Geophysical Characteristics

GRAVITY

History

The earliest gravity survey in Cuba was conducted mostly in Matanzas and Las Villas provinces in 1932–1935 by the U.S. Coast and Geodetic Survey.

Between 1935 and 1958, international oil companies conducted surveys in several local areas. Among these were the southern Pinar del Rio and the northern Isle of Pines; the coastal areas of northern Habana, Matanzas, Las Villas, and Camaguey; parts of southern Camaguey and southwestern Las Villas; and western Oriente. These surveys were of high precision but were not connected to each other.

In 1958, the U.S. Government (Coast and Geodetic Survey) began to establish gravity base stations in Cuba tied to Panama, which is part of the global gravity network with its origin in Potsdam. Four base stations were established: San Julian, Habana, Santa Clara, and Siguanea. After 1959, the Cuban Institute of Geography and Geodesy continued this work, and by 1962, the following bases had been established; 7 first class, 13 second class, and 2500 fill-in. In 1962, in cooperation with the Institute of Earth Physics from the former Soviet Union’s Academy of Science, the Cuban Institute of Geography and Geodesy established a new base network of 62 stations. From then on, all the surveys were tied to the base station network. As of 1971, some 60% of the island had been surveyed at scales of 1:50,000 and 1:100,000. In 1971, Ipatenko and Sashina published a 1:3,000,000 gravity map of Cuba.

The most recently published regional gravity maps were done as an insert in the 1985 Geologic Map (Cuba, 1985a; scale 1:500,000 and contoured at 10-millilgal intervals), based on the published work of Ipatenko and Sashina, and in the 1988 New Atlas of the Republic of Cuba (Sanchez Herrero, 1988; scale 1:1,000,000). The gravity map compiled by Westbrook and published in Dengo and Case (1990), is unfortunately at a 1:5,000,000 scale (contoured at 25 milligals) and, therefore, too generalized to be related to details of the Cuban geology. This map is the base for the Caribbean part of the 1987 Gravity Anomaly Map of North America (Tanner et al., 1987; scale 1:5,000,000). This map is contoured at 10 milligals intervals. It is, however, very useful from a broad regional standpoint. It should be pointed out that the given gravity values are Bouguer on land and Free Air at sea. It is not known where the boundary between the two is in shallow waters, although it is presumed that in these areas, Bouguer and Free Air values are close to each other.

Description of the Gravity Anomalies

In general, the gravity field over the island of Cuba is between –30 and +100 milligals. This is in the general range of continental values. In eastern Cuba, in the Sierra del Purial area, the values climb to more than 160 milligals (see Figure 157). The most obvious features of the gravity field are:

1) A marked gravity low exists, from +70 to +10 milligals southward across the Pinar Fault. This low reflects the presence of the thick, low-density, Tertiary clastics of the San Diego de los Baños Basin.

2) A gravity minimum with values ranging from 0 to –30 milligals extends from Cardenas Bay through the town of Camaguey as far as the town of Gibara; this coincides with the northern contact between the carbonates to the north and the basic igneous-volcanic province to the south. It reflects a major fault. Note that the carbonates outcropping over the gravity low are commonly high density, without much associated low-density material, and therefore, the surface expression of the fault alone cannot explain the
gravity minimum; deeper crustal material must be involved.

3) An east-northeast-trending gravity low, with values reaching $-30$ milligals, in western Camaguey coincides with the Central Depression or the Trocha fault zone. The reason for this anomaly is not entirely clear; although a shallow basin exists, the density contrast of the near-surface sediments is not believed large enough to produce an anomaly of such magnitude, therefore it must originate at basement level.

4) The outcrops of metasediments of the Isle of Pines and the Escambray Massif have relatively low values in the order of $+25$ milligals. The gravity appears to indicate a connection between the two.

5) Everywhere in Cuba, the outcropping volcanics show positive values of up to $+70$ milligals. They also show characteristic high-frequency anomalies.

6) The large positive anomaly in Oriente, reaching more than $+150$ milligals, coincides with extensive ultrabasic outcrops. As will be seen in the next section, it coincides with a shallow (16-km; 10-mi) Moho discontinuity.

7) The generally high gravity values along the south coast of Oriente are over outcrops of lower–middle Eocene volcanics of the Cobre Group, extending westward along the Cayman Ridge, and might reflect a high crustal block adjacent to the Cayman trough. The Cayman trough shows a prominent gravity low with values less than $-150$ milligals.

8) As will be seen later, the Free Air gravity low that reaches $-60$ milligals and extends from south of the Isle of Pines to the south of the Jardines de la Reina Cays might be in part the expression of a presently inactive subduction zone. It might also be an expression of the change in submarine topography.

9) As will also be seen later, the Free Air gravity low that reaches $-80$ milligals and extends from north of Pinar del Rio to Cardenas Bay could be the expression of an important thrust zone, bringing the island of Cuba over the southern Gulf of Mexico. It is the continuation of the thrust front mentioned above, although it could be an expression of the change in submarine topography.

10) There are several long, linear gravity lows and highs, paralleling the coast between Cardenas Bay and Cayo Coco. They must reflect structures (possibly fault blocks) or sediment changes within the coastal area.

The significance of the Cuban gravitational features will be discussed in more detail in Chapter 6 of this publication.
MAGNETICS

History

Reasons exist to believe that the earliest aeromagnetic surveys on the island of Cuba were run for Gulf Oil in 1948. Later, in 1959, an aeromagnetic survey of the north shore of the island was flown for Gulf as part of a larger regional survey of southern Florida and the Bahamas. Aeroservice Corp. ran these surveys. During the years 1956–1957 and 1961–1962, Aeroservice Corp. ran three surveys over western, central, and eastern Cuba. These surveys had arbitrary origins for the values of the magnetic field. From these data, the Cuban Institute of Mineral Resources prepared three maps: Pinar del Rio at 1:50,000 and with 10-gamma contour intervals; northern Habana and Matanzas at 1:40,000, also at 10-gamma intervals; and the rest of the island at 1:192,000 with contour intervals of 25 gammas (5 gammas in magnetically quiet areas). Based on these maps, a 1:250,000 map was compiled, with contours at 25-gamma intervals. Unfortunately, the problem of arbitrary origins remained.

In 1964, Soloviev et al. published a description of the method used to prepare a regional, corrected magnetic map at 1:500,000 with 100-gamma contour intervals in disturbed areas, and 50 gammas in quiet ones. (The Cuban and Russian publications describe the magnetic field in milliOersted [mOe], which is a magnetic field strength unit [1 Oe = 79.577 Ampere/meter]. The North American maps are in nanotesla [nT] or gamma [G], which are magnetic flux density units [1 nT = 1 G, and 1 T = 1 volt second/meter²]. The Cuban and Russian maps show 1 mOe = 10 gammas, which is an error because 1 mOe = 100 G although the two units are not exactly comparable.) In the same article, the authors published a 1:3,000,000 residual magnetic anomaly map of the entire island with 1-mOe (100-gamma) contour interval. Later, a magnetic anomalies map, based on Soloviev et al. publications, was printed as an insert to the 1985 Geologic Map (Cuba, 1985a; scale, 1:2,500,000). The most recently published magnetic map is in the 1988 New Atlas of the Republic of Cuba (Sanchez Herrero, 1988; scale, 1:1,000,000). Like the gravity map, the scale of the magnetic map compiled by Hall and Westbrook and published with the GSA DENAG Volume of the Caribbean Region (Dengo and Case, 1990) is too small to permit comparison with geologic features. In addition, the large number of high-frequency anomalies makes the map very hard to read. This map is the base for the Caribbean part of the Magnetic Anomaly Map of North America (Tanner et al., 1987) at 1:5,000,000, where the data have been smoothed, making the map more interpretative from a regional standpoint. This map is contoured at 100-gamma (100-nT) intervals.

Description of the Magnetic Anomalies

The following features characterize the Cuban magnetic anomaly map (see Figure 158).

1) The north coastal region, from Cardenas Bay to Gibara, shows a featureless magnetic field indicating a deep and/or featureless basement. Depth estimates on Gulf’s surveys indicate as much as 30,000 ft (9100 m) to the basement.

2) The northwestern coastal area of Pinar del Rio also shows a featureless magnetic field, probably indicating a deep basement.

3) A regional magnetic low, extending from Matanzas to Oriente near the north coast of the island, and coinciding with the gravity minimum described under feature 2 in the previous section of this chapter on gravity. It reaches a minimum of less than –200 gammas (–200 nT).

4) In Pinar del Rio, there is also a median magnetic low parallel and immediately south of the Pinar fault. Like the corresponding gravity low, it appears related to the Tertiary fill of the San Diego de los Bahños Basin.

5) South of the province of Matanzas and extending along the southern half of Cuba all the way to Nipe Bay, the magnetic field is characterized by a very large number of high-frequency, mostly positive anomalies. These reflect the presence of the shallow igneous bodies of the basic igneous-volcanic province. They appear to continue westward under the Gulf of Batabano, north of the Isle of Pines, and terminate abruptly in eastern Pinar del Rio (Pinar fault).

6) The above trend of anomalies is interrupted by an east-northeast-trending magnetic low that coincides with the Central Depression gravity minimum (described under feature 3 of the previous section of this chapter on gravity). This supports the possibility that basement is responsible for both the gravity and the magnetic anomalies.

7) To the southwest, coinciding with the Isle of Pines and the Escambray metamorphic massifs are two gravity minimums, the one in the Escambray being less than –200 gammas. A suggestion that these two massifs might be connected has been made. The third metamorphic massif in Asuncion, at the southeasternmost end of the Sierra del Purial, also has a featureless magnetic expression.
8) Habana, Matanzas, and southeastern Pinar del Rio are characterized by a relatively featureless magnetic expression. In places there are sharp anomalies, suggesting isolated igneous bodies within the sedimentary section over a deep basement.

9) Along the southern coast of Oriente, in the southern Sierra Maestra, is a sharp, east–west-trending, high-low feature that is possibly associated with the Cayman trough. A similar feature can be seen 200 km (124 mi) to the west along the south flank of the Cayman Ridge.

The number of correlations between low-frequency gravity and magnetic anomalies suggests that a deep-seated basement determines both. However, a large number of cases exist where strong, high-frequency, magnetic anomalies are superimposed on gravity minimums, revealing the near-surface presence of igneous material over a deep basement.

**CRUSTAL MEASUREMENTS**

From 1972–1975, the All-Union Scientific Research Institute of Geophysics conducted a project aimed at determining the deep crustal structure of Cuba. The method used refraction shooting along long profiles parallel and perpendicular to the regional strike, as well as the conversion of transmitted earthquake waves.

Between 1978 and 1982, B. E. Scherbakova, V. G. Bovenko, and H. Hernandez, among others, published the results of this project.

Figure 159 shows the location of the refraction sections as well as the refraction shot lines. Figure 160 shows the location of the crustal columns as inferred by the earthquake wave conversion method. It should be noted that because of the small scale of the published information, the location of the sections and shot lines is approximate.

Figure 161 shows the crustal thicknesses and the seismic velocity columns based on the refraction shooting; it also shows profiles I, IV, and VIII, which were used for gravity modeling and seismic analysis. Figure 162 is a map of crustal thickness (depth to the Moho discontinuity) after Scherbakova et al. (1978a, b) and Bovenko et al. (1981, 1982).

The results of these studies are difficult to evaluate; in their 1977 and 1988 articles, Scherbakova et al., conclude that the entire island of Cuba is underlain by a sedimentary-volcanogenic cover with thickness ranging from 2.0 to 12.5 km (1.2 to 7.7 mi), a granitic layer with thickness from 5.5 to 12.0 km (3.4 to 7.4 mi), and a basaltic layer 6.0–21.5 km (3.7–13.3 mi) thick.
**Figure 159.** Crustal measurement locations.

**Figure 160.** Crustal measurement locations.
The following velocities were used as criteria for differentiating the layers:

Granitic layer  \( V_p = 6.2 \text{ km/s} \)  \( V_p/V_s = 1.80 \)
Basaltic layer  \( V_p = 7.0 \text{ km/s} \)  \( V_p/V_s = 1.76 \)
Upper mantle  \( V_p = 8.1 \text{ km/s} \)  \( V_p/V_s = 1.80 \)

Furthermore, they state that the island is broken into blocks by deep-seated, vertical to near-vertical faults, and that each block has its own layer thickness distribution and somewhat different physical characteristics. This high-angle, vertically faulted, layer cake, basement tectonic model is certainly not compatible with the surface observations. It is consistent with Soviet-era interpretations elsewhere in the world, so it may be a consequence of standard interpretation methods by Soviet-era or Soviet-era-trained researchers.

Of great significance, however, is the identification of a discontinuity dipping 45–70° to the south that extends from south of La Habana to the Bay of Nipe. The trace of this discontinuity, which is referred to as a suture, is parallel to the regional structural trend and occurs generally south of the main body of ultrabasics and north of the Upper Cretaceous intrusive granodiorites. It seems to follow the axis of the Cretaceous

**FIGURE 161.** Refraction velocity sections.

**FIGURE 162.** Crustal thickness.
volcanic synclinorium. It is not clear whether this suture continues west-northwest toward the Gulf of Mexico or changes course southwestward and parallels the Pinar fault in Pinar del Rio. Perhaps it branches. At any rate, this suture is reflected in both the gravity and magnetic maps.

Although Scherbakova et al. (1978a, b) point out that the Moho is commonly difficult to identify, Figure 163 shows crustal thinning (less than 24 km [15 mi] from a more than 28-km [17-mi] general background) associated with the suture as well as a prominent Moho high (12–16 km [7.4–10 mi] in depth) in western and southern Oriente. Perhaps there, the suture is not as closed as it is in central and western Cuba.

In a more recent article by Bush and Scherbakova (1986), profiles I, IV, and VIII (from the previously mentioned refraction study) were used to do gravity modeling across the island. In this article, the authors appear to have relied more on gravity and surface geology than on seismic refraction data to build their model. The suture concept is maintained, but these profiles, shown in Figure 163, show that the model has been considerably changed:

1) The Moho is not shown but referred to as the top of the asthenosphere, present in the 30–40-km (18–25-mi) range only south of the suture.
2) What was previously the crust has been divided in three layers, with the upper two only being named upper and lower crust and the lower remaining unnamed.
3) What was formerly named the Moho north of the suture, and in Profile 1, in Pinar Del Rio, is now the new base of the crust, making the crust thickness north of the suture considerably thicker than to the south. In profile I, in Pinar del Rio, what was the Moho is now the new base of the crust.
4) The suture zone has become a slab ±8 km (±5 mi) thick with its own physical properties.
5) The previously reported internal velocity variations of the zones are ignored.
6) Finally, and most serious of all, profile I depicts the Pinar fault as a feature similar to the ophiolite front in central Cuba, which is not supported by field observations. In profile IV, the outcropping ophiolites are shown north of the gravity minimum, when in reality, they either coincide with it (or are south of it), and in profile VIII, the gravity minimum does not appear to be properly located in relation to the model. It should be noted that the strike of profile VIII is at an angle of 40–50° to the trend of the gravity minimum and the regional strike, which would have a profound effect in the computations if the model were not three-dimensional.

According to this later article, some of the original conclusions of B. E. Scherbakova must have been changed. The simple, two-dimensional type of gravity modeling (it appears to be a modification of M. Talwani's) that was used certainly does not provide any new data but simply another interpretation of the same data. A familiar problem with this kind of modeling is that there is no unique answer.

Despite the above uncertainties, some interesting interpretations have been made on the nature and structure of the Cuban crust. Pushcharovsky et al. (1988) present a classification of the types of crust and their location. Pushcharovsky et al. (1989) show the same scheme in a 1:2,500,000 insert in the 1989 Tectonic Map of Cuba. According to these authors, the crust consists of the following:

1) The continental North American crust in north central Cuba, 22–30 km (13–18 mi) thick, consisting of three layers; a 5–7-km (3.1–4.3-mi)-thick sedimentary cover over a granitic-metamorphic and a basaltic layer of equal thicknesses. The southern part of this crust is overlain by the sedimentary and ophiolite thrusts.
2) In Pinar del Rio, the crust consists of components from both the North and South American continents. It is somewhat thicker, 24–30 km (15–18 mi), and the granitic-metamorphic layer is 10 km (6 mi) thick versus 15 km (9 mi) for the basaltic layer, and the southern boundary is along the Pinar fault.
3) Separated from the continental crust by the geosuture is a transitional crust (of possible late Cretaceous age), 28–32 km (17–20 mi) thick with a basalt layer up to 20 km (12 mi) in thickness, whereas the granitic-metamorphic layer is only 3.5–8 km (2.1–5 mi) thick and discontinuous. This crust can be divided into two segments: the one under the basic igneous-volcanic province to the north, containing granitoids, and the Escambray–Isla de Pinos to the south, which is considered to contain South American crustal components.
4) In central Oriente, there is a relatively shallow dome of suboceanic ultramafic material, with a greatly reduced crust, 14–18 km (8–11 mi) thick, coinciding with the already mentioned strong positive gravity anomaly.
FIGURE 163. Crustal profiles I, IV, and VIII.
5) In southern Oriente and along the Cayman Ridge is another belt of transitional crust of Paleogene age with well-defined granitic-metamorphic and basaltic layers.

6) The Yucatan Basin and the southern Gulf of Mexico are underlain by a suboceanic crust with thicknesses ranging from 8 to 20 km (5 to 12 mi).

7) The Cayman trough is underlain by oceanic crust.

The above blocks show many offsets by east-northeast-trending left-lateral transcurrent faults.

Here again, it is difficult to evaluate the meaning of these conclusions. They are obviously not entirely derived from geophysical studies; the hypothesis of the South American origin of some of the crustal blocks, although possible, must be based on some geological considerations because it cannot be derived from the geophysical data alone. What is the relationship between the extensive ophiolites and basic volcanics of the basic igneous-volcanic province and the intermediate crust underlying them? Are they part of that crust (velocity inversions have been reported)? Are the metamorphics of the Isla de la Juventud and Escambray massif considered part of the granitic-metamorphic layer of the South American crust, or are they overlying that layer (the problem of reverse metamorphism)?

In conclusion, it can be said that the problem involving the geometry and nature of the crust underneath the island of Cuba is still not resolved. The most significant observations are as follows:

1) The presence of a crustal suture (disturbed zone) along the axis of the island and extending from Habana to the Bay of Nipe (the crustal thinning northward across the suture might be the result of Moho miscorrelations)

2) The deep-seated nature of the Pinar fault

3) The presence of thin crust–shallow mantle in eastern and possibly southern Oriente

4) The general intermediate (noncontinental and nonoceanic) nature and thickness of the crust

5) The general internal complexity of the crust suggesting its involvement in compressional and transcurrent tectonics

**REFLECTION SEISMOGRAPHY**

Seismic reflection surveys were conducted in several places for many years. Before 1960, the results were disappointing as far as resolving pre-Tertiary structures. Since the revolution, seismic parties (Soviet, Compagnie Generale de Geophysique [CGG], and others) have been continuously active. The results have not been released. Echevarria-Rodriguez et al. (1991) stated that more than 50,000 km (31,000 mi) of seismic lines (most of them marine) were analyzed. They published two profiles from the offshore north coast, a north–south 18-km (11-mi) profile in 4000 ft (1200 m) of water north of Cardenas Bay and a northeast–southwest 22-km (13-mi) profile in 1500 ft (450 m) of water some 20 km (12 mi) north of Cayo Coco. These profiles appear to be of recent vintage and must be some of the best available (the article is in the *Journal of Petroleum Geology* and is of a promotional nature). They do show structures at what the authors call the Upper Cretaceous level, but unfortunately, nothing can be resolved below that point. The reflections identified as the Jurassic are very probably multiples. In view that nothing is known about the processing, it is not known whether anything more can be obtained from this type of data because the pre–lower Eocene structures can be extremely complex. However, the authors claim that several north coast fields, including Varadero and Boca de Jaruco, were discovered through seismic surveys. Differing opinions exist that they were found through random drilling (70 deep wells in the area as of 1974). Hernandez Perez and Blickwede (2000) published five short profiles regarding the deep water north of Cuba. The article, in the *Oil & Gas Journal*, is also of a promotional nature, and the prints are of poor quality. The authors present, as line drawings, interpretations of profiles A and B (see Figure 164). Profile A, north of the Havana-Matanzas anticline, shows structurally disturbed, pre-Tertiary sediments over its entire length of approximately 31 km (19 mi), but the thrust front appears to be some 12 km (7 mi) south of the north end of the profile. Assuming an average velocity of 15,000 ft/s (4500 m/s), it also shows a possible décollement surface at ±31,250 ft (±9500 m) below sea level. Profile B, north of western Pinar del Rio (Martin Mesa?), shows the thrust front approximately 10 km (6 mi) north of the southern end of the profile. Assuming the same average sediment velocity, at least ±32,725 ft (±9974 m) exist to a possible décollement, and north of it, ±24,750 ft (±7543 m) of undisturbed sediments below 6750 ft (2057 m) of water exist. These numbers suggest basement or salt at ±32,000 ft (±9753 m) below sea level.

The Institute for Geophysics of the University of Texas ran an extensive multichannel survey in the Yucatan Basin between 1975 and 1980. Although this survey does not cover Cuban territory, it has
bearing on the geology and geologic development of the island. The data have been reported by Holcombe et al. (1990) and Rosencrantz (1990), and it shows a trench and northeast-dipping subduction under eastern and possibly central Cuba, southwest of and paralleling the Jardines de la Reina Cays (Figure 165).

**TEMPERATURE AND HEAT FLOW**

Cermak et al. (1984, 1991) published two articles on temperature and heat flow in several localities throughout the island.

The measurements were made in 36 boreholes (Figure 166) that had not been disturbed for periods ranging from several months to several years and were, therefore, in thermal equilibrium with the surrounding rocks. The depth at which the measurements were taken ranges from 295 to 4887 ft (90 to 1490 m).

Figure 167 shows a table summarizing the results of the study. In general, Cuba is characterized by a low geothermal gradient and a low to very low heat flow. It is difficult to draw conclusions from these data except that the mean of 45 mW/m² (milliWatt per square meter) is close to that of the Gulf of Mexico (<40 mW/m²), the Florida-Bahamas Platform (±50 mW/m²), and the Yucatan Basin (±58 mW/m²). It is in contrast with the high geothermal activity of the Caribbean (±88 mW/m°C in the Cayman trench). Interestingly, the highest heat-flow values were obtained in the Central Depression (63 mW/m²) and Jatibonico (50 mW/m²), whereas, unexpectedly, the lowest heat-flow values were obtained in southeastern Oriente at Puriales.

![Figure 164. Cuba seismic profiles A and B. See Figure 168 for location. Author’s interpretation from sections published by Hernandez Perez and Blickwede (2000).](image)
(25 mW/m²), which is supposedly underlain by the thinnest crust over a mantle dome.

It should be noted that rock samples for thermal conductivity measurements were not available from all the wells, in which case samples were taken from nearby outcrops, therefore introducing a possible source of error in heat-flow calculations.

The heat flow and geothermal gradient of northern Cuba under the carbonates has probably been the same or similar to the present heat flow for a long period of time (perhaps since the Jurassic), whereas the heat flow of the southern volcanic, igneous, and metamorphic provinces must be of much more recent origin, possibly since the late Eocene. These conditions have certainly had an important influence on the kerogen maturation.

Another interesting feature of the Cuban geothermal gradient is an inversion that occurs between 330 and 650 ft (100 and 200 m). At that depth, the temperature can be on the order of 5.5°F (3.0°K) lower than the surface temperature. The undisturbed geothermal gradient is commonly present below 650–820 ft (200–250 m). This anomaly is independent of the surrounding rocks or the depth of the water table and is present in most surveyed locations; it is believed to be the result of the global warming that followed the last glaciation.

**PALEOMAGNETISM**

Several paleomagnetic studies have been made in Cuba.

Renne et al. (1991) discusses southern Las Villas Province on the south flank of the Seibabo syncline. They report the results of the study of 42 specimens in five out of seven localities. Three of the selected localities are in Aptian–Albian volcaniclastics and two are in overlying Cenomanian micritic limestones. The data from the remaining two are unusable. Unfortunately, all the samples have a strong magnetic
overprint of unknown origin that could not be removed. However, they do show between 40 and 50° of counterclockwise rotation. Whether this is indicative of rotation of the entire volcanic belt or rotation of individual blocks caused by the eastward displacement of southern Cuba in relation to North America is open to question. Although a northward displacement is inferred, it is not supported by the data.

Chauvin et al. (1994, p. 1691) conclude that, “the entire Cretaceous succession of the Zaza terrane was remagnetized in the Campanian. The measured latitude is lower by 15° ± 6° with respect to the North American APWP indicating ca. 1600 ± 600 km northward displacement of the Zaza terrane since the Campanian. Also discordant is the measured declination implying 37° ± 11° counterclockwise rotation of the Zaza terrane.”

Bazhenov et al. (1996, p. 65) reached the following preliminary conclusions: “In contrast, well-defined characteristic components were isolated from basalts of the Aptian–Albian Encrucijada and the Late Cretaceous Orozco formations from the Bahia Honda zone in the north of western Cuba; the remanence in the Encrucijada Formation is shown to predate deformation. Mean inclinations in both formations match those in Cretaceous volcanics from central Cuba, and all the results show lower latitudes than expected from the reference data for the North American Plate, thus implying that volcanic domains of Cuba were displaced northward by about 1000 km prior to the middle Eocene. Cretaceous declinations in western and central Cuba differ by about the same amount as the major structural trends of these two areas suggesting oroclinal bending of Cuba. At the same time, both areas are rotated counterclockwise with respect to North America, thus implying movements on a broader scale.”

Alva-Valdivia et al. (2001, p. 716) state that, “The mean palaeodirection obtained in present study is not significantly different from the expected Jurassic–Cretaceous palaeodirections estimated from the North American apparent polar wander path, at least from 140 to 60 Ma. This suggests that no major latitudinal displacements and rotation have affected the Guaniguanico Cordillera since the Jurassic period.”

Fundora Granda et al. (2003) show the eastern Cuba volcanics migrating from 10°S in the Lower Cretaceous to 22°N in the present and, surprisingly, also making a 180° clockwise rotation.

It therefore seems that, so far, the general consensus is that the Guaniguanico sedimentary belts have not moved much in relation to North America, whereas the basic igneous-volcanic terranes have moved more than 1000 km (600 mi) in a north-northeast direction and show a counterclockwise rotation.

Much work along these lines remains to be done.

**AGE DATING**

Iturralde-Vinent et al. (1996) present the results of a large number of K-Ar age determinations. They
are grouped according to broad areal distribution and rock types (igneous, volcanics, metamorphics, Escambray, Sierra Maestra, etc.), but unfortunately, there is no precise location or stratigraphic identification. Some of the results can be summarized as follows:

1) Cifuentes belt basement (Socorro complex): 139–150 Ma, with marble dated at ±900 Ma
2) Escambray metamorphics: 55–85 Ma, with median at 66 Ma
3) Isla de la Juventud metamorphics: 49–78 Ma, with median at 66 Ma
4) Cretaceous volcanics: 53–100 Ma, with median at 77 Ma
5) Cretaceous plutons (Sancti Spiritu granodiorite): 50–99 Ma, with median at 78 Ma
6) Paleogene volcanics (El Cobre): 39–58 Ma, with median at 47 Ma
7) Mafics of northern ophiolites (Domingo*): 52–160 Ma, with median at 105 Ma
8) Mabujina complex: 44–89 Ma, with median at 81 Ma
9) Metamorphic inclusions in the ophiolites: 91–196 Ma, with median at 111 Ma
Without further stratigraphic details and more precise locations, it is impossible to attempt to explain the broad scattering of age determinations. However, the data support the theory that the Paleocene metamorphism of the sedimentary section (Escambray and Isla de la Juventud) is younger than the Campanian volcanic arc and could be related, at least partially, to the obduction process.

**GEOPHYSICAL DATA DISCUSSION**

The geophysical information available to the author indicates several relationships concerning the general structure of Cuba (see Figure 168).

1) A definite continuity exists between the basic igneous-volcanic province of central Cuba and northern Oriente and the Bahia Honda belt of western Cuba. Assuming that the basic igneous-volcanic province had roots between the northern carbonate belts and the Escambray metamorphics, it must also have had roots north of the Guaniguanico Mountains. However, if it originated south of Guaniguanico and was thrust northward, then it must have originated south of Escambray and been also thrust northward over the metamorphics.

2) A regional gravity and magnetic low anomaly extending from Cardenas Bay to Holguin exists. This anomaly coincides approximately with the boundary between the carbonate outcrops to the north and the basic igneous rocks to the south. Its south flank also coincides with what has been interpreted as a crustal discontinuity based on refraction seismography. It has been called a suture by several authors.

3) A few reflection profiles, gravity anomalies, as well as some drilling information suggest that the Cuban structural front extends all along the north coast of the island some tens of kilometers offshore.
4) A seismic reflection profile south of the Jardines de la Reina archipelago shows a buried trench over a possible inactive northeast-dipping subduction. A high-low gravity anomaly, extending past the Isla de la Juventud, suggests that this trench might mark the boundary between Cuba and the Yucatan Basin.

5) The Central Depression is characterized by marked gravity and magnetic lows. They are the basis for the Trocha fault.

6) The Isla de la Juventud and the Escambray massif are also characterized by gravity and magnetic anomaly lows. There seem to be an east–west connection between the two.

7) South of the main island of Cuba and north of the Isla de la Juventud is a pronounced east–west positive gravity and magnetic anomaly extending from La Coloma in southeastern Pinar del Rio to Cienfuegos. The cause for this anomaly is unknown, but together with the refraction seismography, it suggests either a thinner crust or a body of basic igneous material. It is not parallel with the supposed axis of the Los Palacios Basin. The wells Guanal-1 and Guanal-1A, drilled by Esso on the western end of this feature, reached a total depth of 854 and 980 m (2801 and 3215 ft), respectively. Guanal-1A was reported to have bottomed in ultrabasic igneous rocks. Some authors doubt the validity of this report (Iturralde-Vinent, 1996), however, the fact that ESSO stopped drilling both wells at such a shallow depth would confirm the presence of igneous.

8) A very strong positive gravity anomaly and the shallowest Moho in the island characterize southeastern Oriente. However, no noticeable magnetic expression exists.

9) With the exception of the Jatibonico area, the geothermal gradient is low, on the order of ±1°F/100 ft (±2°C/100 m). In the Jatibonico area (Central Depression and Trocha fault), the geothermal gradient is on the order of ±2°F/100 ft (±4°C/100 m).