Apolo formation

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tion 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 These turbulent conditions gradually subsided and were superseded by relatively quiet sedimentary conditions toward the calcilutaceous end-phase of the Peñalver cycle.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-

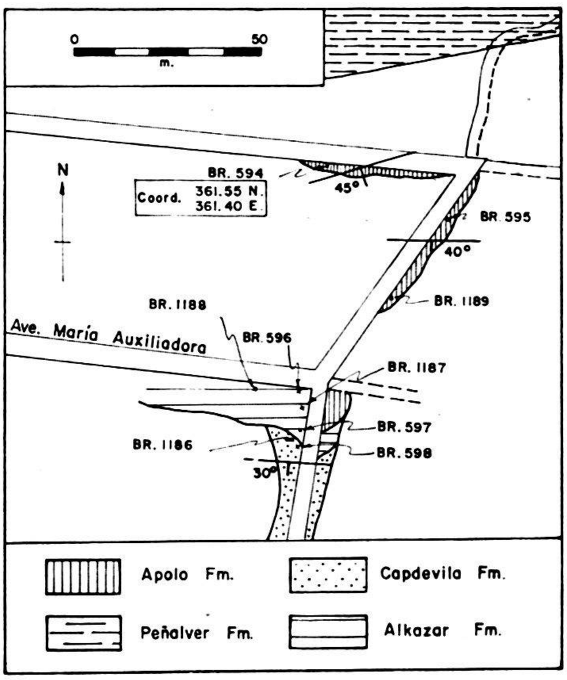

Fig. 23. Index map, type locality of the Apolo formation.

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-

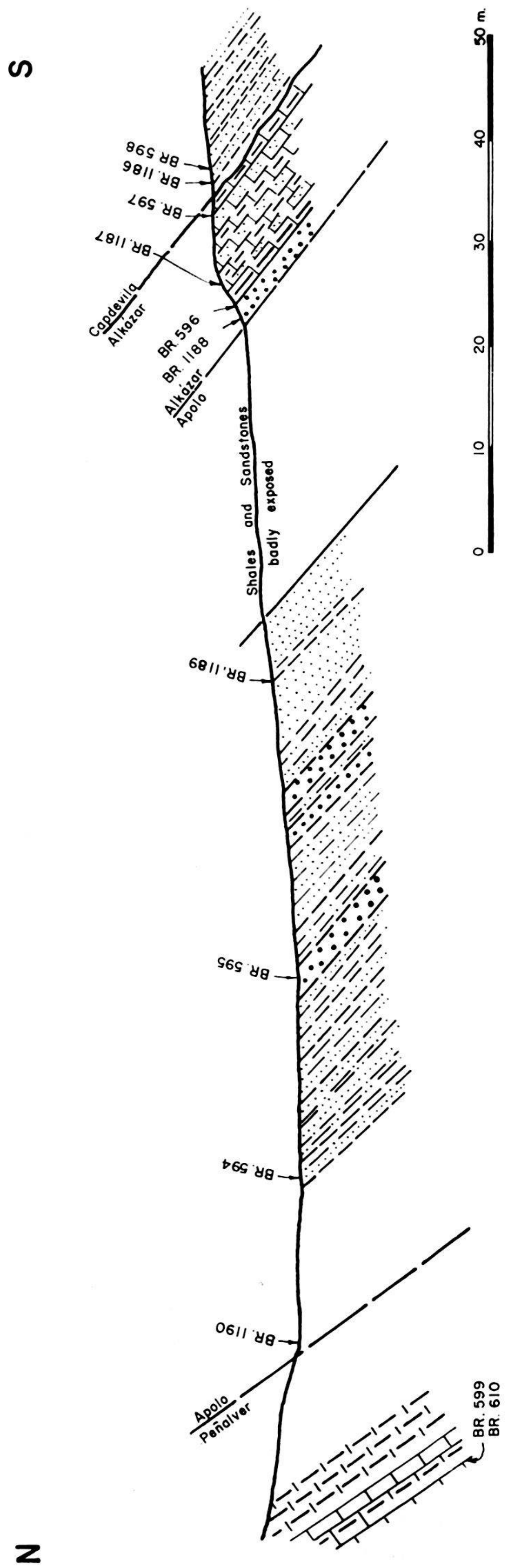

Fig. 24. Section across the type locality of the Apolo formation.

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).

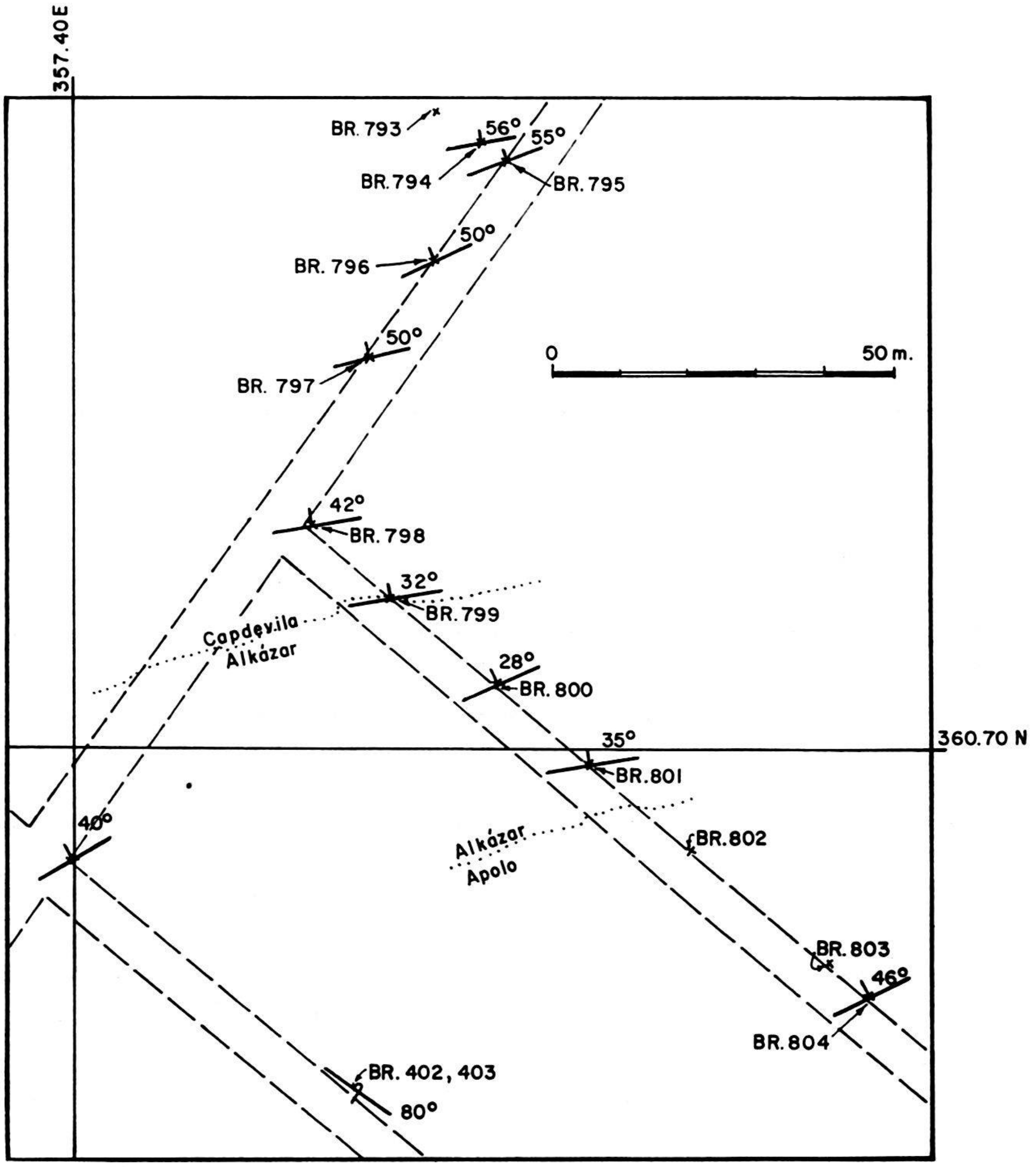

Fig. 25. Index map, Reparto Alta Habana.

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: Pseudoölitic 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.

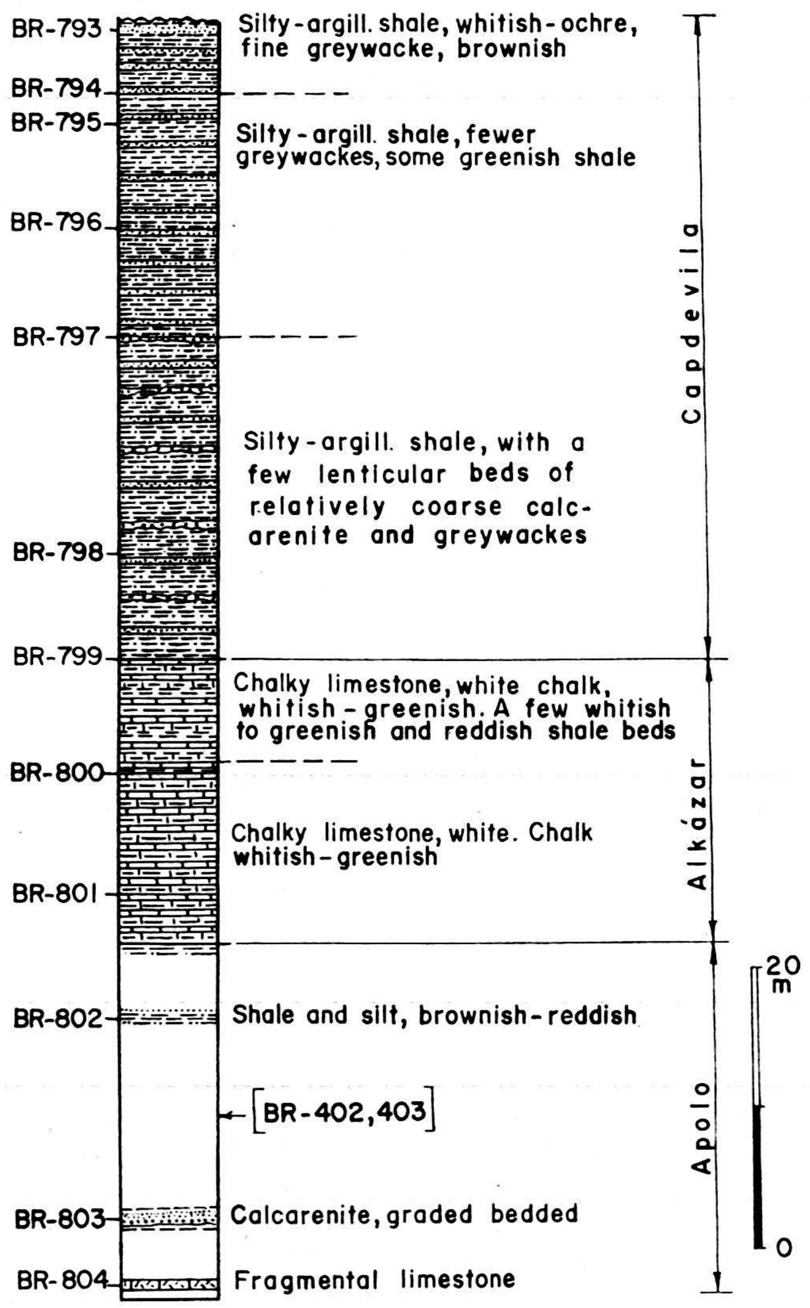

Fig. 26. Columnar section. Reparto Alta Habana.

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 }

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 pseudoölitic, 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