DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
THE ECONOMIC DEVELOPMENT ADMINISTRATION
OF PUERTO RICO

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I–508

INTRODUCTION

The Naranjito 7½-minute quadrangle covers an area of about 180 square kilometers in north-central Puerto Rico; its northeast corner is less than 10 km southwest of metropolitan San Juan.

The earliest geologic work in this area was done by Semmes (1919) as part of a regional investigation of the San Juan district for the New York Academy of Science. This work was useful as a general introduction to the geology of the area.

The stratigraphic units exposed in the Naranjito quadrangle are named and described in a separate report (Pease, 1968).

Geologic setting

Most of the quadrangle is underlain by a sequence of complexly interfingering lava and marine and nonmarine pyroclastic and tuffaceous sedimentary rocks more than 13,000 meters thick. These rocks range in age from Early(?) Cretaceous to early Eocene(?). They unconformably underlie about 160 meters of calcareous epiclastic rocks of Oligocene and Miocene age that are exposed along the northern border of the quadrangle. Dikes and small stocks of quartz-diorite intrude volcanic rocks of Cretaceous age but apparently do not cut or alter Paleocene and younger rocks.

Partly chloritized, albitized, and silicified volcanic rocks are common in the Naranjito quadrangle, particularly within a broad belt that trends west-northwest across the central part of the quadrangle. Thoroughly silicified, sericitized, and pyritized zones within this belt have been mapped as hydrothermally altered rock. In the northeast and east-central parts of the quadrangle where a tight network of quartz-diorite dikes is exposed, the volcanic country rock has also been partly altered; however, it is not shown on the map.

Owing to structural complexities and total absence of diagnostic fossils, the age and relative stratigraphic position of many of the formations in the Naranjito quadrangle are uncertain. Although several formations can be correlated with the regional stratigraphic sequence, the others are isolated from rocks of known stratigraphic position by faults of large apparent displacement.

The Pájaros Tuff is considered the oldest formation in the quadrangle. These poorly exposed, thin-bedded tuffs and tuffaceous sedimentary rocks closely resemble rocks of the Robles Formation (Pease and Briggs, 1960), exposed in the northern part of the Comerío quadrangle, that have been assigned by Norman F. Sohl (written commun., 1962) to the early middle Albian because of the presence of the ammonite, *Oxytropidoceras*, collected from near the base of the Robles Formation north of Comerío.

In support of this rather tenuous correlation, flows and breccias of the Cerro Gordo Lava, which conformably overlie the Pájaros, are almost identical lithologically with flows and breccias that interfinger with and overlie the Robles Formation in the northern parts of the Comerío and Barranquitas quadrangles. These volcanic rocks are the "L" Formation on the geologic map of the Barranquitas quadrangle (Briggs and Gelabert, 1962); they probably correlate with the lower part of the Río Orocovis Group. The nonmarine Cancel Breccia is included in this sequence because it rests with apparent conformity on beds of the El Ocho Formation.

The Río Orocovis Group, represented in the Naranjito quadrangle by the Perchas Formation and the younger Los Negros Formation, is restricted to the southern part of the quadrangle and is separated from the other formations by the Quebrada San Francisco-Cerro Mula fault complex. These rocks are physically connected with the type areas of the formations of the Río Orocovis Group. According to our most recent paleontological evidence, the Río Orocovis Group is older than Campanian but not older than Albian. The lower age limit is well substantiated by the previously mentioned ammonite *Oxytropidoceras* from near Comerío and also by the presence of *Orbitolina* of Albian age collected from the basal Río Maton Limestone Member of the Robles Formation in the northern Cayey quadrangle (N. F. Sohl, written commun., 1960, locality U.S.G.S. 26822). The upper limit for the age of the Río Orocovis Group is established by several collections of fossils of Campanian and Maestrichtian age from strata that overlie the Río Orocovis (H. L. Berryhill, Jr., unpub. data).

Marine pillow lava of the Santa Olaya Lava rests disconformably on the nonmarine Cancel Breccia, and sedimentary strata with intercalated lavas of the Río de La Plata and Camarones Sandstones interfinger with the Santa Olaya. Owing to absence of paleontological data and to structural isolation from strata whose age has been established, the age of this sequence is also uncertain. However, the disconformity at the base of the Santa Olaya represents an hiatus, however small, and therefore a lower age limit of Cenomanian is postulated. Correlation with strata that have yielded meager paleontological data in the Aguas Buenas and Gurabo quadrangles (M. H. Pease, Jr., unpub. data) suggests that the upper part of this sequence may include the Turonian.

The Palmarejo Formation is conformably overlain by the Paleocene or Eocene Corozal Limestone in the Corozal quadrangle just west of the Naranjito quadrangle (A.E.Nelson, 1967). Therefore, the Palmarejo and the Naranjito Formation immediately below it belong to the lower Tertiary.

The Guaracanal Andesite, formerly the Figuera Volcanics of Kaye's (1959) usage, is considered Paleocene in age because it is conformably overlain by the Río Piedras Siltstone which has been assigned to the Paleocene and Eocene(?) on the basis of Foraminifera collected from one locality near its base in the San Juan quadrangle. Mr. Jeremy Reiskind of Yale University (written commun., 1963) tentatively identified this collection as "upper but not uppermost Paleocene." The Palmarejo and Naranjito Formations are probably stratigraphic correlatives of the Río Piedras and Guaracanal, respectively, but different names are used owing to the spatial and structural separation of the formations.

Cretaceous and lower Tertiary volcanic rocks are overlain unconformably by the Oligocene San Sebastián Formation. The Mucarabones Sand, about 50 meters thick, overlies the San Sebastián. In the adjacent Corozal quadrangle, all but the basal 5 meters of the Mucarabones Sand grades laterally westward into the Lares Limestone. In the Bayamón quadrangle, north of the Naranjito quadrangle, the lower part of the Cibao Formation grades laterally eastward into the Mucarabones Sand, which near Bayamón is about 100 meters thick.

As the Lares Limestone and the lower part of the overlying Cibao Formation contain *Lepidocyclina undosa* Cushman, they are generally considered upper Oligocene. The San Sebastián Formation on the basis of fossils collected elsewhere has been considered middle Oligocene (Zapp and others, 1948). The upper part of the Cibao is Miocene.

INTRUSIVE ROCKS

Andesite

A disconnected dike of andesite trends generally northwestward for 5 km from barrio Dajaos to the northwestern side of the large U-shaped bend in the Río de La Plata, Barrio Ortíz. The andesite is grayish olive where fresh, but in weathered outcrop it is leached to very light gray and mottled yellowish brown to brownish gray. It is aphanitic, with sparse, clearly defined lathlike plagioclase phenocrysts about 1 mm long. It is also silicified, plagioclase is albitized, and finely granular pyrite and magnetite are ubiquitous.

This rock is very similar to platy aphanitic lavas with sparse plagioclase phenocrysts that occur in the Río de La Plata Sandstone and the upper part of the Santa Olaya Lava.

The andesite dike, however, cannot be correlated with these lavas because structural relations at its northwest end show that the dike was emplaced after movement along the Quebrada la Yegua fault that dislocated strata younger than these lavas. This dike is transitional into a sill where it is exposed in the fault wedge just south of the Quebrada Cruz fault. On the southeast side of the crest of this ridge, an exposed basal contact of the andesite appears conformable or nearly conformable with the underlying beds, and several thin sills of andesite splay out into the country rock toward the southeast.

Keratophyric dike

A light-yellowish-gray keratophyric dike, less than 5 meters wide, forms a breached dam across the valley of the Río de La Plata about 500 meters north of the mouth of Quebrada La Yegua. The dike was traced westward for a distance of about 450 meters; to the east a similar dike is exposed in several fault blocks near the headwaters of Quebradas Dajaos and La Yegua.

The rock is well indurated and aphanitic but contains very sparse microphenocrysts of plagioclase less than 1 mm long. Microscopic examination reveals a microcrystalline groundmass of interlocking plagioclase microlites, associated with chlorite and quartz. Tiny cubes of magnetite are evenly distributed throughout.

The dike is post-Cretaceous in age.

Quartz diorite

Rocks mapped as quartz diorite include several stocks and numerous narrow dikes of varied composition and texture, all of which are believed to have been derived from one hypabyssal magmatic source and to owe their diversity to variations in the conditions of emplacement and to later alteration.

Most dikes are porphyritic, have a microcrystalline groundmass, and range from porphyries with less than 10 percent groundmass to a porphyritic rock in which the groundmass amounts to as much as 70 percent of the rock. Holocrystalline textures have been observed only in the centers of the larger stocks.

As typically developed, the quartz diorite is a speckled medium- and light-greenish-gray rock composed of coarse plagioclase phenocrysts interspersed with smaller phenocrysts of hornblende and possibly some euhedral biotite; the groundmass is a mosaic of albite and quartz and finely disseminated adularia(?).

Plagioclase phenocrysts range from sodic andesine to albite but most are sodic oligoclase. The quartz content ranges from trace amounts to 15 percent of the rock, and in the porphyries quartz commonly occurs as coarse euhedral phenocrysts.

All these intrusive rocks have been more or less altered, mostly by sericitization and argillization of the feldspar and by chloritization of mafic constituents. Dikes that have been emplaced along major shear zones commonly have been highly silicified by hydrothermal solutions that apparently accompanied this intrusion (M. H. Pease, Jr., unpub. data). Pyrite is a conspicuous associate of the intrusive rocks, and base-metal sulfides are present locally where the quartz diorite occurs in shear zones.

The quartz diorite weathers to yellowish-gray sand containing quartz and flecks of golden mica.

Most dikes seem to radiate from central stocks. In Barrio Minillas, dikes trend generally south, away from a poorly exposed, deeply weathered body of hornblende quartz diorite that underlies much of the northern part of Barrio Minillas. Other dikes, commonly porphyries, along the eastern border of the quadrangle, mostly in barrios Mameyes and Sonadora, trend west away from a large intrusive body exposed immediately to the east in the Aguas Buenas quadrangle.

Pyroxene diorite

Pyroxene diorite forms an elongate southwest trending body along the southeast side of the Río de La Plata in Barrio Ortíz. It is a dike more than 250 meters wide in its northern area of exposure, but in its southwesternmost exposure it is less than 5 meters thick. Phenocrysts of plagioclase and pyroxene make up about 20 percent of the dark-gray porphyritic rock. The groundmass is finely crystalline.

This dike cuts no strata younger than Late Cretaceous, but it closely resembles dikes that cut strata of Paleocene age in the San Juan quadrangle.

Hydrothermally altered rock

Nearly vertical linear zones of hydrothermally altered volcanic rock occur within a broad belt of partly altered volcanic rock that extends across the central part of the quadrangle between the Quebrada La Yegua fault and the Quebrada San Francisco-Cerro Mula fault complex.

The hydrothermally altered rock is greenish gray in fresh outcrop but weathers readily to shades of yellowish gray, brownish gray, and reddish brown. Primary textures are masked by the extensive development of chlorite, quartz, sericite, and pyrite, but in weathered outcrop, primary textures and structures such as bedding may be marked by color variations. The rock varies between two end members, a hard jasperoid type and a soft argillic type. The petrography of these rocks has been more completely described by Pease (1960).

Hydrothermal alteration probably occurred in very late Cretaceous time, accompanying or immediately following invasion by the dioritic dikes, because in places these dikes and their host rocks show evidence of alteration, although neither Paleocene rocks of the Río Piedras Siltstone nor rocks of the Naranjito Formation appear to have been altered.

STRUCTURE

Structurally the Naranjito quadrangle is dominated by west-northwest- to northwest-trending wrench faults which have sliced through a southward dipping monoclinal sequence. This southward-dipping sequence terminates to the south along the Anones and Apostoles de Cristo wrench faults. South of these faults, strata dip generally northward on the south flank of a major west-trending syncline that approximately parallels the wrench fault system, and whose axis has been buried by these faults. The monoclinal sequence of Cretaceous rocks is cut off by the La Muda fault in the northeast corner of the quadrangle; strata of Paleocene and Eocene(?) age are exposed in a west-plunging anticline on the northeast side of this fault. Two principal sets of cross faults trending north-northeast and north-northwest traverse the major wrench faults and commonly offset them. Movement on both sets of cross faults is probably oblique slip, but dip-slip components seem to be dominant on the north-northeast-trending set and strike-slip components on the north-northwest-trending set. Net displacement is small compared with the large transcurrent dislocations on many of the wrench faults. Within this complex mosaic, fault blocks have been rotated, and strata within fault blocks have been deformed.

The locations of faults in the Naranjito quadrangle are based chiefly on indirect evidence, such as alined linear valleys, saddles across spurs or at the heads of valleys, and fault-line scarps.

Strongly sheared rocks and slickensided surfaces characterize the few major faults that have been observed. Strata adjacent to faults commonly dip abnormally steeply or are overturned and strike subparallel to traces of these faults. Most faults, particularly those that trend west-northwest are zones of anastomosing and intersecting fractures rather than sharply defined breaks. Detailed measurements of structural elements in individual outcrops are so diverse as to give little information about the overall movements.

The topographic expressions of most wrench faults suggests that they must be vertical or nearly vertical, although locally dips as low as 60° have been estimated.

Three principal wrench faults in the Naranjito quadrangle, the Cerro Mula, Quebrada La Yegua, and La Muda faults, divide the quadrangle into four structural segments, each of which has a somewhat different structural pattern (M. H. Pease, Jr., unpub. data). As these faults extend beyond the Naranjito quadrangle, the relative direction and magnitude of net dislocation on the faults are difficult to ascertain within the quadrangle.

Dislocation as determined by contortion of strata and the angular relation of associated minor faults appear to have been right lateral on the Apostoles de Cristo fault and left lateral on the Anones fault. The amount of horizontal displacement on these faults could not be measured, but it was large enough to remove all trace of the axis of a major west-trending syncline, the flanks of which are shown by the regional reversal of dip. Apparent stratigraphic displacement is small, at least on the Apostoles de Cristo fault where the basal contact of the Los Negros Formation is offset only a short distance.

Strata of the Río Orocovis Group dip steeply and are strongly sheared. Divergent attitudes, particularly in the area between the Anones and Apostoles de Cristo faults, suggest that these strata have been strongly folded locally. The angles of divergence commonly conform to drag on one or another of the principal wrench faults.

Regional stratigraphic relations (M. H. Pease, Jr., unpub. data) indicate that transcurrent movement on the Cerro Mula fault was left lateral and that the altered block north of the fault has been displaced more than 20 km westward relative to strata south of this fault. This movement sense is also indicated by the northwest orientation of cross faults within the altered block. Movement on the Quebrada La Yegua fault, however, must have been right lateral in order to explain the presence of a much greater thickness of Santa Olaya Lava south of the fault than north of it. The Santa Olaya Lava in the east-central part of the quadrangle is more than 6,200 meters thick, but it thins westward to 120 meters where it is cut off by the Quebrada Cruz fault near the western edge of the quadrangle on the northeast side of the Quebrada La Yegua fault. Because exposures of Santa Olaya in the western part of the quadrangle and in the adjacent Corozal quadrangle south of the Quebrada La Yegua fault are comparable in thickness and lithology to the eastern exposures north of the fault, I conclude that the strata south of the fault have been offset right laterally by as much as 15 km.

The highly fractured rocks between the two principal wrench faults form a zone of structural weakness in which the rocks have also been strongly sheared and in part hydrothermally altered. Apparent stratigraphic displacement on the numerous northwest-trending cross faults in this segment indicates relative downdip movement to the southwest, but right-lateral offset of nearly vertical wrench faults by some of these cross faults denotes horizontal dislocation. Their angular relation with the Cerro Mula fault suggests that they formed initially as splay faults related to left-lateral shear stress on this wrench fault, and that the observed net right-lateral displacement is related to right-lateral displacement on the Quebrada La Yegua fault.

Parts of a graben (Briggs and Pease, 1960) containing Paleocene and Eocene(?) rocks, chiefly of the Naranjito Formation, are exposed between the Cerro Mula and Quebrada San Francisco faults at the western margin of the quadrangle. This graben, which is more extensive in the adjacent Corozal quadrangle, evidently represents a preserved segment of the southern flank of an early Tertiary anticline whose westward-plunging nose is exposed in the northeast corner of the Naranjito quadrangle, northeast of the La Muda fault. Lower Tertiary strata on the southern flank of this anticline apparently have moved several kilometers westward relative to the anticlinal nose.

ECONOMIC GEOLOGY

Copper

A quartz vein containing appreciable chalcopyrite and chalcocite was observed in the canyon of the Río de Bayamón where the river cuts through a zone of hydrothermally altered rock. The vein is only a few centimeters wide and is exposed for a distance of less than 3 meters. This vein is one of a group of highly pyritiferous quartz veins that trend about N. 70° E. in this area (Pease, 1960). No other traces of copper were found here or elsewhere in the quadrangle.

Barite

Two veins of barite have been mapped within the broad belt of partial hydrothermal alteration. One occurs in the valley of the Río de Bayamón a few tens of meters northwest of the copper vein mentioned above; the other is near the headwaters of Quebrada Naranjo. The first vein is about 15 cm wide, trends northeasterly, and cuts silicified epidotized volcanic rocks. The barite is spotty and is associated with quartz and siderite or ferruginous calcite. The second vein consists of 3-8 cm of barite, cuts partly silicified volcanic rocks, and trends N. 60° W. Neither vein could be traced laterally.

Barite float was also observed in many of the stream valleys within the altered belt, but its source was not found. One boulder in the valley of Quebrada Grande was evidently derived from a relatively thick vein, as its smallest diameter is about 50 cm.

Gold

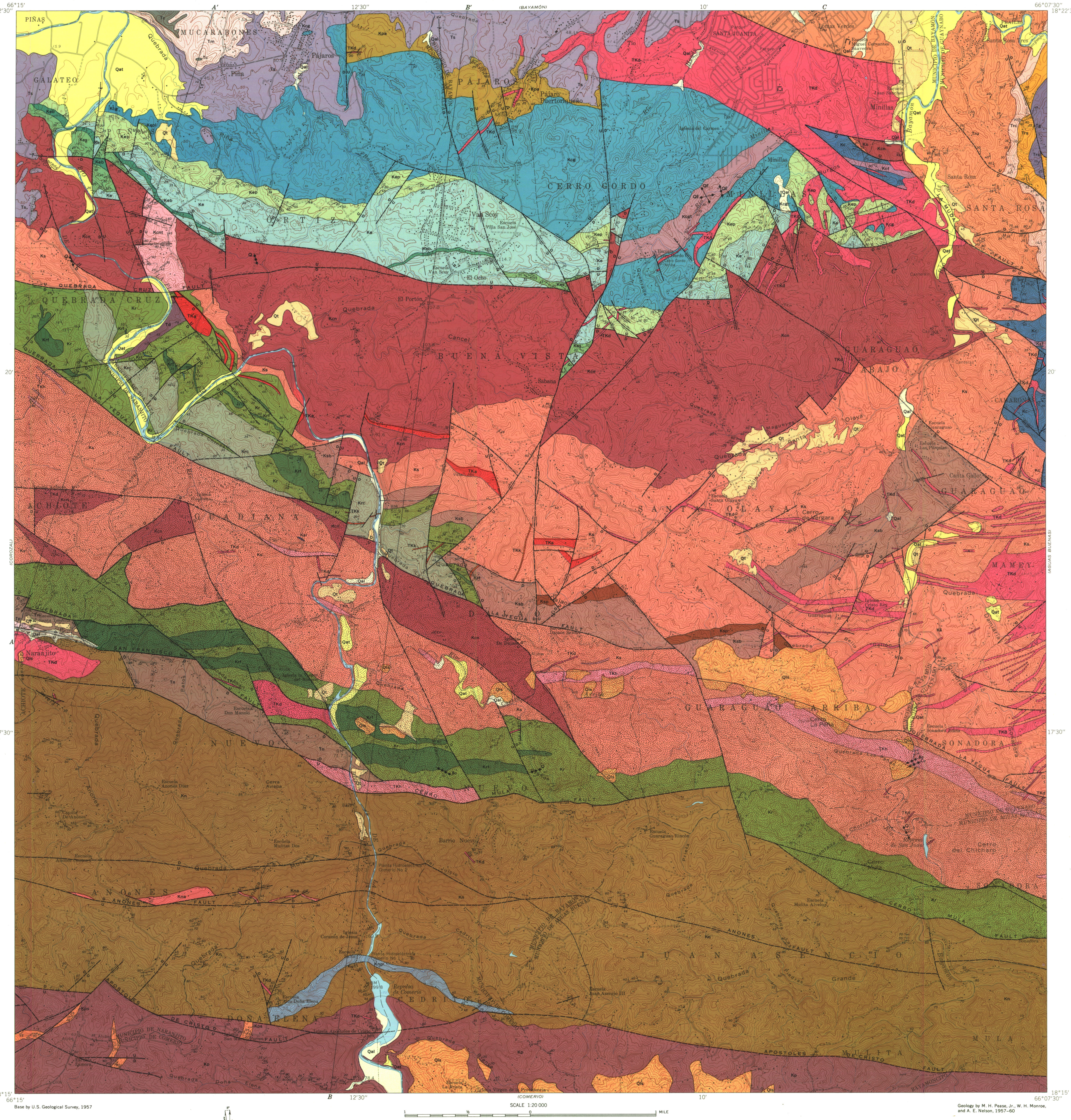
Gold has been panned from gravels in the valleys of the Río de La Plata and Río de Bayamón, and small quantities of gold are being extracted at present, especially near the mouth of the Río Canas in the northwest part of the quadrangle.

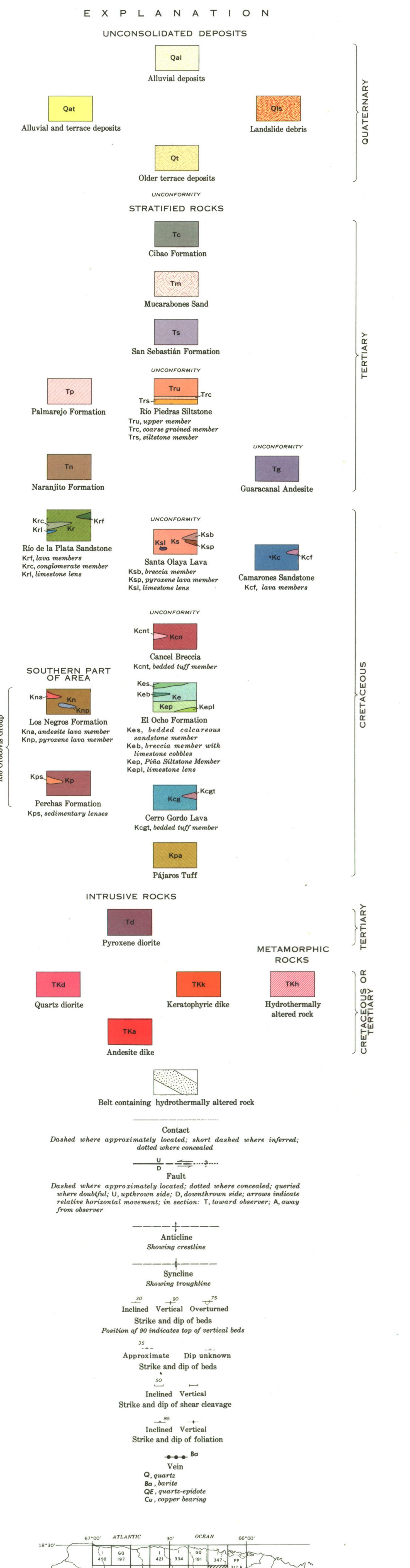
Crushed rock and gravel

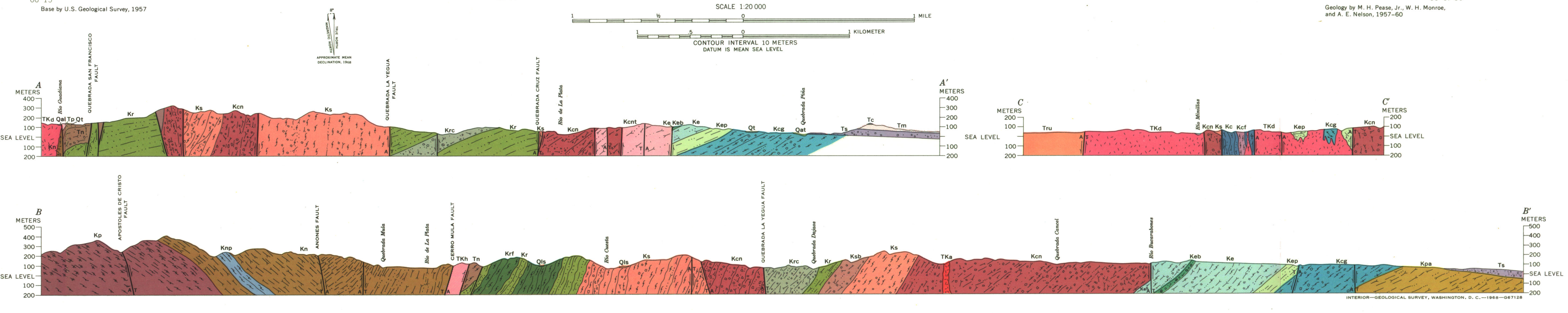
Three quarries in the valley of the Río de Bayamón provide much of the concrete aggregate, road metal, and riprap for the San Juan metropolitan area. Two quarries, in Barrio Guaraguao Abajo on the west side of the river, are in tuff and tuff breccia of the Cancel Breccia. The other, in Barrios Camarones and Guaraguao on the east side of the river, is in pillow lavas at the base of the Santa Olaya.

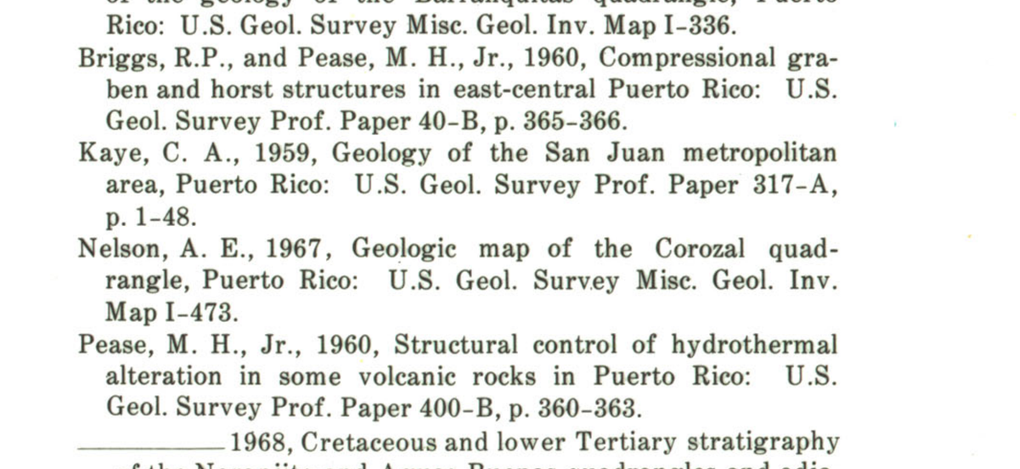
Several quarries in the bedded rocks of the Piña Siltstone Member of the El Ocho Formation have provided material for road fill and, in small quantities, for agricultural lime, but in 1960 none were operating.

Gravel is being removed from Quaternary terrace and alluvial deposits along the lower reaches of both the Río de Bayamón and Río de La Plata. These gravels are used for concrete aggregate and for road fill.









INDEX OF GEOLOGIC MAPPING IN PUERTO RICO

REFERENCES

Briggs, R. P., and Gelabert, P. A., 1962, Preliminary report of the geology of the Barranquitas quadrangle, Puerto Rico: U.S. Geol. Survey Misc. Geol. Inv. Map I-336.

Briggs, R.P., and Pease, M. H., Jr., 1960, Compressional graben and horst structures in east-central Puerto Rico: U.S. Geol. Survey Prof. Paper 40-B, p. 365-366.

Kaye, C. A., 1959, Geology of the San Juan metropolitan area, Puerto Rico: U.S. Geol. Survey Prof. Paper 317-A, p. 1-48.

Nelson, A. E., 1967, Geologic map of the Corozal quadrangle, Puerto Rico: U.S. Geol. Survey Misc. Geol. Inv. Map I-473.

Pease, M. H., Jr., 1960, Structural control of hydrothermal alteration in some volcanic rocks in Puerto Rico: U.S. Geol. Survey Prof. Paper 400-B, p. 360-363.

———— 1968, Cretaceous and lower Tertiary stratigraphy of the Naranjito and Aguas Buenas quadrangles and adjacent areas, Puerto Rico: U.S. Geol. Survey Bull. 1253 (in press).

Pease, M. H., Jr., and Briggs, R. P., 1960, Geology of the Comerío quadrangle, Puerto Rico: U.S. Geol. Survey Misc. Geol. Inv. Map I-320.

Semmes, D. R., 1919, The geology of the San Juan district, Porto Rico: New York Acad. Sci., Sci. Survey Porto Rico and Virgin Islands, v. 1, pt. 1, p. 33-110.

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.

GEOLOGIC MAP OF THE NARANJITO QUADRANGLE, PUERTO RICO

By

Maurice H. Pease, Jr.

1968