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MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-319

GEOLOGY OF THE CAYEY QUADRANGLE, PUERTO RICO

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INTRODUCTION

The geology of the Cayey quadrangle has been mapped as part of a project to make a detailed, systematic geological survey of the island of Puerto Rico, to appraise the mineral resources, and to prepare detailed general purpose geologic maps that can be used as aids in engineering planning. This program has been undertaken by the U. S. Geological Survey in cooperation with the Economic Development Administration of the Commonwealth of Puerto Rico.

Field investigations were begun in December 1955 and were completed in December 1956. Aerial photographs at a scale of approximately 1:15,000 were used as a base for locating and plotting geologic features in the field. In the laboratory the data were transferred by visual inspection and by the use of proportional dividers from the aerial photographs to a topographic base map having a scale of 1:20,000.

The writers were assisted during the field investigations by Martin S. Tischler.

GEOGRAPHY

The Cayey quadrangle, which comprises 154 square kilometers and covers 7.5 minutes of longitude and latitude, is located in the southeastern part of Puerto Rico near the south coast. Cayey, in the northeastern part of the quadrangle, is 60 kilometers by highway south southwest of San Juan and 69 kilometers by highway east northeast of Ponce. The southern boundary of the quadrangle is 5.2 kilometers north of the Caribbean Sea.

The principal topographic feature in the Cordillera Central, which together with its southeastern extension, the Sierra de Cayey, crosses the northern third of the Cayey quadrangle. The Cordillera Central is the mountainous backbone of Puerto Rico. It is the main drainage divide between the Atlantic Ocean and the Caribbean Sea, and it follows a sinuous east-west course across the entire southern part of the island. The regional slope from the Cordillera Central southward to the Atlantic Ocean, 30 kilometers away, is gradual, but the slope southward to the Caribbean, 5 kilometers away, is steep to the coast.

The deeply dissected southern flank of the Cordillera Central—Sierra de Cayey makes up the surface of the southern two-thirds of the Cayey quadrangle. The Río Majada and its tributaries, the Río Lapa and the Río Jájome, have cut deep V-shaped valleys that locally have 35° to 40° slopes. The most prominent topographic feature in this part of the quadrangle is the Sierra de Jájome, which is a spur of the Sierra de Cayey.

The highest point in the quadrangle, is Barrio Guamaní near the east-central boundary, has an altitude of 990 meters. The point of lowest altitude, in the southwest corner of the quadrangle, is 60 meters above sea level. Thus the maximum relief in the Cayey quadrangle, therefore, is 930 meters.

The drainage of the Cayey quadrangle north of the Cordillera Central is carried northward to the Atlantic Ocean by the Río de la Plata and its tributary, the Río Matón. The drainage south of the Cordillera is carried southward to the Caribbean Sea, principally by the Río Majada and its tributaries, the Río Lapa and the Río Jájome, and by the Río Seco.

GENERAL GEOLOGY AND STRATIGRAPHY

The rocks in the Cayey quadrangle are predominantly of volcanic origin including, in addition to lava flows, a variety of volcanic clastic rocks, and a few layers of tuff. Interbedded with these volcanic rocks are conglomerate, sandstone, siltstone—derived principally from volcanic rocks—and limestone. These rocks are cut by intrusive stocks, dikes and sills, and locally they have been metamorphosed by thermal solutions. Small bodies of surficial deposits cover part of the older rocks.

The volcanic and sedimentary rocks can be divided into two general groups: (1) massive, stratified volcanic rocks which consist mostly of intricately intertonguing lava flows and flow breccias and volcanic breccias but which also contain lenticular layers of volcanic conglomerate, sandstone, and siltstone; and (2) younger, well-bedded sandstones and siltstones which contain a few pillow lavas, lenses of bedded conglomerate, and reef-type limestone that occurs mainly as a layer at the base of the sequence. The massive volcanic rocks are the more extensive of the two groups and crop out over approximately the eastern two-thirds of the quadrangle. They are believed to be predominantly water laid, but may be in part subaerial deposits. The well-bedded sandstones, siltstones, pillow lavas, and limestone crop out along the southwestern boundary of the quadrangle and in a narrow belt near north-central parts. These rocks represent in part subaqueous deposition and in part subaqueous extension.

The volcanic and associated sedimentary rocks have been tilted, gently folded, and faulted. Their apparent stratigraphic thickness is approximately 6,500 meters, as measured across the surface of the quadrangle, but they may have been granitized and assimilated by younger plutonic igneous rocks, which are believed to underlie the entire quadrangle. Several small stocks or offshoots from the plutonic rocks, as well as numerous dikes, crop out at the surface.

The volcanic rocks are the products of a prolonged period of volcanic activity that began in the Cretaceous Period and ended in the Eocene Epoch. The lithologic differences in the volcanic rocks are in general a result of periodic variations in the nature and intensity of the volcanic activity and also a result of periodic shifts in the geographic positions of the centers of volcanic activity.

The group of massive volcanic rocks have been subdivided into four formations, partly on the basis of variations both in the content of lava and in the content of sandstone and siltstone and partly on the basis of what appear to be unconformities. The group of well-bedded rocks, conglomerates, and pillow lavas has been subdivided into two formations on the basis of lithologic differences.

The exact age of the rocks in the Cayey quadrangle cannot be given at this time, but a number of fossils have been collected from the various limestones by N. F. Sohl. His studies of these fossils were not completed for this report, but he states (personal communication) that preliminary observations indicate a Late Cretaceous age for the group of well-bedded rocks, conglomerates, and pillow lavas and that the massive volcanic rocks are younger and is believed to be Cretaceous in age, but data for a more precise dating are not available. On the basis of their stratigraphic position, however, the rocks can be arranged in sequence according to relative age. The oldest rocks crop out along the eastern boundary of the quadrangle and progressively younger rocks are exposed toward the west.

The two formations making up the group of well-bedded rocks, conglomerates, and pillow lavas have been assigned formal names because they are mappable units that are widely distributed. The lower of these two formations has been named the Robles and the upper the Cariblanco. The writers prefer not to assign formal names to the four formations making up the group of older, massive volcanic rocks until the units of regional significance have been distinguished from those of only local extent. These four formations are, therefore, tentatively given the informal names of formation A to formation D in ascending order. The Robles formation in the group of well-bedded rocks contains four tongues that are mappable units and have been given informal names. The formations in the group of massive volcanic rocks have also subdivided into mappable units, but most of them so intertongue that only broadly generalized units were mapped and, with the exception of a limestone in formation D, these were not named. Some of the thicker and more distinctive lava flows in the group of massive volcanic rocks have been delineated fairly accurately, but even this proved difficult because lenticular tongues of flow are so interfingered with volcanic breccia that lateral correlations are likely to be uncertain. Because of the intimate intercalculations of the flows and other volcanic rocks, the contacts shown on the map are generalized. The areas shown as underlain by flow are useful areas in which flows are predominant. Moreover, some thin flows are present in the undifferentiated parts of the formations. The combination of generalized mapping of the thicker flows and the taking of dip and strike on the bedded, finer-grained clastic rocks was found to be the most effective method of determining the overall structure of formations A, B, and C.

STRATIFIED ROCKS

Formation A (Ka)

Formation A is exposed over the eastern one-fourth of the Cayey quadrangle. These rocks strike in general toward the north, dip 10°–45° westward, and crop out from the southern to the northern boundary of the quadrangle. The formation extends east of the quadrangle and only the upper 1,675 meters crop out within the quadrangle.

Formation A is overlain by formation B from the southern edge of the quadrangle northward to a point just northeast of Iglesia Santa Marta, and from this point to the northern edge of the quadrangle, because of progressive overlap from the west by younger formations, formation A is overlain by formation C northward to a point just south of Highway 1 and by formation D from there to the northern boundary of the quadrangle. The contact between formation A and formation B in the Cayey quadrangle appears to be conformable, but farther south in the Central Aguirre quadrangle, the strike of the two formations is divergent and an angular unconformity is probable.

The strata making up formation A are interfingering, lenticular units of flow and flow breccia, volcanic breccia, conglomerate, sandstone, and siltstone. The stratigraphic relationship of these rocks is shown in figure 1. Some of the thicker flows and groups of flows have been mapped separately, Ka†, but the other types of volcanic rocks, including relatively thin flows, have not been differentiated.

In the east-central part of the quadrangle in Barrio Guamaní, Barrio Jájome Alto, and Barrio Culebras Alto, formation A consists mainly of thick flows and flow breccias, but includes also some units of volcanic breccia and a few units of conglomerate. Farther west, in the vicinity of Cayey, the rocks are chiefly flow breccias, and volcanic breccias this appreciably and are interbedded with sandstones and siltstones, in places in a cyclic pattern. The repetitive occurrence of flow, volcanic breccia or conglomerate, sandstone, and siltstone in a cyclic pattern, roughly in the order listed, is a feature distinctive to formation A. Although parts of the formation in both the northeastern and southeastern parts of the quadrangle seem to have been deposited cyclically, this feature is best developed in the southeastern part of the quadrangle south of the road to Pulguito Carmen and in the adjacent Cayey Aguirre and Guayama quadrangles. The cyclic character of formation A is not so well developed in the west, where succession of volcanic breccias and volcanic siltstones are exposed in continuous outcrops from the place the 260-meter contour crosses the stream southward and westward for a distance of almost a kilometer.

The succession of massive volcanic rocks that makes up formation A in the east-central part of the quadrangle represents deposition very near a source of volcanism, and the rocks may be in part subaerial deposits. The sandstones and siltstones that lie in the cyclic pattern with the flows and flow breccias are probably water laid. The cyclic repetition of flows, volcanic breccias and conglomerates, volcanic sandstones, and volcanic siltstones probably represents periodic variations in the intensity of the volcanism.

Flows and flow breccia (Ka†).—The best and most extensive outcrops of the flows and flow breccias in formation A are in the east-central part of the quadrangle along the banks of Río Jájome Alto and Río Matón. Most of the flows in formation A seem to be either andesites or basaltic andesites. These flows are typically porphyritic in texture; they contain phenocrysts of zoned plagioclase feldspar, amphibole, and pyroxene—in large part augite—in a microcrystalline groundmass. The feldspars and mafic minerals have been partly altered to calcite, epidote, or chlorite in many of the flows. Accessory minerals, which generally occur as sparsely disseminated, microscopic crystals, are hematite, magnetite, and pyrite. No pillow structure was found in any of the flows in formation A.

The rock makes up a part of many of the flows and its composition is similar to that of the other parts of the flow. Where possible in the east-central part of the quadrangle, the flow breccias were mapped with the flows, but some flow breccias probably occur in areas mapped as volcanic breccia.

The color of these rocks ranges from greenish gray to olive black. The oxidized parts of some of the flows and flow breccias are reddish brown. Because they are porphyritic many of the flows, especially those with feldspar phenocrysts, have a speckled appearance.

Volcanic breccia.—Outcrops of volcanic breccia, which are included in the undifferentiated volcanic rocks, occur at many places on the hills in the southeastern and northeastern parts of the quadrangle. In the southeastern part of the quadrangle they form the coarse, basal unit of the cyclically deposited rocks. Excellent exposures occur locally along the Río Seco, at and in the vicinity of the intersection of the Pulguito Carmen road and Highway 15, and along Highway 15 from the Casa del Gobernador southward for about 500 meters.

The volcanic breccia is thick-bedded rock composed principally of angular fragments of lava that range in size from a few millimeters to 10 centimeters or more. These fragments vary in shape from angular to subrounded, but most are subangular. The degree of roundness of the fragments varies considerably, and in places the volcanic breccias grade almost imperceptibly into conglomerates, so that sharp lines of demarcation cannot be drawn. The fragments in most of the breccias are tightly compacted, and the matrix generally makes up 25 percent or less of the total mass. Fleices of pelecypod shells and cobbles of limestone occur in the volcanic breccia that crops out in the bank of Highway 15 at the Casa del Gobernador.

Conglomerate.—The conglomerate in formation A differs from the volcanic breccia only in the degree of roundness of the fragments, indicating that during deposition it was probably worked by water slightly more than the breccia. It apparently makes up a much smaller percentage of the formation than the volcanic breccia. Although most of the coarse, basal units of the cyclically deposited rocks in the southeastern part of the quadrangle are volcanic breccias, some are just conglomerate. Excellent outcrops of conglomerate occur along Highway 15 about 600 meters south of the Casa del Gobernador and locally along the Pulguito Carmen road.

The conglomerate is thick bedded and is composed mostly of tightly compacted, poorly sorted, subrounded pebbles and cobbles of andesite. Cobbles and boulders of limestone and siltstone occur in the conglomerate in a few places, and thin lenticular beds of volcanic sandstone are locally interbedded.

Siltstone and sandstone.—The siltstone and sandstone occur only in the parts of formation A that crop out in the northeastern and southeastern parts of the quadrangle. In the northeastern part of the quadrangle these rocks crop out mainly across the eastern end of the low ridge that lies northeast of Quebrada El Cedro and across the northeastern part of Monte Llano. In the southeastern part of the quadrangle outcrops of the siltstone and sandstone occur along the Río Seco, in the bank of the Pulguito Carmen road, and on the hills near the southeastern corner of the quadrangle.

The siltstone and sandstone occur as lenticular units interbedded with volcanic breccia in the northeastern part of the quadrangle. The siltstone forms the upper part of the sedimentary cycles in the southeastern part of the quadrangle, and the sandstone in places forms a transition layer in the cycles between the breccia and siltstone.

The thickness of the siltstone units ranges from a few centimeters to as much as 25 meters. The sandstone units are generally somewhat thinner than those of siltstone.

The siltstone and sandstone are hard and compact, well bedded, laminated, and similar in composition to the volcanic breccia and conglomerate. The siltstone is slightly fissile/brittle, as indicated by fissility/brittle tests that were found in thin sections.

Tuff.—Although tuff fragments probably make up a considerable part of the volcanic rocks, not only in formation A but in the other formations as well, alteration during deposition has largely destroyed their character so that they are now hard to identify. In formation A, however, a layer of tuff 1 meter thick was found in a stream at the top of the waterfall on the Río Seco was identified by Earl Ingerson and R. L. Smith (personal communication) as a clastic tuff. Of special note is the fact that this rock contains an appreciable amount of orthoclase, which seems to be rare in other volcanic rocks in the Cayey quadrangle.

Formation B (Kb)

The rocks that make up formation B crop out from the southern boundary of the quadrangle northward to the southern part of Barrio Quebrada Arriba and westward across the northern part of Barrio Pozo Hondo to the western part of Barrio Quebrada Yeguas. In the southern part of Barrio Lapa near the southwestern corner of the map, formation B is exposed in several small, isolated inliers where the overlying formations have been eroded away. Rocks believed to be a part of formation B are also exposed just east of Hacienda Julia, where formation C has been removed by erosion.

The strata of formation B appear to be conformable, if not gradational, with the strata of formation A north of the Río Seco. South of the Río Seco and in the adjacent Central Aguirre quadrangle, however, the two formations appear to be separated by an angular unconformity; this unconformity is the primary basis for considering the two units separate formations.

Formation B is made up of flows and flow breccia, volcanic breccia, small amounts of sandstone, and a few lenticular beds of limestone. The lower two-thirds of the formation north of the Pulguito Carmen road is composed mostly of flows and flow breccia, and interfinger with volcanic breccia that makes up most of the upper third of the Pulguito Carmen Road. Interstratified thin flows, volcanic breccia, some sandstone, and a few thin lenticular beds of limestone make up the upper part of formation B. Figure 2 shows the stratigraphic relationship of these rocks. The rocks in this formation are similar in composition to those in formation A, but their distributive phenocrysts are smaller and also contains no siltstone. The thicker flows and groups of flows were mapped, but the contacts between these units and the clastic rocks are generalized. Some thin flows are included in the undifferentiated volcanic rocks.

The maximum exposed thickness of the formation is approximately 1,200 meters in the southern parts of Barrios Cerros and Quebrada Yeguas. North of Iglesia Sagrado Corazón, formation B is overlapped by formation C.

Flow and flow breccia (Kb†).—Most of the flows and flow breccia in formation B are very similar lithologically to those of formation A, but several flows somewhat different from the others crop out south of Pulguito Carmen Road. They appear to be andesites. Both the plagioclase phenocrysts are smaller and also fewer in number than in the other flows. The pyroxene crystals are also smaller and are commonly altered to chlorite and calcite. These flows are olive-gray on a fresh surface, but they generally weather dark yellowish brown. Instead of forming rounded boulders, these flows tend to break up into angular fragments. A flow of this type, having crude hexagonal jointing, crops out across the crest of the next ridge west of Cerro Canas. No pillow structure was seen in any of the flows in formation B.

Volcanic breccia and conglomerate.—These rocks are similar in composition to those in formation A, being composed chiefly of andesitic fragments. The volcanic breccias are thick bedded, and the sandstone forms thin, lenticular interbeds within the breccia. The volcanic breccia that crops out along the road to Pulguito south of the Pulguito Carmen Road and in the upper part of the formation northeast of central Barrio Quebrada Yeguas contain fragments that average 2 centimeters or more in size. Most of those that crop out along the Río Majada in the upper part of the formation, however, are smaller and consists of those ranges in some places are almost coarse sandstones.

Limestone (Kb).—A few thin, lenticular masses of bioclastic limestone are interbedded with coarse sandstones and thin flows in the upper part of formation B (see map). Tessellated fragments of corals and rudistids are present in the limestone, but generic and specific identifications of the specimens are not as yet available.

Formation C

The rocks in formation C crop out in an arcuate band that crosses the south-central, west-central, central, and northeastern parts of the quadrangle. The contact between formation C and formation B is believed to be unconformable. South of the Río Majada, beds in formation B appear to be truncated in places by basal flow rocks in formation C. North of the Río Majada, formation C apparently overlaps formation B, and in the northeastern part of the quadrangle formation C lies on formation A.

The rocks in formation C are exposed in approximately 1,550 meters in the central part of the quadrangle, but the formation thins toward the south and toward the northeast probably because of removal of the upper part of the formation by erosion before formation D and the Robles formation were deposited.

Massive flow and flow breccia and coarse volcanic breccia, in part stratified, are the predominant types of rock, and in contrast to formations A and B, formation C contains no siltstone and only a few thin, lenticular layers of sandstone. The units of flow and flow breccia and volcanic breccia are so intricately interfingered that mapping of individual units was impractical except in the broadest way. The rocks are well exposed in the Río Majada, where exposed but also contains several distinctive amphibolitic flows, as shown on the map.

North of the Río Majada, contacts are generalized and have been drawn to distinguish areas underlain chiefly by flow and flow breccia from areas underlain by other types of rocks. Flows and flow breccia are more abundant in formation C as a whole than any other type of rock. South of the Río Majada they make up most of the formation. North of the Río Majada, flows and flow breccia form most of the lower half of the formation and are intertongued with volcanic breccia in the upper half. The massive rocks are commonly porphyritic, but in a few places they are fine grained, well-bedded rocks indicate that the formation may represent, at least in part, subaerial deposition—possibly very near a center of volcanic activity.

Flow (Kc†) and flow breccia (Kc†).—The flows and flow breccia in formation C are similar to those in formations A and B. Most seem to be porphyritic andesites although some are probably basaltic andesites. Phenocrysts of plagioclase feldspar, amphibole, and pyroxene are present, but an abundance of large plagioclase phenocrysts is characteristic of the flows in formation C north of the Río Majada. Outcrops of this type of flow occur in the banks of Highway 1 just north of Capilla de Santa Marta near the western edge of the map and in the banks of Highway 15 for a distance of about 2 kilometers south of its intersection with Highway 1 in the northeastern quarter of the map.

The amygdaloidal flows south of the Río Majada, Kc†a, have been differentiated on the basis of textural variations and on differences in the composition of the amygdules. Most of them have a porphyritic texture and contain amygdules composed principally of calcite and chlorite and minor plagioclase feldspar. One of the amygdaloidal flows, however, is a very fine grained and lacks phenocrysts, Kc†a2. It crops out in two general areas: one about a kilometer east of Hacienda Julia and another large area between Hacienda Julia and the Río Majada. Another flow, which contains quartz amygdules, crops out along the base of formation C north of Hacienda Julia. Flow breccia has been mapped with the flows except for a distinctive unit that crops out both east and west of Hacienda Julia. Northwest of Hacienda Julia for nearly a kilometer this flow breccia separates the flow with quartz amygdules from the overlying flows with calcite and chlorite amygdules.

The only other amygdaloidal flows of any extent in the Cayey quadrangle occur in formation D at Cayey, and it is possible that the amygdaloidal flows south of the Río Majada may be correlatives of the flows in formation D.

In addition to plagioclase and mafic minerals, the flows in formation C contain small amounts of magnetite, hematite, chlorite, and epidote as alteration minerals.

The overall color of most of the flows and flow breccia in the formation varies from olive black to dark olive gray, but some of the flows are reddish brown on the oxidized parts of the flows.

Volcanic breccia (Kc†).—Except for a few thin to medium-bedded units, the volcanic breccias in formation C are massive, irregularly-stratified rocks consisting of angular to subrounded fragments that range from less than a centimeter to 40 centimeters or more in diameter. Excellent outcrops of these rocks occur on Peña Hendida and on other hills east of Quebrada Cimarrón near the south-central boundary of the quadrangle, on the hills northeast of Ralo del Buey, along the Río Lapa from the southern part of Proyecto Vázquez southward for more than 2 kilometers, and on the south side of Peñón de los Soldados where massive volcanic breccia forms the cliffs. Because of the intricate interfingering of volcanic breccia and sedimentary rocks, the contacts between bodies of volcanic breccia are included in the areas shown as flow.

The volcanic breccias are made up mostly of andesitic fragments, but they contain some rounded, vesicular masses which seem to be volcanic bombs. The volcanic breccia in formation C, although similar in composition to those in formations A and B, are in general more massive and contain larger fragments. These rocks are apparently subaerial deposits that accumulated very near a center of volcanic activity.

Formation D (Kd)

Formation D crops out only in the north-central part of the Cayey quadrangle in the vicinity of Cayey and on the ridges and slope adjacent to the Río Matón. Farther south along the northeastern side of the Río Lapa valley, the formation seems to be absent.

Formation D lies on formation A in the vicinity of Cayey, but it lies on formation C farther south. In general the formation thins toward the south to the point in Barrio Sumido where it is overlapped by the Robles formation. The formation appears to be thickest on the ridge that lies along the boundary between Barrio Quebrada Arriba and Barrio Sumido, but because of possible faulting in that area, an accurate thickness measurement could be made; the estimated thickness there is about 200 meters.

The principal constituents of the formation is highly weathered stone, which occurs at the base; flows, in part amygdaloidal; and volcanic breccia, which occurs at the top. Limestone in the Río Matón that seems to be formation D have a distinct reddish hue in many places, and where the basal limestone is absent, the formation was mapped mainly on the basis of the reddish color. The base of the formation is very indefinite from the northeastern part of Barrio Lapa southwestward, in part because of weathering and in part because outcrops are obscured in places by float, particularly on the southern side of Cerro Planada. The outcrops of formation D along Highway 1 south of the Río Matón have been strongly weathered and the Río Matón flows in the bed of a characteristic of the rocks is somewhat obscured. Almost continuous outcrops of the formation occur along the road to Barrio Cayey Dentro, beginning at a point 200 meters north of the Cayey quadrangle. At this locality the stratigraphy of the formation from the base to top is as follows: limestone at the base of the formation, interbedded calcareous volcanic breccia and coarse sandstone (approximately 25 meters thick); porphyritic andesite flow that contains many large phenocrysts of pyroxene (approximately 30 meters thick); bedded sandstone (1 meter thick); and amygdaloidal andesite flow, brecciated in the upper part (approximately 100 meters thick).

Agua Buenas? limestone member (Kdl).—Benson (1915, p. 13) correlated the limestone Aguas Buenas limestone to outcrops of limestone that are located 2 miles south of Aguas Buenas, which is about 17 kilometers northeast of Cayey. This limestone also crops in the Comerío quadrangle between Aguas Buenas and Cayey. The lenticular limestone member at the base of formation D is correlated with the Aguas Buenas limestone of Benson.

In the Cayey quadrangle the Aguas Buenas limestone member crops out in three separate areas all in the vicinity of Cayey. The limestone enters the Cayey quadrangle from the adjacent Comerío quadrangle on the north side of Monte El Gato and extends around the hill into the quarry located in the U. S. Military Reservation. From there southwestward it is missing for a distance of about 250 meters along strike, but it crops out again along the eastern edge of Cayey. The third and southernmost area of outcrop is located on top of the high ridge about 2.5 kilometers south of the Cayey Plaza.

The thickness of the member in the Cayey quadrangle ranges from a few centimeters to about 7 meters or perhaps more.

The limestone is massive and fossiliferous, containing at most places mollusks and corals. In the quarry in the military reservation, the limestone is thin bedded and contains numerous fragments of crinoid stems and a very thin lens of coal which appears to be pure vitrain.

Tuffaceous sandstone and siltstone (Kdsv).—Overlying the Aguas Buenas limestone member in the military reservation quarry is a unit of medium-bedded, coarse-grained, calcareous, friable, tuffaceous sandstone, which is about 4 to 5 meters thick. The sandstone grades westward into medium- to thick-bedded, calcareous volcanic breccia, which is well exposed along Quebrada Santa Domingo north of Cayey, and it apparently grades eastward into nonbedded, reddish volcanic breccia, which crops out to the south of the quarry in the U. S. Reservation.

Flow.—The flows in formation D are either andesites or basaltic andesites which occur mainly in the upper part of the formation. North of Highway 1 the upper part of formation D consists of two distinctive flows separated by a thin layer of sandstone. The lower flow is characterized by large pyroxene phenocrysts. Its base is intricately intermixed with the underlying volcanic breccia, and its top contains calcite amygdules. The upper flow, which is thicker and more extensive, is characterized by an abundance of calcite amygdules in its upper half. The upper flow crops out from the north boundary of the quadrangle west of the contact that is shown on the map with the crash of Capilla de Santa Marta and along the Río Jájome and the Río Majada for most of Hacienda Clavell. Terrace deposits also occur along the streams in the southern part of the quadrangle, but they are too small to show on the map. Stream-cut terraces, from which the alluvium has been removed by erosion, lie along the east side of the Río Jájome just northeast of Hacienda Clavell and along the east side of the Río Lapa just south of Capilla de Santa Marta.

The alluvium in the beds of the large streams and on the few flood plains and terraces is made up mostly of silt, sand, gravel, and small to medium boulders, but many large gravel and cobble boulders lie along the upper courses of the main streams and their principal tributaries. These boulders were probably derived in part south of the Cordillera Central-Sierra de Cayey.

Alluvial-fan deposits (Qf).—Alluvial fans are restricted mainly to an area just east and southeast of Cayey where they have been built along the north side of Monte Llano. These fans, which have coalesced to form a small piedmont fan, are composed chiefly of a mixture of silt, fine sand, cobbles, and small boulders. The boulders are confined mainly to the part of the fan that lies nearest the hill. The streams that built these fans are now incised, and the fans are being dissected. Other small alluvial-fan deposits that are contiguous with the extensive alluvial-fan deposits that border the Caribbean Sea lie along the southern boundary of the quadrangle. Several small fans are mapped with the deposits of alluvium adjacent to the Río Lapa south of Capilla de Santa Marta.

Colluvium and landslides (Qc).—Colluvium, which accumulates as a result of transportation by gravity, occurs mainly on the north side of Monte El Gato, on the slopes south of Las Tetas, on the slopes south and west of Vertedero, on the south slopes of Cerro Planada, and on the south side of Sierra de Jájome north of Cayey. Talus and other smaller deposits of colluvium are shown on the map.

The colluvial deposits on the north side of Monte El Gato consist in part of landslide debris and in part of large boulders that have moved downhill by normal creep. The colluvium near Las Tetas, Vertedero, Peñolas Carmen, and on Cerro Planada is made up mostly of talus deposits of boulders and rock debris.

INTRUSIVE ROCKS AND VEINS

Masses of hornblende-quartz diorite, hornblende-gabbro(norite), and andesite crop out in the Cayey quadrangle in the form of small stocks, dikes, and sills. The diorite intrusives and perhaps the hornblende andesite dikes are younger than the youngest Cretaceous strata in the quadrangle, but many of the andesite dikes are probably older than the diorite intrusives and were emplaced during the periods of strong volcanic activity that built the lavas and flow breccias in the lower part of formation A. Veins of calcite and a few veins of quartz are locally associated with the volcanic rocks and with the intrusive bodies.

Hornblende-quartz diorite(Tmd).—The rocks that crops out near the northwestern corner of the quadrangle is a hornblende-quartz diorite and has a granitic texture. The primary minerals in order of their abundance are plagioclase, quartz, hornblende, biotite, magnetite, and orthoclase. Accessory minerals are zircon and apatite. Autoliths that are locally present are richer in hornblende than the hornblende-quartz diorite in which they are enclosed.

Several small bodies of intrusive rock crop out to the east and south of the large body in the Río Matón valley and are believed to be genetically related to the larger body of hornblende-quartz diorite, the smaller masses of intrusive rock seem to be porphyritic hornblende-pyroxene diorite.

Hornblende-magnetite diorite(Tmd).—The small stock that crops out in the Río Jájome in Barrio Río Matón is a diorite that is composed essentially of plagioclase and hornblende, but contains in addition an appreciable amount of magnetite and, therefore, is classified as a hornblende-magnetite diorite. The higher percentage of magnetite and the dark color distinguish this intrusive mass from the others in the Cayey quadrangle. Because of its dark color, it is conspicuous on the aerial photographs.

Diorite(Td).—The very small stock near the southeastern corner of the quadrangle, the dikes along Quebrada Carmen northwest of Pulguito Carmen, and the dikes along the south-central boundary of the quadrangle are diorites having a granitic texture. Plagioclase makes up about 50 to 60 percent of these rocks and ferromagnesian minerals about 20 to 25 percent. Pyroxene, which has been partly uralitized, is the principal mafic mineral, but biotite is present locally. Other constituents in these rocks are magnetite, chlorite, orthoclase, and a very small amount of quartz.

The dikes that crop out near the south-central boundary of the quadrangle are probably offshoots from the stock that crops out in the Río Jájome in the northeastern continuation of the series of alluvial terraces that overlap the Río Lapa just south of Capilla de Santa Marta. Most of the dikes are 100 meters thick in the north-central part of the quadrangle but thins toward the southwest, where it is interrupted with the Lapa lava member and consists of three tongues one lies beneath the lava, another is places separates the two flows making up the Lapa lava member, and a third tongue overlies the lava. The lower and middle tongues pinch out southwestward from Hacienda Clavell.

Lenticulated siltstone is the chief component of the member, but it also includes layers of sandstone and volcanic breccia. In places it includes at the top a distinctive conglomerate.

No megafossils were found in the Cayey siltstone member but tests of foraminifers were found in thin sections.

Lapa lava member (Kcl).—The two basaltic andesite flows which make up the lower part of the Robles formation near the southwestern corner of the Cayey quadrangle, and which intertongue toward the south with the Cayey siltstone member, are named the Lapa lava member for exposures on the hills west of the Río Lapa in the Central Aguirre quadrangle, which is to the south. The type section, which is the U. S. Military Reservation, begins at the base of the hill at a point 1.2 kilometers N. 40° W. of the road intersection at Ralo del Buey and crops out on the ridge southwest. to Vertedero the conglomerate is truncated by a fault and lies in juxtaposition with the Las Tetas lava member of the Robles formation. Along the east side of the high ridge west of Vertedero the conglomerate is in deposition contact with underlying siltstone of the Collao member of the Robles formation. Capping the ridge and overlying the conglomerate is a thin, concordant igneous body that is probably a *flow, Kcl.*

The Cariblanco formation is a nearshore deposit and is characterized by massive sandstone. The formation is much more extensive to the west and to the northwest in the Coamo and Aguirre quadrangles than it is in the Cayey quadrangle, according to the Robles formation. (E. F. Briggs, written communication). The stratigraphic relationship of the Cariblanco formation to the Robles formation is shown in figure 3.

QUATERNARY

Surficial deposits

The Quaternary deposits of the Cayey quadrangle consist of unconsolidated silt, sand, gravel, cobbles, boulders, and angular rock fragments. They occur mainly as alluvium along stream beds and on narrow terraces adjacent to the streams, as alluvial fans, and as colluvium at the base of some of the steep slopes.

Alluvium (Qa).—The only extensive deposits of alluvium are along the lower course of the Río Lapa and the Río Majada, and along the Río de la Plata at the northeast corner of the map. The streams are youthful and generally lack flood plains. Therefore, the alluvium, with the exception of local terrace deposits, is confined to the beds of the streams. A thin veneer of alluvium covers Collao which has a maximum stratigraphic displacement of more than 350 meters. The Proyecto Vázquez fault strikes N. 65° E. the Río Matón fault strikes N. 45° W., and the Quebrada Collao fault strikes N. 80° W. The three large fault blocks that are in part bounded by the three major faults are subdivided into smaller fault blocks by subsidiary faults, some of which strike toward the northwest and others which strike toward the northeast. The town of Cayey is on the northernmost of the large downfaulted blocks. This block is formed by the intersection of the Río Matón fault and another fault which strikes N. 55° E. The second downfaulted block to the east of and adjacent to the Cayey block is bounded along the north side of the Río Matón fault, along the south side by the Proyecto Vázquez fault, and on the east by a fault just south of the Cordillera Central-Sierra de Cayey. The third fault block, which lies between the Proyecto Vázquez and Quebrada Collao faults, has been partly uplifted, in the principal mass of Monte Llano. The part of this block that lies between Las Tetas and Proyecto Vázquez has been cut into several irregularly shaped blocks. South-westward from Las Tetas each of these blocks has been dropped more than the one adjacent to it on the northeast. Just to the Proyecto Vázquez fault, therefore, rocks of the upper part of the Robles formation lie in juxtaposition to rocks in the lower part of the formation. The movement of all three of the large blocks was dominantly vertical, although some horizontal movement is probable on each of the blocks.

Many fractures and joints were seen in the southern, southeastern, and west-central parts of the quadrangle. Most of them strike either toward the northwest or toward the northeast. Hacienda Clavell Carmen, a tributary to the Río Jájome, is controlled by two sets of joints that follow this pattern, as do the dikes and veins that trend east and west of Vertedero, on the south slopes of Cerro Planada, and on the south side of Sierra de Jájome north of Cayey. Talus and other smaller deposits of colluvium are shown on the map.

The colluvial deposits on the north side of Monte El Gato consist in part of landslide debris and in part of large boulders that have moved downhill by normal creep. The colluvium near Las Tetas, Vertedero, Peñolas Carmen, and on Cerro Planada is made up mostly of talus deposits of boulders and rock debris.

INTRUSIVE ROCKS AND VEINS

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