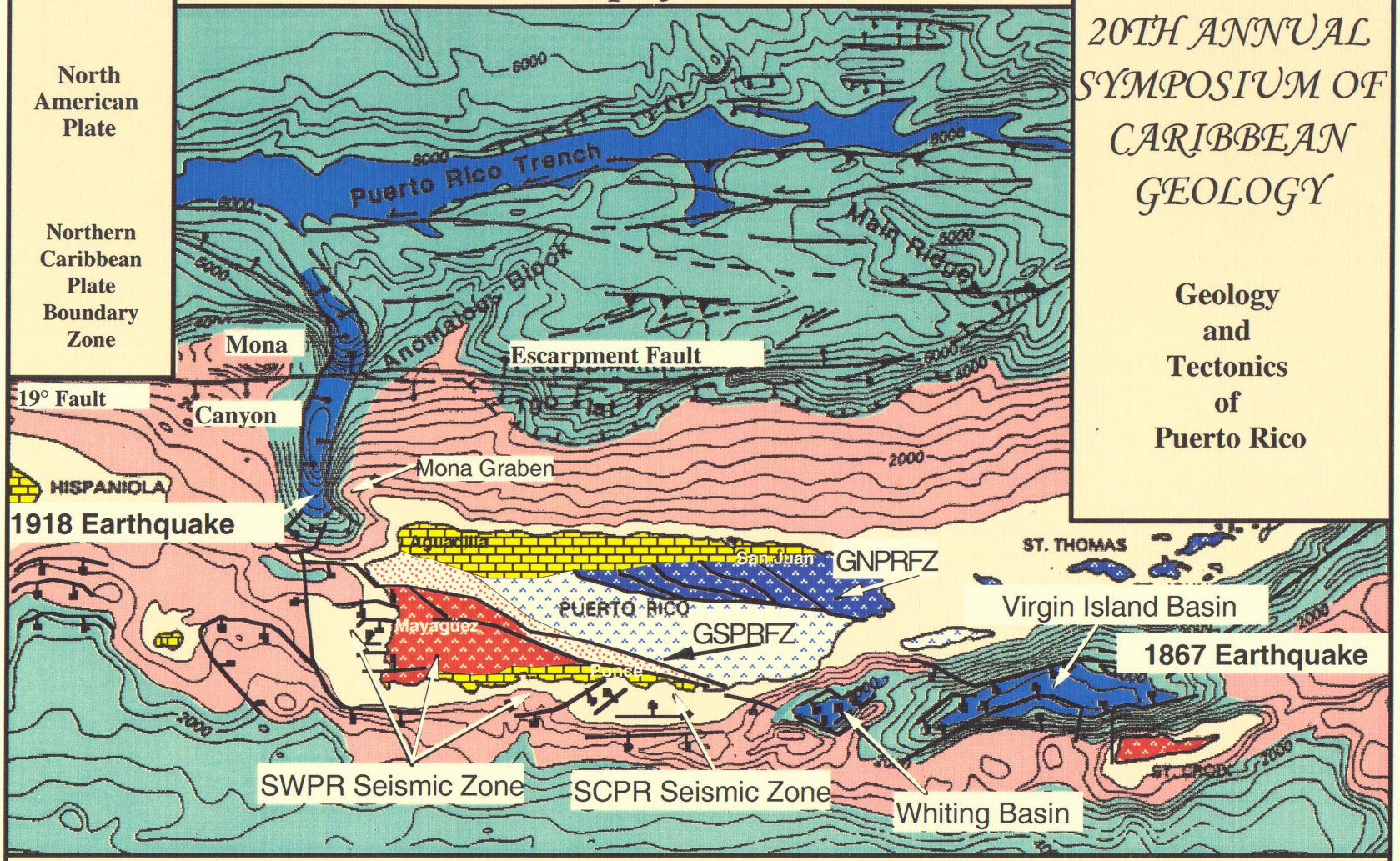
Neotectonic Map Of Puerto Rico



20TH ANNUAL SYMPOSIUM OF CARIBBEAN GEOLOGY

Geology and Tectonics of Puerto Rico

Department of 'Geology - University of Puerto Rico - Mayagüez

Wednesday, February 27 and Friday, March 1, 2002

Salon Eugene Francis - Edificio Física

Invited Guests:

Carol Prentice, Western Earthquake Hazards, U.S.G.S., Menlo Park CA

Nancy R. Grindlay, Coastal&Marine Geophysics Laboratory, UNC-Wilmington NC

Robert D. Rogers, University of Texas Institute for Geophysics, Austin TX

Eugenio Asencio, Tectonics and Geophysics Laboratory, USC, Columbia SC

Day 1 Neogene Tectonics in the Southwest Puerto Rico Seismic Zone

Southwestern Puerto Rico is geologically unique from the rest of the island in having a metamorphosed mafic and ultramafic basement of Jurassic to Early Cretaceous age and wide spread, thick deposits of Late Cretaceous limestones. The ultramafic basement rocks occur as cores of northwest-west trending anticlines. The anticlines and synclines may have formed by crustal shortening in the Eocene or may even have been formed by diapiric intrusion of serpentinized peridotite. It is possible that diapiric protusion of the serpentinite continues today. The serpentinite bodies tend to form the highest ridges in the area (Monte del Estado, Las Mesas, Guanajibo-San German Ridge and Sierra Bermeja). They area also associated with the highest concentration of onland seismicity of the southwestern seismic zone. The Late Cretaceous limestones and their companion island arc volcanic rocks form synclines between the serpentinite bodies. The folded structure of the southwest has been overprinted by east-west trending half grabens (Lajas, Quanijibo, Añasco and Moca Valleys) formed by late Tertiary and Quaternary faulting).

Leave Mayagüez on PR 2 east until the Mall and turn on to PR 100 south until the top of the first hill.

As we drive up the hill road cuts expose the north limb of the anticline which is composed of northward inclined, reverse faulted, and hydrothermally altered Yauco Mudstone that is cut by numerous dikes and sills.

Stop 1 Guanijibo Serpentinite Road Cut
(south side of Las Mesas PR 349).

The serpentinite core of the Guanijibo anticline is exposed and covered by thick Fe-Ni laterite with a prominent (B?) horizon composed of nodules of goethite. The completely serpentinized and tectonized nature of the ultramafic rocks is evident in this outcrop. The serpentinite is highly sheared and cut by numerous shear zones. Foliation in some of the shear zones suggest normal movements towards the boundaries of the body. On the south side of the serpentinite, the exposures of the Fe-Ni laterites are covered by paleo-soils and quartz rich sediment. The southern exposures have the form of a faulted anticline and syncline that has recently been suggested as a Quaternary strike slip fault zone. The faulted laterites and the overlying sediments however may be as old as Oligocene.

Continue down PR 100 to the car wash

Stop 2 Oligocene? Unconformity

Rock cuts on the opposite side (east) of the road expose highly weathered and faulted Cretaceous sedimentary rock. These rocks are unconformably overlain by sandy sediments that contain numerous larger clast of chert. Although some of the faults do not cut through the unconformity, the

sediments appear to terminate on their north side along a fault that continues up from the Cretaceous rocks. Prior to their overgrowth, the construction cuts on the west side of the road had exposed faults in the younger sandy sediments. The sediments are mapped as Quaternary or Tertiary quartz sand deposits. They are probably either Oligocene or Miocene in age.

Continue south on PR100 to the north side of the Lajas Valley.

Stop 3 Lajas Valley-Boqueron Bay

From the hill top we can see the rectangular shape of the bay. The south side of the bay and the Lajas Valley are marked by an east -west trending topographic ridge that includes the south side of the Sierra Bermeja. The ridge is believed to mark the extension of an offshore fault on to land. The fault is north dipping and forms a half graben. Recent studies suggest this fault cuts through the Quaternary alluvial fan deposits on the south side of Sierra Bermeja.

Stop 4 Quaternary Alluvial Fan and Fault Scarp

The Lajas Valley of southwestern Puerto Rico is an E-W trending, 30-km-long, linear depression bounded by abrupt mountain fronts on its northern and southern edges. The geomorphology and closed drainage of this valley suggest it is fault controlled, and therefore we chose this region to focus our studies. From aerial photographs and field reconnaissance, we identified a roughly east-west trending scarp crossing an alluvial fan on the southern side of the Lajas Valley. We excavated a 2-meter-deep trench across this scarp that exposed two fault zones, about 1m apart, disrupting the alluvial fan deposits. Relations indicate normal faulting, valley-side down, with a component of strike-slip motion, though we could not determine whether the horizontal component of displacement is right or left lateral. Structural relations and radiocarbon analyses of organic material collected from the sediments suggest that at least two surface-rupturing earthquakes occurred at this site during the last 7500 years. The earlier event occurred between 5650 and 7550 Cal. years B.P. The younger event occurred post 5040 Cal. years B.P., but no minimum age has yet been established.

Stop 5 Punta Montalva. steep dipping Miocene Ponce Fm

Punta Montalva lies west of Guancia and east of the Parguera Hills that comprise the north limb of the Parguera Syncline. North of the point the topographic ridges are composed of steeply dipping Cretaceous limestone and volcanic rocks. The Cretaceous rocks are unconformably overlain by Oligocene or Miocene limestones. The unconformity is marked by a basal conglomerate overlain by an oyster rich horizon in the limestone. At the point itself the younger limestone layers are notably steeply inclined to the south and strike nearly east-west. Southward along the beach the same thin bedded and crossed bedded grainstone layer that is steeply inclined on the point is nearly horizontal, as is the remainder of the limestone in the hills to the east. The

steeply inclined layers were probably rotated in a fairly narrow fault zone with the south side of the fault having considerable dispacement downward. This fault may continue westward across the bay and on the north side of the Parguera Hills. Its extent eastward towards Ensenada and Guanica is uncertain.

As we drop into Guanica we can see the mudflats on the delta of the Rio Loco. Cretaceous limestone form the hills to the north and the hills to the east thatt mark the end of the Lajas Valley are composed of Oligocene terrigenous and carbonate sediment.

Stop 6 Lunch Yauco Plaza-Los Amigos de Rene

Unfortunately the splendedly faulted Oligocene Juana Diaz Formation has been largely covered over by development. We can still see a few faults on the opposite side of the road. We will therefore move south to the Barinas Hills to enjoy the middle Tertiary formations shown in Figures 1-4 from Frost et al. 1983.

Stop 7 Hacienda El Monte

Oligocene terrigenous and coral rich carbonate layers of the Juana Diaz Formation. The outcrop has a general synclinal form but the layers on either side do not seem to match, suggesting a fault may be covered by the recent landslide between the oppositely dipping sections.

Stop 8 Guanica Landfill

Ponce limestone unconformably overlies faulted Juana Diaz conglomerate. Most of the faults do not cut across the unconformity. North of the landfill is an exposure of gray Cretaceous limestone.

Stop 9 Las Ruinas

I don't know what this place is or was but it looks cool. Maybe we will find out.

Alternates (Si Dios or Michele quiere!)

A Media Quijada

Faulted limestone on serpentinite, meta-volcanic rocks and chert.

B. Rio Grande, Sabana Grande

High river terrace deposits along the Rio Grande on the south side of the Monte del Estado serpentinite belt that may have been uplifted by the Virgen del Poso.

Day 2 Geologic Structure, Geomorphic Provinces and the Impact of the 1918 Earthquake on Northwestern Puerto Rico

The purpose of today's field trip is to explore how geologic stucture, stratigraphy and neotectonic activity have controlled the geomorphic development of northwest Puerto Rico and how this area was affected by the 1918 Mona Canyon earthquake. The text of The Porto Rico Earthquake of 1918, Report of the Earthquake Investigation Commission by Harry Fielding Reid and Stephan Taber has been exerted and appear in quotes throughout the guide to describe the conditions in the areas at that time. Their intensity map of the area is included as Figure 5.

1918 Revisited

"The earthquake began suddenly without warning. No shocks had been felt in this part of the island for seven or eight months. At almost 10:15 am on October 11 there were two severe shocks separated by an interval of two to three minutes. The first shock was the most severe and is described as having a strong vertical movement; it was followed by horizontal oscillations, which caused most of the damage. Shocks of less intensity were felt at frequent intervals thereafter for several weeks, and in the beginning the ground appeared to tremble without cessation for considerable periods. The strong aftershocks on October 24 and November 12 differed from the first disturbance in that they seemed to consist chiefly of horizontal oscillations.

.....the majority of observers report that the principal horizontal vibrations were east and west, and this is supported by much confirmatory evidence. Many facts indicate that in the extreme west and southwestern part of the island the principal horizontal component was in a northwest-southeast direction and, perhaps, in some places nearly north and south. As evidence of vertical motion the following facts are cited.....At **Rincon** the bars of doors were raised permitting doors to open. At a house near **Mayagüez** wooden columns supporting a porch roof jumped up and down, and after the earthquake a shoe was found between the base of one column and the floor of the porch. .... the dominant horizontal motion appears to have been in an east-west direction.... At **Aguadilla** the front and west wall of the church was cracked horizontally at the height of the side walls and the upper portion nearly toppled over. The side walls were not affected. A large building facing east on the plaza has a flat brick roof which showed large cracks running parallel and close to the east and the west parapet walls. These walls were badly cracked above the roof line, and one was tilted towards the west while similar walls running east and west remained in tact. Another nearby building had north-south cracks near the walls but no east-west cracks.

At **Punta Jiguero**, on the other hand, the evidence is indicative of a dominant north and south movement. the lighthouse tower was badly cracked horizontally and the north side was offset toward the south abut 15mm; the parapet walls enclosing the roof were damaged by cracking and scaling on the north and south sides, while the east and west walls were uninjured. Interior

walls one brick thick, running north and south, showed well developed diagonal shearing cracks intersecting at angles of 90°.

At **Central Corsica**, 4 kilometers south of Rincon, observers report visible undulations in the surface soil moving in a southeasterly direction, and the upper third of a brick smoke stack, 38 meters high fell in a direction N30°W. At **Central Eugenia** between Rincon and Añasco, numerous cracks running about northeast and southwest were formed through out the cane fields, which are in soft alluvial ground.

Mayaguez

Mayaguez, the largest town in the western part of the island, having a population of about 17,000 is between isoseismals VIII and IX. The intensity of the shock as measured by its effect on buildings, was nearly as great as at Aguadilla, although Mayagüez is further from the seat of the disturbance. the relatively high intensity at Mayagüez is due to the fact to the fact that much of the town is built on alluvial ground which is in places saturated by water. The theater is on about 5 meters above sea level and here the water stands within a meter of the surface, at times coming up through the floor of the basement.....

The collapse of "La Habanera," a large two story cigar factory in the lower part of the city resulted in the loss of several lives. The walls of this building were of concrete, 6 inches thick, with half-inch rods placed about 1 foot apart. The concrete was deficient in cement and composed of poor materials, so that it could be easily picked to pieces.

In Mayagüez brick and mamposteria buildings were more or less badly cracked, but comparatively few walls were overturned, although many heavy masonry cornices came down. A few concrete buildings of very poor material were seriously damaged, but most concrete and reinforced concrete buildings were uninjured, except where the plaster on thin divisional walls was cracked or thrown down, as in the Science Building at the School of Agriculture and in the parish house of the Redemptorist Fathers. Many of the telephone and electric light poles in Mayagüez are of reinforced concrete and some of them were destroyed by the earthquake."

Western Puerto Rico Ridge and Valley Province

Leaving Mayagüez we cross into the Añasco Valley. The muddy Rio Grande de Añasco and her tributaries have filled the valley with clayey rich alluvial deposits. These deposits are probably responsible for seismic wave amplification and liquefaction during the 1918 earthquake. The Añasco Valley is considered to be a south side down, half graben and the on land continuation of late Tertiary-Quaternary extensional faulting in the Mona Passage (Desecheo Ridge). The valley also lies at the western end of the Great Southern Puerto Rico Fault Zone as marked by the Cerro Mula Fault. This fault passes underneath the northern part of the valley and then crosses to the northwest cutting through the western end of the La Cadena Ridge. The steep topographic gradient, triangular facets, parallel drainage and bottle neck valleys along the ridge at the northern end of the valley suggest a fault origin to the La Cadena

Ridge. As we approach the ridge the highway cuts through and passes over a dissected fluvial or marine terrace at an elevation of about 10 meters. This suggests the younger, half graben, fault lies below the valley and that the escarpment has retreated significantly northward from the fault. The younger fault may coincide in part with the Cerro Mula Fault at the eastern end of the valley. Comparing the terrace to dated marine terrace deposits of similar elevation in Rincon suggests an age of at least 125,000 years for the terrace. Only limited seismic activity occurs in the valley and ridge system here.

The La Cadena ridge and range is composed almost entirely of the Eocene Culebrinas Formation. The Culebrinas Formation is characterized by volcaniclastic sandstone and mudstone turbidites and lenses of coarser grained rocks deposited by debris flows. Basaltic marine lava of the Mal Paso Formation occur in the northern part of the range near Aguada. A complex of volcanic rocks including the Mal Paso Formation underlie the Culebrinas Formation along the Cerro Mula Fault Zone at the southwestern end of the range. The early Tertiary volcanic and sedimentary rocks are folded along NW-SE trending axes and are generally highly fractured and locally faulted. Their deformation and the end of volcanism occurred in Eocene-Oligocene time and may have resulted from the collision of the Caribbean Plate with the Bahamas Banks. Along the northern margin of the range the Culebrinas Formation is overlain by Miocene limestones that are tilted northward up to 15° presumably by the formation of half grabens in the Moca and Añasco Valleys.

1918 "Añasco is built on flat alluvial land about 7 meters above sea level, the water level is close the surface, as water stands in wells a depths of from 1 to 3 meters. Here, the first shock, starting with a vertical vibration, is said to have been most severe. People report having seen undulations of the surface, and cracks were formed in the alluvial ground. All brick buildings were destroyed or so badly injured as to make it necessary to pull them down. The municipal building which was built in 1880 of brick with very poor mortar, was almost completely thrown down, while the walls that remained standing were badly cracked. .....Other buildings, one and two stories in height, built of good concrete and well reinforced with steel rods, were uninjured except for a few cracks of little importance. Wood frame buildings were not damaged except in a few instances where the timbers had rotted.

Continue north on PR 2 and turn left at the intersection with 116 and continue west past the intersection with PR 402 and on towards Rincon. This route takes us along the Cerro Goden Fault Zone which is part of the Great Southern Puerto Rico Fault Zone. As we cruise up to the range steeply dipping rocks of the Culebrinas are evident in the rock quarries.

Stop 1 Cerro Goden Fault Zone- Central Eugenia

Quarry and road cuts in this area expose slices of early Tertiary volcanic and sedimentary formations. Many fault slices show complex internal

deformation including foliations and folds. The deformation in the rock suggests NE-SW shortening and southward thrusting in the fault zone. The outcrop exposes faulted Mal Paso Formation.

1918 "At Añasco the people observed undulations of the surface in the plaza and elsewhere, especially near the coast . Cracks were formed in the ground , and water come up through them, bringing black sand which was deposited on the surface . The water table is here very close to the surface.....

One effect of the squeezing of water from interstitial spaces in saturated alluvium, and perhaps from fractures in rocks was to increase the flow of water in streams and ditches. In cane fields at Central Eugenia many small cracks running about northeast and southwest, were formed and immediately after the earthquake the fields were covered by an outflow of water although the ditches crossing these fields were dry before the disturbance. the water continued to flow in these ditches for several weeks."

Stop 2 Corcega sand pits

The Central Corsica cane fields turned to sand pits and dream homes. The valley lowland between Rincon and Calvache are underlain by thick beach sand deposits which continue inland beyond PR 116. These deposits may have formed during a period of higher sea level or were stranded by regression as the valley filled with alluvium. The valley origin may be related to faults extending inland from the Mona Passage. The low elevation, high water content of the clean sand deposits make them highly vulnerable to liquefaction.

1918 "At Central Corsica, 4 kilometers southeast of Rincon, Mr. Jaime Sifre, the general manager, while standing on the office steps looking in a southwesterly direction, noticed waves moving across the surface to the southeast. He states that the waves moved faster than a railroad train, and estimates the wave lengths at about 1 meter and the amplitude at about 15 centimeters. The high brick chimney of the central was seen to fall during the passage of he sea waves. The local manager, Mr. Antonio Fraticelli states that he saw similar waves at the time of the earthquake on November 12. Cracks were formed in the lowlands in this vicinity and from them water issued bringing up sand.

Continue on PR 116 though the village of Rincon and turn left at the intersection of PR 413 and continue northwest towards Puntas until the Medical Sterile Products Factory and the small municipal museum.

1918 "Rincon is several kilometers nearer the origin of the disturbance than Añasco; yet no walls were thrown down, and the injury to masonry was so much less that it caused general comment. The relative immunity of Rincon is to be explained partly by its foundations in rock and thin residual soil and partly by the character of the buildings, most of which are of concrete or of wood and are only one story in height"

Stop 3 Faulted rock cuts in Culebrinas Formation, Rincon

Faulted and inclined turbidite layers of Culebrinas Formation are exposed in large rock cuts behind the factory. The faults here trend northeast and appear to be largely extensional. This is in contrast to the northwest trending folds and reverse faults that characterize most of the formation and the Cerro Goden Fault Zone. These younger northeast trending normal faults maybe extensions of offshore faults from the Mona Passage. The limited state of weathering and soil development on the Culebrinas Formation in Rincon is probably responsible for the reduced intensity of ground shaking here in 1918.

Continue northwest on PR 413 towards the lighthouse (El Faro) and the Nuclear Plant (Domes). Take the left turn to the Light House.

Stop 4. Punta Higüero Light House with Quaternary-Miocene-Eocene Unconformities.

Quaternary marine terrace deposits unconformably overlie inclined Eocene Culebrinas Formation turbidites on the south side of the point and Miocene Cibao Formation limestone on the north side of the point. The tilted basal conglomerate of the Cibao Formation overlies the unconformity with the Culebrinas Formation at the south side of the beach. A younger unconformity in the Quaternary terrace deposits is seen in the upper cliff face on the north side of the point. This unconformity is marked by solution pits that were filled with fossils and gravel. Corals from the part of Bruce Taggert's thesis study. Karstic weathering dissolution of the mixed terrrigenous and marine terrace deposits have left sections of these deposits devoid of calcareous material.

1918 "The Point Jiguero Lighthouse is also close to the seat of the disturbance. The building is of limestone trimmed in brick, the foundation resting on solid rock. In general plan it is similar lighthouse at Punta Borinquen but the mortar seems to be of better quality, the main walls showed a few cracks, mostly in the mortar, but in places breaking directly across the bricks; the thin divisional walls suffered more damage than the main walls. The tower was cracked horizontally and so was a small chimney; the parapet surrounding the roof was slightly injured on the north and south sides.

At the Point Jiguero lighthouse the keeper, shortly after the earthquake, saw the ocean retire from the shore; and, up on returning almost 2 minutes later, it uprooted coconut palms a short distance north of the lighthouse and crossed the railroad track, leaving fish between the rails, Which are here 5.2 meters above sea level. At the time of our visit the vegetation by the track still showed marks of the rush of the water. For a short distance the coast to the southeast was somewhat protected by the point and the wave was much smaller. About a kilometer from the lighthouse it was 2.7 meters high, and a kilometer further it was only 2.6 meters in height."

If we wish we can walk from here across the domes trail and follow the unconformity over the Cibao limestone to the next beach and Punta Gorda. If not return to PR 413 turn left and continue to the top of the hill and turn left at the Puntas Bakery on to Calle Martillo. Continue on this road to the beach area and park across from Beside the Pointe and The Tamboo Tavern. We can walk back along the beach to Punta Gorda.

Stop 5 Sandy Beach -Punta Gorda

The view from the beach looks out to Aguadilla and the Mona Canyon where the 1918 earthquake took place. The rock outcrop at the end of the beach is composed of 125,000 year old lithic calcarenites overlying fine grained foraminiferal packstones of Miocene age. Between the east and west ends of the outcrop we can see a younger terrace deposit composed of large blocks and pieces of the older deposit. The top of this deposit is marked by wave cut notch at about 3 meters above sea level and along the older Miocene-Quaternary unconformity. Bruce Taggert recovered corals from this deposit that were dated as about 125 thousand years old (like Punta Higüero) and 1,500 to 2,000 years old. We interpreted the older coral to be reworked fossils from the higher deposits. The younger corals indicate the deposit is much younger and that relative sea level was some 3 meters higher than present. Similar deposits were found and dated at Punta Borinquen north of Aguadilla. The significance of this deposit is major but the problem remains unresolved. Most Caribbean sea level works believe regional sea level has not been higher than present for the past 10 ,000 years. If this is true than some 3 meters of uplift of in this area must have occurred over the last 1,500 years at a rate of about 1 meter per 500 years. This is 40 times faster than the uplift of 5 meters per 100,000 years suggested by the elevation of the 125,00 year old deposit! Have we missed a regional sea level high event or has the rate of uplift changed drastically? Could this uplift be a local (Rincon-Aguadilla-Desecho Island) co-seismic event caused by a great earthquake in the past? Stay tuned.

Stop 6 Cibao Formation in the hills south of Sandy Beach

The rock cuts along the bluffs and the valley walls exposes interlayered terrigenous and carbonate units in the Cibao Formation. The thickness and number of conglomerate units increases inland and suggest the proximity of the Miocene shoreline. The outcrop in the inner valley wall exposes conglomerates in channels that cut through paleo-weathering profiles in the underlying limestone layers. Were these facies changes caused by eustatic sea level fluctuations or local tectonic activity?

Return to 413 turn left and continue north to PR116 turn left and continue north to Aguada take the south bypass towards PR

Stop 7 Faulted Cibao Limestone

A normal fault cuts through kufus rich layers in the Cibao Formation just east of the town of Aguada.

1918 "Aguada, stands on flat ground, alluvial in origin, and only about 8 meters above sea level; water is encountered in wells within 1 to 2 meters of the surface. Mamposteria buildings here were largely demolished; some walls, badly cracked by the first shock remained standing and were thrown down by the earthquake of October 24. The church, built prior to 1867, was entirely destroyed; the dome and rear wall collapsed, and parts of the side walls fell, while the walls left standing were badly cracked and apparently on the point of falling. The school house, a one-story, reinforced concrete building, showed a few hair like cracks in the upper corners, but was practically uninjured."

Continue to PR2 and head north to Aguadilla and turn off to Ramey. enter Ramey and turn left into the golf course and continue down to the beach.

From here we continue into the Rio Culebrinas Valley which is also interpreted as a half graben and an on land continuation of the Mona Canyon fault system. Very little seismicity is associated with valley. The last large earthquake to affect Puerto Rico however, did occur offshore in the Mona Canyon. The north side of the valley is marked by the Lares Escarpment which is the southern most end of the north coast karst terrain. Similar to La Cadena the escarpment has probably retreated significantly northward from the fault.

The Rio Culebrinas was probably one of the great Quaternary river systems of Puerto Rico that continued eastward into the Rio Blanco valley as far east as Adjuntas. Stream piracy of the Rio Blanco-Culebrinas River system by Los Rio Grandes de Añasco y de Arecibo diverted most of its water into the Añasco and Arecibo valleys. Low lying and thick fluvial deposits of the Oligocene San Sebastian Formation underlie the valley floor from San Sebastian to Moca. The low elevations and extent of these deposits suggest the Culebrinas and Rio Blanco valleys were the site an important river system in Oligocene.

Northern Limestone Plateau Karst Province

Deposition of the north coast limestone formations began in the Oligocene following the end of volcanism and a period of intense deformation in the Eocene. Limestone deposition was continuous up to the late Miocene and began again in the Pliocene. The presence of an erosional unconformity between Miocene and Pliocene limestones and deeper water character of the Pliocene deposits suggest a major tectonic event in the Late Miocene.

As we rise above Aguadilla on to the Tertiary limestone plateau, we pass along the edge of cock pit karst terrain developed on the Aguada and Aymamón Limestone. Linear patterns in the karst are due to NNW trending faults and folds. Presumably these deformational features are related to Quaternary faulting along the eastern margin of the Mona Canyon. North of Borinquen, cock pit karst features are lost due to Quaternary wave cut terraces that beveled this terrain into low hills and plains.

1918 "Aguadilla, with a population of over 6,000, is the largest town lying within the isoseismal IX. The majority of the buildings destroyed or badly damaged by the earthquake were built on the flat land in the western part of the city bordering the water front; buildings east of the plaza are mostly of wood and their foundations rest on rock or residual soil. Brick and mamposteria buildings were as a rule, badly cracked, and some walls were partly thrown down. .... The concrete and especially steel reinforced-concrete buildings in Aguadilla were practically uninjured, although in a few instances small cracks such as those due to settling, were formed.

At Aguadilla the height of the wave seems to have varied somewhat in different parts of the city but at no place were the measurements less than 2.4 meters above sea level and near the head of the bay the crest of the wave must have been at least 3.4 meters in height. In this town, 32 people are said to have been drowned and about 300 little huts, built along the beach were destroyed. Estimates of the time interval between the earthquake shock and the arrival of the sea wave, made by different observers, range from 4 to 7 minutes."

Stop 8 Punta Boriquen terraces, dunes and lighthouse

"At Point Borinquen Lighthouse the keeper, who was up in the tower when the earthquake began, immediately started down the stairs and when he went down he noticed that the water along the shore had already begun to recede. It returned quickly and the measurements to points indicated by him shows that the height reached by the water, not counting the wash of the wave, was about 4.5 meters. Just southwest of the lighthouse, where the land is lower the water was reported to have washed 100 meters inland into a grove of coconut palms. The lighthouse keeper had the impression that the wave came form the northwest."

"At Point Agujereada the limestone cliffs are 100 to 120 meters in height, and at their base there is a narrow strip of beach which in wider places was planted with coconut palms and used for pasturage. Several hundred palms were uprooted by the wave and the beach was turned into a sandy waste. In this vicinity a few small houses were destroyed and eight people are reported to have drowned. Several people visiting the district soon after the occurrence estimate height of the wave as 5.5 to 6 meters, and the evidence remaining at the time of our visit supported these estimates"

FINAL BASH BEACH PARTY? PLAYA JOBOS ISABELA
Look for the concrete ship!

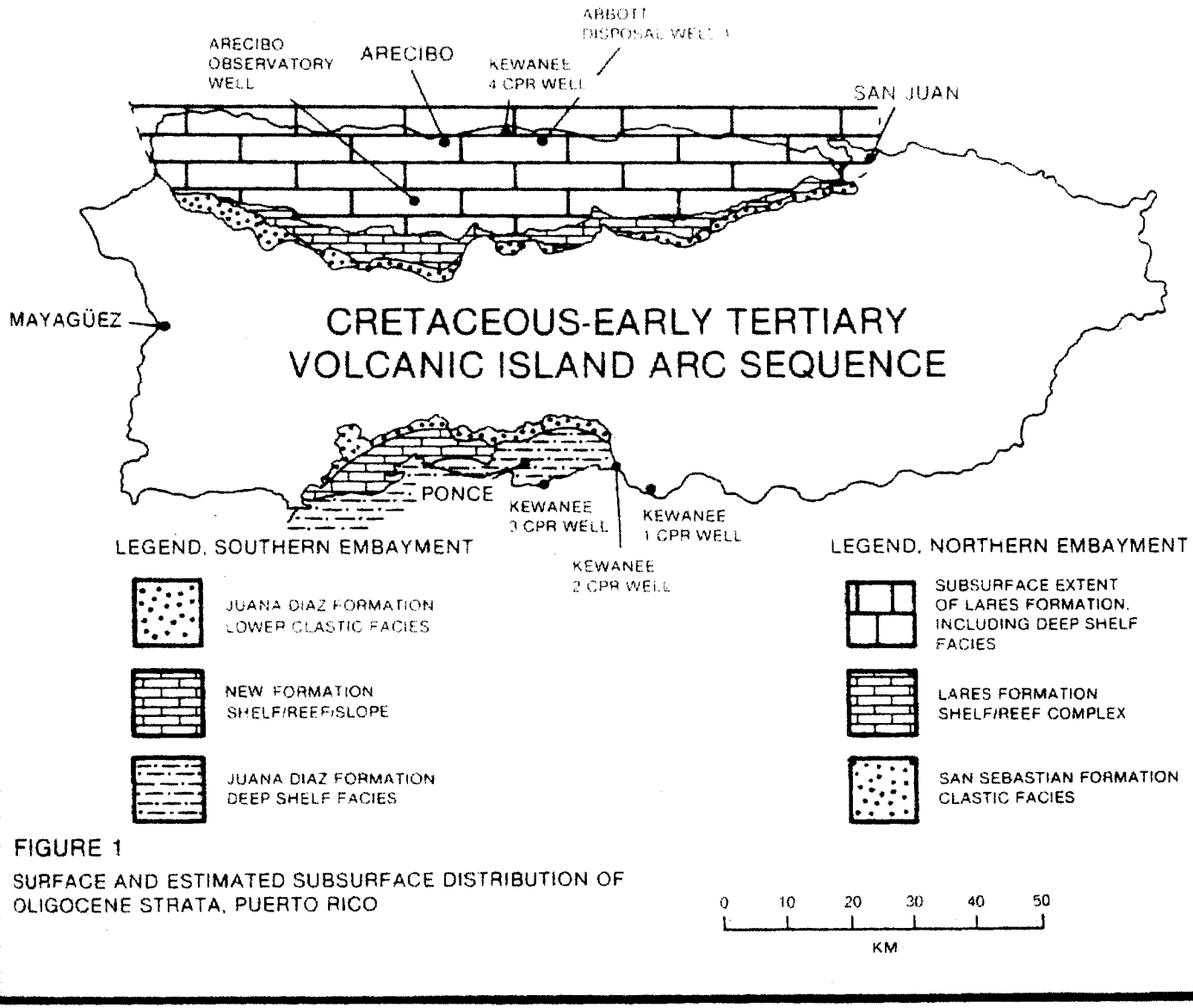


FIGURE 1

SURFACE AND ESTIMATED SUBSURFACE DISTRIBUTION OF OLIGOCENE STRATA, PUERTO RICO

Oligocene Reef Tract Development, Southwestern Puerto Rico
Frost et al, 1983

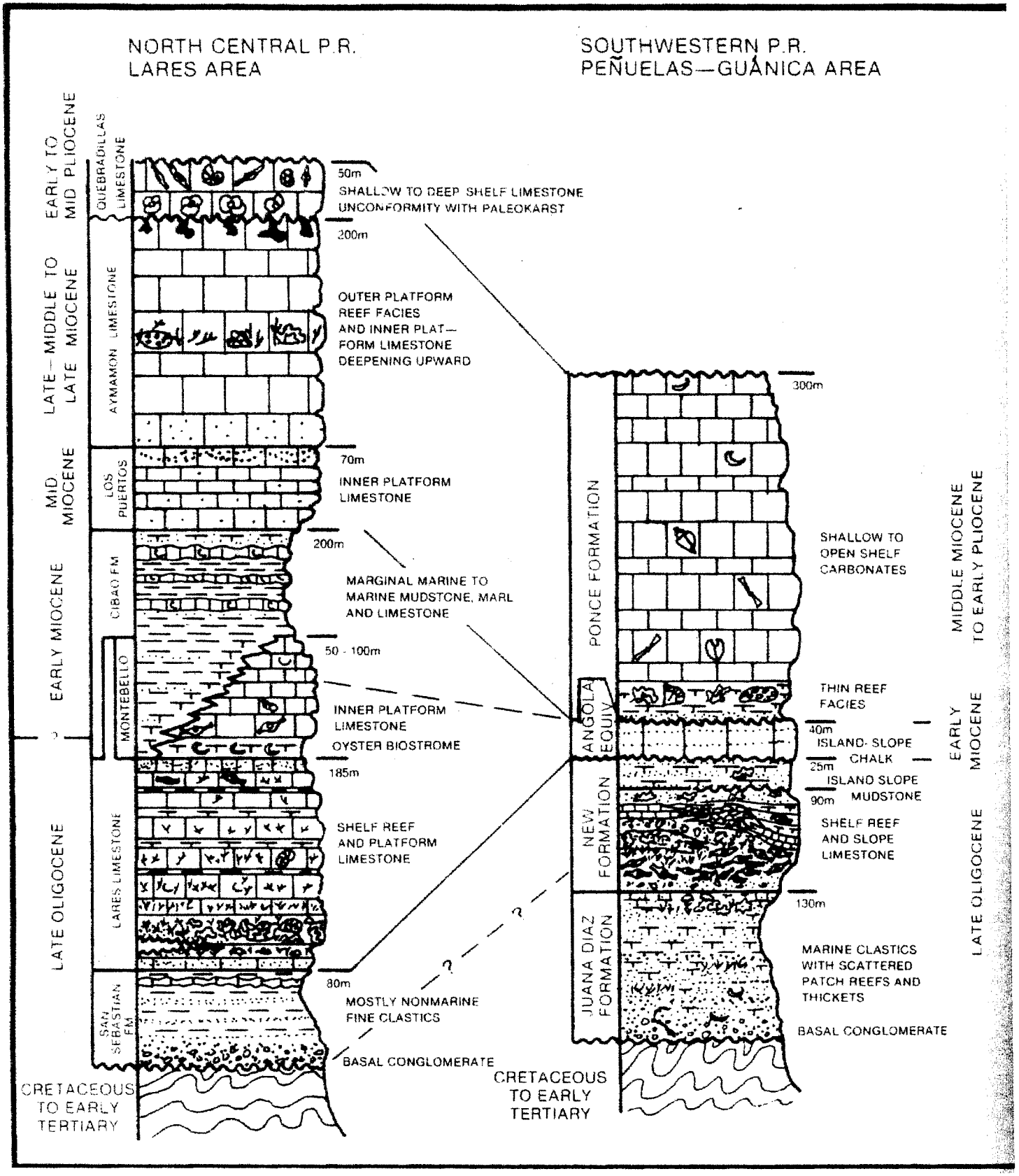


Figure 2 Oligocene to Pliocene Stratigraphic Sequence ,
North Central and Southwestern Puerto Rico
Oligocene Reef Tract Development, Southwestern Puerto Rico
Frost et al, 1983

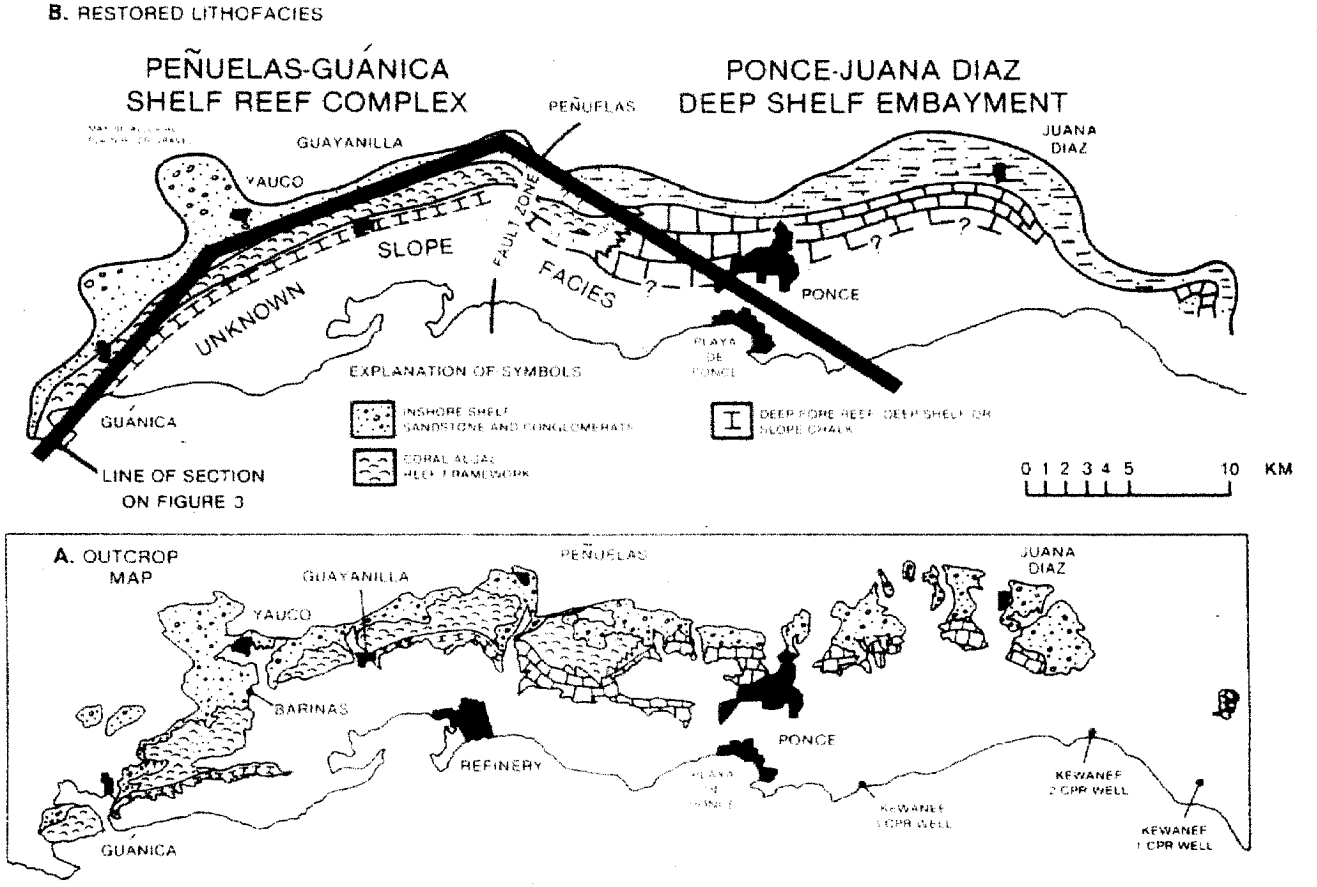


FIGURE 3.
FACIES AND LOCALITY MAP. OLIGOCENE ROCKS OF SOUTHWESTERN PUERTO RICO (AFTER MONROE, 1980 AND MOUSSA AND SEIGLIE, 1970)

Oligocene Reef Tract Development, Southwestern Puerto Rico
Frost et al, 1983

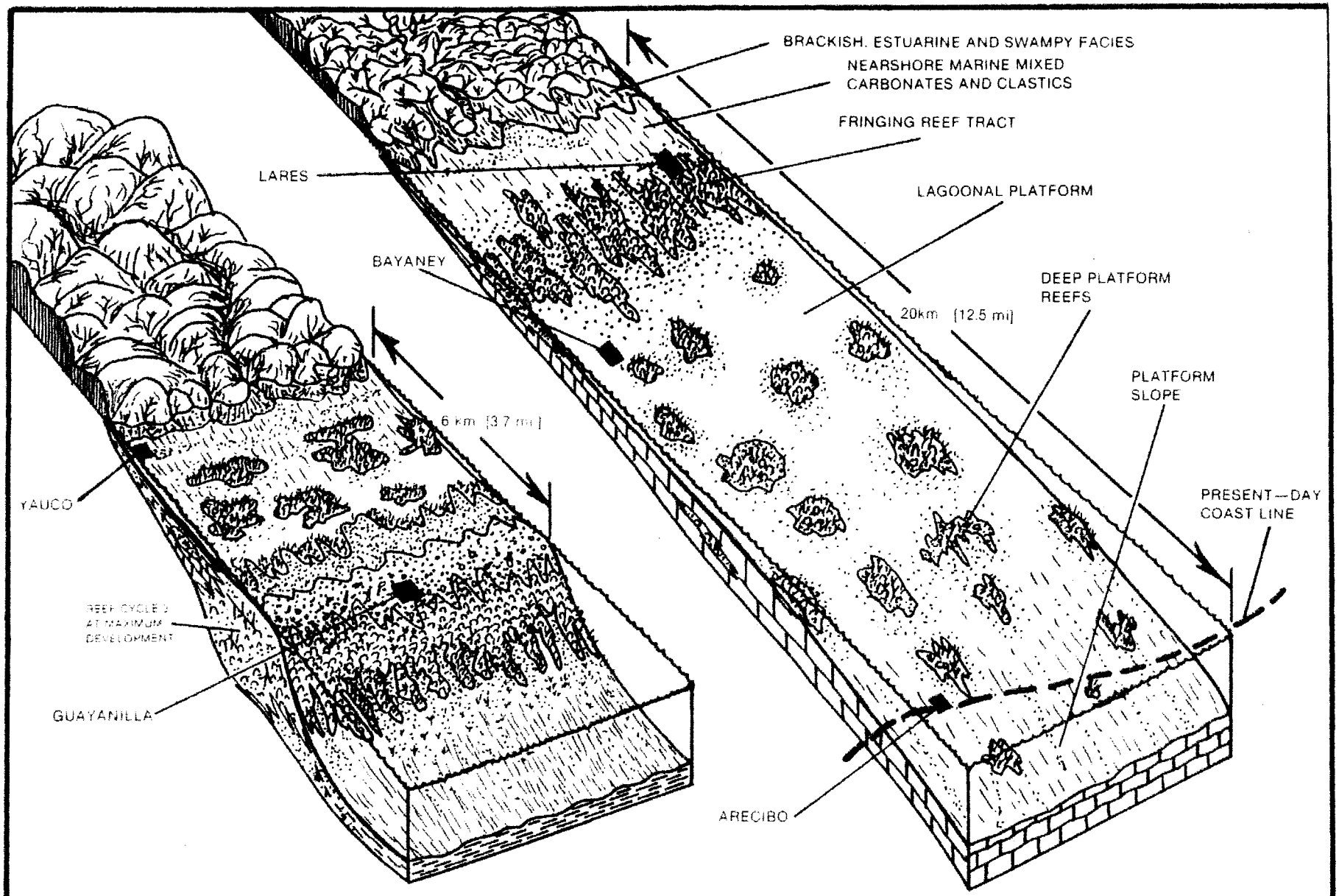


FIGURE 4 . COMPARISON OF THE PEÑUELAS—GUÁNICA AND LARES CARBONATE BUILDUPS.

Oligocene Reef Tract Development, Southwestern Puerto Rico
Frost et al, 1983

Figure 5 Intensity Map-The Porto Rico Earthquake of 1918,
Report of the Earthquake Investigation Commission
by Harry Fielding Reid and Stephan Taber