Capdevila formation

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

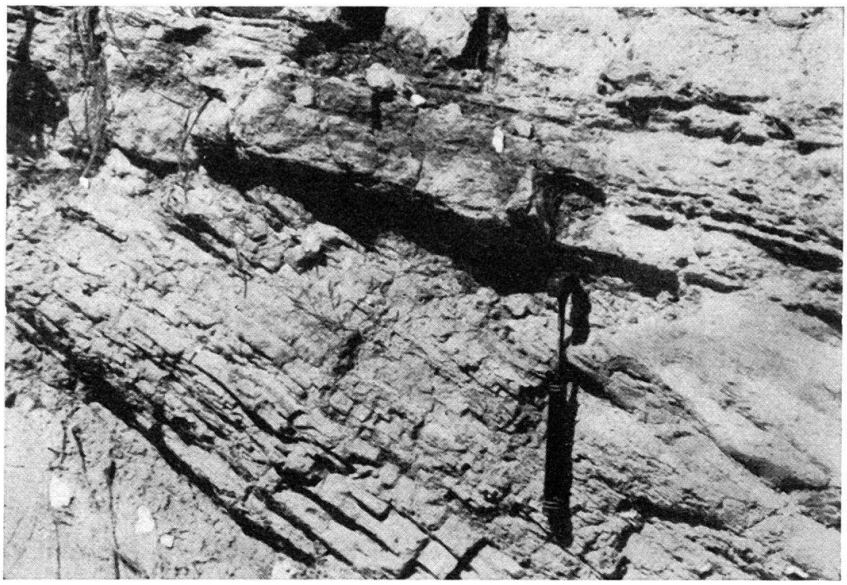


Fig. 30. Detail of the unconformity between Alkázar formation (?), below, and Cojímar formation, above, at Avenida Río, west of Río Cojímar.

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 conser-

vandum. 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

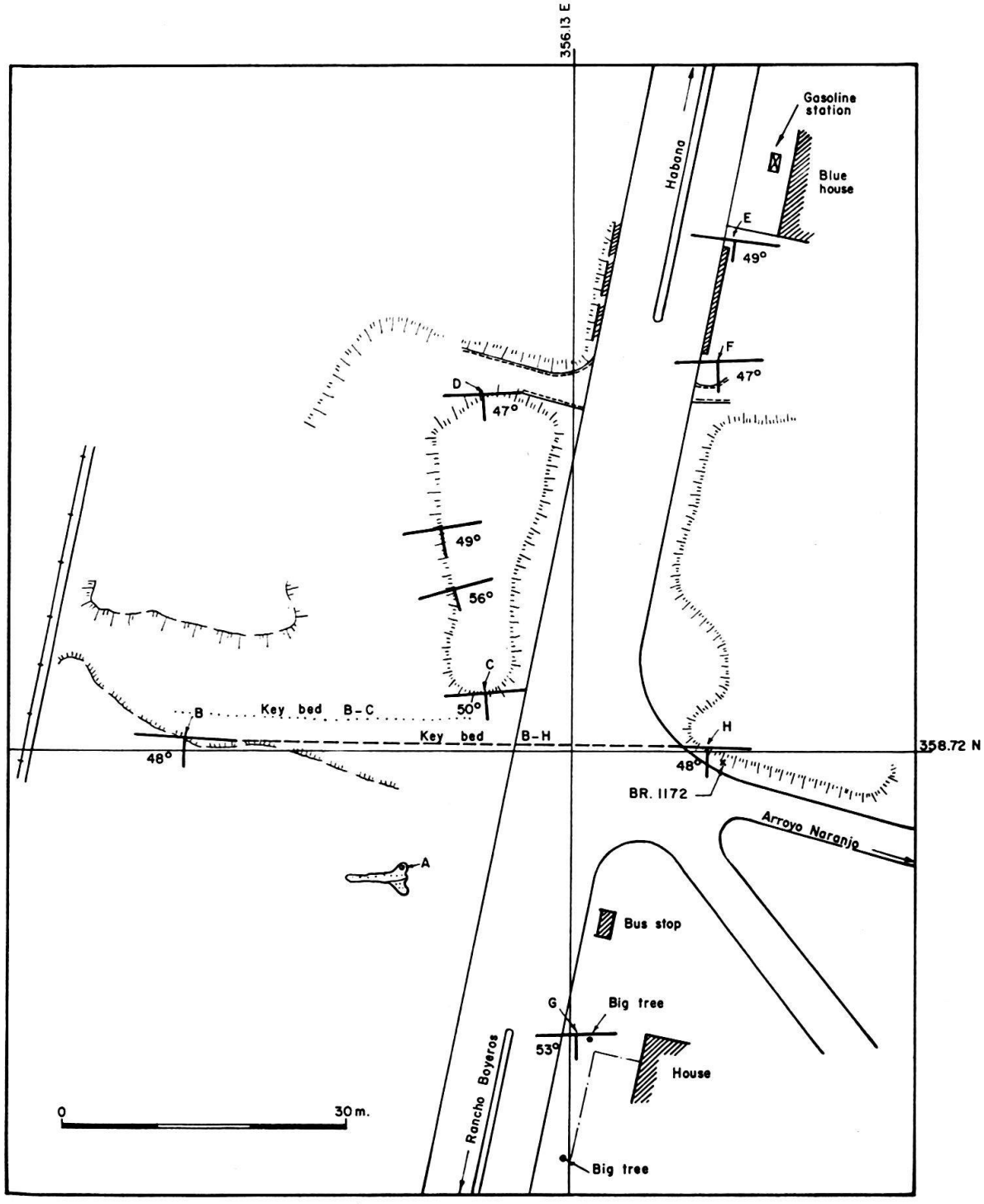


Fig. 31. Index map of the type locality of the Capdevila formation.

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

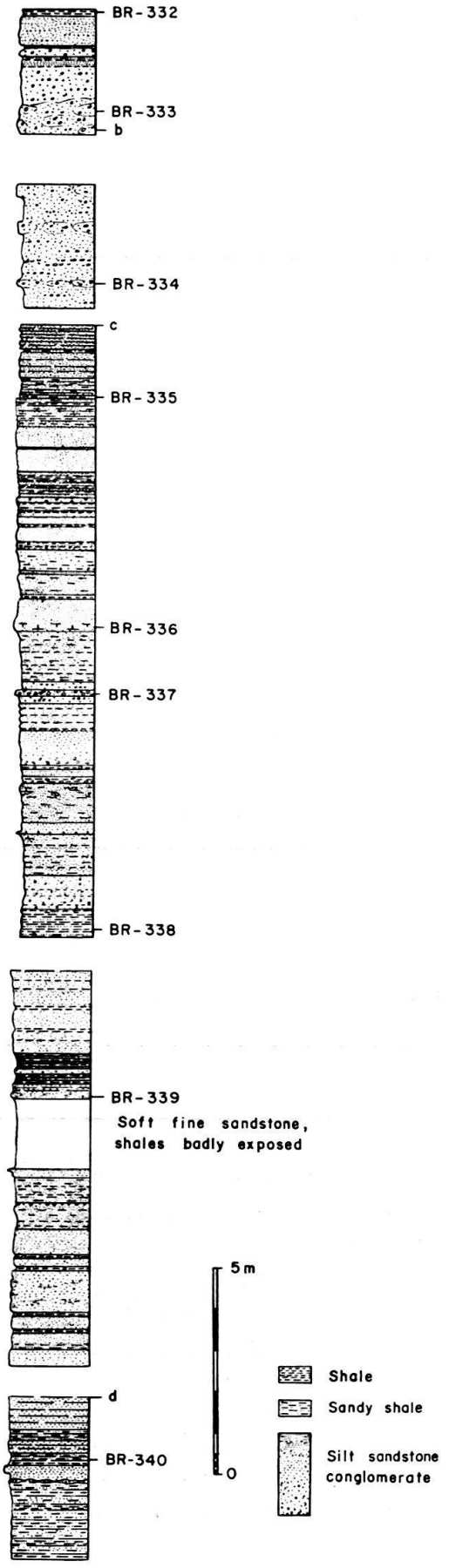


Fig. 32. Columnar section of the type locality of the Capdevila formation (lithologic Unit II).

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

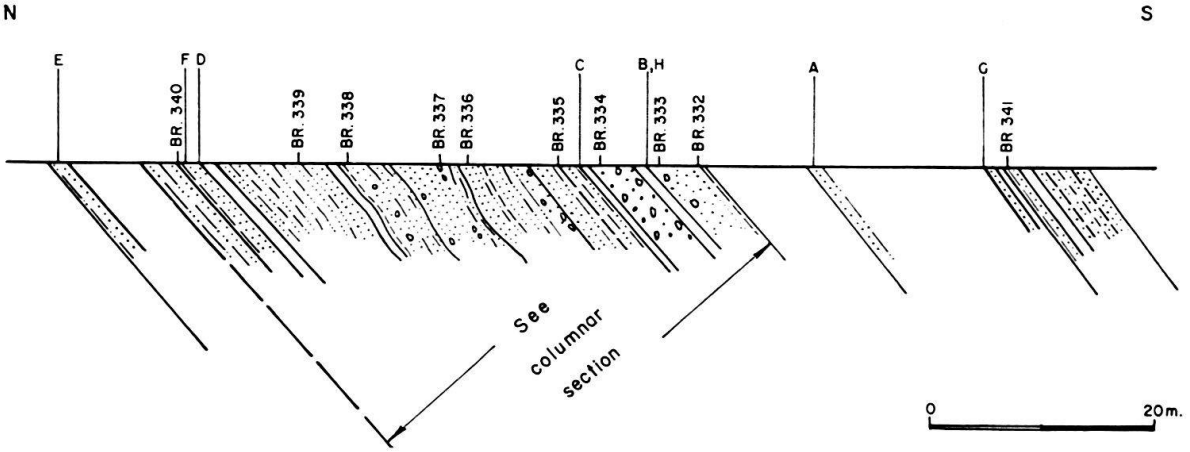


Fig. 33. Section across the type locality fo the Capdevila formation (lithologic Unit II).

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.

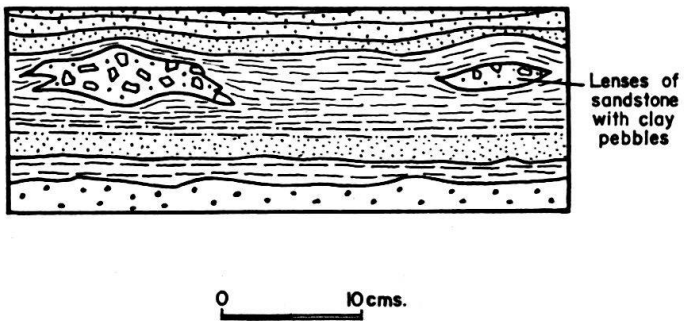


Fig. 34. Lithologic detail of the type locality of the Capdevila formation.

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).

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.

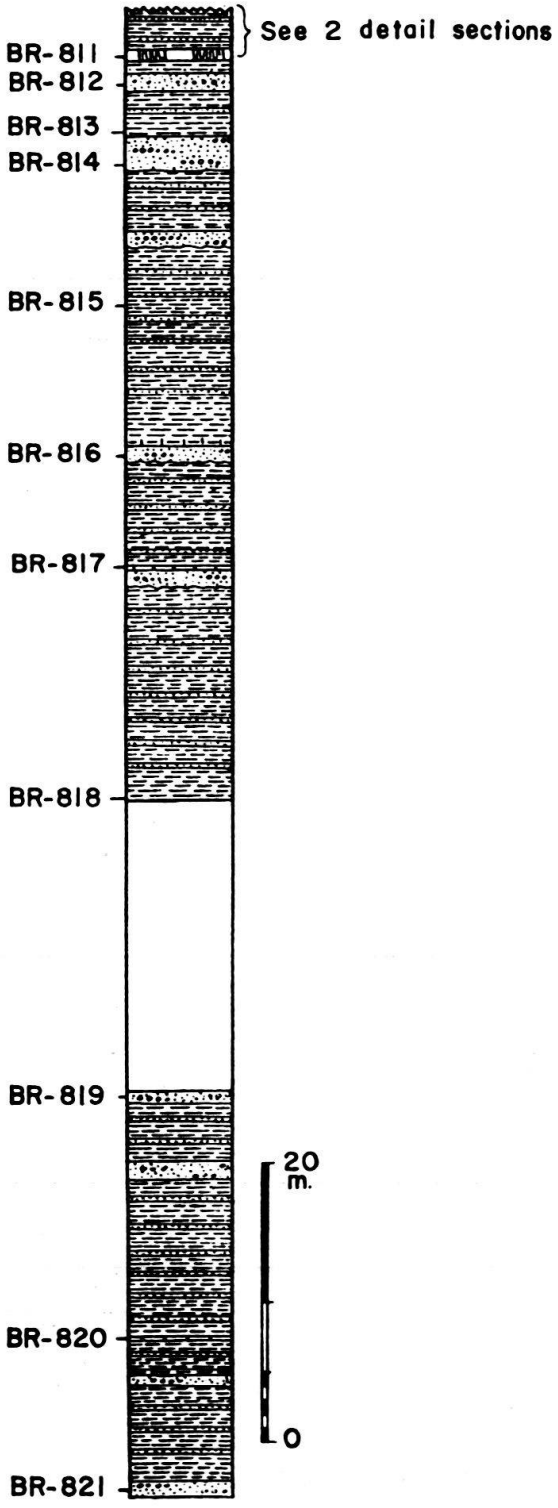


Fig. 35. Columnar section, Reparto Capri.

Chiloguembelina spp.
Globigerina spp. } minute forms

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).

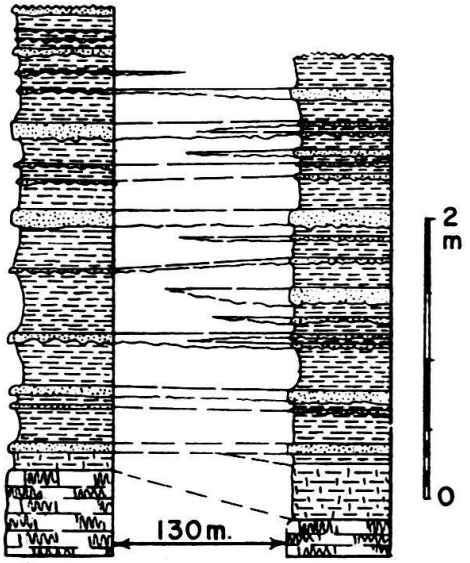


Fig. 36. Detail of the columnar section, Reparto Capri.

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., *Globigerina* spp. } minute forms

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

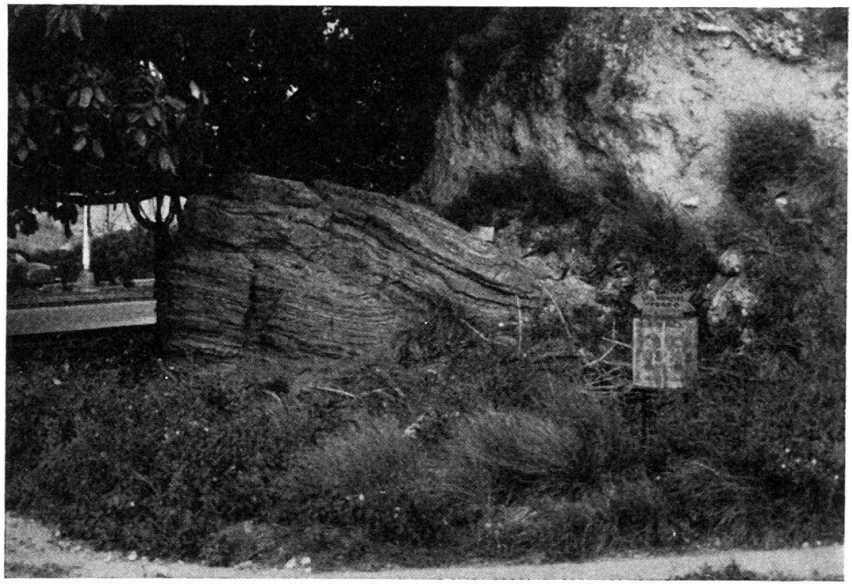


Fig. 37. Capdevila formation overlain by Toledo beds, Universidad formation, at the corner of Avenida de los Presidentes and Avenida de la Universidad.

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

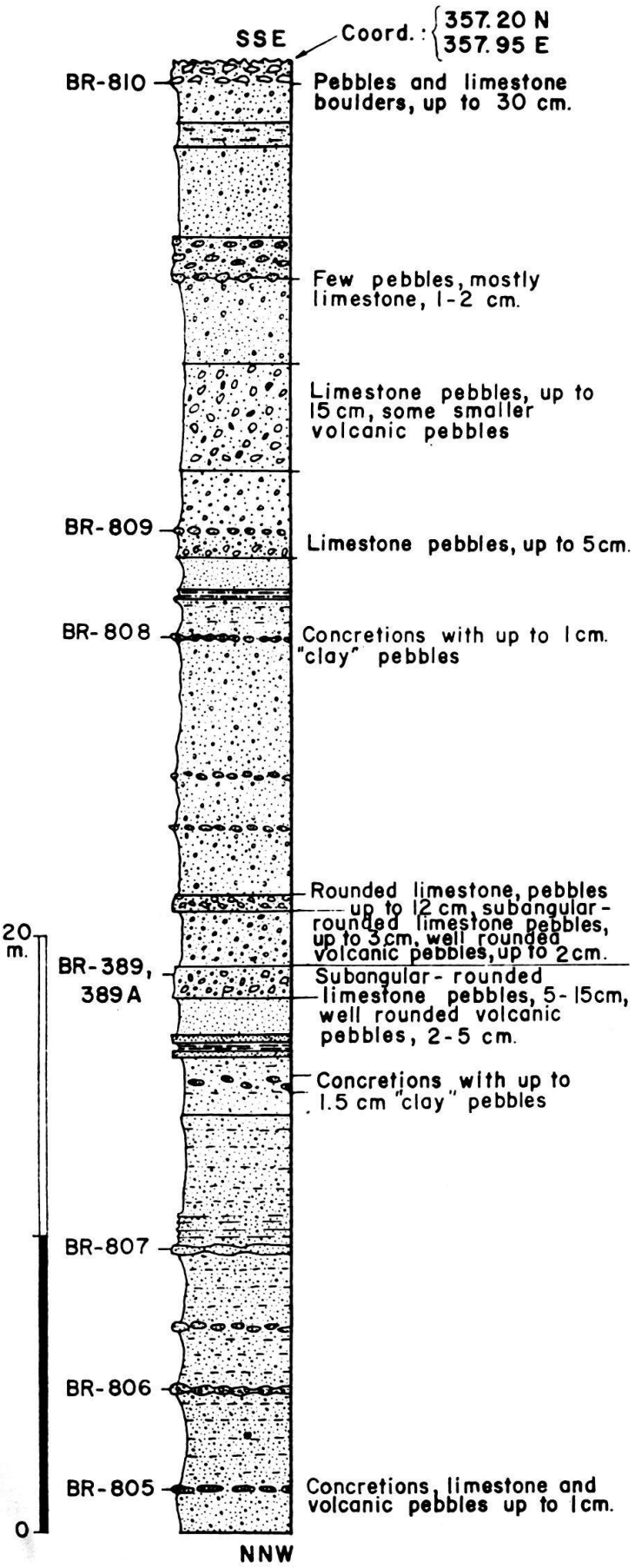
Discocyclina barkeri VAUGHAN and COLE
"Amphistegina" lopeztrigoi D. K. PALMER
Valvulineria extensa CUSHMAN and BERMÚDEZ
Vaginulina midwayana FOX and ROSS
Boldia cf. *madrugaensis* CUSHMAN and BERMÚDEZ
Vaughanina cubensis D. K. PALMER (reworked)
Asterorbis macei D. K. PALMER (reworked)

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



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.

Fig. 38. Columnar section of the lithologic Unit III of the Capdevila formation at the road from Capdevila to Arroyo Naranjo.

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

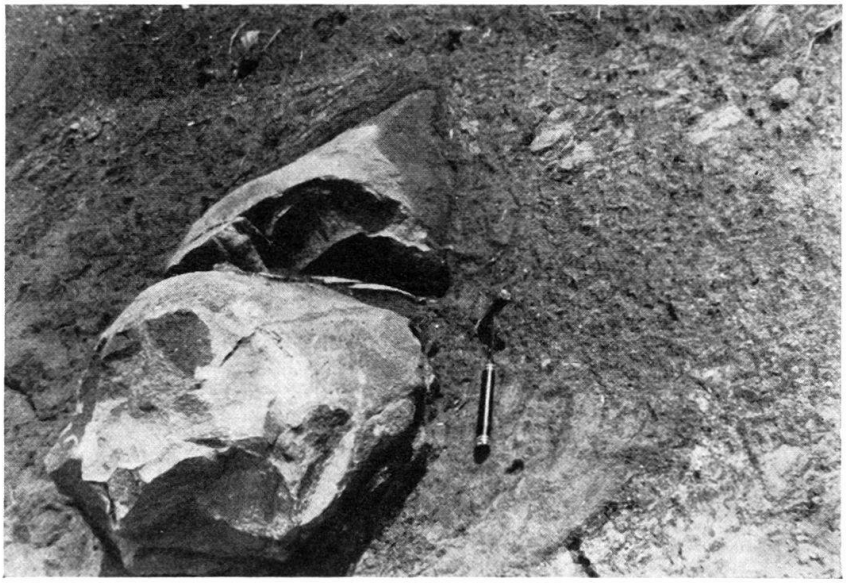


Fig. 39. Sandy concretion in the Capdevila formation southwest of Plaza del Mediodía, at the road to Guatao.

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.

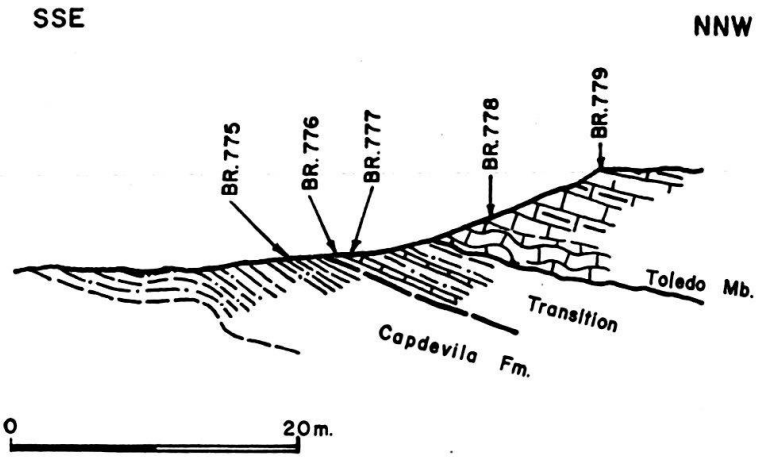


Fig. 40. Contact Capdevila–Universidad formations at Tejar Consuelo.

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.

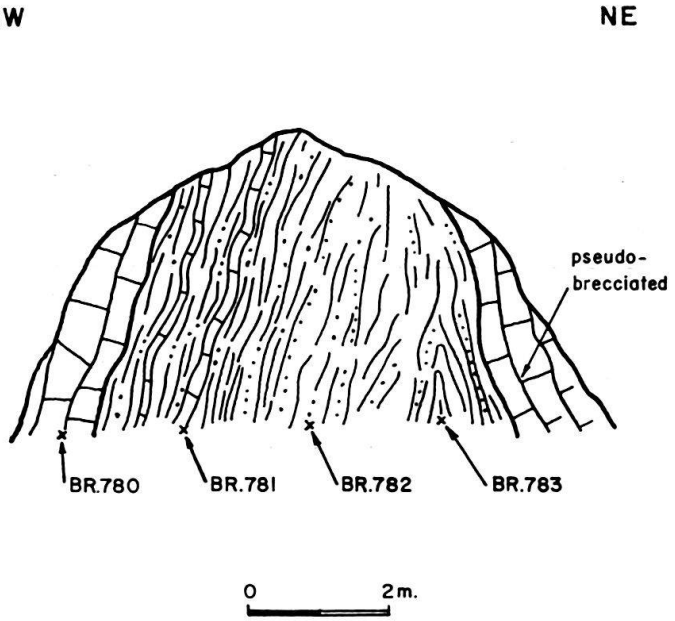


Fig. 41. Anticline with Capdevila beds in the core and Toledo beds at the flanks, eastern part of quarry at Tejar Consuelo.

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)

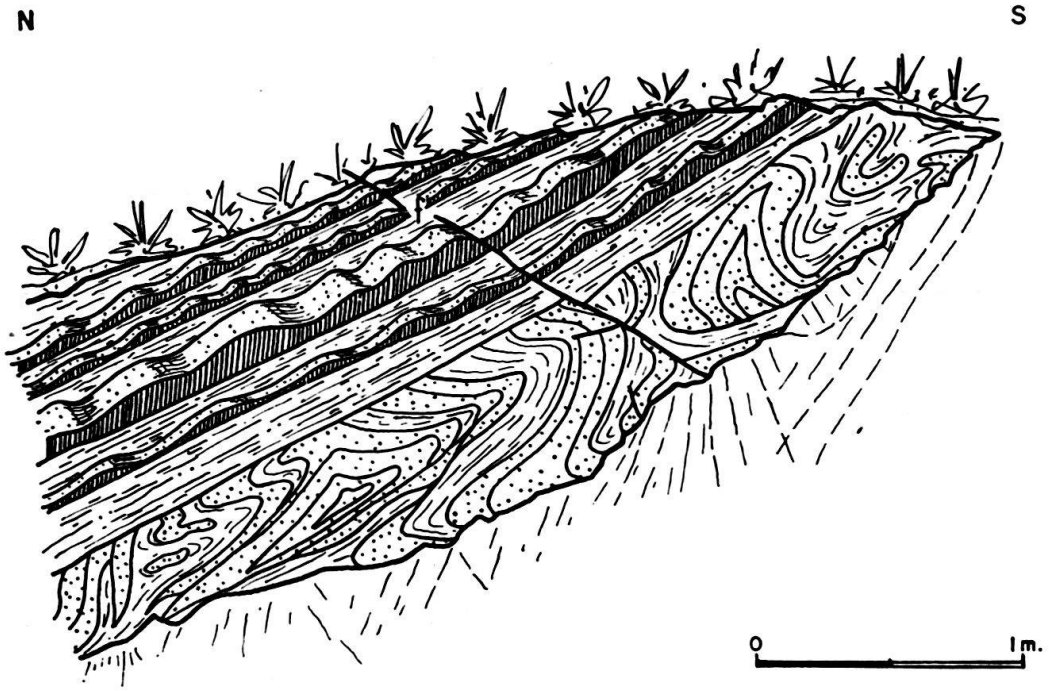


Fig. 42. Slumping in Capdevila beds.

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