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PRINCIPAL FEATURES OF CUBAN GEOLOGY[1]

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ABSTRACT

The Cuban orthogeosyncline consists, from north to south, of a platform region (Bahamas parageosyncline), a foredeep or miogeosyncline (Old Bahamas Channel, Cayo Coco, and Remedios facies-structural zones), a marginal elevation or welt (Las Villas facies-structural zone), and a eugeosyncline. The latter includes several intrageosynclinal depressions, of which the Zaza facies-structural belt is the most extensive, and some intrageosynclinal positive areas. The history of the orthogeosyncline lasted from Early Jurassic to relatively recent time.

The tectonic history may be divided into three gross cycles: Lower-Middle Jurassic; Upper Jurassic-Paleogene; and Paleogene-Neogene. Each gross cycle is divisible into *structural levels* or subcycles. In general, deformation is most intense in the oldest structural level and least intense in the youngest.

Continental drift of Cuba from South America, as postulated by Corral, does not seem likely Instead, an origin more like that which is explained by the tectogene hypothesis seems probable. However, the belt of negative gravity anomalies that underlies north Cuba coincides with the position of the marginal elevation, and not with the positions of the eugeosyncline or miogeosyncline.

Basically, the island of Cuba is part of a more extensive, but inactive, orthogeosyncline or island arc that extends the length of the Greater Antilles. The shape of this island arc probably was determined by the presence of a large island that occupied the present position of the Caribbean Sea. This island subsequently may have been subjected to the processes of basification, or conversion to oceanic crust. If this is true, Cuba now appears to be an intrageanticlinal structure within a new, modern Antillean geosyncline that includes the Greater Antillean arc and the newly formed oceanic areas nearby.

INTRODUCTION

The geology of Cuba is considered in publications by Lewis (1932), Schuchert (1935), Brodermann (1945), Palmer (1954), Butterlin (1956), Rigassi-Studer (1961), and Furrazola-Bermúdez *et al.* (1964). The purpose of the present paper is to summarize the basic geologic framework of Cuba on the basis of literature and work by the writer and his colleagues during recent years.

Cuba is in the northern part of the Antillean orthogeosyncline,[3] where it borders the Gulf of Mexico parageosyncline. In Cuba, the orthogeosyncline is divisible into two parts, a miogeosyncline and a eugeosyncline. The miogeosyncline occupies a zone along the northern side of the island, whereas the eugeosyncline occupies the remainder of the island, *i.e.*, most of Cuba's territory. The Yucatan deep and the Bartlett trough are south of the island, and are separated by the Cayman Ridge. These last-named structures probably are part of the Antillean orthogeosyncline.

ZONAL GEOLOGIC STRUCTURE OF CUBA

GENERAL

The territory of Cuba can be subdivided clearly into different facies-structural zones or tectonic units. Each facies-structural zone contains characteristic rock facies which are recognized by their lithologic composition, by the presence or absence of magmatism, by the character of rock dislocations, and by the presence or absence of characteristic useful minerals. In addition to the characteristic facies of the structural zones (tectonic units), great disjunctive dislocations and deep faults commonly bound them (Furrazola-Bermúdez *et al.*, 1964; Meyerhoff, 1965).

The Cuban orthogeosyncline is subdivided into the facies-structural zones representing depressions (furrows) or positive areas (welts) (Fig. 1). The Bahamas platform is at the north. Adjoining the Bahamas platform on the south is the foredeep (advance depression) of the Cuban orthogeosyncline where the following zones occur, from north to south: depressions of the Old

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[3] The terms: orthogeosyncline, parageosyncline, miogeosyncline, eugeosyncline are used by the writer approximately in the sense of H. Stille (1940).

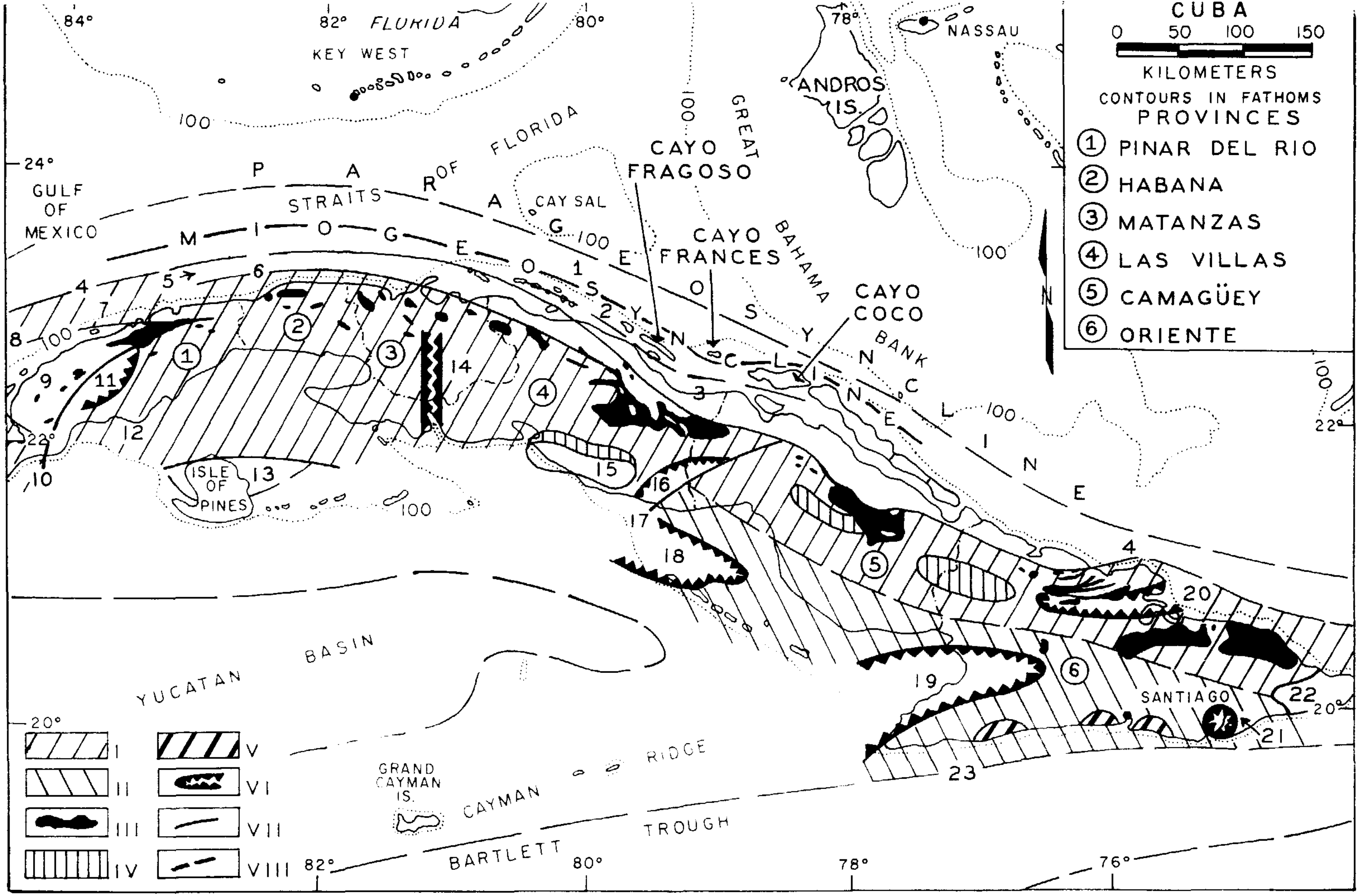

FIG. 1.—Tectonic sketch of Cuba. I–Cretaceous magmatic area (Zaza tectonic unit); II–Tertiary magmatic area (Cauto tectonic unit); III–Upper Cretaceous basic and ultrabasic intrusives; IV–Cretaceous granitoids; V–Tertiary granitoids; VI–Tertiary depressions; VII–deep fault; VIII–boundary between facies-structural zones (tectonic units).

Principal structures (north-south): *parageosyncline; miogeosyncline:* 1–Old Bahamas Channel depression; 2–Cayo Coco tectonic unit; 3–Remedios tectonic unit; 4–Sierra de Jatibonico deep fault; 5–Las Villas tectonic zone or marginal elevation; *eugeosyncline and intrageanticlines of Zaza tectonic unit:* 6–Las Villas deep fault; 7–Bahía Honda tectonic unit; 8–Consolación del Norte deep fault; 9–Pinar del Río tectonic unit; 10–Pinar del Río deep fault; 11–Palacios depression; 12–San Diego de los Baños tectonic unit; 13–Isla de Pinos tectonic unit; 14–Cochinos depression; 15–Trinidad tectonic unit; 16–Central basin depression; 17–La Trocha deep fault; 18–Ana María depression; 19–Cauto depression; 20–Nipe depression; 21–Guantánamo depression; 22–Oriente tectonic unit; 23–North Bartlett deep fault.

Bahamas Channel, Cayo Coco, and Remedios.[4] South of the Remedios depression is the geosynclinal marginal elevation (intrageosynclinal welt, or median belt), the Las Villas zone. This separates the miogeosyncline from the eugeosyncline. Farther south and southwest in the eugeosyncline are the intrageosynclinal structures such as the Zaza and Cauto depressions and smaller welts, or elevated zones, such as the intrageosynclinal uplifts of Pinar del Río, Isle of Pines, Trinidad Mountains, and Oriente. The Cauto zone is adjacent to the Bartlett zone on the south.

The most important deep faults which controlled (by one or another means) the distribution of different types of sediments and magmatism are the Pinar del Río, Consolación del Norte, Las Villas, Sierra de Jatibonico, Tuinucú, and possibly the Northern Bartlett faults.

PARAGEOSYNCLINE

Bahamas platform.—The main part of the present Bahamas platform is below sea-level. Geophysical data and drilled wells (Cay Sal and Andros Island) indicate that the southern part of the parageosyncline is filled with limestone and dolomite interbedded with anhydrite (Fig. 2). The thickness of the Paleogene and Neogene deposits is 1,200 meters, and of the Cretaceous and possibly uppermost Jurassic, 4,500 meters. According to geophysical data, the thickness of section (possibly only of Jurassic age) below the Cay Sal well is estimated to be 4,800 meters. Therefore, the total thickness of horizontally laid sedimentary rocks beneath the platform is approximately 10,500 meters. An almost identical section is present in the northeast part of the parageosyncline. From the foregoing, it can be supposed that, beginning at least from Early Cretaceous time, the southern part of this parageosyncline was covered by the sea, that it has been a basin of evaporation, and that such a basin, with a few interruptions, still exists.

[4] Certain, but not all, names used here for the major structural zones or tectonic units and faults were first used by C. W. Hatten, formerly of the Cuba California Oil Company, G. Pardo, Gulf Oil Corporation, P. Brönnimann, formerly of the Gulf Oil Corporation, and others in unpublished reports, as pointed out by Meyerhoff (1965). Hatten coined the term *tecto-unit* for some of these structural zones. Many details of the zones are published in Furrazola-Bermúdez *et al.* (1964).

MIOGEOSYNCLINE

South and southwest of the Bahamas platform the first geosynclinal structure occurs, the Cuban foredeep (advance depression). According to some geologists, the foredeep is part of the platform (Ducloz and Vuagnat, 1962). This structure is filled with Jurassic, Cretaceous, lower Eocene, and Neogene sedimentary rocks, principally in a carbonate facies (limestone, dolomite, marl) and terrestrial (landlocked) lagoonal deposits (salt, anhydrite). No indications of magmatic activity have been found in the foredeep.

Old Bahama Channel facies-structural zone.—The Old Bahama Channel depression or structure, which is postulated only on the basis of seismic data, is 20–40 kilometers wide. The axis of this zone coincides approximately with the central part of the modern channel, and has a slight inclination toward the west-northwest. The seismic data suggest that the Eocene-middle Miocene rocks are somewhat faulted, whereas the Cretaceous rocks are considerably more deformed, dips being as great as 25°. Even more severe faulting and dislocation of the rocks are seen on records at a depth of 8,000–9,000 meters. Conditionally, these deep strata may be considered to be of Early-Middle Jurassic age.

Cayo Coco facies-structural zone.—The Cayo Coco facies-structural zone (tectonic unit) comprises the northernmost part of the island proper, including the shallow shelf waters and the Sabana-Camagüey Archipelago.

The total width of the stratigraphic facies belt that underlies this zone, based on wells at Cayo Coco, Cayo Francés, and Cayo Fragoso, as well as geophysical data, is believed to be not less than 12 kilometers. Within this facies-structural zone, the section contains limestone and dolomite, with lesser amounts of anhydrite. These deposits range in age from Late Jurassic to Late Cretaceous, including the Maestrichtian Stage. Total thickness of the section is: (1) Upper Jurassic, $>$450 meters; Lower Cretaceous (Neocomian[?], Aptian, Albian), 3,000 meters; Upper Cretaceous, 3,310 meters; Paleogene, 80 meters; and Neogene, 500 meters (Fig. 2). In this zone the transition takes place from the intense geosynclinal type of deformation of the south to the deformation of the platform type on the north. In the Cayo Coco zone, broad structures are present with relatively gentle inclination of beds. Anti-

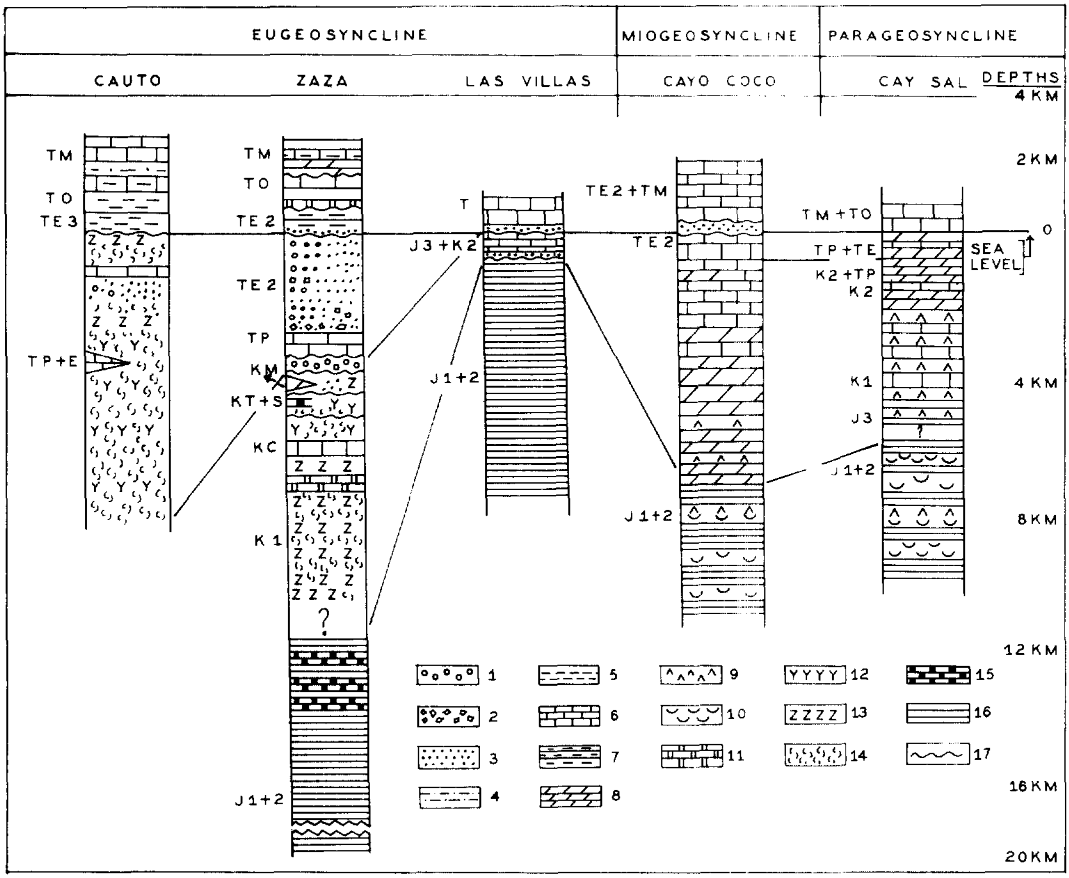

FIG. 2.—Stratigraphic columnar sections from the most important tectonic units, Cuba. 1–conglomerate; 2–breccia; 3–sandstone; 4–siltstone; 5–shale; 6–limestone; 7–marl; 8–dolomite; 9–anhydrite; 10–salt; 11–siliceous rocks; 12—intermediate effusive rock; 13—basic effusive rock; 14—tuff; 15—marble; 16—metamorphic schist; 17—unconformity. Letter symbols: T, Tertiary; TM, Miocene; TO, Oligocene; TE3, upper Eocene; TE2, middle Eocene; TE, Eocene; TP, Paleocene; K2, Upper Cretaceous; K1, Lower Cretaceous; KM, Maestrichtian; KT+S, Turonian plus Senonian; KC, Cenomanian; J3, Upper Jurassic; and J1 + 2, Lower and Middle Jurassic.

clines as well as synclines are present, broken by many faults and thrusts. During Jurassic, Cretaceous, Paleogene, and Neogene times, this zone constantly was sinking. These steady negative movements determined the nature of the sediments that were deposited. After each folding episode there occurred renewed subsidence and deposition, though at a later time deposits were removed by erosion in some places.

Remedios facies-structural zone.—A complete Mesozoic-Cenozoic section and the most complex facies relations of the foredeep are observed in the Remedios facies-structural zone. Beginning with the Upper Jurassic section, the stratigraphic sequence is composed almost entirely of carbonate rocks, limestone, and dolomite. Anhydrite and rock fragments are found in salt domes that intrude the Paleogene and Neogene. The evidence from these rocks indicates that fragments in the salt stocks, under the Upper Jurassic, are Lower-Middle Jurassic strata, consisting of sandstone, schist, anhydrite, and salt. The total section to basement is estimated to be 14 kilometers thick.

All Cretaceous and Eocene rocks are deformed into linear folds; there are also the aforementioned salt-dome structures which intrude and dislocate the Miocene deposits. Within this facies-structural zone, the pre-Maestrichtian, pre-Paleo-

cene, pre-lower Eocene, and middle Eocene unconformities may be seen clearly.

At the beginning of the Jurassic, this zone subsided steadily; subsidence continued at least until early Eocene time, after which moderately pronounced uplift took place.

Sierra de Jatibonico fault.—The foredeep is separated from the miogeosyncline by the great disjunctive dislocation of the Sierra de Jatibonico fault. This fault, approximately parallel with the trend of the island, is at least 450 kilometers long. (According to geological and geophysical investigations, 200 kilometers are on land and 250 kilometers are at sea.) The width of the zone of fracturing and rupture along the main fault ranges from 1 to 2 kilometers. The fault plane is vertical, though in some places it is inclined toward the south at an angle as low as 55°. This deep fault controlled to some degree the distribution and lithologic character of the sediments in the adjacent facies-structural zones.

Las Villas facies-structural zone.—The geosynclinal marginal elevation (intrageosynclinal welt, or median belt)—the Las Villas facies-structural zone (tectonic unit)—bounds the southern margin of the foredeep, which is filled with carbonate rocks, and separates it from the intrageosynclinal zones on the south that contain volcanic rocks. The stratigraphic section of the Las Villas zone is characteristically thin (990 meters), and is composed of Upper Jurassic and Lower Cretaceous limestone, siltstone, and other carbonate and siliceous rocks. These facts indicate that this zone was strongly positive during the Upper Jurassic and Cretaceous Periods. There was no further deposition in this zone after Cretaceous time.

Effusive rocks are not present in this zone. Ultrabasic, basic, and granitoid intrusions are present in the central part as well as at the periphery of the zone.

Las Villas fault.—The marginal elevation is separated from the intrageosynclinal basin on the south (Zaza depression) by the major deep Las Villas fault, whose length is approximately 800 kilometers, generally paralleling the island. Associated in some places with this fault are intrusions of ultrabasic and basic rocks. In many localities, the plane of the fault is almost vertical, but in others it dips toward the south. A very conspicuous facies change takes place approximately along the trace of the fault.

Eugeosyncline

Zaza facies-structural zone.—The Zaza facies-structural zone (tectonic unit) occupies a considerable part of the island. The most characteristic feature of the zone is the presence of Cretaceous effusive and intrusive rocks. These consist of ultrabasic, basic, and intermediate varieties; acid types are scarce. Paleocene, Eocene, Oligocene, and Miocene rocks are represented by various terrigenous and carbonate facies. The total thickness of the Cretaceous through Miocene formations is at least 7–8 kilometers. All of the rocks within the zone, except the Miocene, are very notably faulted and folded. The most intense deformation is in the area between the Trinidad intrageosynclinal geanticline and the Las Villas zone (marginal elevation) where steeply dipping or even overturned folds occur in the Eocene deposits.

It is in the Zaza zone where the Turonian, Campanian, pre-Paleocene, pre-Eocene, middle Eocene, pre-upper Eocene, pre-Oligocene, and pre-Miocene structural discordances were determined.

Intrusive rocks in this zone are distributed as follows. In the northern part of the area, intrusions of Upper Cretaceous ultrabasic and basic rocks are present. These are harzburgite, lherzolite, dunite, and anorthosite which are accompanied by dikes of analogous composition. These intrusions, especially the ultrabasic, are sheet bodies (sills) which have taken part in the folding and are broken into isolated blocks by numerous faults; feeder pipes are not observed. Farther south, intrusions of granitoid composition occur. These include quartz diorite, plagiogranite, granodiorite, and, less commonly, biotite granite. These intrusives are elongated in chain form, and are associated with numerous dikes of differing compositions. The intrusive bodies of granitoid composition possibly are associated with a fundamental tectonic zone through which magma penetrated to the upper part of the earth's crust.

Volcanic activity began during Early Cretaceous time and continued until the Maestrichtian The first cycle of volcanic activity lasted from Early Cretaceous until early Cenomanian time. Basic lavas predominated in this cycle. The second cycle (Turonian-Senonian) is characterized by volcanic eruptions of more acid composition. A third maximum (late Maestrichtian) is characterized by basic volcanic rocks. The greatest vol-

ume of volcanic rocks was extruded during the first cycle.

Zones in western Cuba.—In western Cuba, the Zaza facies-structural zone is divided into two branches by the intrageosynclinal uplift of Pinar del Río. One branch passes south of this uplift, and is called the San Diego de los Baños facies-structural zone; the other passes north of the Pinar del Río uplift and is called the Bahía Honda facies-structural zone. These two zones are very similar structurally but, in the Bahía Honda zone, igneous rocks are relatively abundant.

Cochinos zone.—In addition to the aforementioned structures, smaller depressions are present in central Cuba, oriented almost at right angles to prevailing structural-stratigraphic strike. The Cochinos depression, Matanzas Province, can be traced via gravity anomalies; it trends south-north and seems to be filled with Tertiary rocks. The Cochinos zone is bounded by faults with vertical offsets of 900–1,000 meters.

Central basin depression.—Another depression in the central part of Cuba is the Central basin on the Camagüey-Las Villas Provinces border. This is bounded by faults on all sides and is filled with terrigenous rocks of Eocene and Late Cretaceous ages.

Eastern Cuba.—In eastern Cuba, west of the Bahía de Nipe, is an elongate depression (Nipe depression) with a southerly trend. This is filled largely by clayey rocks of Eocene and Oligocene ages.

Pinar del Río facies-structural zone.—The intrageosynclinal geanticlines within the eugeosynclinal zone occupy a very small area.

In the western part of Cuba is the Pinar del Río facies-structural zone, an intrageosynclinal uplift, which is separated from neighboring zones by the deep faults of Pinar del Río on the south and Consolación del Norte on the north.

The deep fault of Pinar del Río, which can be traced on land at least 150–160 kilometers, is slightly inclined toward the southwest where it is associated with small intrusions of ultrabasic rocks. The deep fault of Consolación del Norte has a latitudinal strike and extends for a distance of at least 90 kilometers. Relatively large, elongate bodies of serpentinite and gabbroid rocks are associated with this fault.

In the Pinar del Río facies-structural zone, the principal sedimentary rocks are sandy and carbonate facies of Jurassic age. In addition there are insignificant quantities of Cretaceous, Paleogene, and Neogene rocks.

The Jurassic rocks are only slightly deformed in the southwest part of the zone, but are markedly deformed in the northeast. This intrageosynclinal structure is bounded by large disjunctive dislocations, which, to judge by their appearance, seem to be closely related to deep faults. Here the discordance of the Upper Jurassic (Oxfordian and pre-Tithonian?) is identified. The characteristics of this zone are the thick Jurassic sedimentary section (implying the presence of a strongly negative area here in Jurassic time) and the thin Cretaceous, Paleogene, and Neogene section (implying that this area was uplifted during much of these times).

Isle of Pines facies-structural zone.—This tectonic zone, southeast of the Pinar del Río structure and south of the San Diego de los Baños depression, does not have clearly visible limits. The island is surrounded by the sea and only a part of the zone is exposed. It is composed of metamorphic rocks among which different kinds of schist, quartzite, and marble are prominent. These are similar to those in the Pinar del Río zone, and conditionally are considered to belong to the Lower-Middle Jurassic and Upper Jurassic Series (the marble is believed to be Upper Jurassic).[5] One can suppose that this zone subsided during the Jurassic and was uplifted during the Cretaceous and Paleogene. Thus, the zone is similar to the Pinar del Río zone. It is possible that this zone is separated from the San Diego de los Baños depression by a fault.

Trinidad facies-structural zone.—The Trinidad tectonic unit, in the south-central part of Cuba, is a great brachyanticlinal structure surrounded by younger formations. These formations overlap the flanks of the metamorphic schist of the Trinidad zone. The metamorphic rocks which comprise this structure are referred tentatively to the Lower and Middle Jurassic. Overlying the marginal parts of this zone with great angular discordance are metamorphosed lava of the Lower and

[5] The age of 190 m.y. reported recently by Kuman and Gavilán (1965) from the Isle of Pines is an error for which the writer is responsible, and he apologizes for this error. For correct age, see Discussion by Khudoley and Hatten, this issue.

Upper Cretaceous Series, and sedimentary rocks of Paleocene, Eocene, Oligocene, and Miocene ages. Based on the analysis of facies, it may be presumed that, after Cretaceous time, the zone was uplifted more or less uniformly.

This zone is bounded on the north by the Zaza zone, and is separated from it by the Trinidad deep fault. Associated with this fault are small bodies of serpentinite and, possibly, a large intrusion of granitoid rocks.

Oriente facies-structural zone.—The Oriente tectonic unit is in the eastern part of the island and has been very inadequately investigated. It is possible that, on the basis of what is known of its geologic structure and the history of its evolution, this zone is similar to that of Trinidad.
zone is a great intrageosynclinal depression. Its
Cauto facies-structural zone.—The Cauto most characteristic peculiarity is the presence of volcanic rocks and lava of Paleocene and early-middle Eocene ages. Deposits of these ages crop out in linear, elongate folds, whereas younger rocks commonly crop out in brachyfolds. Clearly visible pre-Paleogene and middle Eocene structural discordances are present.

Three depressions filled with thick deposits (up to 2.5 kilometers) of Paleogene and Neogene ages are present in the Cauto zone. The Cauto depression, which crosses the entire island and its structural grain, is filled with Paleogene and Neogene formations; the thickness of the Miocene and Oligocene deposits exceeds 1,200 meters. The Guantánamo depression has a rounded shape and is filled with Oligocene and Eocene formations.

During the Cretaceous(?), Paleogene, and Neogene, this zone was primarily one of subsidence, although subsidence alternated with brief periods of uplift.

Bartlett depression.—This depression is south of the island. Its northern limit is a major deep fault along which magma rose to the surface. This is supported by the presence of effusive rocks of Paleocene age and of granitoid intrusions, associated with this fault, that lie along the south coast of Oriente Province. It is now known that granitoid intrusions cut Paleocene-lower Eocene deposits and the Vinent Formation. It is also known that the Vinent Formation is the same age as the El Cobre Formation (Paleocene-early Eocene).

At present, there are no geologic data which prove that the fault along the north side of the Bartlett depression (North Bartlett fault) is a wrench fault; wrench faulting is postulated by Hess and Maxwell (1953), Moody and Hill (1956), and many others.

Tectonics

The orogenic movements during the Jurassic, Cretaceous, and Tertiary Periods affected the entire island. The Nevadan, Subhercynian, and Laramide (Cuban) cycles are conspicuous.

The Nevadan orogenic cycle is definitely identified by a discordance at the top of the Middle and Upper Jurassic; the Subhercynian cycle by a Turonian–pre-Campanian discordance; and the Laramide by discordances which are pre-Paleogene, pre-Eocene, middle Eocene (Cuban), pre-upper Eocene, pre-Oligocene, and pre-Miocene (Fig. 3).

The most notable and most easily observed discordances are the post-Upper-Middle Jurassic, the pre-Campanian-Maestrichtian, and the middle Eocene, which divide the deformed rocks into three distinct, gross structural complexes, or cycles: Lower-Middle Jurassic; Upper Jurassic-Paleogene; and Paleogene-Neogene.

According to the degree of deformation, these complexes are divided into smaller units, *structural levels* (subcycles) and *sublevels* (still smaller cycles), which are separated by structural unconformity surfaces.

In Cuba, the following structural levels are distinguished: (1) Lower and Middle Jurassic; (2) Upper Jurassic-Lower Cretaceous; (3) Lower Cretaceous-Upper Cretaceous (Cenomanian); (4) Upper Cretaceous-Paleocene; (5) lower and middle Eocene; (6) middle Eocene-Oligocene; and (7) Miocene.

The Lower and Middle Jurassic structural level is composed mainly of terrigenous and metamorphic rocks which form elongated linear folds, strongly deformed, overturned in some places, and tilted and complicated by numerous disjunctive dislocations that strike in many directions. In the northern part of the island, where evaporitic domes are observed, the nuclei of the diapiric structures are formed by salt.

The Upper Jurassic-Lower Cretaceous structural level is composed mainly of carbonate rocks, which have different degrees of deformation in different parts of the island. In the western part

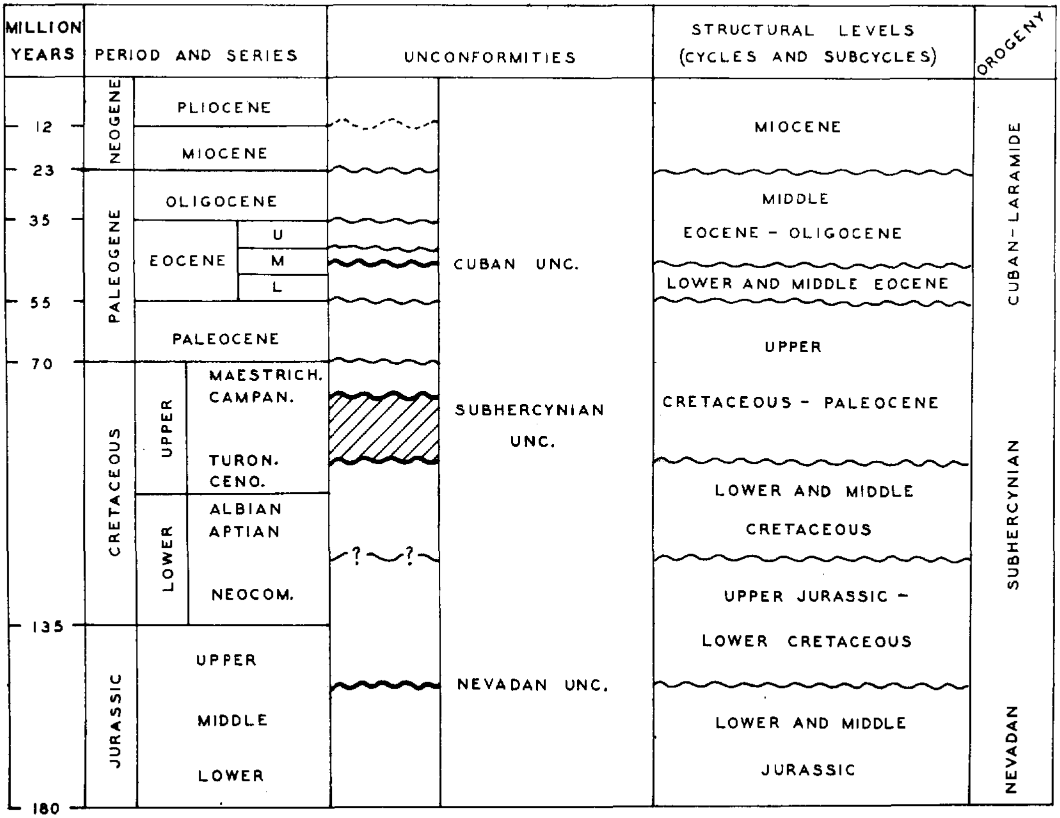

FIG. 3.—Major unconformities and structural levels (cycles and subcycles), Cuba.

of the Pinar del Río zone, the section has low dips, but on the east, stronger deformation is common and steeply dipping folds and vertical dips are observed. It is possible that a discordance separates the Tithonian from the Oxfordian, but this supposition needs verification.

The Lower-Upper Cretaceous structural level, composed of carbonate and volcanic rocks, also is characterized by complicated folding and faulting. Dips differ considerably along the flanks of folds. These rocks are cut by numerous faults and thrusts.

The Upper Cretaceous (Turonian-Maestrichtian)-Paleocene structural level is distinguished from the underlying level by the somewhat simpler structural forms of the folds, and by fewer disjunctive dislocations. In the intrageosynclinal structures, the Paleogene lies discordantly above more ancient formations.

The lower-middle Eocene structural level is similar to the Upper Cretaceous-Paleocene level in the character of its dislocations, although the degree of deformation is less; the inclination of fold flanks ranges from 20° to 50°.

The middle Eocene-Oligocene structural level differs greatly from earlier levels in that deformation is considerably reduced. In deposits of this level, some linear folds are observed with flank dips as high as 20°; 5° angles are observed commonly.

The rocks which compose the Miocene structural level lie on an uneven surface composed of more ancient formations. The Miocene is slightly deformed and the dips of beds in most places do not exceed 10–15°. However, near the disjunctive dislocations and mountains, steeper dips can be observed.

The limited data on rocks of Pliocene age do not permit conclusions of a regional nature, but it is probable that, during this epoch, slight shifts of the earth's crust took place.

Regarding the general structural grain of Cuba, two principal structural directions are observed. The first is properly termed *Cuban,* having a

strike that parallels the trend of the island. The second is the *Cayman* direction which parallels the strike of the Grand Cayman and Little Cayman Islands. This strike is WSW.-ENE., and is almost latitudinal. This direction is very noticeable in southern Oriente Province.

In addition to the principal structural directions mentioned, there are early Tertiary structural trends associated with depressions such as the Cauto, Cochinos, and the Central basin depressions. These cut strongly across both the Cuban and Cayman directions.

Hypotheses Concerning Origin of Island of Cuba

There are two hypotheses concerning the origin of the island of Cuba; these involve continental drift and tectogene formation.

The hypothesis of continental drift as it concerns Cuba is elaborated in the works of J. I. del Corral (1939, 1940), who considered the Greater Antilles to have been situated originally along the northern coast of Colombia and Venezuela, where the Greater Antilles and northern South America formed a single block. At the beginning of the Miocene Epoch, the block began to separate. The Greater Antilles part was displaced first toward the northeast and later toward the west. During Quaternary time, the Greater Antilles acquired its present configuration and orientation.

However, comparison of the geologic structures of Colombia and Venezuela with those of Cuba reveals significant differences. Moreover, the dry hole (Pan American No. 1 Tortuga Shoals) in Ana María Gulf, south Cuba, reveals the presence of Miocene, Oligocene, Eocene, Paleocene, and Cretaceous formations which are markedly different in lithologic character from what should be present if Cuba once was adjacent to northern Venezuela.

Hess and Maxwell (1953) and Eardley (1954) have expressed their opinions on the hypothesis of subcrustal convection currents and the formation of tectogenes in Cuba. According to the opinion of these scholars, there are two tectogenes in Cuba. One extends along the north coast and is characterized by negative gravity anomalies and by peridotite intrusions. The second underlies the southern part of the island from the Isle of Pines to the Trinidad tectonic unit, thence toward the southeast to the metamorphic-rock outcrops of Oriente Province. Eardley supposed that the northern tectogene was of middle Cretaceous age and that the southern was of Late Jurassic age. These two tectogenes are not now active.

According to the classical tectogene hypothesis, the tectogene axis must coincide with the zone of negative gravitational anomalies beneath the northern part of the island; it can not coincide with the southern tectogene, where no negative anomalies are found. However, this is not in accord with geologic data, because the negative anomalies coincide with the Las Villas zone (marginal elevation) in the southern part of the foredeep. Only near the city of Camagüey does the gravity minimum include the northern part of the Zaza intrageosynclinal depression (Soloviev *et al.*, 1964). On the basis of the geologic structure and lithofacies present in Haiti and the Bahamas, it may be postulated that the marginal elevation of the orthogeosyncline has a sublatitudinal strike and lies between these islands; this idea is corroborated indirectly by the presence of the zone of negative anomalies observed in this inter-island region (Hess, 1938, Butterlin, 1956; and others).

In this way, and by using the geologic structure of Cuba as a basis, it may be supposed that the zones of negative gravity anomalies occur near the marginal elevation and foredeep of the orthogeosyncline, where the major deep faults also occur. If this supposition is correct, it may be possible, with some reservations, to project on the basis of the negative gravity anomalies the extent of certain zones of the orthogeosyncline.

The writer believes that the island of Cuba and the island arc of the Greater Antilles represent a sinuous Laramide zone of folding and that this zone has undergone a long period of geosynclinal evolution. Deep faults and vertical movements of the earth's crust have played an important role in the evolution of the geosyncline and the arc.

The curved, sinuous pattern of the Greater Antilles island arc probably represents the original (primary) configuration of this Mesozoic-Cenozoic orthogeosyncline. South of this arc there probably was a large island, which was a land area for a long period of time. This island (the present region of the Caribbean Sea), after submersion, may have undergone the process of basification and oceanic development (*i.e.*, the fusion and dissolution of granitic layers), related to the emer-

gence of superheated basalt masses from the deeper zones of the earth's crust (Beloussov and Rudich, 1960).

The presence of strong positive gravity anomalies (up to 450 milligals) in the Caribbean Sea and areas adjacent to Cuba confirms the hypothesis of basification and ocean formation in this sector of the earth's crust. Moreover, the intense positive anomalies observed in the southern part of Oriente Province (up to 165 milligals) and in regions near the Bartlett depression probably are additional support for the concept of basification processes in the Caribbean area.

The island of Cuba is, in the writer's opinion, an intrageanticlinal structure within a new, or modern, geosynclinal region embracing the Antilles and the Caribbean.

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