Structural and Stratigraphic Elements

The generalized geologic map of Cuba (Figure 54) shows that the island is segmented into eight general areas of pre-upper Eocene outcrops surrounded by relatively undisturbed later Tertiary sediments. Although there are similarities between them, each area has its own stratigraphic and structural characteristics. From northeast to southwest, these areas can generally be grouped as follows: (1) north-central sedimentary terranes: from northern Las Villas to northern Oriente; (2) basic igneous-volcanic terranes: from northern Pinar del Rio to eastern Oriente; and (c) southwestern sedimentary terranes: from Pinar del Rio and Isla de la Juventud to southeastern Oriente.

These areas are complexly deformed structurally and are present-day topographic highs. They are surrounded by a relatively thin and much less disturbed cover of sediments ranging in age from late lower Eocene to Pleistocene. These areas are large-scale, mostly post-Eocene, uplifts.

PRE-UPPER EOCENE

As already mentioned in the Overview section of this publication under the Regional Setting subsection, in Cuba, essentially, no stratigraphic mixing exists between the continental margin and deep-water marine (miogeosyncline) sediments and the volcanics and volcanioclastics (eugeosycline). In other words, with a few exceptions, all the mixing is of structural origin. Eight major outcrop areas exist as follows.

Western Cuba

1) Pinar Del Rio area. Sediments ranging in age from possibly older than Middle Jurassic to lower-middle Eocene are present in a stack of folded and faulted thrusts sheets (nappes) dipping generally to the north. The direction of thrusting is believed to be northward. Along the north coast, near Bahia Honda, ultrabasics and Cretaceous volcanics are present. The general strike is northeast. This area extends into the western Habana Province.

2) Isla de la Juventud area. This consists mostly of a core of relatively low grade, but intensely deformed metamorphics of Middle to Upper Jurassic and possible Cretaceous age, similar to the older part of the section in Pinar Del Rio. This core has the general structure of a dome with the lower metamorphic grades in the center. In contact with the metamorphics, unmetamorphosed Cretaceous volcanics outcrop in the northwestern part of the island.

Central Cuba

1) Habana-Matanzas area. This consists of Cretaceous volcanics and volcanic-derived sediments, as well as sediments as young as lower-middle Eocene, outcropping in an extremely deformed series of fault blocks. Scattered bodies of ultrabasic rock and some rare outcrops of unmetamorphosed Lower Cretaceous limestones exist. Dips are extremely variable, from horizontal to vertical, and the surface expression of the faults is nearly vertical. However, deep drilling along the north coast has proven that these rocks are structurally underlain by Jurassic and Cretaceous carbonates unrelated to the volcanics. The general strike is west-northwest.

2) Las Villas–northwestern Camaguey area. This area is similar to the Pinar Del Rio area in the sense that
numerous facies of Upper Jurassic to lower–middle Eocene sediments are present. However, although the area is highly fragmented by vertical faults and is complexly folded, the general appearance is that of several long (more than 100 km [62 mi]) south-dipping belts. The carbonate sediments are generally found to the northeast, the ultrabasic igneous in the middle, and the Cretaceous volcanics and volcaniclastics in the southwest. The northernmost exposed belt, the Yaguajay belt, shows massive carbonates similar to, and of the same order of thickness, as the Florida–Bahamas banks. The degree of deformation is most intense in the middle, mostly ultrabasic, area, between the carbonates to the north and the volcanics to the south. The general strike is northwest. Near the south coast of Cuba is the massif of Escambray, which consists of an igneous complex and variously metamorphosed, generally low-grade, Jurassic and Cretaceous sediments very similar to the Pinar Del Rio section. The Escambray massif consists of two nearly circular domes and, as in the Isle of Pines, the metamorphic grade is lowest in their cores. The Las Villas–northwestern Camaguey area has the most complete sequences of sedimentary, volcanic, and igneous rocks occurring in the greatest variety of observable relationships on the island. For this reason, it is used here as a type geologic province and is the basis for many interpretations that will be extended to other parts of the island. 3) Central Camaguey area. This area is similar to the Las Villas–northwestern Camaguey area; however, with the exception of the extensive Cretaceous massive carbonate exposures of the Sierra de Cubitas and a few scattered outcrops of sedimentary facies, most of it is covered by ultrabasic and other igneous and Cretaceous volcanics intruded by large bodies of granodiorite. A steep southwestern dip exists, and the general strike is northwest.
**Eastern Cuba**

1) Northern Oriente area. This is very similar to the central Camaguey area and consists mostly of ultrabasics and Cretaceous volcanics, with the exception of an area of massive carbonate exposures north and west of Gibara. The dips are very steep toward the south, and the structures trend in a northwest–southeast direction in the west. Toward the east, the strike swings to an east-northeast direction where the sedimentary and volcanic facies, as well as the ultrabasic bodies, strike out to sea between Gibara and the Nipe Bay. Note that the massive carbonate outcrops of Yaguajay in Las Villas, Cubitas in Camaguey, and Gibara in northern Oriente appear to be three large, northwest–southeast en echelon structural highs partially surrounded by and apparently emerging out of an igneous and volcanic terrane.

2) Southeastern Oriente area. This is located south of Nipe Bay and northeast of the Guantánamo depression. Ultrabasic and other igneous rocks as well as Cretaceous to lower Eocene volcanics make up most of the outcrops. In general, they appear less disturbed than in other parts of Cuba; however, in the Sierra del Purial, nearly horizontal thrust sheets of ultrabasics lie on top of Upper Cretaceous volcanics. In Asuncion, in easternmost Cuba, low-grade metamorphics of Jurassic and Cretaceous age outcrop. Again, as with the previously mentioned metamorphics, they exhibit a strong similarity to part of the sedimentary section of Pinar Del Rio.

3) Southwestern Oriente area. Formed by the Sierra Maestra and located south of the Cauto depression, it consists almost entirely of Paleocene and lower–middle Eocene volcanics and volcanioclastics, with associated intrusives and a few Upper Cretaceous volcanics.

The pre-upper Eocene rocks will generally be described from north to south and west to east, and the most complete sections will be described first. All the sedimentary sections (miogeosynclinal rocks) will be described together and separately from the basic igneous-volcanic sections (eugeosynclinal rocks).

**POST-UPPER EOCENE**

The eight areas described above emerge topographically from a relatively undeformed late lower Eocene or younger cover that, in places, can reach a thickness of several thousand feet. The areas of younger cover are

1) The northern coast of Habana, Matanzas, Las Villas, and Camaguey
2) Southern Pinar Del Rio, Habana and Matanzas, and the Gulf of Batabano
3) Southeastern Las Villas Central Depression and the Gulf of Ana Maria
4) The Cauto depression and the Gulf of Guacanayabo
5) The Nipe Bay
6) The Guantánamo depression

These basins definitely are folded and faulted, but to a much lesser extent than in the pre-upper Eocene rocks.

The post-middle Eocene Tertiary sediments will be described according to their geographic areas. In general, the sections consist of classical epiorogenic sediments, although possible time differences exist in the change from flysch to molasse sedimentation between northern and southern Cuba.

**DEVELOPMENT OF THE CUBAN STRUCTURAL AND/OR STRATIGRAPHIC NOMENCLATURE**

The overall regional-stratigraphic history and the structural evolution of Cuba are relatively simple and not unique in the evolution of orogenies and continental margins. However, the position of Cuba on the southern border of the North American continent has been responsible for a complex tectonic history. The Cuban area was successively (1) part of the African and North American craton, (2) a passive margin north of a spreading center with strong left-lateral component, (3) a foreland of what appears to be a subduction zone (with ophiolite obduction in between), and finally, (4) subjected to strong left-lateral shear. This series of events has tectonized the geologic evidence to such an extent that few interpretations are incontrovertible.

From 1958 to 1985, there was very little communication between Cuba and the West. However, some of the published information that filtered out in the last 30 yr is of outstanding quality, such as the works by Millán and Somin (1975, 1976, 1981, 1985a, b) on the metamorphics, those by Piotrowska (1986a, b, 1987a) and Pszczolkowski (1985, 1987) in Pinar Del Rio and Matanzas, and Iturralde-Vinent (1969, 1970, 1972, 1975a, b, 1977, 1981, 1985, 1996, 1998) in general geology. These authors have used western stratigraphic nomenclature and their work is easily interpretable.
Unfortunately, much other information follows Soviet-era practice of naming rocks by age and interpretive basin classification, such as “Cretaceous parautochthonous miogeosynclinal,” which makes correlation with simple lithostratigraphic units difficult. In a few cases, the Cuban published information appears erroneous when compared to the solidly established pre-1960 data. Therefore, some of the recent information, when added to the natural geological complexities, increases the problems of interpretation.

It has to be mentioned that the Mapa Geologico de la Republica de Cuba (Pushcharovsky et al., 1988), on data collected up to November 1, 1985, is the best overall published source of information available yet. Another excellent publication is the Mapa Tectonico de Cuba (Pushcharovsky et al., 1989).

**Gulf’s Stratigraphic Nomenclature**

When Cuban Gulf Oil initiated systematic geologic mapping of central Cuba in 1951 at the scale of 1:40,000, the confusion over preexisting terminology was such that it was decided to establish a framework of stratigraphic units as if the geology of the island was totally unknown. Conventional rules of stratigraphic nomenclature were strictly adhered to; any association of rocks with characteristic and recognizable lithologic features were given a formation name. The age was determined through fossils or stratigraphic relationships and had no effect on the lithostratigraphic terminology.

The number of formations thus described by the Cuban Gulf Oil was quite large, on the order of 125 for the pre-upper Eocene in central Cuba. With the extreme structural complexities, many groups of outcrops had recognizable characteristics, but were totally disconnected from each other, so that their relationships could not easily be determined in the field. In addition, to avoid misgrouping, it was deemed necessary to separate related lithologies that, under less extreme circumstances, might have been given a member rank and grouped under one formation name.

In addition, the extreme structural shortening juxtaposes many lithologies that normally would be spread across a large area. It can be said that the large number of recognizable lithologic units across such a relatively small area is a measure of the magnitude of the telescoping of the basin. It should be emphasized that many of the stratigraphic units that have been published in the recent literature, notably in Pinar Del Rio and in the metamorphic massifs, are well defined and follow accepted international guide-lines of stratigraphic nomenclature (Hedberg, 1976; Salvador, 1994).

**The Belt Nomenclature Problem**

Several important related terms have been widely used in Cuba throughout the last 39 yr. These are belts, facies-structural zones, structurofacies zones, zones, tectonostratigraphic units, tectonic units, tecto-units, etc. The fact that in central Cuba, the names of these so-called units, zones, or belts have been freely interchanged by different authors increases the confusion considerably. For instance, the Las Villas unit of Hatten is approximately Pardo’s Cifuentes and Placetas belts, whereas Pardo’s Las Villas and Sagua la Chica belts are (more or less) Hatten’s Zulueta unit; Ducloux’s Remedios zone is Pardo’s Yaguaraj, Jatabonico, and Cayo Coco belts or Hatten’s Remedios and Cayo Coco units; and so forth. Figure 55 is a chart showing the terms that have been most commonly used in central Cuba. What follows is an attempt to explain the origin and the reason for such terminology and the ensuing confusion.

Although the complexity of the pre-Tertiary geology of Cuba has long been known (DeGolyer, 1918), Rutten, in 1936, recognized that, broadly speaking, the Las Villas Province could be divided into two terranes: limestone to the north and igneous-volcanic to the south. In 1937, a Cuban geologist, Ortega y Ros, properly identified, described, and named many of the Jurassic, Cretaceous, and Paleogene stratigraphic units of central Cuba. Unfortunately, his work appeared in an obscure publication and remained unnoticed until the middle 1950s.

By the late 1940s, the two-terrane scheme had been further refined by various geologists, and the standard subdivisions of central Cuba became massive Remedios carbonates to the north, serpentine and Tuff series to the south, and the radiolarian-rich, thin-bedded, siliceous Aptychus Limestone in between.

As Cuban Gulf Oil initiated the geologic mapping that began with the pre-upper Eocene of central Cuba, it became apparent that certain areas were characterized by successions and associations of lithologies quite different from those in adjoining areas, although the ages represented were similar. Because these areas tended to be elongated along the strike, they were named “belts.” They were strictly informal operational subdivisions. In 1953, Pardo (Cuban Gulf’s Memorandum 92, p. 4) wrote the following:

Northern Las Villas and northwestern Camaguey can be subdivided in several parallel northwest,
<table>
<thead>
<tr>
<th>Author - Date</th>
<th>Belts - Zones</th>
<th>Facies-Structural Zones</th>
<th>Tectonostratigraphic Units</th>
<th>Tecto-Units</th>
<th>etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>This paper - 2007</td>
<td>Carbonate Platform</td>
<td>Slope or Scarp</td>
<td>Platform to Deep Basin</td>
<td>Basic Igneous-Volcanic</td>
<td>Metamorphic</td>
</tr>
<tr>
<td>Coastal Province</td>
<td>Jaguajay</td>
<td>Jatibonico</td>
<td>Siquia la Chica</td>
<td>Las Villas</td>
<td>Placetas</td>
</tr>
<tr>
<td>Pardo - 1954</td>
<td>Coastal</td>
<td>Jaguajay</td>
<td>Jatibonico</td>
<td>Siquia la Chica</td>
<td>Las Villas</td>
</tr>
<tr>
<td>Hatten - 1958</td>
<td>Cayo Coco</td>
<td>Remedios</td>
<td>Zulueta</td>
<td>Las Villas</td>
<td>Placetas</td>
</tr>
<tr>
<td>Ducloz and Vaught 1962</td>
<td>Remedios</td>
<td>Camajuani</td>
<td>Placetas</td>
<td>Santa Clara</td>
<td>Manicaragua</td>
</tr>
<tr>
<td>Khudoley - 1967</td>
<td>Cayo Coco</td>
<td>Remedios</td>
<td>Las Villas</td>
<td>Zulueta</td>
<td>Manicaragua</td>
</tr>
<tr>
<td>Meyerhoff and Hatton 1968</td>
<td>Cayo Coco</td>
<td>Remedios</td>
<td>Camajuani</td>
<td>Placetas</td>
<td>Santa Clara</td>
</tr>
<tr>
<td>Knipper and Cabrera 1974</td>
<td>Remedios</td>
<td>Camajuani</td>
<td>San Felipe</td>
<td>Placetas</td>
<td>Santa Clara</td>
</tr>
<tr>
<td>Pardo - 1975</td>
<td>Cayo Coco</td>
<td>Jaguajay</td>
<td>Jatibonico</td>
<td>Siquia la Chica</td>
<td>Las Villas</td>
</tr>
<tr>
<td>Dilla and Garcia 1985</td>
<td>Cayo Coco</td>
<td>Remedios</td>
<td>Sagua?</td>
<td>Las Villas</td>
<td>Placetas</td>
</tr>
<tr>
<td>Hatten et al. - 1986</td>
<td>Cayo Coco</td>
<td>Remedios</td>
<td>Zulueta</td>
<td>Las Villas</td>
<td>Placetas</td>
</tr>
<tr>
<td>Geologic map 1988</td>
<td>Remedios</td>
<td>Camajuani</td>
<td>Placetas</td>
<td>Zulueta - Las Tunas</td>
<td>Escambray</td>
</tr>
</tbody>
</table>

**Figure 55.** Central Cuba nomenclature.
southeast trending belts. Each one of these is characterized by its structure and stratigraphy.

In 1954, Pardo (p. 5) modified this definition as follows (the definition was published for the first time in Pardo, 1975, p. 561):

The concept of belts exposed in G. Pardo memorandum no. 92 (1953) has remained essentially unchanged; however, due to the complexity of the tectonics, many of the belts cannot be geographically separated onto continuous areas. They are in many instances scattered in small patches following certain general trends. Therefore, for many of the belts, it is impossible to define them as a geographic unit such as the Yaguajay or Las Villas belts (which are continuous), and one has to recur to a stratigraphic definition of the belt; that is, a belt will be defined as an association of several lithologies that occur invariably together. This definition can be carried even further in a paleogeographic and paleotectonic sense: every part of a belt will have had an identical succession of tectonic, sedimentary and igneous events during geologic time.

It turned out that some belts have characteristic internal structure. Lithologic associations are commonly bounded by faults, but they also grade into one another (or at least are not separated from each other by obvious major faults), making the assignment of lithologies to belts difficult (facies do eventually change). In Cuba, faults are everywhere, and they can be strongly deformed, so their importance is difficult to judge from field mapping alone. The disparity between two adjacent belts was used to determine the probable magnitude of a fault and not the magnitude of the fault to define the belt. In addition, the boundary faults are commonly imbricated with components of the two adjacent belts repeated several times.

The California Company (Chevron) initiated reconnaissance work in 1951 and, in 1957, began their systematic mapping of central Cuba. Of course, they had no access to Gulf reports and, in 1957, formalized a classification scheme, like Gulf’s belts, called “tecto-units,” but differing from Gulf’s by being slanted more heavily toward the present structure instead of stratigraphy. In 1957, in a private California Company report, Meyerhoff and Hatten wrote the following:

A tecto-unit is defined as a large and essentially discrete structural unit, bounded on its two long sides by a tectonic feature (such as a fault system), and characterized by unique petrology. A tecto-unit generally parallels regional stratigraphic strike. The characteristic of the petrology and stratigraphy in each tecto-unit are distinct.

As can be seen, the differences between the Gulf and California Co. definitions are not major, but there were strong differences of opinion relative to the assignment of some rocks to equivalent belts (units).

In 1960, the files of all foreign oil companies were confiscated by the revolutionary government, and the above concepts became public knowledge in the geologic circles of Cuba and of the assisting Soviet block countries; however, they remained virtually unknown in the west, where essentially nothing was published until the late 1960s to mid-1970s. Meanwhile, in Cuba, the application of these definitions, with varying degrees of understanding, resulted in confusion. For example, Dilla and Garcia (1984, 1985) reshuffled the existing terminology and split the existing zones, units, etc., between the Cretaceous and the Paleocene. They created two new zones (Sagua and Cabaiguan) that they thought contained only flysch sediments superimposed on the older rocks of all other zones. This reduced the usefulness of previously recognized zones, units, and belts, and using names that had been previously published added to the existing confusion. Besides, their assumption that flysch sedimentation always and only occurred from the Paleocene to the middle Eocene is surely not correct.

In Pushcharovsky et al. (1988), these belts, units, zones, etc., are referred to as “zonas estructurofaciales” or structurofacies zones.

**General Remarks**

The Gulf data set forms a coherent package, with well-established stratigraphic definitions now in the public domain, and its nomenclature is used as a backbone for this publication. A significant reason to do so is that the author of this publication knows precisely the meaning of the Gulf names whereas much of what has been published later has ambiguous definitions. As will be seen, many Gulf names have been incorporated in today’s official nomenclature or published literature, but are not so credited. In some cases, credit is given to the author of the Gulf name, i.e., Wassall, Truitt, etc., who were Gulf employees, but interestingly enough, Gulf is never recognized; nor is any other capitalist organization for that matter. As a result, it is not always known whether the presently
used Gulf names are the result of a coincidence (i.e., same type locality), or whether they found their way into the terminology from Gulf’s early reports and were sometimes given a somewhat different connotation. This is also true of the work of other companies such as Chevron, Shell, etc.

However, credit should be given to many Cuban and Eastern European workers who made definite efforts to identify the original author of many stratigraphic units. If the political situation had been different, much confusion would have been avoided. No attempt will be made to identify the author of Gulf’s terminology. It was a cooperative effort involving P. Bronnimann, G. Pardo, P. B. Truitt, and H. Wassall. Truitt and Wassall conducted most of the fieldwork and were the originators of much of the terminology (full references can be found in the University of Texas copies of Gulf’s reports).

In some cases, Gulf used already existing names and applied a precise definition that might not have been followed by other authors. In this publication, all the names defined and used by Gulf will be followed by an asterisk (*), for example, to differentiate the Vega* Formation as defined by Gulf from the Vega Formation as used in Pushcharovsky et al. (1988), or Gulf’s Las Villas* belt from Hatten et al.’s Las Villas unit. It is hoped that in this manner, confusion will be avoided. At any rate, these homonyms will be clarified in the text. There certainly will be some departures from original definitions and interpretations because of new information such as age dating, published studies on the metamorphics, deep drilling, new geologic concepts, etc.

Of course, in areas where other sources give more complete information, such as Pinar Del Rio, Camaguey, and Oriente, the published names will be used, and an attempt will be made to correlate them with Gulf’s data when pertinent. An attempt will be made to always give credit where it is due, but this sometimes will be impossible, considering the large volume of unpublished material that is being consulted (Gulf’s and others). However, the primary purpose of this chapter is to give information about Cuba and not to describe all the arguments that have ensued ever since the second geologist visited the island.

The Geologic Map of Cuba, scale 1:250,000, (Pushcharovsky et al., 1988), and the Tectonic Map of Cuba, scale 1:500,000, (Pushcharovsky et al., 1989), published jointly by the Academy of Sciences of Cuba and the Academy of Sciences of the former Soviet Union will be extensively used to provide uniformity in discussing the entire island.

To assist the reader, a table has been prepared (the Localities section of this publication) where the approximate location of geographic localities mentioned in the text is given, using the 10 × 10-km (6 × 6-mi) grid system on the 1988 geologic map (Pushcharovsky et al., 1988). This grid has an arbitrary origin west and south of Cuba, and the grid number refers to 10,000 m (33,000 ft); for instance, 33N means 330,000 m (1,082,677 ft) north of the origin. It should be noted that the southern part of Oriente has a different origin than most of the island (the usual problem of trying to fit a square grid over a sphere). In the Localities section of this publication, the southwestern corner of the quadrangle in which the locality is situated will be identified in the following manner: The locality name will be followed by [sheet number—grid north—grid east]. For instance: Quemado de Guines anticlinorium [12-33-37].