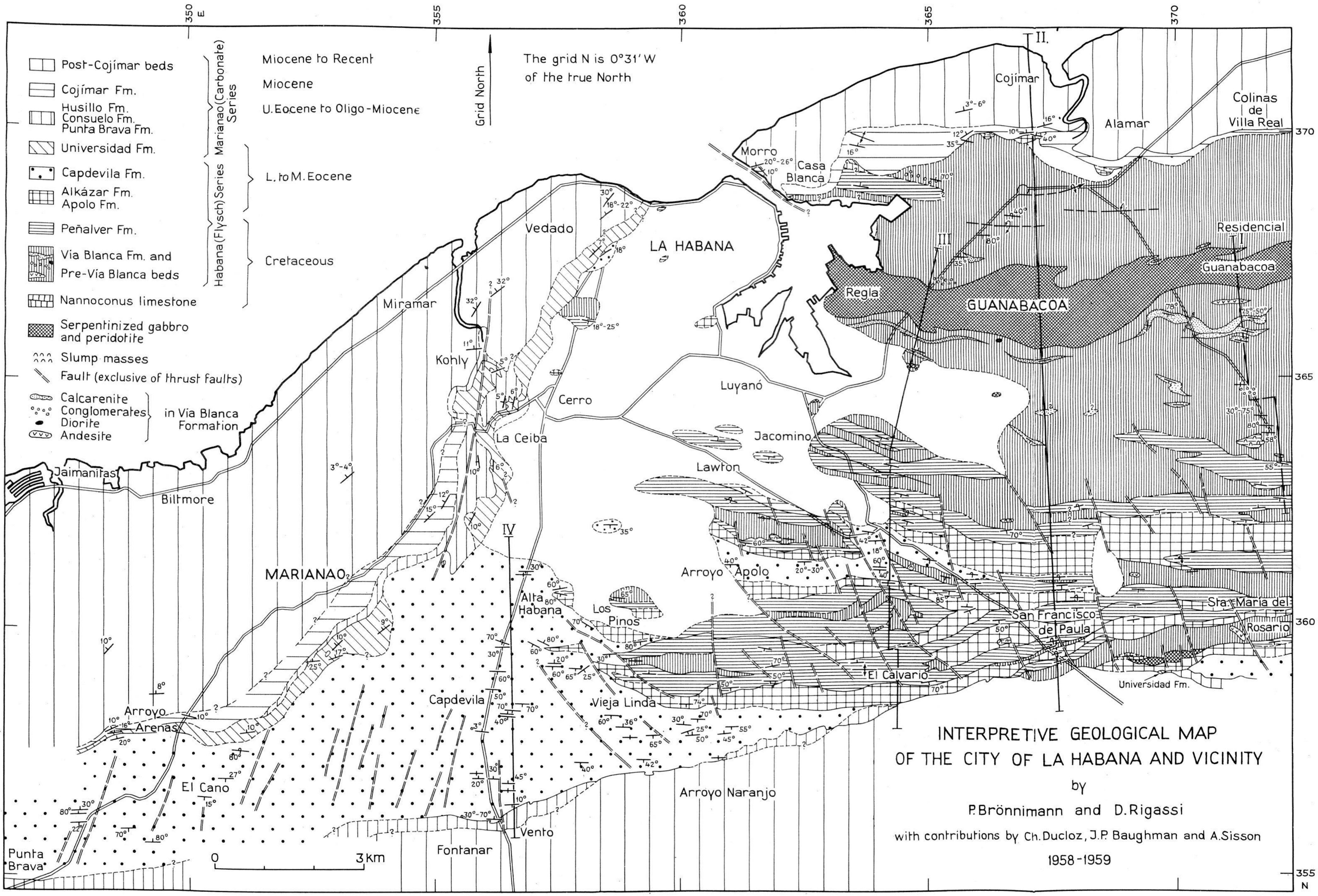

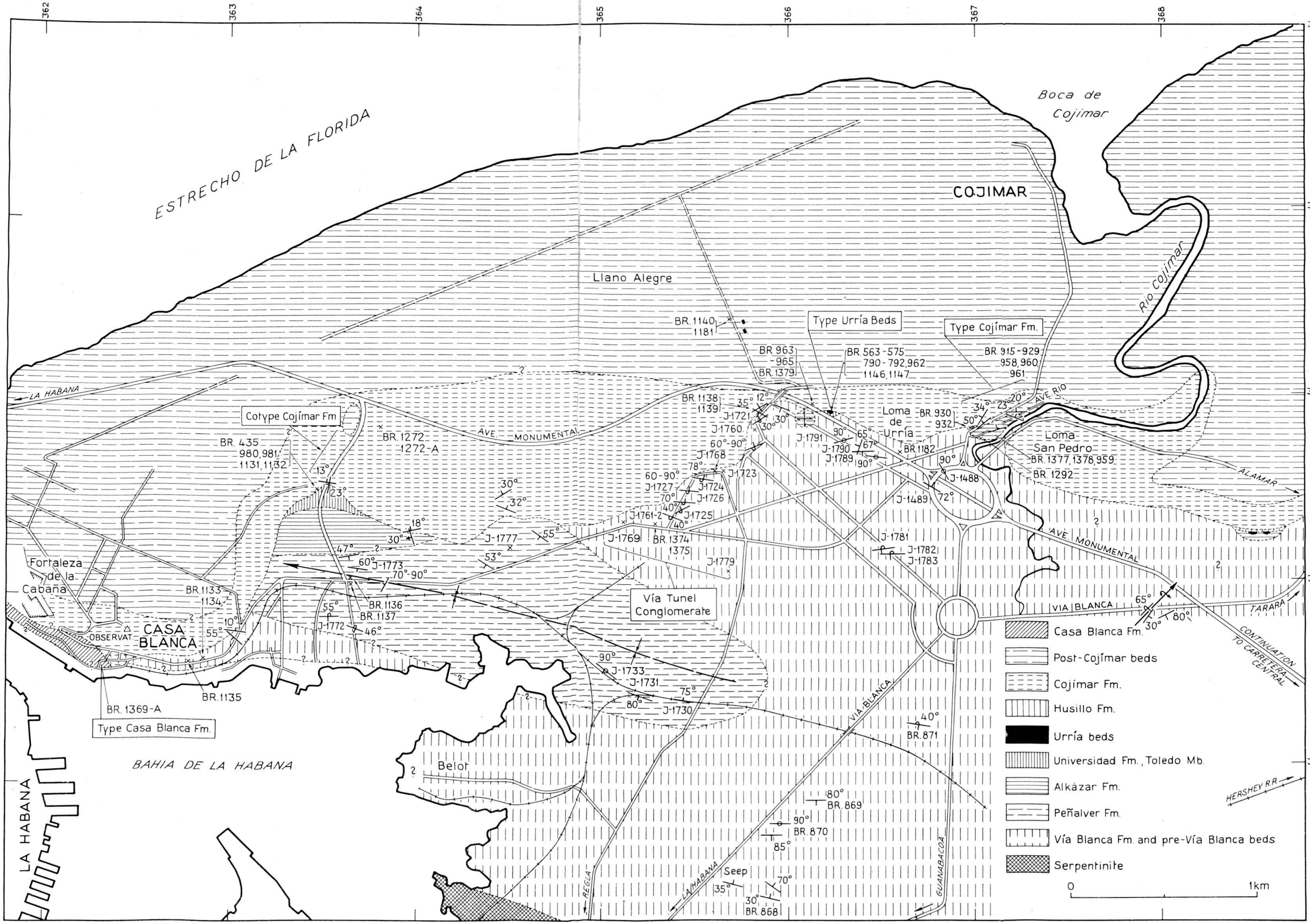
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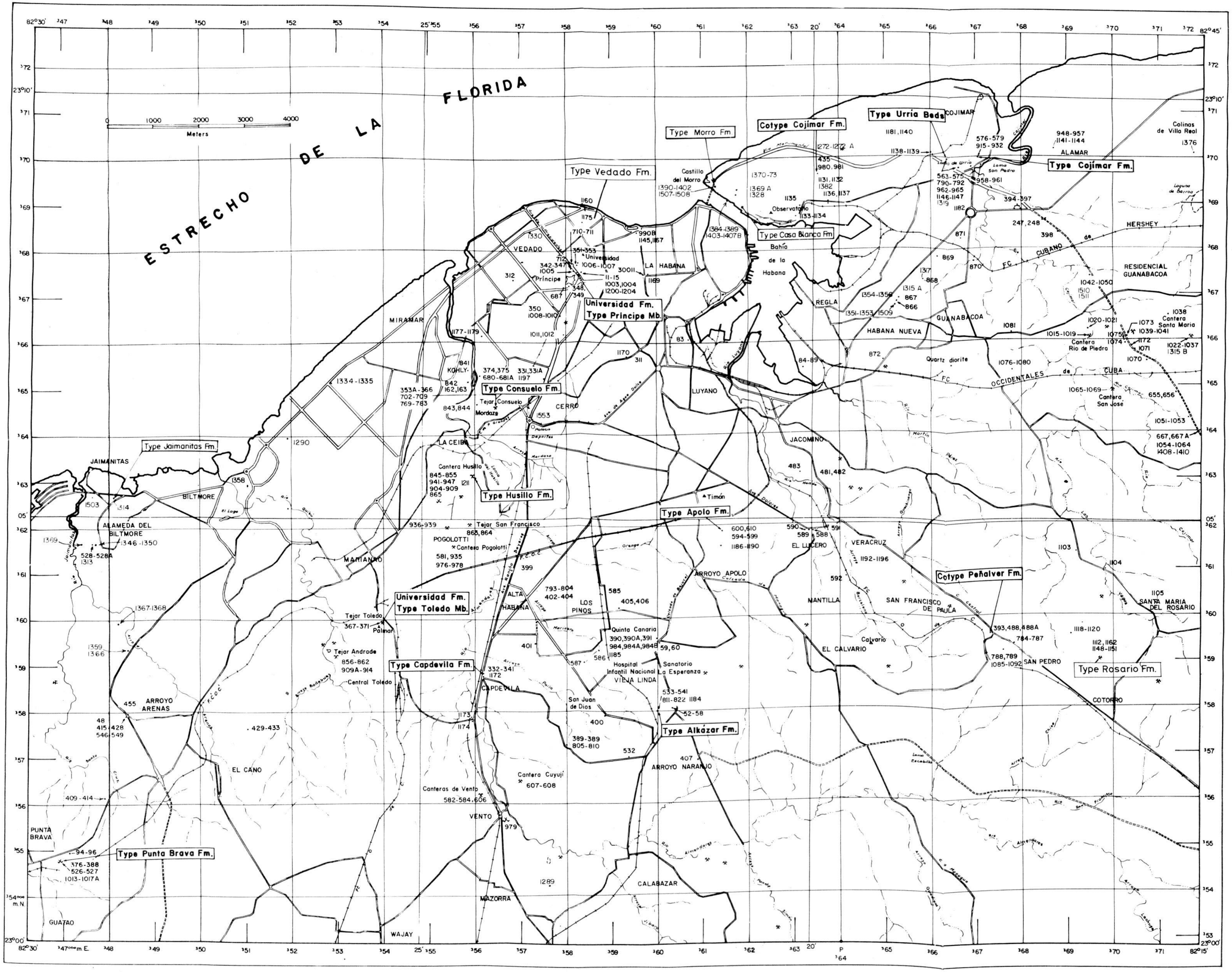
Type Cojímar Fm.
Cotype Cojímar Fm
Loma de Urría
Loma San Pedro
AVE. MONUMENTAL
ALAMAR
AVE. RIO
Fortaleza de la Cabaña
CASA BLANCA
OBSERVAT.
Vía Tunel Conglomerate
Type Casa Blanca Fm.
BAHIA DE LA HABANA
LA HABANA
Belot
VIA BLANCA
TARARA
CONTINUATION TO CARRETERA CENTRAL
HERSHEY R.R.
REGLA
GUANABACOA
Seep
Casa Blanca Fm.
Post-Cojímar beds
Cojimar Fm.
Husillo Fm.
Urría beds
Universidad Fm., Toledo Mb.
Alkázar Fm.
Peñalver Fm.
Vía Blanca Fm. and pre-Vía Blanca beds
Serpentinite
0
1km

 PLATE IV


ESTRECHO DE LA FLORIDA
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Meters
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Type Urria Beds
COJIMAR
Type Cojimar Fm.
Type Vedado Fm.
Castillo del Morro
Type Casa Blanca Fm.
Bahia de la Habana
ALAMAR
HERSHEY
RESIDENCIAL GUANABACOA
Colinas de Villa Real
VEDADO
Universidad
Principe
LA HABANA
Universidad Fm.
Type Principe Mb.
REGLA
HABANA NUEVA
GUANABACOA
MIRAMAR
KOHLY
Type Consuelo Fm.
Tejar Consuelo
Mordazo
CERRO
LUYANO
Quartz diorite
Cantera Rio de Piedra
Cantera Santa Maria
Cantera San José
FC CUBANO
FC OCCIDENTALES DE CUBA
Type Jaimanitas Fm.
JAIMANITAS
LA CEIBA
Cantera Husillo
Type Husillo Fm.
BILTMORE
ALAMEDA DEL BILTMORE
JACOMINO
Timón
Type Apolo Fm.
Tejar San Francisco
POGOLOTTI
Cantera Pogolotti
MARIANAO
VERACRUZ
EL LUCERO
Cotype Peñalver Fm.
ARROYO APOLO
MANTILLA
SAN FRANCISCO DE PAULA
SANTA MARIA DEL ROSARIO
Universidad Fm.
Type Toledo Mb.
Tejar Toledo
Palmar
ALTA HABANA
LOS PINOS
Quinta Canaria
Tejar Andrade
Central Toledo
Type Capdevila Fm.
CAPDEVILA
Hospital Infantil Nacional
Sanatorio La Esperanza
VIEJA LINDA
EL CALVARIO
Calvario
SAN PEDRO
Type Rosario Fm.
COTORRO
ARROYO ARENAS
San Juan de Dios
Type Alkazar Fm.
EL CANO
ARROYO NARANJO
Cantera Cuyují
Canteras de Vento
VENTO
PUNTA BRAVA
Type Punta Brava Fm.
CALABAZAR
MAZORRA
GUATAO
WAJAY
82°30' 82°15' 23°10' 23°00'

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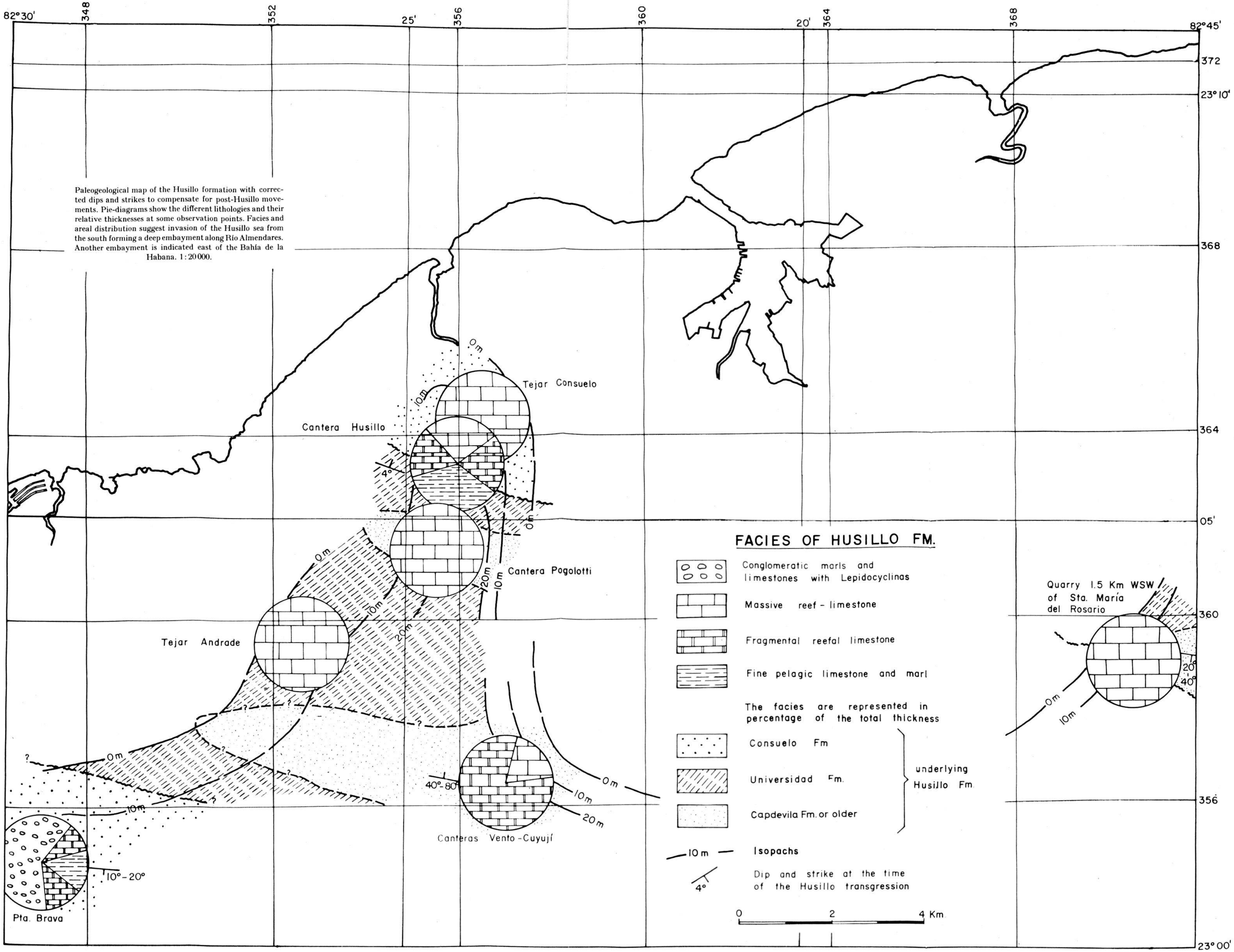
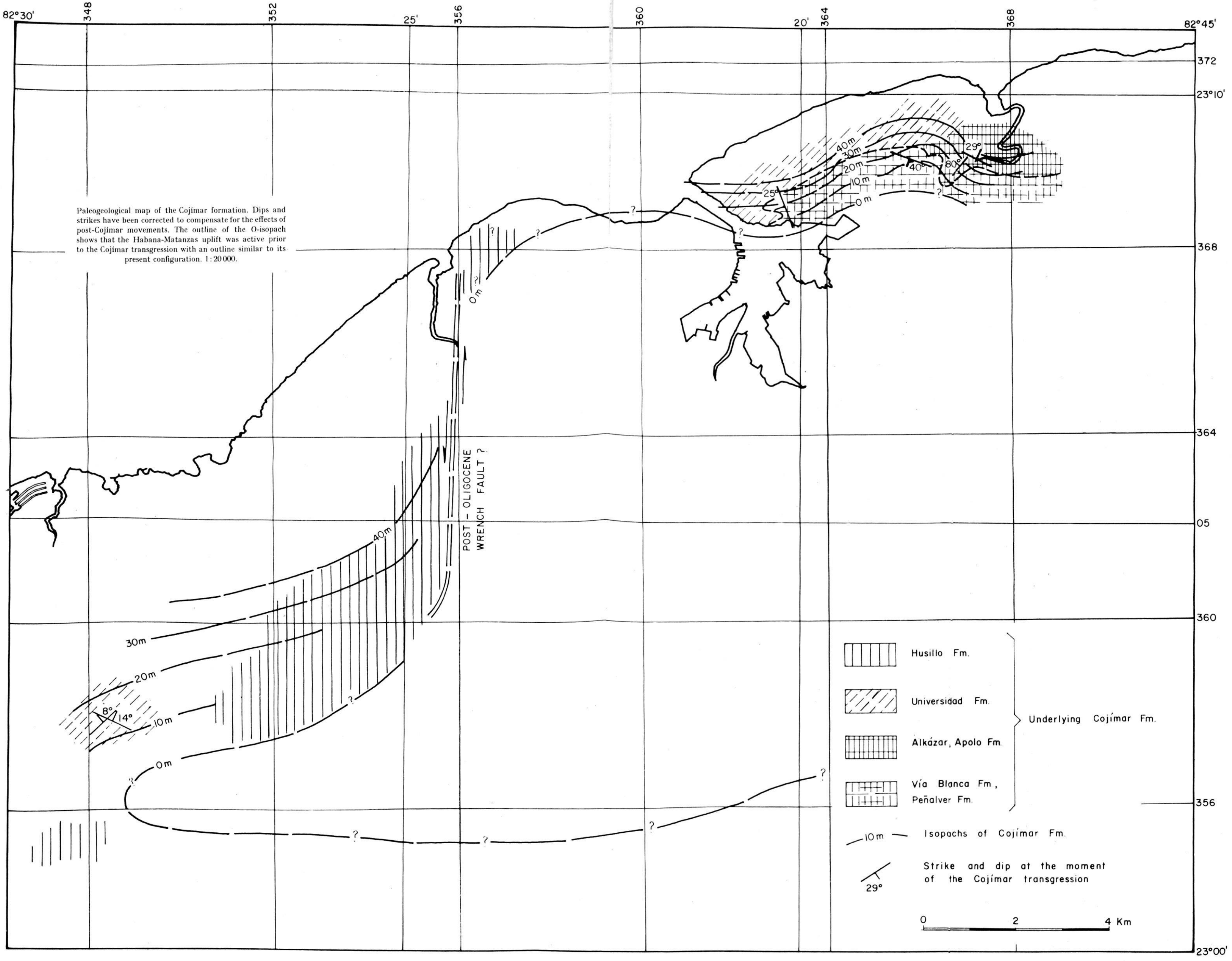


Paleogeological map of the Husillo formation with corrected dips and strikes to compensate for post-Husillo movements. Pie-diagrams show the different lithologies and their relative thicknesses at some observation points. Facies and areal distribution suggest invasion of the Husillo sea from the south forming a deep embayment along Río Almendares. Another embayment is indicated east of the Bahía de la Habana. 1:20000.

P. BRØNNIMANN and D. RIGASSI: Contribution to the Geology and Paleontology of the Area of the City of La Habana, Cuba, and its Surroundings. PLATE VI



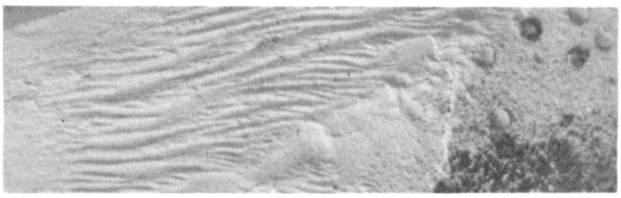
Paleogeological map of the Cojimar formation. Dips and strikes have been corrected to compensate for the effects of post-Cojimar movements. The outline of the O-isopach shows that the Habana-Matanzas uplift was active prior to the Cojimar transgression with an outline similar to its present configuration. 1:20000.

1

2

3

4



5

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Plate VIII

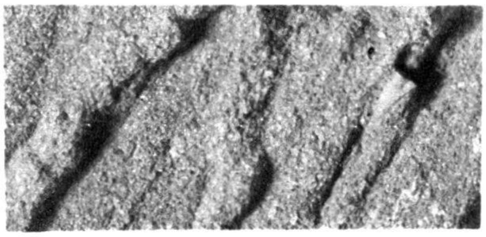
Figs. 1–3. "Hieroglyphic" markings formed by sandy material filling animal borings on mud surface.

Fig. 1. Baughman station 1743. 2.2 ×.
Figs. 2, 3 Baughman station 1944. 2.2 ×.

SEILACHER (1959, p. 1070, text-fig. 29, Tabelle II) explains the forms illustrated by fig. 1 as "Langgestreckte Gangfüllung mit wenigen geweihartigen Verzweigungen. Ursprünglich mit Tonpillen austapeziert, daher stets scharf von der umgehenden Schichtfläche abgesetzt" (cf. *Granularia* POMEL). Our fig. 3 may be identical with SEILACHBR'S problematic form illustrated by his text-fig. 35, Tabelle II (*Terebellina* ULRICH).

Fig. 4. Ripple mark on top of sandy bed. Baughman station 2037. 1.5 ×.

1



2

3

4

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Plate IX

Figs. 1–6. Chondrites of different types from the calcilutite in the upper part of the Vía Blanca formation, continuation of the Avenida Monumental. BR stations 667 and 667 A.

Fig. 1 1.7 ×.

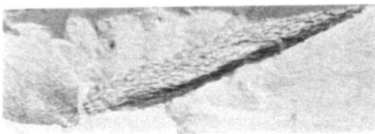
Fig. 2. Detail of surface structure. 2.2 ×.

Figs. 3, 4 1.8 ×.

Figs. 5, 6 2.2 ×.

SEILACHER (1959, p. 1072, Tabelle III, text-fig. 50) refers the form illustrated by our fig. 1 to *Chondrites* ("Fressbau"). Figs. 3 and 4 are identical with SEILACHER's fig. 49, Tabelle 3, referred to *Chondrites intricatus* BROGNIART. Figs. 5 and 6 appear to be intermediate forms of *Chondrites* and fig. 2 shows the filling of the "Fressbau" with ellipsoidal coprolites.

1



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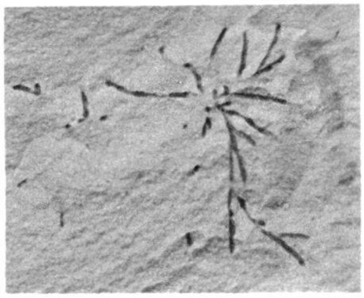

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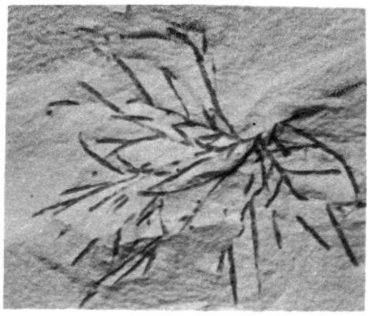

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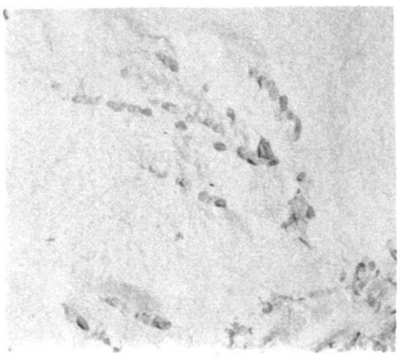

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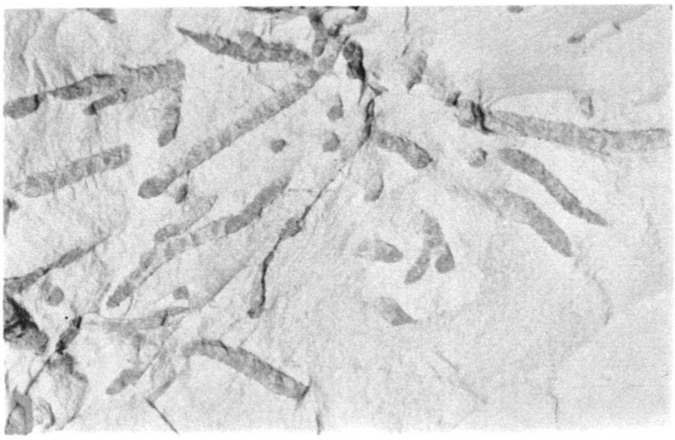

6

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Plate X

Fig. 1. *Discoaster multiradiatus* BRAMLETTE and RIEDEL
a) Facies superior
b) Facies inferior

Fig. 2. *Discoaster bebalaini* (TAN SIN HOK) nov. comb.
a) Facies superior
b) Facies inferior

Fig. 3. *Discoaster aecus* BRÖNNIMANN and STRADNER
a) Facies superior
b) Facies inferior

Fig. 4. *Discoaster geometricus* BRÖNNIMANN and STRADNER
a) Facies superior
b) Facies inferior

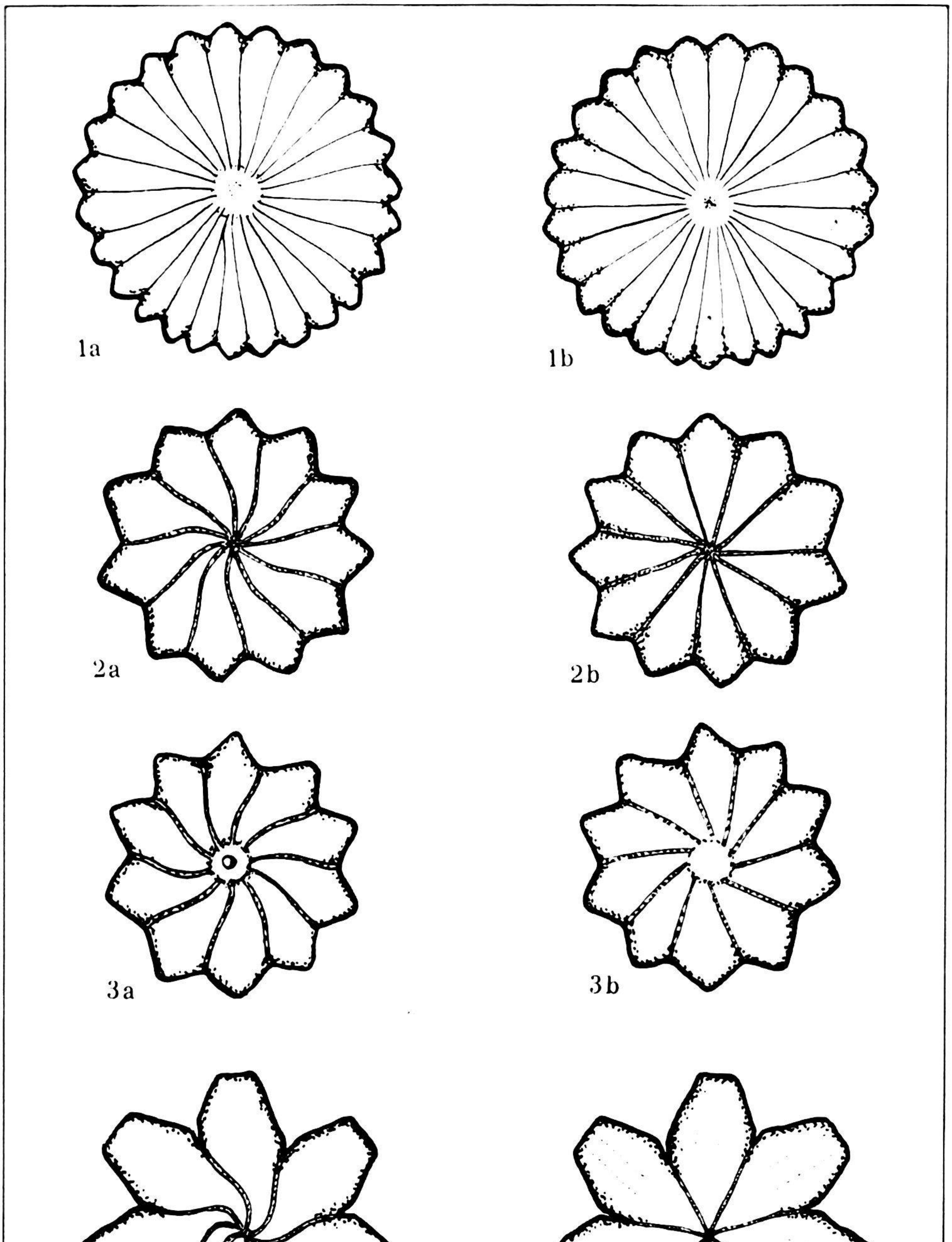

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Plate XI

Fig. 1. *Discoaster uncinatus* BRÖNNIMANN and STRADNER
a) Facies superior
b) Facies inferior

Fig. 2. *Discoaster lodoensis* BRAMLETTE and RIEDEL
a) Facies superior
b) Facies inferior

Fig. 3. *Discoaster hilli* TAN SIN HOK
a) Facies superior
b) Facies inferior

Fig. 4. *Discoaster mirus* DEFLANDRE
a) Facies superior
b) Facies inferior

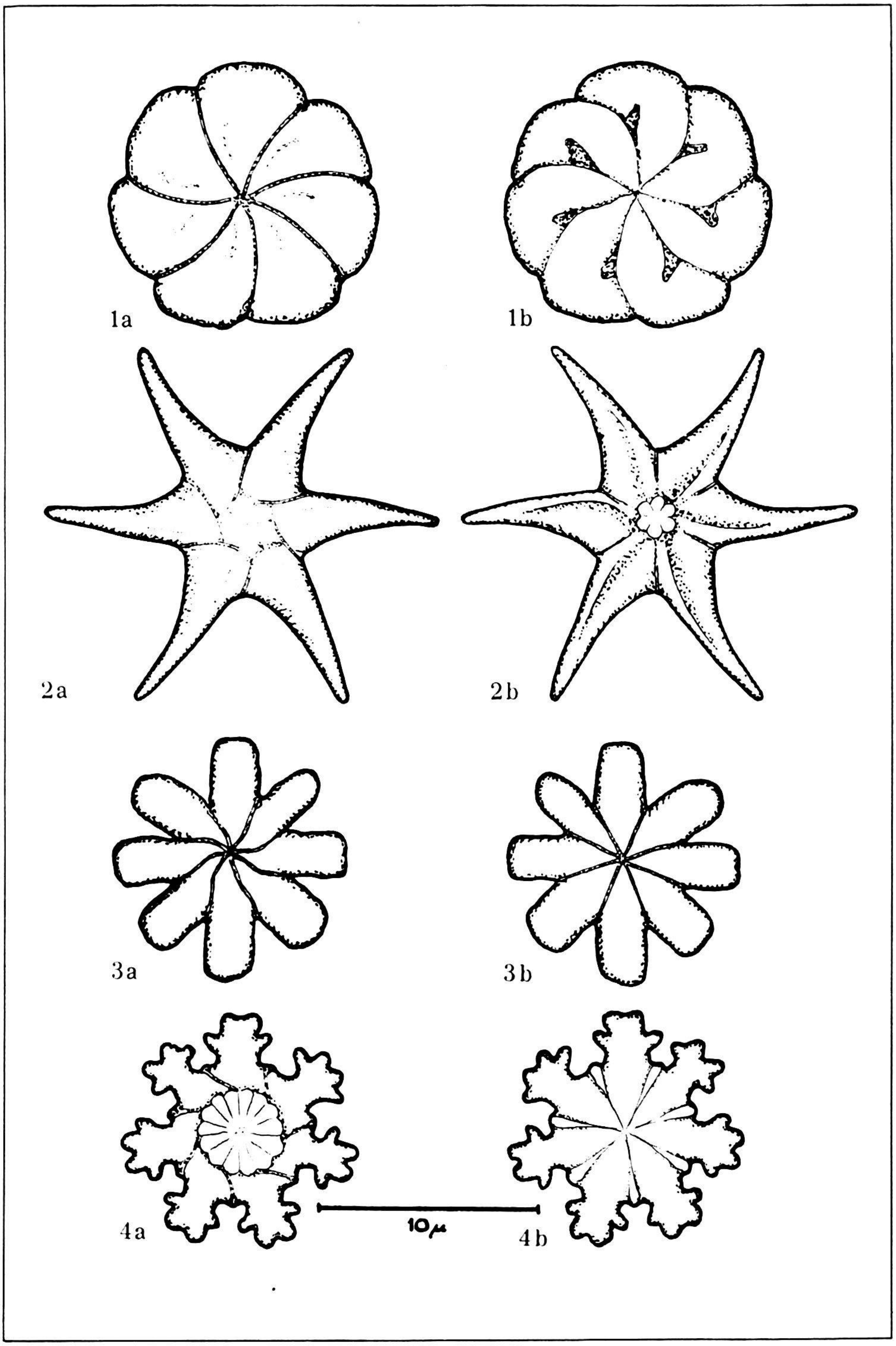

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Plate XII

Fig. 1. *Discoaster binodosus* MARTINI
a) Facies superior
b) Facies inferior

Fig. 2. *Discoaster corniger* SHAMRAY and LAZAREVA
a) Facies superior
b) Facies inferior

Fig. 3. *Discoaster* cf. *molengraaffi* TAN SIN HOK
a) Facies superior
b) Facies inferior

Fig. 4. *Discoaster* cf. *woodringi* BRAMLETTE and RIEDEL
a) Facies superior
b) Facies inferior

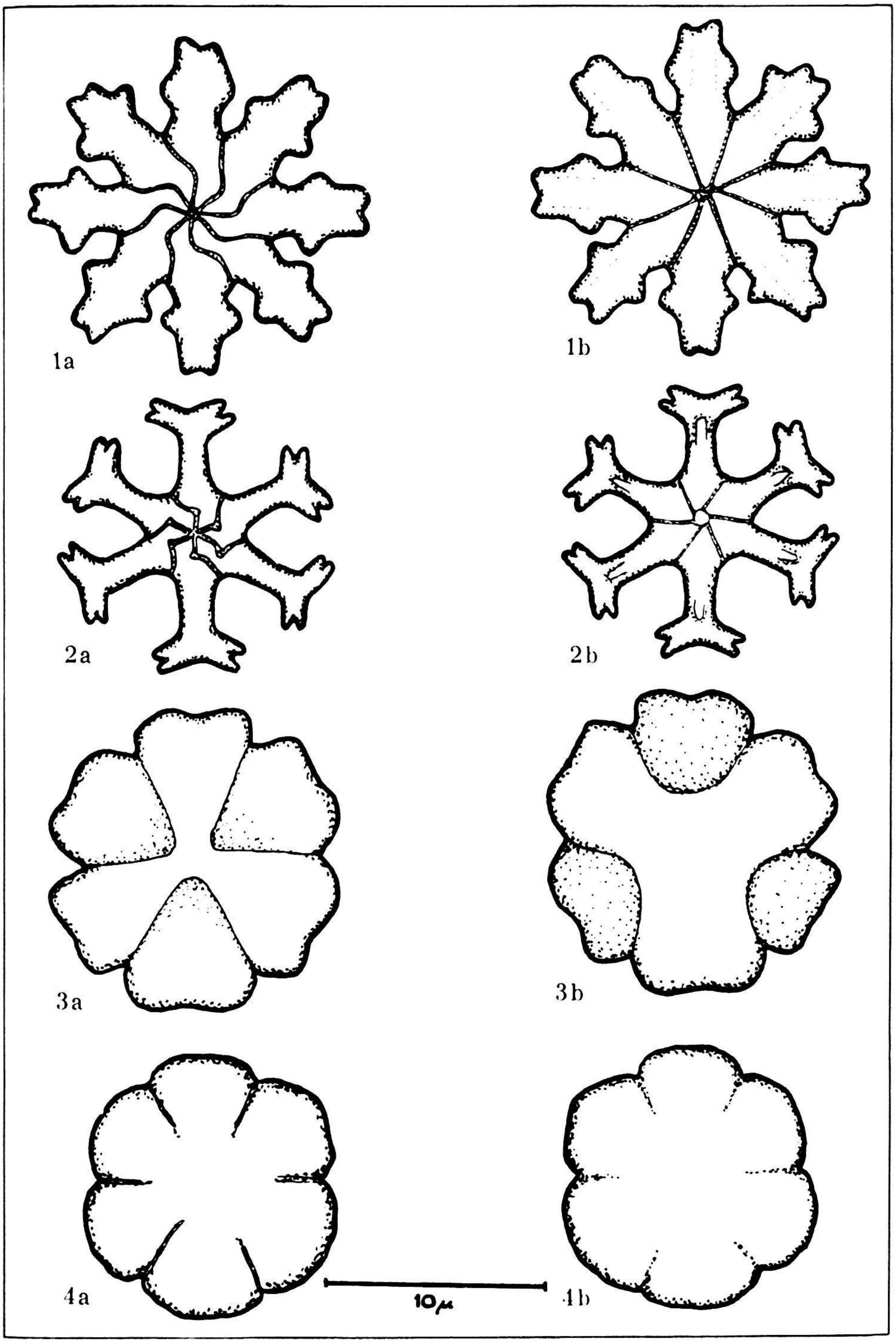

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Plate XIII

Fig. 1. *Marthasterites contortus* (STRADNER) DEFLANDRE
a) Facies superior
b) Facies inferior

Fig. 2. *Marthasterites bramlettei* BRÖNNIMANN and STRADNER
a) Facies superior
b) Facies inferior

Fig. 3. *Marthasterites riedeli* BRÖNNIMANN and STRADNER
a) Facies superior
b) Facies inferior

Fig. 4. *Marthasterites tribrachiatus* (BRAMLETTE and RIEDEL) DEFLANDRE
a) Facies superior
b) Facies inferior

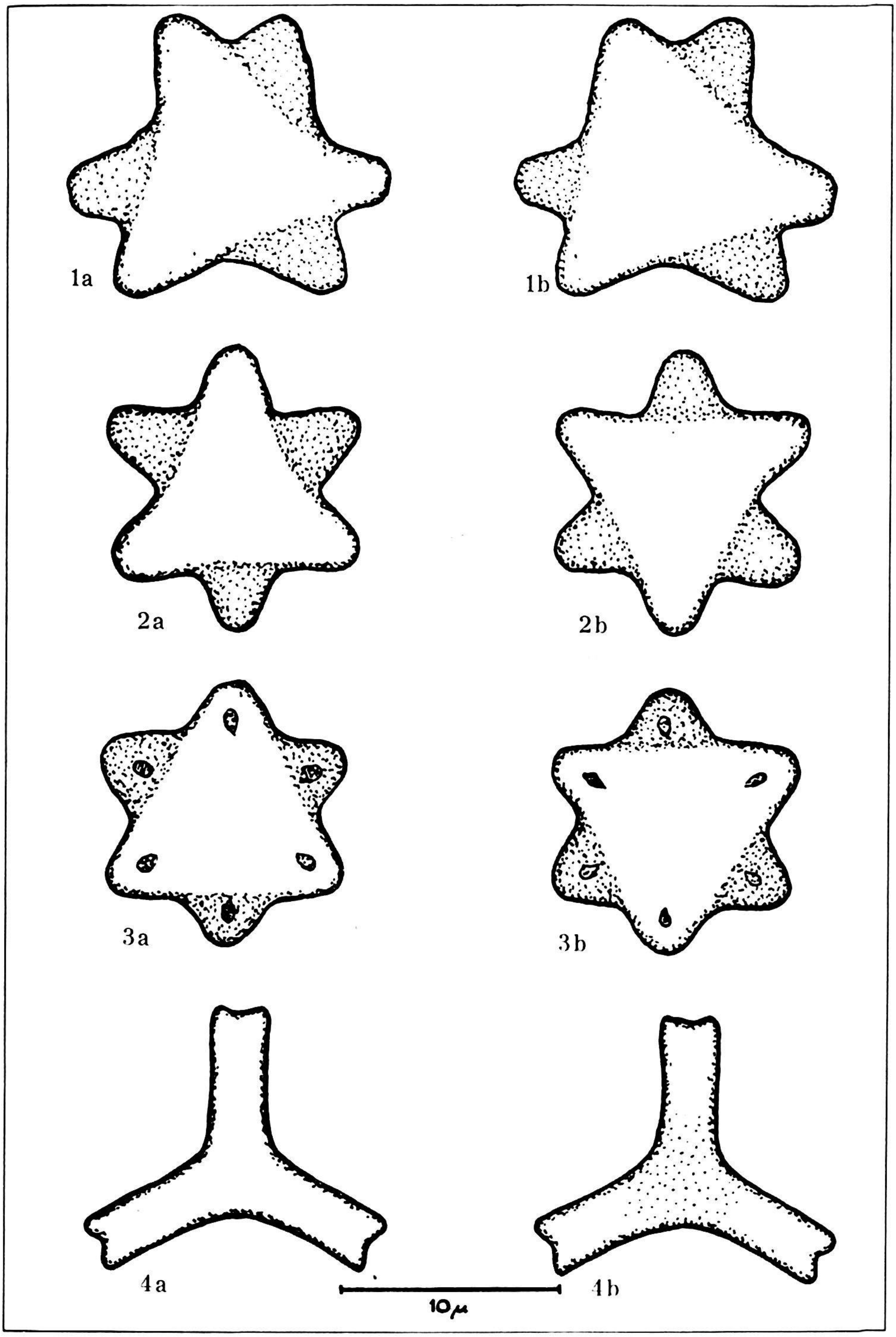

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Plate XIV

Fig. 1. *Nannotetraster swasticoides* (MARTINI) MARTINI and STRADNER
a) Facies superior
b) Facies inferior

Fig. 2. *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE
a) Facies distalis
b) Facies proximalis

Fig. 3. *Braarudosphaera discula* BRAMLETTE and RIEDEL
a) Facies distalis
b) Facies proximalis

Fig. 4. *Braarudosphaera undata* STRADNER
a) Facies distalis
b) Facies proximalis

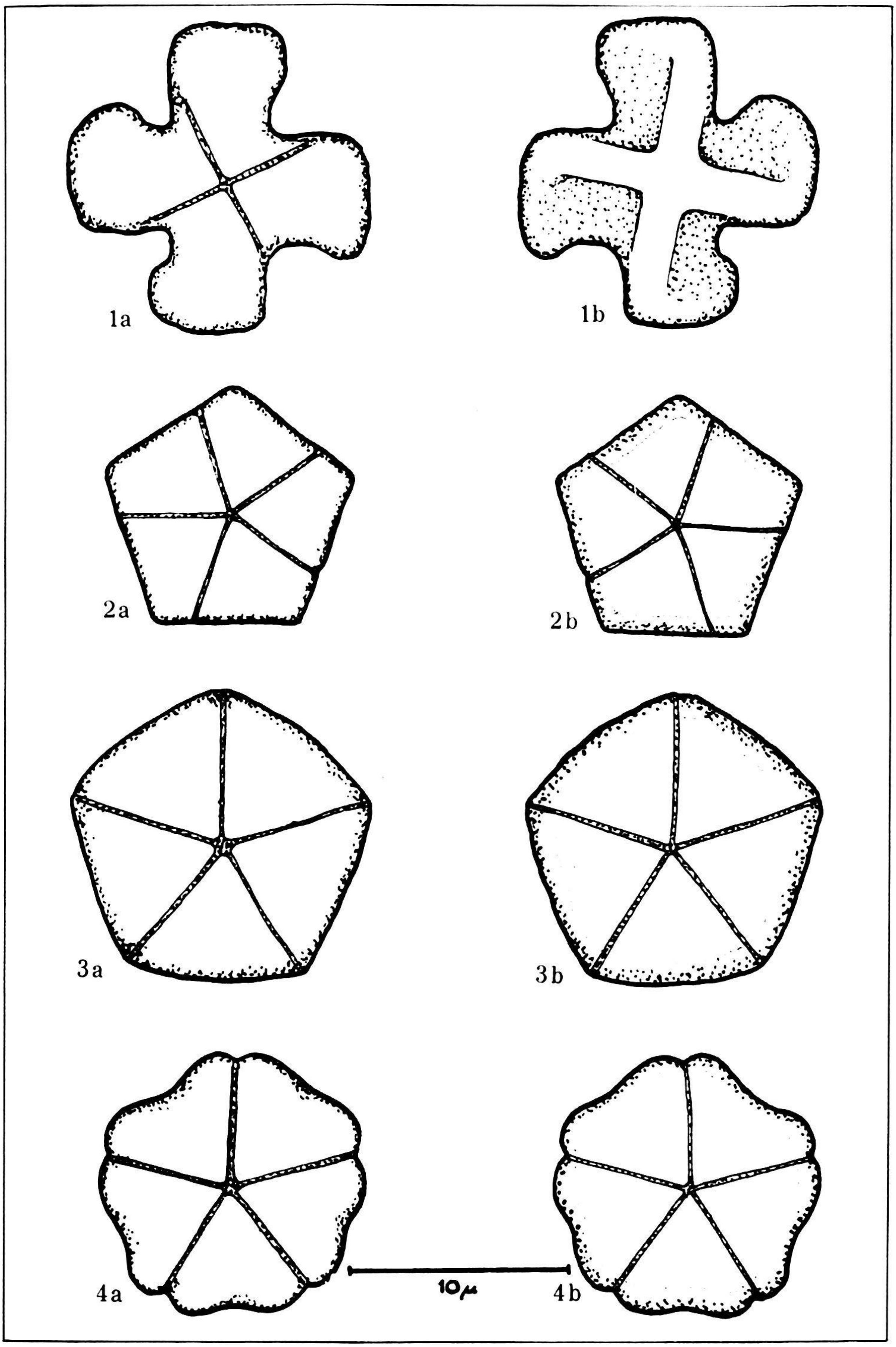

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Plate XV

Fig. 1. *Micrantholithus vesper* DEFLANDRE
- a) Facies distalis
- b) Facies proximalis

Fig. 2. *Nannoturbella moriformis* BRÖNNIMANN and STRADNER
- a) Basal view
- b) Side view
- c) In polarized light

Fig. 3. *Heliorthus fallax* BRÖNNIMANN and STRADNER
- a) Facies distalis
- b) Facies proximalis
- c) In polarized light (different scale)
- d) Side view
- e) Facies proximalis of a paratype with more rugged outline
- f) Facies distalis of a paratype with slender cross and rim

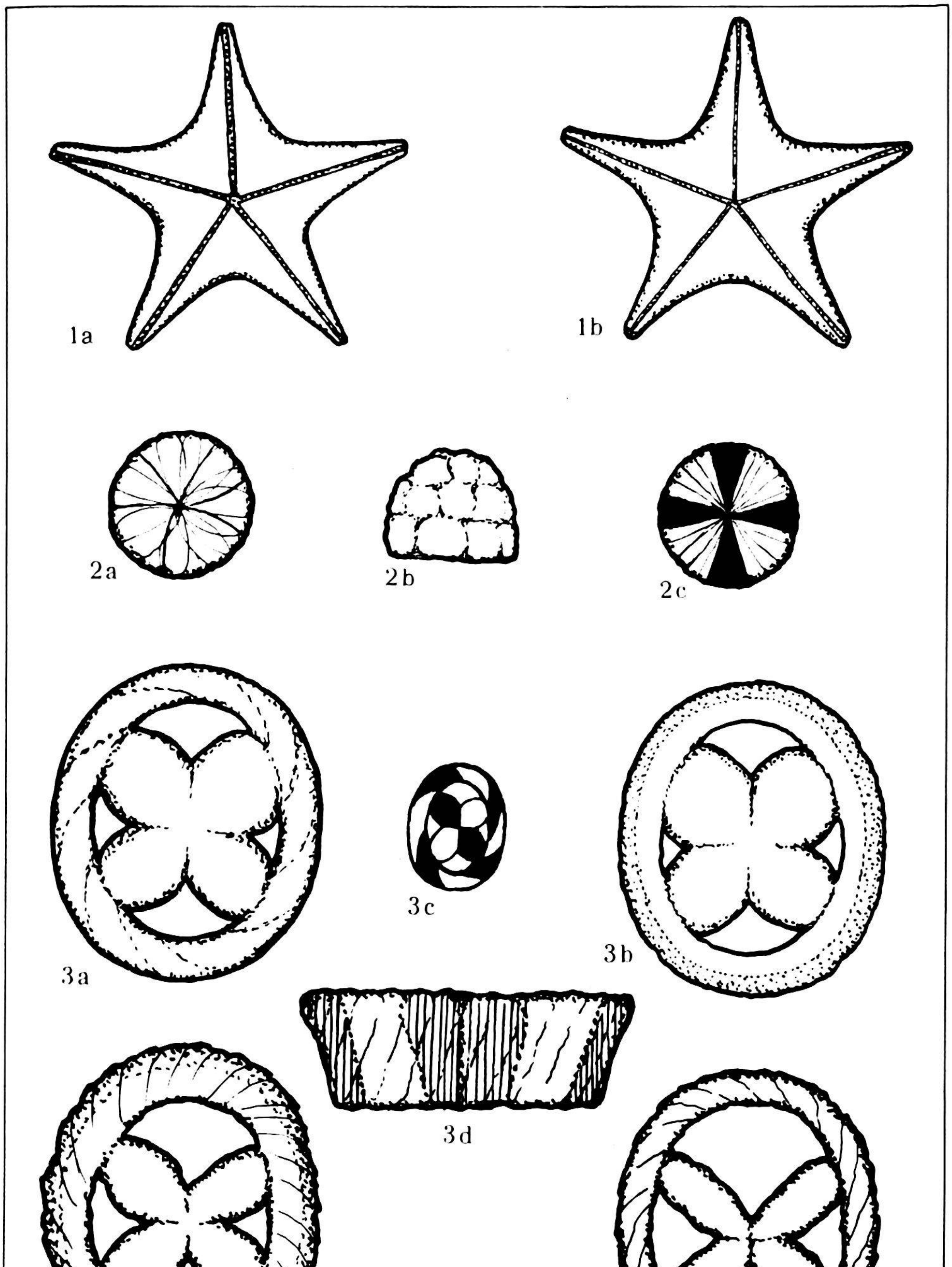

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Plate XVI

Fig. 1. *Rugotruncana gansseri* (BOLLI)
Baughman station 1802, Maastrichtian
95×

Fig. 2. *Globotruncana contusa* (CUSHMAN)
Baughman station 1805, Maastrichtian
60×

Fig. 3. *Trinitella scotti* BRÖNNIMANN
Sisson station 156, Maastrichtian
95×

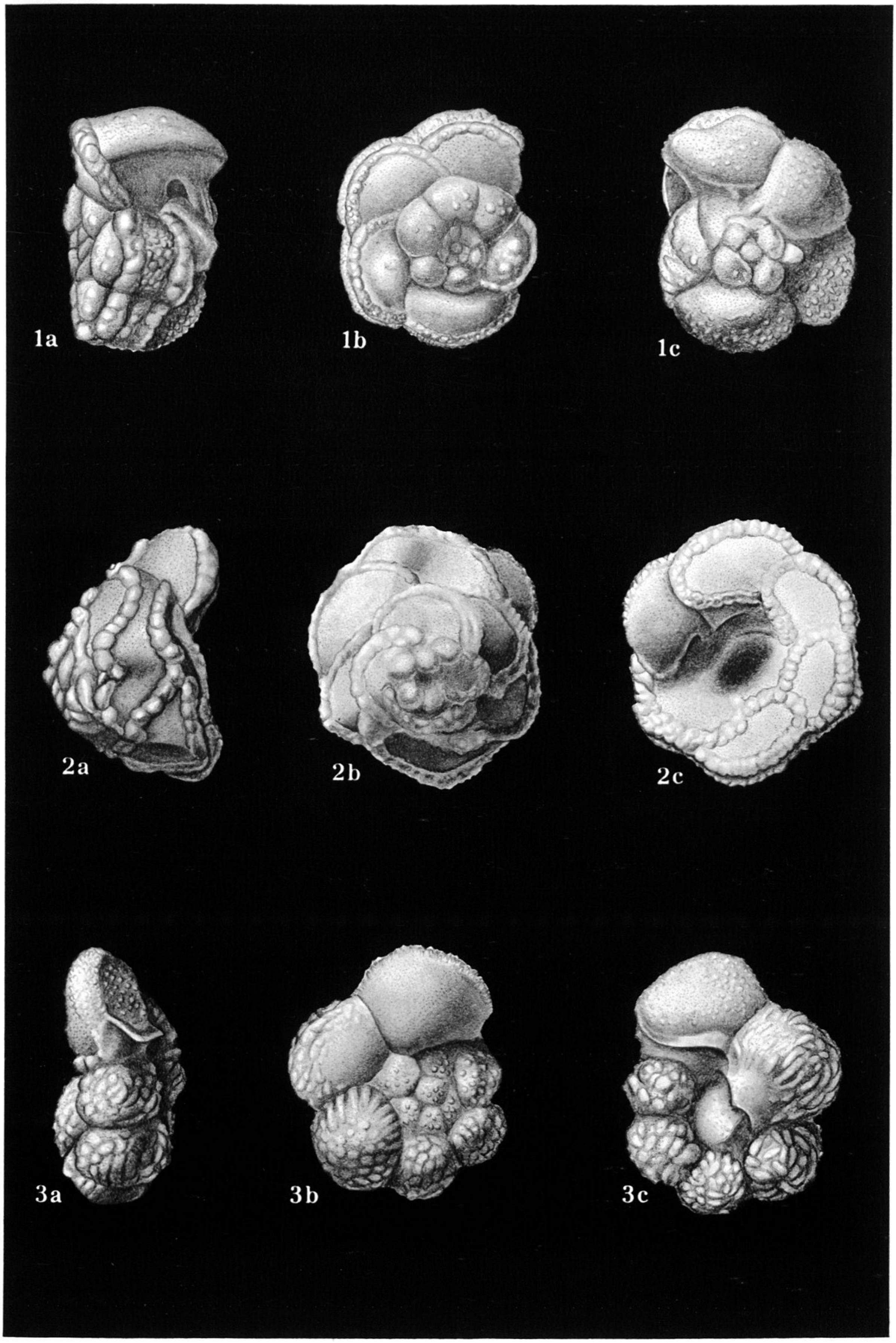

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Plate XVII

Fig. 1. *Rugotruncana calcarata* (CUSHMAN)
Baughman station 1839 B, Campanian
62×

Fig. 2. *Globotruncanella havanensis* (VOORWIJK)
Baughman station 1839 B, Campanian
62×

Fig. 3. *Globotruncana fornicata* PLUMMER
Baughman station 1839 B, Campanian
62×

Fig. 4. *Gublerina ornatissima* (CUSHMAN and CHURCH)
Sisson station 156, Maastrichtian
62×

Fig. 5. *Globotruncana linneiana* (D'ORBIGNY)
Baughman station 1839 B, Campanian
62×

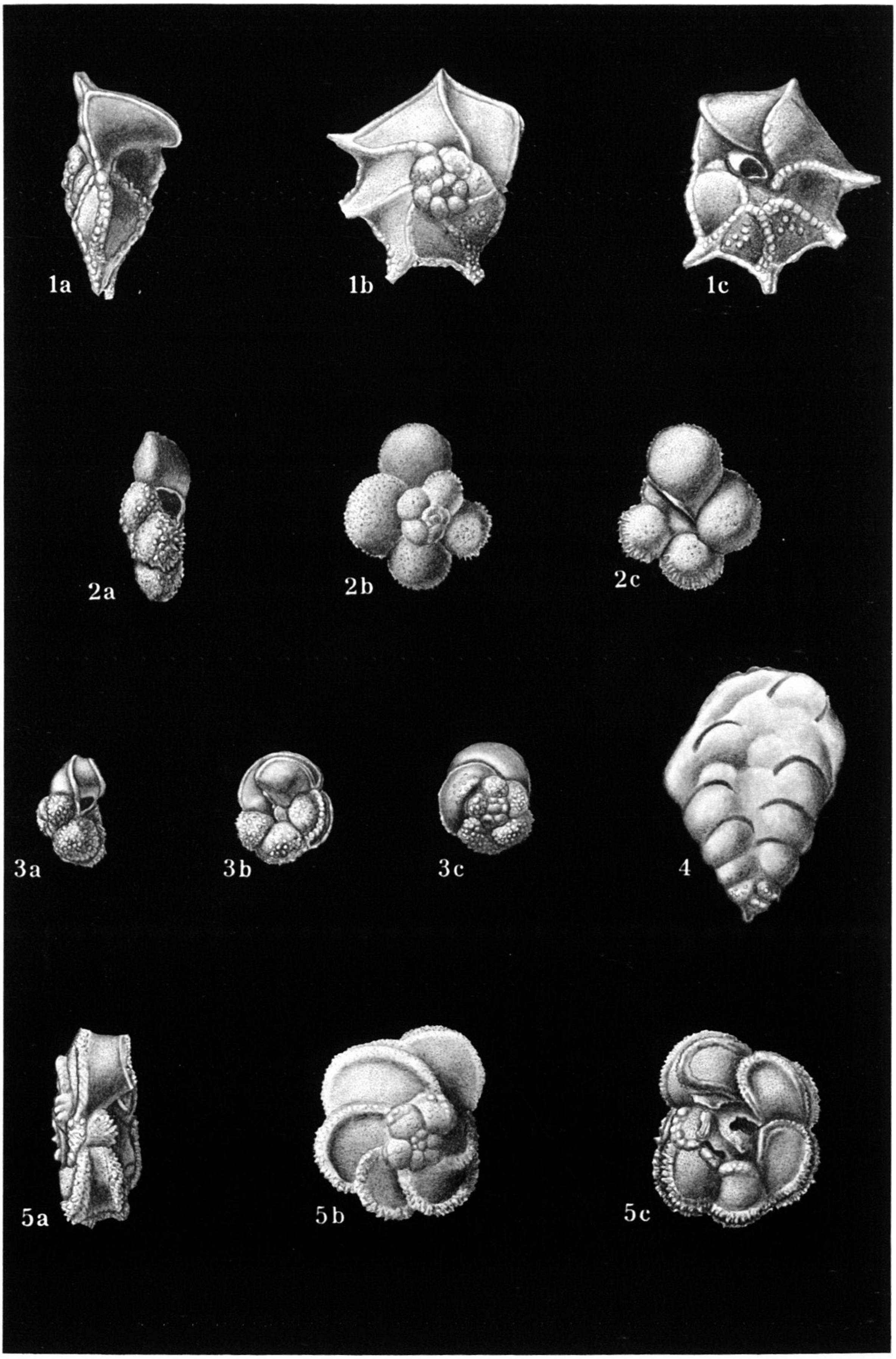

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Plate XVIII

Fig. 1. *Rugoglobigerina rugosa rugosa* (PLUMMER)
Sisson station 156, Maastrichtian
92×

Fig. 2. *Rugoglobigerina macrocephala macrocephala* BRÖNNIMANN
Sisson station 156, Maastrichtian
92×

Fig. 3. *Ticinella roberti* (GANDOLFI)
Sisson station 148, Cenomanian
92×

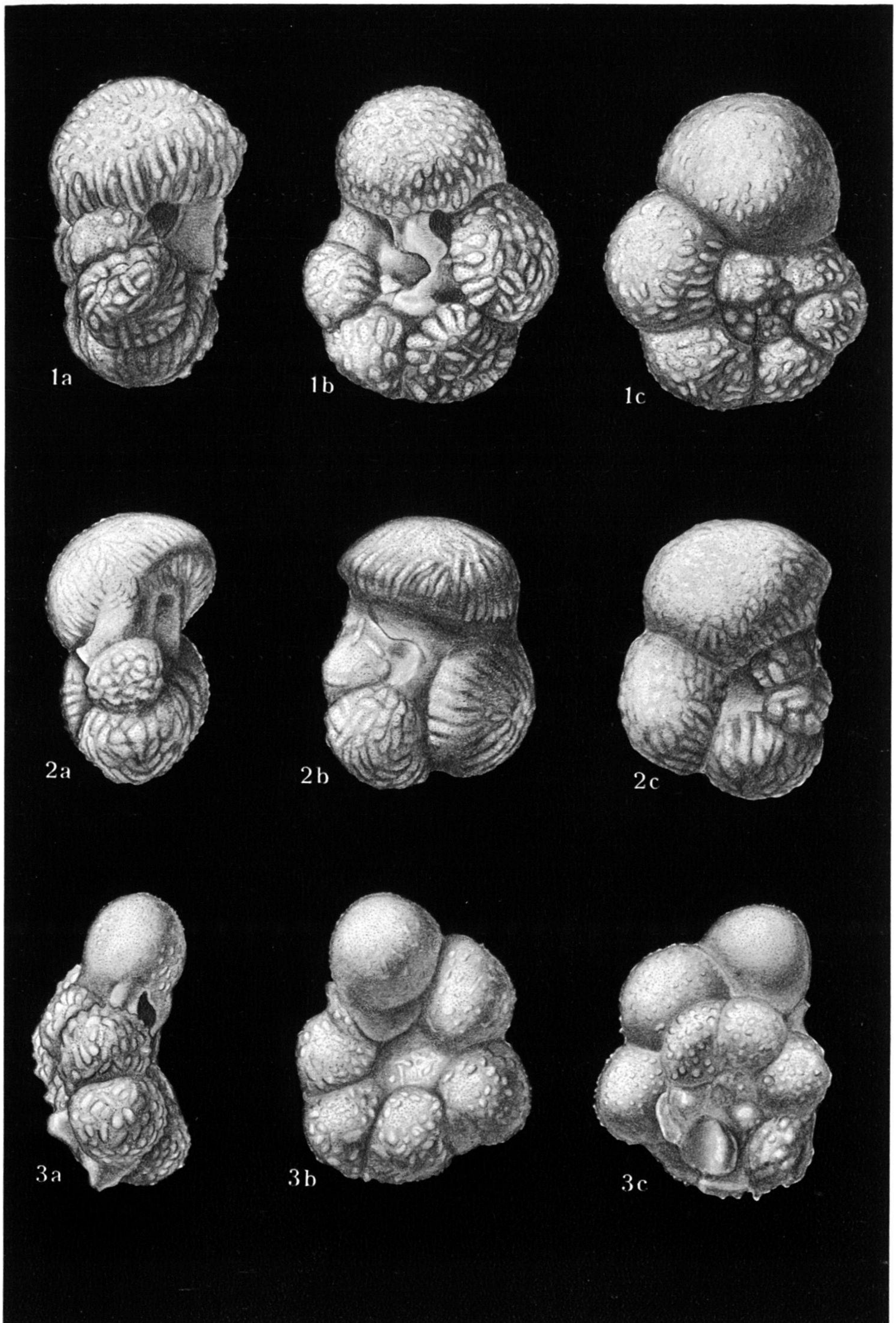

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Plate XIX

Fig. 1. *Hedbergella trocoidea* (GANDOLFI)
Sisson station 148, Cenomanian
96×

Fig. 2. *Planomalina buxtorfi* (GANDOLFI)
Sisson station 148, Cenomanian
60×

Fig. 3. *Globigerina daubjergensis* BRÖNNIMANN
BR station 1221, Danian
96×

Fig. 4. *Globorotalia compressa* PLUMMER
BR station 1221, Danian
96×

Fig. 5. *Globorotalia pseudobulloides* PLUMMER
BR station 1221, Danian
96×

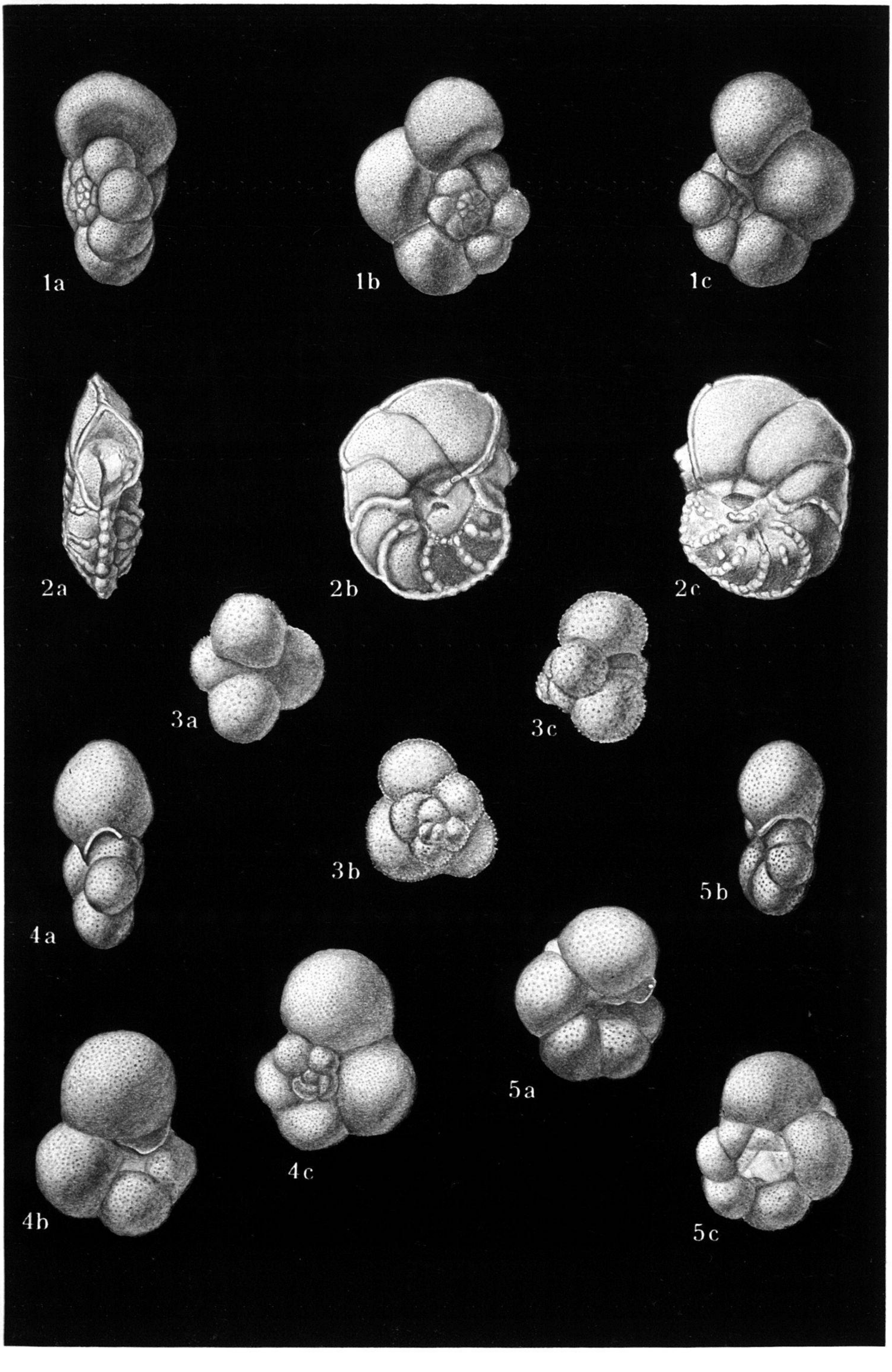

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Plate XX

Fig. 1. *Globigerina ciperoensis angustiumbilicata* BOLLI
BR station 383, Oligocene
97×

Fig. 2. *Globigerina ciperoensis ciperoensis* BOLLI
BR station 383, Oligocene
97×

Fig. 3. *Globigerina ciperoensis angulisuturalis* BOLLI
BR station 376, Oligocene
97×

Fig. 4. *Globorotalia mayeri* CUSHMAN and ELLISOR
BR station 959, Miocene
97×

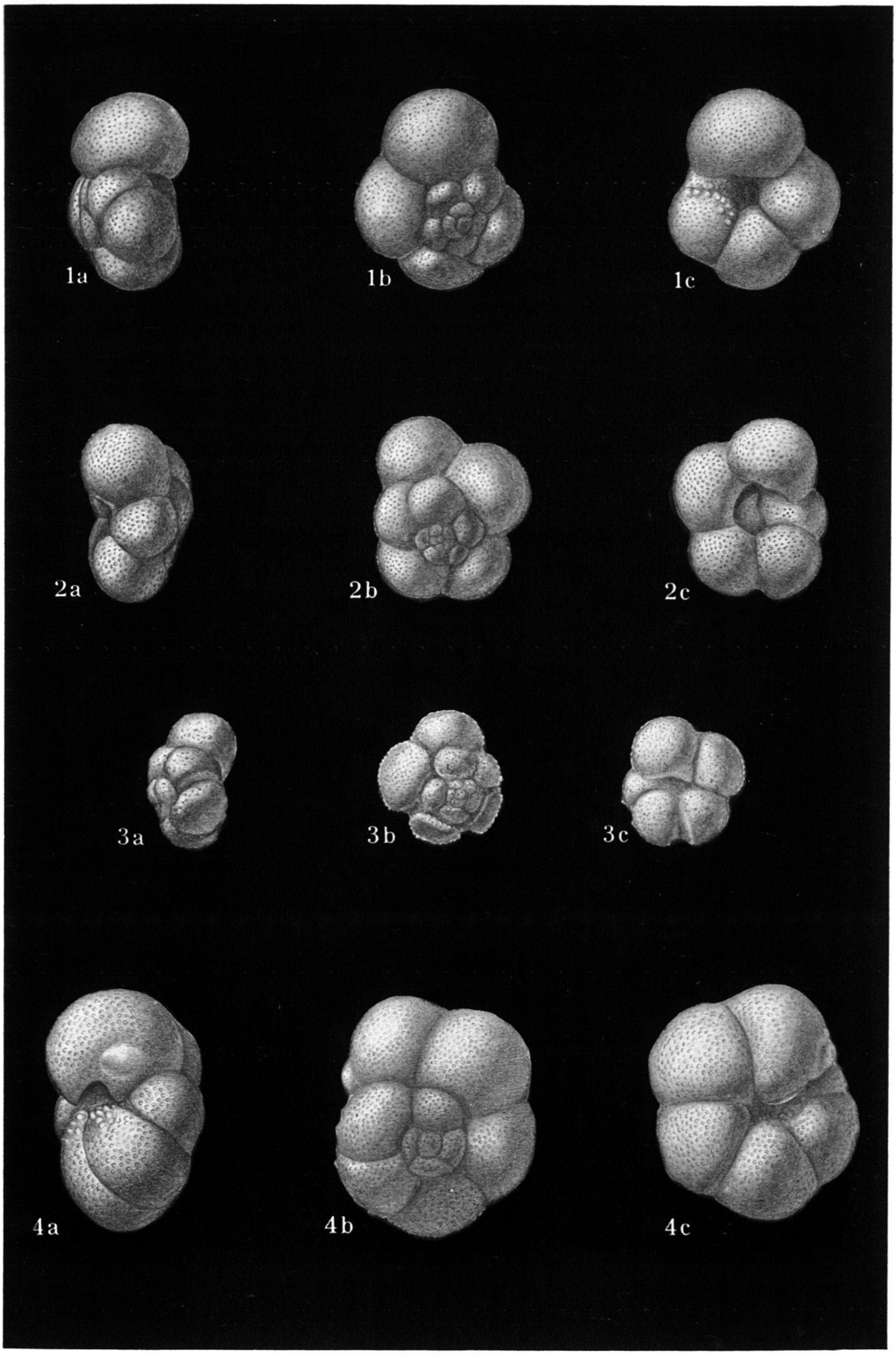

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Plate XXI

Fig. 1. *Globigerina ampliapertura* BOLLI
BR station 366, Oligocene
93×

Fig. 2. *Globigerina euapertura* JENKINS
BR station 383, Oligocene
93×

Fig. 3. *Globorotalia opima nana* BOLLI
BR station 383, Oligocene
93×

Fig. 4. *Globorotalia opima opima* BOLLI
BR station 376, Oligocene
93×

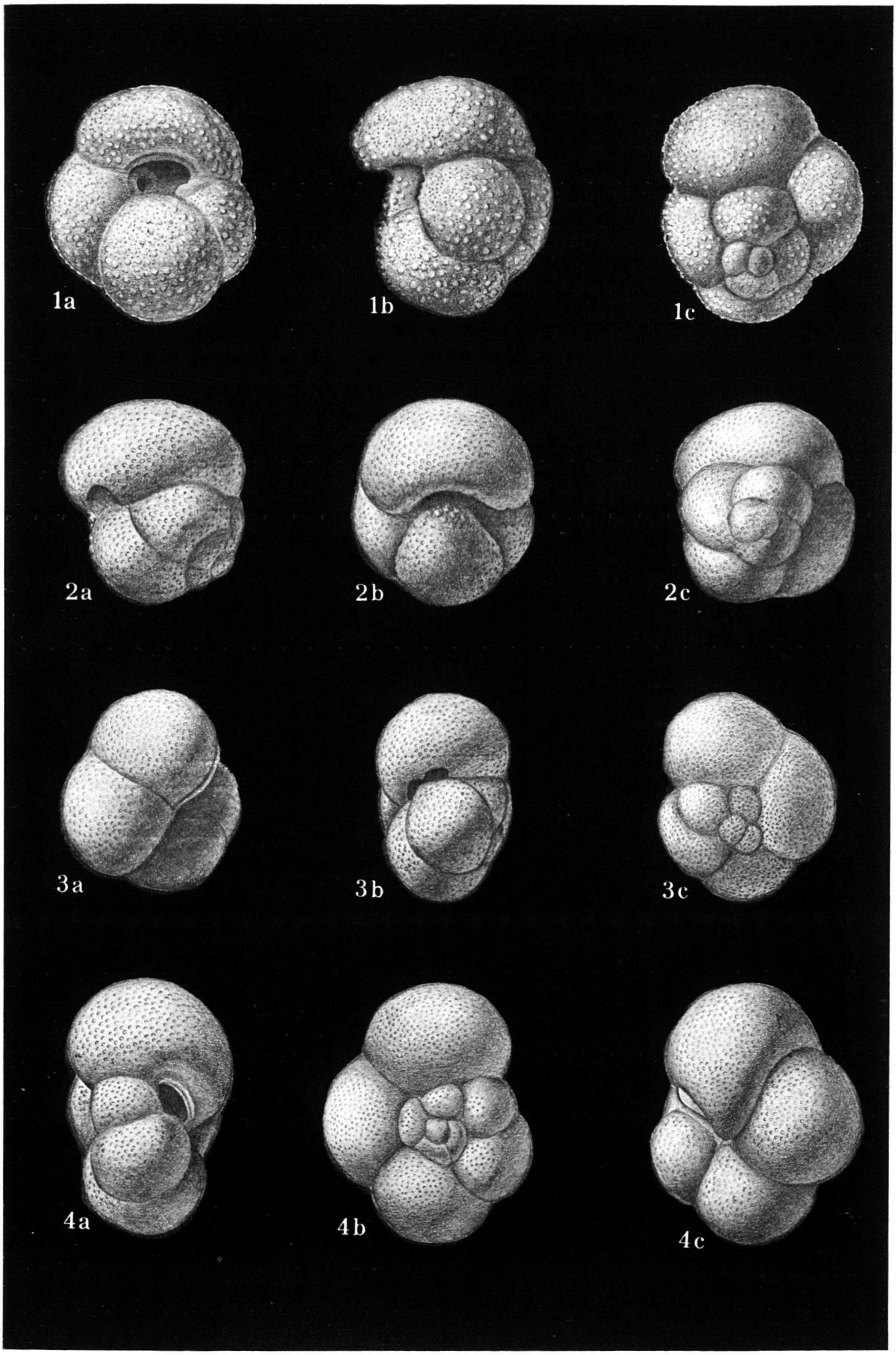

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Plate XXII

Fig. 1. *Globigerina triloculinoides* PLUMMER
BR station 1221, Danian
98×

Fig. 2. *Globigerina* cf. *triloculinoides* PLUMMER
BR station 1221, Danian
98×

Fig. 3. *Porticulasphaera transitoria* BLOW
BR station 933, Miocene
62×

Fig. 4. *Globigerinoides bisphericus* TODD
BR station 933, Miocene
62×

Fig. 5. *Globigerinoides subquadratus* BRÖNNIMANN
BR station 933, Miocene
62×

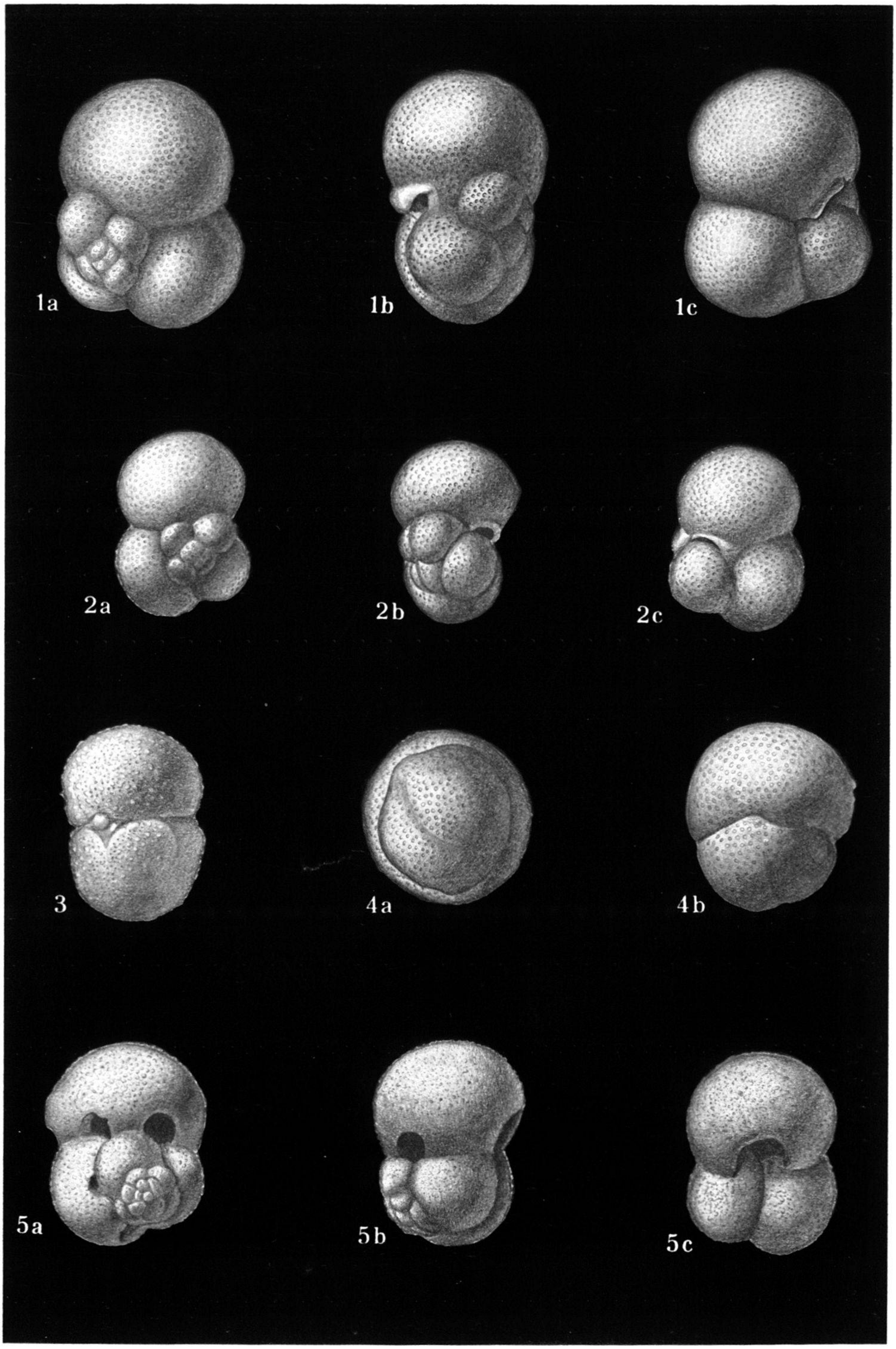

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Plate XXIII

Fig. 1. *Globigerina rohri* Bolli
Finca Adelina, Oligocene
99×

Fig. 2. *Globoquadrina altispira globosa* Bolli
Finca Adelina, Oligocene
43×

Fig. 3. *Globoquadrina altispira altispira* (Cushman and Jarvis)
Finca Adelina, Oligocene
43×

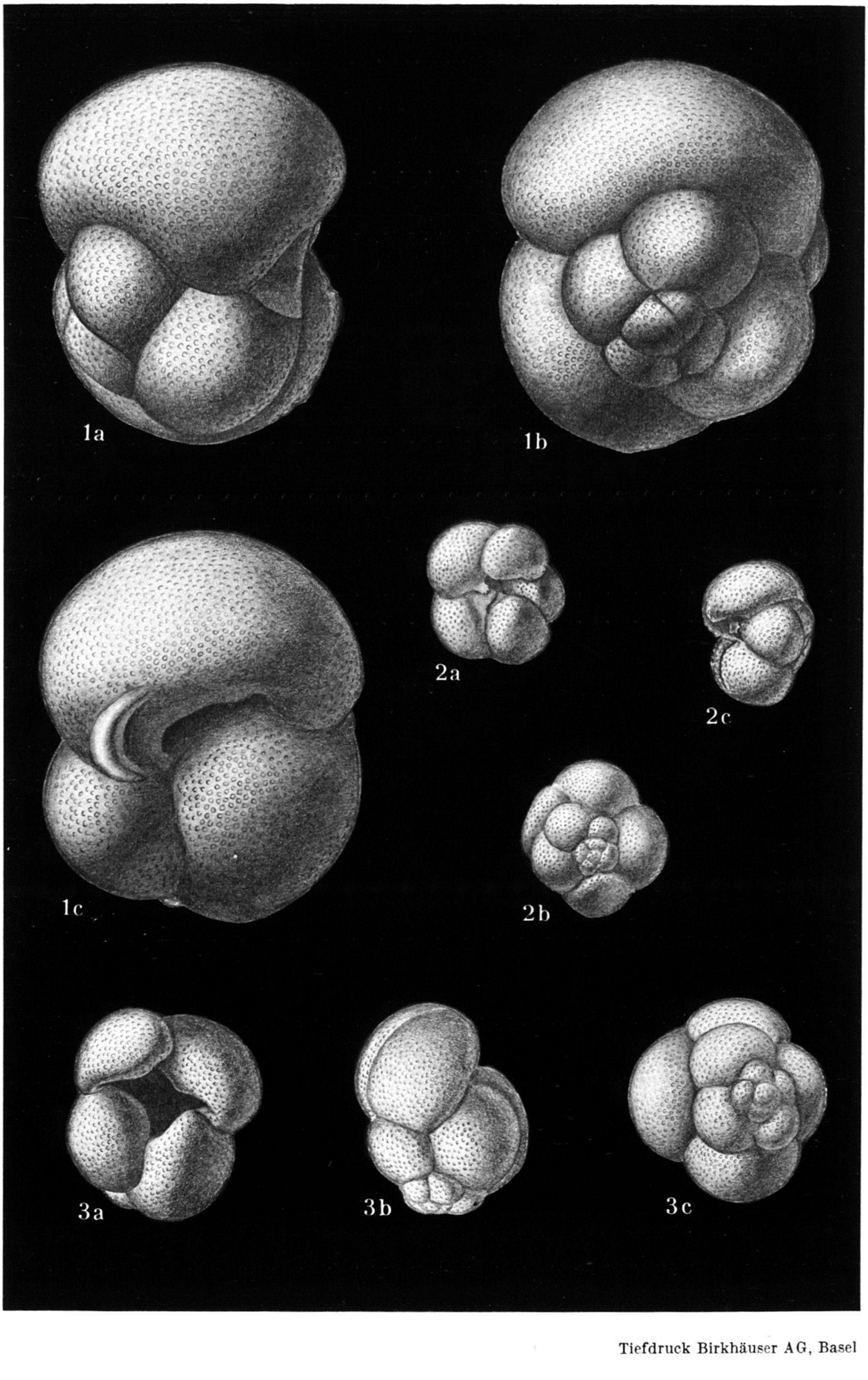

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Plate XXIV

Fig. 1. *Globoquadrina venezuelana* (HEDBERG)
Finca Adelina, Oligocene
92×

Fig. 2. *Globorotalia praemenardii* CUSHMAN and STAINFORTH
BR station 923, Miocene
92×

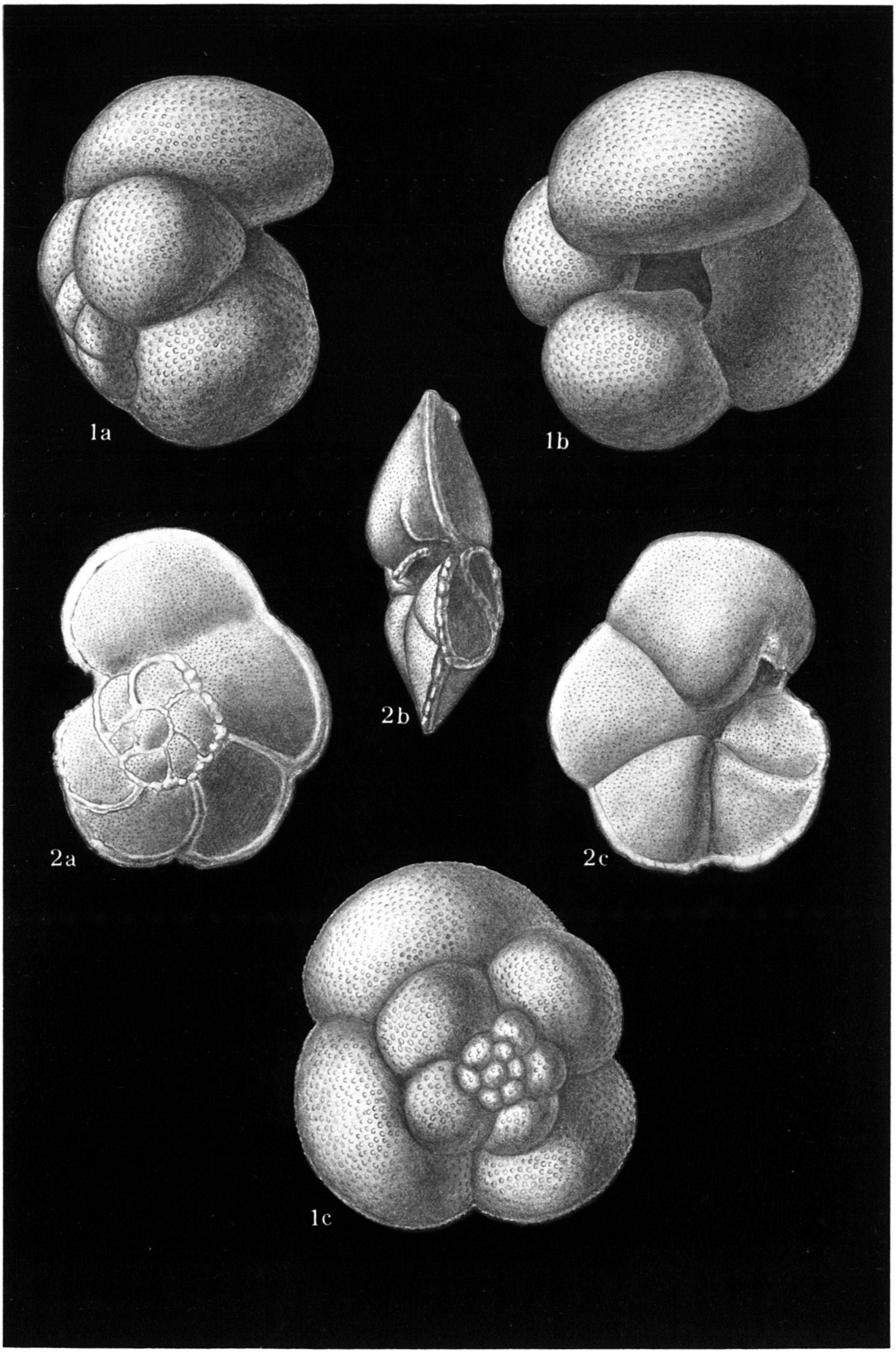

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Plate XXV

Fig. 1. *Globorotalia fohsi lobata* BERMÚDEZ
BR station 908, Miocene
97×

Fig. 2. *Globorotalia fohsi fohsi* CUSHMAN and ELLISOR
BR station 924, Miocene
97×

Fig. 3. *Globorotalia fohsi barisanensis* LEROY
BR station 925, Miocene
97×

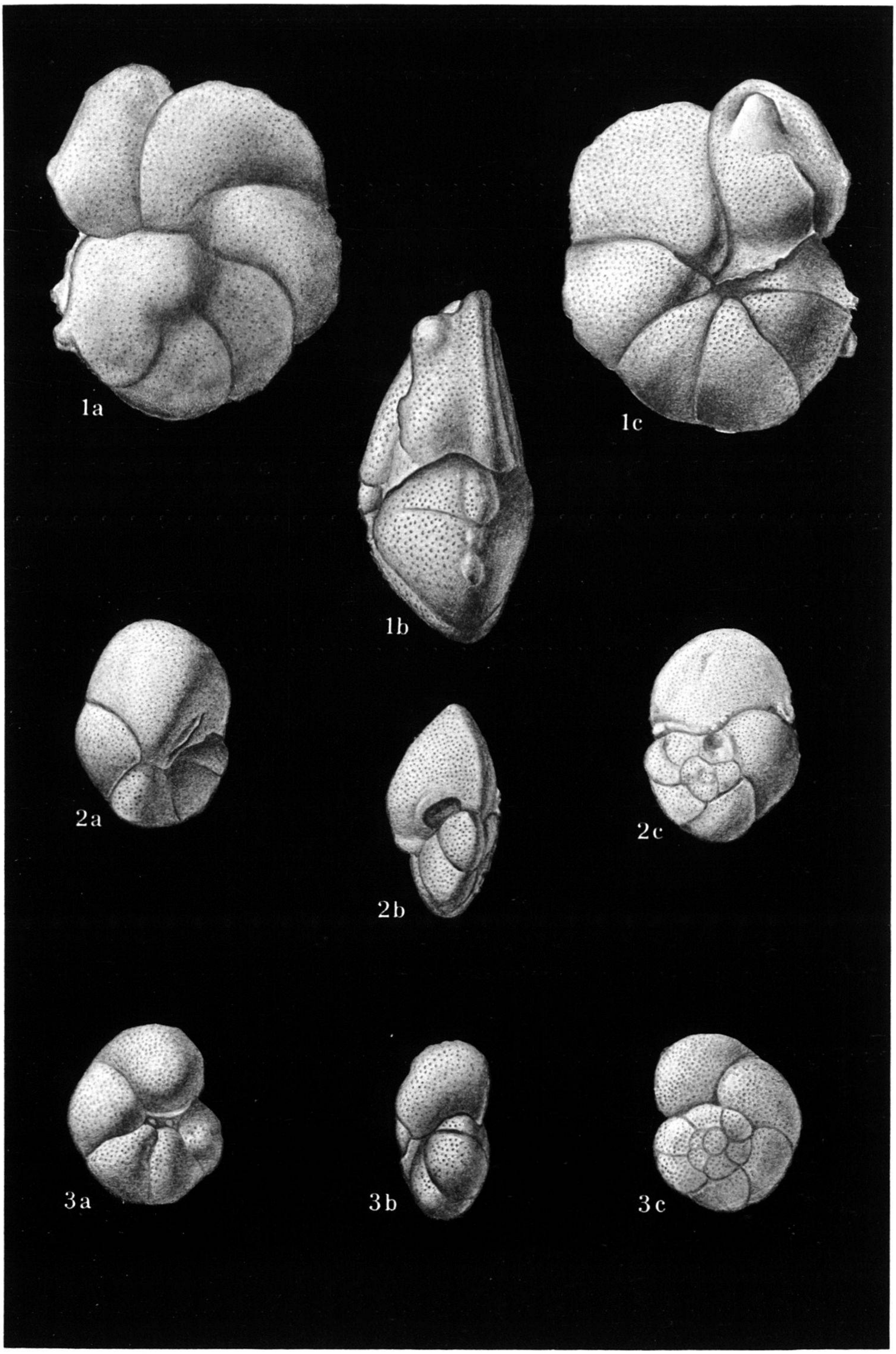

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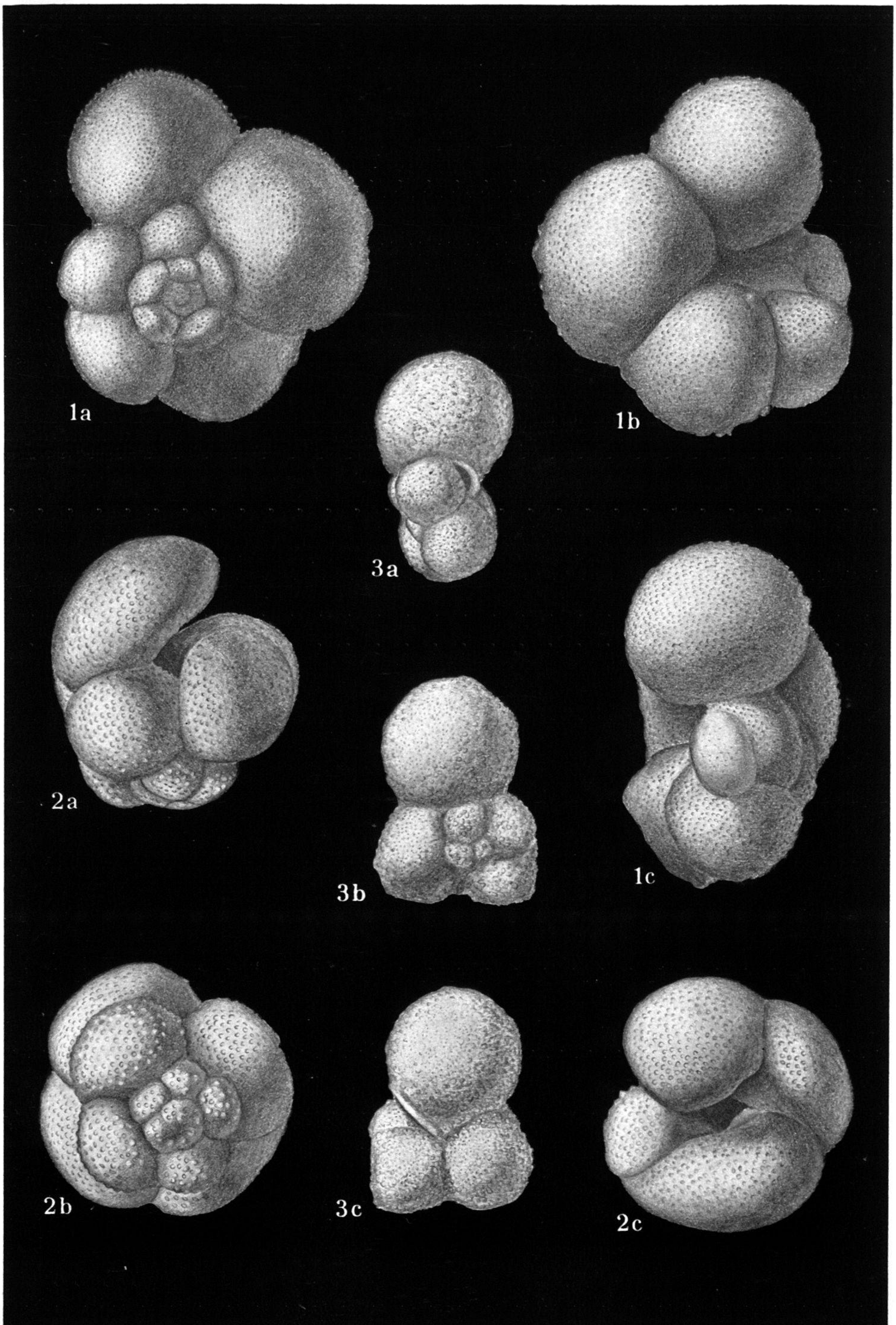
Plate XXVI

Fig. 1. *Globorotalia obesa* BOLLI
BR station 922, Miocene
97 ×

Fig. 2. *Globoquadrina altispira altispira* (CUSHMAN and JARVIS)
Finca Adelina, Oligocene
97 ×

Fig. 3. *Globigerina foliata* BOLLI
BR station 922, Miocene
97 ×



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