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

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

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

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

Serpentinites, diorites and associated igneous rocks

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

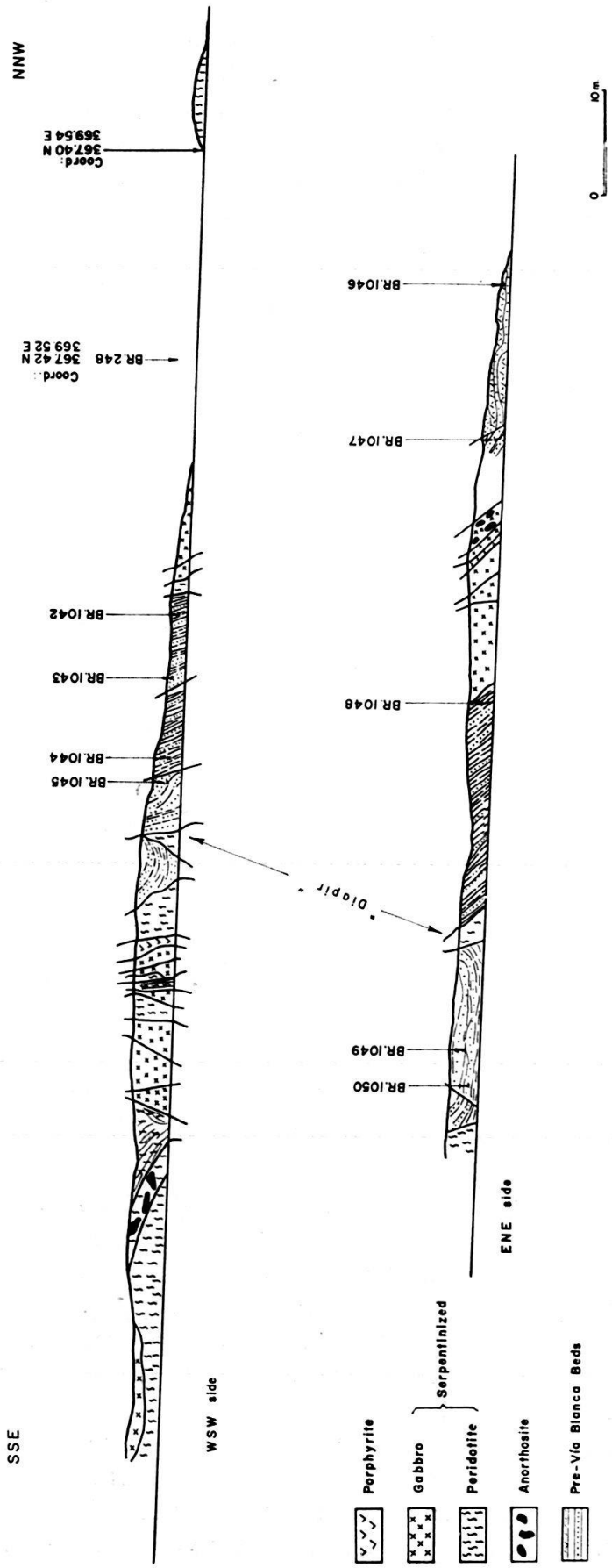

Fig. 1. Road cut at the continuation of the Avenida Monumental, across the serpentinite body of Guanabacoa.

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

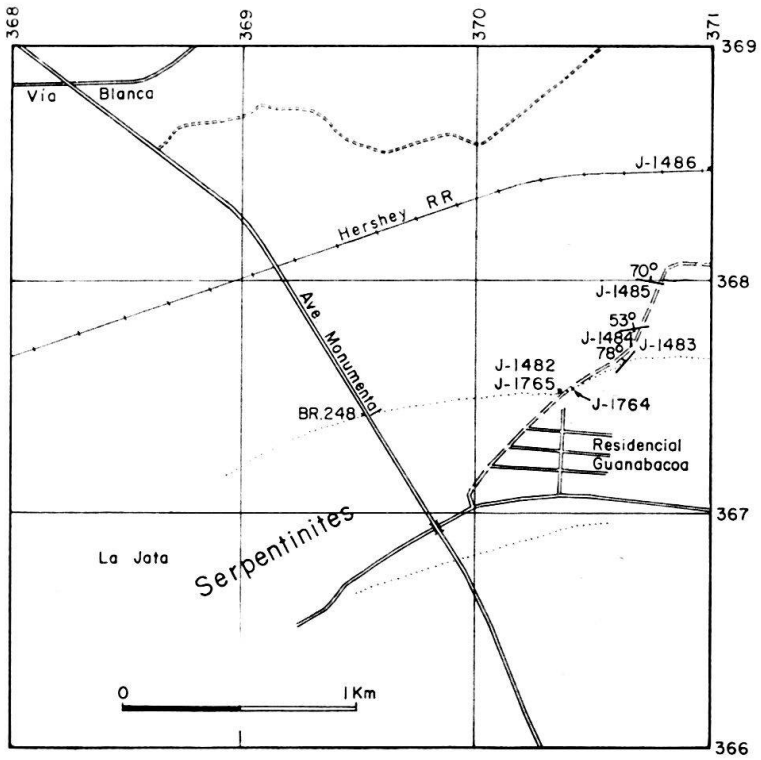

Fig. 2. Index map, Residencial Guanabacoa.

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

olivine and pyroxene crystals in the peridotite indicates slow cooling. This excludes the possibility of the serpentines being flows interbedded in the Upper Cretaceous, except if such flows were very thick, as was postulated by DUBERTRET in the Near East.

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

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

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

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

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

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

SCHÜRMANN (1935, pp. 340, 341) described the serpentines of central Cuba as syn-tectonic intrusions of the late Cretaceous (Laramid) orogeny. Those of western Cuba are according to SCHÜRMANN either intrusions of the Middle Eocene orogeny or they may represent masses tectonically displaced during this orogeny. The granodiorites, tectonically less involved than the serpentines, are regarded as younger, post-tectonic intrusions. According to M. G. RUTTEN (1936, p. 13) serpentine fragments were noted in the "Tuff formation" of central Cuba indicating that serpentine was formed prior to at least part of the tuffs. L. RUTTEN (1940, p. 542) in his note on the age of the serpentines in Cuba stated that on the "base of our [L. RUTTEN, M. G. RUTTEN, A. A. THIADENS, H. J. MAC GILLAVRY, and L. W. J. VERMUNT] field-observations, . . . all the serpentines are pre-eocene and

very probably pre-upper-cretaceous", and discussing PALMER's descriptions of serpentine contacts east of Habana, he (1940, p. 545) finds proof that ". . . the serpentines which occur E. of Habana Bay, are pre-upper cretaceous." As can be inferred from L. RUTTEN's introductory statements about the observations made by himself and his students in Las Villas (former Santa Clara) and Camagüey provinces, "pre-upper-cretaceous" means pre-"Habana formation", that is pre-Campanian, perhaps pre-Cenomanian (?) to Turonian if the pre-Vía Blanca beds are included as in the Habana group of the present interpretation. L. RUTTEN (1940, pp. 545, 546) is moreover of the opinion that "there is no evidence for a different age of the serpentines of the provinces of Habana and Matanzas and those of Santa Clara, Camagüey and Oriente. It would, indeed, be very remarkable, if such rare and 'aberrant' rocks as serpentines had been formed in so small an area as Cuba in two different geological periods." The latter remark refers to R. H. PALMER's (1934, 1938, 1944, 1945) opinion on the age of the serpentinites, which he believed were emplaced at different times, most of them during the Upper Cretaceous. In western Oriente Province, PALMER reported serpentine fragments in the Upper Cretaceous, and in Las Villas Province, a serpentine dike cutting the Eocene, and in Matanzas Province serpentine marmorizing Güines limestones (L. RUTTEN, 1940, p. 544). PALMER (1945, p. 18) also mentioned that THAYER (personal communication) found serpentine fragments in the Lower Cretaceous "Aptychus beds" indicating the occurrence of pre-Lower Cretaceous serpentine. PALMER therefore recognized different serpentine intrusions from pre-Lower Cretaceous to late Tertiary, post-Güines time. L. RUTTEN (1940) visited some of PALMER's serpentine localities in the Habana-Matanzas area and found no evidence for a post-Upper Cretaceous age of the serpentines.

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

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

of the lower volcanics, the intrusion of the Cuban ultramafics at an early date in Early Cretaceous time.

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

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

In Jamaica, the serpentinites, probably derived from peridotites, form together with apparently non-fossiliferous metamorphic rocks the basal complex of the Kingston district (MATLEY, 1929, 1951). The age of this series is pre-Mesozoic according to MATLEY, and the metamorphism probably caused by the Hercynian orogeny, and according to ZANS (1953) the age is Cretaceous, possibly Jurassic. MITCHELL (1955) puts the serpentinites between the Senonian and the Neogene. The basal complex is overlain by conglomerates, sandstones and shales of the Cenomanian to Coniacian *Inoceramus* series which correspond age-wise with the Provincial limestones of central Cuba (CHUBB, 1955, 1956) and with the pre-Vía Blanca beds of the Habana area. According to WILLIAMS (1959, p. 11) the Ceno-

manian to Turonian of the Central Inlier of Jamaica consists from bottom to top of the Basal conglomerate with andesitic and basic igneous pebbles, overlain by brown tuffaceous and calcareous shales of the *Inoceramus* beds, and the Lower Rudist limestone. A gap of Coniacian to probably Santonian age, corresponding to the similar gap in Cuba, separates the Cenomanian to Turonian from the ?Campanian Lower Tuffaceous series consisting of red weathering shales and conglomerates.

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

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

Diorites

There are only two outcrops of diorite near La Habana. A very small exposure occurs south of Guanabacoa, the other much larger is between Peñalver and Arango outside of the mapped area. R. H. PALMER (1934, p. 137, and geological map, text-fig. 1) mentions a small intrusion of serpentine and diorite near the south end of the Bahía de la Habana, west of Río Martín Pérez, which is probably identical with the amphibole diorite of Regla (L. RUTTEN, 1923; SCHÜRMANN, 1935, p. 341, footnote). Diorites are found in many other places in Cuba. They are well developed near Victoria de las Tunas, Oriente Province, and in the northern foothills of the Trinidad-Sancti Spiritus mountains of Central Cuba. These diorites range from gabbro diorite, as for instance at Holguín, Oriente Province, to quartz diorite. Marginal zones are often aplitic. The diorites are often intruding rocks of Upper Cretaceous age. One of the authors (D.R.) observed east of Sancti Spiritus,

Las Villas Province, evidence of contact metamorphism in late Senonian sediments. On the other hand, diorite pebbles occur in Maastrichtian beds (="Habana formation" of previous authors), and it appears that the main intrusive phase took place during the late Senonian. It was not possible to ascertain whether or not in the Habana area the diorites intruded into the pre-Vía Blanca and/or the Vía Blanca formation.

Neocomian limestones

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

From this road cut are the following random samples:

BR station 1118

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

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

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

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

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

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

This isolated outcrop is the only exposure in the Habana area of Neocomian limestones of the *Nannoconus steinmanni* zone. It is of deep-water facies and typical of the Neocomian limestones throughout Cuba. Its field-relationship with