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

Autor: Brönnimann, Paul / Rigassi, Danilo

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

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

Peñalver Formation

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

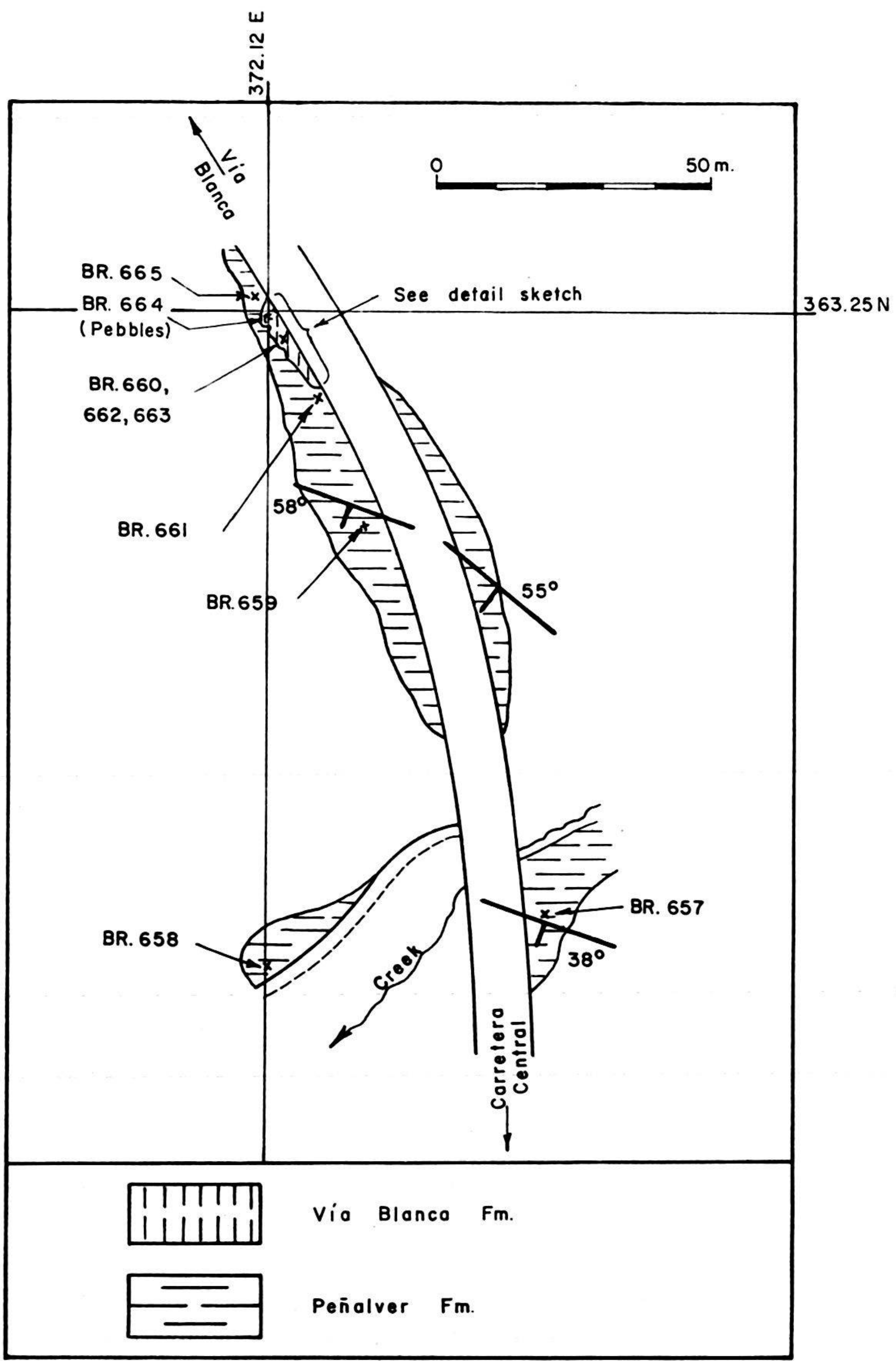

Fig. 11. Index map, type locality of the Peñalver formation.

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

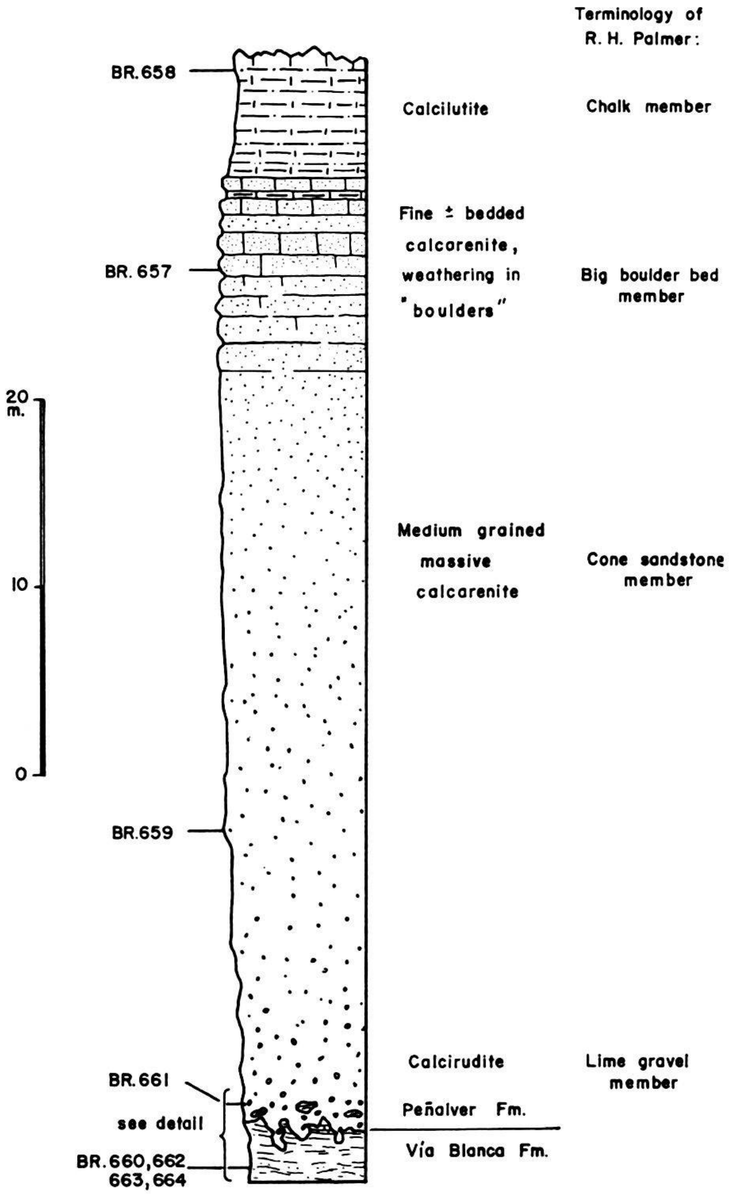

Fig. 12. Columnar section, type locality of the Peñalver formation.

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

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

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

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

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

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

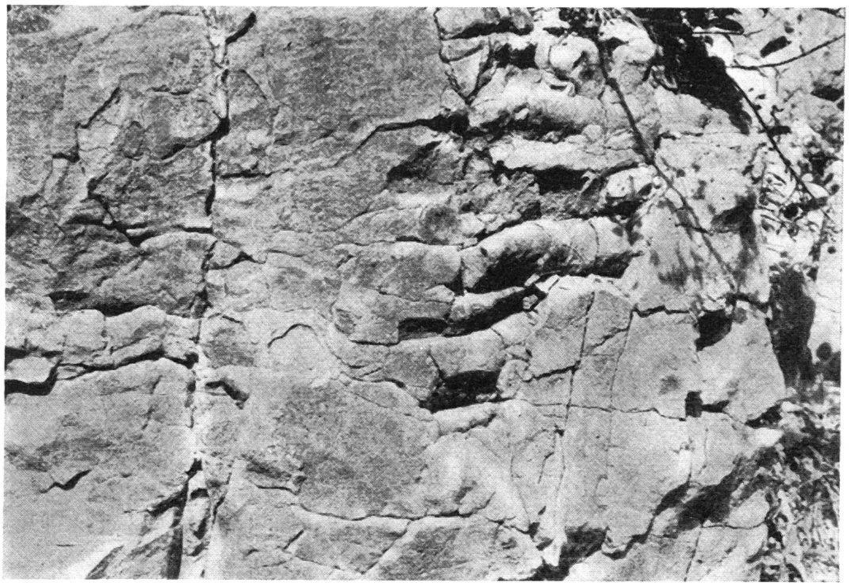

Fig. 14. Calcarenaceous middle part of the Peñalver formation with the elongate cylindrical structures ("cones" of R. H. PALMER). Cotype locality of the Peñalver formation at the southwestern side of the road cut of the Carretera Central, southeast of San Francisco de Paula. The bedding is vertical.

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

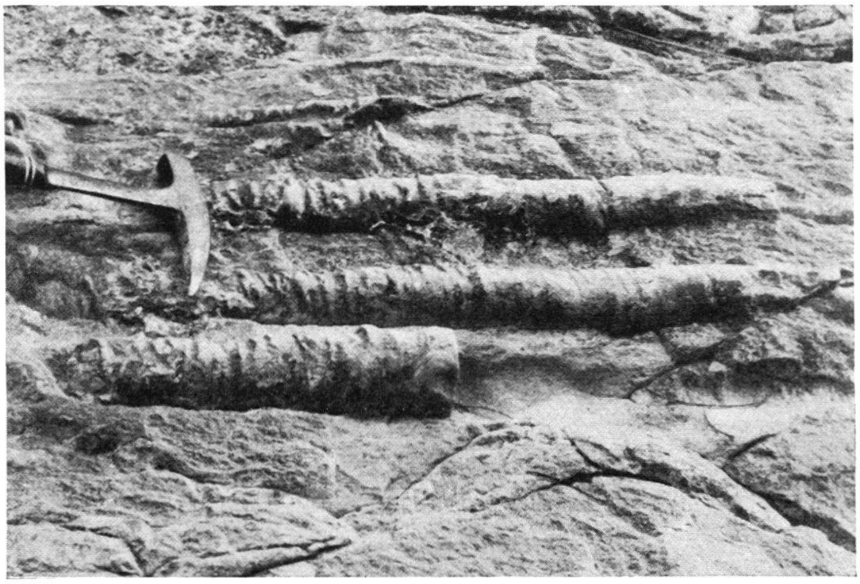

Fig. 15. Elongate cylindrical structures ("cones" of R. H. PALMER) from the middle part of the Peñalver formation at the road from Peñalver to Arango, about 2.4 km east-southeast of Arango. Bedding is vertical as in fig. 14.

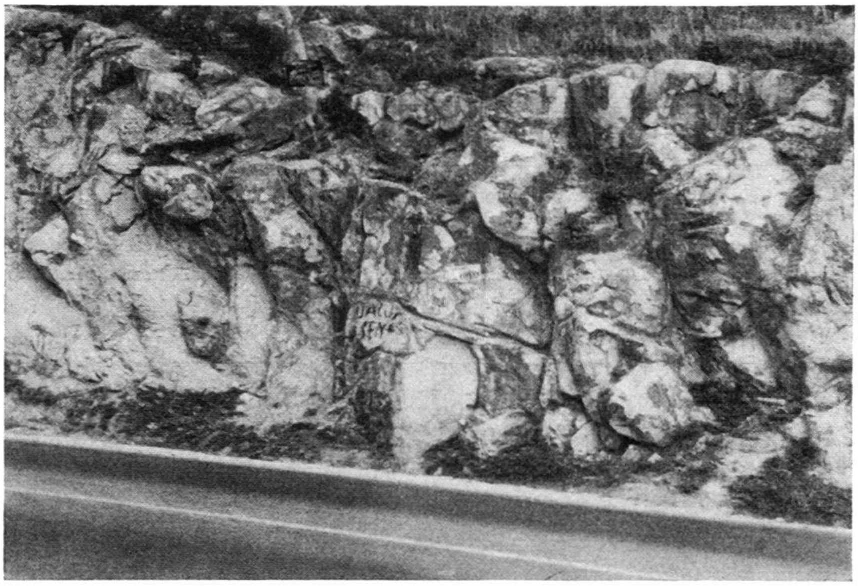

Fig. 16. Calcarenaceous lower middle part of the Peñalver formation with typical exfoliation weathering ("Big Boulders" of R. H. PALMER). Co-type locality of the Peñalver formation at the northeastern side of the road cut of the Carretera Central, southeast of San Francisco de Paula. Dip about 85° to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

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

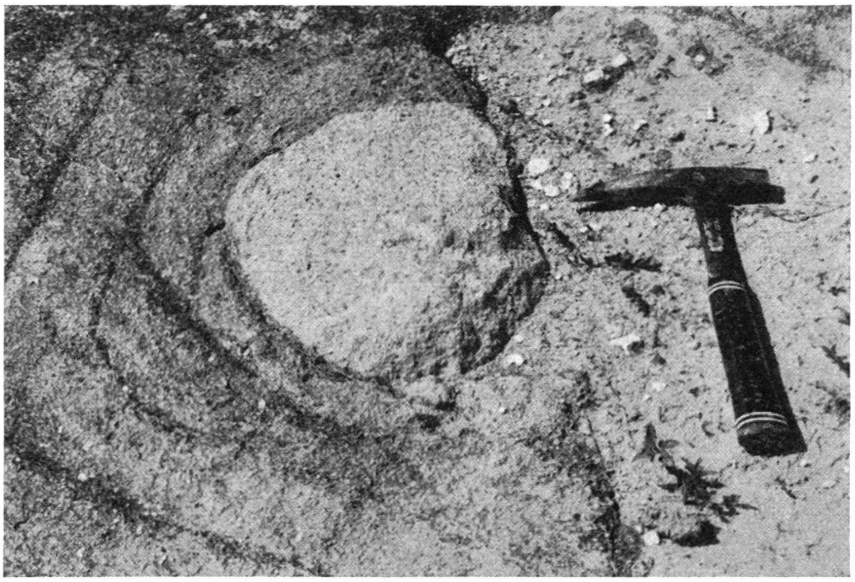

Fig. 17. Exfoliation weathering in the coarse calcarenaceous basal portion of the Peñalver formation on the road from Peñalver to Arango.

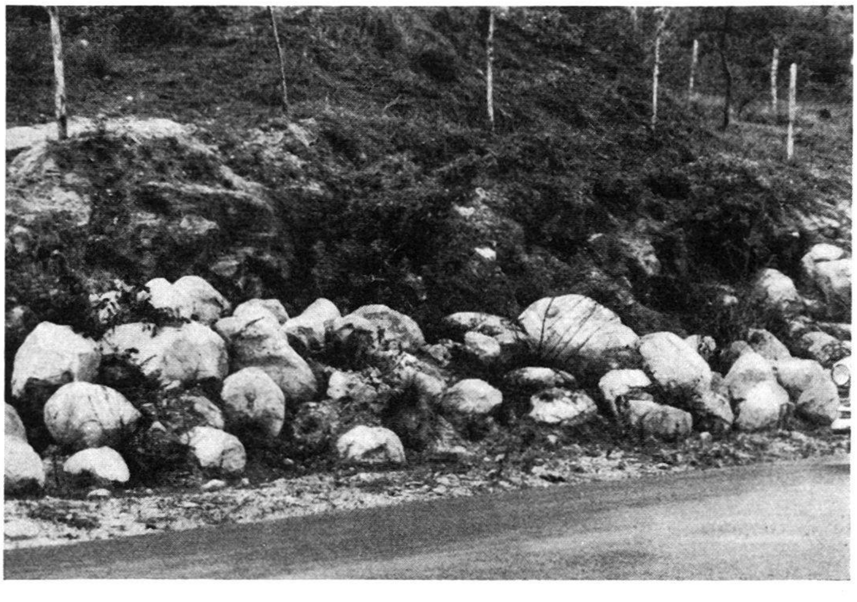

Fig. 18. Accumulation of exfoliation balls from Peñalver calcarenites, south of the type locality of the Peñalver formation on the continuation of the Avenida Monumental.

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

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

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

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

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

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

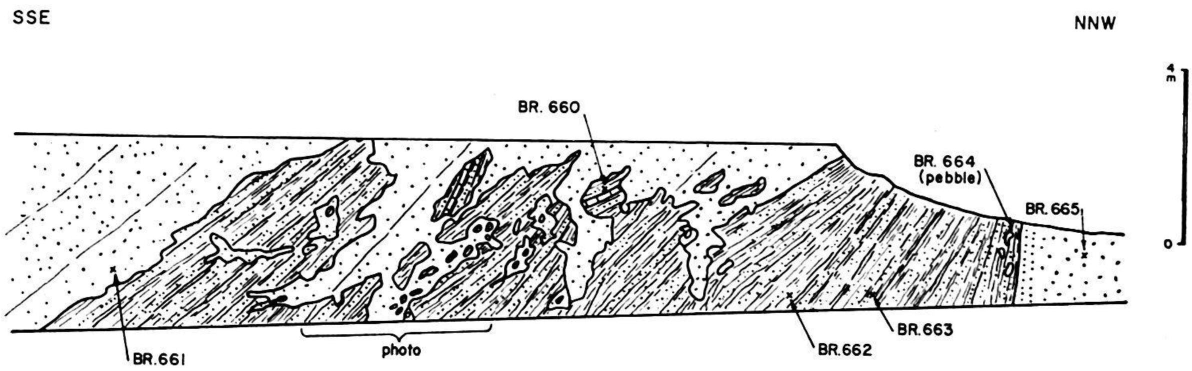

Fig. 19. Detail of the contact Vía Blanca formation (shales and graywackes) and Peñalver formation (calcareous clastics) at the type locality of the Peñalver formation.

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

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

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

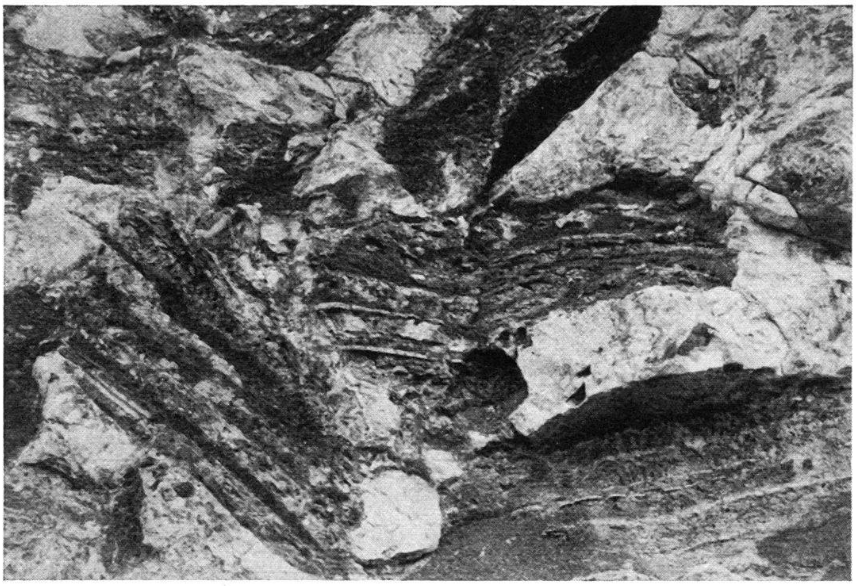

Fig. 20. Detail of the contact Vía Blanca formation and Peñalver formation. Blocks of Vía Blanca material are embedded in Peñalver clastics. Scale 1:20.

BR station 661
Lithology: Calcirudite, not well-cemented, friable, with abundant dark igneous grains, yellowish gray.
Texture: Coarse-fragmental, unsorted. Diameters of average components from 300 to 1000 μ. Components rather densely packed angular to subangular fragments of mollusks, mainly rudists, echinoderms, algae, larger Foraminifera and fragments of different limestones and of dark brown and green igneous rocks. Matrix microcrystalline calcite.
Assemblage: *Omphalocyclus macroporus* (LAMARCK)
Vaughanina cubensis D. K. PALMER
Orbitoides palmeri GRAVELL
Coskinolina n. sp.
Cosinella sp.
Sulcoperculina spp.
Kathina jamaicensis (CUSHMAN and JARVIS)

Siderolites skourensis (PFENDER)
Asterorbis sp.
Calcisphaerula innominata BONET

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

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

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

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

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

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

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

Other outcrops of the Peñalver formation

Quinta Canaria

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

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

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

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

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

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

Globotruncana arca (Cushman)
Globotruncana mariei Banner and Blow
Globotruncanella havanensis (Voorwijk)
Rugoglobigerina rugosa rugosa (Plummer)
Rugoglobigerina macrocephala Brönnimann group
"*Globigerina*" spp.
Pseudoguembelina cf. *punctulata* (Cushman)
Pseudotextularia elegans (Cushman).

San Francisco de Paula

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

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

BR station 393
Lithology: Calcirudite, light olive gray to light olive brown, with angular inclusions of non-calcareous olive gray clay and of yellowish gray calcareous shale with maximum diameter up to 5 cm. This lithology is approximately from the calcarenite-calcirudite portion of the Peñalver formation as illustrated by the photograph fig. 13.

Texture: Coarse fragmental, unsorted. Diameter of average components from about 100 to 900 μ. Components are fragments of mollusks, especially rudists, echinoderms, various types of limestones, dark brown and green igneous grains, and Foraminifera. Microcrystalline groundmass.

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

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

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

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

Jacomino

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

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

BR station 481

Lithology: Calcarenite, hard, yellowish gray.

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

Assemblage:
Globotruncana arca (CUSHMAN)
Globotruncana stuarti (DE LAPPARENT) group
Globotruncana mariei BANNER and BLOW
Globotruncana contusa (CUSHMAN)
Globotruncana lapparenti BROTZEN group
"*Globigerina*" spp.
Rugoglobigerina sp.
Heterohelix sp. or *Pseudoguembelina* sp.
Planoglobulina glabrata (CUSHMAN)
Pseudotextularia elegans (RZEHAK)
Siderolites skourensis (PFENDER)
Vaughanina cubensis D. K. PALMER
Sulcoperculina sp.
Calcisphaerula innominata BONET

BR station 482

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

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

Assemblage:
Globotruncanella havanensis (VOORWIJK)
Trinitella scotti BRÖNNIMANN
Globotruncana mariei BANNER and BLOW
Globotruncana stuarti (DE LAPPARENT) group
Globotruncana lapparenti BROTZEN group
Rugoglobigerina sp.
Heterohelix spp. or *Pseudoguembelina* spp.
Gublerina sp.
"*Globigerinella*" sp.
"*Globigerina*" spp.
Pseudoguembelina excolata (CUSHMAN)
Pithonella ovalis (KAUFMANN)
Coccoliths (abundant)
Nannoconus steinmanni KAMPTNER (rare) } reworked
Nannoconus truitti BRÖNNIMANN (rare) } reworked
Nannoconus globulus BRÖNNIMANN (rare) } reworked

Washed residue with
Globotruncana lapparenti BROTZEN group

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

Reparto San Pedro

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

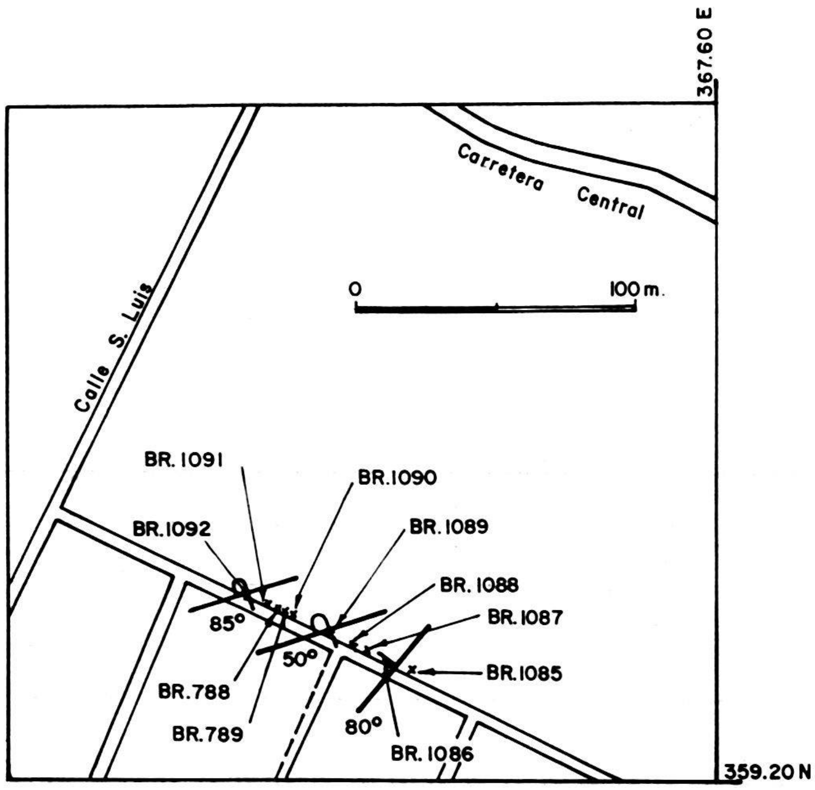

Fig. 21. Index map, Reparto San Pedro.

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

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

BR station 1085 (Vía Blanca formation)
Lithology: Chalk, pale yellowish orange.
Washed residue with
Globotruncana stuarti (de Lapparent)
Pseudoguembelina cf. *costulata* (Cushman)
Pseudoguembelina sp.
Calcisphaerula innominata Bonet.

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

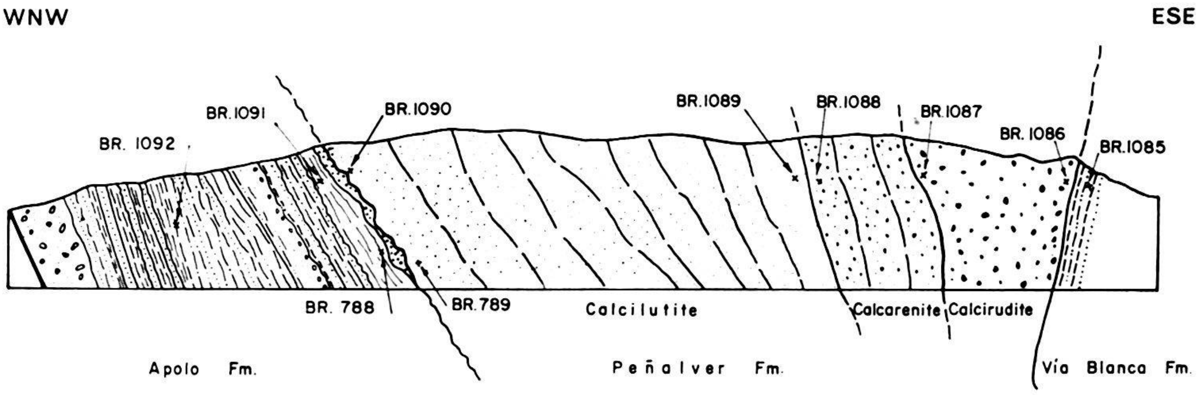

Fig. 22. Road cut at Reparto San Pedro. Scale about 1:600.

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

Vaughanina cubensis D. K. Palmer
Siderolites skourensis (Pfender)
Calcisphaerula innominata Bonet
Pithonella ovalis (Kaufmann).

Washed residue with
Globotruncana spp. (badly preserved)
Gublerina ornatissima (Cushman and Church).

BR station 1088 (Peñalver formation)
Lithology: Calcarenite, fine-grained, friable, pale orange.
Texture: As BR station 1087. Diameter of average components ranges from about 35 to 180 μ.

Assemblage:
Globotruncana lapparenti Brotzen group
Globotruncana stuarti (de Lapparent)
Rugoglobigerina rugosa rugosa (Plummer)
Rugoglobigerina macrocephala Brönnimann
Rugotruncana cf. *mayaroensis* (Bolli)
Rugotruncana sp.
Globotruncanella havanensis (Voorwijk)
Globotruncana mariei Banner and Blow
Globotruncana cf. *fornicata* Plummer (reworked)
Globotruncana cf. *linneiana* (d'Orbigny) (reworked)
Heterohelix sp. or *Pseudoguembelina* sp.
Pseudotextularia sp.
Omphalocyclus macroporus (Lamarck)
Siderolites skourensis (Pfender)
Vaughanina cubensis D. K. Palmer
Sulcoperculina sp.
Calcisphaerula innominata Bonet
Pithonella ovalis (Kaufmann).

BR stations 1089, 1090 and 789 (Peñalver formation)

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

Lithologies: Calcilutite, rather coarse, hard, conchoidal fracturing, yellowish gray.

Textures: Cryptocrystalline-argillaceous groundmass with abundant angular, minute, organic fragments and with minute grains of dark igneous rocks. Diameter of average components ranges from about 10 to 150 μ. Abundant planktonic microfossils.

Assemblage:
Globotruncana lapparenti Brotzen group
Globotruncana stuarti (de Lapparent)
Globotruncana mariei Banner and Blow
Globotruncanella havanensis (Voorwijk)
Rugoglobigerina rugosa rugosa (Plummer)
Rugoglobigerina macrocephala Brönnimann
Heterohelix sp. or *Pseudoguembelina* sp.

"*Globigerinella*" sp.
"*Globigerina*" sp.
Pseudotextularia sp.
Pithonella ovalis (KAUFMANN)
Calcisphaerula innominata BONET
Coccoliths
Nannoconus steinmanni KAMPTNER } reworked
Nannoconus colomi (DE LAPPARENT) } reworked

East of Casa Blanca

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

Environment and age

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

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

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

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

Apolo Formation

The Apolo formation is a new lithological unit between the Upper Maastrichtian Peñalver formation and the lower Eocene Alkázar formation. The type locality is situated about 1 km north of Arroyo Apolo, northeast of the eastern end of Avenida María Auxiliadora, Reparto Vibora Park, average coordinates 361.55 N and 361.40 E (see index map, fig. 23). The name is derived from Arroyo Apolo, a southern suburb of Habana at the junction of the highways from Managua and from Bejucal. The Apolo formation is a sequence of clays, silty shales, calcarenaceous graywackes, with some interbedded graded-bedded calcarenites with rare volcanic elements and nodular marls. The clays and silty shales are dark brown to reddish brown, the graywackes are brownish to grayish and greenish and the