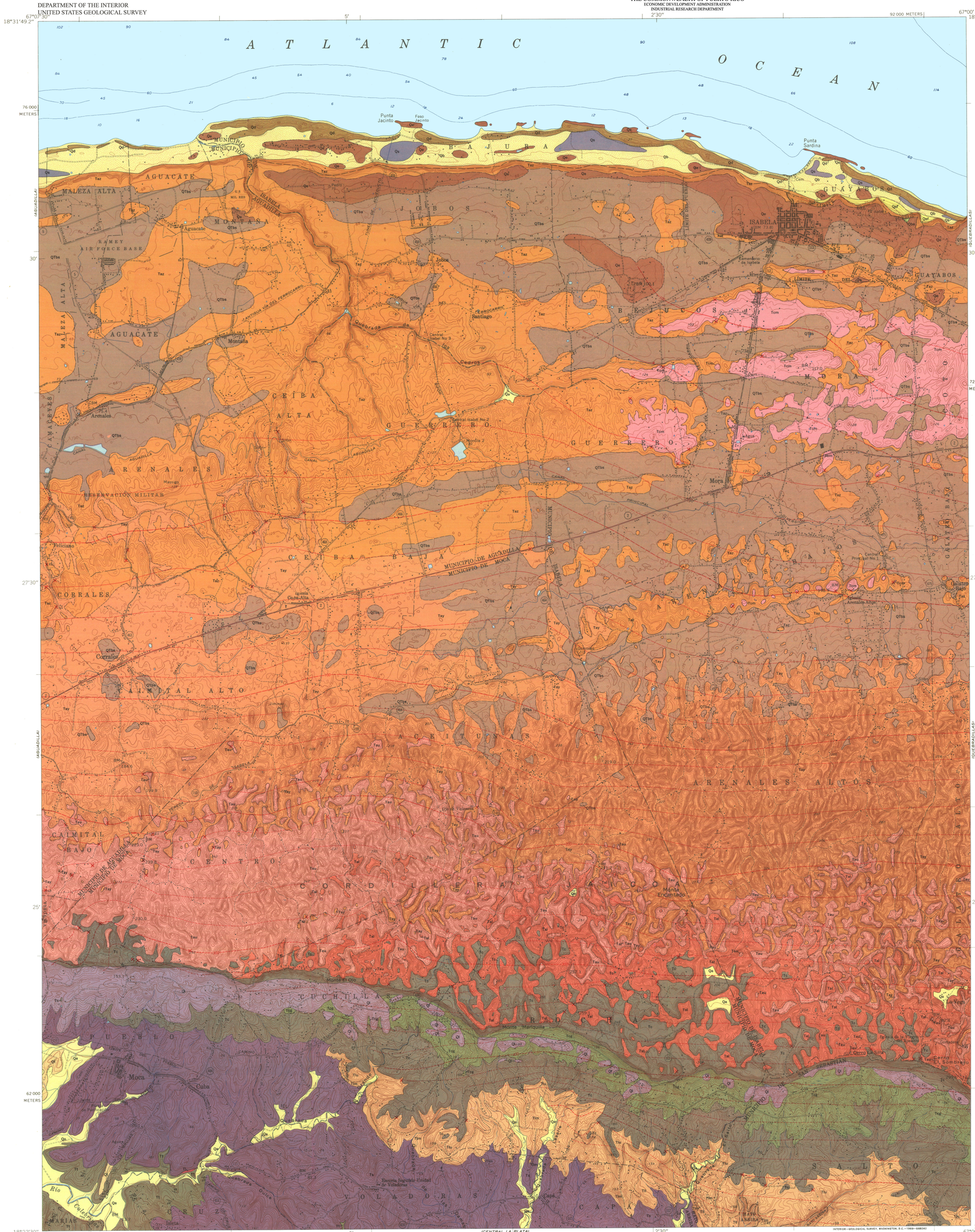
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
THE COMMONWEALTH OF PUERTO RICO
ECONOMIC DEVELOPMENT ADMINISTRATION
INDUSTRIAL RESEARCH DEPARTMENT

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I – 565



Base from U.S. Geological Survey

Geology mapped, 1965-67

APPROXIMATE MEAN DECLINATION, 1969

SCALE 1:20 000

CONTOUR INTERVAL 5 METERS
DATUM IS MEAN SEA LEVEL

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1969—688242

GEOLOGIC MAP OF THE MOCA AND ISABELA QUADRANGLES, PUERTO RICO

By
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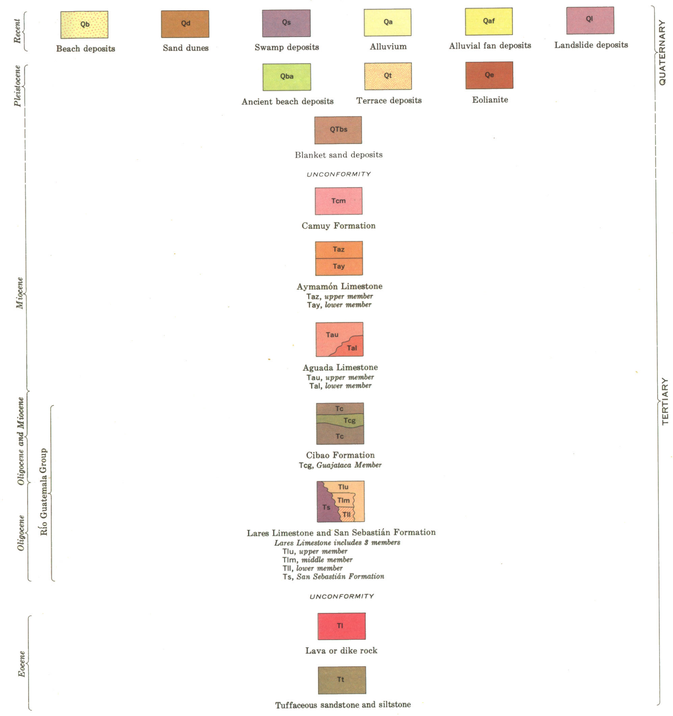
1969

EXPLANATION



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

Inclined 14 — Vertical

Strike and dip of bedding

Structure contours
Drawn on top of Aguada Limestone. Dashed where approximately located or inferred from overlying structure; short dashed where reference plane is above ground surface. Contour interval 20 meters, datum mean sea level

Control point
Showing outcrop of key horizon used in locating structure contour lines

DESCRIPTIONS OF MAP UNITS

Qb *Beach deposits.*—Quartz sand, shell fragments, and scattered grains of other minerals resistant to weathering; cementation by calcium carbonate to beach rock common; older deposits inland from present shore covered by a thin blanket of sand blown from present beaches and dunes. 0–5± m thick

Qd *Sand dunes.*—Generally fine-grained sand composed mainly of shell fragments, but locally containing some quartz grains. 0–30 m thick

Qs *Swamp deposits.*—Sandy organic muck and peat, mostly associated with mangrove swamps. 0–5± m thick

Qa *Alluvium.*—Clayey sand and sandy clay, containing in some areas scattered pebbles and cobbles of volcanic rocks as much as 10 cm in diameter. 0–5 m thick

Qaf *Alluvial-fan deposits.*—Masses of poorly sorted blocks of limestone and eolianite in a matrix of sand and clay eroded from eolianite and blanket sand. 0–10± m thick

Ql *Landslide deposits.*—Blocks of limestone and of sandy clay as long as 50 m in a mass of sandy clay (Monroe, 1964). 0–20± m thick

Qt *Terrace deposits.*—Clayey sand and sandy clay containing scattered pebbles of volcanic rocks and quartz. 0–5± m thick

Qba *Ancient beach deposits.*—Crossbedded and crosslaminated sandstone containing fine to very fine grains of quartz and shell fragments; locally pebbly; containing corals and molds of Quaternary mollusks (Druid Wilson, written commun 1966). 0–12 m thick

Qe *Eolianite.*—Friable to consolidated, highly crossbedded, calcareous eolian sandstone composed of shell fragments and quartz grains; near Isabela consists of crossbedded white sandy chalk that weathers to red clayey sand. 0–20 m thick

QTbs *Blanket sand deposits.*—Mixtures of fine- to medium-grained quartz sand and light- to moderate-brown clay; all material mapped in this category has been lowered by solution of underlying limestone (Briggs, 1966). 0–307 m thick

Tcm *Camuy Formation.*—Thin-bedded and cross-laminated to massive ferruginous chalk and calcarenite varying in color from very pale orange to pale reddish brown; many beds contain black grains and medium grains of dark-yellowish-orange limonitic clay; rests on underlying massive Aymamon Limestone with possibly disconformable sharp contact. 0–30 m thick

Taz *Aymamón Limestone, upper member.*—Very pale orange to bright-yellow chalk containing many beds of large (as much as 15 cm long) *Ostrea haitensis* Gabb and other fossils. Interbedded with solution-riddled very pale orange to white hard limestone, some of which is fossiliferous; upper part commonly white, very pure, commonly recrystallized hard limestone like lower member; intertongues toward east with beds indistinguishable from upper beds of lower member. 50–80 m thick

Tay *Aymamón Limestone, lower member.*—White to very pale orange, locally pale-yellow and grayish-pink, massive to thick-bedded very pure fossiliferous limestone; generally indurated into finely crystalline rather dense limestone, locally a rubble of recemented solution cobbles. Local beds of thin-bedded granular limestone and chalk. Commonly solution riddled and weathered on surface into dense limestone having abundant sharp spires as much as 30 cm high. In eastern part of quadrangle upper part intertongues toward west with lower part of upper member; rests with sharp contact on underlying Aguada Limestone. 110–140 m thick

Tau *Aguada Limestone, upper member.*—Thick layers of very pale orange to pink hard calcarenite alternating with chalky and rubbly limestone; sparsely fossiliferous; at top and locally at lower positions 1 to 9 of orange to pink thin-bedded and cross-laminated calcarenite in which individual beds range in thickness from 1 to 7 cm; in western part of quadrangle lower part intertongues toward east with lower member; deep sinkholes common throughout belt of outcrop. 30–90 m thick

Tal *Aguada Limestone, lower member.*—At base a bed of hard medium-grained calcarenite 50 cm to a meter thick, overlain by soft granular chalky limestone or marl containing discontinuous beds of fine- to medium-grained fossiliferous calcarenite; contains much less clay than underlying Cibao Formation; intertongues toward west with limestone indistinguishable from upper member. 0–60 m thick

Tc *Cibao Formation.*—Interbedded calcareous clay, soft earthy chalk, hard very fine grained calcarenite and soft nongranular limestone, ranging in color from light bluish gray where fresh to pale yellowish orange and moderate orange pink where weathered; includes a few centimeters of carbonaceous clay containing thin stringers of lignite at one locality just east of Monte El Ojo; commonly fossiliferous, locally containing many oysters and other mollusks; lower part contains lenses of silt, sand, and gravel resembling underlying San Sebastian Formation; part above Guajataca Member is about 80 m thick; part below is 40 to 70 m thick. 250–280 m thick

Tcg *Guajataca Member.*—Fossiliferous calcareous clay and limestone containing lenses of sand and gravel as much as 15 m thick; pebbles are mostly quartzite and silicified siltstone, mostly a few centimeters in diameter, but containing scattered cobbles as large as 25 cm in diameter; thickest in eastern part of quadrangle. 100–160 m thick

Tlu *Lares Limestone, upper member.*—Hard fossiliferous limestone interbedded with chalk and calcareous clay; colors range from white to yellowish gray and very pale orange; coral heads common and many beds rich in molds of mollusks. Entire sequence of Lares Limestone mapped in this pattern in southeastern part of quadrangle, but in central part of quadrangle the formation is divided into three members of which this is the upper; grades into and intertongues with sand and gravel indistinguishable from San Sebastián Formation in vicinity of Quebrada Grande. 30–210 m thick

Tlm *Lares Limestone, middle member.*—White to yellow and pale-orange chalk and calcareous clay, containing many oysters and other mollusks and a few corals; locally contains lenses of sand and gravel; toward west grades into and intertongues with sandy clay, sand, and gravel indistinguishable from San Sebastián Formation; in southeastern corner of quadrangle chalk and clay of this member is mapped with the upper member. 40–80 m thick

Tll *Lares Limestone, lower member.*—Sandy marl interbedded with soft limestone, locally very fossiliferous; a few thin lenses of sand and gravel; recognized only in vicinity of Quebrada El Salto; farther west included in middle member. About 45 m thick

Ts *San Sebastián Formation.*—Lenticular beds of olive-brown to dusky-yellow fine- to medium-grained quartz and volcanic rock sand, sand and gravel, and red and greenish-gray clay; locally very fossiliferous, including at western edge of quadrangle beds of greenish-gray to tan shale and thin lignitic clay beds containing some of best-preserved fossil shells in Puerto Rico; basal 20 m contains abundant cobbles and boulders of volcanic rock as much as 60 cm long; upper part grades laterally and intertongues toward the east with the Lares Limestone and possibly with the lower part of the Cibao Formation; rests with angular unconformity on underlying unit. 100–155 m thick

Tl *Lava or dike rock.*—Black glassy igneous rock containing phenocrysts of plagioclase and pyroxene. About 10 m thick

Tt *Tuffaceous sandstone and siltstone.*—Thin- to thick-bedded fine- to medium-grained sandstone and siltstone composed of particles of volcanic ash, in part reworked; occasional beds of massive medium-grained tuffaceous sandstone. Commonly weathered to thin-bedded pink and yellow clay. These rocks are believed to be of Eocene age (D. H. McIntyre, oral commun. Aug. 14, 1967). 500–1,000 m thick

STRUCTURAL, ECONOMIC, AND ENGINEERING GEOLOGY

Structure.—The strata of Oligocene and Miocene age strike nearly due east and dip north over most of the area. In the southern part of their belt of outcrop they dip 5° or 6° N., but farther north the dip is very gentle, at many places less than a degree. This regularity of dip is interrupted near Isabela by a gentle reversal that seems to be a continuation of the syncline and anticline in the northwestern part of the Quebradillas quadrangle. The regular dip is also interrupted north of Moca by an anticline that plunges northwest into the Aguadilla quadrangle.

The volcanic rocks in the southwestern part of the quadrangle are complexly folded and faulted, but exposures are insufficient to work out the structure in detail. The dips recorded suggest that the formation is folded into a syncline, probably faulted near the axis, along the Río Culebrinas valley westward from barrio Cruz.

Limestone.—Very large quantities of limestone are available in the outcrop belts of the Aguada and Aymamón Limestones. The lower part of the Aymamón is very pure calcium carbonate, generally unconsolidated below the surface, but hardened at the surface into a marblelike rock. The upper member of the Aymamón, however, contains large lenses of slightly limonitic chalk, so that it is not pure enough to be of chemical grade; it is quarried as fill because it compresses well.

Sand and gravel.—The extensive sand dunes that border the beaches on the north edge of the area can provide very large quantities of shell sand of a kind that is used extensively in Puerto Rico in the manufacture of concrete. Large quantities of gravel are present in the sand and gravel lenses of the Guajataca Member of the Cibao Formation and of the San Sebastián Formation. Both formations contain considerable clay, however, so the gravel will require washing as well as sieving before use.

Quarries.—Small quarries supplying fill material have been opened at several places in the outcrop belts of the Aymamón Limestone and the Camuy Formation. There is a large quarry for impure chalk and limestone of the upper part of the Cibao Formation at the side of Highway 110 just north of the top of the cliff north of Moca; this rock was probably used as fill in the construction of Highway 110 and is being used as fill on secondary roads. Several small pits have been opened in the San Sebastián Formation to supply fill for building roads through the cane fields. The lava or dike rock north of Quebrada Grande, just west of the mouth of Quebrada Dulce, has been quarried extensively, but the rock is so hard that it is difficult to crush.

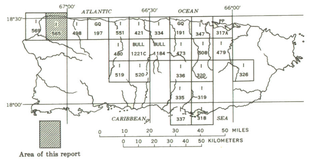
Landslides.—The steep slopes on the escarpment north of Moca and extending toward the east consist of calcareous clay of the Cibao Formation that is overlain at the top of the bluff by the Aguada Limestone. When the clay becomes saturated with water it tends to flow and to sluff off downhill. This removes support from beneath the limestone, which then fractures and slides down the lubricated slope (Monroe, 1964). Consequently this slope is covered by landslide blocks of all sizes, consisting of limestone, calcareous clay, and masses of sand and gravel of the Guajataca Member. Some movement takes place annually, as shown by slight cracking of the pavement at places along Highway 444, but many of the landslide blocks seem reasonably stabilized. The area immediately north of Moca along the present route of Highway 110 (not shown on the map) is the area of most extensive landslides; many of these slide blocks have moved since the highway was paved, possibly because of change in the angle of repose caused by the opening of cuts in the highway.

REFERENCES

Briggs, R. P., 1966, The blanket sands of northern Puerto Rico: Caribbean Geol. Conf., 3d, Kingston, Jamaica, Trans., p. 60–69

Monroe, W. H., 1964, Large retrogressive landslides in north-central Puerto Rico: U.S. Geol. Survey Prof. Paper 501-B, p. B123–B125.

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.



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