Regional Setting

GREATER ANTILLES ORTHOGEOSYNCLINE

The Greater Antilles is a deformed and uplifted Jurassic through early Tertiary orthogeosyncline.[1] Meyerhoff believes that Paleozoic rocks (comprising continental crust) are exposed in the western (Cuban) end of this orthogeosyncline, and that oceanic crust may underlie the eastern (Puerto Rican) end, as Hess (1960) proposed. Khudoley, however, does not believe that Paleozoic rocks are exposed in Cuba.

Meyerhoff believes, as many others, that the Greater Antilles orthogeosyncline probably was an island-arc system from Late Jurassic through early Tertiary times and that the present Caribbean Sea was part of an oceanic basin. Edgar's (1968) work supports these concepts strongly (*see also* Officer and others, 1959). Hess (1955) suggested that the arc, at least in Puerto Rico, was convex toward the Caribbean Sea, and that it was separated from the present Caribbean by an oceanic trench. A. A. Meyerhoff (1966) agreed with this interpretation and postulated that the Greater Antilles, like many modern arcs, consisted of two arcuate segments convex toward an oceanic basin—in this example, the area of the present Caribbean—on the south. One segment

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[1]The term "orthogeosyncline" is used here in the senses of Stille (1940) and Kay (1951); "island arc" is used as an approximate synonym of "eugeosyncline," as explained by Kay (p. 72–77), but the writers also include the median welt and deep-water carbonate facies in the term. This is done for simplicity in text presentation.

Mattson (1968b) adopted a variation of H. A. Meyerhoff's (1933) concept that the Greater Antilles are more like a volcanic pile than a basinal (geosynclinal) accumulation. Mattson (p. 192) wrote: "Cretaceous and early Tertiary marine volcanic and sedimentary materials were deposited . . . in linear welts forming constructional geanticlines rather than in geosynclinal basins." This may have been the manner in which the Greater Antilles, particularly east of Cuba, originated, but four facts must be taken into consideration: (1) What actually localized the belt of orthogeosynclinal (or volcanic pile) accumulation? (2) The Cretaceous sequence alone is 6 to 10 km thick in the eastern Greater Antilles, or 2 to 6 km deeper than the adjacent ocean floor. (3) The Greater Antilles sequence resembles closely that of most other island arcs (for example, Banda arc, Japan, Aleutians, and so on). (4) In Cuba, basins *did* exist on the pre-orthogeosynclinal basement, and these basins were the sites of geosynclinal subsidence and accumulation. The writers believe that the differences expressed by H. A. Meyerhoff, Mattson, the present writers, and others are differences of semantics, and not of genesis.

(Cuba) faced the modern Yucatán basin, whereas the second segment (Jamaica, Hispañola, Puerto Rico, and the Virgin Islands) faced the area of the modern Colombian and Venezuelan basins (Fig. 1). The two segments intersected at the present Bartlett Trough (also called the Cayman Trough). The western end of the arc system was near the existing Yucatán Channel; the eastern end was the northeastern Virgin Islands.

In contrast, Khudoley, following Bucher (1947), Eardley (1954, 1962), Butterlin (1956), and others, believes that the area of the present Caribbean Sea was a landmass through Jurassic time. This landmass began to sink in Cretaceous time by the process of *basification* or *basaltization*,[2] and the Caribbean Sea—as it appears today—continued to deepen until the present. The Greater Antilles orthogeosyncline, in Khudoley's opinion, began to form during Late Triassic time, probably on a Paleozoic basement.

Donnelly (1964, 1967) postulated that the eastern end of the Greater Antilles arc (Puerto Rico and Virgin Islands) was convex toward the Atlantic rather than toward the Caribbean. As evidence for this, he mentioned the facts that (1) most Pacific arcs are convex toward oceanic crust—toward the Atlantic in this example—and concave toward "modified" oceanic crust[3] (Caribbean); (2) the Puerto Rico Trench, which he interpreted to be an island-arc–type trench, is on the northern (ocean) side of the eastern Greater Antilles; and (3) the oldest known rocks in the Virgin Islands are submarine eruptions in the northern part of the Islands (St. Thomas). The apparent convexity of present-day Cuba toward the Bahamas also may be cited in support of Donnelly's view. However, the present shape of Cuba was determined largely by Late Cretaceous and younger orogenic events, particularly transverse and block faulting. More recently, Donnelly (October 31, 1969, written commun.) suggested that the Greater Antilles need not have been one continuous arc early in its history, but an arc which grew eastward as a result

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[2] This concept, or some variety of it, seems to be as old as, or older than, the myth of the "lost continent of Atlantis." Other terms used to describe this process, which may be considered as the opposite of *continentalization* and *granitization*, are *oceanization* and *thalassogenesis*. The latter term, however, refers to downwarping and not to true basification, and oceanization is the end result of basification, which is a process. Beloussov (1954, 1960, 1962) has described the process in the framework of the earth's total tectonic cycle. The *granite stage* causes the formation of granitic crust by the rise of lighter elements to the earth's surface. A period of tectonic activity ensues, and continents grow by accretion. Mobile belts eventually become stable and platforms develop where mobile belts once were active. The *basalt stage* involves the opposite process, and proceeds in one place while the granite stage proceeds at another. During the basalt stage, tectonic activity in mobile belts is transmitted through platforms which then begin to fracture. Grabens form, together with deep (disjunctive or crust-penetrating) faults. Mass extrusions of plateau basalts follow and engulf the continental crust *(basification)*. Red-Sea-type grabens with oceanic crust develop and, as granitic crust is engulfed and absorbed, ocean basins are formed anew *(oceanization)*.

[3] *Modified oceanic crust* is similar to oceanic crust, but is thicker, has a seismic velocity which is slightly lower than that for oceanic crust, and commonly is overlain by a section of low-velocity (1.7 to 5.5 km/sec) materials that is thicker than that which overlies oceanic crust. Modified oceanic crust typically is present in deep-sea basins between island arcs and continents, and in small ocean basins, such as the Gulf of Mexico, and others.

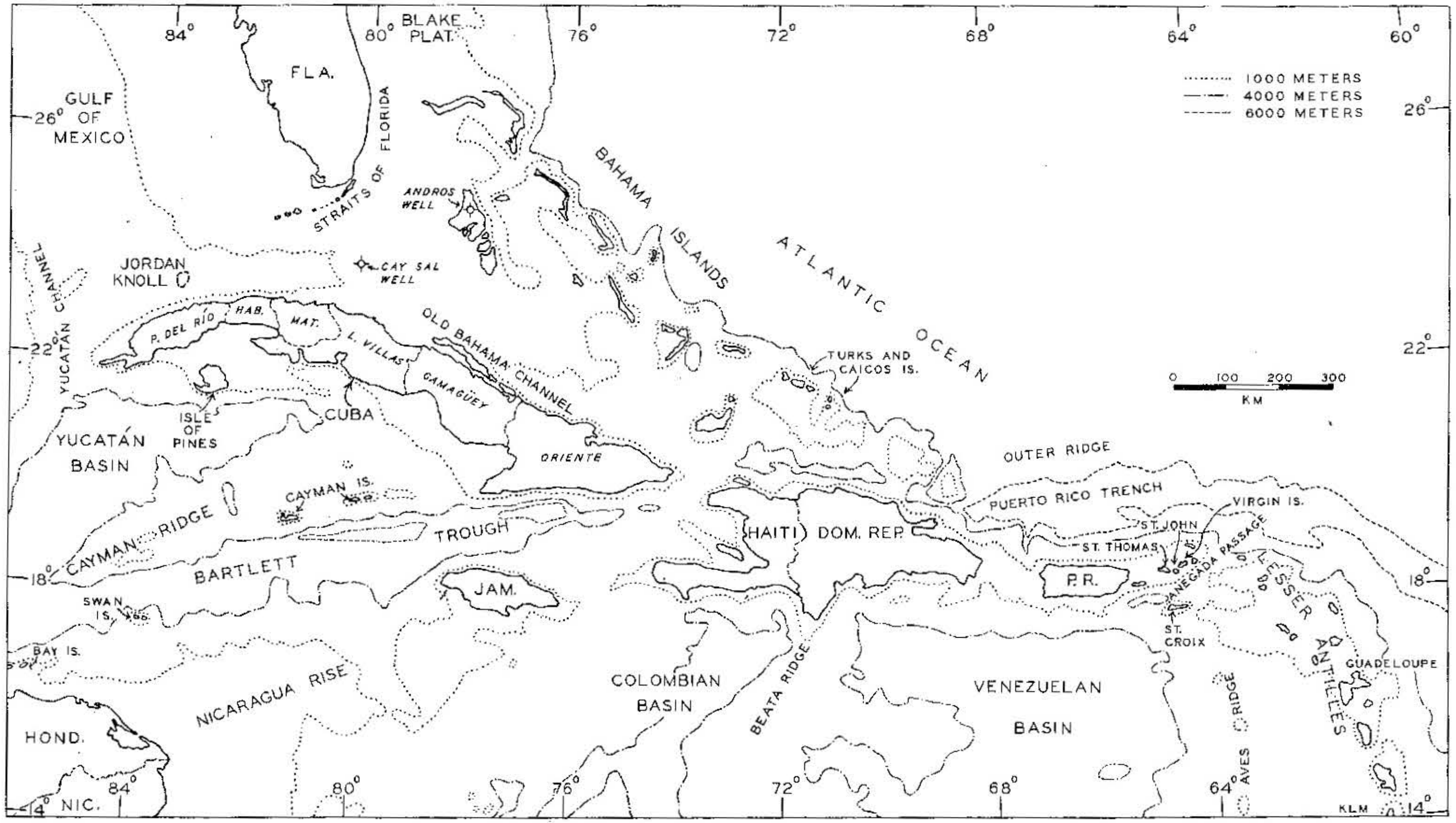


Figure 1. Location and index map to principal features of Greater Antilles.

of spreading of the Atlantic plate along the northern side of the Caribbean plate (*see also* Donnelly, 1967, 1968). Ball and Harrison (1969), in contrast, postulated that the Caribbean-Greater Antilles formed by north-south extension and left-lateral shear in response to sea-floor spreading in the mid-Atlantic.

Assuming that the whole of the Greater Antilles was a Late Jurassic through early Tertiary island arc, and omitting for the moment Khudoley's view that the area of the present Caribbean Sea was a landmass until Cretaceous time, Meyerhoff believes that the Greater Antilles most probably was convex southward. Several points support this interpretation:

1. In Cuba, the foreland was on the north (Bahamas); a miogeosyncline flanked the southern edge of the foreland; and the eugeosyncline was adjacent to the modern Caribbean Sea. In Cuba, the volcanic arc was convex toward the present Caribbean Sea. If Donnelly's interpretation is correct, a complete reversal of the positions of the foreland and the volcanic arc took place between the western and eastern ends of a single arc system *of the same age*. No such reversal is known within any of the 18 arcs active today in the circum-Pacific region. The modern Lesser Antilles arc, although an apparent exception because it is convex toward the Atlantic, actually is *not* an exception because it is a separate arc of probable Eocene to Holocene age. However, there is some evidence that the Lesser Antilles may overlie an older arc.
2. Donnelly's interpretation assumes *a priori* that the Caribbean crust was modified oceanic crust during Cretaceous time (Donnelly, 1964; Rogers and Donnelly, 1966). The writers know of no evidence to support this assumption.
3. Not all active Pacific arcs are "backed" by modified oceanic crust (for example, New Hebrides arc, Benioff, 1954, p. 398, his Fig. 16).
4. For more than 36 years, the Puerto Rico Trench has been interpreted by geologists and geophysicists to be an oceanic trench, typical of those which characterize the oceanic margins of island arcs. Benioff (1954, p. 398, Fig. 16) showed that one characteristic of island-arc trenches is the presence of a zone of earthquake foci dipping beneath the island arc (commonly called "Benioff zones").

Figures 2A through 2C show the bathymetry of the Puerto Rico Trench area and the principal earthquake epicenters which have been recorded there. Figure 3 shows two north-south cross sections on which the hypocenter distribution is plotted (*see* Tables 1A, 1B). Cross section A (Fig. 3) traverses Puerto Rico, whereas cross section B (Fig. 3) traverses the eastern Dominican Republic. The marked contrast in the hypocenter-distribution patterns suggests that the zones crossed by cross sections A and B are in distinct structural provinces, a conclusion also reached by Sykes and Ewing (1965). However, Sykes and Ewing's Figure 2 (reproduced here as Fig. 4) combines the data from Puerto Rico and the eastern Dominican Republic, and led Sykes and Ewing (p. 5072–5073) to conclude that the Puerto Rico Trench represents a stage of island-arc development. By combining the data of the two cross sections of Figure 3, Sykes and Ewing constructed, in the writers' opinion, a

TABLE 1A. EARTHQUAKE EPICENTER LOCATIONS, PUERTO RICO AREA, FROM SOURCES OTHER THAN SYKES AND EWING (1965); SHOWN ON FIGURES 2 AND 3 AS SOLID CIRCLES AND SOLID TRIANGLES

Source	*Page No.*	*Map No.**	*N. Lat.*	*W. Long.*	*Depth (Km.)*
Gutenberg and Richter (1954)	135	1	19.5	69.0	. .
	137	2, 11	18.5	67.5	. .
	147	3‡	18.75	68.5	50
	153	4‡, 24‡	18.5	68.0	80
	172	5	19.0	68.25	. .
	172	6	19.0	68.0	. .
	172	7	18.0	68.0	. .
	172	8	20.0	68.0	. .
	172	9	19.25	67.75	. .
	172	10	18.0	67.5	. .
	172	12†	19.0	67.5	50
	172	13	19.25	67.5	. .
	172	14, 15	18.0	67.0	. .
	172	16, 18	19.0	67.0	. .
	172	17†	18.5	67.0	60
	172	19	20.5	66.0	. .
	172	20	19.0	65.0	. .
	172	21	19.5	64.5	. .
	172	22	19.0	64.5	. .
	172	23	19.0	64.0	. .
	236	25	19.25	69.0	. .
	236	26‡	18.75	68.5	50
	248	27‡	19.0	68.5	100
Simon (1965?)	4	28†	19.0	66.5	47
	7	29†	19.1	67.3	33
	14	30‡	18.2	68.4	183
	19	31‡	18.4	68.8	115
Simon (1964?)	3	32†	19.4	66.3	37
	4	33†	17.8	67.1	33
	5	34†	19.5	65.3	33
	6	35†	19.2	65.9	58
	25	36†	19.6	66.8	30
Simon (1963b?)	12	37†	19.2	64.6	55
	15	38†	19.6	65.6	33
Simon (1963a?)	2	39†	19.0	65.1	25
Simon (1962?)	9	40†	20.5	66.0	38
	11	41†	19.4	65.0	64
Simon (1960?)	1	42	20.0	64.5	. .
	1	43	20.0	65	. .
Pimentel (1963?)	4	44†	20.5	66.0	38
	6	45†	19.4	65.0	64
	9	46†	19.0	65.1	25
Pimentel (1959?)	6	47	18.0	68.5	. .
	7	48	20.0	67.0	. .
	27	49‡	18.0	68.5	100
	31	50	19.0	64.5	. .
Pimentel (1960?)	4	51	19.5	66.0	. .
	8	52	19.5	64.5	. .
	12	53†	19.0	65.0	100
	14	54	19.0	68.5	. .
	17	55	19.5	65.0	. .
	20	56	20.0	64.5	. .
	21	57	20.0	65.0	. .
	35	58‡	18.0	69.0	100

*See Figure 2 for location on map. †These epicenters only are plotted on Figure 3a, because only these are associated with Puerto Rico. ‡These epicenters are only for the Dominican Republic area west of 67°30′ W.

TABLE 1B. EARTHQUAKE EPICENTER LOCATIONS, PUERTO RICO AREA FROM SYKES AND EWING, 1965. SHOWN AS OPEN CIRCLES ON FIGURES 2 AND 3

*Map No.**	*N. Lat.*	*W. Long.*	*Depth (Km)*
59†	19.57	65.43	43
60‡	17.76	68.11	37
61†	19.36	64.44	47
62†	19.33	64.38	55
63‡	17.05	67.91	. .
64§	18.32	64.23	. .
65‡	18.57	68.52	82
66†	17.01	66.40	59
67‡	18.00	68.68	177
68†	18.33	65.70	96
69†	17.79	66.61	116
70†	18.95	67.14	. .
71†	19.09	66.58	52
72†	16.87	66.11	44
73‡	19.33	67.90	. .
74‡	19.00	68.99	. .
75†	18.20	66.22	120
76†	19.16	67.32	. .
77‡	19.04	67.65	. .
78†	19.56	65.57	. .
79†	19.12	65.15	68
80‡	17.31	67.87	231
81‡	18.29	68.05	47
82†	18.78	64.79	. .
83†	19.38	67.23	8
84†	19.63	66.00	9
85‡	18.22	68.19	133
86†	19.28	65.23	. .
87‡	19.02	68.08	74
88†	18.97	64.17	18
89†	19.16	65.30	44
90†	19.28	64.38	. .
91†	19.07	64.38	46
92§	18.73	64.00	18
93†	19.29	64.21	41
94‡	18.09	67.88	22
95†	18.93	66.30	50
96†	19.41	64.54	45
97†	19.86	64.20	. .
98†	19.39	64.46	. .
99†	19.84	64.58	19
100†	18.80	67.25	46
101†	18.27	68.37	62
102†	18.81	64.33	33
103‡	18.90	68.42	194
104§	17.99	64.90	36
105‡	18.13	68.21	64
106†	19.06	66.17	42
107†	19.59	65.75	. .

misleading picture of the hypocenter distribution and, therefore, reached an erroneous conclusion regarding the nature of the Puerto Rico Trench.

The writers believe that the hypocenter-distribution patterns shown on sections A and B (Fig. 3) are most typical of areas of strike-slip and normal faulting, and not of island-arc-type faulting along Benioff zones. Molnar and Sykes (1968) reported that the focal mechanisms of Puerto Rico area earthquakes show that dip-slip movement predominates. Figure 5, constructed from the data of Figure 3 and Tables 1A and 1B, emphasizes the markedly

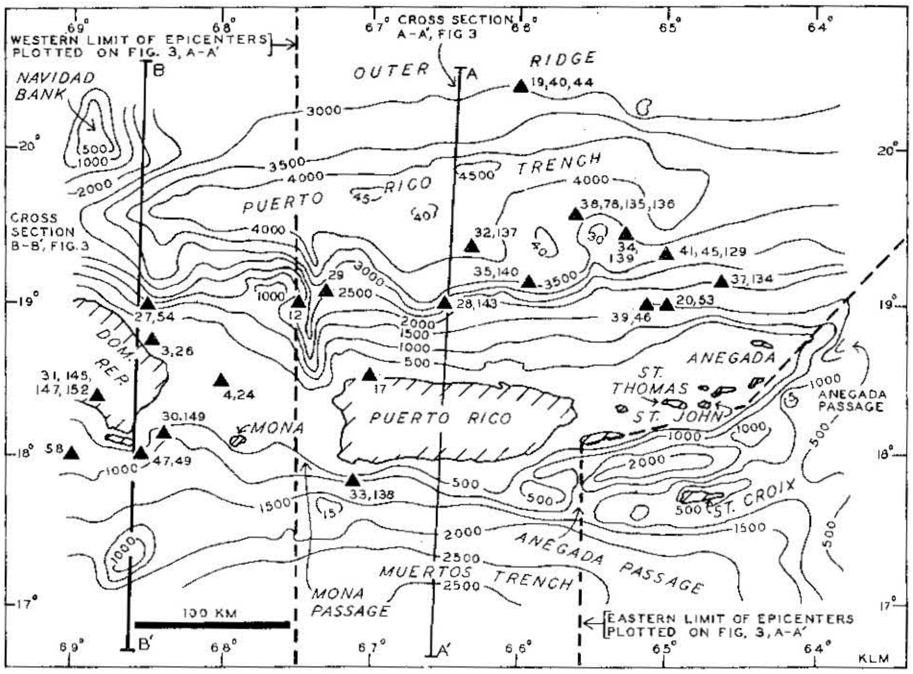
TABLE 1B. *(Continued)*

*Map No.**	*N. Lat.*	*W. Long.*	*Depth (Km)*
108†	18.90	64.35	. .
109†	19.40	65.20	64
110†	18.72	64.52	25
111‡	18.87	68.04	55
112‡	19.59	67.69	12
113†	19.20	64.80	. .
114†	19.93	65.15	. .
115†	19.50	65.64	90
116†	20.02	65.02	. .
117†	19.36	64.79	. .
118†	17.46	65.74	. .
119‡	18.27	68.62	68
120‡	18.44	68.31	150
121†	18.82	67.39	. .
122†	18.49	66.42	131
123‡	18.08	68.81	100
124§	17.82	65.15	31
125‡	18.49	68.92	146
126‡	18.52	69.02	156
127‡	19.33	67.67	31
128†	20.52	65.91	. .
129†	19.40	65.00	64
130†	18.77	65.44	59
131†	19.09	67.06	47
132‡	17.10	68.58	. .
133†	19.3	67.0	39
134†	19.2	64.6	55
135†	19.6	65.6	33
136†	19.5	65.6	33
137†	19.4	66.3	37
138†	17.8	67.1	33
139†	19.5	65.3	33
140†	19.2	65.9	58
141‡	17.9	68.0	98
142†	19.6	66.8	30
143†	19.0	66.5	46
144†	19.1	67.3	33
145‡	18.4	68.8	179
146‡	18.2	68.2	96
147‡	18.4	68.9	178
148‡	19.4	68.7	33
149‡	18.2	68.4	183
150†	19.0	64.6	33
151†	19.0	64.0	55
152‡	18.4	68.8	115

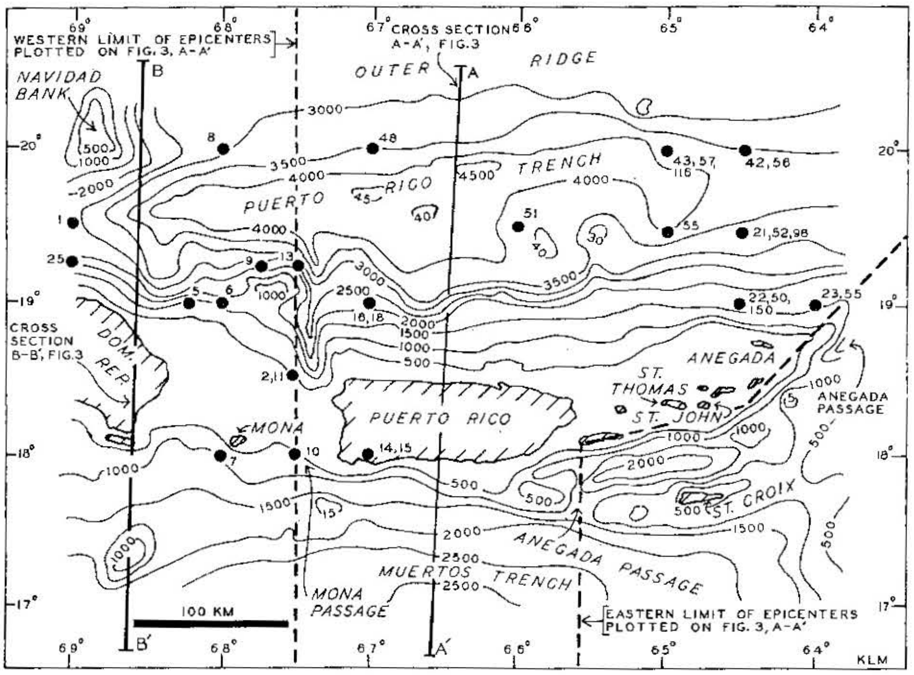
*See Figure 2 for location on map. †These epicenters only are plotted on Figure 3a, because only these are associated with Puerto Rico. ‡These epicenters are only for the Dominican Republic area west of 67°30′ W. §Anegada Trough epicenters.

different earthquake-hypocenter characteristics of Puerto Rico and the eastern Dominican Republic.

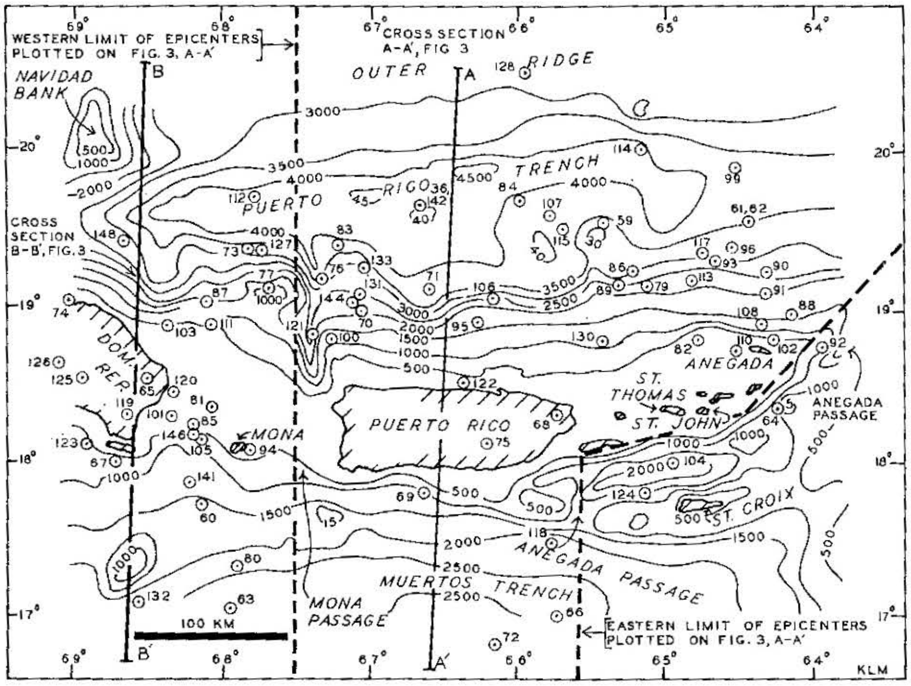
For various viewpoints on the tectonic development of the Puerto Rico Trench, the reader is referred to papers by Talwani and others (1959), Bunce and Fahlquist (1962), J. Ewing and M. Ewing (1962), Hersey (1962, 1966), Van Voorhis and Davis (1964), Donnelly (1964), Talwani (1964), Sykes and Ewing (1965), Hersey and Chase (1965), Bowin and others (1966), Bunce (1966), Bunce and Hersey (1966), and Monroe (1968).


WESTERN LIMIT OF EPICENTERS PLOTTED ON FIG. 3, A-A'
CROSS SECTION A-A', FIG 3
OUTER RIDGE
NAVIDAD BANK
PUERTO RICO TRENCH
CROSS SECTION B-B', FIG. 3
DOM. REP.
MONA
PUERTO RICO
ST. THOMAS
ST. JOHN
ANEGADA
ANEGADA PASSAGE
ST. CROIX
MUERTOS TRENCH
MONA PASSAGE
100 KM
EASTERN LIMIT OF EPICENTERS PLOTTED ON FIG. 3, A-A'
KLM

2A


WESTERN LIMIT OF EPICENTERS PLOTTED ON FIG. 3, A-A'
CROSS SECTION A-A', FIG.3
OUTER RIDGE
NAVIDAD BANK
PUERTO RICO TRENCH
CROSS SECTION B-B', FIG.3
DOM. REP.
MONA
PUERTO RICO
ST. THOMAS
ST. JOHN
ANEGADA
ANEGADA PASSAGE
ST. CROIX
MUERTOS TRENCH
MONA PASSAGE
100 KM
EASTERN LIMIT OF EPICENTERS PLOTTED ON FIG. 3, A-A'
KLM

2B



2C

Figures 2A, 2B, 2C. Earthquake epicenters in eastern Dominican Republic, Puerto Rico, and Virgin Islands area. Epicenter locations shown as solid circles and solid triangles are from Gutenberg and Richter (1954), Pimentel (1959?, 1960?, 1963?), and Simon (1960?, 1961?, 1962?, 1963a?, 1963b?, 1964?, 1965?). Epicenters shown as open circles with dot are from Sykes and Ewing (1965). Numbers refer to those on Tables 1A and 1B. Bathymetry from various sources. Contour interval is 500 fm. A-A' is location of Figure 3A; B-B' is Figure 3B. Dashed lines separate distinct structural and geophysical provinces in area.

Griscom (1968, p. 34) wrote of the Puerto Rico Trench that,

> If the island-trench system and its associated isostatic imbalance have persisted since Oligocene time as a result of some dynamic process, it is somewhat surprising that the coastal plain rocks are as structurally simple as they are. The Cretaceous and early Tertiary island arcs deduced by some writers from the intensely deformed older volcanic and sedimentary rocks of this region appear to be very different, both in lithology and structural style.

If the Puerto Rico Trench is a graben structure, and not an island-arc-type trench, then the matter is not "surprising," and it is not necessary to explain why ". . . the coastal plain rocks are as structurally simple as they are." Nevertheless, it is a fact that, in many active island arcs, middle Eocene to Holocene strata are only moderately folded and tilted. Generally they are tilted and cut by normal faults but "intensely deformed . . . rocks" are not characteristic of most post-early Eocene or post-middle Eocene sections (for example, Lesser Antilles: Christman, 1953; Ryukyus: Foster, 1965; and many other examples).

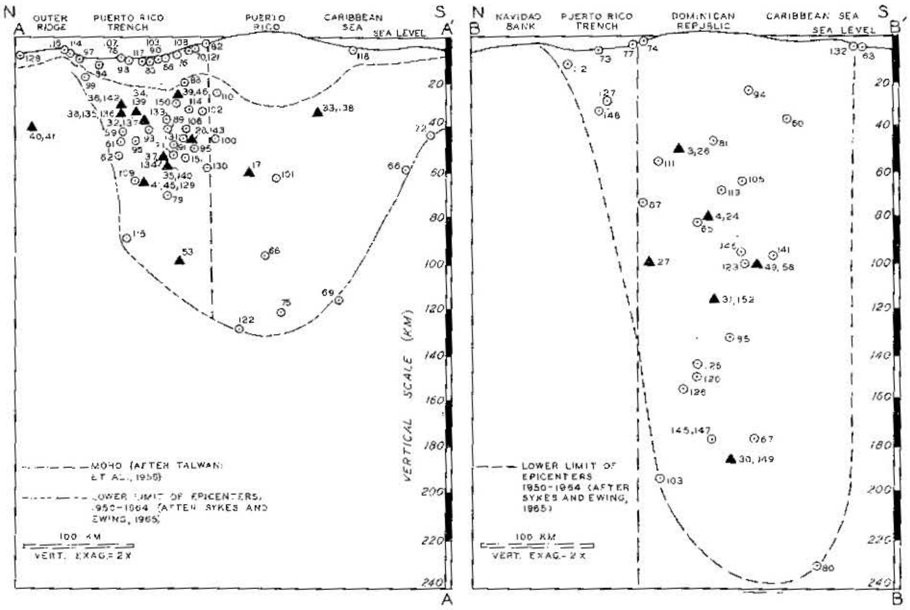


Figure 3. A: North-south section across Puerto Rico-Virgin Islands. Shows earthquake hypocenters projected into line of section. Triangles and open circles with dot are from same sources as those in Figure 2. Focal depths are from Tables 1A and 1B. Location of Mohorovičić discontinuity is from Talwani and others (1959). Vertical exageration is 2×. B: North-south section across eastern Dominican Republic. Same scales, exaggeration, and sources as for A. Note totally different hypocenter distribution in the two areas crossed by sections A-A′ and B-B′.

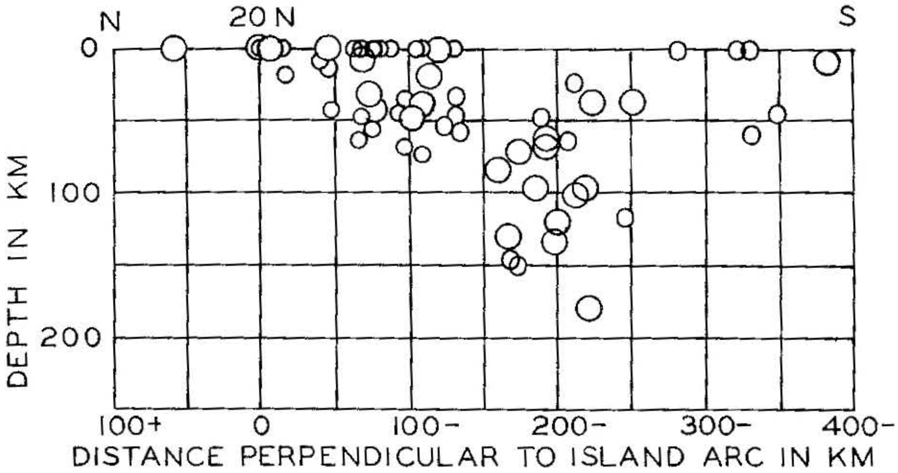


Figure 4. North-south section through Greater Antilles showing hypocenter distribution from 64° W. (Virgin Islands) to 69°W. (eastern Dominican Republic). Larger circles are most accurately located hypocenters (*from* Sykes and Ewing, 1965, p. 5071, published with permission). Hypocenters are same as those in Figures 3A and 3B. Note that, by combining results from both structural-geophysical provinces, a different hypocenter pattern appears and a misleading tectonic interpretation results.

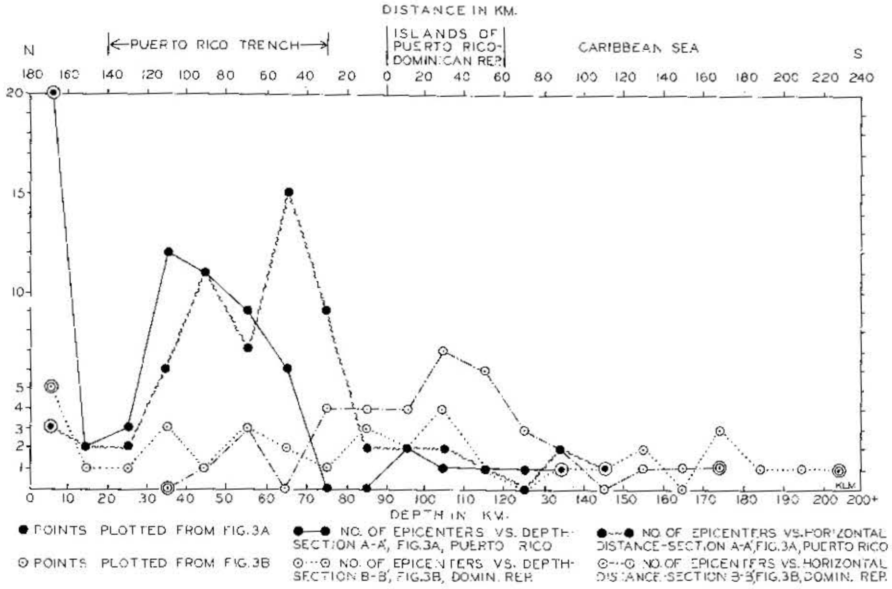


Figure 5. Graphic plots of (1) number of epicenters versus depth and horizontal distance, Puerto Rico-Virgin Islands (section A-A′, Fig. 3A), and (2) number of epicenter versus depth and horizontal distance, eastern Dominican Republic (section B-B′, Fig. 3B). This graph further emphasizes fundamental structural and geophysical differences between the two areas. Data from same sources as for Figures 2 and 3.

Furthermore, two important characteristics of the gently tilted post-middle Eocene strata of all modern, tectonically active island arcs are (1) the presence of volcanic rocks and volcanic-derived detritus, together with limestone and other sedimentary rocks, and (2) the presence of intrusive rocks, some of which are of dioritic to granodioritic composition. In the middle Tertiary sections of Puerto Rico and the western Virgin Islands, contemporaneous volcanic rocks, volcanic debris, and intrusive bodies are absent. These facts further support the concept that the Puerto Rico Trench is not an island-arc-type trench associated with a Benioff zone.

AREAS SURROUNDING GREATER ANTILLES GEOSYNCLINE

North of the western half of the Greater Antilles is the Bahamas platform, a large promontory of continental crust extending from Florida into Cuba and possibly to northwestern Haiti and the Turks and Caicos Islands (Fig. 1). The continental crust beneath the western Bahamas, just north of Cuba, is approximately 30 km thick. The crust thins toward the Atlantic margin of the Bahamas, where it is estimated to be about 23 km thick (Talwani and others, 1960). Southward, across Cuba, the crustal thickness decreases to 20–25 km adjacent to the Caribbean Sea (Soloviev and others, 1964a).

Modified oceanic crust underlies both the Caribbean Sea south of the

Greater Antilles and the Gulf of Mexico (Officer and others, 1959; J. Ewing and others, 1960; Edgar, 1968). Meyerhoff believes that the Caribbean and Gulf always were underlain by ocean crust, and that these areas are being "continentalized" or accreted to the North and South American continents. Khudoley, in contrast, believes that these are areas of former continental crust which have been "basified," and sank during Cretaceous and later times.

East of the Turks and Caicos Islands, oceanic crust is present north of the Greater Antilles, and the Puerto Rico Trench is a prominent feature. Contrary to much published opinion (for example, Hess and Maxwell, 1953), there is no evidence that the Bartlett Trough and the Puerto Rico Trench are connected (A. A. Meyerhoff, 1966). These two fault troughs have different trends and probably are of very different ages. This would rule out Wilson's (1966) suggestion that the two fault troughs are parts of a single transform fault system. The origin of the various fault troughs of the Greater Antilles and their effects on the paleogeography of this area are discussed in subsequent sections.

The Greater Antilles orthogeosyncline is intersected and nearly bisected by the present Cayman Ridge in southeastern Cuba, and by the modern Nicaragua Rise in Jamaica (Figs. 1, 13). These ridges are underlain by continental-type crust (J. Ewing and others, 1960; Edgar, 1968) and are separated by the Bartlett Trough and its associated fault system. This fault system dies out between Cuba and Hispañola (A. A. Meyerhoff, 1966). Meyerhoff postulated that the Cayman Ridge-Nicaragua Rise complex is the remnant of a Paleozoic and younger orthogeosyncline. Subsequent work at the western end of the ridge-rise complex, summarized by Anderson (1969) and Dengo (1968, p. 20), corroborates this conclusion. Arden's (1969, p. 308) statement that "There is no evidence that the rise is older than Jurassic, and no reason to believe that it was the site of a Paleozoic geosyncline" ignores the facts that (1) Paleozoic rocks strike directly offshore from Honduras into, and on trend with, the rise; (2) Jurassic strata in Honduras are of continental, nonvolcanic facies; and (3) Early Cretaceous rocks in Honduras are terrigenous clastic, carbonate, and evaporite strata.

South of Hispañola, the prominent submarine Beata Ridge extends into the Caribbean Sea. The age of this feature is unknown, but the crust beneath it is either modified oceanic or partly continental crust (Edgar, 1968). Pleistocene to Eocene deep-sea sediments have been collected from fault zones and fractured basalt of the ridge (Edgar, 1968; Fox and others, 1968), and Eocene shallow-water sediments have been found high on the ridge (P. J. Fox, October 9, 1968, written commun.). Eardley's (1962) hypothesis that the Beata Ridge is a Paleozoic geosynclinal remnant connecting North and South America is unsupported by facts; the ridge does not reach South America.

At the eastern end of the geosyncline, the Greater Antilles is intersected in the Virgin Islands by the Lesser Antilles island arc. This arc probably formed during latest Cretaceous or very early Tertiary time (oldest dated sediments are middle Eocene: Christman, 1953), and, in its present form, it developed independently of the Greater Antilles orthogeosyncline.