

EXPLANATION

- Qa Alluvium
- Qb Beach deposits
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- Qe Eolianite
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- Qg Blanket sand deposits
- Tcu Camuy Formation, upper member
- Tcm Middle member
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- Ta Aymanon Limestone
- Tm Aguada Limestone
- Tc Ciba Formation, persistent limestone beds

- Strike and dip of bedding
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Drawn at top of Aguada Limestone. Dashed where approximately located; short dashed where datum is above ground surface. Contour interval 20 meters.

INTRODUCTION

The Camuy quadrangle is on the northern coast of Puerto Rico; its eastern edge is 3 1/2 kilometers west of the main plaza of the city of Arecibo. All the rocks exposed in the quadrangle are sedimentary, and they range in age from late Oligocene to Recent. Intricate karst topography having sinkholes as deep as 60 meters and towers as high as 40 meters has been formed in a lower Miocene limestone terrace where the beds dip 3° to 5° N. Rolling topography near the Atlantic coast is formed on alternating beds of middle Miocene marl and limestone. Economic minerals include chemical-grade limestone, limestone suitable for aggregate, and glass sand.

OLIGOCENE AND MIOCENE SERIES

CIBAO FORMATION

The oldest rocks exposed in the Camuy quadrangle are assigned to the Ciba Formation of late Oligocene and early Miocene age. In the type area in barrio Hatillo the south-west corner of the quadrangle the formation consists predominantly of very pale orange marl and chalk; at some places the color varies to pink, white, or yellow. Interbedded with the marl are beds of very pale orange limestone, most of which are discontinuous. The traces of a few more-continuous beds of limestone are shown on the map. The lowest, cropping out in the valley of the Rio Camuy, forms a continuous layer of hard limestone about 30 meters thick. This limestone bed coalesces eastward with higher limestone beds to form a thick sequence of limestone, the top of which crops out near the southeast corner of the quadrangle. Quartz sand is rare in the formation, except at a few places near the top, but in the adjacent Bayaney quadrangle a bed of clayey sand crops out about 80 meters below the top of the formation—Zapp and others (1948) mapped this sand as part of their Guajataca Member of the Ciba Formation.

In the Camuy quadrangle a thickness of approximately 170 meters of marl and limestone of the Ciba Formation is exposed in the valley of the Rio Camuy. Regional studies indicate that the base of the formation is less than 50 meters below the bed of the Rio Camuy at the southern border of the quadrangle. The generally rolling topography of the marls of the Ciba Formation is interrupted by steep hills held up by the numerous limestone layers in the formation. Many streams that originate on the Ciba disappear in sinkholes in blind valleys that end near cliff faces of the overlying Aymanon Limestone.

MIOCENE SERIES

AGUADA LIMESTONE

The Ciba Formation overlies conformably the Aguada Limestone, which consists of thick beds of very pale orange limestone alternating with chalky and rubby limestone, some of which is thin bedded and crossbedded. Quartz sand grains are present throughout the formation in the eastern half of the quadrangle. At many places the top of the Aguada consists of 5 to 10 meters of limestone in beds a few centimeters thick; this slaty limestone is strikingly different in appearance from the thick beds of the overlying Aymanon Limestone.

The Aguada Limestone is about 90 meters thick in the valley of the Rio Camuy. It may be slightly thicker farther east.

The outcrop belt of the Aguada Limestone contrasts markedly with the adjacent beds of the Ciba Formation and the Aymanon Limestone. Thick strata of Aguada form a cliff face on an escarpment about 1 kilometer long. Many streams flowing on the Ciba disappear underground at this cliff, and some reappear at several places in deep sinks farther north, especially in barrios Quebrada and Santiago. The outcrop of the Aguada is riddled by dozens of sinkholes, many of which are more than 50 meters deep; these sinks are surrounded by cliffs of thick-bedded hard and soft limestone, making many of them almost inaccessible. Caves are common. A natural bridge, in barrio Santiago 3.36 kilometers north of the south edge of the map and 4.1 kilometers east of the west edge, is 12 meters wide, 8 meters from floor to roof, and about 15 meters from portal to portal. This bridge is a remnant of a cave that once connected two sinkholes, for stalactites hang from the bridge and large stalagmites make an irregular floor. The walls are composed of thin-bedded, slightly crossbedded granular limestone. Another natural bridge on the north side of the same stratigraphic position formerly existed 1.6 kilometers farther east, but that bridge has now collapsed, leaving only the buttresses to mark its site.

AYMANON LIMESTONE

The Aguada Limestone overlies conformably by massive to thick-bedded very pure limestone, the Aymanon Limestone. Most of the Aymanon is nearly white to very pale orange, but some beds are pale yellow and grayish pink. The lower part of the formation is indurated into very dense limestone but as shown in deep cuts, the upper part is compact chalk. Both parts weather, however, to irregular, solution-scored dense limestone, the upper part probably being indurated by local solution and recementation.

The entire thickness of the Aymanon cannot be measured directly at any single place in the quadrangle, but the southern outliers of the overlying Camuy Formation on both sides of the valley of the Rio Camuy are only a kilometer north of the northernmost exposures of the Aguada Limestone. Projection of the dip of the Aguada-Aymanon contact north for a kilometer yields a calculated thickness of the Aymanon Limestone of 190 meters.

Moderately deep sinkholes are common in the Aymanon Limestone near the contact with the Aguada Limestone, but farther north the Aymanon contains only shallow sinks and is characterized by steep-sided hills and ridges—known as mogotes or peñons, that roughly parallel the strike of the formation. On both sides of the Rio Camuy long valleys, or uvalas, consist of a series of connected, fairly shallow sinkholes parallel to the strike.

CAMUY FORMATION

The Aymanon Limestone is disconformably overlain by a sequence of limestone, marl, sandy chalk, and sandstone named the Camuy Formation. The type locality is designated as the exposures on highway 119 between the town of Camuy and the foot of the ridge one kilometer west-southwest of La Pica. A typical exposure can be seen in cuts at the side of the highway on the north-facing slope at La Pica, 3 kilometers southwest of Camuy, where 20 meters of hard granular grayish-orange to light-brown limestone is exposed. At most places this limestone contains abundant spherical and elongate grains of yellow limonite, but at this locality the grains are not present.

The Camuy Formation has been traced discontinuously from the town of Isabela, 16 kilometers west of the Camuy quadrangle, to the town of Dorado, 52 kilometers east of the quadrangle, a total distance of about 80 kilometers. It extends an unknown distance west of Isabela, but does not crop out east of Dorado. In the Camuy quadrangle the formation is divided into three members, but these members are not readily traceable beyond the borders of the quadrangle.

The lower member of the formation rests apparently disconformably on the Aymanon Limestone. It consists of dark yellowish-orange to grayish-orange, thin-bedded and gently crossbedded chalky marl that contains some slightly indurated limestone beds. Oyster reefs are common in the member. It contains quartz grains locally. The most accessible good exposure of the member is on highway 492 at the boundary between Municipios of Hatillo and Arecibo, 200 meters west of Iglesia Santa Teresita. The gently undulating, sharp contact with the underlying Aymanon Limestone is well exposed in a shallow cut on highway 130 at Lechuga; at this point large oyster shells are common in the lower member of the Camuy Formation about a meter above the contact. The lower member is about 40 meters thick in the eastern and central parts of the quadrangle, but it thins rapidly west of Rio Camuy and pinches out in the eastern part of the adjacent Quebradillas quadrangle.

The middle member consists of hard, granular very pale orange to light-brown ferruginous limestone, typically exposed at La Pica, but forming a notable ridge entirely across the quadrangle. Like the lower member, the middle member locally contains abundant quartz grains. The limestone can be distinguished readily from the Aymanon Limestone by its darker color and by the characteristic grains of yellow limonite that apparently fill molds of Foraminifera. The middle member is 30 meters thick throughout the quadrangle. It may be somewhat thicker in the Quebradillas quadrangle. In the Arecibo quadrangle it has been recognized as a distinct unit only west of the Rio Grande de Arecibo.

The upper member consists of chalk, sandy chalk, sandy limestone, sandstone, and very fine grained, powdery dolomite. The sandstone crops out only in the eastern part of the quadrangle near Radiovilla, where it consists of slightly crossbedded, fine to medium-grained fossiliferous calcareous quartz sandstone. Kaye (1959, p. 122) collected fossils from this sandstone (U.S.G.S. Cenozoic locality 17953) that W. P. Woodring (oral communication) considers of middle Miocene age. Quartz sand occurs farther west in lenses and as grains in chalk at various horizons in the member. The cuts on highway 2 at Alcantavilla, a kilometer southwest of Camuy, expose about 10 meters of rubby-bedded pink to yellow cal-

careous very fine sand that is overlain by rubby sandy limestone. West of Alcantavilla quartz sand is present in the member only in lenses a few centimeters thick. The nonquartz parts of the member consist of white to orange chalk and limestone, much of which contains abundant molds of fossils. Near the western border of the quadrangle, low hills to the north and northwest of Membrillo are made up of very finely crystalline, rather powdery dolomite, similar to dolomite that has been seen in the formation in the Manati quadrangle farther east. The upper member appears to be about 120 meters thick in the central part of the quadrangle.

No direct measurements of the thickness of the Camuy Formation have been made in the Camuy quadrangle, but projection of dips taken at various horizons indicates that it is about 200 meters thick.

Although the Camuy Formation is predominantly limestone and chalk, sinkholes are rare. Two deep, well-like holes, 3 to 5 meters in diameter and somewhat more than 20 meters deep, have been seen in the middle and upper members, one 1.7 kilometers S. 20° E. of Camuy and the other 3 kilometers S. 67° E. of Hatillo. The middle member forms a prominent strike ridge across the quadrangle; the other members give rise to a gently rolling topography. In general, the relatively gentle slopes of the formation form a strong contrast to the steep-sided hills characteristic of the Aymanon Limestone.

PLEISTOCENE SERIES

Blanket sand deposits.—Much of the outcrop belt of the Aymanon Limestone and the Camuy Formation is covered by fine to coarse ferruginous quartz sand that forms plain terraces between the ridges of the two formations. Similar material is present in the bottoms of many of the deep sinkholes in the lower part of the Aymanon and in the Aguada Limestone. A few deep cuts on highway 129, particularly near Las Cuetas, expose crossbedded yellow to light-brown friable sandstone that is mapped with this unit. Near the coast some of the material mapped with the blanket sand deposits is probably residual and slightly reworked sand derived from the upper member of the Camuy Formation and from eolianite; some may have blown in from the beaches and Recent dunes.

Silica sand.—Some parts of the blanket sand have been leached free of iron and blown into dunes of white nearly pure fine quartz sand. The most extensive deposits near Barranca have been mined for glass sand.

Eolianite.—Along the coast are ridges of friable to consolidated, highly crossbedded calcareous eolian sandstone composed largely of shell fragments and quartz. This eolianite rests on a surface that slopes steeply toward the coast. In general the eolianite is less than 10 meters thick, except at Quebras triangulation station where a sea cliff 35 meters high is cut into eolianite.

RECENT SERIES

Landslides.—On the sides of the Rio Camuy are several large masses of landslide material made up of blocks of Aguada Limestone that have slid down slopes of marl of the Ciba Formation. The blocks of limestone in these slides, tilted at all angles, vary in size from cobbles to blocks many meters in diameter.

Swamp deposits.—Along the coast are several elongate swamps containing carbonaceous mud. Most of these are the sites of old lagoons now filled with sediment.

Sand dunes.—Paralleling much of the shoreline are elongate dunes made up of sand that has been blown by the wind from adjacent beaches; most of the dunes are 5 to 10 meters high, but they reach a height of 25 meters near Camuy. The dunes consist of fine sand, mostly shell fragments and quartz but also containing streaks of magnetite in the eastern part of the quadrangle.

Beach deposits.—Generally narrow beaches border the sea at all points in the quadrangle except where rocky headlands of eolianite intervene. The beach sands are composed of fine to coarse shell fragments and quartz, but particularly in the eastern part of the quadrangle they contain local accumulations of magnetite, presumably brought to the shore by the Rio Grande de Arecibo, whose mouth is a few kilometers farther east. At many places the beach sand has been cemented into beach rock by calcium carbonate.

Alluvium.—The narrow valleys of the Rio Camuy in its lower stretches has a floor of sand and clayey sand, locally containing a few lenses of gravel. Many of the blind valleys of the streams that flow across the Ciba Formation to disappear in sinks at the foot of the Aguada escarpment have flat floors of sandy clay derived from the Ciba Formation. At places these streams have carried alluvium through caverns into a series of sinks down dip.

STRUCTURE

The Oligocene and Miocene rocks in the quadrangle have a remarkably regular north dip of 3° to 5°. The only detectable irregularity is shown by a swing in the structure contours 3.5 kilometers south by east of Hatillo; this may reflect a small fault trending northwest for about a kilometer, with the rocks to the southwest dropped less than 15 meters. The exposures in the area are not sufficiently continuous to determine whether this irregularity is merely a slight flexure or a small fault.

ECONOMIC GEOLOGY

The principal mineral resource of the area is limestone. Small quarries have been opened at several places to obtain limestone for fill. The harder parts of the Aymanon and the middle member of the Camuy Formation supply concrete aggregate.

Silica sand has been excavated at Barranca for use in the manufacture of glass, but the much more extensive deposits several kilometers farther east near Manati make unlikely the development of a large industry in the Camuy quadrangle.

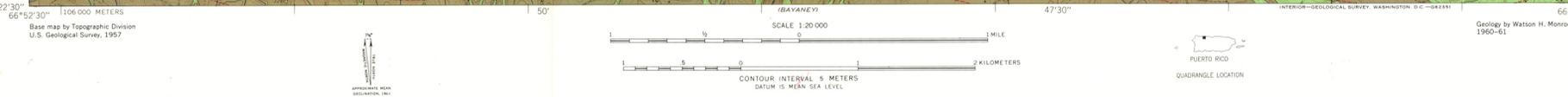
Magnetite has been observed in beach sand and in Recent sand dunes at several places along the shore east of the mouth of the Rio Camuy. Guillou and Glass (1957, p. 301 and table 2) estimate that a narrow dune near Hatillo contains 20,000 tons of magnetite.

The beach sand, the sand in the Recent dunes, and the blanket sand can be used in concrete after they have been washed free of salt, clay, and iron oxide.

Roads built on steep slopes of the Ciba Formation are subject to slides. During the course of geologic mapping two slides were noted in which parts of highway 129 had slumped; one of these was near the southern border of the map in an area of soft marl of the Ciba Formation; the other was in the outcrop belt of the Aguada Limestone at a place where the limestone was underlain by the Ciba Formation about 20 meters below the highway.

REFERENCES

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GEOLOGY OF THE CAMUY QUADRANGLE, PUERTO RICO

By
Watson H. Monroe
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