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-660

DESCRIPTION OF MAP UNITS

Qat ALLUVIUM ALONG THE RIO CULEBRINAS AND TRIBUTARIES —Slightly to moderately weathered gravel, sand, silt, and clay of flood-plain and terraces, undivided.

Qoa ALLUVIAL FILL IN ANCIENT VALLEY OF RIO CULEBRINAS—Chiefly slightly to deeply weathered sand and gravel.

Qa ALLUVIUM ALONG THE RIO AÑASCO AND TRIBUTARIES

Qaf FLOODPLAIN ALLUVIUM—Slightly weathered gravel, sand, silt, and clay.

Qt_1 ALLUVIUM OF LOWER TERRACE—Slightly to moderately weathered gravel, sand, silt, and clay, locally crossed by channels scoured by infrequent floods, probably those accompanying hurricane-induced rain.

Qt_2 ALLUVIUM OF HIGHER TERRACE—Gravel, sand, silt, and clay mantled by thick clayey residual soil.

Qf ALLUVIAL FANS ALONG THE RIO AÑASCO —Gravel, sand, silt, and clay, now moderately to deeply weathered, deposited in the canyon of the Río Añasco by tributaries.

Ql LANDSLIDE DEPOSITS —Blocks of limestone and sandy clay in a matrix of sandy clay located downslope from the Lares Limestone escarpment.

Tc CIBAO FORMATION —Compact calcareous claystone containing *Pecten* sp., *Lepidocyclinas* sp., and other fossils. A 5 m thick section is exposed in the northeast corner of the quadrangle.

Tl LARES LIMESTONE—The upper 60 m is very hard semicrystalline algal limestone containing corals, mollusks, and larger Foraminifera. This limestone rests on about 90 m of very calcareous clay interbedded with unconsolidated clayey flakey limestone containing abundant fossils; lower part of this clay unit is interbedded with hard crystalline limestone containing abundant coral heads. Basal 20 m of unit consists of blue-gray marl containing abundant large *Ostrea collazica* Maury, a few echinoids, and some large Foraminifera. This basal marl grades downward into sandy clay of the San Sebastián Formation. Total thickness: approx. 170 m.

Ts SAN SEBASTIAN FORMATION —Chiefly sand, gravel, and clay, deeply weathered in most exposures. In northwest part of quadrangle lower portion of formation is chiefly boulder and cobble gravel; pebble gravel interstratified with sand and clay is more common toward the east. Fresh sand containing glauconite and Foraminifera occurs near mouth of Quebrada de Loro. Silicified wood is present southeast of Central la Plata and east of the mouth of Quebrada Grande. Upper portion of formation contains fine to coarse sand, lenses of pebble gravel and, locally, lignite and clay beds. Total thickness in northeastern part of quadrangle: approx. 300 m.

RIO CULEBRINAS FORMATION —Total preserved thickness in western part of quadrangle: approx. 2,800 m; in eastern part of quadrangle: approx. 1,700 m.

Trb TUFF BRECCIA—Very thick bedded—Poorly sorted, well indurated, contains subangular to rounded blocks ranging in diameter from more than 1 m to 3 cm suspended in a matrix of poorly sorted coarse crystal-lithic tuff. Blocks chiefly andesite and dacite with phenocrysts of plagioclase and hornblende; some contain clinopyroxene. Quartz occurs rarely. Algal fragments, larger Foraminifera, and blocks of coarse tuff and limestone also present locally. Fresh rock greenish-gray, often occurs as spheroidal boulders in saprolite. Saprolite colors include moderate red, grayish-red, and yellowish-gray.

Trm VERY THICK-BEDDED TO THICK-BEDDED COARSE TUFF—Poorly sorted, well indurated, contains angular and rounded volcanic rock fragments that are aphyric and cryptocrystalline, with plagioclase and hornblende, or plagioclase and clinopyroxene phenocrysts. Altered green pumice fragments common, as are single crystals of plagioclase, clinopyroxene, hornblende, quartz, magnetite, and diagenetic pyrite. Matrix commonly chloritic. Algal fragments and larger Foraminifera common. Fresh rock is greenish-black, dark gray, or dark greenish-gray, and often occurs as spheroidal boulders in saprolite. Saprolite colors include moderate red, grayish-red, and light yellowish-brown. Often occurs interbedded or gradational with tuff breccia or thin-bedded volcanic sandstone and mudstone. Mapped separately only in Barrio Naranjo.

Trt THIN-BEDDED VOLCANIC SANDSTONE AND MUDSTONE—Dark greenish-gray, well indurated, contains same clastic constituents as the massive coarse tuff. Graded bedding common. Planktonic Foraminifera present in some samples. Saprolite colors range from moderate red to yellowish-gray.

Trg GUACIO MEMBER—Siliceous and calcareous mudstone, thin-bedded to laminated, with variable proportions of silt-size volcanic debris and organic detritus, chiefly recrystallized planktonic Foraminifera and Radiolaria(?). Fresh rock ranges from dark greenish-gray to light gray, and weathers to a light brown or brownish-gray brittle, blocky chert-like material interbedded with reddish-brown, reddish-orange, or white clay. Weathered rock in Barrio Dagüey contains relatively large amount of volcanic detritus at some localities, and is not readily distinguished in the field from overlying thin-bedded mudstone.

Tmp MAL PASO FORMATION—Grayish red purple altered amygdaloidal basalt pillow lavas, amygdaloidal basalt breccias, plagioclase porphyry breccias, and reddish-purple, light gray, and grayish-green vitric tuffs. Plagioclase commonly replaced by albite or zeolites. Amygdules and fractures often filled by white calcite, zeolites, or, rarely, quartz. Lenses of pale red purple planktonic Foraminifera-bearing impure limestone a few centimeters thick occur locally between lava pillows. Unit usually very deeply weathered to grayish red purple or grayish purple saprolite. Thickness: more than 850 m near Cerro Pichón.

Tco CONCEPCIÓN FORMATION —Chiefly dark greenish-gray to greenish-gray massive well indurated pumice lapilli tuff and thin-bedded coarse crystal-vitric tuff with abundant pumice. Calcareous mudstone and calcareous vitric tuff containing planktonic Foraminifera present northwest and east of Cerro Gordo. Saprolite often brownish-yellow or reddish-yellow. Maximum thickness: probably about 800 m west of Cerro Gordo.

Kb RIO BLANCO FORMATION —Chiefly grayish purple and grayish red purple massive well indurated tuff breccia containing blocks of basalt and andesite with phenocrysts of plagioclase, clinopyroxene and, rarely, hornblende. Blocks locally amygdaloidal. Massive or thin-bedded coarse tuff also present locally. Secondary epidote and chlorite are conspicuous in most samples. Formation is zeolitized in Barrio Miraflores and in a small area northwest of Escuela Segunda Unidad de Anones. Unit weathers to a brownish-red or purple saprolite. Thickness indeterminate.

Km MARICAO BASALT —Massive well indurated dark greenish-gray or blackish-red tuff breccia and massive to thin-bedded coarse tuff. Breccia blocks, both oxidized red and unoxidized greenish gray, contain clinopyroxene and plagioclase phenocrysts; some are amygdaloidal with chlorite amygdule fillings. Tuffs contain conspicuous large crystals of clinopyroxene or, less commonly, hornblende, in addition to dense volcanic rock fragments, altered pumice, plagioclase crystal fragments, and recrystallized fragments of larger Foraminifera. Some samples contain secondary epidote, chlorite, prehnite. Usually deeply weathered to a brownish-orange or yellowish-brown saprolite locally containing a few spheroidal boulders of fresh rock. Minimum thickness: 1,400 m.

Ky YAUCO MUDSTONE — Chiefly thin-bedded dark gray calcareous mudstone, sandstone and chert, with some thick to thin beds of medium to light gray coarse tuff. One pillowed lava containing clinopyroxene phenocrysts exposed on Highway 108 400 m southwest of the Cerro Goden fault. Pumice-rich lapilli tuff and coarse tuff present west of Hacienda Morales. Usually deeply weathered to a brownish-orange or yellowish-brown saprolite. Minimum thickness: 500 m.

INTRUSIVE ROCKS

Tiz APHANITIC PORPHYRY—Light gray to grayish purple with pale pink zeolitized plagioclase phenocrysts. Specimen from body east of Centro Médico Barrio Espino resembles granodiorite chemically; one from La Curena body resembles "alkali granite" of Nockolds (1954). Locally amygdular border-zone of the La Curena body indicate a shallow depth of emplacement.

Tip APHANITIC PORPHYRY—Medium gray to greenish gray, contains phenocrysts of plagioclase and clinopyroxene; resembles granodiorite in chemical composition.

Tih HORNBLENDE DIORITE PORPHYRY—Bluish-gray, found only on ridge north of Hacienda Lamberti.

Tig GABBRO—Dark greenish-gray and medium bluish-gray, fine-grained.

Tid PYROXENE DIORITE, HORNBLENDE DIORITE, AND QUARTZ DIORITE—Chiefly dark greenish-gray and medium gray, equigranular or porphyritic, occurs south of Cerro Goden fault. Body north of Josefa is very inhomogeneous, containing swarms of inclusions filled with equant or acicular hornblende. Surrounding border-zone is amygdular.

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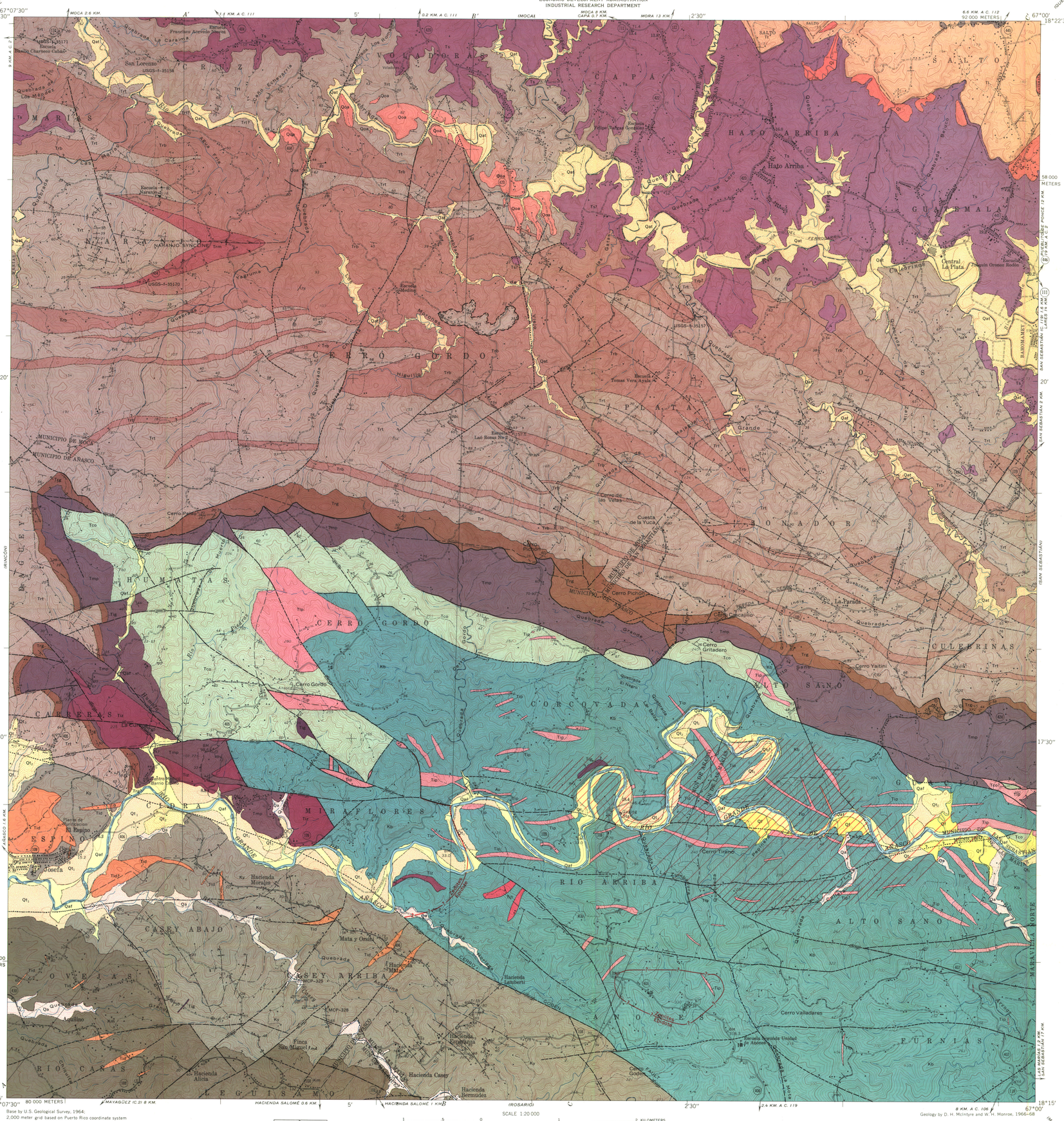


Base by U.S. Geological Survey, 1964.
2,000 meter grid based on Puerto Rico coordinate system

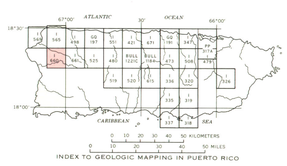
Geology by D. H. McIntyre and W. H. Monroe, 1966–68

APPROXIMATE MEAN DECLINATION, 1971

Monroe | McIntyre
RESPONSIBILITY

SCALE 1:20 000
1 ½ 0 1 2 KILOMETERS
1 ½ 0 1 MILE

CONTOUR INTERVALS 5 AND 10 METERS
DATUM IS MEAN SEA LEVEL



INDEX TO GEOLOGIC MAPPING IN PUERTO RICO

EXPLANATION

Pleistocene and Holocene — QUATERNARY

- Qat — Alluvium of Río Culebrinas
- Qa, Qaf, Qt_1, Qt_2 — Alluvium of Río Añasco and tributaries
  Qa, *alluvium, undivided*
  Qaf, *floodplain alluvium*
  Qt_1, *alluvium of lower terrace*
  Qt_2, *alluvium of higher terrace*
- Ql — Landslide deposits
- Qf — Alluvial fans
- Qoa — Alluvial fill in ancient valley of Río Culebrinas

Oligocene and Miocene — TERTIARY

UNCONFORMITY

- Tc — Cibao Formation

Río Guatemala Group

- Tl — Lares Limestone
- Ts — San Sebastián Formation
  Alluvial deposits questionably assigned to San Sebastián Formation may include some Qoa

UNCONFORMITY

Eocene — TERTIARY

- Trm, Trt, Trb, Trg — Río Culebrinas Formation
  Trt, *chiefly thin-bedded volcanic sandstone, siltstone, and mudstone; locally contains small amounts of coarse tuff and tuff-breccia*
  Trm, *chiefly very thick to thick-bedded coarse crystal lithic tuff; locally contains small amounts of thin-bedded volcanic sandstone, or tuff-breccia*
  Trb, *chiefly very thick bedded tuff-breccia; locally contains small amounts of coarse tuff or thin-bedded volcanic sandstone*
  Trg, *Guacio Member, thin-bedded siliceous and calcareous mudstone*
- Tmp — Mal Paso Formation
- Tco — Concepción Formation

ROCKS SOUTH OF CERRO GODEN FAULT

Upper Cretaceous — CRETACEOUS

Campanian-Maestrichtian

- Kb — Río Blanco Formation
- Km, Ky — Maricao Basalt and Yauco Mudstone
  Km, *Maricao Basalt*
  Ky, *Yauco Mudstone*

INTRUSIVE ROCKS

Eocene — TERTIARY

- Tiz, Tip, Tih, Tig, Tid — Dikes and small stocks
  Tiz, *aphanitic porphyry with pale pink zeolitized plagioclase phenocrysts*
  Tip, *aphanitic porphyry with plagioclase and clinopyroxene phenocrysts*
  Tih, *hornblende diorite porphyry*
  Tig, *fine-grained gabbro*
  Tid, *pyroxene diorite, hornblende diorite, and quartz diorite*

Contact
Dashed where approximately located; short dashed where inferred; queried where existence uncertain

Fault, showing relative horizontal movement
Dashed where approximately located; short dashed where inferred; dotted where concealed by younger deposits; queried where existence uncertain; ?, toward observer; h, away from observer; U, upthrown side; D, downthrown side where sense of vertical movement known

Possible gravity-glide block

Anticline, showing crestline
Dashed where approximately located; queried where existence uncertain

Syncline, showing troughline
Dashed where approximately located; queried where existence uncertain

Strike and dip of beds: Inclined (65), Overturned (70), Vertical, Horizontal

Strike and dip of beds: Inclined (65), Overturned (70), Vertical
Top of beds known from sedimentary features

Strike and dip of shear zone

Area in which Río Blanco Formation contains epidote veins; veins more common in area overlain by closely spaced lines than in area of broadly spaced lines

Zeolites, Epidote
Boundary between zeolite-bearing and epidote-bearing rocks in the Río Blanco Formation

Au
Occurrence of gold

MCP-325
USGS-f-35157
Fossil localities

INTRODUCTION

The Central la Plata quadrangle is located in a hilly, intensely cultivated area in northwestern Puerto Rico. The quadrangle is characterized by deep residual soils. Fresh rock rarely is seen except along major streams or as spheroidal residual boulders within the soil. Most of the area north of the Río Culebrinas-Río Añasco drainage divide is densely planted to sugar cane during much of the year. Geologic features there, chiefly seen in saprolite exposures along trails and roads, are best examined in late spring, after the sugar cane has been cut. Most of the area south of the divide is in coffee or pastureland that is readily accessible except during heavy rains.

The topography in the northern half of the quadrangle is dominated by a long, gentle northerly slope that appears to be a relict of a resurrected erosion surface formerly covered by the San Sebastián Formation (Oligocene). In addition, there is present throughout the quadrangle a series of small upland flats that may correspond to some of the uplifted marine terraces recognized by Weaver (1966) in the Rincón quadrangle, in the coastal area to the west.

Previous geologic studies in the Central la Plata quadrangle include the pioneer work of Hubbard (1923), and geologic mapping near the town of San Sebastián, east of the Central la Plata quadrangle, by Turner (1958).

New age determinations on Foraminifera from the Yauco Mudstone, the Río Blanco Formation, the Mal Paso Formation, and the Río Culebrinas Formation have been made by K. N. Sachs, Jr., U.S. Geological Survey and E. A. Pessagno, Jr., Geosciences Division, University of Texas at Dallas.

STRUCTURE

The principal structural feature of the quadrangle is the Cerro Goden fault, which probably is part of the "Great Southern Puerto Rico Fault zone". Offset of contacts along adjacent subsidiary faults in the Central la Plata quadrangle shows that the dominant sense of motion was left lateral. No features in this quadrangle can be matched across the Cerro Goden fault, so the amount of movement on it undoubtedly was large, on the order of tens of kilometers. In 1968 the fault was well exposed along a truck trail on the north slope of Cerro Goden.

Southwest of the Cerro Goden fault the Yauco Mudstone and Maricao Basalt form a southwest-dipping homocline with some local irregularities due to minor folding in the Yauco. Locally, especially along Highway 108 near Hacienda Esperanza, the Yauco has been tightly folded about northwest-trending axes. The Yauco may be similarly deformed elsewhere, but poor exposures prevent this from being seen.

Immediately northeast of the Cerro Goden fault the Río Blanco and Concepción Formations are exposed in the axial area of a broad, northwest-plunging anticline. This structure is, at least in part, a large-scale drag feature caused by left lateral movement on the Cerro Goden fault. The massive, competent Río Blanco Formation, exposed in the core of this anticline, has been broken into a mosaic of blocks by movement along the many faults that cut it.

The Río Culebrinas Formation in this quadrangle occupies a broad synclinorium, or structural basin. Toward the west, the center of the synclinorium is marked by the Naranjo Syncline. Toward the eastern part of the map, however, the Río Culebrinas is involved in a number of irregular, erratically plunging folds. The irregularity of the structural pattern is due in large part to changes in thickness and competency of the massive breccia unit present in this area.

The basal portion of the Río Culebrinas Formation and the underlying Mal Paso Formation are overturned to the southwest through a distance of about 4 km from the eastern border of the map. An excellent exposure of the contact between the two formations southwest of Cerro Yaitini shows that it is not faulted. About 1 km west of the east border the basal Río Culebrinas locally has been overturned to horizontal and thrust northward. Erosion has removed part of the over-riding allochthonous basal Río Culebrinas unit, leaving a gap about 300 m wide in which the unit is missing. The autochthonous portion of the Río Culebrinas presumably lies hidden beneath allochthonous Mal Paso Formation exposed south of the gap. The maximum northward horizontal component of movement on the fault is estimated to be about 350 m.

From Cerro Pichón to Cerro Pelao the basal unit of the Río Culebrinas dips generally toward the north and has been thrust southward over the Mal Paso Formation. At Cerro Pichón the outcrop belt of the basal unit of the Río Culebrinas has been broadened by imbricate faulting. Poor exposures prevented wholly satisfactory depiction of the fault pattern in this area.

A possible small glide-block in the Río Culebrinas Formation is located 0.8 km southeast of Escuela Medina. Very poor exposures in the area, however, make this interpretation uncertain. The supposed block, made up of thin-bedded to massive coarse tuff, occupies a ridgecrest and apparently is surrounded completely by tuff-breccia.

METAMORPHISM

Over most of its outcrop area the Río Blanco Formation has been affected by low grade metamorphism. Epidote, chlorite, albite, and often prehnite and pumpellyite are common alteration products. Intrusive rocks that cut the Río Blanco also are affected in the same manner. In the area south of Cerro Gritadero veinlets of granular epidote that cut the Río Blanco Formation are common. The area may represent a fossil thermal anomaly over a relatively large intrusive body not yet exposed by erosion.

In two areas alteration of the Río Blanco has reached only zeolite grade. One of these is in Barrio Miraflores, Mun. de Añasco. The other is located northwest of the Anones school, in Barrio Anones, Mun. de Las Marías.

Unpublished results of an aeromagnetic survey by the U.S. Geological Survey show a magnetic high over the area of zeolitized rocks in Barrio Anones. A broad magnetic low occurs over the rocks with epidote veins south of Cerro Gritadero. The destruction of magnetite during metamorphism, only partial in the zeolitized rocks, evidently has been more complete in the epidote-bearing rocks.

Some samples from the Maricao Basalt also contain secondary albite, epidote, chlorite, prehnite, and pumpellyite.

Zeolites, chiefly laumontite, are conspicuous in some samples from the Río Culebrinas Formation, particularly the coarse tuffs. These minerals seem to be restricted in occurrence to tuffs near the base of the formation, and to rocks adjacent to faults. Most of the formation in the quadrangle displays little or no zeolitization.

Zeolites, together with calcite, are abundant in the Mal Paso Formation. Most probably are deuteric in origin, but detailed study may show that some have been produced by alteration postdating emplacement of the unit.

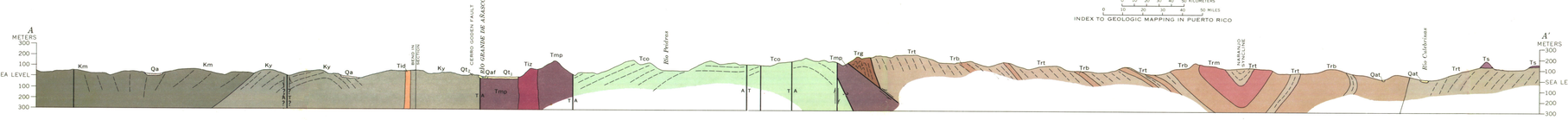
ECONOMIC GEOLOGY

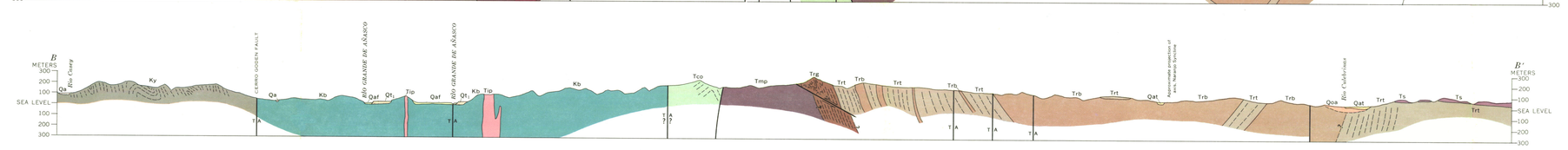
Small gold-bearing quartz veins cutting the Río Blanco Formation are exposed in two ravines north of Route 109 near km 14.7. The largest [widest] vein is about one meter in width, but the others seldom exceed a few centimeters. None of them appear to continue any great distance; however, exposures in the area are very poor. Alteration of the host rock is confined to the borders of the veins. Gold content of ten samples analyzed by the U.S. Geological Survey's Analytical Laboratories ranged from 20 ppm (parts per million) to 0.2 ppm (1 ppm = approx. $1.00/ton). A sample across the width of the 1 m vein contained 6.5 ppm gold. The veins are drusy and contain less than one percent finely disseminated pyrite and a little chalcopyrite. Galena and sphalerite also are present in samples collected by D. P. Cox.

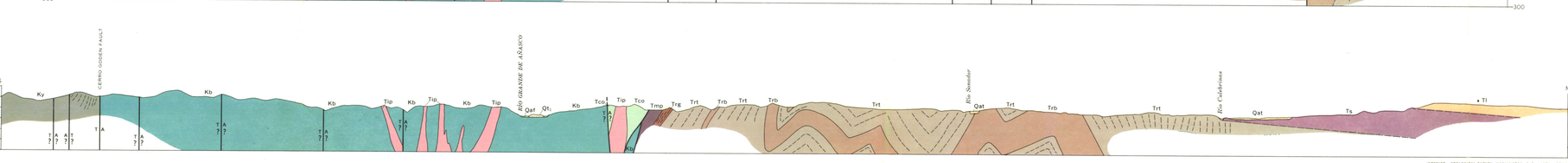
Analyzed samples from quartz veins cutting the Río Blanco Formation in other areas and from alluvial terrace and floodplain deposits of the Río Añasco contained essentially no gold.

Zones of argillic alteration occur along faults in the area south of Cerro Tirano. None wider than about 15 m was noted.

The veins of massive granular epidote that locally cut Río Blanco rocks south of Cerro Gritadero are barren of sulfides or gold.







GEOLOGIC MAP OF THE CENTRAL LA PLATA QUADRANGLE, PUERTO RICO

By
D. H. McIntyre
1971

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1971—G70126

For sale by U.S. Geological Survey, price $1.25