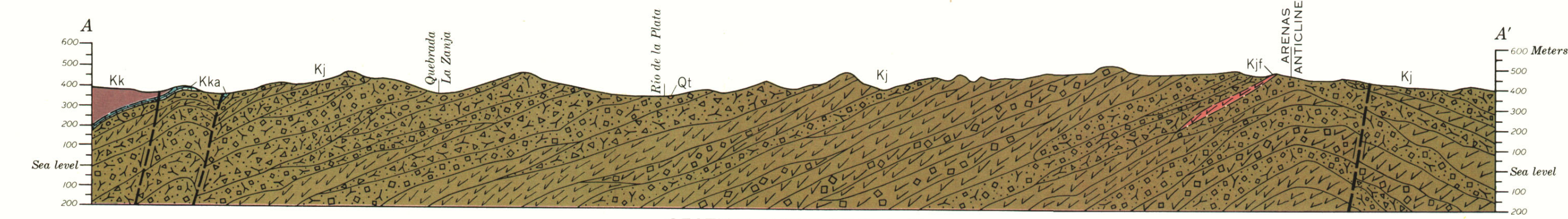
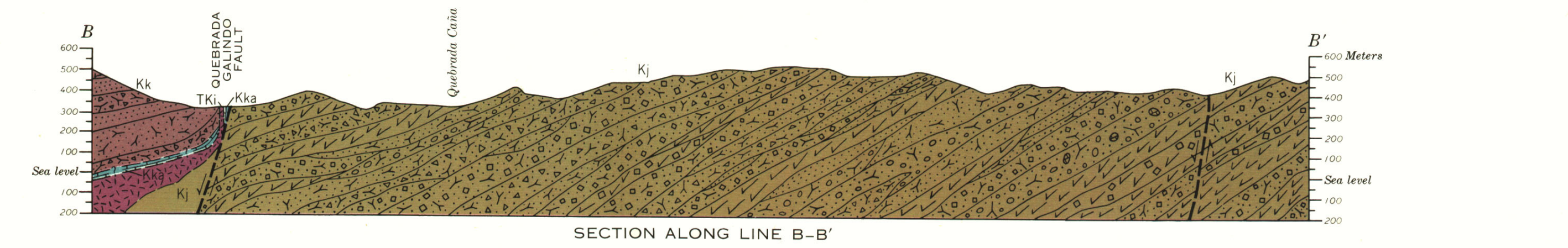
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

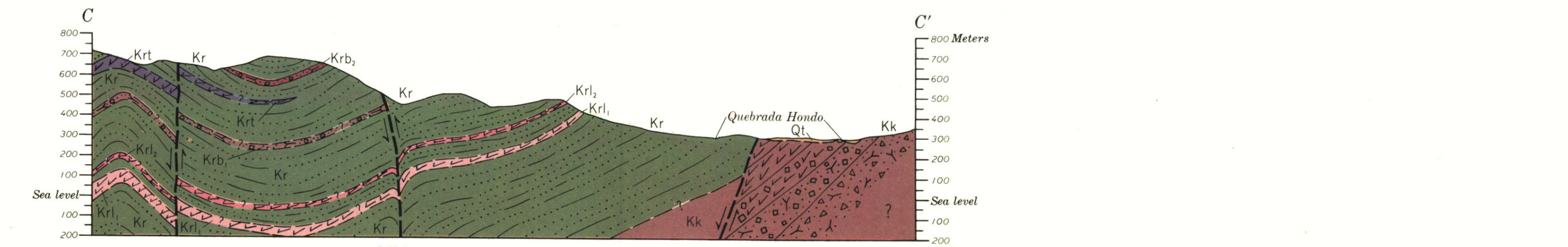
MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-320



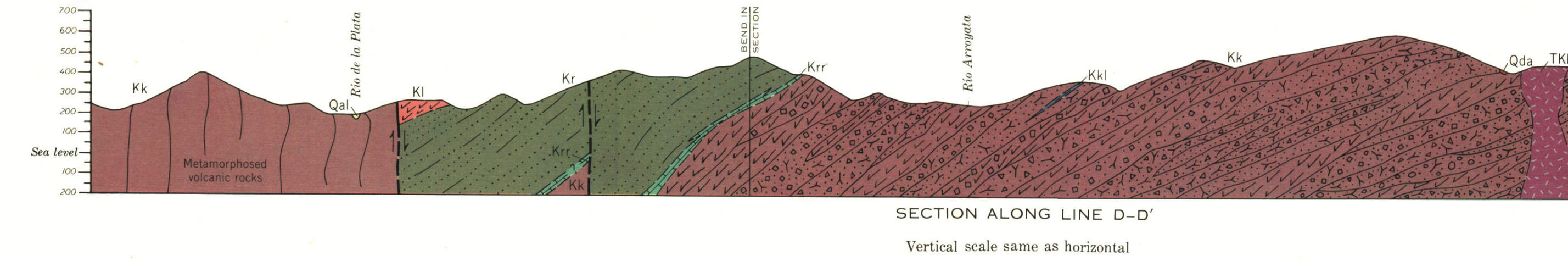
SECTION ALONG LINE A-A′



SECTION ALONG LINE B-B′

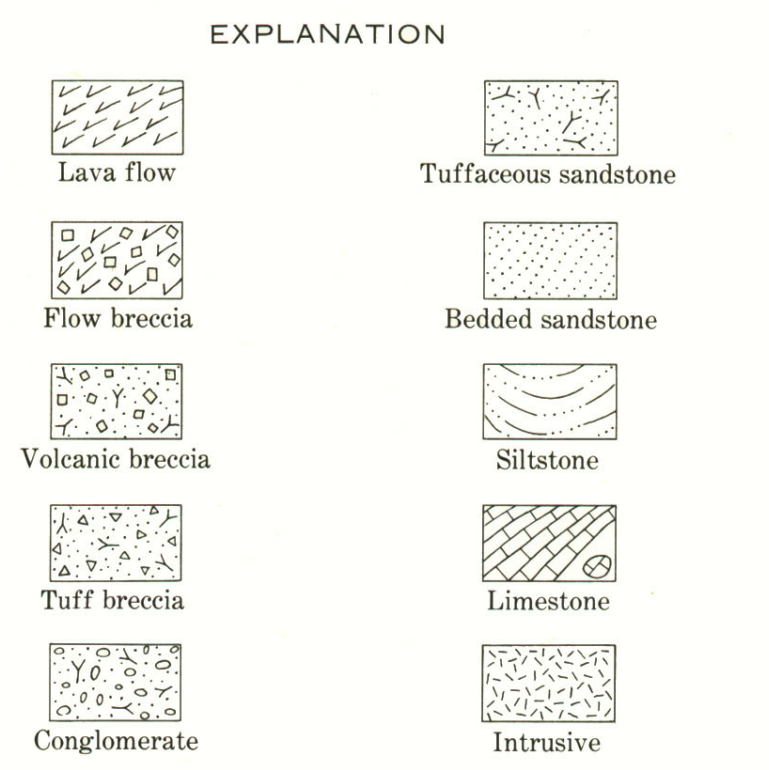


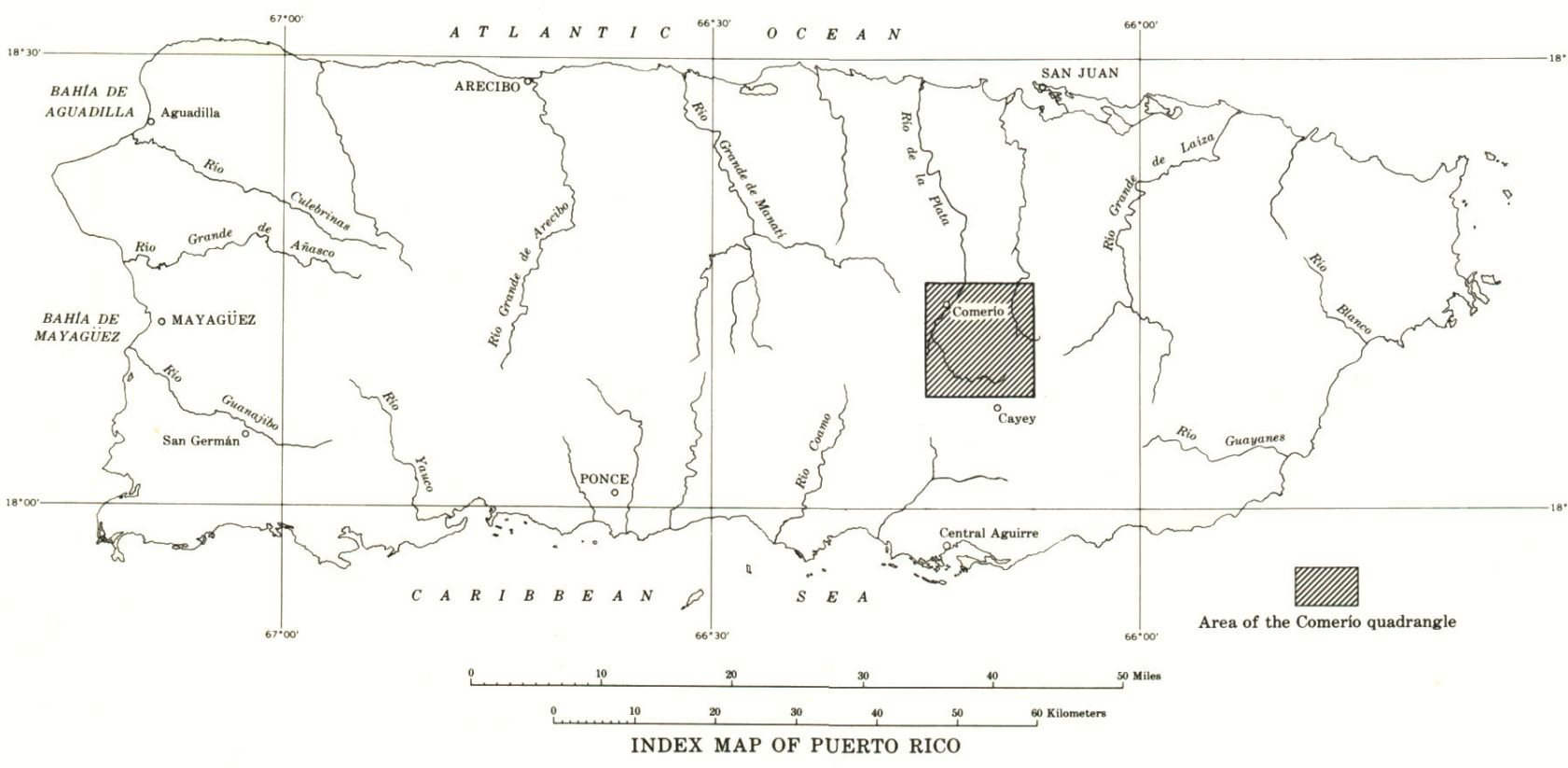
SECTION ALONG LINE C-C′



SECTION ALONG LINE D-D′

Vertical scale same as horizontal





INDEX MAP OF PUERTO RICO

INTRODUCTION

The geology of the Comerío quadrangle has been mapped as part of a continuing cooperative program of the U. S. Geological Survey and the Economic Development Administration of the Commonwealth of Puerto Rico to investigate the geology of Puerto Rico with a view to the discovery of deposits of economic value and to the compilation of a large scale general purpose geologic map of the island.

The field work for the present report began during the fall of 1955 and was completed early in 1957. The authors were assisted during the latter part of this period by P. A. Gelabert and A. O. Perry. Previous geologic investigations in the Comerío quadrangle were conducted during the summer of 1915 by D. R. Semmes (1919) and E. T. Hodge (1920).

GEOGRAPHY

The Comerío quadrangle is an area of about 183 square kilometers in the mountainous east-central part of the island of Puerto Rico. The quadrangle includes parts of the municipios of Cidra, Comerío, Aguas Buenas, Aibonito, Barranquitas, and Cayey. Only two towns are within the quadrangle, Comerío (population 5,031) and Cidra (population 3,146), but this which is an area of considerable agricultural development with a dense rural population. The overall population of the quadrangle is about 38,000 people, and the density of population is about 207 people per square kilometer (537 people per square mile).

Two major highways provide ready access to the Comerío quadrangle, Highway 1 crosses the extreme southeastern part of the quadrangle and Highway 167 passes through Comerío in the northwestern part. The remainder of the quadrangle is adequately serviced by paved roads. Most of the area is less than a kilometer from a road or a trail traversable by a four-wheel-drive vehicle. In 1958 several new roads were under construction.

The topography of the Comerío quadrangle is characterized in the north and west by steep-walled valleys and slightly to moderately rounded ridges and knobs, with a maximum local relief of more than 400 meters in the southwest and almost 500 meters between the top of Cerro La Tiza and the Río de La Plata. In the eastern part of the quadrangle the local relief is more moderate, the valley walls are less steep, and the hilltops are more rounded. The highest point in the Comerío quadrangle is about 760 meters above sea level on the southern border of the quadrangle 270 meters east of the southwest corner of the quadrangle. This point is on the north flank of the Cordillera Central, the mountainous "spine" of Puerto Rico. The lowest point in the Comerío quadrangle is about 175 meters above sea level at the point where the Río de La Plata intersects the northern quadrangle border.

STRATIGRAPHY

The rocks exposed in the Comerío quadrangle are chiefly of volcanic origin composed of extrusive igneous rock and tuffaceous debris. Sedimentary rocks that consist almost entirely of volcanic fragments are interstratified with these igneous and pyroclastic rocks and are the principal rock type in the northwestern and southwestern parts of the quadrangle. Thin lenticular limestone beds are also present in the quadrangle as well as several bodies of intrusive igneous rock. Bedrock has been hydrothermally altered in two large areas and in a few other localities to a rock composed chiefly of quartz, sericite, and clay. Surficial deposits consist of alluvium, terrace deposits, and debris resulting from mass earth-and-rock movement. A thick residual soil, which has not been delineated on the geologic map, mantles the bedrock in some parts of the quadrangle.

The stratified rocks in the Comerío quadrangle have been divided into four formations three of which have been temporarily assigned letter symbols J, K, and L designating respectively younger formations. The fourth formation, whose stratigraphic position is between formation K and formation L, has been formally named the Robles formation. Formal naming of the other three formations has been postponed until a more comprehensive picture of Puerto Rican geology is available. The principal limestone occurrences in the quadrangle have been assigned to two members—the Aguas Buenas limestone member at the base of formation K and the Río Matón limestone member at the base of the Robles formation. An intrusive body exposed in the northwest quarter of the quadrangle has been named the Piñas stock.

The total stratigraphic thickness of the stratified rocks is estimated to be approximately 6,000 meters. However, a scarcity of mappable key beds and an inadequacy of fossil control in conjunction with large-scale displacement by faulting prohibits accurate determinations of stratigraphic thicknesses. Moreover, onlap relationships and local unconformities are probably commoner in this volcanic environment than field observations reveal and probably introduce important local variations in stratigraphic thicknesses.

FORMATION J

Formation J, which includes the oldest rocks exposed in the Comerío quadrangle, underlies most of the southeastern part of the quadrangle and also comprises most of the rocks exposed in the large fault block that trends northwestward across the center of the quadrangle.

This formation is composed chiefly of massive volcanic breccia, but lava flows and flow breccia occur throughout and are the predominant rock type at the base and at the top of the formation. Massive to poorly stratified tuffs are interlayered with the volcanic breccia, and sedimentary rocks ranging from volcanic conglomerate to volcanic siltstone are locally prominent.

Stratigraphic succession.—The oldest rocks of formation J in the Comerío quadrangle are exposed along the crest of the Arenas anticline. Rocks of formation J on the north flank of this anticline are cut by the Río Arroyata fault, but the stratigraphic sequence of formation J appears to be continuous on the south flank of the anticline between its axis and the southwestern corner of Barrio Rincón where the Aguas Buenas limestone member of formation K overlaps rocks of formation J. There is a possibility, however, that the fault that trends southeastward from Cidra continues farther southeastward than is indicated on the geologic map, and that this section of formation J may have been shortened.

Progressively younger strata of formation J are exposed toward the northwest within the confines of the fault block that is bounded by the Río Arroyata and Quebrada Galindo faults. The strata exposed in this fault block and generally west of Highway 171, have apparently been overlapped by strata of formation K near the southern border of the quadrangle. Thus the rocks of formation J that underlie the Aguas Buenas limestone member of formation K in Barrio Vega Redonda are probably younger than the rocks of formation J exposed beneath the same limestone member in Barrio Rincón near the southern edge of the quadrangle.

Rocks assigned to formation J are also exposed beneath the Aguas Buenas limestone member of formation K on the north side of the Río Arroyata fault in the vicinity of Lago de Cidra. There is uncertainty concerning the relative stratigraphic position within formation J of these rocks because the trace of the Río Arroyata fault in this area is hidden by hydrothermal alteration and weathering, and the amount of displacement on the fault is not known.

Areal distribution of lithologic types.—The lithologic character of the rocks of formation J is described in a sequence that is in general accord with the order of the stratigraphic succession described above. The oldest rocks, exposed along the crest of the Arenas anticline, consist chiefly of massive dark greenish-gray volcanic breccia, which crops out in the form of large boulders as much as 10 meters in diameter. Thin units of bedded tuffaceous sandstone are intercalated with this breccia and a lava flow, Kjf, has been mapped within the breccia immediately south of the crest. This is a platy flow less than 25 meters thick that thins toward the west. The rock is dark gray and aphanitic containing bladed phenocrysts of black hornblende. This flow could not be traced westward beyond the point delineated on the geologic map, but a flow similar lithologically but only a meter thick is exposed on the north side of the anticlinal axis at the strike and dip symbol indicating a 35° dip. A series of sparsely porphyritic andesitic lava flows characteristically grayish yellow to white on weathered surfaces is interstratified with a few thin layers of volcanic breccia on the south flank of the Arenas anticline; these flows also crop out west of the anticlinal axis where outcrops of this type of flow are found in contact with hydrothermally altered rocks exposed northeast of the axis.

The lava flows exposed on the south flank of the Arenas anticline are overlain by massive flow breccia and volcanic breccia that crop out along the north side of the alluviated valley of the Río de La Plata. A thin series of well-bedded calcareous rocks exposed in Barrio Vegas near the southeast corner of the quadrangle is probably stratigraphically equivalent to the upper part of these massive breccias, and in the hills on the south side of the Río de La Plata in Barrio Rincón, the massive breccias are overlain chiefly by poorly stratified volcanic breccia and volcanic conglomerate in which are contained an occasional thin lava flow or layer of stratified tuff.

A sequence of well-stratified rocks that strike northward and dip westward is exposed in the hills north and west of Centro Comunal Nogueras chiefly in Barrio Sud. These rocks apparently interfinger with the coarser more crudely stratified volcanic breccia and conglomerate exposed in Barrio Rincón south of the Río de La Plata; their areal distribution is approximately defined on the geologic map by the distribution of strike and dip symbols in this area. These well-stratified rocks contain numerous lenticular bodies of thin-bedded volcanic sandstone and siltstone, but thickly bedded tuff and volcanic conglomerate are nearly as common and thin lava flows were observed at several localities. Limestone, Kjl, is exposed on Highway 171 about 540 meters north of the bridge at the Río de La Plata. This is a well-indurated bluish-gray impure limestone about 2 meters thick that grades into volcanic breccia at its base. This unit could not be traced beyond its outcrop except for a few boulders on the ridge north of the outcrop.

Rocks of formation J that overlie the well-stratified sequence in Barrio Sud consist chiefly of massive flows and flow breccia, but a thin lenticular body of well-bedded fine-grained sedimentary rock similar to those rocks exposed in Barrio Sud crops out in the hill south and east of Quebrada Caña in Barrio Toíta.

Rocks of formation J in the area bounded by the Río Arroyata and Quebrada Galindo faults consist of massive volcanic breccia, lava flow, and volcanic conglomerate. Lenses of irregularly bedded volcanic sandstone or tuff crop out within the volcanic rocks on the west slope of Cerro Almirante, and similar rocks have been observed at other localities in the upper part of formation J. Lava flows and volcanic breccia underlie the Aguas Buenas limestone member of formation K in Barrio Vega Redondo. The apparent dip of the strata of formation J in this area is 20°-40° W., and although the rocks are poorly exposed, the few outcrops on which the strike can be even approximately determined suggest a rather uniform trend of N. 10° W.

Thickness, correlation, and age.—The total maximum exposed thickness of formation J in the Comerío quadrangle is estimated to be about 2,700 meters. This figure is derived from the sum of the approximate stratigraphic thickness of formation J measured from structure sections *A-A′* and *B-B′* minus an allowance for stratigraphic overlap of the two sections.

The oldest rocks of formation J, exposed in the southeastern part of the quadrangle, are stratigraphically equivalent to rocks of similar lithology exposed in the northeastern corner of the Cayey quadrangle. These have been assigned to formation A of the Cayey quadrangle by Berryhill and Glover (1960). Younger rocks of formation J exposed west of Highway 171 within the major northwest-trending fault block and overlapped by strata of formation K in the southeastern part of the quadrangle, may occupy approximately the same stratigraphic position as Berryhill's and Glover's formation B and formation C which are overlapped by their formation D in the northern part of the Cayey quadrangle.

No identifiable fossils have been found within the rocks of formation J. However, these rocks are believed to be late Early Cretaceous or early Late Cretaceous in age, only slightly older than formation K, which overlies formation J with no apparent time hiatus.

FORMATION K

Formation K overlies formation J and in most places the depositional relationship appears to be essentially conformable although formation K appears to overlap progressively older rocks of formation J toward the southeast, and local angular unconformities have been observed. An angular unconformity is evident along the south rim of the canyon of the Río de La Plata in Barrio Toíta just west of the mouth of Quebrada Santo Domingo, but this is apparently a local phenomenon because in the valley of Quebrada Santo Domingo the relationship appears to be essentially conformable. A slight angular discordance is evident beneath the Aguas Buenas limestone member in an outcrop about 1,200 meters N. 50° W. of the northwest corner of the plaza at Cidra where relict bedding in hydrothermally altered rocks of formation J strike at an angle of about 20° to the approximate strike of the limestone.

Specific rock types of formation K are lithologically similar to those of formation J, but their aggregate lithologies differ because clastic rocks comprise a greater proportion of formation K and stratification is more widely apparent in this formation. The base of the Aguas Buenas limestone member has been selected as the base of formation K.

Crudely stratified coarsely clastic rocks ranging from volcanic breccia to coarse tuff compose the major part of formation K, and these are commonly interlayered with volcanic conglomerate and massive tuffaceous sandstone. Lenticular lenses of well-bedded tuffaceous sandstone and siltstone are sporadically distributed throughout the formation. Lava flows too are present, but they are common only in the upper few hundred meters. The Aguas Buenas limestone member is present at the base of the formation almost everywhere in the quadrangle, and thin lenses of limestone and limestone breccia also occur within the formation.

Areal distribution.—The most continuous and least disturbed sequence of formation K is exposed in the northeastern part of the quadrangle between the Río Arroyata and Quebrada Vicente faults. Rocks of formation K are also exposed in a belt that extends from the southern border of the quadrangle in Barrio Toíta to the west central border of the quadrangle. These two areas of exposure of formation K are separated by the large fault block that extends northwestward across the center of the quadrangle, and apparently because of lateral facies changes within the formation, it is not possible to correlate specific lithologic units between the two areas. Strata exposed in the narrow fault wedge formed by the Comerío and Río Hondo faults and stratigraphically beneath the segmented band of limestone just south of the Comerío fault have also been assigned to formation K. The rocks exposed in the northern part of the quadrangle north of the Quebrada Vicente fault have been tentatively assigned to formation K, but these rocks have been sheared and chloritized and have been in part entirely transformed by hydrothermal solutions, nor can they be correlated faunally with other rocks in the quadrangle.

Rock descriptions.—This section is concerned with rocks of formation K other than the Aguas Buenas limestone member which is treated separately. The predominant rock in formation K is probably a tuff breccia composed of approximately equal proportions of flow fragments and pyroclastic debris, but these coarsely clastic rocks range from volcanic breccia containing a minor amount of pyroclastic matrix to coarse tuff in which only a few widely scattered flow fragments are present. Most of these rocks appear to have been deposited in water. Crude stratification is apparent in many outcrops of these breccias, and breccias are commonly interstratified with volcanic pebble to cobble conglomerate and with thin-bedded, faintly bedded, tuffaceous fine-grained sedimentary rocks. The occurrence of a poorly preserved ammonite in massive tuff exposed along Highway 14 is evidence that at least some of the tuffs were deposited in the sea.

These massive to thickly bedded coarsely clastic rocks are best exposed in roadcuts on Highway 14 from the southern border of the quadrangle northwestward to the point where the highway passes into exposures of the Robles formation. Other well-exposed areas of such rocks occur, along the highway from Cidra to Barrio Ceiba north of the Aguas Buenas limestone member and south of the Quebrada Ceiba fault, along the north wall of the canyon of the Río Arroyata in Barrio Ceiba, and in the valley and adjacent hills of the Río de La Plata west of the Quebrada Galindo fault particularly between Cerro Plano and Cerro Amoldadero.

Lava flows in formation K are composed chiefly of medium dark-gray to dark greenish-gray aphanitic igneous rock containing a varied proportion of plagioclase and pyroxene phenocrysts most of which are less than 4 millimeters in diameter. These flows are interlayered with clastic rocks at several localities within the formation, but flow and flow breccia predominate only in the upper part of formation K. Thin coarsely vesicular flows interfinger with bedded tuff and volcanic sandstone that directly overlie the Aguas Buenas limestone member in Barrios Ceiba and Monte Llano. A series of flows at least 100 meters thick but of small areal extent are exposed on the crest of Cerro Plano in Barrio Honduras. These flows are characterized by an abundance of spherical calcite amygdules less than 5 millimeters in diameter and by the large size and tabular shape of the pyroxene phenocrysts. Flows and flow breccias in the upper part of the formation are best exposed near the western edge of the quadrangle in the canyons of the Río Usabón and Río de La Plata. Weathered exposures of these rocks occur beneath the Río Matón limestone member of the Robles formation in the vicinity of Cerro Laso and in the area between the Río Arroyata and Río Hondo faults. Numerous boulders of flow rock are exposed on the highly weathered upland surfaces of Barrios Naranjo and Bayamoncito.

Thin-bedded tuffaceous sandstone, and siltstone occur principally as lenticular bodies of small areal extent within the more crudely stratified rocks of formation K, but a relatively extensive unit of well-stratified rocks whose maximum thickness is about 125 meters is exposed for more than 3 kilometers in the northeast quarter of the quadrangle on the north side of the Quebrada Cieba fault. Its areal distribution is made apparent by the distribution of strike and dip symbols on the geologic map. This stratified zone consists chiefly of thin-bedded volcanic sandstone and siltstone interbedded with volcanic conglomerate and tuffs, but it is characterized by limestone in several forms: as cementing material, as boulders of a volcanic conglomerate, and in one place near the base of the unit as a thin limestone bed. Near the boundary between Barrios Cejas and Vega Redonda a lens of interbedded tuff and fossiliferous impure limestone about 3.3 meters thick, which is delineated on the geologic map, Kkl, is exposed for less than 250 meters along its strike. A thin lens of limestone breccia, also designated Kkl on the geologic map, is located in Barrio Ceiba on the divide between Quebrada Cejas and Quebrada Ceiba drainage basins.

Aguas Buenas limestone member.—The Aguas Buenas limestones were named by D. R. Semmes (1919) for exposures of cavernous limestone which crop out in a karst area about 3 kilometers south of the town of Aguas Buenas just east of the Comerío quadrangle. He also correlated these limestones with the faulted limestone that crops out in an arcuate band beginning near the eastern edge of the Comerío quadrangle in Barrio Sumidero westward to the valley of the Río Arroyata just west of Cidra. This correlation has been confirmed by reconnaissance mapping, and the name Aguas Buenas limestone member has been adopted for the basal limestone member of formation K.

The Aguas Buenas limestone member is a lenticular deposit that averages about 15 meters in thickness. Locally it is as much as 60 meters thick, but in other places it is not present. At several localities this member is divided into two or more layers of limestone by intertonguing sandstone and siltstone lenses. The limestone is medium to dark gray when fresh and weathers to shades of olive gray. It is a well indurated crystalline limestone composed almost entirely of calcite, although impurities locally amount to 30 percent of the rock.

In the Comerío quadrangle, the Aguas Buenas limestone member is best exposed in the arcuate band of outcrop extending from Cidra to the eastern edge of the quadrangle. In this area it is underlain principally by hydrothermally altered rocks of formation J and is overlain by thin bedded tuff and volcanic sandstone interfingering with lava flows. The Aguas Buenas limestone member also crops out: (1) In faulted segments between the Río Hondo and Quebrada Galindo faults where the limestone is overlain by well-bedded tuffaceous rock; (2) in small segments resting directly on intrusive rock at the southwest corner of the Piña stock; (3) in a few small fault slices along the Quebrada Galindo fault; (4) on the low hill between Quebradas Santo Domingo and Morillo; and (5) at two localities on the northeast side of the fault in the valley of Quebrada Morillo.

Thickness, correlation, and age.—The apparent thickness of formation K exposed on the northeast side of the Río Arroyata fault is approximately 2,050 meters (section *D′-D″*). The maximum calculated thickness of formation K exposed southwest of the Quebrada Galindo fault is approximately 2,000 meters. However, a thickness of only about 450 meters of the lower part of formation K is exposed in Barrio Toíta near the southern border of the quadrangle. Apparently the Robles formation has overlapped most of formation K in this area.

Basal strata of formation K exposed in Barrio Toíta at the southern border of the quadrangle adjoin stratigraphically equivalent strata in the Cayey quadrangle that have been temporarily termed formation D by Berryhill and Glover (1960).

Evidence for determining the age of the rocks of formation K is at present limited to occurrences of two faunal species whose relative ages conflict at least in part with their relative stratigraphic positions.

The foraminifera genus *Orbitolina* has been identified by R. C. Douglass in limestone samples from both the Aguas Buenas limestone member of formation K and the Río Matón limestone member of the Robles formation. The former sample was collected from an outcrop about 1.25 kilometers S. 35° E. of the plaza at Comerio, the latter sample from a roadcut on Highway 1 in the northern part of the Cayey quadrangle. Douglass stated that *Orbitolina* sp. is indicative of a late Early Cretaceous age. However, he further states that these fossils are coated with algae and may have been reworked from an older limestone. Assuming that stratigraphic interpretations are correct the *Orbitolina* sp. collected from the Río Matón limestone member must have been reworked because an ammonite collected in the Barranquitas quadrangle from strata equivalent to the upper part of formation K and beneath the stratigraphic horizon of the Río Matón limestone member was identified by N. F. Sohl as *Parapuzosia* sp. of probable early Late Cretaceous (Coniacian) age. It is probable that formation K is entirely Late Cretaceous in age, but there is a possibility that the *Orbitolina* sp. collected from the Aguas Buenas limestone member was not reworked and that at least the lower part of formation K is of Early Cretaceous age.

ROBLES FORMATION

The sequence of stratified rocks that overlies formation K in the Comerío quadrangle is here named the Robles formation of Cretaceous age. This formation, whose type area is Barrio Robles of the Municipio of Aibonito, is best exposed along Highway 14 and the valley of Quebrada Honda in the southwestern part of the Comerío quadrangle. The rocks are essentially conformable with the rocks of formation K, but they may overlap part of formation K toward the southeast.

Southwestward-dipping strata of the Robles formation in the southwestern part of the Comerío quadrangle extend southward into the Cayey quadrangle and westward into the Barranquitas quadrangle; faulted blocks of this sequence are continuous across a major anticlinal structure in the Barranquitas quadrangle and are correlated with northwestward-dipping sedimentary rocks exposed in the northwestern part of the Comerío quadrangle. The Robles formation in the northwestern part of the quadrangle conformably underlies and in part interfingers with lava flows of formation L.

The formation is composed chiefly of well-bedded sandstone and siltstone but contains thin lava flows and breccias of small areal extent several of which have been delineated on the geologic map. Three of the lava flows, the upper and lower flow of the Lapa lava member, and the Las Tetas lava member exposed in the southwestern part of the quadrangle, have been accorded member status and named for stratigraphically equivalent members in the Cayey quadrangle immediately to the south. The Río Matón limestone member, also named for exposures in the Cayey quadrangle, is intermittently exposed at the base of the Robles formation in the Comerío quadrangle.

The Robles formation consists chiefly of thinly bedded, fine- to very fine-grained volcanic sandstone and siltstone intercalated with thickly bedded, medium- to coarse-grained volcanic sandstone and waterlaid tuff. These rocks are medium dark gray to medium bluish gray when fresh, but weather to pale shades of brown and to reddish-brown soil. Calcite is the common cementing agent except in the southwestern corner of the quadrangle where laminated very fine grained rocks of this member are cemented by silica. Fine-grained, thinly bedded strata predominate in the southwestern part of the quadrangle, but in the northwest quarter such strata predominate only in the lower part of the formation on the north slopes of Cerro Laso eastward into Barrio Naranjo and also in Barrio Río Hondo. Rocks in the upper part of the Robles formation that are exposed in the valley of the Quebrada Convento are more thickly bedded and composed chiefly of somewhat coarser grained sandstone and tuff, and toward the west in the vicinity of Escuela de Palomas, the stratified rocks apparently interfinger with massive beds of coarse volcanic breccia.

Two beds of fine volcanic breccia are interbedded with the fine-grained rocks near the top of the sequence in the southwestern part of the quadrangle. The older bed, Krb$_1$, is apparently older than the Las Tetas lava member, but the younger bed, Krb$_2$, overlies the lava flow and apparently is very near the top of the Robles formation in the Comerío quadrangle. A lava flow, Krf, is exposed along the north side of the Quebrada Convento in the northwest part of the quadrangle.

Río Matón limestone member.—The Río Matón limestone member was named by Berryhill and Glover (1960) for extensive exposures of limestones that crop out on the base of the Robles formation along the western side of the valley of the Río Matón in the north-central part of the Cayey quadrangle just south of the Comerío quadrangle. The term Río Matón limestone has also been adopted for the basal limestone member of the Robles formation in the Comerío quadrangle.

The Río Matón limestone member of the Robles formation is a partially recrystallized, well-indurated, medium- to dark-gray fine-grained limestone very similar lithologically to the Aguas Buenas limestone member of formation K. It is chiefly a relatively pure massive lenticular limestone, but in places the member consists of limestone breccia containing abundant angular fragments of volcanic rock in a limestone matrix and in other places consists of stratified beds of impure limestone that contain as much as 40 percent volcanic sandstone. Recrystallization in the Río Matón limestone member in the Comerío quadrangle has destroyed most of the internal structures of the fossils. At several places in the quadrangle the limestone member is separated into more than one bed by as much as 25 meters of volcanic sedimentary rocks.

The most continuous exposures of the Río Matón limestone member of the Robles formation occur in the northwestern part of the quadrangle where a thin arcuate band extends from the valley of the Río de La Plata eastward through Cerro Laso to the valley of the Río Arroyata. This limestone is absent in the valley of the Río Arroyata, and farther east in the area between the Río Arroyata and Quebrada Naranja the limestone is represented only by a lens of stratified tuffaceous limestone and limestone breccia restricted to the westernmost ridge. Limestone tentatively assigned to the Río Matón is also well exposed in faulted segments on the south side of the Río Arroyata fault west of the Río de La Plata. This correlation has been made on the basis of geologic evidence found in the Barranquitas quadrangle immediately to the west, but the available evidence is not conclusive and it is possible that this limestone is equivalent to the Aguas Buenas limestone member of formation K. In the western and southwestern part of the quadrangle the Río Matón limestone member is present only intermittently at the base of the Robles formation.

Lapa lava member.—The type area of the Lapa lava member of the Robles formation is in Barrio Lapa in the southwestern part of the Cayey quadrangle. In this area two contiguous lava flows, the lower characterized by clustered plagioclase phenocrysts and the upper by pyroxene phenocrysts, are well exposed near the base of the formation. Although separated areally and structurally from the type area, the two flows that crop out on Cerro El Indio near the western border of the Comerío quadrangle are correlated with the Lapa lava member because they are lithologically similar and because they occur at approximately the same stratigraphic position.

In the Comerío quadrangle the lower flow, Krl$_1$, is characterized by the presence of clustered plagioclase phenocrysts in a dark-gray aphanitic groundmass; the upper flow, Krl$_2$, is characterized by dark-green stubby pyroxene phenocrysts in a similar groundmass. Pillow structure can be seen in the lower flow where it crops out on Highway 14. In exposures on Highway 14 the lower flow is about 25 meters thick and more than 500 meters stratigraphically above the base of the formation; the upper flow is about 10 meters thick and about 80 meters stratigraphically above the lower flow. These flows pinch out toward the east. The lower flow apparently lies only a few meters stratigraphically above a segment of the Río Matón limestone member where it pinches out on the south side of the Río Usabón fault. Evidently the section of the Robles formation beneath the lower flow of the Lapa lava member is extremely thin here, or possibly the flow and limestone are separated by a fault that was not observed in the field. These flows thicken considerably and coalesce to the west in the Barranquitas quadrangle.

Las Tetas lava member.—The Las Tetas lava member, named by Berryhill and Glover (1960) for more extensive exposures of lava in the Cayey quadrangle immediately to the south, is exposed in Barrio Piedras at the southern border of the Comerío quadrangle. It also occurs in the Comerío quadrangle along the axial part of a small west-trending anticline about a kilometer west of the larger exposure and in a small exposure at the western edge of the quadrangle about 1,130 meters north of the southwest corner. It apparently occurs less than 100 meters stratigraphically below the uppermost beds of the Robles formation in this part of the quadrangle. The Las Tetas lava member is characterized by disoriented pyroxene and plagioclase crystals in a chloritic groundmass that comprises only a minor portion of the rock. Pillow structure has been observed in this flow in the Cayey quadrangle. The flow attains a maximum thickness in the Comerío quadrangle of 250 meters where it is exposed on the ridge west of Quebrada Gómez.

Thickness.—The maximum composite thickness of the Robles formation exposed in the southwestern part of the quadrangle is more than 1,200 meters; a thickness of more than 500 meters is exposed beneath the lower flow of the Lapa lava member near the western border of the quadrangle, and the thickness exposed above this flow in the valley of the Quebrada Honda (section *C-C′*) is approximately 700 meters. In the northwestern part of the quadrangle the thickness of the Robles formation ranges from about 400 meters in the vicinity of Comerío to about 700 meters as estimated along section *D-D′*. In the Río Hondo area the thickness ranges from 450 to 650 meters.

Age.—No diagnostic fossils have been collected from the Robles formation, but these rocks are probably early to middle Late Cretaceous in age as there appears to be little or no hiatus between formation K and basal beds of the Robles formation.

FORMATION L

Formation L which is confined to the northwestern part of the quadrangle is composed chiefly of lava flow and flow breccia and has very few clastic interbeds. Stratification in this formation is rarely apparent. The flow rock is porphyritic and commonly amygdaloidal, with a dark-gray to dark greenish-gray aphanitic groundmass. Phenocrysts are largely pyroxene crystals, but minute plagioclase laths are also present; amygdules are typically composed of calcite.

The most extensive exposures of this formation in the Comerio quadrangle occur principally in the drainage area of the Quebrada Higuero in Barrio Palomas along the south side of the Quebrada Vicente fault. Lava flows exposed along the south side of the Quebrada Convento fault are also assigned to formation L, and in Barrio Río Hondo south of the Río Hondo fault two small patches of this formation are exposed at the western edge of the quadrangle.

Formation L is more extensively exposed in the Barranquitas quadrangle immediately to the west where it comprises most of the bedrock in Barrio Quebrada Grande. Moreover, this formation, composed chiefly of lava flows, is believed to be exposed in the Ciales quadrangle to the northwest, so formal naming of the formation will be witheld until mapping of these quadrangles has been completed. The flows of formation L resemble the Las Tetas lava member of the Robles formation in the Cayey quadrangle, and although they are not spatially connected, the upper part of the Robles formation in the Cayey quadrangle possibly is stratigraphically equivalent to the lower part of formation L in the northwestern part of the Comerío quadrangle. Formation L is slightly more than 300 meters thick in the vicinity of Cerro Magueyes.

SURFICIAL DEPOSITS

At many places in the Comerío quadrangle, bedrock is concealed by alluvial-terrace and flood-plain deposits, by the results of mass movement, or by thick residual products of chemical weathering.

Alluvial deposits.—Terrace sand and gravel deposits of two distinct and considerably time-distant types are recognized in the Comerío quadrangle. Abandoned terrace sand and gravel, QTt, found at about 500 meters above sea level in Barrio Piñas 3,540 meters S. 5½° W. of the southwest corner of the plaza in Comerío and at an altitude of 430 meters in Barrio Doña Elena 2,615 meters N. 18° E. from the southwest corner of the plaza at Comerío (too small to be noted on the geologic map) represent the positions of ancient terraces, flood plains, or channels of probable Quaternary but possible late Tertiary age. Other terrace deposits, Qt, are Recent in age and occur in the southeast corner of the quadrangle, in the vicinity of Lago de Cidra, in Barrio Ceiba north-northwest of Cidra, and at a number of points along the valleys of the major streams. The terrace sands and gravels included under Qt on the geologic map are not all at the same level relative to present stream beds, but they are above the present flood-plain levels and probably receive no more alluvium except at times of extreme flood. Gently sloping deposits of fine-grained unconsolidated material are present on the hillward sides of many terrace deposits. Although derived locally by processes of soil creep and small scale debris avalanche, these fan-shaped deposits coalesce with the terrace deposits and are included under the terrace symbol on the geologic map.

The alluvial flood-plain deposits, Qal, along the valleys of the Río de la Plata, the Río Arroyata, the Río Bayamón, and in some of the minor streams are probably submerged a few times each year following periods of heavy rainfall, and their shapes and limits are therefore not constant. Most of these deposits are sand and gravel, but cobbles and boulders are numerous in the flood plains of the larger streams.

Deposits resulting from mass movement.—Three forms of deposits that have resulted from mass movement have been mapped in the Comerío quadrangle. Earthflows, Qef, which consist of fanlike sheet deposits on slopes of less than 20° and which are characterized by low break-away scarps, are confined to the vicinity of Cerro La Tiza. Much of the bedrock on the southern, western, and northern slopes of Cerro La Tiza is covered by earthflow deposits made up of clayey earth and rock fragments carrying boulders of quartz-rich hydrothermally altered rocks as large as 25 cubic meters. Small earthflow deposits of volcanic rock occur at several other localities in the quadrangle, but they have not been mapped. Earthflow deposits in the Comerío quadrangle are probably Recent in age as they postdate the erosion that formed the gross topography of the area, but they cannot be very young as they are cut by stream canyons and offset by faults.

Debris avalanche deposits, Qda, which occur on slopes of 20° to 40° or more and which are contained in relatively narrow channels, occur throughout the quadrangle. Some large areas of debris avalanche deposits are formed by the coalescence of a number of small avalanches, and a few coherent landslide blocks are included within these deposits. Two types of downhill movement from limestone outcrops in the quadrangle have been noted. Slides of rubble and limestone boulders have been included with debris avalanches, whereas, coherent blocks of limestone have been classified separately as landslides, Qls.

Deposits resulting from chemical weathering.—Thick residual soil and saprolite cover parts of the Comerío quadrangle. These lateritic deposits, which result from chemical weathering and are essentially in place, have not been distinguished from the underlying bedrock formations on the geologic map. They are mostly dark reddish-brown and their principal constituents are kaolinitic clay, iron and aluminum oxide, and quartz. Relict texture of the parent rock is visible in some outcrops.

The principal areas of deeply weathered rock occur in the upland plateaus of the northwestern and southwestern corners of the quadrangle and in the north-central part of the quadrangle south of the Quebrada Vicente fault. Chemical weathering may also have contributed significantly to the alteration of the grayish-orange bedrock exposed in the vicinity of Lago de Cidra.

The maximum depth of weathering has not been measured in the Comerío quadrangle, but a minimum thickness of 30 meters has been estimated for the saprolitic material exposed in the upper part of the valley of the Quebrada Higuero in the northwestern corner of the quadrangle.

HYDROTHERMALLY ALTERED ROCKS

A zone of altered rocks, TKhv, is exposed along the crest of the ridge that forms Cerro La Tiza, and lithologically similar rocks also occur in the vicinity of Lago de Cidra and at a few other localities in the quadrangle. Samples from the zone at Cerro La Tiza were studied by F. A. Hildebrand and R. J. Smith (written communication) who concluded that the altered rocks were derived from volcanic rocks by the process of hydrothermal alteration, and that the hydrothermal solutions emanated from an underlying plutonic body. The writers of this report believe that all rocks indicated on the geologic map by the symbol TKhv are also hydrothermally altered volcanic rocks.

The zone in the vicinity of Cerro La Tiza is exposed in a sinuous band of irregular width that apparently has been dislocated by several faults. Contacts between hydrothermally altered zone and volcanic host rock are sharp and clearly defined especially where exposed in a few stream canyons, but in many places the contact is buried by earthflow deposits. An eastward extension of the Cerro La Tiza zone is exposed in the extreme northeast corner of the quadrangle. This exposure of hydrothermally altered rock extends eastward into the Caguas quadrangle. A small patch of hydrothermally altered rock was also observed in the valley of the Quebrada Doña Elena. Its area of exposure is considerably smaller than is shown on the geologic map, but it has been exaggerated to a size visible at the map scale because it may represent the top of an extensive but unexposed zone of altered rock, and may even be a westward extension of the zone at Cerro La Tiza.

According to Hildebrand and Smith (written communication) the principal mineral constituents of the zone at Cerro La Tiza are quartz, alunite, pyrophyllite, kaolin-group clays, and sericite. The commonest rock exposed in the Cerro La Tiza zone consists of finely divided quartz and sericite, but a banded rock composed of alternating quartz and alunite is also a prominent rock type and forms most of the hard boulders that occur in the earth flow deposits on the slopes of Cerro La Tiza. Pyrophyllite and kaolinite are associated with outcrops of this quartz-alunite rock.

Hydrothermally altered rock composed chiefly of quartz and sericite is exposed in the vicinity of Lago de Cidra in two zones, one along the south side of the lake and the other extending from just west of Cidra in an arcuate band northeastward to the edge of the quadrangle. The area between these two zones is underlain by a soft yellowish-brown homogeneous rock that may have been a volcanic rock that is now severely altered, in part by mild hydrothermal solutions but chiefly by weathering. Irregular gradational contacts between this rock and the quartz-sericite rock are exposed in road cuts on Highway 173 east of Cidra. The contacts indicated on the geologic map are only approximations of an undoubtedly more complex boundary.

The Aguas Buenas limestone member of formation K directly overlies quartz-sericite rock along the northern boundary of the hydrothermally altered zone northeast of Cidra. At one locality about 1,540 meters N. 59° W. of the northwest corner of the plaza at Cidra, the basal part of the limestone was penetrated by hydrothermal solutions that deposited red iron oxide veinlets in the limestone. Apparently the limestone prevented the migration of hydrothermal solutions into the overlying rocks of formation K in the Cidra area.

The youngest rocks that have been altered by hydrothermal solutions are of Late Cretaceous age. Therefore the latest hydrothermal activity must have occurred between Late Cretaceous and Recent time. Moreover, if the hydrothermal activity in the quadrangle is genetically related to emplacement of associated intrusive rocks, it probably occurred before or directly after this emplacement, which is believed to have taken place during Late Cretaceous or early Tertiary time.

INTRUSIVE ROCKS

DIORITIC ROCKS

Intrusive dioritic rocks are exposed at several places in the Comerío quadrangle. Most exposures are thin dikes or small pods less than half a square kilometer in area, but the Piñas stock exposed in the west-central part of the quadrangle covers an area of more than 2.5 square kilometers. It has been possible to assign most of these rocks to one of two categories, either hornblende diorite, TKhd, or pyroxene diorite, TKpd, but several of the smaller bodies, TKi, are so weathered that their mineral composition could not be identified, and they were not classified.

Hornblende diorite.— **The Piñas stock is composed of hornblende diorite. Rocks of the same composition, which are probably offshoots at depth of the same intrusive mass, are exposed in the valley of the Río Arroyata just northeast of the Piñas stock, along the north side of the valley of the Río Arroyata, and beneath the Aguas Buenas limestone member of formation K immediately west of Cidra. Its easternmost outcrop is on the northwest side of the Quebrada La Zapera, Barrio Sumidero.**

Hornblende diorite is directly overlain by the Aguas Buenas limestone member of formation K in at least three and perhaps four widely separated areas in the Comerío quadrangle: at the northern and southen borders of the Piñas stock, immediately west of Cidra, and at least at one locality near the mouth of the Quebrada Galindo. Yet the limestone does not seem to have been deposited on an erosion surface of intrusive rock; it is apparently older than the intrusive rock and owing to its dense nature acted as a barrier to the intrusive magma. The evidence for this conclusion is threefold: (1) Although the limestone shows little effect of thermal alteration a thin shale bed exposed between the limestone and the intrusive body in a roadcut about 1,500 meters N. 59° W. of the plaza at Cidra is highly sheared and seems to have been baked; (2) the base of the limestone contains no fragments or grains of intrusive rock; (3) hornblende diorite exposed in Barrio Río Abajo cuts rocks of formation K that are younger than this limestone.

The hornblende diorite is typically a light olive-gray to medium dark-gray aphanitic rock peppered with black hornblende needles and in weathered specimens salted with white cubes of powdery altered feldspar. The rock weathers to a light-colored, almost white soil that can be readily distinguished from the darker soils of the volcanic rocks. Examination of the rock under the petrographic microscope reveals a porphyritic to equigranular rock whose principal constituents are hornblende and intermediate plagioclase in a cryptocrystalline to microcrystalline groundmass. Accessory grains are apatite and opaque ore. At three localities indicated on the geologic map by the symbol TKhp the hornblende diorite is a porphyry characterized by the presence of broad black hornblende phenocrysts as much as 15 millimeters long and amounting to as much as 40 percent of the rock.

Pyroxene diorite.— **Pyroxene diorite is best exposed in two northeastward-trending dikes in the west-central part of the quadrangle; it also composes the small faulted block of intrusive rock exposed just east of the Quebrada Catalina and other northeastward-trending dikes in Barrio Ceiba.**

The pyroxene diorite is medium gray to pinkish gray on weathered surfaces; it weathers to a light-colored soil that is not readily distinguished in the field from weathered exposures of hornblende diorite, but in fresh hand specimens and especially in thin sections the lithologic difference between the two rock types is clearly apparent. Microscopic examination of several thin sections of this rock reveals that it is a fine-grained dioritic rock composed chiefly of albitized plagioclase and diopside(?). Opaque ore and apatite are ubiquitous accessories and prehnite and biotite(?) are common. Textures range from equigranular to slightly porphyritic with a diabasic groundmass.

Age.—The dioritic rocks in the Comerío quadrangle are believed to have been emplaced in very late Cretaceous time or more probably during Tertiary time. A small body of hornblende diorite exposed in the canyon of Quebrada Gómez, Barrio Piedras, near the southern border of the quadrangle intrudes rocks near the top of the Robles formation. Assuming that all the dioritic rocks are genetically related and were emplaced at approximately the same time, the oldest possible age of emplacement must be post Robles formation or Late Cretaceous. As the hornblende diorite is offset in a left-lateral direction along the Río Arroyata fault, it must have been emplaced before the later movement on this fault in early Tertiary time as is suggested in the section on structure.

LAMPROPHYRES AND APLITES

Numerous, thin, fine-grained to aphanitic dikes are exposed at many localities and are particularly well exposed in the canyons of the Río de La Plata and Río Usabón near the western border. The dikes, which are probably feeders to lava flows of formation K, are mostly lamprophyric, but a few are aplitic. Measurements of their directional trends show no indication of a preferred orientation, and none have been mapped or delineated on the geologic map.

STRUCTURE

The structural pattern in the Comerío quadrangle reveals a broad westward-plunging anticlinal fold whose crest is partly defined on the geologic map by the Amoldadero and Arenas anticlines located in the west-central and east-central parts of the quadrangle respectively. However, the rocks of Cretaceous age that compose this anticlinal fold have been sheared and are dislocated by the many faults that largely dominate the pattern of structure in the quadrangle. Several small folds have been mapped, but these are not a common structural feature in the quadrangle. Most of the faulting apparently took place after the anticlinal fold had formed, but major right-lateral displacement along the Río Arroyata fault evidently preceded this folding as the trend of the axial part of the fold has not been dislocated in this direction.

The configuration of the major upwarp is best defined by the trend and distribution of rocks of the Robles formation, which are exposed in the western part of the quadrangle where they dip northwestward and southwestward away from the crest of the westward plunging fold. Strata of formations J and K exhibit a westerly plunge, but in most of the central and eastern parts of the quadrangle they strike generally north forming a much broader structural arc than rocks of the Robles formation. This anomolous relationship is best explained by postulating that strata of the Robles formation were deposited in a shallow northwest plunging synclinal basin and that uplift occurred only after deposition of this formation.

The Río Arroyata and Río Hondo faults apparently represent a zone of fracture along which major displacement has occurred in opposite directions at different times. The Aguas Buenas limestone member of formation K has a right-lateral displacement of about 5,500 meters along the Río Arroyata fault between Cidra and the southern part of Barrio Vega Redonda, the Río Matón limestone member of the Robles formation has a left-lateral movement of about 4,000 meters along the Río Hondo fault between the valley of the Río de La Plata and the upper part of the Río Hondo in the Barranquitas quadrangle to the west. It is apparent that the major right-lateral displacement along the Río Arroyata fault preceded deposition of the Robles formation because strata of the Robles formation have not been offset in this direction. The westward extension of the Río Arroyata fault probably follows the approximate trace of the Río Hondo fault, but it may be buried, at least in part, beneath strata of the Robles formation; the eastward extension of the Río Hondo fault apparently follows the approximate trace of the Río Arroyata fault, but its actual trace east of Barrio Vega Redonda is not known.

Although it is entirely possible that most of the displacement along these faults was essentially vertical, the present configuration of the strata along these two faults suggests that the major component of movement was strike-slip rather than vertical. Faulted segments of the Aguas Buenas limestone member and associated rocks exposed in Barrio Vega Redonda have a right-lateral drag along the Río Arroyata fault, and strata of the Robles formation in Barrio Río Hondo have a left-lateral drag along the Río Hondo fault. The southward trend of strata of formations J and K immediately north of the Río Arroyata fault may in part represent left-lateral drag that reflects the post-Robles formation movement of the Río Hondo fault along the trace of the Río Arroyata fault.

The Río Arroyata fault forms the northeastern border of a fault block that trends northwestward across the central part of the quadrangle. This block is bounded on the west and southwest by the Quebrada Galindo and Río de La Plata faults, but these faults are not genetically related to the Río Arroyata fault and movement along them apparently was later, less than that of the Río Arroyata fault.

The Quebrada Galindo fault trends almost parallel to the strike of the beds in formation K and basal strata of formation K including small slices of the Aguas Buenas limestone member are exposed along the entire length of the fault. Movement along this fault was essentially vertical as shown by the steeply dipping attitude of this limestone; the east side moved up relative to the west side. This fault apparently abuts against the Río de La Plata fault just south of the mouth of the Quebrada Galindo although the southward-trending fault that passes just east of the Escuela de Toíta in Barrio Toíta may be an extension of the Quebrada Galindo fault offset to the east along the south side of the Río de La Plata fault. The Río de La Plata fault is a left-lateral fault of less than 700 meters apparent lateral displacement that dies out toward the east in Barrio Toíta where the exposed contact between formation J and formation K is depositional.

Evidently the gross structural pattern in the central part of the quadrangle was largely established by displacement and drag along the Río Arroyata fault and by later uplift prior to the Quebrada Galindo and Río de La Plata faults. The dislocation of strata incident to emplacement of the Piñas stock also occurred prior to movement along the Quebrada Galindo fault, which cuts the stock.

Strata of the Robles formation exposed in the northwestern part of the quadrangle are displaced in opposite directions by the Comerío and Quebrada Convento faults. The maximum apparent stratigraphic displacement along the Quebrada Convento fault is about 500 meters and along the Comerío fault about 200 meters. The principal component of movement along these faults is apparently vertical as illustrated by the steeply dipping beds in the vicinity of the faults. The faults merge near the western border of the quadrangle, and west of this point apparent displacement along the fault is virtually cancelled.

The Río Usabón and Río Matón faults in the southwestern corner of the quadrangle also displace strata of the Robles formation, and the Río Usabón fault like the Quebrada Galindo fault trends almost parallel to the strike of bedding in this formation. Strata of this formation occupy the southwestern side of the fault and are in juxtaposition with strata of formation K northwest of the fault. Stratigraphic displacement, however, is not large, as small exposures of formation K are observed at several localities beneath the Robles formation on the southwest side of the fault.

In the valley of the Río Matón the Río Usabón fault coalesces with the Río Matón fault along which displacement was opposite that of the Río Usabón fault. Apparent stratigraphic displacement north of the junction of the two faults is approximately 90 meters, but southward in the Cayey quadrangle the Río Matón fault displaces a maximum thickness of about 350 meters.

The Quebrada Vicente fault delineates the southern boundary of a series of volcanic rocks exposed across the northern part of the Comerío quadrangle. The trace of this fault, which is generalized on the geologic map, consists of a series of westward-trending subparallel shears and fault slices that were not mapped in detail. The fault is best exposed in the valley of Quebrada Vicente where relatively undeformed volcanic sedimentary rocks on the south side of the fault are in juxtaposition with sheared and chloritized rocks north of the fault. The trace of this fault is poorly defined west of the valley of the Río de La Plata, but steeply dipping to overturned strata exposed in the valley of the Quebrada Higuero apparently are restricted to the north side of the fault in this area. The amount of stratigraphic displacement along this fault is not known.

ECONOMIC GEOLOGY

MINERAL DEPOSITS

Pyrophyllite and alunite.—Pyrophyllite and alunite are associated with quartz, muscovite mica, and kaolinitic clay in the hydrothermally altered rocks along the spine of Cerro La Tiza. From an economic standpoint they represent the most promising mineral deposit in the Comerío quadrangle.

Pyrophyllite, ($H_2Al_2\,(SiO_3)_4$) is utilized as a carrier for DDT (dichloro-diphenyl-trichloroethane) in insecticides, and may also be used in the manufacture of ceramic tile, pottery, and electric insulators.

Alunite ($K_2Al_6(OH)_{12}(SO_4)_4$) is used as a source for $Al_2(SO_4)_3$, $KAl(SO_4)_2$, and alum, and these compounds, in turn, are used to produce myriad other compounds. The alumina content of this mineral is high, but as yet no economic process has been discovered for its extraction. Alumina is the principal source of metallic aluminum and is also used in the manufacture of refractory brick.

Kaolinitic clay.—In the Cerro La Tiza hydrothermal-alteration zone kaolinitic clay occurs in moderate-sized lenticular masses. This clay is fairly pure and is iron free. Before 1950 the Puerto Rico Industrial Development Co. removed a reported 500 tons of this kaolinitic clay from a pit about 5,310 meters N. 61° E. from the southwest corner of the plaza at Comerío and about 725 meters south of the northern border of the quadrangle. This material was used in the production of glass. The operation, however, was abandoned owing to legal difficulties. Since then, clay from this pit has been sampled for finished ceramic work and has proved more or less satisfactory for this purpose, although no commercial production has been attempted.

Some of the hydrothermally altered rocks in the Cerro La Tiza zone, as well as in the zone north of Cidra, weather to very colorful clay. However, it is probable that the quartz content of such deposits is too high for successful use in ceramics.

Copper.—Several minor occurrences of native copper and of copper minerals were noted in this quadrangle. Several small copper-bearing deposits occur in and near the area between the Comerío fault and the Río Hondo fault to the west of the town of Comerío. The principal copper minerals are chrysocolla ($CuSiO_3{\cdot}2H_2O\pm$), malachite ($CuCO_3{\cdot}Cu(OH)_2$), and azurite ($2CuCO_3{\cdot}Cu(OH)_2$), but traces of copper sulfides and oxides may also be present. At the time of writing (1958), a copper-mining concern is preparing to undertake a program of geochemical prospecting in this area and in its westward extension into the Barranquitas quadrangle. This same company is also interested in low-grade copper showings from the hydrothermally altered rock east of the town of Cidra.

Some small float of copper-rich material was found in the outcrop of the Río Matón limestone member just southeast of the summit of Cerro Laso, approximately 1,325 meters 63½° E. of the southwest corner of the plaza at Comerío. However, none of this material was discovered in place.

Native copper occurs as a minor accessory constituent in flow rocks at a few places in the quadrangle. These occurrences seem to be generally restricted to formation K, but further petrographic study may reveal that native copper is an accessory mineral in many of the flows of Cretaceous age in eastern Puerto Rico.

WATER RESOURCES

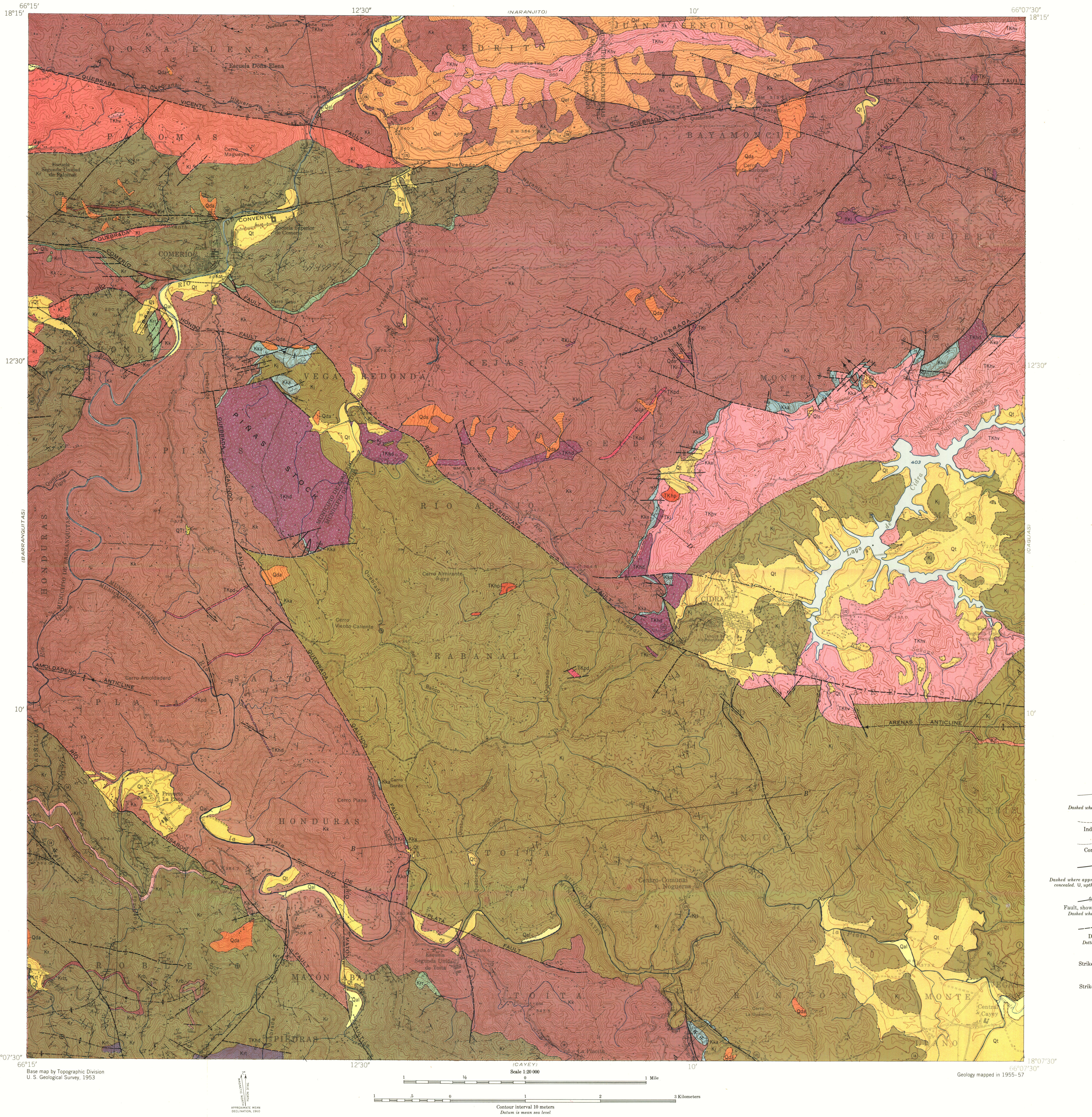
Surface water is available throughout the year from most of the larger stream valleys in the Comerío quadrangle, and such streams supply the needs of most of the rural population in the quadrangle although most of this water is polluted and should be purified for domestic use. Purified water is available only in the towns of Cidra and Comerío and from pipelines along a few major highways.

C. L. McGuinness (1948) noted that the sources of water for Comerío are two springs and a stream, while at Cidra water is obtained by pumping from a diversionary dam on the Quebrada Ceiba. At Cayey, south of the quadrangle border, the principal sources are wells. It is further reported that wells sunk in the alluvium in the Río de La Plata valley near Comerío could be a source for "a few hundred thousand gallons per day" (McGuinness, 1948, p. 564-565). The water stored in the Lago de Cidra is reported to be principally for use in the San Juan metropolitan area on the north coast of Puerto Rico.

McGuinness (1948, p. 190-191) reports that the yield of the Cretaceous rocks which underlie the Comerío quadrangle ".... depends more on the extent of disintegration and the opportunity for recharge than on the kind of rock" that forms the aquifer. He further states "The province is characterized by rather small ground-water supplies, but these are available almost everywhere, and in a few areas moderately large supplies are available" . . . ; and (p. 492), "the recharge is adequate to maintain these supplies". Concerning well sites he states (p. 493), "The best sites for wells are in valley bottoms where any alluvium that may be present is thickest".

REFERENCES

Berryhill, H. L., and Glover, Lynn, 3d, 1960, Geology of the Cayey quadrangle, P. R.: U. S. Geol. Survey Misc. Geol. Inv. Map I-319.
Hodge, E. T., 1920, Geology of the Coamo-Guayama district, Porto Rico, *in* Scientific Survey of Porto Rico and the Virgin Islands, v. 1, pt. 2, p. 111-228, New York, New York Acad. Sci.
McGuinness, C. L., 1948, Ground-water resources of Puerto Rico: Puerto Rico Aqueduct and Sewer Service, 613 p. [mimeographed].
Roberts, R. C., and others, 1942, Soil Survey, Puerto Rico: U. S. Dept. Agriculture, Bur. Plant Industry.
Semmes, D. R., 1919, Geology of the San Juan district, Porto Rico, *in* Scientific Survey of Porto Rico and the Virgin Islands, v. 1, pt. 1, p. 33-110, New York, New York Acad. Sci.



Base map by Topographic Division
U. S. Geological Survey, 1953

Scale 1:20 000

Contour interval 10 meters
Datum is mean sea level

Geology mapped in 1955-57

EXPLANATION

STRATIFIED ROCKS

Qal
Alluvial deposits
Unconsolidated gravel, sand, and silt including large cobbles and boulders of volcanic rock; restricted to lowest deposits adjacent to present stream channels

Qda **Qls**
Deposits of debris-avalanche and landslide
Debris avalanche deposits, Qda, are mixed earth and rock; landslide deposits, Qls, are coherent blocks derived from steep slopes

Qt
Terrace deposits
Unconsolidated sand, gravel, and silt including large cobbles and boulders of volcanic rock; restricted to deposits generally above the level of present stream action

Qef
Earth-flow deposits
Deposits of clayey earth and rock fragments containing siliceous boulders as large as 25 cubic meters; restricted, in Comerio quadrangle, to the slopes of Cerro La Tiza

QUATERNARY

QTt
Older terrace deposits
Remnant deposits of consolidated gravel occurring at about 500 meters above sea level

TERTIARY OR QUATERNARY

Kl
Formation L
Dominantly massive porphyritic amygdaloidal flow; also flow breccia, but few clastic rocks

Krb₁ Krt Kr Krb₂ Krl₂ Krl₁ Krf Krr
Robles formation
Chiefly thinly stratified fine-grained sedimentary rocks, Kr, *but includes fine-grained volcanic breccia,* Krb₁ *and* Krb₂, *and a lava flow,* Krf. *Also includes the Las Tetas lava member,* Krt; *the Lapa lava member, lower flow,* Krl₁, *and upper flow,* Krl₂; *and the Río Matón limestone member,* Krr, *a thin discontinuous unit at the base of the formation*

Kkl Kk Kka
Formation K
Chiefly crudely stratified coarsely clastic volcanic breccia; intercalated with lava flows, volcanic conglomerate, massive tuff and a few layers of bedded fine grained rocks; thin lenticular bodies of impure limestone, tuff, and limestone breccia, Kkl; *Aguas Buenas limestone member,* Kka, *at the base of formation*

Kjl Kjf Kj
Formation J
Principally massive volcanic breccia and lava flows. Contains layers of poorly stratified tuff and volcanic conglomerate; fine-grained bedded rock occurs locally; a thin limestone lense, Kjl, *and a lava flow,* Kjf, *delineated on the geologic map*

CRETACEOUS

INTRUSIVE ROCKS

TKhd
Hornblende diorite
Light olive-gray to medium-gray, fine-grained, generally porphyritic rock; phenocrysts of plagioclase and hornblende

TKhp
Hornblende porphyry
Dark-colored rock characterized by hornblende phenocrysts as much as 15 millimeters in length

TKpd
Pyroxene diorite
Medium-gray to pinkish-gray fine-grained holocrystalline rock composed chiefly of plagioclase and pyroxene

TKi
Undifferentiated intrusive rock
Light-colored weathered rock whose original mineral constituents cannot be recognized

METAMORPHIC ROCKS

TKhv
Hydrothermally altered rocks
Light-gray clayey rock, mottled when weathered by shades of red, brown, and grayish purple; locally highly siliceous and well-indurated; banded in part at Cerro La Tiza

CRETACEOUS OR TERTIARY

Contact
Dashed where approximately located

Indefinite contact

Concealed contact

Fault
Dashed where approximately located; dotted where concealed. U, upthrown side; D, downthrown side

Fault, showing relative movement
Dashed where approximately located

Doubtful fault
Dotted where concealed

Strike and dip of beds

Strike of vertical beds

Horizontal beds

Strike and dip of overturned beds

Strike and dip on questionable bedding plane

Strike and dip of foliation

Strike of vertical foliation

Anticline, showing trace of axial plane or crest line and plunge of axis

Syncline, showing trace of axial plane or trough and plunge of axis

Quarry

Clay pit

ENGINEERING GEOLOGY

LITHOLOGIC TYPE	DISTRIBUTION	EXCAVATION	STRENGTH AND STABILITY	UTILIZATION	MISCELLANEOUS
Massive flow	Widely distributed in formation J and formation K. Some in Robles formation. Available for construction purposes through most of the quadrangle.	Requires extensive drilling and blasting, except where severely shattered.	Foundation strength is good for dams, bridges, buildings, and roads, except where shattered, especially where shears are approximately parallel to the land surface. Slope stability is good with exception as above.	Non-amygdaloidal flow provides good base course and surfacing material for roads. Good concrete aggregate with low alkali cement. Possible rock fill for earth dams.	Tends to be brittle. This rock is less susceptible to mechanical weathering than other rocks in the quadrangle. Not to be used as aggregate with high alkali cement.
Massive tuff and breccia.	Occurs chiefly in formation J and formation K. Readily available for construction purposes in most of the quadrangle.	More easily excavated than massive flow, but drilling and blasting necessary in most cases.	Foundation strength is good for heavy construction, except where shattered. Stability of steep slopes is poor as mass movement may occur thereon.	Road fill and earth dam fill material	Tends to granulate to a shallow depth with weathering.
Stratified fine-grained rocks.	Dominant in Robles formation; few lenticular bodies in formation J and formation K. Occurs principally in northwestern and southwestern corners of the quadrangle.	Requires less drilling and blasting than massive volcanic rocks due to cleavage along bedding planes, except where so cemented that the rocks act as massive rock.	Foundation strength is satisfactory for most purposes, but slope stability may be poor, especially where strata dip steeply and where the bedding planes are approximately parallel to the land surface.	Has been quarried for road metal, but is not recommended for this if other material is available. Fresh rock may be crushed for use as very fine aggregate for concrete block manufacture.	Two quarries: One on the north side of the Quebrada Convento north of Comerio, the other near Highway 14 in the southwestern part of the quadrangle.
Limestone	Aguas Buenas member of formation K; Rio Maton member of Robles formation. Most readily available northeast from Cidra and in the vicinity of Comerio. Minor occurrences elsewhere in the quadrangle.	Requires drilling and blasting	Foundation strength is excellent for heavy construction where limestone is non-cavernous, but may be poor where caverns occur. Slope stability is good, but differential weathering relative to adjacent rocks may impair foundation stability.	Excellent for road metal and concrete aggregate. Also useful as soil conditioner for acid soils. Possible use as commerical marble for building and decorative work.	Five quarries: Two approximately one kilometer north of the dam at Lago de Cidra (commercial marble), one about two kilometers northwest of Cidra, one on the west side of the Quebrada Santo Domingo just north of the southern quadrangle border, and one southeast of the bridge at Comerio.
Intrusive igneous rock.	Piñas stock, about two kilometers south-southeast of Comerío; small bodies, including dikes, elsewhere in the quadrangle.	Some drilling and blasting required, but more easily worked than massive volcanic rocks or limestone because it becomes granular with moderate weathering.	Foundation strength is good for most purposes even with moderate weathering. Slope stability is good due to uniformity of composition.	Moderately weathered intrusive rock may provide good fill as it compacts easily and is stable.	
Hydrothermally altered rock.	From the west end of Cerro La Tinza eastward beyond the edge of the quadrangle, and northeast and east of Cidra.	Readily excavated except locally and at depth where highly siliceous material may require blasting.	Foundation strength and slope stability are generally poor, except in locally extensive areas of silicified rock. Complicated foundation preparation would be necessary for heavy construction.	See section on mineral deposits for use of pyrophyllite, alunite, and kaolinitic clay. Most of the hydrothermally altered rock has no value.	Hydrothermally altered rocks are commonly subject to earthflow.
Alluvial deposits.	Chiefly in the vicinity of Lago de Cidra and in the upper reaches of the Rio de La Plata. Small deposits in the valleys of the Rio de La Plata and the Rio Arroyata and adjacent to other streams.	Easily worked with dragline scraper and power shovel.	Foundation strength for heavy loads is poor; foundations should be anchored to underlying bedrock. Low angle slopes are requisite for road cuts and other permanent excavations.	Suitable for road fill and base course when screened and washed.	When appreciable amounts of clayey material are present and the water table is near the surface, drainage may present foundation problems.
Deposits resulting from mass movement.	Chiefly on the slopes of Cerro La Tiza. Also on north slopes of Cerro Santa Barbara, and south of Highway 14. Minor deposits elsewhere.	Readily worked by dragline scraper and power shovel, but may refill rapidly due to further mass movement. Large included boulders may require blasting.	Foundation strength for most construction is very poor; excavation or pilings to bedrock are requisite. Very low angle slopes and/or adequate drainage provision are necessary. Deposits may have deceptive temporary stability.	Possible use as fill where other rock types are not available.	New slides can be expected in areas where deposits from mass movement are common. Construction should be avoided in these areas.
Deep soils	Chiefly in the upland areas in the northwestern and southwestern corners of the quadrangle and in the north-central part of the quadrangle.	Easily worked with power equipment.	Foundation strength for heavy loads is poor. Foundations should be anchored to solid rock by pilings or other means. Low angle slopes are recommended in cuts.	Is used as road fill, but is compacted with difficulty and may prove unstable. Possible source for iron, aluminum, and heavy ceramic clay.	

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-320

GEOLOGY OF THE COMERIO QUADRANGLE, PUERTO RICO

By

Maurice H. Pease, Jr., and Reginald P. Briggs

1960

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.— MR 3016

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