Geology of the middle Tertiary rocks in the Ponce-Guánica area -- a progress report

by W. H. Monroe

U. S. Geological Survey

[Reports - Open file series]

U. S. Geological Survey
OPEN FILE MAP
This map is preliminary and has not been edited for conformity with Geological Survey standards or nomenclature.

Prepared in cooperation with the Department of Public Works

Area of Natural Resources

1972

The area contains two mappable formations, the Juana Díaz Formation and the overlying Ponce Limestone. The Juana Díaz consists of a lenticular assemblage of sand, gravel, and cobbles, generally overlain by sandy mudstone grading upward into limestone and chalk. In the northeastern part of the area most of the formation consists of reef limestone containing many coral and algal remains. The Ponce Limestone overlies the Juana Díaz unconformably and consists of a thick mass of very fossiliferous limestone. Both formations are cut by numerous faults, some of which have vertical displacements of several hundred meters. The middle Tertiary rocks are overlain unconformably by alluvial and coastal deposits of Quaternary age.

Stratigraphy

Juana Díaz Formation

The Juana Díaz Formation is a lenticular mass of clastic materials interbedded with and generally grading upward into limestone. The formation rests with angular unconformity on volcanic and sedimentary rocks of Cretaceous and early Tertiary age, but the base can be seen at only a few places in the area, for at most places the formation is in fault contact with the older Cretaceous and early Tertiary rocks. On the ridge 300 m south of Escuela Segunda Unidad de Santo Domingo, near the eastern edge of the Yauco quadrangle, the basal beds of the Juana Díaz consist of a conglomerate of cobbles of igneous rock and coral heads; only 2 m above the contact is a mass of limestone pebbles that form a fine-grained calcirudite. In this area gravel is relatively scarce in the Juana Díaz, but at other places gravel and cobbles are common in the lower hundred meters. The basal contact of the formation can also be seen in a fault block 600 m west of highway 335 and 2.6 km west of Central San Francisco in the Punta Verraco quadrangle. Here the basal beds consist of sand, gravel, and cobbles of volcanic rock, immediately overlain by massive tightly cemented calcirudite. Farther up the slope more sand and gravel is exposed. The contact was also seen at two places near the east end of La Cóvana.

Commonly near the base of the formation are beds of very light olive gray calcareous very finely sandy clay that weathers to yellowish brown mudstone; these beds commonly contain abundant prints of mollusks and in some places Lepidocyclina undosa. Lenses of gravel are found throughout the clastic part of the formation as shown in the section described below, which is exposed in a small quarry between the old and new routes of Highway 2, about 500 m west of Escuela Quebradas, northwest of Guayanilla. The beds in the quarry strike N 55 W and dip 14 SW.

Section of Juana Díaz Formation in quarry
2.5 km northwest of Guayanilla

Description (top to bottom)	Thickness (meters)
Chalky clayey calcareous sand containing several lenses of gravel and well-rounded cobbles up to 10 cm long	5.
Sand, gravel, and well-rounded cobbles up to 15 cm long	1.
Calcareous sand containing large calcareous concretions	4.
Very carbonaceous brown clayey sand about 2 m, interlensing with light brown calcareous sandy clay. Many small cobbles at base	5.
Very pale orange sandy rubbly limestone containing fingers of Porites sp. and several larger coral heads ----------	about 5.5

Blocky calcareous light brown sand containing scattered coral heads. A few scattered pebbles ----------		7.
Total thickness ----------	about	27.5

Beds of limestone are present at many stratigraphic positions in the Juana Díaz, but the upper part is predominantly calcareous. In the eastern part of the Yauco quadrangle and the western part of the Peñuelas quadrangle about 400 m of tightly cemented somewhat rubbly limestone crudely stratified in beds about a meter thick rests on sandy clay and mudstone. The limestone contains many algal remains, some coral heads, and scattered molluscan remains, and it apparently is an organic reef built up by marine organisms in fairly shallow water at a place where the sea was relatively free of coarse sediments brought in by rivers. Near its base the limestone contains lenses of cobbly sand as thick as 10 meters. The reef-type limestone is well developed on both sides of Río Macaná and it extends eastward into the Peñuelas quadrangle to a point somewhat east of the Río Tallaboa, where it intertongues with sandy clay. West of the Río Macaná the limestone interfingers with sandy clay and chalky limestone and does not extend as a massive body as far west as the valley of the Río Guayanilla. There are, however, several exposures of limestone in cuts of Highway 132 at the side of the valley that may be tongues extending westward from the main body of limestone. A cut on the new route of Highway 2 about 300 m southeast of the crossing of Highway 132, and about 700 m north of the school in the urbanization of Santa Elena of Guayanilla, exposes 25 m of very hard, wavy-bedded coralline limestone in beds 10 to 30 cm thick that rests on 10 m of gray to light brownish gray sand that itself contains layers of coralline limestone; this limestone is probably a tongue that extends westward

from the main body of limestone. The limestone is overlain by calcareous sandstone and by sandy gravel in exposures in the valley north of Magas Abajo. Exposures are so rare however in that area that it is not certain whether the dominant rock is limestone or clastic; it is shown as clastic on the map.

In the eastern part of the area mapped the upper part of the Juana Díaz consists of about 50-150 m of chalk and chalky limestone in beds 15-30 cm thick. No rock like this was seen west of the Río Guayanilla.

At the top of the Juana Díaz Formation is a unit of sand that is best exposed in the quarries of the Puerto Rico Cement Company, where it fills a channel more than 30 m deep. In the channel the unit consists of thin- to thick-bedded fine to medium grained quartz sand that is carbonaceous in some beds. A few oysters near the base of the unit suggest that it was deposited in shallow marine water. This unit has been recognized at the top of the Juana Díaz at several other places, including good exposures in the road west of Río Tallaboa, but at those places it varies in thickness from only a few centimeters to as much as 4 m. It apparently is a regressive sand deposited in shallow marine water.

West of the Río Guayanilla the lower part of the sequence is much like that described above, consisting of gravel and cobbles in sand, grading upward into sandy silt and clay or mudstone, much of which is fossiliferous. Overlying these clastic beds is a lenticular mass of limestone of unknown thickness. Much of the limestone is overlain by such a thick layer of caliche, described below, that its presence can only be inferred, but good outcrops of massive crystalline limestone containing algal remains and coral columnals were seen on the west bank of Río Guayanilla at a small dam, 1 km north northwest of the athletic park in Guayanilla. It seems likely that much of the northern part of the Montes de Barina is underlain by similar limestone.

On the east side of Guánica Bay cuts on Highway 333 and adjacent sea cliffs expose about 70 m of grayish orange to very pale orange coarse calcarenite in beds 10-30 cm thick separated by beds of soft chalk 2-5 cm thick. Interbedded with this limestone are a few thick, massive beds of calcirudite. Lepidocyclina undosa is very common in this section.

The fossils of the Juana Díaz have not been critically studied, but C. Wythe Cooke made extensive collections in 1955. The most distinctive fossil is Lepidocyclina undosa and its alternate Lepidocyclina gigas. On the maps the localities at which Lepidocyclina has been seen are marked with an L. In the eastern part of the area Lepidocyclina has been found in the lower part of the clastic member, near the base of the formation, in the overlying limestone, and as high as the top of the limestone sequence. It was not seen in the uppermost chalky limestone. In other parts of the area Lepidocyclina has been found at many places in the clastic member, but not at places where the unit is made up of cobbles. It is present at many places in the limestone part of the sequence, but was not seen in the northwestern part of the Punta Verraco quadrangle, although it is present in the limestone in the adjacent part of the Yauco quadrangle. In the cuts on Highway 333 on the east side of Guánica Bay the limestone at the top of the Juana Díaz contains abundant Lepidocyclina undosa. At some places, particularly in the northeastern part of the area, Lepidocyclina is so abundant in certain beds that it forms a coquina. At several of these places associated with it is the large echinoid Clypeaster oxybaphon. Some beds in the Juana Díaz, especially the

limestone beds, contain other fossils, some as molds of the interior or exterior. Among these Cooke collected several species of Pecten, Ostrea aff. haitensis, Kuphus, and rarely other mollusks. Coral heads are abundant in some horizons, especially at the base of the formation, and finger-like columnals of Porites are locally abundant in colonies. The fossils indicate that in the eastern part of the area most of the Juana Díaz is Oligocene, although the upper chalky limestone may be younger. In the area near Guánica the entire formation is Oligocene.

The thickness of the formation is uncertain, mainly because so much of it has been cut by faults, so that it is difficult to find unfaulted sections in which it is possible to calculate the thickness. Based on rather insecure data the clastic lower part of the formation may be as thick as 700 m in the eastern part of the area and thins to about 100 m in the western part. It is missing west of Guánica, where reconnaissance studies near Cabo Rojo have shown that the normally overlying Ponce Limestone rests directly on Cretaceous rocks. Sand and gravel in the Lajas Valley may be a western quivalent of the Juana Díaz, but the only fossils seen nearby appear to be of Ponce age. The limestone unit appears to be about 400 meters thick in the reef deposit that crops out in the Río Macaná valley, but it is entirely possible that there may be some duplication of thickness by faulting, although none was seen. The limestone is certainly much thinner farther west and in the Guánica area it is only 65 m thick; it seems to be about 180 m thick in the western part of the Punta Verraco quadrangle. The chalky limestone at the top of the formation has been seen only east of the Río Guayanilla. The thinning of the formation westward, especially of the upper part, is probably the result of overlap by the Ponce Limestone.

Ponce Limestone

The Ponce Limestone rests unconformably on the Juana Díaz Formation and apparently overlaps it toward the west, until west of the Guánica quadrangle the Ponce rests directly on rocks of lower Tertiary to Cretaceous age. Because of the nearly universal cover of secondary calcium carbonate, caliche, the contact of the Ponce and the Juana Díaz has been seen at only a few places in the area. On Highway 333 the contact is poorly exposed 400 meters north northeast of Faro de Guánica, where the uppermost Juana Díaz is coarse calcarenite in beds 10-30 cm thick, containing abundant Lepidocyclina undosa, and the basal Ponce is several meters of white chalky limestone and chalk containing a rubble of molds of mollusks and coral heads. At several places the chalky limestone contains many oyster shells; the most accessible is a small quarry on the west side of the road 600 m south of Campamento Borinquen in the Bosque Estatal de Guánica in the Punta Verraco quadrangle. The chalk contains abundant oysters and Kuphus tubes at the crest of the low ridge a kilometer east of Punta Montalva, near the western edge of the Guánica quadrangle. Similar chalk is present in a small quarry at the side of a secondary road 900 m west of Central Rufina, but there is no evidence of the presence of Juana Díaz nearby; rather poor outcrops of limestone in the valley west of Piedras Blancas, northwest of the quarry, and west and northwest of Los Indios all seem to be Ponce Limestone. Thus the chalk in the quarry is mapped as Ponce well above the base.

Evidence of the unconformity at the base of the Ponce Limestone is shown on the hill 4 km west of the northeast corner of the Guánica quadrangle where limestone containing Ponce fossils rests directly on gravel of the lower part of the Juana Díaz Formation; the upper limestone beds of the Juana Díaz have been overlapped by the Ponce.

Thin-bedded or laminated limestone that crops out at Punta Montalva has been questionably mapped with the Ponce on the basis of the presence of a few oysters and Kuphus tubes, both of which are present in the undoubted Ponce a kilometer farther east. Laminated limestone like this has not been seen elsewhere either in the Ponce or Juana Díaz.

Typical Ponce Limestone consisting of grayish orange to very pale orange more or less rubbly calcarenite containing abundant molds of solitary corals, mollusks, and distinctive foraminifera crops out in most of the area shown as underlain by Ponce on the maps. Outcrops are especially good in the cuts on Highways 2 and 127 east of Guayanilla, at Piedras Blancas, in cuts on Highway 335 southwest of the Barrio Indios urbanization, at Cerro Toro at the west end of the Punta Verraco peninsula, and in the cuts on Highway 334 from Cerro Caprón, a kilometer northeast to the bend just north of the 149 m hill.

At many places, however, especially along the coast, the limestone has been completely recrystallized to very pale orange porous to dense limestone containing few recognizable fossils. Some of this recrystallized limestone is grayish orange pink to moderate pink, and does not look at all like the typical "yellow" calcarenite of the Ponce. The presence of distinctive Ponce fossils in limestone both up and down dip from such outcrops have determined that this nontypical limestone should be mapped with the Ponce.

Most of the peninsula of Punta Verraco is covered by a mantle of caliche 2-3 m thick, and the bedrock is called Ponce entirely on the basis of the resemblance of the limestone exposed in the low sea cliff a kilometer east of Cerro Toro to the limestone definitely of the Ponce exposed at Punta Ventana. In the bottom of a large scraped area half a kilometer farther north, however, gravel like that seen in the lower part of the Juana Díaz rests on indeterminate limestone beneath 2 m of caliche. No fossils were seen in this limestone in a careful search, however, and it is probable that Lepidocyclina would be present if the limestone were Juana Díaz. The gravel is probably a terrace deposit, but the possibility remains that the limestone should be mapped as Juana Díaz, and separated by faults from definite Ponce Limestone exposed in the sea cliffs of Cerro Toro and in the cuts of Highway 335.

The thickness of the Ponce Limestone in the Yauco-Guánica area can not be determined until stratigraphic test wells are drilled through the formation at several places near the coast. Projection of dips in the eastern part of the area, east of Guayanilla, indicate that the thickness is about 700 m, but this figure is probably grossly excessive, for several faults may cross the outcrop and cause repetition of section. In the area just east of Guánica Bay, southeast of Guánica, projection of dips indicate a thickness of 250-300 m, which seems reasonable. Farther west no reliable attitudes are available, but a thickness of about 250 m seems reasonable considering the width of the belt of outcrop.

The Ponce Limestone is best identified by the abundance of fossils in the more typical outcrops, especially by a profusion of molds of mollusks. The echinoid Clypeaster cubensis has been found only in the Ponce, and in some areas is fairly abundant. Molds of small cup-shaped solitary corals are common in the Ponce and have not been seen in other limestone units. The foraminifers Marginopora sp., and Gypsina pilaris, are common in some areas and have not been found in the underlying rocks. Dr. K. N. Sachs (written communication) has identified Archaias angulatus and a probable Archaias floridanus, which suggest a Miocene age, from limestone cropping out at sea level 500 m west of the end of the pavement on Highway 333 near Playa de Tamarindo. At many outcrops Kuphus tubes are common, but they are also found in the Juana Díaz. And in the basal beds an oyster, probably Ostrea aff. haitensis is common.

Gordon (1961) described a number of Miocene foraminifera from the Lajas Valley, west of the mapped area. The foraminifera came from "an exposure of a crumbly light yellow chalky limestone, showing no bedding, which is seen in a low road cut between kilometer stone 17.8 and 17.9 on Puerto Rico highway 4." The present writer independently discovered the same bed, but the material cropping out now is weathered to crumbly silty clay containing many prints of mollusks. The fossils that Gordon lists are common in the Ponce Limestone and some have not been found in the Juana Díaz. This suggests, therefore, that the outcrop is non-typical Ponce Limestone, perhaps deposited in an area with more detritus than is common in the Yauco-Guayanilla area. If the material described by Gordon is of Ponce age, the nearby gravel and cobble deposits are most likely of Ponce or younger age, rather than Juana Díaz as has been generally believed.

Alluvial deposits

Thick deposits of clay, sand, gravel, and in some places boulders fill the bottoms of the larger river valleys in the area. Boulders were seen only in the valley of the Río Macaná at the edge of the outcrop belt of the Juana Díaz Formation, but cobbles are common in most of the river valleys. The alluvium varies in thickness from place to place. According to available water well logs (McGuinness, 1946) at most places it is less than 10 m thick, but in the Río Loco valley, probably near the northeast corner of the Guánica quadrangle but possibly in the southeastern part of the adjacent Sabana Grande quadrangle, several wells of uncertain location penetrated nearly 25 m of alluvium before entering hard rock, presumably of Cretaceous or early Tertiary age.

Mapped with the alluvium are river terrace deposits, particularly in the Río Yauco valley north of Yauco. Also included with the alluvium are accumulations of thick colluvium at the edges of several alluvial plains and of fairly large alluvial fan deposits debouching from upland valleys, such as the fan at La Luna in the Guánica quadrangle.

A large landslide (Ql) was mapped 1.3 km northwest of Central San Francisco in the Punta Verraco quadrangle. Less conspicuous landslides on most steep slopes were ignored in the mapping.

Coastal deposits

The large rivers of the area, the Río Guayanilla, the Río Yauco, and the Río Loco have all built extensive deltas of clay, sand, gravel, and cobbles, with sand and clay dominant at the surface. These deltaic deposits are mapped with the alluvium of the rivers. At several places along the coast, however, longshore currents have carried the finer sediments, principally sand along the shore and deposited it in reentrants to form beach sand. The beach sand consists mainly of a mixture of shell fragments and dark mineral grains derived from volcanic rocks. Locally they contain small quantities of magnetite (Guillou and Glass, 1957). Deposits of beach sand are extensively developed around Guayanilla Bay, along the south side of the Punta Verraco peninsula, in the lowland just east of Punta Ventana, and near the Balneario de Caña Gorda. Large sand spits have developed in Punta Guayanilla on the east side of Guayanilla Bay, and at Punta Ballena in the western part of the Punta Verraco quadrangle.

Included with the coastal deposits are the common fringing reefs built of coral. These reefs are present along the coast at most places away from the mouths of the larger rivers. Associated with the coral reefs at many places, such as the north side of the Punta Verraco peninsula, are extensive growths of mangrove, which tend eventually to kill the coral reef. Mangrove swamps also are present behind protected beaches and at the edges of the deltas of the rivers, mentioned above. Both the coral reef deposits and the mangrove swamps are shown by appropriate symbols on the topographic base maps.

Caliche

Covering large areas underlain by limestone is a deposit of secondary limestone or caliche that varies in thickness from a few centimeters to several meters. A good exposure of the full development of the caliche is in a pillar left near the center of a large scraped area near the western end of the Punta Verraco peninsula, about 2.6 km east southeast of Central San Francisco. At the top of the pillar is nearly a meter of hard limestone banded in white and light brown. This limestone grades downward into nearly white massive chalk, locally slightly indurated into soft limestone. The chalk rests on a gravel-strewn surface of limestone that is interpreted as a wave-cut terrace on Ponce Limestone that at one time had a cover of river terrace deposit, probably of the Río Yauco. The chalk phase of the caliche can be seen at many road cuts in the urbanization of Barrio Indios north of Central San Francisco and elsewhere in the mapped area. At some places it has been confused with the chalky beds at the top of the Juana Díaz Formation and with the basal chalky member of the Ponce Limestone. The overlying hard limestone forms a cap rock over most of the limestone units of the Juana Díaz and Ponce. It is generally recognizable by the banding, by distinctive cracks that look like dessication cracks on the lower side of slabs of the limestone, and by its attitude, for unless it has been disturbed by landslide or creep, the slabs of limestone strike parallel to the sides of hills and dip with the slopes of the hills.

Structure

The middle Tertiary rocks in the Ponce-Guánica area rest unconformably on an irregular surface of folded and faulted rocks of Cretaceous and early Tertiary age. The unconformable contact is well exposed on the ridge crest south of Santo Domingo in the northeastern part of the area, at several places northwest of Yauco, and at two places at the east end of La Cóvana in the Punta Verraco quadrangle, but at most places the middle Tertiary rocks are in fault contact with the older rocks. At most places the boundary fault is concealed by colluvium that has crept down hill from the essentially unconsolidated Juana Díaz Formation, but it can be seen at several places in the Peñuelas quadrangle.

A boundary fault has been traced ~~west~~ east from Río Cañas into the adjacent Ponce quadrangle. The fault is exposed on Highway 10 at the side of Iglesia San Marcos, where the fault plane dips 70° south.

Another segment of the boundary fault has been traced west from Highway 501. This fault is probably the same as the former, but it has been displaced northward by a fault down the Río Cañas. The fault is well exposed in the volcanic rocks in cuts on Highway 501 and it has been observed at several places on the north slope of the high ridge west northwest of Magueyes and in its continuation for a kilometer west of Río Cañas.

Roughly parallel to this fault is another a kilometer farther north, which is well exposed on the east side of a ridge 1.6 km due north of the village of Pastillo. The high pointed knob at the south end of the crest of this ridge is held up by an isolated outcrop of limestone of the Juana Díaz. The fault can be recognized cutting the volcanic rocks exposed in Quebrada Limón and is easily traceable toward the west up the quebrada, 350 m north of Highway 132; the quebrada follows the fault roughly, at some places being a few meters north of it and at others just south of it. An excellent exposure 200 m north of a cattle barn (shown by open square on the map) shows sandy limestone containing abundant Lepidocyclina undosa dipping due north 10° (reverse drag?) in the bottom of the quebrada and tuffaceous siltstone 20 m farther north and 10 m above the bottom. Farther west the fault has been seen at several places and is well exposed in a cut on west side of Highway 132. In cuts just south of this outcrop secondary faults are well exposed in good outcrops around the bend on the highway. Outcrops in the southern part of the village of Tallaboa Alta are somewhat obscured by colluvium of gravel of the Juana Díaz coming from the high ridge to the south, but the fault was located at two places. Apparently it then bends to west northwest and can be seen on cuts on Highway 132 separating thin-bedded tuffaceous siltstone from massive tuff breccia. The west end of the fault apparently is overlain by alluvial deposits of Río Tallaboa at the place it intersects the large north-trending Río Tallaboa fault which forms the boundary between the Juana Díaz and older rocks for about 1.2 km almost due north.

This north-trending fault is apparently one of a pair that drop Juana Díaz deposits in a graben in which crop out the gravelly deposits of Juana Díaz on the hill west of Peñuelas. Another west-northwest trending fault separates the Juana Díaz from older rocks about a kilometer north of Peñuelas.

North-trending faults of more than 100 m displacement follow roughly the valleys of Río Canas and Río Tallaboa. Both intersect and displace the boundary faults described above.

Farther west boundary faults can be seen along the secondary road near La Capital near the center of the Yauco quadrangle, along the new route of Highway 2 about 400 m east of the divide between the Río Guayanilla and Río Yauco, on a trail east of Río Yauco about 550 m north of old Highway 2 at Lucchetti, at the sides of the fault blocks southwest of Yauco, on Highway 371 200 m northwest of the intersection with 128, along the northeast side of the ridge west of La Quinta, on south side of Palomas, on a street of La Joya at the extreme northeast corner of the Guánica quadrangle, on Highway 335 1.2 km west northwest of Central San Francisco, and at the west end of a small quarry near the western end of the village of Media Quijada west of Central San Francisco. One of the best exposures of the boundary fault, however, is at Punta Montalva, near the western edge of the Guánica quadrangle, where a thick bed of grayish orange chalky limestone overlain by laminated limestone dips 80 degrees south just south of the projected trace of a fault that is required by exposures of Cretaceous and middle Tertiary rocks 300 m farther east.

Block faulting is probably common within the outcrop belt of the middle Tertiary rocks, but only a few of the faults have been recognized because of difficulty in distinguishing definitely the various stratigraphic units. A large fault is exposed in the quarries west of the Río Canas, raising Juana Díaz against Ponce Limestone; this fault may extend as far west as the Río Tallaboa, but could only be traced for about 4 km. The most spectacular faults are those west of Central San Francisco first observed by Grossman (1963) and those involving Cretaceous rocks in La Cóvana. Several small faults were seen on Highway 335 from 100 to 400 m south of Escuela Segunda Unidad de Barinas, but these could not be recognized farther west in the upland. Large faults apparently determine the courses of the Río Guayanilla and the Río Yauco, but the exact location of the traces of these faults is not known as they are buried by river alluvium. A broken fault is shown crossing the Montes de Barina from northeast to southwest, but this fault is hypothetical, based on probable evidence on the trail up from the Río Yauco valley at the southwest about a kilometer south of Cambalache, by strong lineation shown by stream valleys on the upland and by the presence of clastic Juana Díaz near the top of the ridge east of Cambalache and of Ponce Limestone low in the stream valleys at Piedras Blancas. No study was made of the rocks in the midst of the Montes de Barina because of a lack of trails and because of ubiquitous thick cover of caliche at the places visited in that area, which precluded observation of the bedrock.

The wide expanse of clastic beds of the Juana Díaz Formation northwest, west, and southwest of Yauco suggests that the sand and gravel has been repeated several times by faulting, but diagnostic key beds were not found that would permit delineation of the faults. The notable alinement of some of the stream valleys is very suggestive of faulting in that area.

No folding of any consequence was seen in the area. The few reversals in the general southerly dips are near faults and apparently are the result of drag or reverse drag along the fault.

Economic geology

Limestone.--The principal economic mineral resource in the Yauco-Guánica area is limestone, which has been used entirely as fill, especially for causeways of roads, and formerly of railroads that connected cane fields with the Centrals. The limestone of the middle Tertiary formations has not been used as concrete aggregate because of the ready availability of the more tightly cemented limestone of Cretaceous age, which is present at many places, particularly near Guánica.

Sand and gravel.--A few small quarries for fill have been opened in the clastic phase of the Juana Díaz Formation, but most of these are now inactive. The alluvium of the larger river valleys contains abundant sand and gravel, but large sand pits are relatively rare.

Beach sand is being extracted in small quantities inland from the shore line just east of Punta Ventana and at Punta Manglillo south southwest of Guánica.

Salt.--An important industry in the area is production of salt from evaporated sea water. Elaborate salinas, in which beach sand is raised in a low dam on the seaward side of salt pools, have been built at many places along the coast in the Guánica quadrangle; most of these are noted as "salinas" on the topographic base map.

Oil and gas.--The clastic beds of the Juana Díaz Formation and the thick reef limestone in the Juana Díaz could both prove to be source rocks and reservoir rocks for oil or gas. In the central part of the area the chalky limestone at the top of the Juana Díaz may prove to be sufficiently impermeable to form a cap rock over any accumulations of petroleum. The Ponce Limestone also has the characteristics of a source rock and reservoir rock, but no overlying impermeable bed is known that would trap possible accumulations of petroleum.

The faulting of the middle Tertiary rocks is sufficient to form structural traps in which petroleum in a permeable reservoir bed is trapped against impermeable rock faulted against the reservoir. Such traps would be most effective at places in which the rocks are faulted down toward the north--up dip-- but the only large fault of this kind recognized in the area is the one north of the Cretaceous rocks west of Central San Francisco, and little hope can be had for finding petroleum in the Cretaceous volcanic rocks, although it is possible.

As a considerable thickness of potential reservoir rocks is desirable when drilling for oil and gas, the southern part of the area is more favorable than areas near the older rocks. A potential structural trap is present along the fault that extends west from the southwest corner of Ponce in the southeastern part of the Peñuelas quadrangle. Several hundred meters of Juana Díaz are present in this area and any oil that may be present could be trapped against that fault. This area is readily accessible for moving in drilling equipment and locations could be selected near the road that goes west and then north up Quebrada de los Cedros.

The area northwest of there may offer several favorable locations with a thick sedimentary section cut by the probable faults that may be responsible for repetition of section that causes an abnormal thickness of Juana Díaz shown, but most of the possible area is difficult of access at present.

If a serious attempt to find oil in the area is made, a series of core holes for stratigraphic and structural information should be drilled on the upland from Quebrada de los Cedros southward along the eastern border of the Yauco quadrangle, on Punta Guayanilla in the Punta Verraco quadrangle, and at several places in the Montes de Barina, in search for faults down to the north and up to the south.

References

Gordon, W. A., 1961, Miocene foraminifera from the Lajas Valley, southwest Puerto Rico: Jour. Paleontology, vol. 35, p. 610-619.

Grossman, I. G., 1962, Stratigraphy and hydrology of the Juana Díaz formation in the Yauco area, Puerto Rico: U. S. Geol. Survey Prof. Paper 450-D, p. D62-D63.

Grossman, I. G., 1963, Geology of the Guánica-Guayanilla Bay area, southwestern Puerto Rico: U. S. Geol. Survey Prof. Paper 475-B, p. B114-B116.

Guillou, R. B., and Glass, J. J., 1957, A reconnaissance study of the beach sands of Puerto Rico: U. S. Geol. Survey Bull. 1042-I, p. 273-303.

McGuinness, C. L., 1946, Records of wells in Puerto Rico: Puerto Rico Aqueduct and Sewer Service mimeographed report, 267 p.

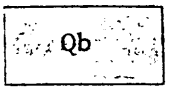
Mitchell, G. J., 1922, Geology of the Ponce district, Porto Rico: New York Acad. Sci., Sci. Survey of Porto Rico and the Virgin Islands, v. 1, pt. 3, p. 229-300.

Moussa, M. T., and Sieglie, G. A., 1970, Revision of mid-Tertiary stratigraphy of southwestern Puerto Rico: Am. Assoc. Petroleum Geologists Bull., v. 54, p. 1887-1898.

Seiglie, G. A., and Bermúdez, P. J., 1969, Informe preliminar sobre los foraminíferos del Terciario del sur de Puerto Rico: Caribbean Jour. Sci., v. 9, p. 67-80.

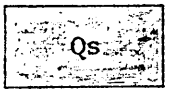
Zapp, A. D., Bergquist, H. R., and Thomas, C. R., 1948, Tertiary geology of the coastal plains of Puerto Rico: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 85.

EXPLANATION



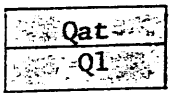
Coastal deposits

Sand composed of mixtures of shell fragments with volcanic rock fragments; mangrove swamps; and fringing coral reefs.



Swamp deposits

Sand and muck, commonly covered by mangrove.



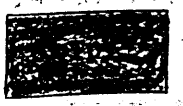
Alluvial deposits

Alluvium and river terrace deposits consisting of clay, sand, gravel, and cobbles; Ql, landslide of blocks of limestone and soil.

Holocene

QUATERNARY

UNCONFORMITY



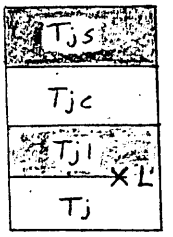
Ponce Limestone

Limestone, very pale orange to grayish orange, calcarenite and recrystallized. Generally very fossiliferous.

Miocene

TERTIARY

UNCONFORMITY



Juana Díaz Formation

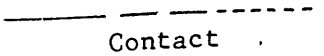
Tjs, sand, clay, and lignite
Tjc, chalk and chalky limestone, white to very pale orange
Tjl, limestone, very pale orange to grayish orange, locally white, calcarenite to dense and porous
Tj, sand and gravel, cobbles, sandy clay, mudstone
L, Lepidocyclina undosa, L. gigas

TERTIARY

UNCONFORMITY

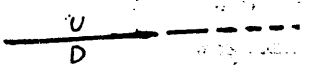
Rocks of Cretaceous to Eocene age consisting of tuff, lava, sandstone, siltstone, and limestone.

CRETACEOUS AND TERTIARY



Contact

Dashed where approximately located; short dashed where gradational or inferred.



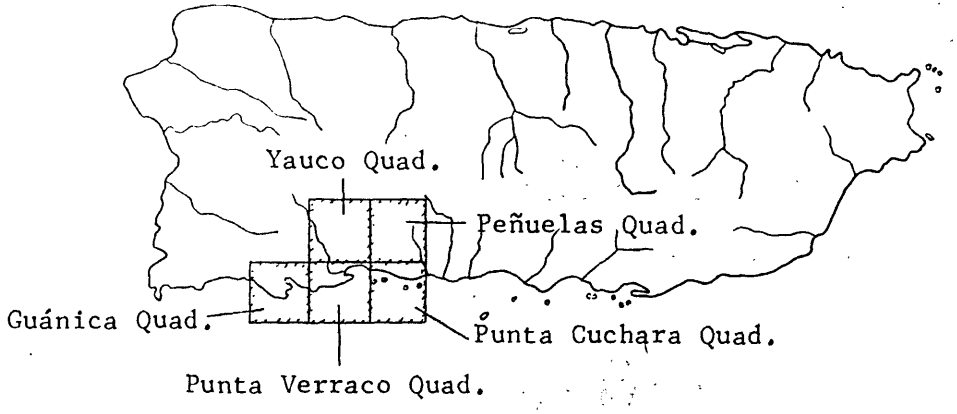
Fault

Dashed where approximately located; short dashed where indefinite; dotted where concealed. U, upthrown side; D, downthrown side.

Strike and dip of beds

Quarry

PUERTO RICO



INDEX MAP