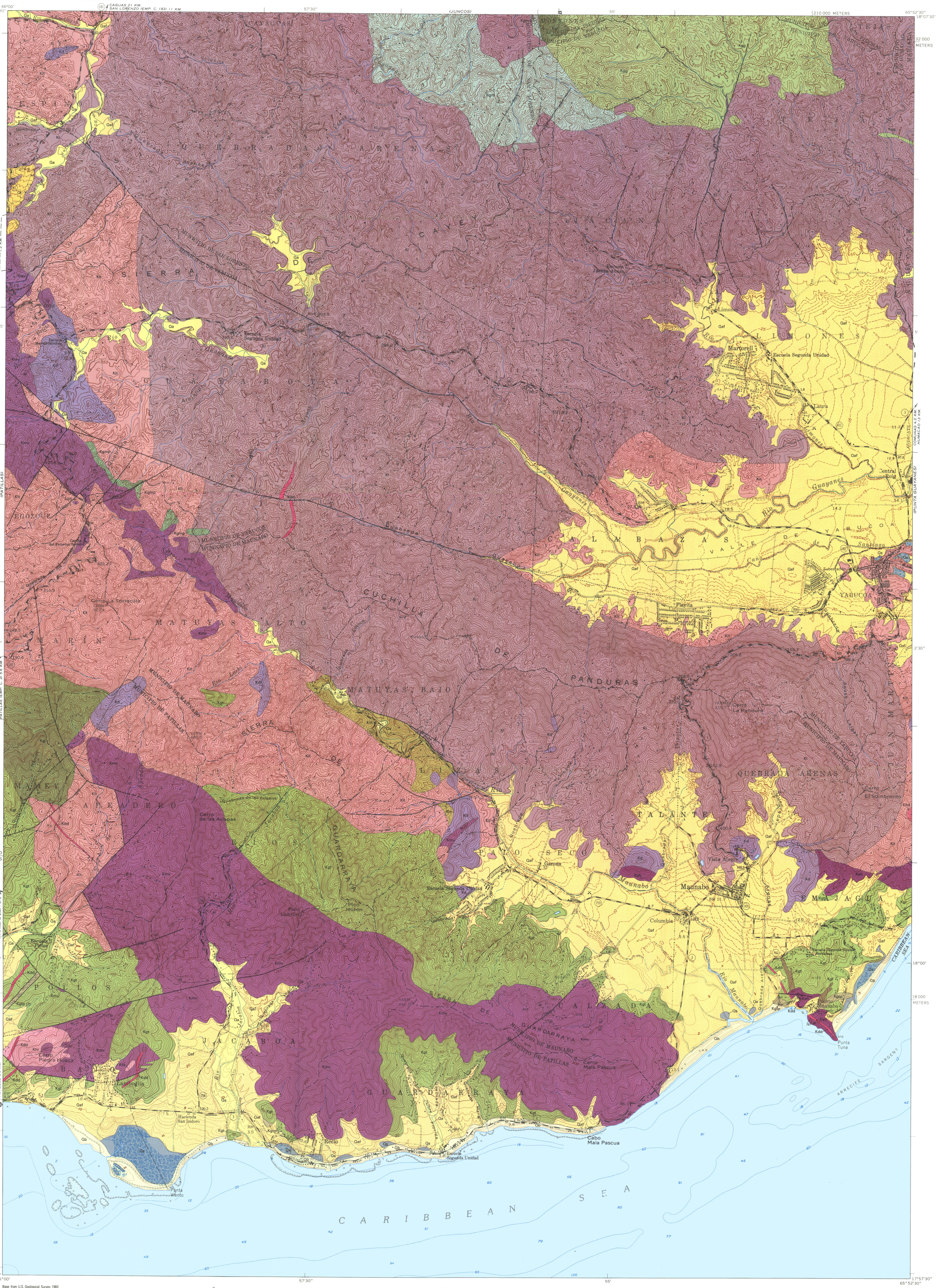
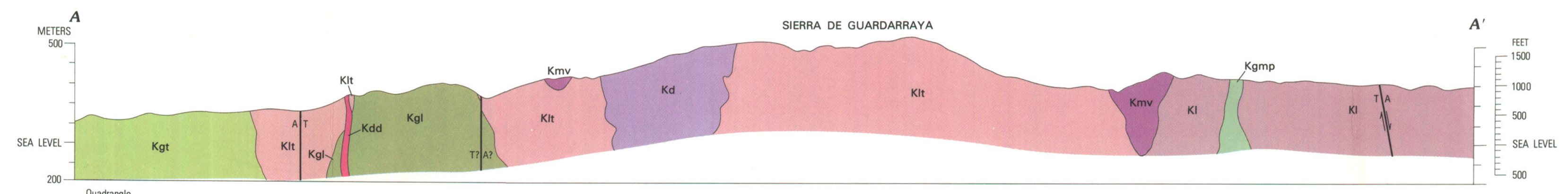


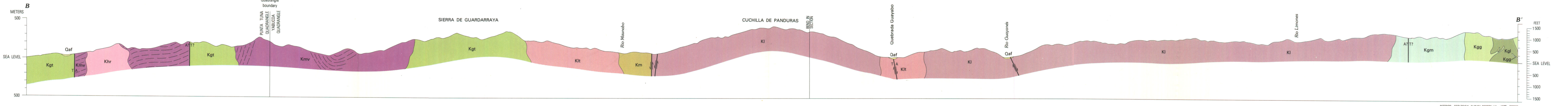
Base from U.S. Geological Survey 1960
2000-meter grid based on Puerto Rico coordinate system

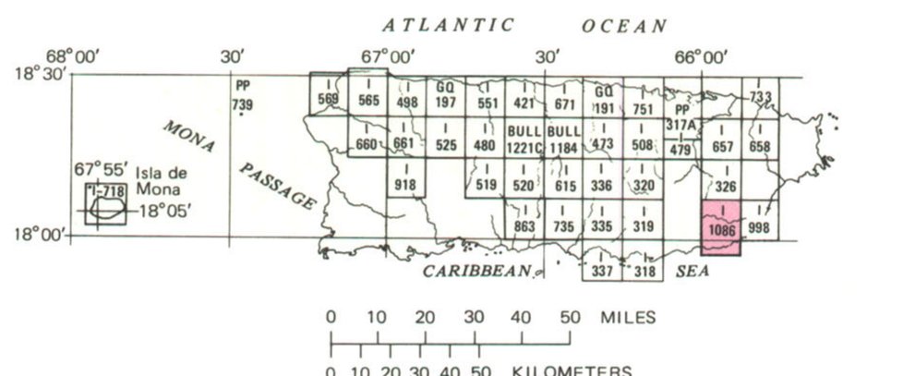
APPROXIMATE MEAN DECLINATION, 1979

SCALE 1:20 000
1 ½ 0 1 MILE
1 .5 0 1 2 KILOMETERS
CONTOUR INTERVAL 10 METERS
DASHED LINES REPRESENT 5-METER CONTOURS
DOTTED LINES REPRESENT 1-METER CONTOURS
DATUM IS MEAN SEA LEVEL

Geology investigated by J. P. Owens and R. B. Guillou, 1954–1956; J. P. Owens, M. S. Tischler, and P. A. Gelabert, 1956–57; M. H. Pease Jr., 1957, C. L. Rogers and C. M. Cram, 1974–75







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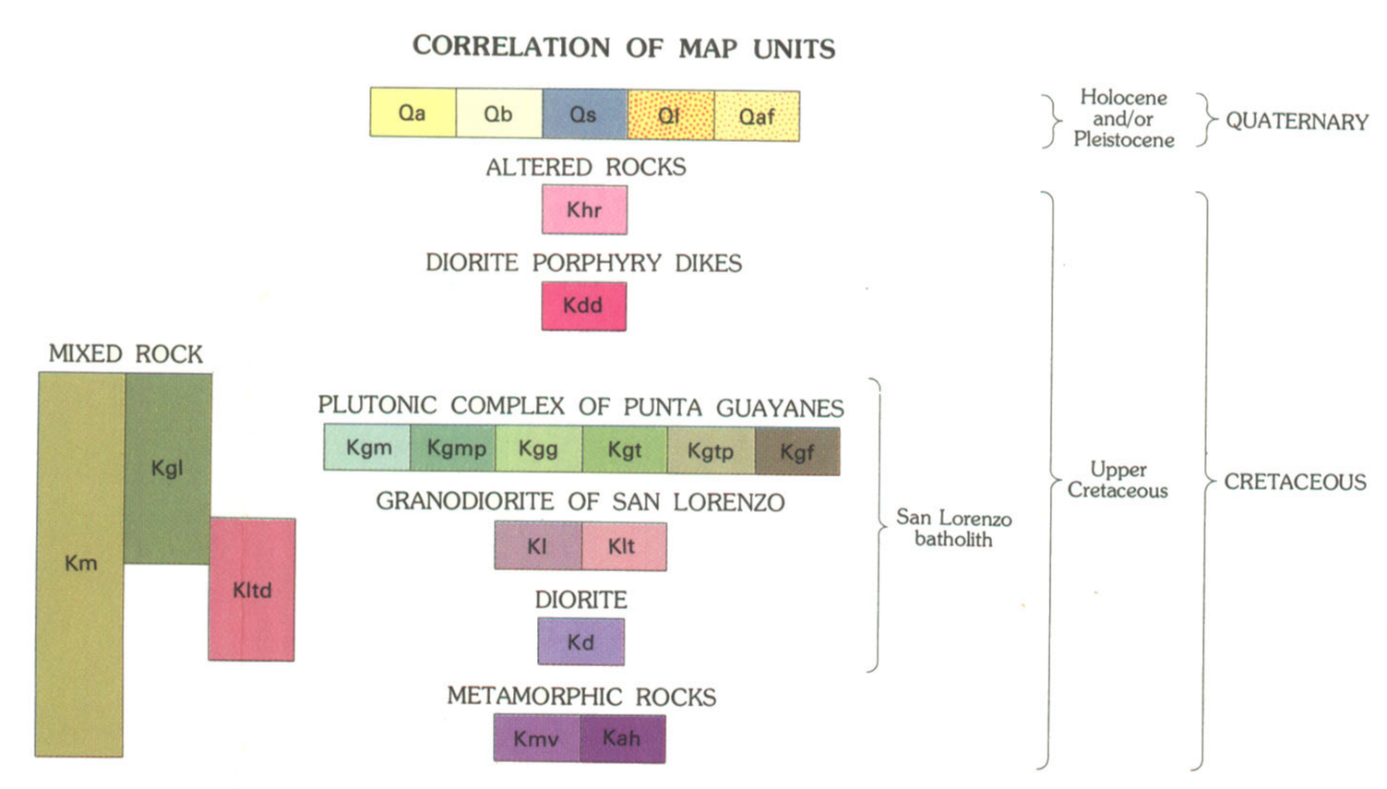
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qa ALLUVIUM (HOLOCENE AND/OR PLEISTOCENE)—Unconsolidated clay- to boulder-size material deposited in major stream channels. Locally includes small remnants of low terraces. Thickness locally more than 10m

Qb BEACH DEPOSITS (HOLOCENE AND/OR PLEISTOCENE)—Largely unconsolidated fine- to medium-grained sand composed of quartz, feldspar, and igneous rock fragments, with some magnetite and calcareous shell and reef debris. Locally includes subrounded pebbles, cobbles, and boulders composed of plutonic rock and reef material

Qs SWAMP DEPOSITS (HOLOCENE AND/OR PLEISTOCENE)—Dark-gray to black muck and peaty soil underlying low swampy areas; mostly behind present beaches. Thickness probably as much as 5 m

Ql LANDSLIDE DEPOSITS (HOLOCENE AND/OR PLEISTOCENE)—Debris avalanche type, composed of abundant boulders in soil and weathered rock matrix

Qaf ALLUVIUM AND FANGLOMERATE (HOLOCENE AND/OR PLEISTOCENE)—Poorly to weakly consolidated, clay- to boulder-size material. Predominantly in alluvial-plain deposits underlying broad lowland areas. In many places unit grades into marginal fan, slopewash, and minor landslide deposits. Locally includes stream-channel and terrace deposits. Terraces prominent behind beaches in small coastal lowlands of Punta Tuna Quadrangle. Thickness locally more than 25 m

Khr HYDROTHERMALLY ALTERED ROCKS (UPPER CRETACEOUS)—Altered metavolcanic rocks mapped in the Cerro Piedra Hueca area of Punta Tuna quadrangle. Light-pinkish-gray, commonly porous, and streaked with reddish-brown hematite stain; composed mainly of finely divided quartz and sericite, with some clinozoisite and muscovite

Kdd DIORITE PORPHYRY DIKES (UPPER CRETACEOUS)—Forms a few sizable dikes that have been mapped and numerous smaller dikes with dominant north to northeast trend that have not been mapped. Medium-dark-gray to greenish- and yellowish-gray, containing abundant phenocrysts of medium-grained, zoned, commonly albitized, intermediate plagioclase and hornblende. Rare phenocrysts of quartz, biotite, and pyroxene, with variable amounts of fine-grained matrix that is largely plagioclase and hornblende, with a little quartz. Accessory magnetite, sphene, apatite and zircon, and rare pyroxene, biotite, potassium feldspar, pyrite and chalcedony. A few dikes contain rare to moderately common granophyric intergrowths of quartz and sodic plagioclase bordering plagioclase crystals and in discrete grains. Plagioclase and hornblende extensively altered

Km MIXED ROCK (UPPER CRETACEOUS)—Underlies lower part of Rio Maunabo valley. Mainly intimate mixture of tonalite of plutonic complex of Punta Guayanés with tonalite facies of granodiorite of San Lorenzo, diorite and metavolcanic rock. Includes a little tonalite porphyry and quartz monzonite porphyry of plutonic complex of Punta Guayanés

Kgl MIXED ROCK (GRANODIORITE OF PLUTONIC COMPLEX OF PUNTA GUAYANÉS AND GRANODIORITE OF SAN LORENZO) (UPPER CRETACEOUS)—Small mass on north edge of mapped area is predominantly granodiorite of San Lorenzo intimately injected by granodiorite of plutonic complex of Punta Guayanés; minor hybrid rock. Larger mass in southwest part of mapped area is predominantly a highly fractured and altered hybrid rock. Additional areas of mixed rock are common along San Lorenzo-Punta Guayanés contacts, but are too small to map. Hybrid rocks are varied and abnormal in appearance, with modal composition falling between those of the two primary rocks.

Kgm QUARTZ MONZONITE OF PLUTONIC COMPLEX OF PUNTA GUAYANÉS (UPPER CRETACEOUS)—Light-gray to very light gray, predominantly medium grained, unfoliated, with hypidiomorphic-granular to allotriomorphic-granular texture; commonly weathers to light red or pink. Locally contains aplite dikes, small quartz and feldspathic quartz veins, and small masses of light-gray quartz monzonite porphyry. Ranges locally to granodiorite but average modal composition (7 analyses) is 35 percent plagioclase, 28 percent potassium feldspar (45 percent of total feldspar), 33 percent quartz, 1.5 percent hornblende, 2 percent biotite, 0.5 percent magnetite, and minor accessory sphene, apatite and zircon. Plagioclase is largely oligoclase, occurs in tabular subhedral crystals <0.5–4 mm long, exhibits polysynthetic (generally combined Albite-Carlsbad) twinning, and is commonly zoned; most crystals altered in varying degrees to sericite and clay with epidote common locally and minor clinozoisite and calcite. Potassium feldspar occurs largely in anhedral crystals that are <0.5–6 mm in longest dimension and is commonly microperthitic with moderately coarse and moderately abundant sodic plagioclase. A few potassium feldspar grains exhibit Carlsbad twinning and may be orthoclase. However, potassium feldspar is probably microcline in large part, although good microcline twinning is rare. Quartz occurs in anhedral crystals and aggregates that are <0.5–6 mm in longest dimension, and is strained. Green hornblende (<0.5–3 mm long) occurs in stubby to elongate subhedral crystals and clusters, is commonly poikilitic, and partly altered to chlorite and epidote. Biotite is fine-grained and generally brown; locally pleochroic from pale yellowish-brown to yellowish-brown

Kgmp QUARTZ MONZONITE PORPHYRY OF PLUTONIC COMPLEX OF PUNTA GUAYANÉS (UPPER CRETACEOUS)—Light-pink to light-gray, fine- to medium-grained, composed largely of potassium feldspar, plagioclase (oligoclase to albite), and quartz, with minor biotite and rare magnetite. Quartz, in part, is intergrown with the feldspars. Phenocrysts and groundmass have essentially the same mineralogy. Mapped bodies in west-central part of Yabucoa quad., but few small unmapped masses occur elsewhere in area of study

Kgg GRANODIORITE OF PLUTONIC COMPLEX OF PUNTA GUAYANÉS (UPPER CRETACEOUS)—Light-gray predominantly medium-grained unfoliated granodiorite that commonly weathers to light red or pink. Locally contains aplite dikes, small quartz and feldspathic quartz veins, and small masses of light-gray quartz monzonite porphyry. Ranges locally to quartz monzonite, but average modal composition (8 analyses) is 46 percent plagioclase, 16 percent potassium feldspar (26 percent of total feldspar), 33 percent quartz, 1.5 percent hornblende, 3 percent biotite, 0.5 percent magnetite, and minor accessory sphene, apatite and zircon

Kgt TONALITE OF PLUTONIC COMPLEX OF PUNTA GUAYANÉS (UPPER CRETACEOUS)—Includes two facies; an older coarser-grained tonalite, and a younger more felsic tonalite that is abundant and locally predominant (mapped separately, where possible, as Kgtp and Kgf). Older tonalite resembles quartz monzonite and granodiorite of northern Punta Guayanés pluton in occurrence and general aspect, although generally more strongly altered and weathered, and more fractured and friable. Contains relatively few autoliths (?) and metavolcanic xenoliths, although latter are common in a few areas. Average modal composition (14 analyses) is 55 percent plagioclase, 0.5 percent potassium feldspar (present in three thin sections), 38 percent quartz, 1 percent hornblende (present in four thin sections), 4 percent biotite, 1 percent magnetite, minor accessory sphene, apatite and zircon, and minor pyrite, with limonite and hematite stain. Plagioclase largely oligoclase, ranging locally to albite, and exhibits incipient to moderately strong alteration to sericite, clay, and epidote. Hornblende extensively altered to chlorite, epidote, and biotite, with some magnetite and sphene. Biotite partly altered to chlorite and epidote. Sparse to moderately abundant albite and quartz occur as fine- to very fine-grained interstitial material. Younger felsic tonalite facies is light gray to pinkish gray, commonly yellow to rusty weathering, fine to medium grained, and is more resistant and thus better exposed than the older tonalite that it intrudes. Forms dikes, but more commonly occurs in small to moderately large irregular masses that locally are transitional into the older tonalite host rock. Also occurs in small unmapped masses in adjacent diorite and San Lorenzo plutonic rocks. This younger felsic tonalite facies is characterized by two textures; a fine- to medium-grained fraction, with crystals generally measuring <3 mm in diameter; and a fine- to very fine-grained younger fraction, with the same mineralogy, that occurs interstitially and in part replaces the older material. The younger fraction generally subordinate to the older, locally equally abundant. Locally the younger felsic tonalite facies contains sparse phenocrysts of plagioclase and quartz (partly euhedral) that range up to 6 mm in size. Average modal composition (11 analyses) is 55 percent plagioclase, 0.5 percent potassium feldspar (present in three thin sections), 42 percent quartz, 2 percent mica, and 0.5 percent dark opaque minerals, including magnetite, and pyrite with related limonite and hematite stain. The plagioclase ranges from oligoclase to albite. The mica ranges from normal brown biotite to light yellow to colorless muscovite. Locally the rock contains granophyric intergrowths of quartz and plagioclase

Kgtp TONALITE PORPHYRY (UPPER CRETACEOUS)—Light-gray, consisting of evenly distributed clots of quartz-oligoclase aggregate, ranging up to 30 mm in diameter, in a much finer-grained matrix of quartz and oligoclase containing traces of reddish-brown biotite and evenly distributed fine- to coarse-grained pyrite. Southern contact well defined north of Punta Tuna, but northern contact gradational

Kgf FELSITE (UPPER CRETACEOUS)—Pale yellow-brown layered fine-grained, with granoblastic texture. Largely quartz and sodic plagioclase, with numerous patches of myrmekite, about 2 percent biotite, and accessory magnetite

Kltd MIXED ROCK (TONALITE FACIES OF GRANODIORITE OF SAN LORENZO AND DIORITE) (UPPER CRETACEOUS)—Underlies small area in southeast part of Yabucoa quadrangle. Largely an intimate mixture of tonalite and diorite, with some hybrid rock. Hybrid rock is varied and abnormal in appearance, with modal composition falling between tonalite and diorite

Kl GRANODIORITE OF SAN LORENZO (UPPER CRETACEOUS)—Medium-dark-gray predominantly medium grained with hypidiomorphic-granular texture. Largely unfoliated but locally has simple planar arrangement of hornblende and biotite grains. Locally contains small subrounded autoliths (?) that are darker and in part more mafic than the host rock, angular to subrounded and lenticular metavolcanic xenoliths, and a few areas of older diorite that are too small or partly assimilated and thus too poorly defined to map. Commonly contains aplite dikes. Average modal composition (58 analyses) is 51 percent plagioclase, 11 percent potassium feldspar (18 percent of total feldspar), 20.5 percent quartz, 11 percent hornblende, 4.5 percent biotite, 1.5 percent magnetite, with accessory sphene, apatite and zircon, and minor myrmekite and augite. Although granodiorite in average composition, the rock ranges locally to tonalite, very rarely to quartz monzonite. Plagioclase occurs in stubby to elongate subhedral crystals generally 1–5 mm long, and is largely andesine, but locally ranges to calcic oligoclase. Exhibits polysynthetic (generally combined Albite-Carlsbad) twinning and is commonly zoned; many grains partly sericitized and argillized, with relatively rare alteration to epidote, clinozoisite and calcite. Potassium feldspar occurs mainly in anhedral crystals <0.5–4 mm in diameter, may enclose other minerals, commonly characterized by fine, sparse to moderately abundant microperthite. The potassium feldspar in this rock (and other major plutonic units) includes a little normal microcline; most appears to be transitional from orthoclase to microcline. Quartz occurs in anhedral crystals and aggregates generally 0.5–4 mm in diameter and is strained. Green hornblende occurs in stubby to elongate subhedral crystals and clusters, which are generally 1–5 mm in long dimension but range up to 8 mm or more; some crystals moderately to strongly poikilitic, with inclusions of plagioclase, quartz, biotite, magnetite, apatite, and sphene. A few hornblende crystals contain small relict areas of slightly pleochroic pale-green augite, and numerous crystals are partly altered to chlorite and epidote, with less common magnetite and rare sphene. Biotite crystals generally 1–3 mm in diameter, and poikilitic in part; some appear derived from hornblende; commonly altered to chlorite, with subordinate epidote

Klt TONALITE FACIES OF GRANODIORITE OF SAN LORENZO (UPPER CRETACEOUS)—Similar in occurrence, general appearance and mineralogy to the granodiorite of San Lorenzo, and separately mapped only where it forms bodies sufficiently large and well defined. In eastern and southern parts of quadrangles mapping based largely on petrography; boundaries are transitional and indefinite. In west tonalite facies is locally more distinctive and can be recognized in the field. Average modal composition (35 analyses) is 57.5 percent plagioclase, 2 percent potassium feldspar (3.5 percent of total feldspar), 20.5 percent quartz, 13 percent hornblende, 0.5 percent augite, 4.5 percent biotite, 1.5 percent magnetite, minor myrmekite, and accessory sphene, apatite, and zircon. The plagioclase is largely andesine

Kd DIORITE (UPPER CRETACEOUS)—Includes numerous small mappable plutons in southern and western parts of Yabucoa quadrangle, near border of San Lorenzo batholith, and additional masses within the younger plutonic rocks that are too small, or partly assimilated and thus too poorly defined, to map. Darkest and most heterogeneous of the plutonic units; locally contains small subrounded autoliths (?) darker and in part more mafic than the country rock, and contains relatively abundant metavolcanic xenoliths; locally contains younger more mafic diorite and hornblendite as fracture filling or in small irregular intrusive masses; locally much epidotized along fractures. Considerable intimate mixing with San Lorenzo or Punta Gayanés rocks locally, particularly along margins of plutons, with some development of hybrid rock. Average modal composition (21 analyses) is 63 percent plagioclase, 3.5 percent quartz, 25 percent hornblende, 5 percent clinopyroxene, 3 percent magnetite, with minor potassium feldspar and biotite in a few thin sections, perhaps as a result of contamination by younger rocks, and accessory sphene, apatite, and zircon. Although diorite in average composition, the rock ranges locally to gabbro, which is characterized by abundant clinopyroxene and more calcic plagioclase. The plagioclase forms subhedral lath-shaped crystals 0.5–4 mm long, and is predominantly andesine, ranging to labradorite; commonly zoned. Most grains exhibit incipient to moderately strong alteration to sericite and clay, with rare epidote, clinozoisite and calcite. Quartz generally present in fine anhedral interstitial crystals and aggregates. Green hornblende occurs in stubby to elongate subhedral crystals and clusters that are generally 0.5–5 mm in longest dimension but locally range up to 15 mm; commonly poikilitic; many crystals partly altered to chlorite and epidote, with minor magnetite and sphene. The pyroxene is augite and occurs as relict areas within some hornblende crystals, and less commonly in discrete crystals and clusters that range from <0.5 to 3 mm in diameter; may be moderately poikilitic, and in turn occurs as very fine inclusions within some plagioclase crystals. Augite ranges from colorless to weakly pleochroic. May be weakly pleochroic from colorless to pale green, or from light grayish-green to light yellowish-green, or may be weakly to moderately pleochroic from pale green to red. Reddish clinopyroxene occurs only in the more gabbroic rocks, in which pyroxene predominates over hornblende, and may be titaniferous

Kmv METAVOLCANIC ROCKS (UPPER CRETACEOUS)—Weakly metamorphosed volcanic rocks derived from lava flows, with some flow (?) breccia, and tuffs and tuffaceous siltstones and sandstones. Lava flows are dark-gray to dark-greenish-gray, predominantly fine-grained, porphyritic and amygdaloidal in varying degrees, and characterized by subtrachytic to felted and granoblastic textures. Predominantly plagioclase (originally intermediate in composition but now extensively albitized) and green to bluish-green hornblende or actinolite. Minor clinopyroxene, minor sporadic quartz and potassium feldspar (obviously secondary, in large part), ubiquitous fine- to very fine-grained magnetite and pyrite, and common alteration products, including sericite, clay, epidote, clinozoisite, chlorite, and limonite stain. Tuffs are dark greenish gray, composed of lithic and mafic-crystal fragments in aphanitic matrix spotted with light greenish-gray plagioclase-crystal fragments. Rocks near western margin of mapped area and north of Rio Maunabo are predominantly siltstone and sandstone and are dark gray to greenish gray, fine grained, massive to finely laminated, with granoblastic texture; locally show graded bedding. Predominantly plagioclase, clinopyroxene and quartz, in variable proportions, with some hornblende or actinolite, ubiquitous fine- to very fine-grained magnetite and pyrite, and usual alteration products,including clay, sericite, chlorite and epidote; grains generally angular to subangular, but locally subrounded. Impossible to estimate thickness of major mass in southern part of mapped area, but thickness of partial stratigraphic sections can be estimated in several localities; maximum thickness of sequence exposed near eastern end of the Sierra de Guardarraya may total about 1,600 m, and probably at least 1,000 m of stratigraphically lower section is exposed at northwest end of the Sierra de Guardarraya; rocks best exposed near Cabo Mala Pascua, where almost complete section about 200 m thick is exposed and is representative of the entire sequence

Kah AMPHIBOLE HORNFELS (UPPER CRETACEOUS)—Comprises three small bodies in southeast part of mapped area that are more metamorphosed than Kmv. These rocks are dark-gray to greenish-gray, predominantly fine-grained hornfels, with granoblastic texture; composed largely of intermediate plagioclase and hornblende, with some accessory quartz, very fine-grained magnetite and pyrite, and usual alteration products, including clay, sericite, chlorite, epidote and iron stain. Grades to hornblende schist locally in areas of more intense metamorphism. Body near Punta Tuna includes porphyritic flow rocks and laminated to thin-bedded volcaniclastic rocks; other bodies largely massive, and nature of primary rock uncertain

CONTACT—Alluvium and fanglomerate (Qaf) contacts are approximately located; contact between granodiorite of San Lorenzo and associated tonalite facies is queried, since it is gradational and based, in large part, on petrography

FAULT—Showing dip and relative strike-slip movement; strike-slip movement queried where doubtful. Dashed where approximately located; dotted where concealed; queried where doubtful. Bar and ball on downthrown side. A, away from viewer; T, towards viewer, in cross-sections

SHEAR ZONE

STRIKE AND DIP OF BEDS
- Inclined
- Vertical

STRIKE AND DIP OF PRIMARY FOLIATION IN PLUTONIC ROCKS—Shown by planar arrangement of mafic minerals and orientation of mafic-rich segregations and platy metavolcanic inclusions
- Inclined
- Vertical

SAND AND GRAVEL PIT—Material recovered from river bed

ROCK SAMPLE LOCALITY—Showing field number of sample for which potassium-argon age date was determined

CORAL REEF—Showing approximate boundary

ROCKS OF THE SAN LORENZO BATHOLITH

The greater part of the mapped area lies within the San Lorenzo batholith, a composite body occupying an area of about 500 km² in southeastern Puerto Rico. The batholith is composed of three major units, which in chronologic order (oldest to youngest) include diorite and gabbro (Kd), the granodiorite and associated tonalite of San Lorenzo (Kl, Klt), and the plutonic complex of Punta Guayanes; the latter complex ranges from tonalite (Kgt)to quartz monzonite (Kgm). The relations between these units were worked out largely from good exposures in the sea cliffs of the Punta Guayanés quadrangle (Rogers, 1977), and were later corroborated by potassium-argon age dating (Cox, and others, 1977; Rogers, 1977, table 1). Two samples of the diorite gave an age of about 78 m.y.; two samples of the granodiorite of San Lorenzo gave an age of about 73 m.y.; and a single sample of granodiorite from the plutonic complex of Punta Guayanés (Kgg) gave an age of about 66 m.y. However, this time span of about 12 m.y. must be considered a minimum figure, as the diorite pluton dated was engulfed and possibly reheated by the tonalite facies of the granodiorite of San Lorenzo, and thus may be older than indicated. Also, the youngest major unit, the plutonic complex of Punta Guauanés, is characterized by the presence along pluton margins of late-stage differentiates, with related hydrothermal alteration, that may be, at least in part, of early Paleocene age. In the absence of age data relating to the latest intrusive and hydrothermal activity, however, the batholith is provisionally assigned wholly to the Late Cretaceous Epoch.

The plutonic complex of Punta Guayanés is more varied than the other major units composing the batholith. It forms numerous small to moderately large plutons that are generally concentrated in the outer portion of the batholith, except for one sizable body in its center. These plutons exhibit a gradual compositional change from quartz monzonite and granodiorite in the core of the batholith to tonalite near its margin, and with rare exceptions, the associated younger rocks reflect this change. The abundant porphyries and felsites associated with the Punta Guayanés plutons appear to be genetically related late-stage differentiates. This relationship has not been substantiated by chemical analyses, but is borne out by lithologic similarities and spatial relations. The younger rocks have been intruded in several stages and locally are autointrusive. Some of the larger masses of these rocks (Kgmp, Kgtp, Kgf), occurring largely outside the major plutons, have been separately mapped. The felsite (Kgf) that forms two small lenticular areas near Puerto Maunabo appears to have replaced xenolithic metavolcanic layers. In the eastern lens, layering conforms generally to the attitude of relict bedding within the adjacent metavolcanic rock. The western lens is characterized by float and a few possible outcrops of metavolcanic rock that may be interlayered with the felsite.

The oldest known plutonic rock in the mapped area is a very small body of tonalite near the western border of the quadrangle that is enclosed by the younger, more felsic tonalite facies of the granodiorite of San Lorenzo. This rock was sampled by Dennis P. Cox and gave a potassium-argon age of 109±9 m.y. (Cox and others, 1977, sample 52–1). It is a dark, amphibole-rich tonalite, and resembles an older diorite in the Patillas quadrangle that was sampled by Cox and gave a potassium-argon age of 100±16 m.y. (Cox and others, 1977, sample 51–4). Other similar relict bodies may well be present within the San Lorenzo batholith.

MAFIC DIKES

Mafic dikes (as distinct from the less mafic diorite porphyry dikes, Kdd) are sparse in the mapped area and none have been mapped, because they are small and difficult to trace. They are generally less than 2 m wide, have a random orientation, and are dark, fine- to very fine grained rocks composed largely of plagioclase and hornblende.

STRUCTURAL GEOLOGY

The mapped area lies within the central tectonic block of Puerto Rico, which is bounded by west-northwest-trending fault zones having large left-lateral displacement, and perhaps also considerable vertical displacement (Cox and Briggs, 1973). This block contains two batholiths of Late Cretaceous age that have intruded older Cretaceous volcanic rocks, and also contains some small stocks and volcanic rocks of Eocene age.

Faults are difficult to recognize in large homogeneous units like the granodiorite and associated tonalite of San Lorenzo, which underlie a large part of the mapped area; but a number of moderately large faults have been mapped in areas of sharply contrasting lithologies, particularly in the south and west sections of the study area. About half of these faults have a northeast to north-northeast trend and apparent left-lateral displacement, but the remaining faults mapped fail to exhibit any obvious pattern. Numerous very small faults observed but not mapped also have a northeast to north-northeast trend and may control small streams; some have been intruded by diorite porphyry dikes. Strike-slip movement is not easy to prove in the mapped area, where actual fault zones are rarely exposed; it can be assumed in the case of faults horizontally displacing diorite porphyry dikes, for the dikes are essentially vertical, but is queried where other contacts are involved. However, the fact that so many northeast- to north-northeast-trending faults appear to exhibit left-lateral displacement is strongly suggestive, for such a uniform pattern would not be expected in the case of normal faults in an area where the contacts are highly irregular and variable in dip.

The Quebrada Guayabo and Rio Guayanés valleys are characterized by numerous exposures and appear to be controlled by comparatively large faults. The structure following the Rio Guayanés may be a simple gravity fault dipping about 65° to the northeast. Although the outcrop pattern of the granodiorite and tonalite of San Lorenzo in the northwest corner of the Yabucoa quadrangle suggests left-lateral displacement, this type of displacement is not evident on the unpublished mapping of the adjacent Patillas quadrangle. The fault along the quebrada is less well exposed but appears to be a major structure having left-lateral strike-slip displacement, as shown by the offset of several contacts. Its dip-slip component amounts to more than 500 meters in the Punta Guayanés quadrangle and eastern part of the Yabucoa quadrangle, but diminishes gradually to the west. The contrast between the comparatively subdued topography that characterizes most of the San Lorenzo batholith and the rugged topography of the higher Cuchilla de Panduras to the south is striking.

This southern block may also be bordered by a large offshore fault on the south and southeast (Kaye, 1959, p. 51–52; Rogers, 1977), and has undergone recent uplift of 20–25 m on that side, as indicated by the alluvial terraces near Punta Toro and Punta Quebrada Honda at the east end, in the Punta Guayanés quadrangle, and similar terraces in the Barrio de Guardarraya to the west, in the Punta Tuna quadrangle. All of these terraces lie immediately behind the present beaches and are being rapidly dissected.

The mapped area appears to have been subjected to relatively recent uplift, for the streams are youthful, and in places the remnants of a series of low terraces that indicate several stages of uplift were noted, but not mapped, owing to their small size. These terrace remnants occur mainly along Rio Limones-on the north side of the Valle de Yabucoa, where locally as many as four terraces are present, along the Rio Grande de Loiza and its tributaries in the northwest corner of the mapped area, and along the Quebrada Arenas north of Maunabo.

Several published compilations of Puerto Rican geology (Briggs, 1964; Briggs and Akers, 1965; Cox and Briggs, 1973) have shown a fault along the Rio Maunabo. Detailed mapping by the authors has revealed only minor Tertiary faulting in this valley, but it seems to mark a fundamental break between the rocks to the north and south and may represent a fault zone that existed during the development of the San Lorenzo batholith in Late Cretaceous time but was eventually healed. This break is marked by a sharp change in the batholith rocks, and by a sharp change in the abundance and nature of the metavolcanic rocks, which occur largely to the south and, since they are roof pendants, suggest that the south side of the postulated fault was dropped relative to the north side. Metavolcanic rocks to the south are largely flows and flow(?) breccias, with subordinate tuffaceous sedimentary rocks; metavolcanic rocks within the valley and to the north are composed largely of siltstone and sandstone. In its upper reaches the valley is underlain by a long narrow tongue of laminated fine-grained volcaniclastic rocks (Kmv) in which the laminae exhibit an almost uniformly northwest strike that parallels the valley, but variable dips. The lower part of the valley is underlain by a narrow zone of mixed rock (Km), in which metavolcanic rock, diorite, tonalite of San Lorenzo, and several facies of the plutonic complex of Punta Guayanés are mixed in a very intimate and complex manner. Small xenolithic masses of volcaniclastic rock resemble the rock underlying the upper part of the valley and exhibit the same predominant northwest strike. The volcaniclastic rock is intruded in many places by stringers and thin sills of igneous rock that parallel the lamination and are locally foliated parallel to the enclosing walls. The intimate mixture of plutonic and metavolcanic rocks in the Punta Tuna area, and the presence there of a large dike that parallels the trend of the Rio Maunabo valley, suggest that the postulated fault continued at least as far as the present coastline. The laminated volcanic siltstone along the Rio Maunabo suggests a correlation with part of the Lower and Upper Cretaceous Robles Formation of south-central Puerto Rico rather than formation A (also referred to as formation J), the unit shown on the unpublished mapping of the Patillas quadrangle in the area immediately to the west.

ECONOMIC GEOLOGY

The mapped area contains no known mines or prospects. Rare traces of copper mineralization were noted in all of the major plutonic units and generally include chalcopyrite, malachite, and azurite, which occur sparsely disseminated through the rock, or in veinlets following fractures. A small but rich mineralized zone crossing a contact between diorite and metavolcanic rock was found on a hillside about 1.2 km west-northwest of Maunabo. A semiquantitative spectrographic analysis of a composite sample taken across the 40-cm-wide zone shows a content of more than 10 percent of both Cu and Fe, 0.2 percent Ti, 700 ppm V, and 300 ppm Mn.

Pease (1976) noted that the rocks in the southern part of the mapped area appear to lie close to the margin or the roof of the San Lorenzo batholith. The border-phase albitized tonalite (Kgt) in this area contains a genetically related oligoclase-quartz porphyry (Kgtp) and associated hydrothermally altered metavolcanic rocks (Khr) that suggest a parallel with the rocks associated with base-metal deposits in the Utuado district of west-central Puerto Rico. The rocks in the Punta Tuna quadrangle exhibit some evidence of sulfide mineralization, and the oligoclase-quartz tonalite porphyry was probably the source of mineralizing hydrothermal solutions. The altered rocks represent the east end of a belt of disconnected outcrops of hydrothermally altered metavolcanic rock shown on the metallogenic map by Cox and Briggs (1973); this belt contains iron sulfides and traces of gold and silver and may represent a complexly faulted zone that parallels the principal trend of mineralization in Puerto Rico but has not yet been generally recognized and mapped.

The hydrothermally altered rock in the Punta Tuna quadrangle has not been dated, but a sample collected from similar rock in a major belt of alteration in the southern part of the Naranjito quadrangle gave a potassium-argon age of about 75 m.y. (Cox and others, 1977, sample 22–1). This suggests that all of the closely similar west- to west-northwest-trending altered zones in east-central Puerto Rico are genetically related to the San Lorenzo batholith.

Weathered and saprolitized bedrock has been used within the mapped area as a source of fill, and some granodiorite and tonalite have been crushed and used for aggregate and road metal. River sands are the best source of aggregate and are presently being recovered from the Rio Maunabo and Rio Limones.

ENGINEERING GEOLOGY

The greater part of the bedrock in the quadrangle consists of plutonic rocks ranging in composition from diorite or gabbro to quartz monzonite. All of these rocks are granular in texture, predominantly medium grained, and, except where highly fractured, are massive and exhibit low porosity. Where the rocks are fresh, all have adequate bearing and shearing strength for any ordinary engineering uses, such as foundations for buildings, highways, dams, and other structures, for the construction of tunnels, and as material for fill, aggregate and riprap.

In general, the diorite and gabbro should furnish the strongest material, owing to the interlocking texture of the lath-shaped plagioclase and hornblende grains that comprise most of the rock, and to a lack of platy minerals; the Punta Guayanés rocks would be the weakest, because of pervasive fracturing of the rock and because of the presence of large biotite (or chloritized biotite) grains. Tonalite in the southern part of the mapped area is the most highly fractured and friable of the various facies forming the plutonic complex of Punta Guayanés. Because it tends to break down easily and requires less crushing than other rocks in the area, it should be useful as base course for highways, and for concrete aggregate.

Volcanic rocks in the mapped area have been subjected to low-grade contact metamorphism, and are generally hard, dense rocks. Most would be excellent for ordinary engineering uses.

Zones of weakness, such as areas of hydrothermal alteration, major fault zones, and closely jointed areas should be avoided in the placement of tunnel or dam sites.

Alluvium and beach deposits within the mapped area range from weakly consolidated to wholly unconsolidated. They are easily excavated but are characterized in part by poor stability, and might form insecure foundations for many structural purposes. The degree of instability depends in part on the clay content, which is high in many alluvial deposits. Also, most of these deposits underlie lowland areas that are subject to flooding during periods of torrential rainfall, or might be inundated during occasional hurricanes, or by tsunamis, and these hazards should be carefully considered before any construction is undertaken. (See Fields (1971) for data on recent floods in the Yabucoa area).

Another hazard is posed by landslides and potential landslides on steep slopes within the mapped area.

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GEOLOGIC MAP OF THE YABUCOA AND PUNTA TUNA QUADRANGLES, PUERTO RICO

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