GEOLOGY OF QUADRANGLES H-12, H-13, AND PARTS OF I-12 AND I-13,
(ZONE III), IN NORTHEASTERN SANTANDER DEPARTMENT, COLOMBIA

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GEOLOGY OF QUADRANGLES H-12, H-13, AND PARTS OF I-12 AND I-13,
(ZONE III), IN NORTHEASTERN SANTANDER DEPARTMENT, COLOMBIA

By
Dwight E. Ward and Richard Goldsmith
U. S. Geological Survey

and

Jaime Cruz B. and Hernan Restrepo A.
Instituto Nacional de Investigaciones Geológicas-Mineras
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ABSTRACT

A program of geologic mapping and mineral investigation in Colombia was undertaken cooperatively by the Colombian Instituto Nacional de Investigaciones Geológicas-Mineras (formerly known as the Inventario Minero Nacional), and the U. S. Geological Survey, sponsored by the Government of Colombia and the Agency for International Development, U. S. Department of State. The purpose was to study and evaluate mineral resources (excluding of petroleum, coal, emeralds, and alluvial gold) of four selected areas, designated Zones I to IV, that total about 70,000 km². The work in Zone III, in the Cordillera Oriental, was done from 1965 to 1968.

The northeast trend of the Cordillera Oriental of Colombia swings abruptly to north-northwest in the area of this report, and divides around the southern end of the Maracaibo Basin. This section of the Cordillera Oriental is referred to as the Santander Massif.
Radiometric age determinations indicate that the oldest rocks of the Santander massif are Precambrian and include high-grade gneiss, schist, and migmatite of the Bucaramanga Formation. These rocks were probably part of the Precambrian Guayana Shield. Low- to medium-grade metamorphic rocks of late Precambrian to Ordovician age include phyllite, schist, metasiltstone, metasandstone, and marble of the Silgará Formation, a geosynclinal series of considerable extent in the Cordillera Oriental and possibly the Cordillera de Mérida of Venezuela. Orthogneiss ranging from granite to tonalite is widely distributed in the high- and medium-grade metamorphic rocks of the central core of the massif and probably represents rocks of two ages, Precambrian and Ordovician to Early Devonian. Younger orthogneiss and the Silgará are overlain by Middle Devonian beds of the Floresta Formation which show a generally low but varying degree of metamorphism. Phyllite and argillite are common, and infrequent marble and other calcareous beds are fossiliferous. Except for recrystallization in limestones of the Permian-Carboniferous Diamante Formation, sedimentary rocks younger than Devonian are unmetamorphosed.
The effects of Precambrian regional dynamothermal metamorphism and plutonism on Precambrian geosynclinal deposits reached the upper amphibolite facies in the Bucaramanga Gneiss. The geosynclinal Silgara Formation was subjected to similar conditions in Late Ordovician and Early Silurian time but reached only the greenschist or lower amphibolite facies. Orthogneisses generally show a concordance of foliation and lineation with the neighboring Silgara Formation and the Bucaramanga Gneiss, as well as similarities in grade of metamorphism. Regional dynamothermal metamorphism in Late Permian and Triassic time reached low grade in the Floresta Formation and caused recrystallization of limestone of the Diamante Formation. The Bucaramanga and Silgará metamorphic rocks show evidence of retrogressive metamorphism accompanied by high activity or potassium and water, but whether this occurred at the time the Floresta was metamorphosed or later is not clear.

Batholiths, plutons, and stocks of igneous rocks in the Santander massif range from diorite to granite. Radioactive age data indicate that most belong to a single plutonic interval. These are referred to as the Santander Plutonic Group and are Jurassic and Jurassic-Triassic. Two suites of this group are pink granite and quartz monzonite, and gray quartz monzonite and granodiorite. Contact relations indicate that the pink and more granitic rocks are younger than the gray and more mafic rocks, but radioactive age data are in conflict with this. Undated plutonic rocks that are not clearly related to the group are assigned to relatively older or younger age positions.
West of the Bucaramanga fault rhyolite makes up a small body at one locality and forms an intrusive sheet with granophyre and intrusive breccias in Triassic sedimentary rocks at another locality. Its age is unknown, but it probably is younger than the Santander Plutonic Group.

Felsic, mafic, and lamprophyric dikes are common in the batholiths, plutons, and adjacent rocks, and most appear to be genetically related to the larger igneous bodies, whereas rarer dikes of dacite porphyry, basalt, and diabase are not related. Basalt and diabase dikes are widely scattered and have been found nearly as high in the section as the Jurassic-Cretaceous boundary. Dacite porphyry is the only igneous rock that intrudes Cretaceous rocks.
With the uplift that accompanied emplacement of batholiths in Latest Triassic and Jurassic time, erosion of the roof rocks furnished fine-grained redbeds and conglomerates of the Jordán Formation, followed by erosion of the batholiths themselves that provided the coarse-grained and conglomeratic arkosic sediments of the Giron Formation in thick accumulations off the flanks of the uplift. This period was followed by marine invasion and sedimentation of the Cretaceous period. In the Magdalena Valley area, Lower Cretaceous sedimentation began with quartz sands of the Tambor Formation and continued with fossiliferous limestone of the Rosa Blanca Formation, black shale of the Paja Formation, fossiliferous limestone, glauconitic sandstone and black shale of the Tablazo Formation, and still more black shale of the Simití Formation. In Late Cretaceous time, calcareous black shale with chert and phosphatic beds in the upper part of the La Luna Formation were deposited during the time of most widespread marine transgression. Thereafter gray shale and limonitic beds of the Umir Formation accumulated as marine conditions were gradually succeeded by continental deposition including coal beds in the latest Cretaceous.

Cretaceous deposits over the area are mostly uniform in character if not in thickness, and remnants of these rocks that have escaped erosion in the massif are similar to the Cretaceous rocks of the Magdalena Valley to the west and the Maracaibo Basin to the east.
Continental conditions prevailed in the Magdalena Valley area through the Tertiary, with the deposition of sandstone, shale, and coal beds in the Paleocene Lisama Formation; followed in the Eocene by thick conglomeratic sandstone of the La Paz Formation and sandstone, siltstone, and shale of the Esmeraldas Formation; in the Oligocene by shale of the Mugrosa Formation and shale with coarse conglomeratic sandstone of the Colorado Formation; in the Miocene by even coarser and thicker deposits of the Real Group; and continuing into the Pliocene and Pleistocene with the Mesa Group. Most of the section of Tertiary rocks in the Colombian part of the Maracaibo Basin is similar in origin and lithologic character but is thinner than that in the Magdalena Valley. These rocks were eroded from, or were never deposited, in the area that is now the highest part of the massif.

Alpine glaciation occurred on the Santander massif during the Pleistocene, and widespread terraces in the lower valleys may date from this period. Orogeny is probably at or near its highest level at the present time, with streams eroding the flanks of the massif at a high rate, aided by deep weathering and landslides.

The Bucaramanga fault, a major fault of regional extent, trends north-northwestward across the area. It apparently extends to the north coast as the Santa Marta fault, defining the western boundary of the Santa Marta Mountains. The investigations reported here indicate a long and complex history for the Bucaramanga fault, from early lateral displacement followed by uplift of the Santander massif to the east that continues to the present time.
West of the Bucaramanga fault are three areas of rather distinct structural character: 1) A wedge-shaped, down-faulted block between the Bucaramanga and Suárez faults is mostly an area of mesas, tilted slightly westward, and capped by basal Cretaceous sandstone. At the thin north end of the wedge, Quaternary gravels and mudflows accumulated in the fault-formed basin and now form the dissected terrace on which Bucaramanga, the main city of the region, is located. 2) A plateau belt bordering the mesas west of the Suárez fault consists mostly of dissected beds, undulating to steeply dipping, of the thick Girón Formation. 3) West of the plateau area all sedimentary rocks from Jurassic to Tertiary plunge westward into the deep trough of the Nuevo Mundo syncline. This narrow syncline is on the deeper eastern side of the geosynclinal area of the Magdalena Valley basin. Most of it is separated from the shallower part of the geosyncline to the west by the north-trending La Salina fault, which places Upper Cretaceous rocks on the east side in contact with Oligocene and Miocene rocks on the west.

In the high country that continues south and east of the metamorphic and igneous rocks of the Santander massif, two north-trending structural basins are separated by the regional Servitá fault. The western basin contains sedimentary rocks ranging from Devonian to Upper Cretaceous and is complexly faulted. Rocks of the eastern basin range from Lower Cretaceous to Eocene and have undergone compressional folding that is more intense toward the west.
Many faults were mapped to the east and west of the Bucaramanga fault, and many more are indicated by lineaments on aerial photographs. Most have trends within a range of north-northeast to north-northwest, mostly parallel to the trend of structure. Only a few major faults cut across this trend. On the east and west flanks of the Santander massif, belts of sedimentary rocks that include mostly Cretaceous formations have escaped erosion on the downthrown sides of long faults. On the east flank the downthrown sides are on the west, and on the west flank the downthrown sides are on the east, which suggests either more active uplift of the flank areas or collapse of the central area relative to the flanks.
INTRODUCTION

Purpose and scope

The southern half of Zone III of the Colombia Inventario Minero Nacional (IMN), is principally in the Department of Santander, but also embraces small parts of the neighboring Departments of Norte de Santander and Boyaca (fig. 1). Zone III is one of four areas in Colombia selected for mapping and field investigations. The work was conducted by the Inventario Minero Nacional, now included as part of the Instituto Nacional de Investigaciones Geológico-Mineras (INGEOMINAS), an agency established under the Ministry of Mines and Petroleum of the Colombia Government to work in collaboration with the United States Geological Survey (USGS). The work was partly financed by the Agency for International Development, U. S. Department of State.

This report is concerned with the southern half of Zone III and summarizes results of mapping and investigations made during the period October 1965 to September 1968. The area covered includes all or parts of four quadrangles of the Colombia Gauss grid system: H-12, H-13, I-12, and I-13 (fig. 2). The geology of the area is shown in plate 1. The total area mapped is 10,370 square km.
FIGURE 1. Index map showing the area of the southern half of Zone III of the Inventario Minero Nacional, Colombia.
History of the Project

Four Colombian geologists and a USGS advisor (D. E. Ward), began field work October 30, 1965, in Zone III. The group was very fortunate to have the company of Dr. Jaime de Porta, geologist of the Universidad Industrial de Santander, on initial trips to become familiar with the sedimentary geology. Richard Goldsmith, advisor in igneous and metamorphic geology, joined the group in December 1966. The number of geologists assigned to the Zone III area ranged from 13 to 17.

In January 1966, field work was started in the Surata area northeast of Bucaramanga. From there the mapping was expanded into the surrounding area by assigning specific areas to each geologist. Also in 1966, a photogeologic map of Zone III was completed by Geophoto Services, Inc., under a contract with IMN. In the later part of the contract period, all geologists in the zone were assigned to a one-month field check of the preliminary photogeologic maps. Although deep weathering, vegetative cover, and locally complex structure prevented accurate photogeologic mapping of many parts of the zone, the final photogeologic maps were helpful in field mapping and in interpretation of regional structure.

A reconnaissance of phosphate rock in Colombia was made in the second half of 1966. When it became evident that major resources of phosphate rock are present in Zone III, phosphate investigations were later assigned to a separate group within IMN.
Acknowledgements

The material presented in this report was gathered by the following geologists of INN-INGEOMINAS who worked much of the time under difficult conditions, and but for whose perserverance and enthusiasm the report would not have been possible:

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The authors express their appreciation and gratitude to Drs. Eduardo Sánchez, Gilberto Manjarres, Andrés Alvaro, Hernán Restrepo, and Jaime Cruz, who at various times were Colombian counterparts supervising Geologists, for their smooth and efficient management of the work, in the Zone.

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Geography

Location and access

Except for the northwestern side of the Zone which extends to
the Magdalena Valley, most of the southern half of Zone III lies in
the Cordillera Oriental of the Andes in northeast Colombia (fig. 1).
This region of the Cordillera Oriental is referred to as the
Santander massif. The Santander massif is just northwest of where
the Cordillera Oriental changes trend from northeast to northwest,
and in a sinusoidal plexus where the Cordillera branches into the north-
ward-trending arc of the Serranía de Perija that forms the boundary
between Venezuela and Colombia and the northeast-trending Cordillera
de Merida of west-central Venezuela.

The south half of Zone III is relatively well covered by roads
(fig. 2). The main north-south highway from Bogotá to the coast at
Santa Marta follows the east side of the range and passes through
Bucaramanga. This highway is paved within the zone. It is located
along the trace of the Bucaramanga fault through much of the map area.

A paved east-west highway passes through Bucaramanga from
Barranquilla on the Magdalena River across the Santander massif to
Pamplona, Cúcuta, and into Venezuela. On the east side of the
range, and partly outside the zone, is a major unpaved north-south
highway from Pamplona to Bogotá. This highway provides access to the
east side of the Zone along most of its length.
Smaller unpaved roads cross the range in the southern part of the zone to connect the main highways. The piedmont slopes to the Magdalena in the northwestern part of the area (H-12) on the western side of the Magdalena Valley are relatively inaccessible. The right-of-way of the Ferrocarriles Nacionales which passes down the Lebrija gorge to the Magdalena Valley provides some access to this country. Short dead-end roads lead from the principal roads to some of the smaller towns.

Most of the area between the roads is accessible only by mule, horse, or foot. No place in the zone is more than a day's ride or walk from a road.
Topography, drainage, and climate

The southern half of Zone III can be divided into several topographic regions. (1) One is the massif proper which comprises the main high range, and slopes to east and to the west as far as the break in slope at the Bucaramanga Front. (2) Another is the somewhat lower drainage basin of the Río Chicamocha to the south and southeast. Altitudes of ridges in this basin range from 2,000 to 2,600 m, whereas the river flows from 1,200 to 500 m northwesterly across the range. (3) Another region includes the mesas which extend from Bucaramanga to the southern limit of the zone and which border the main high range and the Chicamocha basin on the west. These are, from north to south, the Mesa de Ruitoque, Mesa de Los Santos, and the Mesa de Barichara; they range from 2,250 to 1,300 m. The basin in which Bucaramanga lines at about 1,000 m and the valleys between the mesas are considered to be part of the region of the mesas. (4) A fourth region includes the plateaus west and northwest of Bucaramanga and west of the region of the mesas, and the ridges and valleys west of the plateaus. General altitudes here are 1,200 to 1,000 m. (5) The fifth region is the Magdalena Valley, at an altitude of 100 m.
The massif forms a three-way divide between the Río Magdalena drainage to the Carribean Sea on the west, the Río Zulia-Río Catatumbo drainage into Lake Maracaibo and the Caribbean Sea on the northeast, and the Río Orinoco and the Atlantic Ocean on the east. The principal rivers draining the massif into the Magdalena are Río Chicamocha and Río Suarez which combine to form Río Sogamoso west of the Mesa de Los Santos (pl. 1). Only a small part of Río Suarez lies within the zone.

North of the Río Chicamocha-Río Sogamoso drainage is Río Lebrija with its major tributaries: Río de Ora, draining the mesas and the front of the massif south of Bucaramanga, and Río Surata, Río Negro, and Río Cachiri draining the west front of the massif north and northeast of Bucaramanga.

Río Chicamocha is the dominant stream draining the southern part of Zone III. It flows roughly northwest out of the massif; its larger tributaries, Ríos Manco, Umpala, Perchiquez, Guaca, and Servita flow into it from the north and north-east. Only Río Onzaga flows into it from the south. South-flowing Río Servita is the largest tributary of the Chicamocha and drains much of the east side of the zone.
Only the headwaters of Río Zulia drainage are within the southern half of Zone III. The principal streams are Río Cucutilla and its tributaries which drain the northeast side of the Paramo de Santurban, and Río Parlonita, draining the Pamplona area.

Drainage into Río Arauca is by way of Río Chitana and its tributaries the Río Caraña, Río Augosturas, and Río Santo Domingo which taps a relatively small area from the south side of Paramo de Santurban and the general Berlín area, southeastward on the east side of the zone to the Paramo del Almorzadero which forms the divide with Río Servita-Río Chicamocha drainage.
At any given altitude the temperature changes little with the season. The range indiurnal temperature varies only slightly from cloudy to sunny season. Mean annual temperatures at altitudes lower than Bucaramanga at 1,000 meters range from 23° to 27°C. Temperatures at Bucaramanga range from 27°-28°C. In the high paramo at altitudes of 3,200 to 3,500 meters, mean annual temperatures are 7° to 10°C.

Rainfall varies seasonally and in total amount from place to place. In the Bucaramanga area total annual rainfall is about 1,000 to 1,500 mm. In the canyon of Rio Chicamocha, annual rainfall is about 500-1,000 mm. Only on the higher flanks of the range and in the southern part of the zone is annual rainfall about 1,500 to 2,000 mm.

The largest amount of rain throughout most of the zone falls in two seasons with maxima in May and October. Little rain normally falls during December, January, and February.

The paramo is cloudy during most of the year. Precipitation is sometimes in the form of snow at elevations near 4,000 meters or higher. However, no records are available for this area. Sub-freezing temperatures are not uncommon during the clear nights of the dry season.
Culture

Cucaramanga, with a population of about 220,000 (1964) is the largest city in the zone and is the center for industry, trade, and transportation. Regularly scheduled airline service is available with other cities of Colombia and with some smaller towns in Santander and Norte de Santander. Good roads connect Cucaramanga with Bogotá, the cities of the Caribbean coast and with Venezuela to the northeast. A branch line of the Ferrocarriles Nacionales de Colombia connects Cucaramanga with the main Bogotá to Santa Marta line in the Magdalena Valley.

In Norte de Santander, Pamplona, an educational center of about 20,000 inhabitants, is the next largest city in the southern half of Zone III. Numerous smaller towns of less than 7,000 inhabitants are scattered over the zone mainly near Cucaramanga and to the southeast in the upper reaches of Rio Chicamocha and its tributaries. Most of the population is rural. The most thinly populated sector is the high paramo above 3200 meters and the zone of cloud forest below this, down to about 2700 meters. The bulk of the population lives at altitudes below 3500 meters.
Farming is an important occupation and potatoes and onions are the principal crops in the highlands, some attention recently being given to raising sheep. In the mountain slopes at lower elevations, fiber for rope, twine, and bags is grown, and at slightly lower elevations, coffee. Fruits and vegetables of many kinds for the local market are raised at intermediate and lower elevations throughout the zone. Most important are corn, yuca, legumes, and wheat. Pineapple is cultivated in the plateau country west of Bucaramanga and much is shipped to other areas. Sugar cane is an important product in the piedmont south of Bucaramanga and in the broader valleys at suitable low altitudes elsewhere in the zone. Tobacco is also a major crop, and manufacture of cigarettes and cigars is an important industry. The dairy industry is scattered in small farms and ranches throughout the zone. Beef cattle are raised chiefly in the lower elevations, particularly in the piedmont of the Magdalena Valley.
Exposures

The slopes of the range vary from heavily wooded to cleared with many small farms. The lower limit of forest is apparently being driven upward as the expanding rural population clears land for new farms at continually higher elevations. Cloud forest is now largely limited to the less accessible areas above 2,500. This wooded zone between the treeless paramo at about 3,100 and the cultivated lower slopes has been breached at many places, usually in the areas of major roads. More forest remains on the west slope of the range than on the east slope within Zone III, except in the headwaters of Río Cucutilla in northern H-13. Exposures are poor in the forested areas and movement is extremely difficult. Slopes are steep and streams are usually choked with vegetation. Some streams have abundant outcrop, but others are filled with rubble. Cascades and waterfalls are common in small streams and at the headwaters of nearly all streams, making ascent difficult.

Deep weathering is characteristic, with the greatest depth of weathering on hilltops and spurs at elevations of 1500 to 2500 meters. This was particularly noticed along the Bucaramanga front. Somewhat fresher rock is exposed on lower slopes along the front near Bucaramanga where erosion is currently active.
The canyon of Río Chicamocha and the drainage area around it lie in a partial rain shadow and the climate is semi-arid. Here the vegetation is sparse and xerophytic, the soil less deep, and outcrops somewhat more abundant. In part, of course, the relative abundance of outcrop is the result of the deep dissection by the river. The barrenness of much of the Chicamocha drainage area east and southeast of Pescadero is due in part to high permeability of the granular soil derived from granite. However, south of the Chicamocha basin at higher elevations there is more rain, and the forest cover increases. The extreme south part of the zone is heavily wooded and exposures are poor.

The southeastern corner of the zone north and south of Malaga is relatively open with little forest. This is primarily farming country, and exposures and access are relatively good. Local relief, however, is as much as 1000 meter.

The country above the tree line (about 3100 meters) is relatively open. Outcrops are fairly abundant, especially in the more dissected parts and where glaciation has scoured off weathered rock.

Alluvial fill of Pleistocene and Holocene age covers bedrock in some of the larger valleys and basins, such as in the Bucaramanga basin, in the Guaca area, and near Mogotes. However, as most valleys are narrow with steep sides, such fill is not generally a problem.
The area of mesas south of Bucaramanga offers good exposures in open country, readily accessible except for some of the steeper canyons walls of Ríos Chicamocha, Suarez, and Sogamoso and their tributaries. The plateau country west of Bucaramanga is similarly open, at least in the Lebrija area. However, farther north, west, and northwest, the country is extensively covered with brush and forest on the slopes. Farms are mainly on the ridges. Río Lebrija and its tributaries have cut canyons into this country with slopes covered in part by forested land-slide debris. Exposures are good in many of the gorges, but they are rather inaccessible. The railway right-of-way provides access down the Lebrija gorge. Toward the Magdalena Valley farms alternate with forest and the climate is hot and humid.
Previous Work

The gold mining area of California and Vetas has been known and worked since the 16th Century, and was apparently worked by Indians in pre-Colombian times. An entertaining as well as scholarly summary of the literature on gold region in Santander prior to the 20th century has been made by Vicente Restrepo (1888, republished in 1937). Mention is made of the mines, but with little detail, by Modesto Bargallo (1955) in his book on mines and mining in Spanish America during the Colonial epoch.

Recent literature on economic deposits in the zone is not particularly extensive. Many of the reports are general or summary reports such as those by Singewald (1950) and Nokittel (1957) in which mineral localities were reported from a variety of secondary sources. Radelli (1961) in a theoretical paper attempted to relate the epochs of mineralization with magmatic deposits over the entire Colombian Andes.

Most of the studies are of individual mines or prospects, investigated briefly, such as the report by Gilberto Botero R. (1945). A few individual mines or prospects were investigated intensively. The gold mining area of California and Vetas has received by far the most attention (Nokittel, 1954; Nelson, 1955; Pagnacco, 1962; Arce, 1951; Bueno, 1955a, 1955b; Champetier de Ribes and Alvarez, 1961). Reports on nonmetallic minerals in Santander have been made by Martinez (1962, 1964) on lime, gypsum, and barite deposits; and by Jimeno and Yepes (1963) on gypsum deposits near Los Santos. A survey of phosphate deposits of Colombia by Cathcart and Zambrano (1967), with reference to the deposits within the area has been recently published.
Relatively little work has been done on the general geology of the Santander massif. Until recently only passing references have been made to the geology of the massif by Hettner (1892), Stille (1907), Eugster (1922), Scheibe (1938), Oppenheim (1914), and Trumpy (1943). These men either made brief tours or described areas of the Eastern Cordillera primarily south of the Santander massif. Hettner (1892, p. 15-30) gives an excellent account of the early discoveries and scientific expeditions into the Eastern Cordillera and describes briefly two profiles across the area of the Santander massif. More recently Burgl (1959, 1961, 1964) and Radelli (1961, 1962) have made observations on the stratigraphy of the Eastern Cordillera including the Santander region. Julivert (1958, 1959, 1961a, 1961b, 1963) is probably the first to do any detailed geologic work in the massif. Some of his work deals with the structure and crystalline rocks of the massif, particularly the area near Bucaramanga. This work is summarized in a recent regional synthesis (Julivert, 1970).

Probably the first map to show the geology of the massif was the 1944 Geologic Map of Colombia compiled by the Servicio Geologico Nacional at a scale of 1:2,000,000. A later revised edition of the map compiled by H. Hubach and L. Radelli with the cooperation of H. Burgl, was published at a scale of 1:1,500,000 in 1962. These maps are, of course, very general.
Mapping of small areas near Bucaramanga has been done by faculty and students of the Universidad Industrial de Santander. Recent maps at a scale of 1:50,000 chiefly of sedimentary rocks have been made by Julivert, Barrero, and Navas (1964) in the Mesa de Los Santos area and by Tellez (1964) of the contiguous Mesa de Barichara area to the south. More recently, F. Cediel (1968) has made a study of the Girón Formation at the type section along Río Lebrija and in adjacent areas.

The areas of sedimentary rocks in and flanking the Magdalena Valley have been studied intensively by geologists of oil companies holding concessions in the region. Although not published, their work has been incorporated in the geologic maps of Colombia (Servicio Geologico Nacional, 1944, 1962).
Present investigations

In order to provide a systematic and adequate geologic background for evaluation of possible mineral deposits encountered in the zone, a program of regional geologic mapping was established. The mapping was done by geologists, each assigned individual planchitas measuring 10 to 15 km. Base maps used in the field and for primary compilation were preliminary topographic maps at a scale of 1:25,000, and contour interval of 50 meters or 25 meters published by the Instituto Geografico Agustin Codazzi, Bogota. Field mapping was expedited by use of aerial photographs at a scale of 1:60,000.

One geologist, usually with an assistant, mapped a planchita in from one to two, or rarely three months. The time spent per planchita depended on access, relief, complexity of the geology, and the experience of the geologist. The field assistant arranged for local guides, handling mules, clearing trail, transporting samples, and other tasks. Periods of field work lasted 20 to 30 days but at times lasted as long as 50 days.
Traverses were made along trails and streams. Trails are abundant and provided rapid coverage. However, generally only weathered rock can be seen and outcrops are few and generally slumped. On the other hand, the soil and rock chips exposed and churned up in the trails by the hooves of horses and mules provide a fairly continuous look at the lithology of underlying rock, if not at the structure.

Streams were variably useful. Some are so steep and filled with brush, and cascades and waterfalls are so common, that the time spent on such a stream did not justify the result of the traverse. Some streams have abundant outcrops, but others are filled with alluvium or colluvium. In some places adjacent streams show quite opposite characteristics. The larger streams, excluding the main rivers, at low altitudes were the easiest to traverse. At low water these are more satisfactory than at high water, when outcrops are covered and the swift current and large volume of water prohibited wading. In general, the smaller streams and the heads of streams are too steep and forested to be of use in traverse.

Streams in the high paramo, where not filled with terrace or glacial deposits, provide excellent exposures. The dissected paramo in the north part of the area offers good exposures, but steep gradients of streams in the headwater areas and the jagged character of the ridges make considerable scrambling necessary.
About 700 thin sections were made; however, few geologists had the time or petrographic training to make a study of them. Most petrographic description was done by the technical advisors.

Photogeologic maps of the zone at a scale of 1:50,000 were prepared under contract by Geophoto Services, Inc. These proved to be useful in outlining general distribution of igneous and metamorphic versus sedimentary rocks and in indicating the location of possible faults and lineaments to be checked in the field. They were not particularly helpful within areas of metamorphic rocks.
Localities of minerals or rocks of possible economic value encountered during the mapping were noted and briefly checked during mapping. Detailed investigations and evaluations were made at the completion of the mapping phase of the program. This work usually consisted of detailed sketch mapping and sampling, and the measurement of stratigraphic sections if warranted. Mineral investigations on the California and Vetas gold mining area were carried out by a special team who worked continuously throughout the duration of the project. Preliminary semi-quantitative geochemical sampling was done in the California area and at two lead-zinc prospects in the southern part of the zone. No geophysical work was done although a geophysical advisor visited several of the sites and offered recommendations. No drilling was done under the Inventario program, but a Japanese team carried out a small drilling program at La Baja near California under a separate concession not connected with the Inventario. Phosphate investigation was initiated as a separate phase of the Inventario after the early realization of the amount and significance of the phosphate resources in Colombia.
Definitions and usage

Rock Classifications.--

The classification of igneous rocks used in this report is that given by Compton (1962, p. 276, 254-255). Rocks present in the map area with more than 10 percent quartz are:

Granite - ratio of potassium feldspar (including microperthite) or albite to plagioclase > An 10 is greater than 2:1.

Aphanitic equivalent - rhyolite

Quartz monzonite - ratio of potassium feldspar to plagioclase > An 10 or more calcic between 2:1 and 1:2. Aphanitic equivalent dellenite (quartz latite)

Granodiorite - ratio of potassium feldspar to plagioclase > An 10 between 1:2 and 1:7. Aphanitic equivalent - dacite

Tonalite - ratio of potassium feldspar to plagioclase > An 10 less than 1:7. Aphanitic equivalent dacite or andesite

Only the following rocks with less than 10 percent quartz are present in the map area:

Diorite - ratio potassium feldspar to plagioclase less than 1:7. Plagioclase is andesine. Aphanitic equivalent - andesite.

Basalt, diabase - Aphanitic (basalt) to fine-grained (diabase) rocks with potassium feldspar to plagioclase ratio less than 1:7. Plagioclase is labradorite or more calcic.
Rock classifications are based on visual estimates of modal compositions in thin section. All estimates were by R. Goldsmith.

The use of metamorphic rock names follows Compton (1962, p. 293-302) with the addition of terms indicating the nature of the original rock as deduced from relict primary structures, texture, and mineral assemblages where it is considered more descriptive; e.g. meta sandstone, meta-wacke, meta-siltstone. Modifiers used with rock names are given in order of increasing abundance. For brevity in some cases only significant minerals are used as modifier in a rock name even though the amount of this component may be small. Certain metamorphic rock names carry connotations of mineral assemblages that need not be repeated as modifiers, as biotite gneiss and not biotite-quartz-feldspar gneiss.

Use of the terms lineation and foliation is standard and also follows Compton (1962, p. 305-307). However because compositional layering can reflect relict bedding as well as metamorphic differentiation or line-par-lit injection, we do not consider compositional layering to be equivalent to foliation unless a preferred mineral orientation parallels the layering. In most of the rocks of high metamorphic grade, a preferred mineral orientation parallels layering. With emphasis on mineral orientation as a criterion of foliation, the distinction between relict primary structures and superimposed metamorphic structures can be kept more clearly in mind. Similarly with layering removed as a criterion of foliation, foliation is useful as a measurable property of a nonlayered rock with a preferred mineral orientation such as a biotite granite gneiss.
Locations.--

Locations are referred to in the text in one of three ways, depending mainly on the size of the location. General locations are given with reference to towns or prominent topographic feature that can be readily located by reference to the geologic quadrangle maps or to the index map, figure 2. Areas or localities that cannot be indicated in this way are designated by the coordinates given on the 1:100,000 geologic map (plate 1) where the planchitas are numbered 1-12 along the left margin and lettered a-h across the top. Thus, a locality might be referred to as plate 1A, b4-NE.

Where more precise locations are felt to be necessary, reference is made to the topographic maps at 1:25,000 scale of the Instituto Geografico de Colombia Agustin Codazzi. These maps, planchitas, are 10 kilometers north-south by 15 kilometers east-west and are partitioned by a grid into one-kilometer squares. Coordinates of the grid from north to south are lettered from A through J, and coordinates from west to east are numbered 1 through 15. Positions within a single square kilometer of the grid can be further fixed by indicating the quadrant where it is located, NW, NE, SW, or SE. Thus a location would be given as planchita 110 III-C, J-13 NW. Planchitas can be located by referring to figure 2. Names of quebradas, fincas, and haciendas are used when accurately known, but experience has shown that these are not always accurately located or named on the planchitas.
PRE-DEVONIAN METAMORPHIC ROCKS

Bucaramanga Gneiss

Definition.--The name Bucaramanga Gneiss is here introduced for a layered sequence of metasedimentary rocks of high metamorphic grade consisting primarily of pelitic, semipelitic, and arenaceous paragneiss and schist, and subordinate calcareous gneiss, marble, hornblende gneiss, and amphibolite. The Bucaramanga Gneiss also includes zones of migmatite of two types: one in which the paragneiss is mixed with gneissic granitic rock, and the other in which both are cut by many small masses of non-foliated granite of much younger age. The type locality may be considered the mountain front just east of the city of Bucaramanga.

Distribution.--The Bucaramanga Gneiss crops out in three belts in the southern half of Zone III. The westernmost belt here named the Bucaramanga belt lies east of the Bucaramanga fault in the vicinity of Bucaramanga. It extends northward with a wide mixed contact zone into the Rio Negro batholith. To the northeast the belt is overlain by the lower grade metamorphic rocks of the Silgara Formation. The east side of the belt is bounded by the Santa Barbara batholith. The belt tapers southward between the Bucaramanga fault and that batholith to the Cepita area where it appears west of the Bucaramanga fault. Further south, in I-13, the gneiss crops out in thin elongate roof-pendants shot through with dikes along the east edge of the Menotes batholith.
The second belt of Bucaramanga Gneiss, here named the central belt, extends from the Carlín area in northern H-13, north beyond the map area, and from the California-Cachiri area to the Morro Nevada area west of Mutiscua. To the west the belt is overlain by Mesozoic and Cretaceous sedimentary rocks. To the east and south it is overlain by the lower grade rocks of the Silgará Formation. The belt is separated in the Tona area from the Bucaramanga belt to the southwest, by younger intrusions, the overlying sedimentary cover, orthogneiss and by slightly lower grade rocks of the Silgará Formation.

The third and smallest belt of the Bucaramanga Gneiss, here called the eastern belt, trends north near the east edge of the map area in quadrangle H-13 near Chitaga and south of Pamplona. Here the gneiss lies in separate fault blocks.

Description.--The rock types in the three belts of Bucaramanga Gneiss are more or less similar, although proportions differ. The gneiss in the Bucaramanga belt is well displayed along the Bucaramanga-Pamplona highway and on the road from Bucaramanga to Surata. The gneiss consists of interlayered meta-pelites, semi-pelites, and meta-arenites, with thin local layers of calc-silicate rocks and marble. Hornblende gneiss and amphibolite are subordinate and restricted to zones near the calc-silicate horizons. Detailed stratigraphy within the gneiss was not worked out. The scale of layering in the paragneiss varies widely, but gross compositional layering is a few centimeters to a few meters thick.
Layers of pelitic schist and gneiss alternate with layers of meta-arenite, and broader zones either chiefly pelitic or chiefly arenaceous alternate with one another. The pelitic gneiss contains sillimanite and cordierite. The meta-arenites are mostly biotite-feldspar-quartz gneiss and minor biotitic quartzite with thin micaceous partings containing sillimanite. Arenaceous zones contain sparse thin layers of gray quartzite. A band of epidote-amphibole rock in the gneiss east of Bucaramanga can be traced southward to where it is truncated by the Bucaramanga fault between Bucaramanga and Piedecuesta. This band may coincide with a narrow zone of diopside-bearing calc-silicate rocks and marble exposed on the ridge between Río Suratá and Tona. Layers of amphibolite and calc-silicate rock also crop out to the north along the slopes on the west side of the Río Suratá. Marble was seen at one place near Jaboncillo about on the northward projection of the epidote amphibole rock. The amphibolite and calc-silicate rocks may be a good marker horizon, but they were not systematically traced during Inventario mapping.
Migmatite zones containing paragneiss mixed with augen gneiss and granitic gneiss (pDbm) are abundant in the Bucaramanga Gneiss adjacent to the La Corcova pluton, but these rocks are deeply weathered. Lit-par-lit gneiss and nonmappable zones of augen gneiss in paragneiss are exposed on the road from Los Curos to Guaca between the La Corcova pluton and the Santa Bárbara batholith. Lit-par-lit migmatitic gneiss of meta-arenite affinity can be seen in good exposures at the junction of Río Tona and Surata. Orthogneiss zones are less abundant north of Bucaramanga. Granitoid layers in the lit-par-lit gneiss are biotite augen gneiss or gray to light-gray, fine- to medium-grained biotite quartz monzonite gneiss. Zones where dikes in which small masses of La Corcova quartz monzonite or granodiorite are abundant are shown by an overprint pattern on the map (plate 1A).
The central belt of Bucaramanga Gneiss in the Berlin-California-Cachirí area contains similar rocks and is much better exposed.

Good, easily accessible, exposures are on the road from Berlin to Vetas and on the adjacent páramo. Excellent, but rather inaccessible, exposures are present over much of the high country north of Vetas and east of Cachirí. East of Cachirí, exposures were sufficiently good to show arenaceous gneiss, pelitic gneiss, and hornblende gneiss, respectively, predominate in successive zones from west to east. Westerly dips predominate, suggesting that, if the section is not overturned, the hornblende gneiss is stratigraphically the lowest rock type. However, pelitic gneiss reappears on the east side of the belt, near the orthogneiss. Possibly the sequence is folded. Distribution of the rock types to the south in the California and Vetas areas is much less straightforward.
Rock types in the central belt are similar to those in the Bucaramanga belt, except that more hornblendic gneiss is present, commonly in thin layers intercalated with layers of other composition. Quartzite, biotite-feldspar-quartz gneiss, biotite-quartz-feldspar gneiss, sillimanite-biotite-quartz-feldspar gneiss with and without muscovite cordierite-sillimanite-quartz-feldspar gneiss with and without muscovite, hornblende-biotite-quartz-plagioclase gneiss, hornblende-quartz-plagioclase gneiss, amphibolite, and granitoid layers of different compositions are the predominant rocks. Some of the layers with sillimanite and biotite are schistose.

The central belt contains many discrete masses of orthogneiss as well as extensive areas of migmatite in which the granitic portion is orthogneiss. Most of the hornblende gneiss is spatially related to the migmatite. If the hornblende gneiss is a stratigraphically lower unit of this part of the belt as was suggested above, migmatite in the central belt may be restricted to the oldest and lowest rocks of the belt.

The trend of the gneiss is mostly north-northwest, but on the east side of the belt, north from Vetas, the trend is northeast. To the east the gneiss is overlain by lower grade metasedimentary rocks assigned to the Silgará Formation.
In the eastern belt, the rocks are less well exposed and seem to be more limited in composition. East of Chitaga, the dominant rock type is layered cordierite-sillimanite-biotite-quartz-feldspar gneiss, much injected by muscovite pegmatite presumably related to the Durania granite, and by light-gray granite that resembles the La Corcova quartz monzonite. No orthogneiss was observed. Some amphibolite was noted north of Chitaga on the road to Pamplona. Coarsely crystalline marble crops out on the Chitaga-Cacota road 3 km southeast of Cacota, planchita 110 IV. A, G-11 MV.

The belt west of Pamplona passes northward into highly sheared orthogneiss and minor paragneiss. The gneiss dips toward and presumably under the Silgará Formation in the Morro Negro area. However, the Durania granite intervenes between the two units.

Migmatitic gneiss contains granitic material in lit-parlit fashion, or irregular lenses. In places only remnants of paragneiss are preserved as dark seams or lenses rich in biotite and aluminum silicates in otherwise light-colored quartz-feldspar rock. Texture of the granitic material ranges from equigranular, or inequigranular, to pegmatitic, commonly within one exposure. Granitic layers range from augen gneiss to light-gray aplitic gneiss and weakly foliated equigranular to inequigranular granitic gneiss. Generally the layers and foliation in these rocks are folded in plastic fashion.
Some of the granitic material is clearly introduced, particularly that resembling phases of the larger masses of orthogneiss and that which has relatively sharp and discordant contacts. Other material could be locally derived or be in large part recrystallized and possibly mobilized within the paragneiss of chemical composition originally close to that of granite. Some of the gneiss, particularly the impure meta-arenites and semipelites, have a pronounced granitoid texture although the layered sedimentary character of the rock is obvious. These rocks have a migmatitic aspect where strongly folded and recrystallized. Some hornblende gneiss with appreciable feldspar also has a migmatitic appearance.

The bulk of the granitic material in the migmatitic gneiss appears to be introduced rather than derived through the simple recrystallization of the parent rock, primarily because of disproportionate volume relationship. Much more granitic material is present than could have been supplied by the parent rock alone. Large but not mappable zones of granitic gneiss (orthogneiss) in the Bucaramanga Gneiss are common in some areas, such as the migmatitic zones flanking the La Corcova quartz monzonite in the Bucaramanga belt in H-12.
A different type of migmatite is formed where the Bucaramanga Gneiss is cut by nonfoliated granite or by quartz-monzonite. This type of migmatite occupies a zone east of La Corcova south through Sevilla and north toward the Río Suratá. A similar migmatite constitutes the gneiss north and northeast of California.
The Bucaramanga Gneiss is clearly derived primarily from sedimentary rocks. Quartzite, and quartzite-rich gneiss represent metaarenites, most of which appear to have been subgraywackes containing appreciable detrital feldspar and mica. Biotite-quartz-feldspar gneisses, with or without muscovite and sillimanite, are semipelitic. Quartz-biotite-feldspar gneiss and biotite-cordierite-quartz-feldspar gneiss, and biotite cordierite-feldspar quartz gneiss with a high content of quartz are transitional in composition from wackes to pelites represented by biotite-sillimanite-cordierite gneiss and biotite-muscovite-sillimanite quartz feldspar gneiss. Prograde muscovite may or may not be present, depending on grade of metamorphism. However, secondary muscovite after aluminum silicates is fairly abundant. Feldspar is normally plagioclase, but some orthoclase is present in some sillimanite-bearing rocks, cordierite-bearing rocks without muscovite, and in granite layers in migmatitic gneiss. Some of the hornblende gneiss and amphibolite contain quartz and biotite in varying amounts. These are probably paragneiss; other hornblende-gneiss poor in quartz may be of igneous origin. Calc-silicate gneiss and marble are very subordinate. The epidote-amphibole layers, because of their paucity of sodium and association with diopside-bearing layers and marble, were probably derived from calcareous strata.
Age and stratigraphic relations.--The Bucaramanga gneiss is host for all the igneous and meta-igneous rocks recognized in Zone III and appears at least in part to underlie the Silgará Formation. It is thus all or in part the oldest rock unit in the zone. A whole rock-sample of biotite gneiss (see IMN-13199, table 1) from a cut on the road from Berlin to Vetas gave a Rb/Sr whole-rock age of 680 ± 140 m.y. This sample has a considerable margin of error and could be as young as Cambrian. On the other hand, a much older age might be marked by subsequent events. Hornblende from a sample of hornblende gneiss taken near Ocaña from Bucaramanga gneiss west of the Bucaramanga fault gave a potassium-argon age of 945 ± 40 m.y. (IMN-12263, table 2). This age is clearly Precambrian. Tschanz (written commun., 1968) reports a date of 940 ± 34 m.y. on a hornblende granulite from the west side of the Sierra Nevada de Santa Marta. Other Precambrian ages from the Sierra Nevada and western Venezuela, however, are around 1,300 m.y. Precambrian granites in the Guaviare region of the eastern llanos of Colombia give ages of about 1,205 m.y. (Pinson and others, 1962). Most radiometric ages from the Guyana Shield of eastern Venezuela and Guyana according to Tschanz, however, are older and range from 1,570 to 2,100 m.y., being chiefly in the 1,800-2,100 m.y. range.
Table 1. Location, analytical data, and calculated whole-rock Rb-Sr ages of samples collected in the Santander and Norte de Santander, Colombia (from Goldsmith and others, 1971).

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Sample location</th>
<th>Latitude (°</th>
<th>Longitude (°</th>
<th>Rock type, formation, or intrusive body</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMN-12264</td>
<td>Riebeckite granite, Department of Santander; boulder near outcrop, Rio Cachira; planchita 97-III-B, coordinates E-12 NE, quadrangle G-12.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Rb (ppm)</th>
<th>Sr (ppm)</th>
<th>Rb/Sr</th>
<th>Sr/Sr 87/86</th>
<th>Sr 87/86</th>
<th>Radio-active Sr</th>
<th>Total Sr 87 (m.y.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMN-12264</td>
<td>7°39'N.</td>
<td>73°16'W.</td>
<td>92.6</td>
<td>17.0</td>
<td>0.048</td>
<td>0.7406</td>
<td>0.708</td>
<td>0.052</td>
<td>450 ± 80</td>
</tr>
<tr>
<td>DIN-13199</td>
<td>7°09’N.</td>
<td>72°54’W.</td>
<td>190</td>
<td>15.78</td>
<td>0.7433</td>
<td>0.708</td>
<td>0.7387</td>
<td>0.046</td>
<td>160 ± 30</td>
</tr>
</tbody>
</table>

Note: Initial Sr/Sr 87/86 assumed to be 0.705.
The Bucaramanga Gneiss may reflect a cycle of Precambrian orogeny, tentatively placed around 940-945 m.y. that is younger than orogenies recorded to the north and east.

The contact of the Bucaramanga Gneiss with the overlying Silgará Formation could not be determined with certainty.
Correlation.--The Bucaramanga Gneiss probably corresponds to the "basement" of Hea and Whitman (1960, p. 354) and the Perija Series of Sutton (1946) in the western Serrania de Perija, State of Zulia, Venezuela. The description of the Iglesias Series (Kundig, 1938) and the Santo Domingo Gneiss in the Merida Andes by Sutton (1946) resemble that of the Bucaramanga Gneiss. Possibly the Sierra Nevada Formation in the Merida Andes (Bass and Shagam, 1960) is also equivalent, but a definitive description of this unit is not available. Radiometric data from the Sierra Nevada Formation (Bass and Shagam, 1960, p. 331) indicate that the age of the Sierra Nevada could be Early Paleozoic.

The basement in the Serrania de la Macarena east of the Cordillera Oriental and the related Garzon massif in the Cordillera Oriental in central Colombia are probably Precambrian (Gansser, 1954). Other Precambrian rocks of dated equivalent age are in the Sierra Nevada de Santa Marta (Tschanz and Cruz, written commun., 1968).
Silgara Formation

Definition.--The Silgara Formation is a sequence of typically thin and cyclically bedded metamorphosed clastic rocks consisting of slate, phyllite, meta-siltstone, impure metasandstone, metawacke and metawacke grit with minor amounts of calcareous slate and phyllite. The formation is here named after Quebrada Silgara in northeastern quadrangle H-12 south of Río Cachirí where much of the formation is well exposed across a 15 kilometer-wide belt. Even though the base of the Silgara has not been established with certainty, the Silgara Formation appears to overlie the Bucaramanga gneiss.

Distribution.--The most extensive exposures of the Silgara Formation are in a rather inaccessible belt extending from south of Matanzas in quadrangle H-12 northward beyond the limits of the quadrangle northwest of Cachirí. This belt includes the type area of the formation. Many of the rocks can be seen along a trail parallel to and south of the Río Cachirí from Cachirí westward to the Río Negro batholith.

A second extensive but narrower belt of the Silgará lies west of the Bucaramanga fault from near Piedecuesta south to Aratoca, in H-12, I-12 and I-13. These rocks are relatively well exposed along the Bucaramanga–San Gil highway south of Pescadero and along part of the road leading from Los Curos to Los Santos.
Another extensive area of the Silgará Formation, partially wrapping around orthogneiss and Bucaramanga Gneiss, extends from south of Berlin northward through the Silos-Berlin area through Mutiscua to beyond the limits of the geologic maps. The Silgará crops out again to the east in fault slices in a belt northwest, west, and southwest of Pamplona where it is invaded by orthogneiss and Durania granite.

Isolated exposures of Silgará Formation crop out to the south in I-12 and I-13 between the Mogotes batholith and the overlying Devonian and Mesozoic sedimentary rocks as far south as the Mogotes area.

The Silgará Formation also crops out below the Floresta Formation east of the Bucaramanga fault from Coverachia to the San Andres area (I-13, H-13) and northward to the Berlin area in H-13.

Thickness.—The thickness of the Silgará Formation cannot be determined in the type area. The section is incomplete because this belt is bounded by the Río Negro batholith to the west and by the unconformably overlying Girón Formation or by the Surata fault to the east. Further south, where in contact with the Bucaramanga Gneiss, much of the section has been cut off by the Surata fault on the east. In outcrops along Quebrada Silgará and quebradas to the east across the 15-kilometer wide belt in the type area, the steep foliation is in zones that alternately dip east and west, a relationship which suggests appreciable folding. The foliation is probably, in part, an axial plane foliation of slaty cleavage and may not represent the attitudes of bedding. Stratigraphic thickness may, therefore, be much less than the 15-kilometer outcrop width of the belt.
An incomplete stratigraphic section/measured along the Bucaramanga-San Gil highway between Pescadero and Aratoca (fig. 3).

The section is cut off at the north end by the Pescadero granite and at the south end the Silgará is much faulted and obscured by unconformably overlying Mesozoic sedimentary rocks. The section dips generally southward, but is much folded. Nevertheless, making allowance for observed faults and folds, the approximate thickness of the faulted and folded section from Pescadero to the Mesa de San Pedro area is 3,700 meters. South of the Mesa de San Pedro area about 700 meters of section is indicated, but it is not certain how this correlates with the northern part of the section. It is possible that rocks of the Floresta Formation of Devonian age are present in the upper part of the section near Aratoca.

Other sections of the Silgará Formation are either more fragmentary or less carefully mapped than the Quebrada Silgará or Pescadero-Aratoca sections.
Quebrada Silgara:—

In the Quebrada Silgara area the rocks are dark green, greenish gray, and gray slate, phyllite, metasiltstone, fine-grained quartzite, and brown to gray meta-wacke. All are within the greenschist facies of regional metamorphism. Bedding is typically laminar to thin and is cyclic, particularly in the fine-grained rocks. In some quartzite, for example, dark laminae are about 0.5 mm thick and the alternating gray silicious layers are 2 to 3 mm thick. Metawacke beds are thicker, but rarely exceed a meter; a sequence of metawacke beds with phyllitic partings may be collectively much thicker. Graded bedding is common in metawacke and the bases of beds are conglomeratic.

Phyllites in the Quebrada Silgara area are typically quartzitic. In order of increasing abundance they are composed of chlorite, sericite, and quartz. In the metasiltstone and phyllitic metasiltstone, quartz generally exceeds 50 percent, plagioclase is about 5 to 10 percent, and the remainder is muscovite and chlorite, with muscovite being five to ten times more abundant than chlorite. The more pelitic rocks contain about 25 percent quartz, and about 75 percent muscovite and chlorite with some biotite. Muscovite again is normally much more abundant than chlorite. Graphitic phyllite is composed of quartz and muscovite, traces of chlorite, and evenly distributed fine-grained graphite. Some phyllite contains small porphyroblasts of chlorite and magnetite. The magnetite porphyroblasts are relatively abundant in chlorite-poor and chlorite-free quartz-muscovite phyllite.
Some greenish-gray phyllite contains laminae of calcite, but no distinct limestone or marble beds were observed in this area. Dark gray to black graphitic slate with pyrite is present in some places, and white to light-greenish-gray quartz-sericite phyllite in others. Some white sericite-quartz phyllitic metasiltstone shows little apparent metamorphism in outcrop, but the metamorphic fabric is clear in thin section.

Dark laminae in thinly laminated quartzite are rich in sercite, chlorite, magnetite, and biotite. Heavy-mineral suites in quartzite, metasandstone and metasiltstone consist of tourmaline, apatite, sphene, zircon, allanite (rare), and rutile. Tourmaline and zircon are the most abundant. Blue-green tourmaline is characteristic of the Silgar Formation in all belts.

In the meta-wacke, clasts of quartz as granules and pebbles usually exceed 50 percent of the rock. Clasts of plagioclase and potassium feldspar also form an appreciable component. Biotite, chlorite, and muscovite occur in the matrix and in part may be detrital. Metasiltstones and fine-grained meta-sandstones contain small clasts of white potassium feldspar as well as bluish-gray quartz pebbles. Some chloritic meta-siltstones contain no muscovite; their composition is approximately 50 percent quartz, 10 percent chlorite, 35 percent feldspar, and small amounts of opaque minerals. Metawacke beds make up about 10 percent of the section in the Ouehrada Silgar area.
The grade of metamorphism in the Silgará belt increases to the south. The meta-arenite beds show little change with this increase of metamorphism, but the more pelitic beds are changed to porphyroblastic phyllite and schist. Porphyroblasts in the phyllite are andalusite and cordierite and sillimanite, as fibrolite, is present near the contact of the Bucaramanga Gneiss. East of the Río Surata the schists are coarse-grained and not porphyroblastic. No staurolite was observed in the Silgará belt and traces of garnet occur only in the southern part. A layer of marble about 2 meters thick below a thick section of meta-sandstone was observed in the area southwest of Matanzas.
East of the Suratá-Matanzas fault south of Matanzas is a thick section of interbedded metawacke and coarse-grained biotite-muscovite schist locally injected by orthogneiss. These rocks may be near the base of the Silgara section. They are well exposed along the road from Bucaramanga to Suratá 10 to 12 kilometers south of Matanzas, where the road is east of the Río Suratá.

**Piedecuesta-Aratoca belt.**—The rocks in the Piedecuesta-Aratoca belt are similar to those in the Quebrada Silgara except that metawacke beds are absent. The metamorphism in this belt ranges from greenschist facies to lower amphibolite facies (staurolite grade). Garnet and staurolite are relatively common, in contrast to their absence in the Silgara belt suggesting different conditions of metamorphism between the two areas. The grade of metamorphism of the Piedecuesta-Aratoca belt appears to be lowest near Aratoca.
The stratigraphic section along the road from Pescadero to Aratoca mentioned earlier is illustrative of much of the rock in this belt (fig. 3). The lower part of the section (see fig. 3) is primarily thin-bedded to laminated greenish-gray to brownish-gray quartzite with minor quartz-mica schist. These rocks are intruded by many dikes of Pescadero Granite. The upper part of these beds contains a zone of metamorphite. Further south, the section is more pelitic. The rocks are chiefly quartz-mica schist with some garnet and staurolite. Minor beds of green to black amphibole schist and chlorite schist are present near B'. The amphibole schist consists of about 70 percent tremolitic hornblende and 25 percent saussuritized plagioclase, with minor biotite, epidote, and apatite. Section B-B' continues the section up and back toward the north. Here the rocks are stratigraphically above those in section A-A'. In section B'-B the rocks are chiefly interbedded mica schist and meta-sandstone that become more muscovitic and quartzose toward B' and the start of section C-C' at the next major curve in the road. In the lower part of the section B-B' are thin beds of "pseudo diorite," a porphyroblastic hornblende-bearing rock representing metamorphosed argillaceous calcareous beds. At the start of section C-C', and continuing for about a kilometer along the road, are abundant beds of clean white quartzite and silvery muscovite schist. Stratigraphically above these rocks is a monotonous section of greenish-gray silty-phyllite and phyllitic meta-siltstone and minor fine-grained, thin-bedded to laminar-bedded meta-sandstone.
exhibiting cross-bedding, graded bedding, and intraformational breccias and slump structures on a fine scale. These rocks continue to the area of Mesa de San Pedro. The upper part of the section, from the Mesa de San Pedro area to the south, is less clear because of folds and faults. Black graphitic phyllite near Mesa de San Pedro is apparently bounded by faults. Near Aratoca, the grade of metamorphism is less than elsewhere along the section but rocks are similar to those to the north except for the presence of light-tan sandstone and a fine-grained conglomerate that crop out on the road facing Aratoca. The sandstone may belong to the Floresta Formation.
A dark-gray, schistose rock (metaporphry in section A-A') with fairly uniform, aumen-like feldspar megacrysts up to 3 mm long is a meta-trachyandesite (?) porphyry consisting of plagioclase in clusters and individual megacrysts, rare hornblende megacrysts, and a groundmass of fine-grained biotite and plagioclase and accessory apatite, epidote, allanite, and rutile. A somewhat similar but coarser-grained rock is present in the Silgará south of Matanzas (109-IV-D, A-8, NW).

The Silgará Formation observed west of Pescadero and to the north is similar to the section along the Pescadero-to Aratoca highway described above. Silvery garnet-staurolite schist underlies the Mesozoic rocks capping the Mesa de Los Santos. Thin meta-wacke beds were noted near the contact with the Pescadero Granite on the road from Los Curos to Mesa de Los Santos.

Rocks of the Piedecuesta-Aratoca belt in I-12 and I-13 and southward to the Mogotes area they are similar to those described above. Near Mogotes meta-wacke beds are again present as in the Silgará Belt. East of Mogotes toward Onzaga, the grade of metamorphism is again lower and the rocks are not clearly distinguishable from the overlying Floresta Formation which is slightly metamorphosed in this area. It is possible that part of the area mapped as Silgará Formation has been confused with the Floresta Formation.
In eastern I-i3 near Covarachia, greenish-gray phyllite beneath the Floresta Formation is interlayered with orthogneiss but is too thin to show on the map. Further north, near San Andres and Guaca, the Silgará is of medium metamorphic grade and is more readily distinguished from the overlying Floresta Formation of low metamorphic grade.

Pamplona-Chitaga belt.-- The Silgará Formation in this belt consists largely of mica schist with lesser interbedded meta-sandstone and metawacke. The rocks are of middle to high metamorphic grade and resemble the Silgará Formation in the area south of Matanzas. The Silgará Formation at Morro Negro appears to overlie the Bucaramanga Gneiss to the east in the Cacota area, although the rocks are separated by the intervening Durania granite and orthogneiss.

East of Chitaga, in planchitas 110-IV-C and 121-II-A, layered cordierite-sillimanite gneiss of the Bucaramanga Gneiss is overlain by sillimanite-bearing schist and minor meta-quartzite. An interval of micaceous quartzite at the base of the schist forms a distinct scarp. This quartzite may be the base of the Silgará Formation, and has been mapped as such in this part of Quadrangle H-13. The same sequence of schist-quartzite-cordierite-bearing gneiss also was observed north of Berlín, south of Volcan Amarillo, 110-III-A, G-11 SW.
Berlin-Silos-Mutiscua Area.— The Silgar Formation in the Berlin Silos-Mutiscua area resembles the Pescadero-Aratoca section except for the presence of carbonate beds but appears to be a different part of the formation than that to the east in the Pamplona belt. The rocks are quartzite and lesser associated quartz-pebble conglomerate, silvery to light-gray quartz muscovite schist with garnet, staurolite, or sillimanite (depending on the grade of metamorphism), gray garnet biotite-muscovite schist, and minor calc-silicate beds, dark-gray marble, and white to light-gray to pink and green layered marble.
In the Mutiscua area, the Silgará appears to lie in a north-plunging syncline whose east limb has been truncated close to the axial plane by a fault along the valley. Westward from Mutiscua one passes apparently down section in the west limb from interlayered white, gray, and buff marble and quartz mica schist through a thick section of micaschist into fairly pure quartzite and quartz pebble metaconglomerate. In some places mica schist appears to underlie the quartzite, possibly disconformably, but this could not be proven in the field. The quartzite or the underlying mica schist generally lies on orthogneiss, a relationship observed in many traverses in the Berlín-Silos-Mutiscua area. This contact bounds on the east most of the mass of orthogneiss that extends from Río Caraba northward, follows the northern nose of this mass, and appears again on the north side of the wedge of orthogneiss southeast of Morro Nevado. From the evidence of a few traverses, it seems likely that the quartzite is present around the south and east side of the large mass of orthogneiss northeast of Morro Nevado as well. Quartzite and metaconglomerate at sillimanite grade of metamorphism crop out on the west and north sides of the Río Caraba mass of orthogneiss in the Río Caraba area. These rocks are exposed on the Bucaramanga-Pamplona highway north of the Río Caraba.
Quartzite and quartz-pebble conglomerate are also present on Loma Palencia south of Berlin. Unfortunately, the Santa Bárbara batholith nearly encloses these outcrops so their spatial relationship to the orthogneiss in this area cannot be confirmed. Schist along the highway to Pamplona, east of Berlin, contains beds of white quartzite, and quartzite crops out along the southern edge of the orthogneiss northeast of Berlin. Infolds of apparently the same quartzite are present within the orthogneiss immediately to the north. Similar quartzite crops out in the Vetas-California area still farther north. However, no quartzite or metaconglomerate was observed near the contact of the Silgará with the orthogneiss in Río Caraba west of Silos, or along the south side of the Río Caraba mass.
Careful mapping and walking out beds wherever possible would probably reveal the stratigraphic significance of this quartzite and metaconglomerate. It was thought at one time during the mapping that the quartzite and metaconglomerate and the underlying schist represented the base of a sedimentary sequence younger than the orthogneiss. However, it was found that these rocks were not always present near the orthogneiss and furthermore that in places the orthogneiss was intrusive into meta-sediments of which the quartzite seemed to be a part. However, orthogneiss of two different ages may be present.

The quartzite and metaconglomerate may mark the base of the Silgara Formation. The schist and the gneiss below, with perhaps older quartzites, may all belong to the Bucaramanga gneiss. However, in the Silgará belt and the area south of Matanzas, no quartzite or meta-conglomerate equivalent to the quartzite and meta-conglomerate of the Silos-Mutiscua area was observed. White quartzite in the Pescadero-Aratoca section appears to lie well within the Silgara Formation.
South of Berlín in quadrangle H-13 the sequence is somewhat similar to that at Musticua. West of fossiliferous marble and barren quartzite of the Floresta Formation, a thick sequence of gray-green silty phyllite passes westward into light-gray to silvery white muscovite-quartz schist and interbedded quartzite. Toward the contact with the orthogneiss near Alto El Purgatorio are black graphitic garnetiferous phyllites, with, in the lower part, thin-bedded interbedded marble and quartzite observed only in float blocks. The contact with the orthogneiss is not exposed. Lineation in the underlying orthogneiss and fold axes in the phyllite have similar attitudes suggesting probable synchronous deformation. The top of the Silgará Formation here has been drawn somewhat arbitrarily to the west of the fossiliferous marble and the associated quartzite.

Relationship of the Silgará Formation to the Bucaramanga gneiss.—A difference in gross lithology exists between the Silgará Formation and the Bucaramanga Gneiss. The Silgará Formation tends to be more quartzitic and thin-bedded to laminated, with abundant quartz-rich silty phyllite, and biotite-poor quartz muscovite phyllite, and schist particularly in the upper part. The Bucaramanga Gneiss, on the other hand, is thicker bedded and contains biotite-rich and hornblende rocks. Even so, considerable similarity in rock types exists between the two formations, particularly in what may be the lower part of the Silgará, and no consistent distinctive horizon indicating a stratigraphic break useful in mapping was found to mark the boundary between the two formations.
Structural attitudes suggest that the Silgara Formation overlies the Bucaramanga Gneiss but are not everywhere clear and more detailed mapping is probably needed in these areas. For example, in the Paujil district, in quadrangle H-12, 3-d, north of Bucaramanga, metawackes of the Silgara can be followed along strike into the Bucaramanga Gneiss with no discernable break. East of Mutiscua, quartzite and schist, possibly near the base of the Silgara, seem to trace to the west into highly metamorphosed paragneiss of the Bucaramanga Gneiss. Quartzite and meta-pelite flank orthogneiss in the Quebrada Los Salados-Quebrada Grande area, quadrangle H-13. However, this may be coincidence, for the rocks east and above the quartzite appear to be a different sequence of rocks from those west of the quartzite. For example, marble layers present to the east were not observed to the west.

The contact as drawn coincides rather closely with the sillimanite isograd. Sequences of thin-bedded rocks containing appreciable quartzite and quartzitic metasiltstones are assigned to the Silgara Formation and sequences of thicker-bedded metapelites and metaarenites are assigned to the Bucaramanga Gneiss. The former are typically at low to medium grade and the latter are typically at high grade.

Some of the medium-grade metasandstones and schists mapped as part of the lower part of the Silgara, as for example south of Matanzas, are thicker bedded and lithologically similar to some high-grade paragneisses in the Bucaramanga Gneiss. These rocks may be Bucaramanga Gneiss and the boundary between the Silgara Formation and
Bucaramanga Gneiss may lie at a high horizon. It is also possible that the Bucaramanga Gneiss represents the lower and more metamorphosed part of a single sedimentary series of which the Silgará Formation is the upper and less metamorphosed part. The pattern of isograds would support this interpretation. However, in most places where the Bucaramanga Gneiss and the Silgará Formation are separated from one another by igneous intrusion or faults, the two units generally can be distinguished on the basis of bedding characteristics.

**Age and correlation.**—Near Floresta, in the Department of Boyaca south of the map area, at the southern tip of the Santander massif, in the type area of the Floresta Formation, unmetamorphosed Floresta Formation containing fossils of Middle Devonian age rests unconformably upon metasedimentary rocks similar to the Silgará Formation. Similar relationships have been observed in the Mogotes area and near Covarachia. The Silgará Formation is certainly pre-Middle Devonian, and a period of regional metamorphism, uplift, and erosion must have occurred between the time of deposition of the Silgará and the deposition of the Floresta. Orthogneiss whose minimum age based on radiometric dates is Ordovician (table 1) intrudes the lower part of the Silgará Formation, indicating that the Silgará is no younger than Ordovician. Because of the uncertain stratigraphic in some places to the underlying Bucaramanga Gneiss, it cannot be unequivocally said that all the Silgará as mapped is younger than the Bucaramanga Gneiss. Radiometric dates on the Bucaramanga Gneiss are Precambrian. The Silgará Formation is tentatively placed in the lower Paleozoic and is probably Ordovician or Cambrian age.
The Silgara Formation has been observed in several places north of the map area. It crops out west of Durania, apparently continuous with the Silgará Formation northwest of Pamplona in H-13, and in a belt on the west side of the Aguablanca batholith from north of the road from Sardinata to Ocaña between the batholith and Alto El Pozo (86-II-D, H-13 NW) south to the Villa Caro area. Silgara Formation crops out at slightly higher grade in a belt further west along the same road in the Río Tarra area east of Abrego. The Silgará Formation in the Quebrada Silgara belt near Cachiri continues northward beyond the limits of the map area at least as far north as Cachirá in quadrangle G-12. Slates possibly belonging to the Silgará Formation were observed east of the Bucaramanga fault near Guamarita, quadrangle F-12.

The Silgará Formation is possibly the equivalent of the Gúejar Group of the Serrania de la Macarena as described by Trumpy (1943). The description of the rocks of the Gúejar Group as thin-bedded quartzite, sandstone and micaceous locally phyllitic shales, somewhat resembles the description of the Silgará Formation. However, the Gúejar Group is unmetamorphosed to only slightly metamorphosed and the section is thin. Hubach (1957, n. 162) cites thicknesses of 150 to 160 meters on the east side of the Macarena, but says that farther to the west 2000 meters of Gúejar is present. The Gúejar Group contains fossils of Late Cambrian and Ordovician age.
The Silgará Formation is possibly also equivalent to the Quetame Group cropping out in the area east of Bogotá. The Quetame, as described by Campbell (1965) consists in part or all of continental strata slightly metamorphosed and highly folded. These beds are overlain unconformably by unmetamorphosed Middle Devonian strata. Campbell estimates the thickness of the Quetame to be about 2,750 meters.

In the Barinas Basin of southeastern Venezuela, the unfossiliferous Bella Vista Formation and the overlying Caparo Formation, considered to be of Ordovician and Cambrian age, are 3,000 meters thick (Pierce, 1960, p. 217-221. The Bella Vista Formation is metamorphosed to greenschist facies and consists of schists, phyllites, and quartzites. The Caparo Formation is less metamorphosed and consists of lightly metamorphosed siltstone, silty shale, and contains a Middle Ordovician sandstone. The base of the Bella Vista Formation is not exposed but it is presumed to overlie metamorphic rocks of higher grade and older age in the adjacent Merida Andes. In the Merida Andes the Ordovician and Cambrian systems are apparently represented by the Sierra Nevada Formation (Bass and Shagam, 1960), which has been dated by Rb-Sr on muscovite as 410 m.y. (Bass and Shagam, 1960, p. 38).
The Silgará Formation is probably equivalent to unfossiliferous meta-sediments of low metamorphic grade lying below unmetamorphosed rocks of Devonian age on the west flank of the Serranía de Perijá (Tschanz and Cruz, written commun., 1968; Trumny, 1943; and Radelli, 1962) and possibly to part of the Perija Series of Sutton (1946) in the east flank of the Serranía. Hea and Whitman (1960, p. 354-355) restrict the Series de Perijá to metamorphic rocks of greenschist facies overlying gneisses and schists of possible Precambrian age (Perijá series of Sutton). According to their definition of the Series de Perijá, it could be equivalent to the Silgará Formation; however they suggest a tentative Early Devonian age for the rocks.

**Orthogneiss**

**Definition.**—Quartz-feldspathic gneiss ranging in composition from granite to tonalite is widely distributed in the high- and medium-grade metamorphic rocks of pre-Devonian age in the core of the massif. These rocks are on the whole massive but contain septa of foliated metasedimentary rocks and thin screens of hornblende gneiss and amphibolite, some of which appear to be metamorphosed dikes. Only the diorite gneiss was mapped separately.

The massive aspect of these rocks, the general lack of layering except on a gross scale, the presence of endogenous inclusions in some of them, and the fact that compositions are those of magmatic rocks have led to the use of the name orthogneiss for these rocks. South of Matanzas and west of Tona (in H-12 and H-13) orthogneiss occurs as sills and dikes in the medium-grade rocks of the Silgará Formation.
Two styles of emplacement of the orthogneiss are evident. In one the orthogneiss is intimately related to migmatite. In this the orthogneiss consists of somewhat inhomogeneous masses that grade into migmatite in which the gneiss appears as septa or sill-like masses of different sizes in paragneiss of high metamorphic grade. This type is transitional with lit-par-lit gneiss containing about equal amounts of paragneiss and granitoid gneiss. This kind of orthogneiss is prevalent and well displayed in the Páramo de Santurban and the extensive migmatite zone that continues north and northwestward to the northern edge of quadrangle H-13. Areas of migmatite with small masses of orthogneiss were described with the Bucaramanga Gneiss.

The other type of orthogneiss forms large, discrete, mappable units. These have fairly sharp contacts, although in some places they may pass into migmatite as does the large mass of orthogneiss northeast of Berlín. This type of orthogneiss is not confined to the high-grade metamorphic rocks but may be present in medium grade or even greenschist facies rocks, as, for example, in the Onzaga area in I-13.
The style of emplacement of the orthogneiss is probably a function of the depth at which emplacement or formation took place in the crust. The orthogneiss in the Páramo de Santurban area is clearly an integral part of a paragneiss-orthogneiss complex. Other areas of orthogneiss, except those forming migmatite, are not clearly a part of such a complex. The more discrete the mass, the higher and possibly the later it was emplaced. Hence it is possible that orthogneiss of more than one age is present in the massif. However, all the orthogneiss is clearly of pre-Devonian age, but some may be older and some may be younger than the Silgará Formation. The suggestion that quartzite and metaconglomerate in the Silgará might be younger than some orthogneiss has been pointed out.

**Distribution.**--The general distribution of the orthogneiss is indicated in figure 4. Most of the orthogneiss is in the northern part of the map area in H-13, to the southwest, north, and northeast of Berlín. Narrow wedges of orthogneiss crop out in fault slices in a belt west of Pamplona and extending south to the vicinity of Chitagá and Silos. Orthogneiss crops out along the east side of the Santa Bárbara and Mogotes batholiths to the southern end of the zone in the vicinity of Onzaga.
The masses of orthogneiss cropping out in the southern part of the zone east of the batholiths have been intruded and cut out by younger granite or are partly covered by younger sedimentary or metasedimentary rock so that the actual size of these masses and their original contacts are obscure. In some places, however, it appears that the nature of their contacts with the enclosing medium-and high-grade metasedimentary rocks is similar to that observed in the northern part of the map area.

The presence of narrow zones of orthogneiss flanking the Santa Bárbara batholith in the area south of Berlín suggests that orthogneiss was fairly continuous before intrusion of the batholith. The isolated masses of orthogneiss near Santa Bárbara were probably part of the mass of orthogneiss near Tona prior to the intrusion of the batholith.

It is possible that in some places during the mapping, sheared younger plutonic rocks have been mistaken for orthogneiss. However, shearing of the younger plutonic rocks is restricted to narrow zones that have pronounced cataclastic textures, whereas the orthogneiss has a pervasive crystallization foliation without evident cataclasis.
Contacts.--Contacts of the large masses of orthogneiss are concordant in most places with foliation in the enclosing rock. This can be seen clearly at the contact of the orthogneiss with the Silgará Formation in the Río Caraba west of Silos and along the Bucaramanga-Pamplona highway below Alto El Pichacho west of Berlín, quadrangle H-13. Tabular bodies of orthogneiss in the Silgará Formation in the Tona and Río Suratá areas have contacts that transect laminae in the host rock at low angles.

Some pegmatite injection and a slight coarsening of grain size of schist in contact with orthogneiss is evident at the junction of Río Mataperros and Quebrada Pescadero east of Berlín in quadrangle H-13. West of Silos in the Río Caraba, the amount of gneissic pegmatite and granite in schist and paragneiss of the Silgará Formation increases toward the contact with the orthogneiss.

Southeast of Covarachía a sill of lineated orthogneiss lies in markedly sheared, gently dipping silicious phyllite of the Silgará Formation. The main mass of orthogneiss below is also quite sheared and locally has been converted to laminated mylonite. The shearing post dates the emplacement of the orthogneiss and the metamorphism of the Silgará Formation, but it is probably a localized late dynamic phase of the metamorphism. The unmetamorphosed Floresta Formation, lying about 50 meters above, shows no evidence of deformation.
The above observations show that some of the orthogneiss is at least intrusive into rocks as young as the Silgará Formation and that it was metamorphosed at the same time as the rocks it intruded. Whether emplacement occurred penecontemporaneously with the metamorphism or much earlier is not certain. On the supposition that plutonism and regional metamorphism are co-related processes, we are inclined to the view that the orthogneiss is syntectonic or penecontemporaneous with the regional metamorphism of the Silgará Formation. The evidence does not rule out, however, the possibility of some of the orthogneiss having been emplaced after the metamorphism of the Silgará Formation but prior to the deposition of the Floresta Formation.

Description.—The orthogneiss has a considerable range of texture and composition. The rocks are primarily recognized by their quartzofeldspathic composition, their nonlayered character, and their pervasive gneissic structure. The orthogneiss usually has a marked lineation as well as foliation. In some places lineation predominates, in other places foliation predominates. The rocks range in composition from granite to tonalite and diorite; however, quartz-monzonite and granodiorite predominate. The histograms of estimated modes in figure 5 indicate the range in composition. They also show a weak bimodal distribution of abundance of plagioclase, potassium feldspar, and muscovite.
The different kinds of orthogneiss were not separated in the field mapping and their relative amounts are known only approximately. Some idea of the relative amounts can be obtained, however, from the following descriptions.

Coarse-grained biotite augen gneiss composed of plagioclase, quartz, and biotite with large augen of pink potassium feldspar is the predominant rock in the eastern side of H-13 west of Pamplona. The amount of biotite differs from place to place. Augen gneiss is also present in the mass of orthogneiss northeast of Morro Nevado (Fig. 4). It is also a subordinate type in the Río Caraba mass and in a few places south of Alto El Picacho. Farther south, the belt of Bucaramanga Gneiss passing southward across Río Mancos and Río Umpala in southwestern H-13 and northwestern I-13 contains lit-par-lit augen gneiss. Augen gneiss also constitutes parts of the orthogneiss along the east side of the Santa Bárbara Batholith in H-13 and I-13. It was observed near Santa Bárbara and east, west, and south of Molagavita. Augen gneiss is also present in the Bucaramanga Gneiss west of Río Surata (H-12, planchita 109-IV-D, b-7), although it is not shown on the map.
Biotite flaser gneiss characterized by small, often flat lenses of feldspar and quartz set in an anastomosing fabric of biotite, quartz, and feldspar is a common type. It grades into lineated to foliated biotite-quartz-feldspar gneiss in which biotite is less abundant and in discontinuous streaks. Composition is usually quartz monzonitic to granodioritic. These gneisses are fairly abundant in the Río Caraba mass of orthogneiss, less so in the Tona mass and in places east of the Santa Barbara batholith.

A strongly lineated, weakly foliated, equigranular to slightly inequigranular pinkish-gray gneiss of granitic to quartz-monzonitic composition with scattered uniformly oriented biotite crops out in much of the Río Caraba and Páramo de Santurban areas. It also crops out northwest of Tona in southeastern H-12. An associated rare biotite-free muscovite gneiss crops out locally.

A widely distributed but volumetrically small type is a granite gneiss with flat lenses of quartz and with muscovite and biotite in discontinuous subparallel arcuate foliae. These rocks contain a sodic plagioclase: oligoclase or rarely albite. The light-colored granitic types are alaskitic and contain only 1 to 2 percent biotite. Some of these have lenses and rods of feldspar and quartz that impart a "granulite" texture. There is no evidence, however, that these rocks ever were granulites of the granulite metamorphic facies. At the contact of orthogneiss with the Silgara Formation west of Alto El Picacho and also west of Tona is a fine-grained, pale pink to cream alaskite gneiss having marked lineation. Similar rock was observed associated with quartzite southeast of Mutiscua. In the field this rock is difficult to distinguish from meta sandstone.
The orthogneiss near Tona is a gray to greenish-gray hornblende biotite flaser gneiss of granodiorite to tonalite composition. It appears to be less mafic to the east and south. The gneiss contains lenticular oriented fine-grained dark-gray inclusions of the type usually considered to be cognate. Similar gneiss occurs east of the Mogotes and Santa Barbara batholiths and near Onzaga. South of Molagavita and south of Covarachia in I-13 gray non-foliated to slightly gneissic granodiorite and tonalite occur in the same areas with more gneissic rock. These less foliated rocks are interpreted as plutonic rocks synchronous with other orthogneiss but which did not undergo the degree of deformation during crystallization that the orthogneiss did elsewhere.

In some places the predominantly uniform biotite orthogneiss contains muscovite layers. These layers are interpreted as local zones of high water vapor pressure in which retrograde muscovite has formed from feldspar during crystallization or metamorphism. No aluminum silicates are present in these rocks.

Diorite gneiss locally strongly sheared, crops out in fault slivers between Silos and Babega in H-13. These rocks have been mapped separately as a dioritic phase of the orthogneiss. They consist of hornblende and plagioclase with little or no quartz.
Layers of orthogneiss in lit-par-lit gneiss are of somewhat variable composition, although nearly all are poor in mafic minerals. They are either medium grained and granitoid, locally pegmatitic, and intimately mixed and plastically folded with the paragneiss, or they are distinct layers of uniform augen gneiss, flaser gneiss, or fine-grained gray biotite-quartz-feldspar gneiss.

General composition of orthogneiss is shown in figure 5. Augen gneiss is composed of about 30 percent quartz, 25 percent oligoclase, 40 percent microcline, and about 5 percent mafic minerals, chiefly biotite and chlorite. Accessories are apatite, iron oxide, and zircon (fig. 6). Alteration products are sericite and chlorite.

The flaser gneiss and granitic gneiss differ little in composition. Quartz, plagioclase, and microcline and orthoclase are present in about equal amounts, or the potassium feldspar is slightly more abundant. Microcline is the predominant type of potassium feldspar, as in the augen gneiss. However, microperthite is present in some biotite gneiss and biotite flaser gneiss. Orthoclase is common in others. Plagioclase is usually oligoclase to albite. Granitic gneiss has less than 5 percent biotite, whereas flaser gneiss approaching granodiorite may have up to 15 percent biotite, but normally contains 10 percent or less. Some specimens of granite gneiss contain trace amounts of hornblende.
The granodiorite gneiss like that at Tona contains about 15 to 25 percent quartz, 50 to 65 percent andesine to calcic-oligoclase, and 0 to 5 percent orthoclase with biotite and hornblende. Some flaser gneiss approaches this composition with 5 to 15 percent orthoclase or microcline, 30 percent quartz, and 45 to 55 percent oligoclase to andesine.

Muscovite is present in amounts up to 5 percent in some granite gneiss, and is present in small amounts in some of the other rocks. Sphene is an accessory mineral in the Tona Type gneiss. Allanite is present sporadically in all types. Some of the granitic rocks contain traces of garnet.

The texture of the orthogneiss is crystalloblastic in thin section, although the rock may be strongly lineated or foliated in hand specimen. Cataclastic and rehealed cataclastic textures are present in varying degrees, but on the whole, the textures are those of crystallization foliation, particularly in the gneiss within rocks of the higher grades of metamorphism.

Some augen gneiss has sublenticular potassium feldspar megacrysts enclosed in shells of mica, quartz, and feldspar that suggest the gneiss was subjected to differential movement. However, none of the minerals appear to be particularly crushed. Quartz in many specimens forms lenticular mosaics, but is not usually strained. Micas tend to be in laminae of locally shredded flakes that interweave with larger unbent muscovite flakes. Some specimens do show cataclasis, but these are from areas of late shearing affecting other rocks also.
Plagioclase is unzoned or has only a faint relic oscillatory zoning. In many rocks it has large clinozoisite or zoisite inclusions suggesting a history of saussuritization followed by recrystallization and consolidation of the zoisite or clinozoisite component into larger grains. Perhaps this reaction took place under high activity of $\text{H}_2\text{O}$ accompanied by shearing. The plagioclase with the large epidote grains is typical of the tonalite and granodiorite orthogneiss. In some specimens of these rocks the plagioclase is albite, suggesting greenschist facies conditions of metamorphism. Some plagioclase in migmatite is antiperthitic.

Microcline and orthoclase are the common types of potassium feldspar. In contrast to the younger batholithic rocks of the Santander massif discussed below, microperthite is rare. Myrmekite in adjacent plagioclase is common. In some specimens the potassium feldspar is large, mottled, and poikiloblastic.

Muscovite in some specimens appears to have been derived from preexisting minerals in the gneiss, possibly from feldspar, and like the epidote has recrystallized from sericite derived from altered feldspar. Mafics tend to be clustered in laminae. Biotite is typically greenish-brown to brownish-green.
Summary.—The composition of the orthogneiss, its homogeneous, nonlayered character, the presence of cognate inclusions, and local discordant contacts indicate a primary intrusive igneous origin for these rocks. Microscopic textures, structures, and the mineral parageneses of the orthogneiss indicate that it has undergone metamorphism during or after emplacement. That foliation and lineation of the orthogneiss and adjacent rocks are roughly concordant indicates that this metamorphism was regional in extent. Mineral parageneses and degree of recrystallization of the orthogneiss conform to a considerable degree with the grade of metamorphism of the surrounding rocks. Most orthogneiss mapped is either pre- or syn-metamorphic or both. Some rocks mapped as orthogneiss could be locally sheared younger intrusions.
Age.--The orthogneiss is unconformably overlain by the Floresta Formation of middle Devonian age. Orthogneiss intrudes the Silgara Formation of probable Cambro-Ordovician age, and the Bucaramanga gneiss that contains rocks of Precambrian age. From field evidence the orthogneiss could range from early Devonian to Ordovician, but could be in part of Precambrian age. A Rb-Sr whole-rock radiometric determination on a specimen of orthogneiss from the Río Caraba mass northeast of Berlín (IMN-12256, table 1) gave an age of 450±80 m.y. indicating a late Ordovician age for the gneiss. A K-Ar radiometric determination on hornblende from meta-diorite northeast of Ocaña, north of the map area in quadrangle F-12 (IMN-12262, table 2) gave an age of 413±30 m.y. This rock is correlated with dioritic rock in the Bucaramanga gneiss. Radiometric ages of 436 m.y. and 484 m.y. on biotite from pegmatite from the Serranía de la Macarena (Pinson and others, 1962) confirm a plutonic episode in Colombia about this time. However, a problem remains in that the orthogneiss is also intimately associated with high-grade paragneiss of the Bucaramanga Gneiss in such a way that both rocks appear to have formed during the same plutonic-metamorphic event. A Rb-Sr whole rock age on paragneiss gives a Precambrian age (IMN-13199, table 1), although the age admittedly is somewhat questionable. If this orthogneiss were also Precambrian then it means that during the Ordovician metamorphism the rock did not remain a closed system and the age was reset. Another interpretation is that whereas paragneiss formed during the Precambrian high-grade metamorphism, it later underwent anatexis and a second high-grade metamorphism in Ordovician time, during which time the orthogneiss was emplaced. The structure and texture of much of the orthogneiss suggest a two-stage history of metamorphism, and we postulate that the event occurred in the Precambrian and Ordovician.
Because some of the orthogneiss is so intimately associated with the migmatitic phases of the Bucaramanga gneiss from which Precambrian radiometric ages are obtained, we must conclude that some or much of the orthogneiss is of Precambrian age. This puts into question the observation that orthogneiss intrudes rocks of the Silgará Formation. Either the Silgará Formation is not lower Paleozoic, but Precambrian, or orthogneiss of more than one age exists. The latter probability is the most likely considering the evidence reviewed. We suggest that the larger distinct masses of orthogneiss are the younger, or Paleozoic age, whereas the smaller masses intimately associated with migmatitic gneiss are Precambrian. The other alternative is that the Precambrian ages from the Bucaramanga gneiss are erroneous. This does not seem likely.
IGNEOUS ROCKS

A number of batholiths, plutons, and stocks throughout the Santander massif (fig. 4) consist of nonfoliated igneous rocks; types range from diorite to granite. Gradational phases, similarity of rock types within as well as among different batholiths and plutons, stratigraphic relationships, and radiometric ages (tables 1,2) indicate that most of the igneous rocks belong to a single plutonic interval. Age data indicate contemporaneity of rocks of most of the batholiths. The rocks of these dated batholiths are sufficiently distinctive so that undated batholiths can be correlated with them with some confidence. The name Santander Plutonic Group is here introduced as a useful term to embrace the major batholiths of the Santander massif. The Santander Plutonic Group can be divided into two suites: 1) pink granite and quartz monzonite, and 2) gray quartz-monzonite and granodiorite. A difference in relative age between the two suites has been suggested, although field relations and radiometric age determinations conflict. The rocks of both are assigned to the Jurassic and Jurassic-Triassic (pl. 1). Plutonic rocks not clearly related to the Santander Plutonic Group are assigned inferred relative positions in the map explanation.
The larger batholiths are predominantly pink quartz monzonite and granite. Gray colors are generally restricted to smaller masses which are composed of granodiorite, tonalite, and diorite, the only exceptions are the white Durania Granite and the gray La Corcova Quartz Monzonite, although this too has a local porphyritic pink phase.

Contact relations indicate that generally the pink, more granitic rocks are younger than the gray, more mafic rocks. However radiometric age determinations do not everywhere support this view. K-Ar ages on biotite from gray granodiorite on the Río Negro batholith gave a Middle or Early Jurassic age, whereas K-Ar ages on biotite from the pink Santa Bárbara Quartz Monzonite and the Pescadero Granite gave ages on the Jurassic-Triassic boundary. The gray La Corcova Quartz Monzonite gives a K-Ar age similar to that of the pink granites (table 2, spec. 13197). We are inclined to think that the Jurassic age is aberrant rather than reflecting a spread in the time of plutonism.

The pink granites include the Pescadero Granite, quartz monzonite of the Río Negro and Mogotes batholiths, and the Santa Bárbara Quartz Monzonite. Gray granodiorite of the Río Negro batholith, in spite of the younger radiometric age, and granodiorite of the Mogotes batholith are considered to be penecontemporaneous, although field relations suggest they are slightly older than the pink phases. The La Corcova Quartz Monzonite occupies a somewhat ambiguous position: relatively younger than tonalite and granodiorite, but similar in age to the pink granites. No relative position for the Durania Granite has been determined.
Batholiths in the northern part of Zone III north of the area mapped, whose rocks on lithologic grounds are correlated with the suite of pink granites and quartz monzonites in the southern half of the zone are the batholith west of Sardinata, centering on Quebrada Aguablanca (Aguablanca batholith) and the coarser grained phases of the igneous complex in the Ocaña and Abrego areas (Ocaña batholith). A batholith of gray granodiorite lying mainly east of Río Tarra between the Aguablanca and Ocaña batholiths is correlated with a gray granodiorites of the Mogotes and Río Negro batholiths. A K-Ar radiometric age on biotite from quartz monzonite of the Aguablanca batholith (IMN-13201, table 2) indicates a Jurassic-Triassic age similar to the Santa Bárbara Quartz Monzonite and Pescadero Granite. Possibly the Río Tarra and the Ocaña batholiths are somewhat younger, corresponding to the younger age from the Río Negro batholith.

A compilation of estimated modes and types of feldspar of the major plutonic rock units is shown by histograms in figure 5. These histograms show qualitatively the absolute and relative amounts of essential minerals in the different rock units. Figure 6 shows the distribution of some accessory minerals among some rock units. Samples of the quartz monzonitic and sparser samples of the granodioritic phases of both the Río Negro and Mogotes batholiths have been combined in the set of histograms for each batholith. This accounts for the weak bimodal and asymmetric form of the histograms.
An insufficient number of samples of some rock types are available for really meaningful histograms, and many nontypical rocks are included in the samples, but on the whole the similarities and differences seen in the field and hand specimen among the different rock units is borne out by the diagrams. Many of the details of the figures will be referred to later. However, attention is called to the general similarity in form of the histograms and the curves of accessory mineral abundance of the Santa Barbara Quartz monzonite and the quartz monzonites of the Mogotes and Rio Negro batholiths, ignoring the granodioritic part of the histograms.
**Batholiths and plutons**

**Diorite and tonalite**

**Diorite of Río Guaca.**—A small stock of hornblende diorite crops out on the west side of Río Guaca and its junction with the Río Chicamocha in northeast I-13. The rock is intruded by quartz-monzonite of the Mogotes batholith, which near the contact contains hornblende, suggesting contamination from the diorite. The Bucaramanga fault cuts it on the east side. The diorite is medium-grained; with somewhat irregularly distributed white plagioclase in a dark matrix composed of hornblende grains of different sizes. The rock is somewhat altered and crushed near faults. In thin section the rock is hypidiomorphic granular in texture. Major minerals are indistinctly zoned extensively sericitized plagioclase, and bluish-green hornblende. Accessories are sphene, apatite, and epidote, plus traces of quartz and potassium feldspar.

On the east side of the Río Guaca across from the diorite is a fine-grained tonalite or diorite clearly intrusive into the Silgará Formation. It is not certain whether this rock is part of the same body as the diorite to the west. Superficially, it resembles fine-grained tonalite and diorite that are fairly common as small masses throughout the zone. These rocks usually contain some quartz. No thin section is available from this mass. To determine the possible equivalency of these rocks is critical, as the diorite and the fine-grained diorite or tonalite lie on opposite side of the Bucaramanga fault.
Diorite and Tonalite of Rio Surata area—A small mass of tonalite and diorite—almost 3 kilometers long, largely altered and crushed by faulting, is exposed in the Rio Surata just north of its junction with the Rio Tona in northwestern H-12. To the west the tonalite is in contact with amphibolite-bearing gneiss and paragneiss, and to the east it is bounded by a fault along which in places the rock has been converted into chlorite schist. The tonalite in a few places, however, can be seen clearly to intrude metasedimentary schist and gneiss.

The rock is medium-grained, equigranular, and gray-green in color. Inclusions of fine-grained diorite are common. In thin section the texture is hypidiomorphic where not crushed. Quartz ranges from 1 to 15 percent, zoned andesine from 40 to 60 percent, brownish-green biotite from 0 to 25 percent, and blue-green hornblende from 0 to 45 percent. Accessories are potassium feldspar, sphene, apatite, iron oxide, and secondary chlorite and epidote.
Numerous small masses of tonalite and diorite of similar composition and texture cut the Bucaramanga Gneiss both north and south of Bucaramanga and are cut in turn by white to pink quartz monzonite and granite. Similar rock was observed along the Bucaramanga fault near Umpala. None of these masses are of mappable size. They have been observed from the Umpala area to the Río Negro batholith and may be related to the diorite in the Río Guaca and small masses of fine-grained tonalite scattered throughout the zone, as well as to the larger mappable masses.

Tonalite (t) similar in texture and composition crops out south of Cachiri in northwestern H-12 within a small stock of quartz-monzonite. Another stock of tonalite intrudes the Bucaramanga Gneiss about 4 kilometers to the east.
Fine-grained tonalite.--Scattered throughout the metamorphic and igneous rocks of the southern half of the zone are masses of fine-grained tonalite, most too small to show on the maps, composed principally of plagioclase and hornblende. They appear to be dikes or small stocks and are most abundant in areas of La Corcova Quartz Monzonite. Many small masses are encountered on the road to Los Curos from Guaca in the Río Mancos area and on the Bucaramanga-Pamplona highway near and east of La Corcova. The more mafic phases of the La Corcova Quartz Monzonite are similar in texture and approach the composition of the fine-grained tonalite. These rocks may represent a mafic phase of that unit. On the other hand, fine-grained tonalite is clearly cut by quartz monzonite correlated with the La Corcova in northern quadrangle I-13, about 6 kilometers southwest of San Andres.

The fine-grained tonalite has a uniform salt-and-pepper texture and is usually nonfoliated, the one exception noted being a small mass cropping out on the Bucaramanga-Pamplona highway in northeastern H-13, below Morro Negro. Typical rock is composed of about 50 percent zoned andesine, 10 to 20 percent quartz, 0 to 10 percent potassium feldspar, and 30 to 40 percent biotite and hornblende, plus accessory apatite, sphene, iron oxide, and secondary epidote and chlorite.
Age and correlation.--Whether all the tonalite and diorite are of the same age is open to question. These rocks are post-metamorphic, probably younger than the metamorphism of the Silgara Formation, but some may be late metamorphic. They are cut by La Corcova Quartz Monzonite and could be as young as Triassic. Some tonalites resemble certain less gneissic phases of orthogneiss in the Onzaga and Capitanejo area, and metadiorite in the Vetas-California-Cachiri area. Some of these rocks might be as old as Ordovician, because they resemble nonfoliated metadiorite near Ocaña that gave a radiometric age of 410 m.y. (table 2).

Tonalite and granodiorite of the Paramo Rico Pluton.--The Paramo Rico pluton covers an area of about 50 square kilometers centered on Paramo Rico in northeastern H-13. The southern appendage north of Berlin (fig. 4) is bounded chiefly by faults. The pluton is composed almost entirely of tonalite and granodiorite (tgd). Small stocks of La Corcova quartz monzonite and quartz monzonite, aplite, and porphyry on its southwest and northwest corners, respectively, are not considered part of the pluton. Granodiorite predominates in its southern part and tonalite in its northern part. Its contact with the Santa Bárbara batholith is concealed.
The pluton consists of gray medium- to coarse-grained tonalite and granodiorite. Fresh and accessible exposures can be seen on the road from Berlín to Vetas, about 5 kilometers north of Berlín, and near California where fresh rock crops out on the banks of the Río Vetas below the town.

In the southern appendage north of Berlín, the rock is coarse grained, somewhat inequigranular, gray, and nonfoliated. Near contacts and in apophyses it is slightly gneissic and of granodiorite composition. Dark fine-grained inclusions interpreted as autoliths are common. Mafic minerals tend to form clots. Sphene is a prominent accessory. The rock weathers spheroidally where massive to produce conspicuous corestone boulders.
The contact of the tonalite and granodiorite with the Santa Barbara Quartz Monzonite is not exposed. The tonalite clearly intrudes the Bucaramanga gneiss in the Paramo Rico area and is overlain unconformably by the Tambor Formation of Early Cretaceous age. Dikes of alaskite, aplite, and La Corcova Quartz Monzonite cut the tonalite, but no dikes of Santa Barbara Quartz Monzonite or Pescadero Granite were observed. Near California, the tonalite is cut by quartz monzonite, aplite, and quartz porphyry. Small masses of gneissic tonalite are exposed in road cuts on the Berlín to Vetas road west of Vetas. These are probably offshoots from the main mass of tonalite. In the northern part of the pluton, the rock is medium grained and somewhat more equigranular and is predominantly tonalitic rather than granodioritic.

In thin section the rock is hypidiomorphic and contains weakly zoned to nonzoned subhedral tabular plagioclase with complex twinning, large subhedral hornblende, brownish-green biotite, and interstitial quartz and clear (limpid) potassium feldspar. Finer grained rocks lack potassium feldspar. Estimated modes are 10 to 15 percent quartz, 45 to 60 percent andesine, 5 to 15 percent hornblende, 5 to 20 percent biotite, and 0 to 10 percent potassium feldspar. Typical accessory minerals are sphene, apatite, iron oxide, and rare allanite. Chlorite and epidote are common alteration products. A trace of augite was observed in one thin section.
This rock, particularly in its southern part, shows textural and compositional similarities to granodiorite in the Río Negro and Mogotes batholiths. It is older than the La Corcova Quartz Monzonite, but perhaps not much older. It is certainly pre-Girón and later than the major regional metamorphism which is considered to be Ordovician. The tonalite and granodiorite could be as old as Silurian or as young as Triassic. Its age is probably toward the young end of this range.
La Corcova Quartz Monzonite

A gray, fine- to medium-grained quartz monzonite which makes up the main mass of the La Corcova pluton (fig. 4) is here named the La Corcova Quartz Monzonite from exposures in the vicinity of La Corcova on the Bucaramanga-Pamplona highway. The Pluton is remarkably linear and bounded by faults along most of its length. It is 35 km long and about 3 km wide. Dikes of the La Corcova Quartz Monzonite are particularly abundant north of the pluton east of Bucaramanga. However, dikes and small masses of La Corcova are widespread elsewhere in the zone. They are present in the California district, near Vetas, in the Paramo Rico stock, and in granodiorite of the Río Negro batholith. No dikes of the La Corcova have been observed in the Santa Barbara batholith, nor have the Santa Barbara Quartz Monzonite or Pescadero Granite been seen to cut the La Corcova. Small stocks of La Corcova Quartz Monzonite crop out northeast of the main mass in quadrangles H-12 and H-13. Rock resembling the La Corcova is present as small bodies in Bucaramanga gneiss east of Chitaga. Smaller masses of La Corcova are present near Vetas and Morro Nevado, H-13. A gray quartz monzonite in northern I-13 south of San Andres is tentatively correlated with the La Corcova Quartz Monzonite. La Corcova Quartz Monzonite is well exposed on the road from Los Curos to Guaca in quadrangle H-12. Here, exposures of the intrusive contact of the La Corcova with the Bucaramanga Gneiss can be seen. A porphyritic phase is exposed west of La Corcova and on the road to Tona near the Río Tona. A minor fine-grained biotite-rich phase with some hornblende is exposed east of La Corcova.
Typical La Corcova Quartz Monzonite is fine grained to medium grained, mostly equigranular and sugary textured with evenly disseminated biotite. It is gray where fresh, but weathers to light gray or to yellowish gray. In places it shows a little flow structure. Where massive, it tends to weather spheroidally forming corestone boulders. In thin section the texture is xenomorphic to subhypidomorphic granular, or aplitic. The rock is composed of 30 to 35 percent quartz, 25 to 45 percent zoned oligoclase, 30 to 45 percent potassium feldspar, predominantly microcline, about 3 percent biotite, and traces to 2 percent muscovite. Accessories are apatite, iron oxide, and zircon; alteration products are chlorite, epidote, and sericite. The amounts of epidote are unusually high for a rock otherwise appearing to be relatively low in calcium (figs. 5 and 6). Most of the epidote is in plagioclase. The relatively abundant epidote and the ubiquitous muscovite suggest high H₂O activity in the deuteric stage. The oligoclase is tabular to stubby with irregular margins, and is normally zoned. The microcline has a pronounced grid pattern, but some potassium feldspar is perthitic. Micropegmatite is present in some specimens. The biotite is brownish green to greenish brown and tends to be shreddy.
The composition of typical La Corcova Quartz Monzonite is distinctive. The abundances of plagioclase and quartz are less than in the other quartz monzonites, and the abundance of potassium feldspar is slightly greater (fig. 6). The abundance of potassium feldspar is unsuspected in the hand specimen because the potassium feldspar is white instead of pink. It should also be noted that microcline is the common potassium feldspar rather than the microperthite common in the pink quartz monzonites. The La Corcova contains the least allanite of any of the rocks.

The porphyritic phase (JKclp) forming the mass near Tona (quadrangle H-12) contains pink potassium feldspar phenocrysts in a fine- to medium-grained matrix identical to, though slightly coarser grained than, normal La Corcova Quartz Monzonite. In thin section, the texture is similar to that in the normal phase, except that microcline is large and poikilitic. Plagioclase is slightly more abundant than microcline and is calcic rather than sodic oligoclase. Biotite is also slightly more abundant.
A biotite-rich phase with similar sugary, fine-grained texture is present locally in masses too small to be mapped. This rock seems to be gradational in composition with both the La Corcova and to the fine-grained tonalites described in a previous section. Outcrops of this type of rock can be seen on the Los Curos-Cuaca road south and east of the Río Manco, and at a few places on the Bucaramanga-Pamplona highway east of La Corcova. Some of this rock is slightly porphyritic with white plagioclase phenocrysts. Texture is similar to that of the La Corcova but tends to be hypidiomorphic with tabular calcic-oligoclase to andesine. Potassium-feldspar tends to be microperthite rather than microcline. The amounts of quartz and potassium feldspar are less, whereas the amounts of plagioclase and biotite are greater than those in the La Corcova. Hornblende is present, and sphene is an accessory. Muscovite is lacking. Inclusion of estimated modes of these rocks in the histograms of figure 5 probably gives the histograms their somewhat bimodal and asymmetric character.
A K-Ar age on muscovite from the normal La Corcova (table 2, specimen 13177) is similar to K-Ar ages from biotite from rocks from the principal batholiths of the massif. The age of the La Corcova Quartz Monzonite relative to other rocks of the Santander Plutonic Group is uncertain. Dikes of La Corcova cut granodiorite of the Río Negro batholith and tonalite and granodiorite of the Paramo Rico stock, as well as fine-grained tonalite. At one outcrop on the road to Tona, pink quartz monzonite of the porphyritic phase of the La Corcova cuts the normal gray quartz monzonite. No crosscutting relationships of La Corcova with the Santa Barbara Quartz Monzonite, Pescadero Granite, or pink quartz monzonite of the Río Negro and Mogotes batholiths were seen. The La Corcova would thus appear to occupy an intermediate position in time between the gray granodioritic igneous rocks and the pink and more granitic igneous rocks. The strongest argument for the penecontemporaneity of the La Corcova Quartz Monzonite with the pink quartz monzonites of the batholiths is that phases transitional in texture and composition seem to exist between them. The distinctive texture of the La Corcova is observed in rocks of medium grain size rather than the typical fine grain size of the La Corcova, and in rocks containing potassium feldspars pinker than those in the La Corcova. Thus, the typical La Corcova grades into medium-grained and porphyritic rocks like those which make up the bulk of the Santander Plutonic Group. This is particularly striking when samples of the La Corcova porphyritic phase are compared, for example, with porphyritic granodiorite of the Río Negro and Mogotes batholiths, and the La Corcova normal phase with the more biotitic of the quartz monzonites of the Río Negro and Mogotes batholiths. There does not seem to be a clear transition, however, to pink to pinkish-white mafic-poor granite such as the Pescadero.
Quartz monzonite, granite, and quartz porphyry

Stocks and plugs of pinkish-gray to light-gray and light-tan quartz monzonite, granite and quartz porphyry, and rare granodiorite are scattered in the Silgará Formation and the Bucaramanga Greiss in the northern parts of H-12 and H-13. Many of these stocks and plugs are east of the Río Negro batholith. Other stocks and sill-like masses are located north and northeast of the main mass of La Corcova Quartz Monzonite. Some of the small stocks in the area of the big bend of the Río Surata south-southwest of Matanzas contain porphyritic rock. Most of these rocks are deeply weathered and fresh rock is difficult to obtain. An isolated stock of light-colored quartz monzonite 11 kilometers north-northwest of Mutiscua (H-13) appears to be similar to those in the Matanzas area.

The small stocks and plugs of quartz monzonite and granite differ somewhat in texture and composition from one another. Some tan to light-gray rocks resemble the La Corcova Quartz Monzonite in that they have the same sugary texture and evenly disseminated biotite, although they are medium grained rather than fine grained. Some masses contain muscovite and resemble certain border rocks of the Río Negro batholith. A few are light pink like some quartz monzonite in the Río Negro batholith.
Quartz monzonite, aplite, and porphyry (cpg) form a composite stock near California in quadrangle H-13 and appear to be similar to pale-pink phases of the quartz monzonite granite and quartz porphyry. Much of the rock in this area has been extensively fractured, leached, and impregnated with silica and sulfides, primarily auriferous pyrite. This composite stock contains outcrops of rock of the La Corcova type as well as dikes of rhyodacite and dacite porphyry.

The bulk of the rock near California is fine-grained, pale-pink to white, locally medium-grained granite or quartz monzonite with characteristic bipyramidal quartz phenocrysts. Two phases have been noted: a porphyritic phase with quartz and feldspar phenocrysts, and an even-grained aplitic phase. Some fresh rock contains disseminated fine-grained biotite similar to that in the La Corcova Quartz Monzonite. The texture is aplitic in thin section, with equant nonzoned oligoclase and perthitic potassium feldspar.

The stocks and bosses described above appear to differ enough to suggest that they are not all of the same age or origin. Some appear to be related to the La Corcova Quartz Monzonite; others to the quartz monzonite of the Río Negro batholith; and yet others are not clearly related to any of the other major plutonic units. They all, however, have been assigned to a single unit on the geologic map. Conglomerate of the Bocas Formation of Triassic age contains pebbles of rocks of this unit. Some or all of the quartz monzonite, granite, and porphyry is, therefore, of Triassic or older age, possibly Permian.
The Durania Granite is a white muscovite granite forming small plutons and stocks in a north-south belt extending from the Pamplona area in eastern K-13 north to and beyond the towns of Durania and Villa Sucre in Norte de Santander beyond the limits of the map area. The granite is named for the town of Durania, near which the typical granite is well displayed.

The largest mass of Durania Granite is in the Pamplona pluton 17 kilometers long by 1 kilometer wide south of Pamplona in northeastern K-13 (fig. 4). A smaller mass crops out to the south near the Silos-Chitaga road, and another small mass lies partly in the quadrangle northeast of Pamplona. White muscovite-bearing pegmatites with the same minerals as the granite are relatively abundant in the metasedimentary rocks surrounding the Durania Granite and are obviously related to it. Some of these pegmatites have been exploited for mica and feldspar near Bochalema north of the map area. Elsewhere, garnet and tourmaline are prominent.
The Durania Granite is white, equigranular, medium- to coarse-grained, and slightly gneissic in places. It weathers readily by disaggregation to grus. Major constituents are subequal amounts of quartz, microcline, and plagioclase (albite to sodic oligoclase). The plagioclase is shown as oligoclase in figure 5. Muscovite is prominent generally in amounts up to 5 percent, rarely 10 percent. Accessories include garnet, tourmaline, iron oxide, and zircon. One atypical specimen contained no potassium feldspar. Only three specimens suitable for thin sectioning were obtainable, and two of these came from north of the map area.

The age of the Durania Granite is not known. The youngest formation it is seen to cut is the Silgara Formation. It is late or post-metamorphic and is overlain by the Tibu Formation of early Middle Cretaceous age. The range of possible ages of this rock is from Ordovician to middle Cretaceous. It is more likely, however, to fall between the Devonian and Jurassic. Because of the uncertainty in age of this granite and because of its different lithology, it is not included in the Santander Plutonic Group, and has been placed arbitrarily below it on the map explanation.

A K-Ar age determination on muscovite collected by Paul Duran from a pegmatite cutting Bucaramanga Gneiss east of Chitaga thought to be related to the Durania Granite gave an age of 432-457 m.y. (table 2, specimen 14362). This indicates that either the Durania Granite is Ordovician in age rather than younger, or that the pegmatite is not related to the Durania granite. The age is in the range of radiometric ages shown by the orthogneiss (tables 1 and 2).
Santa Barbara Quartz Monzonite

The Santa Barbara Quartz Monzonite is a fairly uniform, coarse-grained and inequigranular biotite quartz monzonite that makes up the bulk of the Santa Barbara batholith. The quartz monzonite and the batholith are named for the settlement of Santa Barbara, which is near the center of the mass (fig. 4).

The Santa Barbara Quartz Monzonite batholith extends from near Berlin, in east-central quadrangle H-13, southward to the Bucaramanga fault near the junction of Ríos Chicamocha and Guaca. The batholith is about 60 km long and its width ranges from 5 to 12 km. Its shape is linear and its borders are only locally faulted. Two small plugs of Pescadero Granite occur at its northern end near Berlin. The rock within the batholith is almost entirely a fairly uniform, coarse-grained, pink, quartz monzonite.
Although the Santa Barbara Quartz Monzonite is largely confined to the Santa Barbara batholith, small areas of quartz monzonite crop out to the east, east of Río Angosturas in the southern part of northeastern H-13, and in an area near Lago del Ortíces south of San Andres in I-13. The quartz monzonite has been recognized at places within the Mogotes batholith north of Mogotes and near San Joaquin.

The Santa Barbara Quartz Monzonite is megascopically coarse grained, somewhat inequigranular, and orange-pink to purplish-gray with prominent orange-pink to grayish-red potassium feldspar, white plagioclase, and gray quartz, and 2 to 3 percent biotite. In inequigranular phases, potassium feldspar forms phenocrysts as large as 20 mm. In more equigranular phases, potassium feldspar may be as much as 15 mm in long dimension, plagioclase 12 mm, and rounded quartz 5 mm. Mafics tend to be in small clusters, locally as much as 5 mm in diameter. Quartz, potassium feldspar, and plagioclase are present in subequal amounts, but generally the potassium feldspar is slightly more abundant than the plagioclase (fig. 5).
In thin section, the typical quartz monzonite is hypidiomorphic inequigranular with subtabular to equant, slightly zoned oligoclase and calcic albite. Centers are usually saussuritized, whereas rims are fresh. Potassium feldspar is dusty microcline and fine string and rod or screen perthite. Biotite is greenish brown and usually altered to chlorite and clustered with apatite. Typical accessories are sphene, apatite, iron oxide, zircon, and allanite. Alteration products are chlorite and epidote. A few grains of hornblende were noted in the quartz monzonite in the Berlin area. Except for having more samples containing sphene, the relative amounts of accessory minerals are more or less similar to those in the quartz monzonite of the Mogotes batholith (fig. 6).

In the darker-colored more mafic phase, the plagioclase is tabular and well zoned. The plagioclase is calcic oligoclase, and accessory hornblende may be present with biotite. Plagioclase is more abundant than potassium feldspar.
The quartz monzonite weathers readily to grus and forms a somewhat porous soil with a consequently low water table. Slopes in saprolite on the Santa Barbara at one place measured 40 degrees.

The rock is well exposed, although quite weathered, on the road from Los Curos to Guaca where it crosses the width of the batholith. Weathered outcrops are accessible southeast of Berlin from the road from Berlin to Baraya and Guaca.

A darker colored, medium-grained phase with 5 to 10 percent biotite and a trace of hornblende crops out in places. This rock is exposed on the Los Curos-Guaca road just east of Quebrada El Retiro west of the Río Umpala (H-13, 12-I-C, J-5).

Dikes of pink aplite locally in swarms cut the quartz monzonite. These are more resistant to weathering and stand out as ledges. These can be seen on the Los Curos-Guaca road west of the turnoff to Santa Barbara (H-13, 12-I-C, J-6, J-7, J-8).
Conglomerate and arkose of the Girón Formation of Jurassic age contain detritus from the Santa Barbara Quartz Monzonite; unroofing and erosion of the Santa Barbara must have taken place prior to Giron time. Two K-Ar radiometric ages on biotite from the Santa Barbara Quartz Monzonite (table 2) give ages of 192\(^\pm\)7 and 194\(^\pm\)7 m.y. These ages are in accord with a radiometric age obtained from a biotitic phase (similar to quartz monzonite of the Mogotes batholith) of the Pescadero Granite to the west (table 2). In addition, a whole-rock K-Ar age determination on a specimen of phyllite taken south of Berlin about 1 km horizontally and probably less vertically from the contact of the batholith gave an age of 198\(^\pm\)7 m.y. These ages are about on the boundary of the Jurassic-Triassic boundary. Considering the probable slow cooling rates of a batholith this size (Winkler, 1967, p. 83; Hamilton, 1965, p. 71), it is likely that the actual age of displacement is latest Triassic rather than earliest Jurassic; however, the age designation here given is Jurassic-Triassic.
Pescadero granite

The Pescadero Granite (Jurassic) is a fine-grained, orange-pink, leucocratic granite named for exposures in the vicinity of Pescadero in the municipality of Umpala (H-12). The Pescadero granite forms an elongate, somewhat irregularly shaped pluton lying west of the Bucaramanga fault from north of Los Curos to the vicinity of Cepita on Rio Chicaniocha. To the west the granite intrudes metasediments of the Silgará Formation. The Pescadero granite in this area could be considered part of the Mogotes batholith, because the main mass of Mogotes to the south contains rock like the Pescadero, and a biotitic phase in the Pescadero is similar to biotite quartz monzonite of the Mogotes.

The Pescadero is overlain unconformably by the Jordan Formation of Jurassic age whose basal conglomerate contains fragments of Pescadero-type rock. Rhyolite dikes that cut the Jordan south of the town of Los Santos are apparently younger. To the north, the Pescadero granite passes into a rhyolite porphyry exposed along the road south of Piedecuesta. This rock, which is similar to dikes within the main mass, has not been mapped separately.

The Pescadero Granite weathers to a light-colored, porous, sandy soil. Near Los Curos, the granite is appreciably brecciated and weathered. In the canyon of the Río Manco to the south, however, the granite is fresh, although intensely jointed and faulted owing to its proximity to the Bucaramanga fault.
A contact zone in which numerous aplite and pegmatite dikes of the Pescadero cut the Silgara Formation is well exposed along the Bucaramanga to Bogota highway 1.4 km south of the bridge over the Río Chicamocha at Pescadero.

Some evidence suggests that the original intrusive contact of the Pescadero with Bucaramanga gneiss on the east lies along the site of the Bucaramanga fault. This is suggested by outcrops in fault slices northwest of Umpala in tributaries of the Río Manco which expose fairly sharp, apparently intrusive contacts between granite and gneiss.

Typical Pescadero granite is orange-pink, very fine to fine-grained, equigranular to slightly porphyritic, with phenocrysts of potassium feldspar only slightly larger than the average grain of the rock, and a few scattered clots of mafic minerals. Some of the rock has vugs containing drusy quartz, but these are believed to be related to faulting. The rock is typically leucocratic. Albite or sodic oligoclase, orthoclase and microperthite, and quartz are present in from subequal amounts to a 40 to 25 ratio of potassium feldspar to albite-oligoclase (fig. 5). Accessories are sparse with generally less than 1 percent iron oxide, muscovite, biotite, zircon, and apatite. The microperthite ranges from a string-and-rocd type to a braid perthite. Micropegmatite is common. Muscovite is tabular and contains small grains of exsolved iron oxide. Some muscovite (?) is in radial aggregates. The plagioclase is generally not zoned. Porphyritic phases contain phenocrysts of albite and rarely quartz; the remainder of the quartz is in micropegmatite or graphic texture.
A medium-grained orange-pink biotite granite and quartz monzonite similar to some biotite quartz monzonite in the Mugtoos pluton to the south crops out in places northeast of Pescadero along the Río Manco. It was this rock from which biotite was obtained for the K-Ar age determination on the Pescadero granite (table 2). It is slightly coarser grained and contains more biotite than the typical Pescadero but is apparently related genetically to it. This rock is slightly inequigranular in thin section and hypidiomorphic. Relative amounts of minerals are about the same as in the typical Pescadero, except that biotite or chloritized biotite is present in amounts up to 3 percent. Plagioclase is tabular, zoned, and is calcic albite or sodic oligoclase. Many grains of quartz and particularly orthoclase contain inclusions of the tabular plagioclase. Orthoclase is slightly perthitic; quartz tends to have an equant or bipyramidal habit. Allanite is a sparse accessory in addition to the suite normal in the Pescadero.

Dikes within the Pescadero Granite consist of pegmatite, aplite, and porphyritic rhyolite and rhyodacite. The porphyritic rhyolite dikes have phenocrysts of albite or sodic oligoclase and less abundant phenocrysts of quartz, orthoclase, and chlorite (apparently after biotite). The matrix is microcrystalline with nebulous subspherical feldspars and quartz, or distinct spherulites of quartz and potassium feldspar. Some samples of rhyodacite have a felty texture with small euhedral feldspars. The textures are similar to those of the porphyritic rhyolite south of Piedecuesta.
Two pluglike masses of Pescadero Granite cut the Santa Barbara Quartz Monzonite and metasedimentary rocks south of Berlin in northwest H-13. Another mass, poorly known, is located at the Río Cucutilla at the extreme north edge of quadrangle H-13. Pescadero granite containing a little muscovite crops out in the Bucaramanga gneiss northeast of Chitaga in H-13. An area containing abundant small bodies of Pescadero Granite is located near San Joaquin in quadrangle I-13. Pescadero Granite crops out here and there in bodies too small to map in the Mogotes batholith and Santa Barbara Quartz Monzonite.

A K-Ar radiometric determination on biotite from the biotitic rock in the Pescadero Granite gave an age of 193±6 m.y. (table 2). This falls between the two ages obtained from biotite in the Santa Barbara batholith; it places the Pescadero, and by extrapolation the quartz monzonite of the Mogotes batholith, in the same age group. They are at least, penecontemporaneous if not all of virtually identical age.
The Mogotes batholith

The Mogotes batholith, one of the larger batholiths in the southern half of the zone, is in quadrangle I-13, southwest of the Bucaramanga fault (fig. 4). The batholith is about 40 kilometers long and 15 kilometers wide at its widest part; the average width is about 10 kilometers.

The batholith consists of several distinctive rock types. The main mass is a light pinkish-gray to pinkish-white biotite quartz monzonite and granite (Trc) predominantly medium-grained equigranular. Coarse-grained phases similar to the Santa Bárbara Quartz Monzonite and fine-grained pink phases similar to the Pescadero Granite crop out within the main mass. The Pescadero Granite (JTrgd) north of the main mass is considered part of the batholith. A mappable mass of Pescadero Granite is near San Joaquin. Toward Onzaga the rock is a porphyritic granodiorite and granodiorite (JTrgd). Dikes of rhyolite, rhyolite porphyry, aolite, quartz latite, and lamprophyre are fairly common, particularly in the southern part near Mogotes. A small stock of rhyolite near Onzaga is just south of the map area.

Most of the eastern margin of the batholith is bounded by the Bucaramanga fault. The batholithic rocks are intrusive into screens or roof pendants of Bucaramanga Gneiss in places west of the fault. Elsewhere the batholith intrudes the Silgará and Floresta Formations or the orthogneiss.
Quartz monzonite of the Mogotes batholith

The quartz monzonite of the Mogotes batholith is orange pink, pinkish gray or pinkish white, equigranular to subporphyritic with a grain size of 1 to 3 mm. The subporphyritic rocks have grains of potassium feldspar only slightly larger than the average grain size of the rock. The rock weathers readily to grus and makes a cream-colored to buff soil, becoming a deeper orange color where derived from more biotitic rock.

The typical rock is leucocratic and contains subequal amounts of white oligoclase, pink potassium feldspar, and gray quartz (fig. 5) and less than 3 percent biotite. Less biotitic varieties contain more potassium feldspar than plagioclase and more biotitic varieties contain less. It should be noted that the histograms (fig. 5) include modes of samples of the granodiorite near San Joaquin.

In thin section the texture of the quartz monzonite of the Mogotes batholith is hypidiomorphic and slightly inequigranular. Oligoclase is tabular and normally zoned. The potassium feldspar is a rod or bead microperthite. Quartz is in subequant grains or is interstitial. Greenish-brown biotite is in laths, commonly with inclusions of apatite. Accessories are apatite, iron oxide, zircon, and allanite, with secondary chlorite, epidote, and sericite. Sphene is present only in relatively biotite-rich rocks approaching granodiorite in composition. Some fine-grained varieties are white in color and aplitic in texture. They contain albite or sodic oligoclase, and micrographic or micropegmatitic texture is common as in some of the Pescadero granite. The porphyritic varieties differ only in having phenocrysts of microperthite.
similar to the Santa Barbara Quartz Monzonite and the Pescadero granite crops out within the main mass of quartz monzonite. Pink dikes in the Mogotes area have the usual graphic and spherulitic textures of dikes in the Pescadero. Biotite is in very thin flakes recalling the thin muscovite flakes with the exsolved iron oxide in the Pescadero granite. Dikes of porphyry have a mosaic groundmass of quartz, plagioclase, and orthoclase with phenocrysts of plagioclase, quartz, orthoclase and platy biotite.

Histograms of the quartz monzonite of the Mogotes batholith (fig. 5) approach those of the Pescadero granite with which it is associated. The influence of Pescadero-like samples included in the modes probably accounts for the slight difference in form of the histograms from those of the Río Negro batholith.

Granodiorite of the Mogotes batholith

East and southeast of San Joaquin is a gray inequigranular to equigranular granodiorite similar in appearance and composition to the granodiorite at the southern end of the Río Negro batholith. As in the Río Negro batholith, the contact of the granodiorite with the quartz monzonite is not clear. It may be gradational.
The granodiorite of the Mogotes batholith is gray to pinkish gray, medium to coarse grained with scattered large orange-pink orthoclase phenocrysts and smaller grains of gray quartz, white plagioclase, and black biotite. Equigranular phases with grains ranging from 2 mm to 2 cm make up an appreciable percentage of the rocks in this area. They resemble much of the rock in the Mogotes batholith to the northwest but with somewhat more biotite and fewer but larger potassium feldspars. In thin section the porphyritic type is hypidiomorphic with phenocrysts of relatively large perthitic orthoclases and smaller tabular-zoned ardesine or oligoclases. Quartz is anhedral to interstitial. Biotite, iron oxide, sphene, apatite, and rare hornblende tend to be in clusters. Sphene, allanite, zircon, apatite, iron oxide, and epidote and chlorite are accessory and secondary minerals. Oligoclase and andesine are more abundant than potassium feldspar. Hafics make up 5 to 10 percent of the rock. Brownish-green biotite typically has numerous inclusions of apatite. Equigranular phases of the granodiorite have a similar composition. Although relatively few samples of the granodiorite from the Mogotes batholith were available, the rock appears to contain more allanite than the granodiorite of the Rio Negro batholith which it otherwise resembles.

In some places, gray granodiorite without pink feldspar resembles the less foliated granodioritic phases of the adjacent orthogneiss. It is possible that some areas of orthogneiss have been mapped as granodiorite of the Mogotes batholith.
Ace of the quartz monzonite and granodiorite of the Mogotes batholith

The quartz monzonite of the Mogotes batholith is probably related to the Pescadero Granite and the Santa Barbara Quartz Monzonite, on the basis of the general similarity of lithology of the three rocks, their gradational facies, and their stratigraphic and structural relations with older and younger sedimentary rocks. The sample from the Pescadero Granite from which the radiometric K-Ar Jurassic-Triassic age was obtained (table 2) is lithologically quite similar to the quartz monzonite of the Mogotes batholith. This quartz monzonite is probably also Jurassic-Triassic in age. The granodiorite is considered to be of about the same age because it appears to be a phase of the same batholith.
Río Negro batholith

The southern end of the Río Negro mass of quartz monzonite, granite, and granodiorite lies east of the Bucaramanga fault in northeastern H-12 (fig. 4). The west side of the batholith is obviously cut off by this fault. The southern end of the batholith is a thin tail projecting southward along the fault toward Río Suratá. The pluton is at least 50 km long and extends north for an unknown distance. At the quadrangle boundary the batholith is 14.5 km wide. Further north, beyond the map area, the batholith is about 20 km wide. From its trend, it is doubtful that it is continuous with the Ocana batholith in the Ocana-Abrego area.

The batholith is composed of pink to pale-pink quartz monzonite and granite (Jc) in its northern part. North of the quadrangle along the Río Cachira, a gray phase was encountered west of La Vega and a pink phase east of La Vega. Near Río Negro and south of Santa Cruz is gray to pinkish-gray granodiorite (Jgd). The southern tail of the batholith consists of the granodiorite with appreciable tonalite, both cut by pink to white medium-grained quartz monzonite (cq) which predominated toward the Río Suratá. A small isolated mass of similar pink quartz-monzonite intrusive into tonalite is exposed in the area of Los Jardines and Pan de Azucar, east of Bucaramanga.
Granodiorite of the Río Negro batholith

The southern end of the Río Negro batholith in the vicinity of Río Negro and along and south of the Río Santa Cruz consists of gray granodiorite, usually porphyritic, and subordinate equigranular tonalite resembling tonalite of the Paramo Rico pluton. The granodiorite in this area has many inclusions and septa of Bucaramanga gneiss and its southern border is an extensive mixed zone.

The Bucaramanga fault forms the western border of the granodiorite.

To the north of the Río Santa Cruz, the granodiorite is in contact with more felsic pink to white quartz monzonite and granite. Little is known about this contact, and it may be gradational. The northeast contact is a mixed zone with both the Bucaramanga Gneiss and the Silgar Formation. The southeastern contact is a sharp and fairly straight contact with the Bucaramanga Gneiss.

Scattered outcrops of the granodiorite of the Río Negro batholith can be seen on the road from Río Negro to Santa Cruz and on the spur road southeast from Sardinas at the junction of the Río Santa Cruz and Quebrada Guayana.
Typical granodiorite is gray, medium- to coarse-grained, and sub-porphyritic with scattered phenocrysts of large orange-pink potassium feldspar and slightly smaller white plagioclase set in a matrix of gray quartz, biotite, and smaller feldspar grains. The rock is nonfoliated to slightly gneissic. In thin section the texture is hypidiomorphic. The rock is composed of about 10 to 20 percent quartz, 45 to 60 percent euhedral to subhedral, zoned andesine, 10 to 20 percent potassium feldspar, chiefly microcline, and 5 to 10 percent biotite. Hornblende is present only in a few tonalitic rocks. Quartz and potassium feldspar, except where the latter form phenocrysts, tend to be interstitial. Common accessories are sphene, apatite, allanite, rare zircon, and secondary chlorite and epidote. The presence of the granodiorite phase can be readily detected in the asymmetric and bimodal nature of the histograms of the Río Negro batholith (fig. 5). The distribution of accessory minerals in the granodiorite resembles that of tonalite, except for a difference in sphene content (fig. 6).

Small masses of tonalite within the granodiorite show compositional and textural similarities to the masses of fine-grained tonalite and diorite described in an earlier section. These rocks are dark, fine-grained, equigranular to slightly porphyritic, and consist of about 10 percent quartz, 65 percent tabular, zoned andesine which locally forms phenocrysts 0 to 5 percent microcline, 10 to 25 percent blue-green hornblende, and 5 to 15 percent brownish-green biotite. Accessories and secondary minerals are identical to those in the granodiorite. The granodiorite is cut by rare dikes of diabase and gray aplite that resembles the La Corcova Quartz Monzonite.
Quartz monzonite of the Río Negro batholith

Quartz monzonite of the Río Negro batholith is a pink to light-gray, equigranular to subporphyritic, medium-grained biotite quartz monzonite consisting of about 5 percent black biotite, and approximately equal amounts of gray quartz, white plagioclase, and orange-pink to pale-pink potassium feldspar. Porphyritic phases have phenocrysts of pink potassium feldspar and locally phenocrysts of plagioclase also. The rock is generally quite weathered and fresh exposures are not readily accessible but may be seen along some of the streams east of the Bucaramanga fault. The quartz monzonite weathers to a yellowish light-gray soil that is locally orange where the rock is more mafic.

The texture of the quartz monzonite in thin section is hypidiomorphic. The rock is composed of 25 to 35 percent quartz, 25 to 45 percent indistinctly zoned subhedral oligoclase, 20 to 40 percent anhedral microcline and microperthite, and 1 to 10 percent biotite. Accessory minerals are zircon, sphene, allanite, apatite, iron oxide, and secondary chlorite, epidote, and sericite. The abundance and distribution of accessory minerals are similar to those in the quartz monzonite of the Mogotes batholith (fig. 6).

White to pale-pink granite crops out in places near contacts with the Silgara Formation. The composition and texture of this rock is similar to that of the main mass, except that it contains albite rather than oligoclase and as much as 5 percent muscovite, whereas biotite and iron oxide together are less than 2 percent.
In comparison with the quartz monzonite of the Mogotes batholith, the quartz monzonite of the Río Negro batholith is less pink, somewhat more biotitic, and potassium feldspar is microcline rather than microperthite.

Two K-Ar age determinations on biotite from granodiorite near Santa Cruz (EH-10894, table 2) gave ages of 172 ± 6 m.y. and 177 ± 6 m.y. or Middle to Early Jurassic. This age is about 20 million years younger than the ages of the other batholiths dated in the zone with which the Río Negro batholith had been thought to be roughly coeval. Accordingly, the Río Negro batholith is shown as of Jurassic age on plate 1.

The quartz monzonite is presumably penecontemporaneous with the granodiorite, although field relations suggest it might be slightly younger. In spite of the biotite age, the rocks of the Río Negro batholith are included in the Santander Plutonic Group because of their petrographic similarity to other rocks in the group.
Rhyolite in the Bocas Formation

Sheets of apparently intrusive rhyolite, granophyre, and breccia lie within the Bocas Formation in northern H-12 west of the Bucaramanga fault.

The rocks are greenish white, pale tan, light gray, purplish gray to pinkish gray, and aphanitic, porphyritic or fragmental. Breccias contain greenish-gray, pinkish-gray, and red fragments. Some of the rocks have prominent gray spheroids with white rims in an aphanitic grayish-white matrix with rare green mafics. Scattered small pyrite crystals are present in some samples. Some rocks are flow banded.

In thin section many of the rhyolitic rocks have a spherulitic texture similar to phases of the Pescadero granite, others are fine-grained aplite composed of plagioclase, quartz, and orthoclase with rare opaque minerals and traces of zircon. Small clusters of orange biotite are present in some samples. Porphyritic varieties have phenocrysts of quartz and orthoclase. Samples of breccia have fragments of the rocks described above. Some fragments contain spherulites, others are aplitic. Some contain tiny laths of plagioclase. Abundance of mafic minerals differ from fragment to fragment in the breccias. Some fragments appear to be of sedimentary rock with clastic quartz grains. Much of the opaque material present is red-brown oxides of iron. Where present, orthoclase phenocrysts are perthitic. Plagioclase has low relief and appears to be albite or sodic oligoclase. Zircon is about the only identifiable accessory mineral. Fractures in some specimens are filled with quartz and less commonly with fine-grain ed biotite.
Dikes

Felsic, mafic, and lamprophyric dikes are common in the batholiths and plutons of the Santander massif and in the adjoining rocks. Most appear to be differentiates or otherwise genetically related to the rocks of the major batholiths and plutons, because they bear mineralogical and textural similarities to them. Aplite, pegmatite, and felsite porphyry dikes similar in composition to the host rock are common in the quartz monzonitic and granitic rocks. Lamprophyre dikes are also common. Dikes of fine-grained tonalite, fine-grained diorite, or andesite porphyry predominate in granodioritic and tonalitic rocks. Dikes of a distinctive dacite porphyry, basalt, and diabase are more restricted and do not seem to be related to the batholithic suite. A few of the dikes are shown on the geologic maps, but most are too small or too closely grouped to be shown and have been omitted.
Felsic dikes.—Felsic dikes other than aplite and pegmatite, some of which have already been briefly described or mentioned (see Durania granite, for example) range from rhyolite porphyry or vitrophyre to dellenite (quartz latite). Rhyolites are white to pale pink, light gray, or gray black to gray green where aphanitic. Phenocrysts of albite to sodic-oligoclase, rounded quartz, and less commonly orthoclase are set in a cryptocrystalline, spherulitic, or granular matrix of quartz and feldspar, plus unresolved semipaque material. Graphic texture is present in some specimens. A few flakes of biotite are normally present, as well as iron oxide and alteration products. In dellenites, phenocrysts are predominantly oligoclase, with some quartz, and minor orthoclase. The matrix is similar to the rhyolites but is generally microaplitic rather than cryptocrystalline or spherulitic. Dellenite dikes are particularly prominent in the Santa Barbara Quartz Monzonite southeast of Berlin, but they also are found in less well exposed areas of this and other quartz monzonitic batholiths and relatively abundant plutons. Felsic dikes are near Pescadero and Aratoca, but only a few of those near Pescadero could be shown on the geologic map.
Mafic dikes.—Fine-grained, gray to dark-green, equigranular to locally porphyritic dikes of andesite and fine-grained diorite are common in the granodiorite of the Rio Negro batholith as well as in the Mogotes batholith and in the areas of the La Corcova Quartz Monzonite. In porphyritic dikes phenocrysts are commonly zoned subhedral andesine or euhedral hornblende crystals smaller than the plagioclase set in a diabase matrix of plagioclase and hornblende. Trace amounts of quartz are present in some samples, and pigeonite was found in one. Accessories are sphene, iron oxide, apatite, biotite, and alteration products are chlorite, epidote, and calcite.

Lamprophyre dikes.—Lamprophyre dikes are common in the Mogotes and Rio Negro batholiths. They are fine-grained, dark gray, slightly porphyritic with small hornblende phenocrysts. The texture of the groundmass is subdiabasic; laths of mostly saussuritized plagioclase and greenish-grown hornblende are commonly altered to chlorite, and quartz, in amounts of 10 to 15 percent, is present as interstitial grains as is minor orthoclase. Minor biotite is usually chloritized. Apatite, sphene, allanite, iron oxide, epidote, and chlorite are the common accessories. Zircon is rare. Normally zoned euhedral plagioclase forms small phenocrysts in some samples.

Dacite porphyry.—Dikes of dacite porphyry are common in the California district. These dikes are the only igneous rock in the zone that cut rocks of Cretaceous age. East and southeast of Cachiri these dikes cut the Giron Formation of Late Jurassic age and the overlying Tambor Formation of Early Cretaceous age.
The dacite porphyry is gray, fine grained to aphanitic with prominent large euhedral plagioclase phenocrysts as much as 2 cm long and rare smaller phenocrysts of rounded quartz and amphibole. The plagioclase is zoned and complexly twinned andesine or calcic oligoclase. Mafic minerals are generally altered, but some chlorite is pseudomorphic after hornblende. Hornblende preserved in one specimen is a jade-green color. This same specimen was the only one with potassium feldspar as irregular grains in the groundmass. The groundmass in thin section is composed of a mosaic of fine-grained quartz and plagioclase. Accessory minerals are sphene, apatite, iron oxide, and rare allanite. Alteration products are sericite, calcite, and chlorite. A similar rock with smaller (7 mm) plagioclase phenocrysts was observed just east of the Bucaramanga fault near Río Negro. This rock, too, has bright-green amphibole as rare phenocrysts and smaller grains in the groundmass.

Basalt and diabase—A few black to deep-gray-green aphanitic to fine-grained dikes of basalt and diabase are present chiefly along the Bucaramanga front on either side of the Bucaramanga fault. They cut high-grade paragneiss east of Bucaramanga and the Río Negro batholith north of Río Negro; they are found in the area of intrusive rhyolite west of the Bucaramanga fault in northern H-12, and cut the Jordan Formation as dikes and sills near Río Negro and Mesa de Los Santos. Similar dikes are widely scattered though sparse elsewhere in the zone cut rocks and nearly as high in the section as the Girón-Tambor boundary. Some of the dikes, particularly those in the sedimentary rocks, are so altered that their initial composition cannot be determined.
The fresher rocks have a diabasic texture with labradorite laths and intergranular diopsidic augite or pigeonite. Chlorite and iron oxides plus calcite and epidote are alteration products. The altered mafic igneous sills and dikes in the Bocas and Jordan Formations west of the Bucaramanga front have features and alteration products similar to the fresh rocks and are probably also diabase. One sill in the Jordan Formation near Río Negro contains interstitial potassium feldspar.

Altered dikes, possibly originally diabase, have altered plagioclase laths in a chloritic matrix or with intergranular pyroxene. Larger chlorite flakes are pseudomorphs of mafic mineral phenocrysts.

Age of dikes.—The aplites, pegmatites, rhyolites, and dellenites, as well as the lamprophyres and mafic dikes, all are probably contemporaneous with the major batholiths and, therefore, are Jurassic-Triassic in age. The dacite porphyry of the California area is post-Early Cretaceous in age and may correlate with porphyry in the Ocana area which has been dated as 127+3 m.y., or Early Cretaceous (IMN-10953, table 2). Other felsic dikes assigned to the Triassic might be also Early Cretaceous. The basalt and diabase are Jurassic or younger. If the emplacement of these rocks was controlled by movement on the Bucaramanga fault (see section on structural geology), their age may be much younger.
Structure of the igneous rocks

The batholiths and plutons of the southern half of Zone III have a pronounced north-south alignment (fig. 4 and plates). Most striking in this regard are the Santa Bárbara batholith and the La Corcova pluton. The Mogotes batholith has a remarkably straight western border and the Río Negro batholith has fairly straight segments along its eastern border. The irregularities in the eastern and western contacts of the La Corcova pluton and the Santa Bárbara batholith are in large part due to lateral displacement on northeast-striking faults. The Pamplona pluton and some of the smaller stocks have a general north-south alignment.

The eastern and western contacts of the batholiths and plutons are relatively sharp with few apophyses. Exceptions are the La Corcova Quartz Monzonite and the Durania Granite. The first is apparently flanked by a swarm of dikes, and the second has many pegmatite dikes in a wide contact zone. The straightness of the north-south contacts suggests that these are fairly steep.

Some of the contacts are faults. The Bucaramanga fault cuts off the Río Negro batholith on the west and the Mogotes batholith on the east, and cuts off the southern end of the Santa Bárbara batholith. Part of the east contact of the La Corcova pluton is a fault, and its west contact is mylonitized for about ten kilometers near its southern end. Mylonite also crops out at its eastern contact east of Los Curos on the Río Manco.
The northern and southern ends of the batholiths are less straight where not cut off by faults. The wide contact zone in which granodiorite of the Río Negro batholith has intimately intruded the Bucaramanga Gneiss near Santa Cruz, (quadrangle H-12), is located at a place where the contact of the batholith trends nearly east-west. The north end of the La Corcova Quartz Monzonite is similarly quite irregular. The south contact of the Mogotes batholith has an irregular pattern suggesting that the contact dips south at a low angle. This view is supported by the observation that this part of the batholith and the adjacent metasedimentary rocks are shot full of dikes. This contact zone in the metasedimentary rocks, however, is no more than 1500 m wide. The north end of the Santa Bárbara batholith broadens near Berlín where a roof pendant of metamorphic rocks partly separates the main mass from an equant area of the quartz monzonite southeast of Berlín. The presence of quartz monzonite about three kilometers southeast of El Portillo (121 1-3, C-11 NW) in a small exposure surrounded by quartz monzonite-wash at the base of the Girón Formation suggests that the granite lies at no great depth under much of this northern area. The general map pattern of the north end of the Santa Bárbara batholith suggests that its surface is spoon-shaped, plunges southward, and is tilted to the east so that the west contact is steeper than the east contact. The shape of the batholith at depth is unknown. Possibly the northern contact dips to the south following the grain of the metamorphic rocks. However, a small plug of quartz monzonite lithologically similar to that of the Santa Bárbara batholith crops out about 10 km north of Berlín, a relationship that suggests a northward rather than a southward dip.
The alignment of the batholiths suggests a strong north-south structural control of their emplacement. As the Santander Plutonic Group is of Jurassic to Triassic age, this control has to be Triassic or older. Jurassic sediments which contain material derived from the batholiths were deposited in elongate north-south trending troughs, possibly bounded by faults (see p. 384). Structural control of these troughs is possibly inherited from or is a continuation of the same control that guided the emplacement of the Santander Plutonic Group. These relations imply the presence of a fundamental north-south structural grain to this part of the Cordillera Oriental during the Triassic period. Such a structural grain appears to have prevailed on into the Tertiary and Quaternary as is evidenced by the position of the Magdalena Basin.

Little information is available on structural features within the batholiths. Dike swarms in the southern end of the Mogotes batholith trend generally east-west although some north-striking dikes have been observed. In the Pescadero area dikes are oriented either roughly east-west or north-south to north-northeast-south-southeast. Near the northern end of the Santa Barbara batholith, dikes trend north-northeast and northwest. Flow banding and other primary structural features within the batholiths were not mapped.
SEDIMENTARY ROCKS

Because they are the source of the country's petroleum and natural gas, the rocks of the Cretaceous and Tertiary systems are the best known, and the units mapped during the present survey are those recognized in the petroleum-producing areas of the middle Magdalena Basin to the west and the Maracaibo Basin to the northeast. The pre-Cretaceous rocks, which are considered "basement" rocks by the petroleum industry, are less known and consequently have been the source of the most problems and have received the most original study during the investigations reported here.

The post-Paleozoic sedimentary rocks display no noticeable alteration of their sedimentary characteristics due to metamorphic processes, which is in contrast to the Paleozoic rocks where, with increasing age, the sedimentary character has been altered to phyllite, schist, and gneiss by regional dynamothermal metamorphism. The Devonian rocks are the oldest ones that retain enough of their sedimentary character to be recognized more or less generally as a formal unit with definite upper and lower boundaries.
The name "Floresta Series" was first introduced into the literature by Caster (1939, p. 10) for Devonian beds discovered by A. A. Olsson and Teófilo Ramírez in 1935 (Dickey, 1941, p. 1789) in the vicinity of the village of Floresta in the Department of Boyaca. Caster's work was the first detailed study of the fossils of the Floresta beds. Since then other studies have been made by McNair (1940), Caster (1942), Royo y Gomez (1942), and a study of the Floresta and adjacent areas by Botero (1950). Botero introduced the name Floresta Formation for the Devonian beds that overlie schists and gneisses and which are overlain by clay slates and argillites of the Cuche Formation of Permian and Carboniferous age, which crops out apparently only in the Floresta area. On the basis of abundant fossils, the age of the Floresta beds has been generally recognized as of Middle Devonian. Since the Devonian beds were found at Floresta, beds with similar fauna and lithology have been found widely in the Cordillera Oriental of Colombia, including the area reported here. A summary of the present knowledge of the Devonian faunas has been published by Morales (1965).
In the area of this report, mention was made by Hubach (1957, p. 70) that beds underlying the Cretaceous strata north of Guaca may be of Devonian age. During the course of the present survey, Devonian beds were found a few kilometers north of Bucaramanga where pre-Mesozoic rocks are exposed in a small area west of the Bucaramanga fault. Because of limited exposures and complicated structure, it was not possible to measure and describe a section in the usual manner. However, descriptions made at several places reveal the general character of the formation in its relatively unmetamorphosed state.
Descriptions of exposures of the Floresta Formation which outline its general stratigraphy about 6 kilometers north of Bucaramanga, Department of Santander. (Made by A. Castro, October, 1968)

1. Old Bucaramanga-Rionegro highway, east of the junction with the new highway (planchita 109 IV-C, D-15 SE)

Diamante Formation (lower beds only):

Sandstone, dark-purple and gray, hard, silty,
slightly micaceous, fine- to very fine grained,
thin bedded; interbeds of medium-hard, friable,
argillaceous purple siltstone, N. 38° E.,
67° SE. ........................................... 14.0

- - - - - - - - - - - - unconformity - - - - - - -

Floresta Formation:

Argillite, purplish-green, hard, siliceous, thin-
bedded. ........................................... 11.0

Sandstone, greenish-gray, hard, micaceous, medium-
grained, in beds up to 50 cm thick,
N. 3° E., 67° SE. ................................. 7.5
2. Bucaramanga-Rionegro highway, (planchita 109 IV-C, D-15 Center)

Floresta Formation:

Sandstone, purplish-gray, hard, medium-grained, feldspathic, slightly micaceous, thin-bedded; interbedded near the top with thin-bedded silicaceous argillite, N. 45° E., 18° SE.  

(Quebrada La Lomera, which contains alluvium, lies between the exposures described above and those that follow. This quebrada marks the northern end of the regional Suárez fault that terminates at the Bucaramanga fault.)
3. Quebrada Santuario, from the confluence with the Quebrada La Lomera upstream northwestward for 600 m to fault contact with the Bocas Formation (planchita 109 IV-C, C-15 SW)

Floresta Formation:

Siltstone, greenish-gray, hard, argillaceous, thin-bedded. .................................................. ?
Covered interval ................................................................. ?

Claystone, dark-gray, silty, micaceous, N. 81° E.?; 44° SE.? ................................................................. ?

Siltstone, dark-gray, hard, argillaceous, slightly calcareous, micaceous, fossiliferous, with fragments of bryozoans, brachiopods, and trilobites ................................................................. ?
Covered interval ................................................................. ?

Claystone, gray, silty, micaceous, slightly calcareous; N. 15° E., vertical .................................................. ?
Covered interval ................................................................. ?

Claystone, dark-gray, silty; contains pyrite in disseminated grains along joints and fractures; N. 3° E., vertical .................................................. ?
Covered interval ................................................................. ?
Meters

Siltstone, dark-gray, hard, argillaceous, mica-ceous, thin-bedded; contains veinlets of calcite,
N. 22° W., 78° NE. ................................. ?
Covered interval ................................. ?

Siltstone, dark-gray, argillaceous, micaceous,
thin-bedded, N. 15° W., 78° NE. ................... ?
Covered interval ................................. ?

Limestone, dark-gray to black, hard, fine- to medium-crystalline, in beds of 50-60 cm; contains veinlets
of calcite, N. 10° E., 68° SE. ........................ ?
Covered interval (fault contact with Bocas Formation) ................................. ?

Bocas Formation:
Colluvium with angular fragments of hard, yellowish-gray, plane-bedded feldspathic sandstone and
yellowish-gray siltstone ................................. ?
Considering the width of the belt in which the above-described exposures occur and the generally steep dips that were measured, but disregarding the unpredictable effects of faulting, the thickness of the section is estimated at 350 to 400 meters. At the type section near Floresta, 145 km south of Bucaramanga, the thickness of the formation is estimated at 600-700 meters (Botero, 1950, p. 259). The formation is not highly resistant to weathering and tends to form rounded topography without conspicuous relief.

The normal contact of the Floresta Formation with underlying rocks is not known in the Bucaramanga area, but about 2 kilometers west of San Joaquin, where the Floresta presumably overlies pre-Devonian metamorphic rocks (planchita 136-III-C, H-13 W1/2), massive beds of conglomerate with sub-rounded pebbles of white quartz form a basal section 20 meters or more in thickness.
North of Bucaramanga, the boundary between the Floresta and the overlying Diamante Formation is not well-exposed or well-defined even though this contact is apparently one of unconformity. However, the fine-grained beds of the Floresta are noticeably argillitic, slaty or phyllitic as compared with the claystones and siltstones of the Diamante. The fine-grained rocks of the Floresta Formation tend to display phyllitic surface textures, and this is usually more noticeable east of the Bucaramanga fault.

The fossiliferous bed found in Quebrada El Santuario is poorly exposed, but 600 meters to the north, highly fossiliferous beds crop out on the upper slopes to the west of Quebrada La Lomera (109 IV-C, C-15 NW). Apparently the calcareous fossils and cement have been leached from a hard, calcareous siltstone leaving a rather soft, porous, light yellowish-brown rock with abundant molds and casts of fossils that are mostly fragmentary. Bryozoans are very abundant, brachiopods are common, corals, trilobites, and gastropods are relatively rare. Samples were submitted to the U.S. Geological Survey from this location and yielded the following information:
Paleontologist reporting: J. T. Dutro, Jr., 6/27/67

Sample Nos.: RV-520 (USGS 8003-SD), RV-521 (USGS 8004-SD),
RV-522 (USGS 8005-SD), RV-523 (USGS 8006-SD), RV-524
(USGS 8007-SD), RV-525 (USGS 8008-SD), RV-526 (USGS 8009-
SD), RV-527 (USGS 8010-SD), ST-1049 (USGS 8011-SD)

Location: Planchita 109-IV-C, C-15 NW

Stratigraphic Range: (Late Early Devonian, possibly equivalent to the Schoharie interval in the eastern United States)

Fossils contained:

bryozoans: fenestrate and ramose, undetermined

brachiopods: chonetid, indeterminate

schuchertellid, indeterminate

rhipidomellid, indeterminate

Australospirifer sp.

Australospirifer cf. A. antarcticus Morris and Sharpe

Atrypa? sp.

Athyris sp.

Elytha colombiana Caster

Cynostrophia? sp.

Eodevonaria imperialis Caster

Leptaena boyaca Caster

Megastrophia sp.

Schellwienella? sp.
Pholidops sp.

Dictyostrophia cf. D. cooperi Caster

corals: tabulate, indeterminate

rugose horn, indeterminate

syringoporoid, indeterminate

trilobites: Phacopina? sp. (free cheek)

Phacops? sp.

echinoderms: debris, indeterminate

ostracods: undetermined

gastropod: high-spired, undetermined

According to the report, most of the identifiable species are the same as those described by Caster (1939) from the Floresta area. The lithologies of the fossiliferous beds are also quite similar.
Fossiliferous beds that are thought to be of Devonian age have been found in several other places in the report area:

- North of Guaca, planchita 121-III-B, C-2 NE
- East of Guaca, planchita 121-III-B, F-5 SE
- Northeast of San Andrés, planchita 121-III-D, C-4 SE
- Southeast of Mogotes, planchita 136-III-C, G-10, G-12 SW, H-12 N1/2

Except for some of the bryozoans, deformation of the beds has usually distorted the fossils beyond recognition.

In the northern half of Zone III, Floresta beds were found during the field checking of photogeologic maps during the contract period with Geophoto Services, Inc. In planchita 76-I-D, the beds are exposed north of Las Mercedes along the main highway to Convención and along the road from Las Mercedes to Teorana. Fossiliferous samples were collected about 1 kilometer north of Las Mercedes (planchita 76-I-D, G-7 SW) that appear to be identical in fossil content and lithology to those submitted for study from north of Bucaramanga.
Metamorphosed Floresta Formation.--Very lightly metamorphosed Floresta Formation overlies the Silgara Formation near Mogotes and San Joaquin in the southwestern part of the map area in quadrangle I-12 and I-13. Because metamorphism in the Silgara Formation in this area is fairly low grade, it is difficult to distinguish the two formations in the absence of exposures of the basal beds. R. Calpa (written commun., 1968) has indicated that approximately 750 to 1,000 meters of the Floresta Formation is present near Mogotes. Fossiliferous horizons lie an estimated maximum of 250 to 300 meters above the basal sandstone and conglomerate in dark-gray marble and in gray and dark-gray phyllitic argillites and calcareous metasiltstone. Associated light gray marble is barren. Bryozoans from the Floresta have been identified by Srta. Diana Gutierrez of the Servicio Geologico Nacional, Bogota, as types common in the Devonian.
The Floresta Formation occupies an extensive belt along the east sides of the Mogotes and Santa Bárbara batholiths. In quadrangles I-13 and H-13 rocks probably belonging to the Floresta Formation crop out in the northern part of the map area north of Mutiscua. The Floresta Formation in the southern part of this belt shows a very low grade of metamorphism, but its metamorphic grade increases northward, although apparently the highest grade reached is still within the greenschist facies in the area southeast of Berlin and southwest of Silos.
The Floresta Formation in the belt from Covarachia to Silos is well exposed west of Guaca on the road from Guaca to Los Curos and north of Guaca on the road from Guaca to Berlin west of Baraya and northeast of El Portillo. Nowhere has the complete section been seen with certainty, although the base of the formation may be present southwest of Molagavita, and southwest of San Andres. Dark graphitic slately phyllites low in the section in some places are associated with marble and fossiliferous beds. The section shown in figure 7 is probably representative of part, probably the lower part, of the Devonian section in this belt. The marble is dark gray to light gray and is similar to that in the Mogotes area.

Conglomerate and quartzite are present in the slopes west of San Andres, but it was not determined if these beds are basal.

Higher in the section are greenish-gray to tan meta-sandstone, meta-siltstone and silty phyllites. Purplish-gray argillite is present locally. Light-gray and dark-gray marble similar to that in the Mogotes area crops out near Molagavita, a few kilometers north of Guaca, north of El Portillo, the Silos area, and near Mutiscua.

Fossils were found in the Covarachia area (136-III-D,E-15), Molagavita area (136-I-D, D-2, E-2). North of Guaca (121-III-B, C-2), and north of El Portillo (121-I-U, E-4, F-3). The assemblages consist principally of bryozoa and crinoid fragments.
The thickness of the formation in this belt, along the east side of the massif is almost impossible to estimate because of the folding and faulting. The width of outcrop suggests that the formation might be thicker here than in the Mogotes area or in the Bucaramanga area. The contact with the underlying Silgará Formation is in some places clear, but throughout most of the belt it is indistinct, particularly in the area from north of Guaca to Silos. The contact in this zone is somewhat arbitrarily drawn to include the fossiliferous marble beds and associated black phyllite, which are considered to be near the base of the section. Near El Portillo, black graphitic phyllitic slates and minor interbedded tan-colored meta-sandstone and gray slate lying to the east of the fossiliferous marble horizons seem to pass by interbedding into the Diamante Formation of Permian age. The Diamante limestone in this area as well as in the Mutiscua area is somewhat recrystallized.
Carboniferous, Permian, and Triassic Systems

Surata Group

This term is here used in place of "Surata series"

which Dickey (1941, p. 1790) used for fossiliferous Paleozoic beds

which are exposed between the Río Suratá and Puente de Tierra on the

old highway from Bucaramanga to Bocas. The beds were mapped and a

section was measured and described by Navas (1962). The name Suratá

is retained as the group name for the two units here recognized as

the Diamante and Tiburón Formations.
Diamante Formation (PCd).—This unit is here named for the lower part of the Suratá series described very briefly by Dickey (1941, p. 1790) and includes the lower part of the section that was mapped and described by Navas (1962). The name is derived from quarries of Cementos Diamante S.A. which obtains limestone for manufacture of cement from the upper beds of this formation a few kilometers north of Bucaramanga. The type section is in these quarries and northwestward along the old Bucaramanga-Ríonegro highway where it extends along the east side of Quebrada La Mona for a distance of approximately 2 kilometers. This section is described below.

A total of 440 meters of Diamante was measured at the type locality. Of this, the lower 139 meters is dark purple to dark purplish-gray, fine- to medium-grained sandstone of varying hardness, and interbedded claystone of similar color. Some of the sandstones are feldspathic and micaceous, and some near the middle are coarse-grained to conglomeratic with quartz pebbles up to 7 mm in diameter. A middle section of 97 meters has dark gray shale with interbedded dark gray limestone in the lower half and greenish-gray silty claystone in the upper half. The upper section of 204 meters is dark gray, fine- to medium-crystalline, slightly argillaceous limestone with small amounts of interbedded silty claystone or argillaceous sandstone at some levels.
Type stratigraphic section of the Diamante Formation of the Surata Group in quarries of Cementos Diamante S.A. (planchita 109 IV-D, E-1 SW) and along the old Bucaramanga-Rionegro highway (planchita IV-C, D-15 SE and E-15 NE), Municipality of Bucaramanga, Department of Santander. (Measured and described by A. Castro in September, 1963)

Meters

Tiburón Formation (lower beds only):

Conglomerate, dark-gray, hard, massive; semi-rounded pebbles of limestone and dolomite from the underlying Diamante Formation, and a few of chert, 2 to 6 cm in diameter, in a matrix of light-gray sandy limestone. ................ 19.4

- - - - - - - - - - unconformity- - - - - - - - -

Diamante Formation:

Limestone, light-gray, argillaceous, slightly hard, with thin interbeds of light greenish-gray, calcareous, silty claystone. Unit is highly sheared and fractured, N. 15° W., 36° NE. ....... 18.4

Claystone, gray, sandy, calcareous, medium-hard, thin-beded, with basal bed 1.2 m thick and other thinner, lenticular beds of hard, dense, light-gray limestone ................. 12.3

Claystone, gray, sandy, calcareous, medium-hard, thin-beded, containing lenticular beds of dark-gray, hard, argillaceous limestone up to 15 cm thick. Argillaceous and micaceous, calcareous, thin-beded, light-brownish-gray sandstone near the middle and top, N. 45° E., 61° SE. ........... 11.5
Limestone, dark-gray, hard, fine- to medium-crystalline, fossiliferous, in beds 2.0 to 3.5 m thick; thin lenses of gray calcareous chert; slight gassy odor on fresh fracture, N. 4° W., 58° NE. .......... 16.0

Limestone, dark-gray, hard, fine- to medium-crystalline, in beds 15-30 cm thick; contains fossil fragments, N. 3° E., 62° SE. .......... 15.0

Limestone, dark-gray, hard, massive, fossiliferous with fragments of brachiopods and crinoids .......... 7.0

Chert, light-gray, hard, very calcareous in beds up to 40 cm thick. Dissolved calcite leaves porous weathered surface ................. 1.0

Limestone, dark-gray, hard, fine- to medium-crystalline, slightly argillaceous, in beds 20-60 cm thick separated by thin beds of argillaceous, calcareous, friable, gray sandstone. Contains pyrite in disseminated grains and filling small fractures, N. 6° W., 78° NE. ............. 28.0
<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, dark-gray, hard, fine- to medium-crystalline, slightly argillaceous, in beds 0.4-1.2 m thick. Bedding planes have thin films of graphitic material, N. 2° W., 72° NE. .................................. 52.0</td>
</tr>
<tr>
<td>Limestone, dark-gray, hard, fine- to medium-crystalline, slightly argillaceous, in beds 10-20 cm thick, N. 10° W., 76° NE. ........... 14.0</td>
</tr>
<tr>
<td>Claystone, greenish-gray, medium-hard, silty, slightly calcareous, in beds 5-12 cm thick, N. 2° E., 58° SE. ................ 51.0</td>
</tr>
<tr>
<td>Shale, dark-gray to black, weathering reddish-brown, and dark-gray, hard, argillaceous limestone in basal 1 meter .................... 12.0</td>
</tr>
<tr>
<td>Shale (50 percent), dark-gray to black, and limestone (50 percent), hard, dark-gray, in beds up to 1 meter thick. Shale is more abundant in the upper part, limestone in the lower part, N. 10° E., 78° SE. ......................... 29.0</td>
</tr>
<tr>
<td>Limestone, dark-gray, hard, fine- to medium-crystalline, slightly argillaceous at the base, N. 9° E., 79° SE. ......................... 4.8</td>
</tr>
</tbody>
</table>
(The section above is mostly in limestone quarries; that which follows starts 500 meters along strike to the north and continues along the old Bucaramanga-Rionegro highway.)

Partly covered—sandstone, dark-purple to greenish-gray in the basal part, fine- to medium-grained, argillaceous, feldspathic, micaceous; light yellowish-gray, micaceous and more argillaceous in the middle part which is interbedded with hard, violet-gray limestone in beds up to 15 cm thick. At the top is greenish- to yellowish-gray, thin-beded, slightly micaceous claystone, N. 5° E., 35° SE. 16.2

Partly covered—sandstone, dark-purplish-gray, medium-hard, fine- to medium-grained, feldspathic, micaceous, in beds up to 30 cm thick; middle and upper parts contain thin beds of dark-purple, micaceous, sandy claystone, N. 2° E., 31° SE. 17.2

Sandstone, light-yellowish-gray, hard, medium-grained, micaceous, in massive beds up to 3 m thick 14.6
| Claystone, yellowish-gray, medium-hard, thin-bedded; sandy, micaceous, and thicker beds near the top, N. 26° E., 39° SE. | 8.2 |
| Sandstone, light-yellowish-gray, hard, fine-grained, slightly micaceous, in beds up to 50 cm thick; argillaceous, feldspathic, highly micaceous, greenish-gray near the top in beds up to 1 meter thick | 9.5 |
| Sandstone, dark-purple, medium-hard, fine- to very fine grained, argillaceous, feldspathic, micaceous; medium- to coarse-grained, harder beds at the top are conglomeratic with quartz pebbles up to 5 mm in diameter | 11.0 |
| Sandstone, dark-purple, medium-hard, fine- to very fine grained, argillaceous, feldspathic, micaceous, interbedded with friable, purple, sandy claystone in the lower part, and conglomeratic in the middle with small quartz pebbles, N. 21° E., 34° SE. | 22.0 |
Meters

Sandstone, dark-purple, hard, medium- to coarse-grained, feldspathic, micaceous; conglomeratic in the upper beds with quartz pebbles up to 7 mm in diameter; friable, silty, dark-purple claystone in the middle, N. 20° E., 35° SE. ... 16.2

Claystone, purple, silty, slightly micaceous, friable ... 5.5

Sandstone, grayish-purple, hard, medium-grained, micaceous, in beds 15-40 cm thick; contains interbedded argillaceous siltstone, N. 20° E., 41° SE. ... 5.5

Sandstone, dark-purple and gray, hard, silty, slightly micaceous, fine- to very fine grained, thin-bedded; contains interbedded medium-hard, friable, purple argillaceous siltstone ... 14.0

Total thickness of the Diamante Formation 440.0

--- - unconformity ---

Floresta Formation (upper beds only):

Argillite, purplish-green, hard, siliceous, thin-beded ... 11.0

Sandstone, greenish-gray, hard, medium-grained, micaceous, in beds up to 50 cm thick, N. 3° E., 67° SE. ... 7.5
The Diamante Formation is apparently unconformable over the Floresta Formation, but the boundary has not been found sharply defined. The beds of the Floresta display a slightly phyllitic character as compared with those of the Diamante. At the top of the Diamante, the limestone pebble conglomerate of the Tiburón Formation marks a sharp boundary of unconformity.

The type section of the Diamante Formation is not far from the regional Bucaramanga fault to the east, and small calcite-filled fractures are common in many of the steeply-dipping limestone beds. Northward from the type section, the Diamante Formation is in contact with the Bucaramanga fault in a low indistinct ridge that extends for nearly 8 kilometers. Southward from the type section it is covered by unconsolidated Quaternary deposits of the Bucaramanga terrace and does not reappear beyond it except for one small fault slice exposed in Planchita 120-II-B, D-5 SW and E-5 NW.

Fossiliferous beds are few and thin in contrast to the Cretaceous limestones of the region which contain many highly fossiliferous beds. Fossils collected from limestone outcrops in the general area of the type section were identified by paleontologists of the U. S. Geological Survey. Ages for those collections which could be dated most closely range from Middle Pennsylvanian to Middle Permian. The following reports were received:
Sample N-. DW4/68 (IMN 13850); Location: planchita 109-IV-D,  
F-1 NW

Stratigraphic range: Permian

Fossils contained:  
  brachiopods:  
      *Kochiproductus* sp.  
      *Neospirifer* sp.  
      *Waagenoconcha* sp. (most common in Middle Permian)  
  crinoids: numerous columnals and some plates

Sample No. DW5/68 (IMN 13851); Location: planchita 109-IV-D,  
F1 SW

Stratigraphic range: Late Paleozoic

Fossils contained:  
  brachiopod:  
      *Linoproductus* sp.  
  bivalves: see report next following  
  crinoids: numerous columnals, indeterminate  
  echinoids: spines, indeterminate
Paleontologist reporting: John Pojeta, 5/17/68

Sample No. DW 5/68 (IMN 13851) (USGS 23268-PC)

Location: planchita 109-IV-D, F-1SW

Stratigraphic range: Late Paleozoic

Fossils contained:

- pelecypods: Myalina sp.
  - Aviculopecten sp.
  - Nuculanid pelecypod of the *Phestia-Polidevcia* type

Paleontologist: J. T. Dutro, Jr., 6/4/68

Sample No. DW 40/-8 (IMN 13908) (USGS 23332-PC)

Location: planchita 109-IV-C, D-15 NE

Stratigraphic range: Pennsylvanian, probably Middle Pennsylvanian; resembles fauna described from Tarma Group of Peru by Newell and others (Geol. Soc. America Memoir 58, 1953)

Fossils contained:

- brachiopods: Cancrinella? aff. *C. villiersi* (d'Orbigny)
  - Anthracospirifer aff. *A. opimus* (Hall)
  - Composita aff. *C. subtilita* (Hall)
  - Cleiothyridina cf. *C. barbata* Chronic

- echinoderms: debris, indeterminate

- tabulate coral: Chaetetes? sp.

- bryozoans: fragments, indeterminate

- worm tubes: indeterminate
Paleontologist reporting: R. C. Douglass, 6/13/68

Sample No. DW 39/68 (IMN 13907); Location: planchita 109-IV-C, D-15 NE
Stratigraphic range: Early Permian (late Wolfcamp equivalent)
Fossils contained:
- fusulinid foraminifer: Monodiexodina sp.

Sample No. DW 43/68 (IMN 13911); Location: planchita 109-IV-D, E-1 SW
Stratigraphic range: Early Permian (late Wolfcamp to early Leonard equivalent)
Fossils contained:
- Schwagerinid fusulinids resembling thick-walled Parafusulina

Sample No. DW 44/68 (IMN 13912); Location: planchita 109-IV-D, G-1 NE
Stratigraphic range: Middle Pennsylvanian
Fossils contained:
- foraminifers: Climacamina sp.
- Bradyina sp.
- Fusulinella sp.
Foraminifers are reported here from the Diamante Formation for the first time. The other fossils, principally brachiopods, were studied previously by J. S. Williams and reported by Trumpy (1943, p. 1294) to be of either Mississippian or Early Pennsylvanian age.

The limestone section of the upper part of the Diamante Formation indicates that at least this part of the unit was originally widespread, but that subsequent erosion has removed all but rather limited remnants in the mapped area. Dark gray limestones that are thought to be part of this section crop out intermittently about 40 km east of the type section in a belt in quadrangle H-13 that extends approximately 35 km north-northeast from El Portillo in b-5 SW to Mutiscua and beyond in b-2 E-1/2. The unit overlies Devonian rocks and is in turn overlain by beds of Triassic (Bocas Formation), Jurassic (Girón Formation) or Cretaceous (Tambor Formation) age. Two single specimens of brachiopods that were found were submitted to the U.S. Geological Survey:

Paleontologist reporting: R. E. Grant, 3/27/68

Sample No. DW 3/68 (IMN 13849) (USGS 23266-PC)

Location: planchita 121 I-B, I-6 SW

Stratigraphic range: Permian (Leonard equivalent)

Fossils contained:

brachiopods: _Meekella_ sp. (resembles those of Leonard age in southwestern U.S.)

cf. _Orthotichia_ sp.

No report was received on two single specimens of horn corals from the same locality.
The limestones show evidence of recrystallization to coarser calcite which tends to obscure finer features of the fossils. Near Mutíscua, the recrystallization is much stronger and the rock displays textures approaching that of marble. North of Mutíscua, phyllitic shales occur in some places at the top of the Diamante, underlying Cretaceous rocks.

At El Portillo, some of the beds of the Diamante contain dolomite. Barite mineralization occurs in one such zone in veins sufficiently large to be mined in small surface pits. Another dolomite zone about 10 meters thick occurs lower in the section and is exposed for a distance of about 100 meters.

On the basis of similar fossils and lithologies, the Diamante Formation is correlated with Carboniferous and Permian rocks in northern Colombia. C. Tschanz (written commen.) describes follliferous rocks near Manaure, at Rio Seco north of Valledupar, and in the Chundua mountains, that are all assigned to the Carboniferous. This confirms earlier mention of Carboniferous rocks in the Serranía de Perijá by Trumpy (1943, p. 1295) and of Carboniferous and Permian rocks by Miller (1962, p. 1571).
Fusulinids of Permian age have been reported from unnamed beds near Manaure in the Serrania de Perija, Department of Magdalena (Thompson and Miller, 1949), which are of an age equivalent to Wolfcamp, Leonard, and Guadalupe of West Texas. Other fossils are abundant, including crinoids, brachiopods, gastropods, and cephalopods (Trumpy, 1943, p. 1925; Miller and Williams, 1945).

**Tiburón Formation (TrPt).**—This unit is here named for the upper part of the Surata series of Dickey (1941, p. 1790) and includes mostly massive beds of conglomerate with pebbles of limestone from the underlying Diamante Formation imbedded in a fine-grained gray, calcareous matrix. It corresponds to the calcareous conglomerates in the upper part of the section measured and described by Navas (1962). The name is derived from the Club Tiburones which is near the best exposures of the unit about 2 kilometers north of Bucaramanga. This section is described below.

Because of the covered intervals, the measurement of a continuous section was not possible. The thickness of exposed beds totals 212 meters. On the basis of the attitudes measured in the belt of outcrops, which is about 600 meters wide, the Tiburon Formation is estimated to be from 450 to 500 meters thick at the type locality.
(Upper beds of the Tiburón and those of the overlying unit, which is probably the Bocas Formation in this area, are covered by Quaternary deposits of the Bucaramanga Terrace.)

Tiburón Formation:

<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conglomerate, gray, hard, with abundant pebbles of gray limestone, some of dolomite, and few of sandstone, 3-18 cm in largest dimension, firmly embedded in matrix of fine- to medium-crystalline limestone, in beds up to 1 meter thick</td>
</tr>
<tr>
<td>Siltstone, gray to dark-gray, medium-hard, calcareous, argillaceous, in beds up to 1.2 m thick, N. 12° E., 62° SE.</td>
</tr>
<tr>
<td>Covered interval</td>
</tr>
<tr>
<td>Limestone, dark-gray, hard, slightly argillaceous, fine- to medium-crystalline; 5 m of hard, gray limestone pebble conglomerate near the middle, N. 22° E., 47° SE.</td>
</tr>
<tr>
<td>Meters</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Covered interval</td>
</tr>
<tr>
<td>Covered interval</td>
</tr>
<tr>
<td>Conglomerate, dark-gray, hard, massive, with pebbles of limestone, few of sandstone and very few of black calcareous chert, from 1-14 cm in diameter, mostly 2-5 cm, in matrix of fine- to medium-crystalline limestone; near the middle are 7.5 m of light-gray, slightly argillaceous limestone, medium-hard, in beds 1.0-1.5 m thick</td>
</tr>
<tr>
<td>Covered interval</td>
</tr>
<tr>
<td>Limestone, light- to dark-gray, medium-hard, argillaceous, slightly micaceous, in beds 30-45 cm thick, N. 4° E., 64° SE.</td>
</tr>
<tr>
<td>Conglomerate, dark-gray, hard, massive, with pebbles mostly of limestone, few of dolomite and sandstone, from 1-8 cm in diameter, in matrix of fine-crystalline light-gray limestone.</td>
</tr>
</tbody>
</table>
Covered interval ........................ ?
Conglomerate, dark-gray, hard, massive, with pebbles
of hard, gray limestone that reach cobble size
(up to 22 cm) near the base, in matrix of fine,
light-gray limestone; some pebbles contain frag-
ments of crinoids, N. 2° E., 65° SE. .......... 30.0
Covered interval ........................ ?
Conglomerate, dark-gray, hard, massive, with pebbles
mostly of limestone from 2-12 cm in diameter,
mostly 3-5 cm, in matrix of fine, light-gray lime-
stone; near the middle are 8 m of light- to dark-
gray, medium-hard, argillaceous limestone in beds
0.8-1.5 m thick, N. 6° W., 56° NE. .......... 27.5
Covered interval ........................ ?
(The basal part of the Tiburón described below is above
the type section of the Diamante Formation in plan-
chita 109 IV-D, F-1 NE.)
Conglomerate, dark-gray, hard, massive; pebbles are
mostly of gray limestone from 0.5-3 cm in diameter,
mostly 1-3 cm, in matrix of fine, light-gray lime-
stone; some pebbles are fossiliferous with fusulinids
and fragments of brachiopods and crinoids ....... 4.0
Covered interval ........................................... 10.0

Conglomerate, dark-gray, hard, massive; abundant
pebbles of gray limestone and dolomite, very few
of chert, 2-6 cm in diameter, firmly imbedded in
matrix of fine, light-gray limestone; size of
pebbles and number of dolomite pebbles increases
in upper part and some sandstone pebbles are
present; limestone pebbles predominate at the top,
up to 16 cm in diameter ............................ 19.4

--- unconformity ---

Diamante Formation (upper beds only):

Limestone, light-gray, slightly hard, argillaceous,
with thin interbeds of light-gray, calcareous,
silty, claystone, highly fractured .............. 18.4
Although there are noticeable variations in pebble size and in the ratios of pebble material from bed to bed, the conglomerates display remarkable uniformity throughout the formation. Limestone pebbles predominate in all beds in colors of dark to light gray and rarely pink. Dolomite pebbles are numerous in some of the lower beds and have a highly fractured appearance. A few are present throughout the formation. A few pebbles of sandstone and a very few of chert are present also. On weathered surfaces the limestone pebbles and the matrix weather rather uniformly to a smooth surface, whereas the more resistant dolomite, sandstone, and chert pebbles stand out in relief.

In most of the conglomerate beds the subangular to subrounded pebbles are rather densely packed and firmly cemented by the fine-grained calcareous matrix. This matrix is similar in texture and color to some of the limestone pebbles and suggests that it originated largely from the fine materials derived from the erosion of the limestone beds which supplied the pebbles. Quartz grains, locally ranging up to pebbles 5 mm in diameter, are present in the matrix of some beds.
The limestone pebbles are fossiliferous to the extent that would be expected from the sparsely fossiliferous source beds of the Diamante Formation. Some of the conglomerates in the lower part apparently have greater concentration of pebbles containing fusulinids, but even there they probably do not represent more than 5 percent of the pebbles. Three of these pebbles submitted to the U.S. Geological Survey for fossil identification yielded the following results:

Paleontologist reporting: R. C. Douglass, 12/12/66

Sample No. IMN 10824; Location: planchita 109-IV-D, H-1 NE

Stratigraphic range: Permian (probably equivalent of Leonard of West Texas)

Fossils contained:

Pebble A: foraminifers: Parafusulina sp. thick-walled form
Parafusulina sp. thin-walled form
bryozoans: rare, indeterminate

Pebble B: foraminifers: Climacamina sp. common
Parafusulina sp. thin-walled form

Pebble C: foraminifers: Parafusulina sp. thin-walled form
ostracods: common, undetermined
The boundary of the Tiburón with the underlying Diamante Formation is not well exposed, but the change in lithology across this boundary is very conspicuous and quite evidently one of unconformity. In the area of the type section south of Río Suratá, the contact with the overlying Bocas Formation is covered by unconsolidated Quaternary deposits of the Bucaramanga terrace. North of the river, the reversal of dips in the Bocas Formation as compared with those in the Tiburón suggests that the contact there is a fault surface.

Areal distribution of the Tiburón Formation is virtually limited to the narrow outcrop which extends northward 2 kilometers from the major portion of the type section on the south side of Río Suratá. At its northern end, this outcrop terminates at the Bucaramanga fault. One other small lens-shaped body about 400 meters long crops out adjacent to the same fault about 2 kilometers farther north (planchita 109 IV-C, D-15 NE).

In the Department of Magdalena, Permian beds with fusulinids have been reported in the Serranía de Perijá near Manaure (Thompson and Miller, 1949), and farther south, on the Río Mula, limestone boulders in conglomerate contain Permian fusulinids (Trumpy, 1943, p. 1297). The conglomerates are in red beds that contain volcanic material and have been assigned to the Late Triassic (Trumpy, 1943, p. 1292).
The age of the Tiburon Formation can be indicated only approximately as older than the Diamante Formation of Carboniferous to Permian age, from which it was derived, and younger than the Bocas Formation the age of which is probably, but not conclusively, Triassic.

The lithology of the Tiburon Formation, its relationship to the underlying Diamante Formation, and its position immediately west of the Bucaramanga fault seem to indicate that it was derived almost exclusively from Diamante beds in higher areas just east of the fault. The eroded material was deposited abruptly over Diamante beds west of the fault. The origin, transportation, and deposition of the constituent sediments may have all been confined to an area of less than 100 square kilometers.

Bocas Formation.--The Bocas Formation was first referred to as the "Bocas series" by Dickey (1941, p. 1790) to include the "less fossiliferous series from Puente de Tierra to Bocas" overlying the "Surata series" along the highway north of Bucaramanga. The beds were thought to be of Paleozoic age.
Inasmuch as nothing more than a brief description has been given of the Bocas Formation in the literature up to this time, the type area has received rather careful study, and a description is given below.

The area of outcrops of the Bocas between Puente de Tierra and Bocas displays a roughly synclinal structure with many minor folds and faults that confuse the overall picture, particularly in the middle part of the formation. The section presented here is in two parts, the lower one including a sequence of beds overlying the Diamante Formation and another sequence underlying the Jordan Formation. There does not appear to be any repetition between the two series, but it is possible that some beds in the middle of the formation are not included.

The approximate thickness of the Bocas Formation shown below is 590 meters. The boundary with limestone of the underlying Diamante Formation is indicated as normal, but the fractured condition of the limestone and of the sandstone at the base of the Bocas section indicate possible faulting that may be a northward continuation of the fault between the Bocas and Floresta Formations about 600 meters to the south. North of the type section, the contact with the Diamante may be a normal one, but the section appears to be overturned. The contact of the Bocas with the overlying Jordáñ Formation is transitional and includes a conspicuous color change from greenish-gray Bocas beds to reddish-brown Jordáñ.
Type stratigraphic section of the Bocas Formation.

the lower part measured along the Bucaramanga-Rionegro highway

from Calera San Luis to Quebrada Santa Elena (planchita 109 IV-A.

j-14 S1), and the upper part measured southward from the

village of Bocas along the railroad to the contact with the

Jordan Formation (planchita 109 IV-C, A-12 E+ and B-12 NE),

Municipality of Bucaramanga, Department of Santander.

(Measured by E. Aya, September, 1968)

Meters

Jordan Formation (lower beds only):

Sandstone, reddish-brown and greenish-gray,

hard, very fine grained to silty, slightly
calcareous, in beds up to 1 meter thick,

N. 45° E., 35° SE. ................ 5.0

Bocas Formation:

Siltstone, greenish-gray to reddish-brown,

argillaceous, micaceous, slightly calcareous,
in beds up to 1.1 m thick; highly fractured
normal to the bedding, N. 30° E., 38° SE.;
N. 46° E., 33° SE. ................ 120.0

(change of strike indicates possible faulting)

Siltstone, greenish-gray, slightly calcareous,
massive; contains gray, calcareous nodules up
to 4 mm in diameter; exposure nearly parallel
to the strike, N. 15° W., 43° NE.; N. 22° E.,
40° SE.; N. 5° E., 43° SE. .............. 65.0

(approx.)

Covered interval (change of strike indicates

possible faulting) ................ 50.0

Sandstone and siltstone, greenish-gray, hard,
calcareous, massive, conglomeratic with granules

of dark-gray chale, N. 86° E., 50° SE. ...... 12.0
Conglomerate, greenish-gray, hard, massive, with
subangular pebbles of gray limestone, dark-gray
shale and quartz in calcareous sandy matrix,
N. 65° E., 38° SE. .................. 20.0
Shale, dark-gray and gray, calcareous to noncal-
careous; calcareous, pyritiferous nodules up to
20 mm in diameter and 5 mm thick ............ 8.0
Claystone, dark-gray, calcareous, slightly mica-
ceous, thin-bedded; contains calcite-filled
fractures, N. 36° E., 70° SE. .............. 10.0
Covered interval that probably includes dark-gray
shale and claystone .................. (approx.) 85.0

(The above section ends at a probable fault extending
north-northeastward through the village of Bocas and
up the valley of the Río Negro. The section that
follows was measured along the Bucaramanga-Rionegro
highway from near the limestone kiln at San Luis for
about 500 meters northwestward to the Quebrada Santa
Elena.)
Claystone, greenish-gray, slightly hard, with interbedded dark-gray shale; somewhat crumpled,
  N. 40° W., 75° SW. ........................................ 31.0

Siltstone, greenish-gray, medium-hard, slightly micaceous, N.-S., 30° W. ................ 30.0

Siltstone, greenish-gray, hard, calcareous, micaceous, in beds up to 10 cm thick, N. 12° E., 54° NW. ... 16.0

Shale, dark-gray, slightly hard; contains fragmentary plant fossils ........................................ 8.0

Siltstone, greenish-gray, hard, calcareous, bluish at the top ............................................... 6.0

Shale, dark-gray, easily weathered ................ 5.8

Siltstone, greenish-gray, hard, calcareous, slightly micaceous, N. 43° W., 51° SW. ................... 7.0

Shale, gray, micaceous, easily weathered ........ 4.0

Shale, dark-gray, sandy, calcareous ................ 2.4

Sandstone, greenish-gray, hard, fine-grained, slightly calcareous, N. 5° W., 34° SW. ............... 2.6

Shale, dark-gray, easily weathered ................ 1.0

Claystone, greenish-gray, soft, massive .......... 17.7

Siltstone, greenish-gray, hard, calcareous, in beds 25-75 cm thick ......................................... 19.5
<table>
<thead>
<tr>
<th>Sandstone, greenish-gray, hard, medium-grained, feldspathic, N. 32° E., 67° NW.</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siltstone, greenish-gray, argillaceous, medium-hard</td>
<td>4.0</td>
</tr>
<tr>
<td>Sandstone, light-gray, hard, feldspathic</td>
<td>1.8</td>
</tr>
<tr>
<td>Shale, black, carbonaceous, with lenses of dark sandstone</td>
<td>2.2</td>
</tr>
<tr>
<td>Siltstone, dark-gray, medium-hard, with intercalations of black shale in the upper part, N. 25° E., 45° NW.</td>
<td>3.1</td>
</tr>
<tr>
<td>Sandstone, dark-gray to black, hard, medium-grained, calcareous, micaceous; contains fragments of black shale, impressions of fish scales? and plant fossils, N. 5° E., 55° NW.</td>
<td>9.5</td>
</tr>
<tr>
<td>Siltstone, greenish-gray, calcareous, medium-hard</td>
<td>44.0</td>
</tr>
<tr>
<td>Sandstone, greenish-gray, hard, coarse-grained, feldspathic, fractured, N. 50° W., 42° SW.</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Total thickness of Bocas Formation 589.6

---

fault contact ? --- --- --- --- ---
Diamante Formation (upper beds only):

Limestone, dark-gray, hard, fine-crystalline, highly fractured, slightly fetid; contains scarce fossil shell fragments and abundant veinlets of white calcite, N. 10° W.,

76° SW. .................................................. 40.0?

Clay, reddish-brown, highly weathered,

(probable fault zone) ................................... 20.0?

- - - quartz monzonite, pink, coarse-grained
The dark siltstone, shale, and claystone of the Bocas are not highly resistant to weathering and erosion, and the resulting topography is well dissected but does not display great relief. The soils are of a yellowish-to orangish-brown and are distinctive in some areas.

Fossiliferous samples of the Bocas Formation were submitted to the U.S. Geological Survey for identification and age determination. The following report was received on the first samples:
### Fossils contained

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location (planchita)</th>
<th>Fossils contained</th>
</tr>
</thead>
<tbody>
<tr>
<td>DW 27 (IMN 12236)</td>
<td>109-I-B, G-10 SW</td>
<td>Conchostracans, undetermined</td>
</tr>
<tr>
<td>DW 28 (IMN 12237)</td>
<td>109-II-A, G-4 NE</td>
<td>Gastropod, indeterminate, (two genera may be present)</td>
</tr>
<tr>
<td>DW 29 (IMN 12238)</td>
<td>109-II-A, H-3 NE</td>
<td>Gastropod, indeterminate, (compare with DW 28)</td>
</tr>
<tr>
<td>DW 30 (IMN 12239)</td>
<td>109-II-A, I-1 NW</td>
<td>Conchostracans, undetermined</td>
</tr>
<tr>
<td>DW 31 (IMN 12240)</td>
<td>109-II-C, E-7 SW</td>
<td>Conchostracans, undetermined</td>
</tr>
<tr>
<td>DW 32 (IMN 12241)</td>
<td>109-II-C, A-6 NE</td>
<td>Ostracods, undetermined</td>
</tr>
<tr>
<td>DW 34 (IMN 12243)</td>
<td>109-IV-A, J-13 N. Cen.</td>
<td>Stroebus-like gastropod</td>
</tr>
<tr>
<td>DW 35 (IMN 12244)</td>
<td>109-IV-A, J-13 N. Cen.</td>
<td>Schizodus? sp. indeterminate</td>
</tr>
<tr>
<td>DW 36 (IMN 12245)</td>
<td>109-IV-B, F-11 SE</td>
<td>Edmondia-like pelecypod</td>
</tr>
<tr>
<td>DW 37 (IMN 12246)</td>
<td>109-IV-C, A-12 NW</td>
<td>Stroebus-like gastropod (abundant)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conchostracans, undetermined</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conchostracans, undetermined</td>
</tr>
</tbody>
</table>
This report states further that the globose gastropod of samples DW 35 and DW 34 is most common in North America in the Middle and Late Pennsylvanian. The conchostracans (one of four types of branchiopods which belong to the same order, Crustacea, as ostracods) are probably indicative of fresh-water rather than marine conditions.

Ostracods were reported later as follows:

Paleontologist reporting: I. G. Sohn, 3/5/68

Stratigraphic range: indeterminate for all samples.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location (planchita)</th>
<th>Fossils contained</th>
</tr>
</thead>
<tbody>
<tr>
<td>DW 32 (IMN 12241)</td>
<td>109-II-C, E-7 SW</td>
<td>Abundant ostracods, indeterminate, in limestone.</td>
</tr>
</tbody>
</table>
| DW 33 (IMN 12242) | 109-II-C, A-6 NE     | Smooth, indeterminate ostracods. Ostracods on a weathered surface of the rock could be either Paleozoic or Mesozoic in age.
The report states further that the presence of conchostracans, the nesting of valves in the ostracods and their smooth cross sections suggest but do not prove a nonmarine environment and a post-Paleozoic age for the limestone in which the fossils occur. Also the samples submitted may represent both Paleozoic marine and post-Paleozoic nonmarine rocks.

Because of the poor state of preservation of the fossils, more samples were submitted, some from new localities and some from locations sampled previously. A report was received for two of the new locations:

Paleontologist reporting: I. G. Sohn, 9/6/68
Stratigraphic range: probably post-Paleozoic

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location (planchita)</th>
<th>Fossils contained</th>
</tr>
</thead>
<tbody>
<tr>
<td>DW 35/68 (IMN 13903) 121-III-B, G-8 SE</td>
<td>Two poorly preserved ostracods, indeterminate.</td>
<td></td>
</tr>
<tr>
<td>DW 36/68 (IMN 13904) 121-III-B, H-8 SE</td>
<td>One incomplete mold of ostracod that could be from either the Theriosynoecum group of Early Cretaceous age or possibly Tungchuanian of Triassic age.</td>
<td></td>
</tr>
</tbody>
</table>
Conchostracans are the fossils most commonly found in the Bocas Formation where they occur in some of the dark shales and siltstones. Most resemble the genus Cyzicus (formerly called Estheria) which ranges from Devonian to Holocene and has world-wide distribution. A few resemble Estheriella costata Weiss of the Lower Triassic of Germany (Moore and others, 1952, p. 545).

Plant fossils occur sparingly in the Bocas Formation. In the area of the type section, fragmentary fossils were collected and described by Langenheim (1961, p. 107) from dark gray shale and siltstone in the road cut at the east end of the highway bridge that crosses the Rio de Oro to the village of Bocas (planchita 109-IV-C, A-12 NE). The report states that the fossils are from near the top of the formation, but investigations for the present report indicate they are from near the middle. On the basis of the identification of two genera, Cordaites sp. and Mesocalamites sp., Langenheim (1961) postulates an Early to Middle Pennsylvanian age for the Bocas, more probably Early Pennsylvanian. No other identifications of plant fossils from the Bocas are known.

In the area of the type section in Quebrada Santa Elena (planchita 109-IV-A, J-14 SW), an attempt has been made to develop a coal bed in the Bocas Formation by tunnelling into the hillside. The tunnel has caved in so the coal bed cannot be seen. According to the inhabitants of the area, no coal of commercial value was ever produced.
Northward from the area of the type section, the Bocas is exposed in a narrow belt between the Bucaramanga fault on the east and a fault contact with the Girón on the west. This belt widens into a large area of exposure in the north-central part of quadrangle H-12 where the Bocas is well exposed along the road southwestward from the main highway toward Cuestarica (planchita 109-II-A). The upper 230 meters of the Bocas in this area is described with the overlying section of the Giron Formation (see p. 207). Rhyolite and intrusive breccia intrude this large area of Bocas beds in a belt west of and parallel to the Bucaramanga fault. Between the Bucaramanga fault and the intrusive breccia, the Bocas contains a central section of clean, light gray, highly fractured quartzite. The quartzite belt is more than 1 kilometer wide at the northern margin of quadrangle H-12 and narrows gradually southward until it pinches out southwest of Rionegro. It is not present in the area of the type section.

About 15 km northeast of Bucaramanga, in a block of sedimentary rocks downfaulted against pre-Devonian rocks on the northwest, the Bocas Formation overlies Pre-Devonian metasediments of the Silgará Formation. In the south-central part of quadrangle H-13, the Bocas overlies the Floresta Formation in several places. It is usually overlain by beds of the Girón Formation, but in some places by the Jordán Formation.
Because of the various ages that have been suggested for the Bocas Formation, based on poorly preserved plant and invertebrate fossils, it has been necessary to reevaluate the previous age assignments in the light of the newer information. A Triassic age now seems more likely than Carboniferous, as indicated in previous reports, and this change is made for the following reasons:

1. Invertebrate fossils in the older Diamante Formation that were originally thought to be of Mississippian and Pennsylvanian age are now thought to be of Middle Pennsylvanian to Early Permian age. This change is reinforced by the finding of fusulinid Foraminifera of similar age that are reported here for the first time.

2. The thick limestone pebble conglomerates of the Tiburon Formation that overlies the Diamante Formation were derived from the Diamante beds and can therefore not be older than Middle to Late Permian.

3. Ostracods in the Bocas Formation, although not identifiable with certainty, display characteristics that are more suggestive of post-Paleozoic than of Paleozoic forms, and one of the conchostracans present strongly resembles a Triassic form.
Considering the similarity of lithology and fossil content (poorly preserved gastropods, bivalves, ostracods, and conchostracans or estherids) of the Bocas to the Los Indios Formation near Fundación in Department of Mgdalena (C. Tschanz written commun.), the Bocas Formation appears to be correlative with the Los Indios. This suggested correlation is further strengthened by the lithologic similarities of the overlying formations, the Jordan Formation of the Bucaramanga area to the Guatapuri Formation that overlies the Los Indios.

**Jurassic System**

**Jordan Formation**

The Jordan Formation was first recognized by Cediel (1968, p. 66) in his study of the Girón Formation in the Bucaramanga area. The type section is 1 kilometer west of the village of Jordán on the north slope of the canyon of Río Chicamocha (planchita 135-II-B, D-3 and E-3). The Jordán there includes two facies (Cediel, p. 67) divided by a transitional zone of approximately 10 meters that does not indicate any pause in deposition.

Upper facies (200 m)--uniformly reddish-brown siltstone and very fine grained sandstone, well-stratified in beds from 30-80 cm thick.

Lower facies (100 m)--principally coarse-grained, greenish-gray sandstone in beds up to 1 meter thick and a few beds of greenish-gray shale up to 2 meters thick; a few thick beds with cross stratification contain conglomeratic zones with pebbles up to 2 centimeters in diameter.

The base of the section is not exposed, but elsewhere in the area the Jordán overlies phyllitic and schistose metamorphic rocks.
Acid volcanic rocks associated with the Jordán in the area of the type section are referred to as welded tuffs (Cediel, 1968, p. 67). One bed 30 centimeters thick in the upper facies of the type section is composed principally of angular fragments up to 1 centimeter in diameter of acid volcanic and metamorphic rocks. About 2 kilometers to the northeast, on the trail from Los Santos to Jordán, two thicker beds of this tuff are exposed and are separated by 80 meters of siltstone and sandstone.

For the beds overlying the Jordán in the area of the type section, Cediel (1968, p. 58) has proposed the name Los Santos Formation in place of Tambor Formation, with the type section of the Los Santos in the same area as that of the Jordán. He found angular discordances up to 30° between the two formations in the area of the type sections.

In the present report, the conglomeratic beds immediately overlying the Jordán at the type section are mapped as a thin section of the Girón Formation which is in turn overlain by the Tambor Formation (Los Santos Formation of Cediel).

The Jordán Formation has previously been included in the Girón Formation, and on maps of the mesa area south of Bucaramanga by Julivert and others (1964) and Tellez (1964), the lower shale member in the Mesa de Los Santos area corresponds approximately to the Jordán Formation. North of the mesa the Jordán is covered by the Girón.
In the western part of Mesa de Los Santos, the Jordán Formation is exposed in a large area where erosion has removed the overlying Girón and Tambor Formations that form the cap of the mesa. In the precipitous western slope of Quebrada del Angelino (or Quebrada Grande on planchita 120-IV-3, H-1 and I-1), the Jordán section may be more than 800 meters thick. The base is not exposed.

In the Bucaramanga area, the Jordán Formation is well exposed in the canyon of Río de Oro south of Bocas where it overlies the Bocas Formation. A section measured is given below.

The Jordán measured section is almost uniformly fine grained and reddish-brown in color throughout. South of Piedecuesta, where the formation overlies pre-Devonian phyllites, the lower 50 meters contain conglomerates with fragments of porphyritic igneous rock that are derived from a phase of the Pescadero Granite which crops out nearby. This conglomeratic lower section of the Jordán can be traced southward to the beveled edge of the formation on the eastern slope of Mesa de Los Santos. Northward the conglomerates grade to feldspathic sandstones. A description of the lower conglomeratic section of the Jordán is given below.

The basal conglomeratic section is slightly overturned and the beds dip steeply toward the east. Westward, and higher in the section, dips are normal and steep to the west. The section is mostly reddish-brown siltstone and includes units of harder, very fine to medium-grained feldspathic sandstone up to 11 meters thick.
Stratigraphic section of the Jordan Formation measured along the railroad on the west side of the canyon of the Rio de Oro south of Bocas (planchita 109 IV-C, B-12, B-13, C-13 and D-13), Municipality of Bucaramanga, Department of Santander.

(Measured and described by E. Aya, September, 1968)

Girón Formation (lower beds only):

Conglomerate, gray, massive, with sub-angular pebbles of white quartz and few pebbles of volcanic rocks, black chert and shale in coarse, sandy, micaceous, slightly calcareous matrix, N. 25° E., 43° SE. ................. 10.0

--- unconformity ---

Jordan Formation:

Siltstone, reddish-brown and greenish-gray, hard, slightly calcareous, with interbeds of reddish-brown, slightly calcareous claystone ........ 26.0

Sandstone, reddish-brown, hard, fine-grained to silty, slightly calcareous and micaceous, in beds 1.0-2.5 m thick, N. 32° E., 18° SE. ............... 15.0

Sandstone, reddish-brown, hard, fine-grained to silty, slightly calcareous and micaceous, with interbeds of soft reddish-brown shale, N. 75° W., 10° SW. ................. 15.3

Sandstone, reddish-brown, hard, fine-grained to silty, slightly calcareous and micaceous, in beds 1-3 m thick, horizontal ............... 11.0
<table>
<thead>
<tr>
<th>Description</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siltstone, reddish-brown and greenish-gray interbedded, hard, slightly calcareous and micaceous,</td>
<td>40.0</td>
</tr>
<tr>
<td>N. 60° E., 14° SE.</td>
<td></td>
</tr>
<tr>
<td>Siltstone, greenish-gray, hard, slightly calcareous and micaceous</td>
<td>5.0</td>
</tr>
<tr>
<td>Sandstone, greenish-gray, slightly calcareous, conglomeratic with granules of white quartz,</td>
<td>2.5</td>
</tr>
<tr>
<td>N. 20° W., 5° SW.</td>
<td></td>
</tr>
<tr>
<td>Sandstone, reddish-brown, hard, fine-grained to silty, slightly calcareous and micaceous; interbedded</td>
<td>37.5</td>
</tr>
<tr>
<td>with siltstone of similar color and hardness, N. 20° W., 10° SW.</td>
<td></td>
</tr>
<tr>
<td>Claystone, dark-gray, slightly calcareous and micaceous, highly fractured, N. 30° W., 23° SW.</td>
<td>7.0</td>
</tr>
<tr>
<td>Siltstone, reddish-brown, argillaceous, slightly calcareous; interbedded with reddish-brown shale</td>
<td>21.0</td>
</tr>
<tr>
<td>and fine-grained, thin-bedded sandstone, N. 25° W., 25° SW.</td>
<td></td>
</tr>
<tr>
<td>Claystone, greenish-gray, medium-hard, massive, slightly calcareous, with thin interbeds of sandy claystone; contains small calcareous concretions</td>
<td>23.5</td>
</tr>
</tbody>
</table>
Sandstone, greenish-gray, hard, fine-to medium-grained, slightly calcareous, with interbeds of massive, slightly calcareous claystone, N. 25° W., 20° SW. .......... 18.0

Sandstone, dark-gray to black, hard, coarse-grained, slightly calcareous, somewhat feldspathic; conglomeratic in lower 5 m with small pebbles of black shale; contains scattered grains of chalcopyrite, N. 80° E., 17° SE. ........... 21.0

Covered by vegetation .......... 55.0

Claystone and siltstone, medium-hard, slightly calcareous and micaceous ........ 3.9

Sandstone, greenish-gray, hard, medium-grained, slightly calcareous and micaceous, in beds up to 1 m thick, N. 65° E., 40° SE. ......... 20.0

Sandstone, reddish-brown, hard, fine-grained, slightly argillaceous and calcareous, micaceous, N. 60° E., 40° SE. .............. 4.5

Sandstone, reddish-brown, hard, fine-grained to argillaceous, slightly calcareous and micaceous, with softer interbeds of reddish-brown claystone, N. 65° E., 58° SE. .............. 65.8
Sandstone, reddish-brown, medium-hard, very fine-grained to silty, somewhat micaceous, with thick sections of softer, slightly calcareous, reddish-brown claystone; sandstone contains calcite-filled veinlets up to 5 mm wide, N. 50° E., 33° SE. ... 104.0

Sandstone, reddish-brown, hard, fine-grained to silty, slightly calcareous, slightly micaceous in some beds, in beds up to 1 m thick; contains small, greenish-gray calcareous concretions throughout, and small pebbles of black shale in the middle, N. 33° E., 30° SE. .................. 54.0

Claystone, reddish-brown, medium-hard, slightly calcareous, massive, N. 30° E., 40° SE. ............ 15.0

Sandstone, greenish-gray, hard, fine-grained to silty, slightly calcareous .................. 5.0

Claystone, reddish-brown, medium-hard, with harder interbeds of reddish-brown siltstone and fine-grained sandstone, N. 45° E., 40° SE. ................. 18.5

Sandstone, reddish-brown, hard, fine- to medium-grained, slightly calcareous and micaceous, with interbeds of soft, reddish-brown claystone, N. 46° E., 70° SE... 28.5
Covered by vegetation; probably sandstone and claystone similar to those above ............... 35.0

Sandstone, reddish-brown and greenish-gray, hard, very fine-grained to silty, slightly calcareous, in beds up to 1 m thick, N. 45° E., 35° SE. ........ 5.0

Total thickness of Jordan Formation 657.0

Bocas Formation (upper beds only):

Siltstone, mostly greenish-gray, some reddish-brown, argillaceous, micaceous, slightly calcareous, in beds up to 1.1 m thick; highly fractured normal to the bedding, N. 30° E., 38° SE. ........ 120.0
Stratigraphic section of the lower, conglomeratic
part of the Jordan Formation exposed along the top of a
small ridge (2 km) kilometers southeast of Piedecuesta (planchita
120 II-D, H-10 NE), Municipality of Piedecuesta, Department
of Santander.

(Measured and described by R. Vargas, 1968)

Jordan Formation (lower beds only):

<table>
<thead>
<tr>
<th></th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siltstone, reddish-brown, soft</td>
<td>11.0</td>
</tr>
<tr>
<td>Sandstone, gray to pale-reddish-brown, medium- to coarse-grained, feldspathic, somewhat conglomeratic with pebbles of quartz and greenish-gray phyllite up to 5 mm in diameter</td>
<td>3.5</td>
</tr>
<tr>
<td>Siltstone, reddish-brown, soft</td>
<td>9.0</td>
</tr>
<tr>
<td>Conglomerate, pale-reddish-brown, with abundant angular pebbles of pink biotitic porphyry up to 3 cm in diameter and few smaller pebbles of white quartz</td>
<td>0.8</td>
</tr>
<tr>
<td>Siltstone, reddish-brown, soft</td>
<td>3.6</td>
</tr>
<tr>
<td>Conglomerate, pale-reddish-brown, with abundant angular pebbles of porphyry up to 20 cm in diameter and few small pebbles of white quartz</td>
<td>0.5</td>
</tr>
<tr>
<td>Siltstone, reddish-brown, soft</td>
<td>6.8</td>
</tr>
<tr>
<td>Conglomerate, pale-reddish-brown, with subangular to subrounded pebbles of porphyry up to 8 cm in diameter and fewer smaller pebbles of white quartz, in four main beds</td>
<td>3.3</td>
</tr>
<tr>
<td>Siltstone, reddish-brown, soft</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Conglomerate, pale-reddish-brown, with subangular to subrounded pebbles of pink porphyry up to 15 cm in diameter and fewer small pebbles of gray quartzite  

Siltstone, reddish-brown, soft  

Conglomerate, pale-reddish-brown, with pebbles of pink porphyry and pinkish-gray quartzite up to 2 cm in diameter  

Siltstone, reddish-brown, soft  

Conglomerate, pale-reddish-brown, with subangular pebbles of pink porphyry up to 3 cm in diameter and fewer pebbles of white quartz and gray quartzite, in a lenticular bed that changes laterally to coarse-grained feldspathic sandstone; porphyry pebbles contain quartz and biotite phenocrysts  

Siltstone, reddish-brown to pale-reddish-brown; contains pink feldspar grains up to 1 mm in diameter  

Conglomerate, reddish-brown, weathered, with subangular pebbles of pink biotitic porphyry and siliceous aphanitic igneous rock up to 12 cm in diameter; other pebbles are of pink quartzite, feldspathic conglomerate containing pebbles of greenish-gray phyllite, and white quartz
Siltstone, reddish-brown, soft; contains grains of pink feldspar .................................. 2.3

Conglomerate, pale-reddish-brown, with pebbles of light-yellow, reddish-brown, and greenish-gray phyllite up to 2 cm in diameter .................. 0.6

--- unconformity ---

Silgará Formation (pre-Devonian metasediments):

Phyllite, light-yellow to reddish-brown and greenish-gray, sericitic, weathered .................
One kilometer north-northwest of the conglomeratic section described, the lower beds of the Jordán are less conglomeratic. An estimated 800 meters of the formation is partly exposed from the basal contact with pre-Devonian phyllite westward along a low ridge toward the main highway (planchita 120-II-D, G-10 NW and G-9 NE). At the highway and westward to Río de Oro, the beds are concealed by alluvium for a distance of about 250 meters. From the Río de Oro northwestward, about 300 meters of fine-grained reddish-brown sandstone and siltstone in the upper part of the formation are partly exposed along the ridge that extends to the top of the hill that is situated immediately to the west of Piedecuesta (planchita 120-II-D, G-9 NW, G-8 NE, and F-8 S1/2). At the top of this hill the Jordán is overlain with slight angular unconformity by weakly consolidated conglomerate beds of the Girón Formation. Thus the Jordán Formation may be more than 1,100 meters thick at Piedecuesta, but large changes in strike and dip that occur under the alluvial cover between the two exposed sections leaves this figure open to question.
About 200 meters below the top of the Jordán southwest of Piedecuesta (planchita 120-II-D, G-9 NW), a single 3-meter thick layer of pale reddish-brown igneous rock containing abundant fragments of white feldspar crystals and sparse fragments of gray to brown porphyry appears to represent a welded volcanic ash flow concordant with the beds of the Jordán. The content of igneous rock of this type in the formation increases toward the area of the type section about 26 kilometers to the south.

From the type section of the Jordán northward, the intermittent exposures of the formation indicate that it is continuous possibly as far as the exposures south of Bocas. Elsewhere, however, only isolated exposures occur. Structural and stratigraphic relationships suggest that these are mostly remnants of a once widespread unit of considerable thickness that have been preserved from erosion in downfaulted blocks. Such exposures occur in the Rionegro area west of the Bucaramanga fault (H-12, c-3), northeast of Bucaramanga along Río Suratá (H-12, d-3), west of Guaca (H-13, b-7), and southwest of Chitagá (H-13, b-5, c-5).
In quadrangle H-12, except for the conglomeratic lower beds such as those described the formation is very uniform reddish-brown siltstone and fine-grained sandstone. The formation is apparently conformable and transitional with the underlying Bocas Formation north of Bucaramanga, but south of Piedecuesta it lies on pre-Devonian metasediments. The upper boundary with conglomerates of the Girón is one of unconformity which is quite noticeably angular in parts of the Mesa de Los Santos area (H-12, c-7).

East of Guaca in quadrangle H-13, b-7, b-8, in addition to the beds that are typical of the formation in H-12, thick conglomerates in the upper part of the section contain pebbles mostly of pre-Devonian metasediments and are overlain with angular unconformity by Girón conglomerates that contain abundant quartz pebbles (planchita 121-III-B, I-7). But southwest of Chitaga (planchita 121-II-A, F-1 NE) the Jordán-Girón boundary is conformable and gradational over 100 meters of section or more. Hard reddish-brown siltstone of the Jordán decreases upward as conglomeratic beds of the Girón increase.

No fossils have been found in the Jordán Formation, and therefore age determination must be based on other evidence. The assignment of an Early Jurassic age is based on two main considerations:
1. The conglomerates near the base of the Jordán in the Piedecuesta area (H-12, d-6) contain angular pebbles of the porphyritic phase of the Pescadero granite (Trgp) that crops out nearby. A radioactive age determination of the granitic phase (JTrgp) yielded an age of 193±6 million years which is near the Triassic-Jurassic boundary of 190 million years. Pink feldspar similar to that of the Pescadero granite is abundant in the sandstones and siltstones of the Jordán in this area.

2. The very thick Giron Formation (4,650 meters according to F. Cediel, 1968, fig. 6) rests unconformably over the Jordán Formation in the Bucaramanga area and also unconformably beneath the Tambor Formation of Early Cretaceous age.

The Jordan Formation is very similar in lithologic character to the Guatapuri Formation in the southern part of the Sierra de Santa Marta about 325 km to the north-northwest. However, the Guatapuri contains much more volcanic material. Both are unconformably underlain by formations that have similar lithologic characters and fossil content, the Bocas Formation in the Bucaramanga area and the Los Indios Formation in the Sierra de Santa Marta. The Los Indios and Guatapuri are both assigned to the Triassic (C. Tschanz, personal commun.).

The Jordán Formation may be the lateral equivalent of the Bata Formation of Liassic age in the Guavio quadrangle (K-12) which has a thickness of some 1,115 meters (D. H. McLaughlin, personal commun.).
The term "Giron series" was first used by Hettner (1892) for the thick assemblage of sandstones, conglomerates, and reddish-brown siltstones that are widely exposed west of Bucaramanga and named for the town of Girón. Also included were rocks that are now recognized as the Bocas, Jordán, and Tambor Formations. The series was referred to the Lower Cretaceous.

Other writers made references to the Girón (Schuchert, 1935; Oppenheim, 1940; Dickey, 1941; and Trumpy, 1943), but further field study was not made until Langenheim (1954) designated the exposures in the gorge of Río Lebrija as the type section (H-12, c-3, c-4) and defined the limits there as the unconformable boundaries with the underlying Bocas Formation and the overlying Tambor Formation. He divided the section of approximately 3,500 meters into a lower sandy member of 750 meters, a middle shaly member of 1,250 meters, and an upper sandy member of 1,500 meters.
Further study of the Giron Formation was made by Julivert (1958), and later a more detailed study of the Río Lebrija section was made by Navas (1963) who measured a section totalling 2,650-2,690 meters in seven facies:

120-150 m Upper conglomerate

230 m Red shales

700 m Upper arkosic sandstones and conglomerates

850 m Upper red shales alternating with sandstones

170 m Lower arkosic sandstones and conglomerates

550 m Lower shale with interbedded conglomerate and sandstone in the upper middle part.

30-40 m Conglomerate with pebbles of igneous rocks.

Navas (1963, fig. 1, p. 29) shows that, with the exception of the upper conglomerate and the lower arkosic sandstones and basal conglomerate, the facies can be traced from the Río Lebrija section southward toward Zapatoca and Los Santos.

The latest study of the Giron Formation was made by Cediel (1968). At the Río Lebrija type section (fig. 8), he measured a total of 4,650 meters of Girón in seven lithologic facies (Cediel, 1968, p. 26-28). From top to bottom these facies are:
G (1080 m) - sandstone, coarse-grained, in cross-stratified beds up to four meters thick. Conglomeratic beds are present and increase in number in the upper part. Grain size diminishes toward the top of the unit and thickness of beds decreases to 40-80 cm. Highly muscovitic beds are present locally. Colors change upward in the unit from greenish gray at the base to yellowish gray and finally to grayish yellow.

F (250 m) - sandstone (70 percent) and interstratified red beds (30 percent) of siltstone and claystone in beds up to one meter thick. The sandstones are greenish-gray and conglomeratic with quartz pebbles. The red beds are grayish-red to reddish-brown. At the base are dark-gray beds.

E (1040 m) - sandstone, medium-grained, in beds up to 70 cm thick that grade laterally and vertically to shale and in some places to claystone. Conglomeratic beds are present but less frequently than in the lower facies. Bluish gray is the dominant color, varying to dark gray toward the base and top and to yellowish gray in the middle. Cross-stratification is well-developed locally. This facies is generally characterized by irregular stratification and frequent development of fine sandstone and shale or claystone with small lenses of carbonaceous material containing poorly preserved plant remains.
D (650 m) - red beds (60 percent) of siltstone and sandstone, and interstratified sandstone (40 percent) in beds up to one meter thick. The red beds vary in color between grayish-red and dark reddish-brown. The sandstones are greenish-gray and in the upper part they contain numerous beds of conglomerate with quartz pebbles. At the base are a few scattered small lenses of carbonaceous material with poorly preserved plant remains.

C (430 m) - sandstone, medium- to coarse-grained in cross-stratified beds up to 2.5 m thick. Numerous conglomeratic beds contain pebbles exclusively of quartz up to four centimeters in diameter. The sandstones are generally very hard, well-sorted, and vary in color between greenish gray and light olive gray.

B (590 m) - sandstone (60 percent), medium- to coarse-grained, and interstratified red beds (40 percent) of siltstone and claystone. Sandstone is light bluish-gray in cross-stratified beds up to one meter thick. Scattered beds of conglomerate contain quartz pebbles of varying color. The red beds grade laterally to greenish-gray shales and finally to sandstones. They vary in color from grayish-red purple to grayish-purple.
A (610 m) - sandstone, coarse-grained, conglomeratic, medium
light-gray and light-gray, in thick cross-stratified beds up
to two meters thick. Thin beds of conglomerate contain quartz
pebbles, and a few also have limestone pebbles up to four
centimeters in diameter. Lenses of bluish-gray shale up to
three meters thick make up not more than 5 percent of the
facies.

In the Girón Group (distinct from the Girón Formation), Cediel
(1968, fig. 6) includes an eighth facies, (H), the Tambor Formation,
which he proposes to re-name the Los Santos Formation (ibid. p. 58).

In the canyon of Río Lebrija, the Girón overlies beds of the
Bocas Formation with angular unconformity according to Cediel (fig. 8),
but investigations for the present report indicate that a fault
contact is present here that continues far to the north as the eastern
boundary of the Girón.

Near the northern boundary of quadrangle H-12, a thin sequence of
the Girón is well exposed on the road to Cuestarica. This section is
shown below. It does not contain the conglomeratic beds that are
typical of the Girón in thicker sections.
-Stratigraphic section of the Giron Formation measured
along the road from 1.7 to 1.5 kilometers northeast of
Cuestarica (planchita 109 I-B, I-15 SE), Municipality of
Rionegro, Department of Santander.

(Measured and described by R. Vargas, September, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tambor Formation (lower beds only):</td>
</tr>
<tr>
<td>Sandstone, light-yellowish-gray, fine-grained</td>
</tr>
<tr>
<td>Giron Formation:</td>
</tr>
<tr>
<td>Sandstone, pale-reddish-brown, fine-grained, micaceous, somewhat feldspathic, in beds 0.3-1.0 m thick; interbeds of micaceous reddish-brown shale up to 0.3 m thick</td>
</tr>
<tr>
<td>Shale, reddish-brown, with patches of light-greenish-to bluish-gray, micaceous; interbeds of pale-reddish-brown sandstone up to 0.3 m thick</td>
</tr>
<tr>
<td>(Partly covered) siltstone, reddish-brown, micaceous</td>
</tr>
<tr>
<td>Sandstone, light-reddish-brown, fine-grained, in beds 10-30 cm thick</td>
</tr>
<tr>
<td>Siltstone, reddish-brown, micaceous</td>
</tr>
<tr>
<td>Sandstone, light-reddish-brown, fine-grained</td>
</tr>
<tr>
<td>Siltstone, reddish-brown, micaceous, with thin lenticular interbeds of greenish-white siltstone</td>
</tr>
<tr>
<td>Sandstone, light-gray, fine- to medium-grained, feldspathic, micaceous</td>
</tr>
</tbody>
</table>
Siltstone, reddish-brown, micaceous, with three inter-beds up to 30 cm thick or fine-grained, reddish-brown sandstone ........................................ 5.8
Sandstone, pale-reddish-brown, fine-grained, feldspathic, in beds 0.2-1.8 m thick ........................................ 7.9
Sandstone, greenish-gray, fine-grained, micaceous, feldspathic, conglomeratic with pebbles of greenish-gray siltstone and pink, fine-grained, micaceous sandstone up to 2.5 cm in diameter; light-gray and less conglomeratic near the top .......................... 15.2

Total thickness of the Giron Formation ..................................................... 135.3

--- unconformity ---

Bocas Formation (upper beds only):
Siltstone, greenish- to bluish-gray, with thin inter-beds of reddish-yellow weathered shale occurring in subangular pebbles up to 10 cm in diameter; pebbles are smaller in the top 30 cm ........................................ 7.3
During his study of the Giron Formation, Langenheim (1954, p. 6) found fossil ferns in the middle shaly member in Quebrada Honda. A collection from this locality was studied and reported by J. H. Langenheim (1959, 1961). On the basis of six genera recognized from this locality (Pecopteris, Callipteridium, Asterotheca, Rhodea, Calamites, and Carpolithus) and the stratigraphic position above the Bocas Formation (in which two Early Pennsylvanian plant fossils were identified), the age of the assemblage was considered to be probably Late Pennsylvanian and not younger than Permian (Langenheim, J. H., 1959, p. 118). In another collection of plant fossils from the Giron just south of Floridablanca in the Quebrada Mensuli, two genera, Ptilophyllum sp. and Elatocladus sp., were identified, which indicate a Jurassic age (ibid., p. 110).

Plant fossils and ostracods were collected by Bruckner (1954) in the Rio Lebrija section of the Giron at Quebrada Las Palmas (the same as Quebrada Honda of Langenheim). The genus Callipteridium was identified by R. Krausel in Germany and confirmed by N. J. Jongmans in Holland, with the age indicated as Carboniferous and not younger than Permian. The ostracods were identified by E. Triebel in Germany as members of the genus Darwinula known from the Carboniferous. However, as Bruckner (ibid., p. 113) points out, so little is known about ostracods in the Permian and Triassic, that a younger age for these ostracods is possible.
In his study of the Giron Formation, Cediel (1968, p. 50) states that plant remains or silicified wood occurs in all seven of the facies of the Río Lebrija section, and he mentions in particular those in basal red beds of facies B and in gray beds of facies F. They are no better preserved than those found in the Quebrada Honda beds (facies E). Most are ferns, but sphenopsids (horsetail rushes) are also represented. No microfossils were found.
The type section of the Giron is in a large triangular area of exposure in the central part of quadrangle H-12. Within this area it ranges in thickness from zero on the eastern side of the Mesa de Los Santos (H-12, d-7) to possibly 4500 meters at the type locality (H-12, c-3, c-4). The thick section extends in a north northeast-trending belt east of and parallel to the outcrops of the Cretaceous and Tertiary formations that dip steeply westward into the middle Magdalena Valley basin. North of Bucaramanga this thick section ends against a fault that places it in contact with the Bocas Formation.

Where the Bocas crops out over a large area near the northern border of H-12, the unconformable section of Giron above it is thin.

South of Bucaramanga, the thick section of Giron thins eastward over Mesa Ruitoque (H-12, d-6), and thins more rapidly to zero over Mesa de Los Santos (H-12, d-7, d-8). On the basis of his study of the geometrical form and extent of the basin in which the Giron sediments accumulated, the lithologic associations and their cyclical nature, and the character of the petrology and facies of the sediments, Cediel (1968, p. 81) concluded that the Giron Group is a typical molasse deposit in which the principal rock type is subgraywacke according to the classification of Pettijohn (1957, p. 291). He states (Cediel, 1968, p. 79) that the character of the Giron deposition makes it doubtful that the facies that have been described in the Río Lebrija section can be regarded as laterally continuous units as shown on maps by Navas (1963, fig. 1), by Julivert et al (1964) and by Tellez (1964).
The contact of the Girón with the underlying Jordan Formation is one of angular unconformity which is as great as 10°-15° in the eastern part of Mesa de Los Santos. The contact with the overlying Tambor is generally regarded as one of unconformity in the area of quadrangle H-12 and H-13 where isolated remnants of the Tambor overlie many different rocks and represent the beginning phase of the Cretaceous deposition that probably covered the entire area. In the area west and south of Bucaramanga, however, the boundary is not so sharply defined. It is placed where well-sorted and well-bedded sands of the Tambor first appear in the section above the poorly sorted conglomeratic sands of the Girón. Reddish-brown siltstones at the top of the Girón are mottled with sharply defined light greenish-gray in irregular patterns that in some places appear to be controlled by bedding planes and in others to be controlled by fractures normal to the bedding. Reddish-brown siltstones occur also in the lower part of the Tambor, but their coloring is usually lighter than those of the Girón, and light greenish-gray siltstones and mudstones are also present. The stratigraphic sequence and lack of angular unconformity between the Tambor and Girón (well-illustrated near the top of Mesa Ruitoque, H-12, d-6) suggest that after the rapid deposition of the Girón there was a period of little or no new deposition, and some re-working of the upper beds of the Girón to produce the lower beds of the Tambor.
Another large area of exposure of the Giron Formation in the southern half of quadrangle H-13 is associated with a large, structurally complex synclinal feature that includes sedimentary rocks from the Devonian to the Upper Cretaceous. The great variation in thickness of the Giron Formation is as evident here as it is in the Bucaramanga area. No Giron occurs between the Devonian and Lower Cretaceous rocks on the western side of the synclinal area (H-13, b-5 SW), whereas a few kilometers to the east the formation is more than 700 meters thick (H-13, b-5 SE). Feldspathic to arkosic conglomerates and sandstones are predominant in the section. The feldspar is pink in color, similar to that of the Santa Bárbara Quartz Monzonite to the west from which it was probably derived.

Other than the two large areas of exposure of the Giron Formation that have been discussed, the formation elsewhere is usually thin or missing altogether as a result of non-deposition or erosion. Probably both conditions are responsible for the present distribution of the Giron.

The Giron beds are clearly derived mainly from the erosion of large areas of crystalline rocks. In the region of this report they are the rocks now exposed mostly east of the Bucaramanga fault. Quartz pebbles derived from igneous rocks and quartzite pebbles from metamorphic rocks are the most common coarse materials that have survived the disintegration and decomposition in the source areas and the rigors of transportation to sites of deposition. Only where source and deposition sites are comparatively close together have fragments of the original whole rocks been deposited as such.
Despite the wide area of distribution of Gíron-type sedimentary rocks in northern and eastern Colombia and western Venezuela, the age and correlation of the formation have long been the subjects of much uncertainty and speculation. Ages assigned to the formation in the area of the type section have ranged from Carboniferous to Cretaceous. As noted before, ages based on meager plant and invertebrate fossils range from Carboniferous to Jurassic. The Gíron has generally been correlated with the La Quinta Formation of western Venezuela which is similar in lithologies, in its variable thickness (up to 3000 meters), and in its grading into light-colored sandstones of the overlying Lower Cretaceous (Oppenheim, 1940, p. 1613). The La Quinta has been assigned to the Upper Jurassic on the basis of fossil remains of a ganoid fish of the genus *Lepidotus* (ibid., p. 1611).

The investigations for the present report have not encountered any new fossil evidence, but other new information lends support to a Jurassic age for the Gíron. As discussed under previous headings, new fossil evidence from the rocks of the Suratá Group and the Bocas Formation now places these rocks in the Carboniferous to Permian and Triassic respectively, whereas formerly they were all placed in the Carboniferous. Further evidences for a Jurassic age of the Gíron are the radioactive ages of the igneous rocks from which the sediments were largely derived (table 2, sample nos. IMN-10924, -11045, and -11547). These ages (192 ± 7 million years to 194 ± 7 million years) are near the Triassic-Jurassic time boundary of 190 million years, and as noted in the discussion of the Jordán Formation, fragments of the porphyritic phase of one of these rocks, the Pescadero Granite, occur in the lower beds of the Jordán near Piedecuesta.
Cretaceous system, Middle Magdalena Valley section

In the western part of the report area (quadrangles H-12 and I-12), the Cretaceous sedimentary rocks have been mapped in accordance with the standard nomenclature adopted by representatives of the Colombian petroleum industry (Morales et al., 1958, p. 647). In the eastern part (quadrangles H-13 and I-13), this nomenclature is used to a lesser extent than that of the Maracaibo Basin of northeastern Colombia and western Venezuela that is treated in several publications (Notestein et al., 1944; Sutton, 1946; Roberts et al., 1959; Trump and Salvador, 1964). Figure 9 shows the age and general relationship of the Cretaceous and younger formations in the two provinces.

Deposition during the Cretaceous covered the area between the Magdalena Valley of Colombia and Lake Maracaibo in Venezuela, but uplift of the Cordillera Oriental has caused the sedimentary rocks there to be stripped away by erosion except for isolated blocks that have been preserved by downfaulting. Thus the sedimentary rocks of the two areas are similar in many ways even though the formation names (except for the La Luna Formation) are different. In some places in the southern part of the report area, some map units are taken from the Magdalena Valley section and some from the Maracaibo Basin section.
<table>
<thead>
<tr>
<th>System</th>
<th>Series or Stage</th>
<th>Standard Nomenclature of Middle Magdalena Valley</th>
<th>Nomenclature of the Maracaibo Basin (Colombia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUATERNARY</td>
<td>Pleistocene</td>
<td>Mesa Group</td>
<td>Alluvium and terraces</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Necessidad Formation</td>
</tr>
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<td></td>
<td>Pliocene</td>
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<td>Guayabo Group</td>
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<td>Upper</td>
<td>Miocene (?)</td>
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</tr>
<tr>
<td>TERTIARY</td>
<td>Oligocene (?)</td>
<td>Chuspa Group</td>
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</tr>
<tr>
<td></td>
<td>Eocene (?)</td>
<td>Charro Group</td>
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<td>Paleocene</td>
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<td>Donian (?)</td>
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<td>Maestrichtian</td>
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<td>Campanian</td>
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<td>Santonian (?)</td>
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<tr>
<td>Upper</td>
<td>Canianian</td>
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<td>Turonian</td>
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<td>Cenomanian</td>
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<td>Albian</td>
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<td>Middle</td>
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<td>Aptian</td>
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<td>Barremian</td>
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<td>Hauterivian</td>
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<td></td>
<td>Valanginian (?)</td>
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<td>Lower</td>
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<td>JURASSIC-TRIASSIC</td>
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1. Adapted from Morales et al., 1958, fig. 5, p. 647.

FIGURE 9. — Age and Nomenclature of the Cretaceous and younger formations of the Middle Magdalena Valley and the Maracaibo Basin (Colombia).
The studies of the Cretaceous rocks by the petroleum industry have included much work with the macrofossils and microfossils found in them. Therefore no paleontologic studies were included in the investigations for the present report. Various reports which include information on the Cretaceous faunas are those by Sutton (1946), Morales et al (1958), Burgl (1961), and Etayo (1964). Ammonites have been especially useful in dating the stratigraphic sequence of the Cretaceous in the Cordillera Oriental (Burgl, 1961, p. 163-165). Foraminifera, pelecypods, echinoids, and more rarely gastropods are other forms that are present and useful in varying degrees. The studies of fossils have indicated that the formational units mapped in the Cretaceous of the middle Magdalena Valley transgress time boundaries and are older in the south than in the north (fig. 9). This is especially noticeable in the formations of the Lower and Middle Cretaceous.

The Cretaceous section reaches a maximum thickness of more than 4000 meters in the middle Magdalena Valley, and in the area of this report the maximum thickness may exceed 3500 meters beneath the Tertiary section in the western part of S-12 (Morales et al, 1958, fig. 4). The formations are generally thinner over the Cordillera Oriental to the east, and total thickness there may have been not more than half of that in the Magdalena Valley.
Tambor Formation

The type section of the unit is in continuity with that of the Girón Formation in the valley of the Río Lebrija (planchita 109-IV-A, E-2, F-2, G-2) between kilometers 92 and 95 of the railroad from Bucaramanga to Puerto Wilches (Morales et al., 1958, p. 643). The name was first used by H. D. Hedberg in 1931 in an unpublished report, and was supposedly derived from a village of that name nearby. No village of that name is present in the area, but the Hacienda Tambor is located four kilometers to the north. Much of the formation is not well-exposed at the type locality because the canyon of the Río Lebrija is nearly parallel to the strike of the beds as it cuts across them. A better section is exposed a short distance to the south where Quebrada Piedra Azul cuts the beds more nearly normal to the strike.

A section measured in this quebrada is given below.

The 366 meters of Tambor measured is much less than the 650 meters reported at the type section. About 25 kilometers farther south, where the Río Sogamoso cuts through the Cretaceous section, the Tambor is estimated to be more than 500 meters thick. About 18 kilometers north of the type section of the Tambor, the formation is well-exposed along the road to Cuestarica. The description of this section is also given below. In this section there is conglomerate sandstone only near the base, and the pebbles are of siltstone, whereas at Quebrada Piedra Azul, the sandstones are conglomeratic to some extent throughout the section and the pebbles are of quartz.
measured in Quebrada Piedra Azul beginning about 100 meters from the confluence with the Rio Lebrija and extending upstream to the west and southwest for approximately one kilometer (planchita 109 IV-A, I-2 NW and I-1 E), municipality of Lebrija, Department of Santander.

(Measured and described by F. Montero, October, 1968)

Rosa Blanca Formation (lower beds only):

- Limestone, dark-gray, hard, massive, highly fossiliferous

Tambor Formation:

- (Partly covered) claystone, reddish-brown, medium-hard, fractured, with interbedded hard, reddish-brown calcareous claystone and reddish-brown and gray, medium- to fine-grained, micaceous, partly feldspathic sandstone, N. 11° E., 52° NW

- Sandstone, light-gray, hard, fine-grained, micaceous, crossbedded, slightly conglomeratic with quartz pebbles up to 4 cm in diameter

- Covered

- Sandstone, light-gray, fine-grained, micaceous, crossbedded, slightly feldspathic and conglomeratic

- Covered, probably sandstone similar to that above and below

- Sandstone, light-gray, hard, fine-grained, micaceous, crossbedded, conglomeratic in some beds with pebbles of quartz up to 4 cm in diameter
Meters

Claystone, greenish-gray, soft; contains two beds
1.1 and 1.2 meters thick of grayish-white, conglomeratic sandstone, N. 10° E., 52° NW. ........ 10.8

Sandstone, light-gray, hard, fine-grained, micaceous, crossbedded, conglomeratic in some beds with pebbles of quartz up to 4 cm in diameter .......... 31.7

Covered ........................................ 9.6

Sandstone, light-gray, hard, fine-grained, micaceous, crossbedded, conglomeratic with numerous pebbles of white quartz and few of feldspar, in massive beds 4 to 6.5 m thick; contains a few beds of greenish-gray claystone ...................... 118.2

Conglomerate, brownish-gray, hard, crossbedded, with pebbles of white quartz, claystone and feldspar up to 4 cm in diameter in matrix of dark-gray, micaceous, silty sandstone ................................. 2.3

Claystone, reddish-brown in lower half, greenish-gray above, hard, siliceous, micaceous, N. 16° E., 52° NW. ......................................................... 0.9

Total thickness of Tambor Formation 366.3
Girón Formation (upper beds only):

Sandstone, greenish-gray, hard, fine- to very fine 
grained, crossbedded, highly conglomeratic with 
abundant pebbles of white quartz, feldspar, clay-
stone, and few of muscovitic chloritic schist;
some beds are light-gray, very fine grained, non-
conglomeratic ....................................................... 98.7
Stratigraphic section of the Tambor Formation measured along the road from about 1.5 to 1.0 kilometers northeast of Cuestarica (planchita 109 I-B, I-15 SE and J-15 NE), Municipality of Rionegro, Department of Santander. (Measured and described by R. Vargas, September, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosa Blanca Formation (lower beds only):</td>
</tr>
<tr>
<td>(Partly covered) shale, yellowish-gray, very sandy, slightly fissile, with thin interbeds of yellowish-to bluish-gray fissile shale</td>
</tr>
<tr>
<td>Covered</td>
</tr>
<tr>
<td>Tambor Formation:</td>
</tr>
<tr>
<td>Covered; sandy, fine-grained, reddish-yellow soil</td>
</tr>
<tr>
<td>Sandstone, reddish-yellow, medium-hard, fine-grained, micaceous, in beds up to 6 m thick, with interbedded bluish-gray to reddish-brown sandy shale</td>
</tr>
<tr>
<td>Sandstone, reddish-yellow, medium-hard, fine-grained, in beds up to 1 m thick, with interbeds of bluish-gray sandy shale</td>
</tr>
<tr>
<td>Covered; clayey and sandy reddish soil</td>
</tr>
<tr>
<td>Shale, reddish-yellow, sandy, with interbeds of fine-grained, reddish-yellow sandstone</td>
</tr>
<tr>
<td>Sandstone, reddish-yellow, fine-grained, micaceous</td>
</tr>
<tr>
<td>Covered; reddish, clayey soil</td>
</tr>
<tr>
<td>Shale, bluish-gray, sandy, micaceous</td>
</tr>
<tr>
<td>Sandstone, light-yellowish-gray to yellowish-brown, with interbeds of bluish-gray sandy shale up to 20 cm thick</td>
</tr>
<tr>
<td>Description</td>
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<td>-----------------------------------------------------------------------------</td>
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<tr>
<td>Shale, reddish-brown, with bluish-gray spots and few thin interbeds of fine-grained, pale-reddish-brown sandstone</td>
</tr>
<tr>
<td>Sandstone, pale-reddish-brown to light-yellowish-gray, fine-grained</td>
</tr>
<tr>
<td>Shale, light-reddish-yellow to light-bluish-gray, with irregular sandy zones</td>
</tr>
<tr>
<td>Sandstone, light-reddish-brown to light-yellowish-gray, fine-grained, micaceous</td>
</tr>
<tr>
<td>Shale, reddish-brown, sandy, micaceous</td>
</tr>
<tr>
<td>Sandstone, light-reddish-brown to light-yellowish-gray, fine-grained, micaceous, with 2.0 meters of sandy, micaceous shale in the lower half</td>
</tr>
<tr>
<td>Siltstone, reddish-brown with patches of greenish-to bluish-gray, micaceous</td>
</tr>
<tr>
<td>Sandstone, light-reddish-brown to light-yellowish-gray, fine-grained, micaceous</td>
</tr>
<tr>
<td>Sandstone, light-yellowish-gray, fine-grained, with thin interbeds of greenish-to reddish-gray sandy clay</td>
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<tr>
<td>Meters</td>
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</table>

Total thickness of Tambor Formation 254.3

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Girón Formation (upper beds only):

|        | Sandstone, pale-reddish-brown, fine-grained, micaceous, somewhat feldspathic, in beds 0.3-1.0 m thick; interbeds of micaceous, reddish-brown shale up to 0.3 m thick | 66.7 |
Eastward from this eastern margin of the middle Magdalena basin, the Tambor thins considerably. In the eastern half of quadrangle H-12, and in H-13, it ranges from 100 to 250 meters. Where the beds are inclined, it usually weathers as a distinct ridge, and south of Bucaramanga, Tambor sandstone forms the cap of several of the mesas of that region.

The lower boundary of the Tambor is one of unconformity, although this is not always evident where the upper beds of a thick Giron section have been reworked into cleaner and better sorted beds of the lower Tambor. The upper boundary is conformable with the overlying Rosa Blanca Formation. Fossils of Late Hauterivian age have been reported from upper neritic facies of the Tambor near Totumal, about 100 kilometers north of the area of the present report (Morales et al, 1958, p. 647), and Valanginian to Early Hauterivian fossils from the Leiva area about 100 kilometers to the south (ibid., p. 648). The top of the Tambor is thus indicated to be older in the south than in the north. The age range in the lower beds of the formation is not known because fossils have not been found in this part of the section.
East of the Bucaramanga fault, where downfaulted blocks of Cretaceous rocks have been preserved from erosion, the Tambor overlies rocks ranging in age from pre-Devonian to Jurassic. This is indicative of the original blanketing nature of this and younger Cretaceous formations over a planed-down pre-Cretaceous erosion surface. The basal beds are conglomeratic in many places but vary greatly in this respect. In some places the coarser materials are angular fragments of Giron conglomeratic sandstone and conglomerate, in others only well-rounded small pebbles of white quartz.

Although the Tambor in the western (middle Magdalena Valley) part of the report area does not appear to correlate with rocks of equivalent age in the eastern (Maracaibo Basin) part (fig. 9), there is a good facies correlation with a thin basal section of the Tibú Formation in which clean somewhat conglomeratic quartzitic sandstones overlie pre-Cretaceous metamorphic or igneous rocks or Giron beds in the Pamplona area (H-13, c-2). The thin, basal sandstones of the Tibú are quite persistent northward and are present in the type section of the formation 135 kilometers to the north (Notestein et al, 1944, fig. 4, p. 1176). The dark-gray fossiliferous limestones that make up the major part of the Tibú Formation are similar to those of the Rosa Blanca Formation of the western section. In western Venezuela, the basal sandstones of the Tibú are much thicker and constitute the Rionegro Formation from which fossils have been collected that range in age from Hauterivian to Aptian (Trump and Salvador, 1964, p. 5).
In an unpublished report of 1929 by O. C. Wheeler (Morales et al, 1958, p. 648), the Rosa Blanca Formations in named for Cerro Rosa Blanca, a high ridge in quadrangle H-12, b-5 NE. The type section, however, is generally accepted as the one in the canyon of the Río Sogamoso (planchita 120-I-D, A-8), upstream about 1.5 kilometers from the highway bridge over the river at El Tablazo. There the formation consists of about 425 meters of hard, bluish-gray, coarse-textured, fossiliferous, massive limestone with many marly beds that grade into black, shaly, very fine-textured limestone at the top. It is conformable with the underlying Tambor and overlying Paja Formations.

The Rosa Blanca is better exposed in the Quebrada Pujamanes, about four kilometers north-northeast of the Río Sogamoso location; and a section measured follows.
Stratigraphic section of the Rosa Blanca Formation measured in the Quebrada-Puñamanes about 2 kilometers upstream from the confluence with the Quebrada Aguablanca (planchita 120 I-B, G-9 E½, G-10 W½), Municipality of Giron, Department of Santander.

(Measured and described by F. Montero, September, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
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<tbody>
<tr>
<td>La Paja Formation (lower beds only):</td>
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<tr>
<td>Covered; apparently soft shales of the La Paja Formation .....................................</td>
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<tr>
<td>146.0</td>
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<tr>
<td>Rosa Blanca Formation:</td>
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<tr>
<td>Limestone, dark-gray, hard, massive, medium-textured, in beds from 0.6-2.0 m thick; abundant thick-shelled fossils in top and basal beds, fewer elsewhere, N. 25° E., 43° NW. ...................................................</td>
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<tr>
<td>58.0</td>
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<tr>
<td>Limestone, gray, hard, fine-textured, nonfossiliferous, with few interbeds of black, fissile, calcareous shale from 2-10 cm thick, N. 20° E., 46° NW. ..........</td>
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<tr>
<td>15.0</td>
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<tr>
<td>Limestone, dark-gray, hard, massive, medium-textured, abundantly fossiliferous with pelecypods and echinoids, in beds 0.4-1.8 m thick; few interbeds of dark-gray to black, fissile, slightly calcareous, fossiliferous shale from 10-70 cm thick; shale beds more frequent in the lower part, and fossils more abundant to the extent of forming beds of coquina up to 15 cm thick, N. 24° E., 47° NW. ...........................................</td>
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<td>141.2</td>
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Covered interval ........................................ 3.0

Limestone, dark-gray, hard, massive, medium-textured,
  abundantly fossiliferous ............................ 39.6

Shale, black, fissile, slightly micaceous, calcareous,
  slightly silty near the base, fossiliferous with
  pelecypods, N. 25° E., 54° NW. .................. 15.1

Covered; contact with Tambor Formation apparently occurs
  about 10 meters below the base of the black shale
  described above .................................... 10.0

  Total thickness of the Rosa Blanca Formation 427.9

Tambor Formation (upper beds only):

Covered interval .................................... 20.3

Claystone, gray, green, violet, soft, slightly micaceous,
  N. 20° E., 47° NW. .......................... 29.0

Sandstone, gray to grayish-white, hard, fine-grained,
  micaceous, N. 24° E., 48° NW. ................ 10.0+
The thickness of 428 meters shown is the maximum that has been reported. In the mesa area of the southern part of quadrangle H-12, I. de Julivert (1963) measured 318 meters. About 42 kilometers north of the type section, the Rosa Blanca is partly exposed along the road to Cuestarica. The measured section is given below. The noticeably sandy character of the lower part of the section contrasts with that in Quebrada Pujamanes where no sandy beds were found. One oolitic bed occurs in the lower part of the Cuestarica section. Taborda (1965, p. 6) notes a similar contrast in sand content between the outcrops of the type locality and the section penetrated in wells about 50 kilometers to the west where sand grains, oolitic limestone and some oolitic chert are present. The section studied by I. de Julivert (1963, fig. 2) at Quebrada Lagunetas, west of Mesa de Los Santos (H-12, c-8 SW) contains detrital quartz grains and a zone of quartzite in the upper part.

The formation thins greatly to the east over the Santander massif. At Quebrada Lisagura, 3 kilometers south of San Andres (H-13, b-8 SW), J. Abozaglo and A. Otero measured only 43 meters. Because of rapid weathering in the humid climate, and also because of varying content of shale, the unit rarely displays a prominent outcrop or ridge. In some areas it can be delineated on aerial photographs by the sinkholes that have developed.
Stratigraphic section of the Rosa Blanca Formation
exposed along the road from about 1.0/0.6 kilometers northeast of Cuestafrica (planchita 109 I-B, J-15 NW), Municipality of Rionegro, Department of Santander.

(Measured and described by R. Vargas, September, 1968)

<table>
<thead>
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| Paja Formation (lower beds only):
| Shale, very dark gray, sandy, weathers dark-brown; contains several widely separated beds of very dark gray, hard, fine-textured, argillaceous limestone from 20-70 cm thick and one 20 cm bed with cone-in-cone structure |
| 55.9 |
| Rosa Blanca Formation:
| Limestone, dark-gray, hard, fossiliferous, pyritiferous at some levels, in beds 0.3-1.0 m thick, with softer, thin interbeds of highly fossiliferous argillaceous limestone |
| 27.2 |
| Covered; numerous blocks of limestone |
| 17.2 |
| Limestone; three beds are gray, hard, nonfossiliferous; two interbeds are gray, hard, argillaceous, and highly fossiliferous with small pelecypod shells |
| 4.7 |
| Limestone, gray, hard, argillaceous, highly fossiliferous with small pelecypod shells |
| 3.5 |
| Limestone; three beds are gray, hard, fossiliferous; two interbeds are gray, hard, argillaceous, highly fossiliferous with small pelecypod shells |
| 4.3 |
Limestone, gray, hard, argillaceous, highly fossiliferous with small pelecypod shells .................. 15.2

Limestone; three thicker beds are gray, hard, argillaceous, highly fossiliferous with small pelecypods, alternating with three thinner beds that are gray, hard, crystalline ........................................... 5.5

Limestone, gray, hard, crystalline, fossiliferous, in beds 0.3-0.8 m thick; one bed argillaceous, highly fossiliferous .................................................. 4.1

(Partly covered) sandstone, yellowish-gray, hard, fine-grained, interbedded with soft, sandy, yellowish-to bluish-gray shale .................................................. 43.0

Limestone, gray, hard, sandy, fossiliferous with small pelecypod shells .............................................. 2.3

Limestone, gray, hard, sandy to very sandy, glauconitic in some beds, argillaceous and highly fossiliferous near the base ................................................................. 3.5

Limestone, light-gray, hard, slightly sandy, slightly glauconitic, slightly fossiliferous, argillaceous at the base ................................................................. 5.2

Limestone, gray, hard, oolitic, weathers pale-brown ........ 0.9
(Partly covered) shale, yellowish-gray, very sandy, slightly fissile, with thin interbeds of fissile, yellowish- to bluish-gray shale .......... 23.3
Covered; fine- to medium-grained sandy soil, yellowish- to brownish-gray ................. 29.4
Total thickness of the Rosa Blanca Formation 189.3

Tambor Formation (upper beds only):
Covered; sandy, fine-grained, reddish-yellow soil ... 24.9
Sandstone, reddish-yellow, medium-hard, fine-grained, micaceous, in beds up to 6 m thick; with interbedded bluish-gray to reddish-brown sandy shale ........ 74.8
The age of the Rosa Blanca Formation ranges from Hauterivian in the south to Barremian in the north, and the presence of heavy-shelled molluscs, and rounded, re-worked limestone pebbles indicate deposition under upper neritic, near-shore conditions of a shallow marine environment (Morales et al, 1958, p. 648). In lithologic character, if not in age, it is similar to the Tibú Formation of the Maracaibo Basin section (fig. 9).
A detailed petrographic study was made of the Rosa Blanca section exposed in Quebrada Lagunetas (planchita 120-IV-C, E-7, F-7, F-8) in the area west of the Mesa de Los Santos by I. de Julivert (1963). Figure 10 taken from this study shows the various zones that were identified on the basis of the nomenclature and classification of Folk (1959, 1962), and the depositional environments which they indicate. The lowermost zone of dolomite and dolomitic limestone with thin beds of gypsum (satin spar) up to two centimeters thick, a zone of bioliths formed by the deposits of calcareous algae, and presence of pyrite in all the beds indicate that a restricted environment was present that was favorable to the deposition of evaporites (I. de Julivert, 1963, p. 27). Two kilometers south of this section, across Río Sogamoso on the western slope of Mesa de Los Santos, individual gypsum beds in this lower zone reach thicknesses of more than 2 meters and are being quarried for the cement industry. Two other quarry sites are located 2.5 and 3.8 kilometers to the south and south-southeast respectively. The size outline of the evaporite basin has not been fully defined at this writing, but it is clear that the evaporite facies is well-developed. This deposit is treated further in the section on economic geology.
FIGURE 10  Diagram of the variations in the environment of deposition of the facies of Rosa Blanca Formation at Quebrada Lagunetas (after Zamarreno de Julivert, 1963, fig. 4, p. 29).
Paja Formation

The type locality for the Paja Formation is Quebrada La Paja where this stream enters Río Sogamoso one kilometer upstream from the highway bridge at El Tablazo (planchita 120-I-D, A-8 NW). The formation was named and described by O. C. Wheeler in an unpublished report of 1929 (Morales et al, 1958, p. 650). The section reaches a maximum thickness here of 625 meters and is composed of thinly laminated, slightly calcareous, silty, and micaceous black shales. The lower 250-300 meters contain limestone concretions, septarian nodules and calcite veins. The section is not well enough exposed to measure a continuous section; and the upper beds are included in the description of the type section of the overlying Tablazo Formation (see below).

About 42 kilometers north of the type section, the Paja Formation is well-exposed along the road to Cuestarica.

Boundaries are conformable and well-defined with the underlying Rosa Blanca and overlying Tablazo Formations.

In this section, described below, concretions are abundant in only one zone in the lower half of the formation. They increase in abundance southward toward the type section. Farther south, in the southwestern part of Mesa de Los Santos, they have been reported throughout the formation (Téllez, 1964, p. 16), and also gypsum in thin laminae interbedded with the shale. These gypsum platelets were gathered as a source of gypsum for the cement industry until thicker beds that could be quarried were discovered in the lower part of the Rosa Blanca Formation on the southwestern slopes of the mesa. A study of the gypsum resources in the Paja Formation in this area was made by Jimeno and Yepes (1963).
Stratigraphic section of the Paja Formation along the road from about 600 meters east to 500 meters west of the village of Cuestarica (planchita 109 I-B, J-14 N 1/2), Municipality of Rionegro, Department of Santander.
(Measured and described by R. Vargas, September, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tablazo Formation (lower beds only):</td>
</tr>
<tr>
<td><strong>Sandstone, light-yellow to light-pink, hard, fine-grained, in beds 0.3-0.8 m thick, with interbeds of yellow to light-brown, sandy, micaceous shale,</strong></td>
</tr>
<tr>
<td>N. 50° W., 37° SW.</td>
</tr>
<tr>
<td><strong>Shale, light-reddish-brown, slightly micaceous</strong></td>
</tr>
<tr>
<td>Paja Formation:</td>
</tr>
<tr>
<td><strong>Shale, very dark gray, sandy, very micaceous</strong></td>
</tr>
<tr>
<td><strong>Shale, very dark gray, micaceous, alternating in thin beds with grayish-black sandy shale; contains two 1 m thick beds of hard shaly sandstone at 3 and 30 m above the base of the unit, N. 56° W., 35° SW.</strong></td>
</tr>
<tr>
<td><strong>Shale, gray, calcareous, with thin beds of fine-textured, very dark gray limestone near the top</strong></td>
</tr>
<tr>
<td><strong>Shale, very dark gray, fissile, weathers brown; lower beds have abundant impressions of ammonites up to 5 cm in diameter, N. 55° W., 34° SW.</strong></td>
</tr>
</tbody>
</table>
Shale, very dark gray, calcareous, with limestone
concretions from 0.1-2.0 m in diameter which contain
ammonites (up to 50 cm in diameter) and gastropods,
some of which are pyritized; contains beds of fibrous
white gypsum up to 1 cm thick, N. 65° W., 25° SW. . . 13.1
Shale, very dark gray, weathers dark-brown ........ 41.9
Limestone, very dark gray, hard, fine-textured,
arillaceous ....................................... 3.0
Shale, very dark gray, sandy, weathers dark-brown;
contains several widely separated beds of very dark
gray, hard, fine-textured, argillaceous limestone
from 20-70 cm thick and one 20-cm bed with cone-in-
cone structure .................................. 55.9

Total thickness of the Paja Formation 328.5

Rosa Blanca Formation (upper beds only):
Limestone, dark-gray, hard, fossiliferous, pyritiferous
at some levels, in beds 0.3-1.0 m thick, with softer
thin interbeds of highly fossiliferous, argillaceous
limestone ...................................... 27.2
The Paja thins rather uniformly toward the eastern part of the report area. At Quebrada Liagura (H-13, b-8 SW) the section is only 41 meters thick. Although it is shown as a thin map unit in the southeastern part of H-13, it is probably not more than 25 meters thick. Because it is less resistant to erosion than the adjacent Rosa Blanca and Tablazo Formations, it forms an erosional valley between these formations where the beds are tilted.

As in the case of the Rosa Blanca and Tambor Formations, the Paja beds are older in the south than in the north of the middle Magdalena Valley (fig. 9). The formation ranges from Barremian to Aptian in the south to Aptian in the north. This time transgression has been revealed by a study of the ammonite fauna found in the lower part of the formation in various places (Morales et al, 1958, p. 650). A similar strong transgression at the top of the formation is not evident.

Inasmuch as the Paja Formation thins so greatly from west to east, there is no formational unit with which it may be correlated in the Maracaibo Basin section (fig. 9). At the top of the Tibú Formation, however, there is a strong break from limestone to black shale in the base of the Mercedes Formation. Shales make up a large part of the lower third of the Mercedes in the area of the Barco Concession (Notestein et al, 1944, p. 1177).
The type section for the Tablazo Formation is at El Tablazo where the highway from Bucaramanga to San Vicente crosses Río Sogamoso which cuts through the strong ridge formed by the Tablazo at this point. The formation was named in an unpublished report of O. C. Wheeler who reported a section of 150 meters consisting of extremely fossiliferous, massive-bedded limestone in the upper part and marls or clayey limestone in the lower part (Morales et al, 1958, p. 651). It is conformable and gradational with the underlying Paja Formation and conformable with the overlying Simití Formation. A section was measured at the type locality (see below).

The Tablazo at the type locality is more calcareous than it is to the north and northeast. About 42 kilometers to the north, the section contains much more sandstone, as indicated in a second measured section shown below. The 278 meters measured in this section may include some repetition due to faulting which is indicated by erratic strikes and dips near the middle of the outcrop. According to the report of Téllez (1964, p. 17), sandstone is also dominant in the Tablazo section south of Barichara (I-12, c-2 SW) about 50 kilometers south-southeast of the type section. The thickness is about the same.

From the belt of Cretaceous rocks where the type section is located, the Tablazo thins eastward, although probably not as much as the Rosa Blanca and Paja Formations. At Quebrada Lisagura (H-13, b-8 SW), the section of 114 meters includes dark gray shales and fossiliferous limestone, with sandy beds and sandstone prominent only in the upper quarter of the unit.
Type section of the Tablazo Formation on the north side of the Rio Sogamoso at El Tablazo, from about 300 meters upstream to 200 meters downstream from the highway bridge (planchita 120 I-B, J-7 S½), Municipality of Girón, Department of Santander. (Measured and described by A. Castro, September, 1968)

Simiti Formation (lower beds only):
Covered; apparently soft black shales

Tablazo Formation:
Limestone, gray, hard, fine- to medium-textured,
glaucous, thin-bedded changing to massive-bedded
at the top, N. 18° E., 34° NW. ................ 2.6
Limestone, dark-gray, hard, medium-textured, slightly fossiliferous; finer textured, more massive, and harder at the top, N. 20° E., 37° NW. ........ 5.2
Limestone, dark-gray to black, hard, massive, fine-
to very fine textured, pyritic; light-gray, fine-
to medium-textured and fossiliferous at the top, N. 23° E., 38° NW. ........ 4.9
Limestone, dark-gray to black, hard, massive, medium-textured, glauconitic, pyritic; middle beds are thinner, fossiliferous, nonglaucous, N. 22° E., 36° NW. ................ 6.7
Covered ........................................ 6.1
Limestone, dark-gray, hard, massive, medium-textured,
slightly glauconitic .......................... 1.0
Sandstone, yellowish-brown, medium-hard, argillaceous,
calcareous, glauconitic, slightly micaceous .... 5.5
<table>
<thead>
<tr>
<th>Covered</th>
<th>22.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, gray, hard, massive, medium-textured, fossiliferous in the upper part</td>
<td>6.3</td>
</tr>
<tr>
<td>Sandstone, gray, hard, thin-bedded, fine- to very fine grained, calcareous</td>
<td>1.0</td>
</tr>
<tr>
<td>Limestone, light-gray, hard, thin-bedded, fine- to very fine textured</td>
<td>1.4</td>
</tr>
<tr>
<td>Limestone, light-gray, hard, medium-textured, glauconitic in a few beds, in beds up to 1 m thick</td>
<td>4.6</td>
</tr>
<tr>
<td>Covered</td>
<td>4.0</td>
</tr>
<tr>
<td>Limestone, dark-gray to black, hard, medium- to coarse-textured, veins of calcite, in beds up to 50 cm thick</td>
<td>2.0</td>
</tr>
<tr>
<td>Sandstone, dark-gray to black, thin-bedded, fine- to medium-grained, argillaceous, calcareous, micaceous, N. 16° E., 38° NW.</td>
<td>2.1</td>
</tr>
<tr>
<td>Limestone, dark-gray to black, hard, massive, coarse-textured, fossiliferous; fine- to medium-textured and veins of calcite at the base</td>
<td>5.4</td>
</tr>
<tr>
<td>Limestone, dark-gray, hard, massive, fine- to medium-textured; lighter colored and coarser textured at the base</td>
<td>7.7</td>
</tr>
<tr>
<td>Covered</td>
<td>26.9</td>
</tr>
<tr>
<td>Meters</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Sandstone, brown, medium-hard and porous, thin-bedded,</strong></td>
<td></td>
</tr>
<tr>
<td>fine- to medium-grained, argillaceous, micaceous,</td>
<td></td>
</tr>
<tr>
<td>slightly calcareous .............................. 3.6</td>
<td></td>
</tr>
<tr>
<td>Covered ........................................... 14.3</td>
<td></td>
</tr>
<tr>
<td><strong>Limestone, dark-gray, hard, medium-textured, in beds</strong></td>
<td></td>
</tr>
<tr>
<td>up to 40 cm thick, N. 15° E., 40° NW. .......... 2.0</td>
<td></td>
</tr>
<tr>
<td><strong>Sandstone, gray, thin-bedded, medium-grained, micaceous,</strong></td>
<td></td>
</tr>
<tr>
<td>calcareous ........................................ 0.8</td>
<td></td>
</tr>
<tr>
<td>Covered ........................................... 25.6</td>
<td></td>
</tr>
<tr>
<td><strong>Limestone, gray, medium-hard, medium-textured, highly</strong></td>
<td></td>
</tr>
<tr>
<td>fossiliferous with fragments of pelecypods ..... 1.0</td>
<td></td>
</tr>
<tr>
<td><strong>Limestone, dark-gray to black, hard, medium-textured,</strong></td>
<td></td>
</tr>
<tr>
<td>thin calcite veins, in beds up to 40 cm thick ... 1.0</td>
<td></td>
</tr>
<tr>
<td><strong>Sandstone, dark-gray, hard, massive, medium-grained,</strong></td>
<td></td>
</tr>
<tr>
<td>micaceous, slightly calcareous, N. 17° E., 39° NW. .. 4.6</td>
<td></td>
</tr>
<tr>
<td>Covered ........................................... 19.2</td>
<td></td>
</tr>
</tbody>
</table>

**Total thickness of Tablazo Formation** 186.5

**Paja Formation (upper beds only):**

**Shale, black, brittle, laminar, silty, micaceous,**
| slightly calcareous .............................. 1.0 |
| **Limestone, dark-gray to black, hard, massive, fine-** |
| to medium-textured ............................... 1.0 |
Shale, black, laminar, silty, micaceous, slightly calcareous, interbedded with dark-gray, thin-bedded, micaceous and argillaceous siltstone .... 16.2

Covered; appears to be soft black shale ........ 60.0

Shale, black, brittle, laminar, slightly micaceous, with thin plates of selenite gypsum; contains ellipsoidal calcareous concretions from 15-25 cm in largest dimension; in the middle are lenticular beds of dark-gray, hard, fine- to medium-textured lime-stone up to 1 m thick ........ 30.0
Stratigraphic section of the Tablazo Formation along the road from about 500 meters west to 1600 meters west of the village of Cuestarica (planchita 109 I-B, J-13), Municipality of Rionegro, Department of Santander. (Measured and described by R. Vargas, September, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Simii Formation (lower beds only):**

- Shale, very dark gray, fissile, micaceous ......... 75.0

**Tablazo Formation:**

- Limestone, gray, hard, massive, highly fossiliferous with pelecypods ............... 18.0
- Shale, very dark gray, weathering yellowish to reddish, with thin interbeds of light-tan to gray, highly porous fine-textured siliceous rock (tripoli?), N. 58° W., 45° SW. ............... 46.0
- Sandstone, light-yellow to pale-brown, hard, massive, fine- to medium-grained, glauconitic and micaceous, N. 5° E., 65° SE. ............... 55.7
- Shale, very dark gray, weathering yellowish-brown, with local units of fine-textured, highly porous siliceous rock (tripoli?) ............... 45.2
- Tripoli?, light-tan, medium-hard, fine-textured, very porous, siliceous, in beds 40-80 cm thick, N. 70° W., 45° SW. ............... 19.1
- Shale, very dark gray, micaceous ............... 33.4
Meters

Sandstone, light-yellow to light-rose, medium-hard, fine-grained, in beds 30-30 cm thick; interbeds of yellow to light-brown, sandy, micaceous shale . . . . 57.9 Shale, pale-reddish-brown, slightly micaceous . . . . 2.3

Total thickness of Tablazo Formation 277.6

Paja Formation (upper beds only):

Shale, very dark gray, sandy, very micaceous . . . . 11.0
Due to the variation in lithologic composition, the Tablazo does not display a uniform, characteristic outcrop pattern as do such formations as the Tambor and Paja. Because the sandstones are more resistant to weathering than the limestones, in areas underlain by this formation there appears to be more sandstone in the section than is actually the case.

An age variation in the Tablazo, from Late Aptian-Early Albian in the south to Albian in the north (fig. 9), has been postulated on the basis of fossils found in the underlying Paja and overlying Simití Formations (Morales et al, 1958, p. 651). Lithologically, the Tablazo is similar to the Mercedes Formation of the Maracaibo Basin section, which is of Late Aptian-Early Albian age.

Simití Formation

The Simití Formation was named by geologists of the International Petroleum Company (Colombia) in 1953 for the excellent outcrops on the south side of Cienaga (marsh) Simití on the west side of the Río Magdalena in the southern part of the Department of Bolívar (Morales et al, 1958, p. 651). There the formation is 410 meters thick and consists of soft, platy, carbonaceous, gray to black, locally calcareous and concretionary shale. The concretions reach a size of three meters in longest dimension where they are most abundant in the uppermost part of the formation. Thin conglomeratic streaks containing small pebbles, phosphate nodules, fish teeth and sand occur locally very near the top. The contacts with the underlying Tablazo and overlying Salto Formations are conformable and correspond to well-defined changes in lithology.
Because it has very few resistant beds, the Simití is characteristically expressed as a valley in the topography, and a good exposure of the whole formation was not found in the report area.

Some of the beds near the base and top are described with the Tablazo La Luna Formations.

Estimates of the thickness of the Simití in the Cretaceous belt west of Bucaramanga range from 460-550 meters. The following description of the Simití in wells of the La Cira-Infantas and Llanito oil fields in quadrangle H-11 east of the report area is given by Taborda (1965, p. 8):

"In the subsurface, the shale is very calcareous and contains thin beds of argillaceous limestone. The shale is very hard, dark brown to brownish-gray to black, with calcite-filled joints. The interbedded limestones are usually thin, very dense, dark brown to black, and commonly pyritic. Fossils are rare and consist of flattened pelecypod shell fragments."

In Llanito No. 1, the Simití measures 598 meters and in Infantas No. 1613 it measures 655 meters.

The age of the Simití is based on ammonites of early, middle and late Albian age found in the area of the type section. Late Albian foraminifers are also present (Petters, 1954).
Eastward from the Magdalena Valley, the Simiti Formation becomes progressively sandier and less shaly, particularly in the lower part. In the Matanza area (H-12, d-2 SE) sandstone units are prominent, and the formation is estimated to be 600 meters thick or more. Thirty kilometers farther east, in the faulted belt of sedimentary rocks that extend north and south of Mutiscua, thick sandstones are predominant and the unit forms the most prominent ridge of the Cretaceous section. Here the formation is typical of the Maracaibo Basin and the name Aguardiente Formation is used. The upper part of the Simiti retains its shaly character to a large extent and is correlated with the Capacho Formation of the Colombian part of the Maracaibo Basin.

Salto Formation

This unit was named by the committee of petroleum company geologists who agreed on the standard nomenclature of the stratigraphy of the middle Magdalena Valley (Morales et al, 1958, p. 652). The type section is in the Quebrada El Salto about 80 kilometers north of the northwest corner of quadrangle H-12. There the unit contains dark-gray, dense, hard limestone with numerous interbeds of black, calcareous, thinly laminated, medium-soft shale with ovoid concretions developed locally. The formation there is 50 meters thick.
In the area of the present report, the Salto has not been recognized as a continuous, well-developed, distinct unit and has therefore not been mapped as such. This is true also to the west in quadrangle H-11 where the Salto has not been found in wells of the de Mares Concession (Taborda, 1965, plate II). In the investigations of the La Luna Formation and adjacent parts of the section, no beds have been found that correspond to the formation as it is developed to the north (E. K. Maughan, personal commun.). In any event, the unit is of limited thickness and underlies the Salada Member of the La Luna Formation so that it tends to be part of the distinctive ridge formed by the La Luna between the less resistant Simití and Umír Formations.

The age of the Salto is Late Albian to Cenomanian, based on ammonites and other fossils (Morales et al, 1958, p. 652).
The name of this unit was first used in the Serranía de Perija in the northwestern part of the state of Zulia, Venezuela, by Garner (1926). Because of its wide regional extent, the name has been retained in northeastern Colombia (Morales et al, 1958, p. 653), where it is subdivided into the Salada, Pujamana, and Galembo Members. The members were first named in an unpublished report of O. C. Wheeler for Quebradas Pujamana and Salada and Cerro (hill) del Galembo all of which are near the Río Sogamoso where it cuts across the La Luna in H-12, b-5 SW. In this type area, the Salada Member contains hard, black, thin-bedded limy shales with slaty appearance in outcrop. A few thin beds of fine-textured black limestone are present and streaks and concretions of pyrite. Limestone concretions of elliptical cross section and 10-15 centimeters in largest dimension are characteristic of this member. The Pujamana Member contains gray to black, calcareous, thin-bedded shale. In the Galembo Member, hard, black, thin-bedded calcareous shale is predominant, with thin inter-beds of argillaceous limestone. Discoidal limestone concretions containing ammonites reach eight meters in maximum dimension, and thin layers of bedded blue-black chert are present. Persistent phosphatic beds near the top of the Galembo contain abundant bone and vertebrae fragments of fish, and rare teeth. The contact of the La Luna with the underlying Simití Formation is conformable. That with the overlying Umir is one of unconformity and represents a varying amount of erosion of the La Luna Formation prior to deposition of the Umir shales as has been revealed by studies of the phosphate resources of the La Luna Formation (E. K. Maughan, personal commun.).
The following tabulation shows the thickening of the members of the La Luna Formation from the area of the type section and Quebrada La Sorda westward about 55 kilometers to the wells of the La Cira-Infantas and Llanito oil fields:

<table>
<thead>
<tr>
<th>Member</th>
<th>Type section</th>
<th>Quebrada La Sorda</th>
<th>La Cira-Infantas &amp; Llanito oil fields (quadrangle H-11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galembo</td>
<td>180 m</td>
<td>43 m</td>
<td>247 m</td>
</tr>
<tr>
<td>Pujamana</td>
<td>?</td>
<td>156</td>
<td>213-234</td>
</tr>
<tr>
<td>Salada</td>
<td>50</td>
<td>61</td>
<td>107-131</td>
</tr>
</tbody>
</table>

A section of the La Luna measured at Quebrada La Sorda, about 12 kilometers north-northeast of the type area follows.
**Stratigraphic section of the La Luna Formation in Quebrada La Sorda (plancha 109 III-D, F-11 NE, F-12 NW), Municipality of Lebrija, Department of Santander.**

(Measured by J. Abozaglo, A. Castro, F. Pachon, R. Duran, P. Saenz and E. Maughan, November, 1967)

<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
</table>

**Umir Formation (lower beds only):**

- Sandstone, dark-gray, hard, calcareous, glauconitic; contains black phosphatic grains .......... 1.5

**La Luna Formation:**

**Galembo Member**

- Shale (poorly exposed), dark-gray, laminated with calcareous concretions .............. 3.2
- Shale, dark-gray, hard, with interbeds of gray calcareous chert; contains foraminifers ........ 5.6
- Shale, dark-gray, hard, laminated .............. 1.0
- Chert, dark-gray, calcareous; at the base is a dark-yellowish-brown, calcareous phosphatic bed 4 cm thick, containing phosphorite pellets, foraminifers, and veinlets of calcite .............. 0.3
- Shale, dark-gray, hard, calcareous and siliceous, varying to argillaceous and cherty limestone, in plane regular beds 2-20 cm thick; contains foraminifers, few scattered grains of apatite and few calcareous concretions up to 25 cm in diameter; more siliceous in the upper part .............. 20.0
Shale, dark-gray, calcareous, phosphatic ........ 2.2
Chert, dark-gray to black, calcareous, slightly phosphatic, foraminiferal, in beds 5-10 cm thick, with interbedded siliceous shale ........ 2.1
Chert, dark-gray to black, calcareous, in beds 1-10 cm thick, with thin interbeds of calcareous siliceous shale ..................... 2.3
Limestone, dark-gray, hard, siliceous, slightly phosphatic ..................... 0.3
Chert, dark-gray to black, and siliceous shale in beds 1-3 cm thick ........ 2.9
Shale, black, slightly calcareous, thin-bedded .... 2.0
Chert, dark-gray, and siliceous shale in beds 1-5 cm thick ..................... 1.5
Phosphorite, yellowish-brown, calcareous, with abundant grains of apatite ........ 0.2
Chert, dark-gray, calcareous, and calcareous siliceous shale ..................... 0.3
Phosphorite, yellowish-brown, calcareous, with abundant grains of apatite ........ 0.3
Chert, dark-gray, calcareous, and calcareous siliceous shale in beds 1-10 cm thick ........ 1.1
Shale, dark-gray, slightly calcareous and phosphatic ................................. 0.2

Phosphorite, yellowish-brown, hard, calcareous, with abundant phosphatic pellets; 24.74 percent

$P_2O_5$ in channel sample .................................................. 1.5

Limestone, dark-gray, hard, siliceous, phosphatic near top .................................. 0.4

Phosphorite, yellowish- to dark-brown, hard, calcareous, with abundant phosphatic pellets;
contains teeth of fish .................................................. 0.3

Limestone, light-gray, hard, fine-textured ..................................... 0.1

Limestone, yellowish- to dark-brown, hard, siliceous, argillaceous in some beds, slightly phosphatic,
in plane regular beds 2-8 cm thick ..................................... 1.1

Shale, dark-gray, hard, calcareous, thin-bedded, slightly phosphatic in the upper part ........... 0.6

Phosphorite, yellowish- to dark-brown, hard, very calcareous; contains abundant pellets and cylindrical particles of apatite and fish remains .................................................. 0.2

Shale, dark-gray, hard, calcareous, slightly phosphatic .................................. 0.6
Phosphorite, yellowish- to dark-brown, hard, calcareous, abundant phosphatic pellets, fish remains and foraminifers; contains lens of dark-gray, siliceous, phosphatic limestone up to 10 cm thick

Meters

0.2

Shale, dark-gray, calcareous, with thin phosphatic bands

0.3

Chert, black, dense, calcareous

0.7

Shale, dark-gray, calcareous, finely banded; scattered concretions near the top

1.0

Total thickness of Galembo Member

4.25

Pujamana Member

Covered

12.9

Shale, dark-gray, calcareous, slightly phosphatic, with small calcareous concretions near the top

5.8

Covered

14.3

Shale (poorly exposed), yellowish-brown

8.5

Shale (poorly exposed), yellowish- to dark-gray, calcareous, laminated

4.0

Shale, dark-gray, calcareous, thin- to medium-bedded; contains concretions with asphalt impregnation; 10-cm bed of black chert near the top

17.8
Shale, dark-gray, calcareous, with scattered concretions; black chert beds near the base ... 6.8

Shale, dark-gray, hard, calcareous, with few lenticular beds of limestone and small calcareous concretions .................................. 19.4

Covered ................................................................................. 3.2

Chert, black, lenticular-bedded, with thin inter-beds of dark-gray, hard, calcareous shale ... 1.5

Limestone, dark-gray, hard, and calcareous shale in regular plane beds .. .......................... 6.5

Covered ................................................................................. 3.2

Shale, dark-gray, hard, calcareous, with calcareous concretions ............................................... 13.0

Limestone, dark-gray, hard, fine-textured, lenticular ................................................................. 0.4

Limestone, dark-gray, argillaceous, with black chert beds at the base and ellipsoidal to spherical calcareous concretions near the top where the beds change along strike to purer limestone ... 1.6

Shale, dark-gray, finely laminated, with lenticular beds of gray, fine-textured, concretionary limestone ................................................................. 2.4
<table>
<thead>
<tr>
<th>Material Description</th>
<th>Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, gray to light-gray, fine-textured, slightly argillaceous</td>
<td>0.7</td>
</tr>
<tr>
<td>Shale, dark-gray to black, calcareous, in thin beds; calcareous concretions vary from 10 cm to 2 m</td>
<td>2.5</td>
</tr>
<tr>
<td>Covered</td>
<td>31.3</td>
</tr>
<tr>
<td><strong>Total thickness of the Pujamana Member</strong></td>
<td>155.8</td>
</tr>
</tbody>
</table>

**Salada Member:**

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, dark-gray, hard, argillaceous; contains spherical concretions and few beds of black chert</td>
<td>11.5</td>
</tr>
<tr>
<td>Claystone, light-gray, soft</td>
<td>0.1</td>
</tr>
<tr>
<td>Limestone, dark-gray, argillaceous to silty, with calcareous concretions; beds of black chert near the top and bottom, and large calcareous concretions at the top</td>
<td>4.0</td>
</tr>
<tr>
<td>Claystone, light-gray, soft</td>
<td>0.6</td>
</tr>
<tr>
<td>Limestone, dark-gray, hard, argillaceous, with few thin layers of soft, light-gray claystone from 3-8 cm thick; several beds of black chert and a middle zone with ellipsoidal calcareous concretions</td>
<td>4.1</td>
</tr>
</tbody>
</table>
Limestone, dark-gray, hard, argillaceous,
scattered concretions, in regular plane beds
5-20 cm thick ........................................... 13.3
Limestone, dark-gray, hard, fine crystalline;
contains veinlets of calcite and small impreg-
nations of asphalt ...................................... 0.4
Limestone, dark-gray, hard, argillaceous,
scattered concretions, calcite veinlets, frag-
ments of fossil shells .................................... 2.2
Limestone, dark-gray, hard, fine-crystalline,
calcite veinlets ........................................... 0.5
Limestone, dark- and light-gray banded, argillaceous,
thin-bedded, calcareous concretions ................... 0.6
Limestone, gray, hard, lenticular, calcareous con-
cretions with ammonites near the top .................. 0.4
Limestone, dark-gray, hard, argillaceous, thin-
bedded, small to large calcareous concretions
near the top, very few thin beds of black chert .... 6.8
Limestone, dark-gray to black, hard, argillaceous,
thin-bedded, small pyrite concretions and fractures
filled with asphalt ........................................ 3.0
Limestone, dark-gray to black, hard, argillaceous, thin-bedded, small pyrite concretions and lenses of gray, more crystalline limestone from 3-6 m long ........................................ 7.2

Limestone, dark-gray to black, hard, argillaceous, thin-bedded, abundant spherical calcareous concretions with ammonites as the nucleus in some specimens .................................................. 2.0

Limestone, dark-gray, hard, argillaceous, fine-textured, thin-bedded, interbeds of dark-gray shale ................................................................. 4.5

Total thickness of Salada Member ........................................ 61.2

Simiti Formation (upper beds only):

Shale (partly covered), dark-gray, medium-hard, laminated .................................................. 16.3

Covered ........................................................................ 9.0

Siltstone, black, hard, thin-bedded, argillaceous in upper beds .................................................. 3.6

Shale, black, soft, laminated .................................................. 3.4

Sandstone, gray, hard, fine-grained, calcareous .................................................. 0.8

Shale, black, soft, laminated .................................................. 0.4

Sandstone, gray, hard, fine-grained, calcareous;
irregular bands of light- and dark-gray .................................................. 2.8
The unique lithology and extent of the La Luna Formation make it exceptionally useful in mapping field geology in the Cordillera Oriental. The lithologies involve varying mixtures of clay, carbonate and chert which result in siliceous to calcareous shales, argillaceous to cherty limestones, and porcellanite to pure chert as illustrated by one face of the quartz-clay-carbonate-chert tetrahedron of rock classification (Krumbein and Sloss, 1963, p. 154). The Salada and Galembo Members are characteristically composed of hard beds 5-20 centimeters thick with very regular and uniform bedding planes, properties that are not characteristic of any other part of the sedimentary rock section. These beds have been highly fractured by the regional deformity so that they slump into a rubble of angular blocks and fragments that provides a good material for surfacing local roads. The beds of the Salada and Galembo Members are resistant enough that the La Luna crops out as a sharp ridge. However, because of the limited thickness of individual beds and fractured condition due to regional deformity, they have limited competence and tend to slump and contort more in the manner of thin-bedded rocks. Where folding has occurred, the softer beds of the middle Pujamana Member are contorted even more. Much of the slumping and contortion that is common in the La Luna ridge has apparently resulted from removal by erosion of the adjacent less resistant shales of the Simiti and Umir Formations.
Freshly broken surfaces of the Galembo limestone and shale have a strong odor of gas, and asphalt occurs in fractures in some places. Lens-shaped bodies of asphaltite are mined locally, one of which is located in Quebrada La Sorda in the Galembo Member. This body has apparently developed along a fracture that cuts obliquely across the bedding without involving appreciable movement. The lens has been mined by short underground tunnels extending along its strike from the northeast and southwest sides of the quebrada for distances of 50-60 meters. The lens is about eight meters wide at its known maximum, but its vertical dimensions are not known. Gas odor is very strong in the mine tunnels.

Phosphatic beds in the Galembo Member are persistent over a wide area of northeastern Colombia and western Venezuela, and their economic potential is being investigated. The phosphatic zone in the lower part of the Galembo Member at Quebrada La Sorda can be traced at least 20 kilometers along strike both to the north and south, and it probably extends even farther.
Eastward from the type area of the La Luna members in the Magdalena Valley, the formation is probably thinner, but the beds are commonly too contorted to measure sections accurately. The formation is included in the down-faulted blocks of Cretaceous rocks in the northeast part of quadrangle H-12 and the northwest part of H-13, and a small area of outcrop about three kilometers southeast of Guaca (H-13, b-7 SW) represents the youngest Cretaceous rock remaining in that area. In the eastern half of H-13, the La Luna is included in down-faulted blocks in several places. The formation in this part of the report area and in the western part of Táchira in Venezuela has a two-member character (Trump and Salvador, 1964, p. 6). The lower part, unnamed, consists of gray to black calcareous shales interbedded with gray cryptocrystalline limestone and calcareous chert, with dark gray to black limestone concretions up to one meter in diameter. The upper part is bedded black chert in uniform layers 5-20 centimeters thick. Siliceous limestone and phosphatic beds are also present. The lower portion is similar in lithology to the Salada Member and the upper part to the Galembo Member of the middle Magdalena Valley. In western Venezuela the upper member is named the Táchira Chert (Trump and Salvador, 1964, p. 6).
Based on ammonites, pelecypods and foraminifers, the La Luna ranges from the early Turonian in the Salada Member to late Turonian and possibly early Coniacian in the Pujamana Member, and to Late Turonian, Coniacian, and possibly Santonian in the Galembo (Morales et al, 1958, p. 653, 654). A time transgression is indicated in the Pujamana-Galembo boundary. In the eastern part of the area, the La Luna ranges from late Turonian to late Coniacian (Trump and Salvador, 1964, fig. 2).

Umir Formation

According to Taborda (1965, p. 10), the name Umir was probably first used by L. G. Huntley in 1917 for shale exposed on the west side of Cerro del Umir near the southwest side of the report area (H-12, a-7). He included what is now known as the Lisama Formation of Paleocene age (Morales et al, 1958, p. 655). In 1925, T. A. Link redefined the formation, confining it to the Cretaceous part of the section. A definite type section has not been designated.

The lower part of the formation contains dark bluish-gray to black shales with carbonaceous and micaceous laminations. The upper part is composed of soft, dark-gray to greenish-gray shale with a few interbeds of hard, fine-grained sandstone and thin seams of coal. Thin layers, lenses, and small concretions of brown clay ironstone are present in varying amounts throughout the formation. In oil wells drilled in the Magdalena Valley (quadrangle H-11), the Umir is gray, soft, thinly laminated, carbonaceous shale (Taborda, 1965, p. 10). Coal beds are up to three meters thick in some places, and bands and nodules of siderite are common.
The Umir is unconformable over the La Luna Formation which was eroded to varying degrees before deposition of the Umir sediments. In the western half of quadrangle H-12, conglomeratic basal beds of the Umir up to five meters thick contain a few coarse sand grains and small quartz pebbles, glauconite, and varying amounts of phosphatic pebbles and nodules derived from phosphatic beds of the La Luna Formation.

In the Suratá area (H-13, a-2), the basal Umir is a zone of hard, massive beds up to 20 meters thick that grade gradually from dark-gray phosphatic limestone at the base to brown limonitic sandstones more typical of the Umir at the top.

The Umir grades conformably into the overlying Lisama Formation in the report area. To the west, however, in some wells drilled in the Magdalena Valley, Taborda (1965, p. 10) states that the Lisama has been completely eroded and the Umir is unconformably overlain by younger Tertiary beds.

Because it is predominantly soft, incompetent shale, the Umir tends to form broad valleys. Consequently, continuous exposures showing true dips have not been found where the full section can be measured and described. The best exposures were found in the upper part of the Umir in road cuts along the new highway from Bucaramanga to Barrancabermeja in planchita 120-I-B, E-2 NE. These beds are described in the measured section of the overlying Lisama Formation.
Although the Umir appears to form a regular and uniform outcrop area in the western part of quadrangle H-12, structural deformations make the formation appear much thicker than it actually is. This is well-illustrated north of where Río Sogamoso crosses the Umir (H-12, b-5, b-4). Immediately north of the river, the dips at the boundaries with the underlying and overlying formations are much steeper than those near the middle of the outcrop belt, and farther to the north, remnants of the Lisama overlie the Umir east of the main outcrop belt of the Lisama.

On the basis of well-established foraminiferal zones and supported by ammonites, the Umir is assigned an age of Campanian-Maastrichtian and possibly Danian (Morales et al, 1958, p. 656 and fig. 5). The faunal evidence indicates a mid-neritic origin for the Campanian and lowermost Maastrichtian parts of the Umir and an upper neritic to continental origin for the beds above.

The Umir Formation correlates faunally, lithologically, and chronologically with the Colón and Mito Juan Formations in the Maracaibo Basin of Colombia and western Venezuela (fig. 9). It correlates also with the Upper and Lower Guadalupe Formations as defined by Inventario geologists and the lower part of the Guaduas Formation farther to the south in the Cordillera Oriental (D. H. McLaughlin, personal commun.).
Cretaceous system, Maracaibo section of Colombia

Uribante Group

In this report, the Uribante Formation as used by Notestein et al (1944) has been raised to group status and the Tibú, Mercedes, and Aguardiente Members to formation status. Trump and Salvador (1964, p. 3) have noted that the Uribante Formation named by Sievers (1888) for the Río Uribante in the state of Táchira, Venezuela, was poorly defined originally and has since been used in a rather inconsistent manner. As a formation, the Uribante contains such a variety of lithologies that reference to it has to be in terms of the three subdivisions. These express the different lithologies quite well and are still sufficiently thick and widespread to be referred to as formations.

In field mapping in the eastern part of quadrangle H-13, it has been found necessary to map the usually poorly exposed Tibú and Mercedes together as one unit and the Aguardiente as another to give a two-fold division of the Uribante Group on the geologic map of quadrangle H-13.
Tibu and Mercedes Formations (Kjtr).--These formations were named for the Río Tibu and the Mercedes Valley in the Barco Concession area of quadrangle F-13 (Notestein et al., 1944, p. 1177). There the Tibu has basal, coarse-grained, pebbly sandstone 5-12 meters thick overlying igneous and metamorphic rocks. Above the sandstone is gray, dense, fossiliferous limestone with a few interbeds of shale and fine-grained sandstone in the lower half. Above the limestone there is a sharp but conformable boundary with dark-gray shales at the base of the Mercedes Formation. The Mercedes consists of interbedded limestone, shale and sandstone. The shale is dark-gray to black, micaceous, and carbonaceous, and is most abundant in the lower third of the formation. Sandstones are gray, fine- to medium-grained, commonly glauconitic, and some are very calcareous. They are most numerous in the upper half. The limestones are similar to those of the Tibu, and some are sandy. Limestone and shale are predominant at the top of the Mercedes.

A partially exposed section of the Tibu and Mercedes Formations southwest of Pamplona in quadrangle H-13 is given below. The basal sandstone section of the Tibu is not well-exposed, but apparently it is much thicker than in the area of the type section 130 kilometers to the north. The actual contact with the underlying granite is not exposed in this section, but in exposures elsewhere in this area it is very sharp, with only slightly conglomeratic sandstone making a depositional contact. Above the limestone section of the Tibu, the basal part of the Mercedes contains sandstone, limestone and shale, but most of the Mercedes is shale with a few interbeds of sandstone.
Stratigraphic section of the Tibu and Mercedes Formations in Quebrada El Volcan (planchita 110 II-C, D-6 S\textsuperscript{3}), Municipality of Pamplona, Department of North Santander.

(Measured and described by F. Montero, October, 1968)

Aguardiente Formation (lower beds only):

- Sandstone, yellowish-white, hard, feldspathic, micaeous, with few interbeds of dark-gray shale
  - 10-30 cm thick ........................................ 60.0

Mercedes Formation:

- Shale, black and dark-gray, brittle, calcareous in some beds, with few interbeds of fine-grained, argillaceous, micaeous, yellowish- to brownish-gray sandstone of low hardness ........... 30.5
- Shale, black and dark-gray, brittle, micaeous, with few interbeds of fine-grained, argillaceous, micaeous, yellowish- and grayish-brown, fairly soft, sandstone in beds 40-80 cm thick .............. 19.8

Covered .................................................. 58.0

- Shale, black and dark-gray, brittle, micaeous ........... 16.1

Covered .................................................. 12.7

- Sandstone, yellowish- and brownish-gray, fine-grained, argillaceous, micaeous, in beds 2.0-3.5 m thick, with thin interbeds of brittle, micaeous, black and dark-gray shale ........... 12.3
Meters

Shale, dark-gray, brittle to fissile, micaceous,
with few interbeds of fine-grained, argillaceous,
yellowish-gray sandstone 25-60 cm thick,
N. 5° W., 68° SW. 39.0
Covered 56.0

Shale, black and brownish-gray, brittle, micaceous,
with few interbeds of fine-grained, argillaceous,
yellowish-gray sandstone 31.0

Sandstone, brownish-gray, fine-grained, argillaceous,
slightly micaceous, fairly soft 6.0

Limestone, dark-gray to black, hard, crystalline,
fossiliferous, with veinlets of calcite; thin inter-
beds of dark-gray shale and of argillaceous gray
sandstone 15-30 cm thick, N. 14° W., 53° NE. 9.7

Sandstone, brownish-gray, hard, fine-grained,
argillaceous, micaceous, with thin interbeds of
micaceous black shale 12.6

Limestone, dark-gray to black, very fine crystalline,
slightly argillaceous, with 20-cm bed of black
shale in the middle 7.8

Shale, gray, laminar, micaceous 8.7
Meters

Sandstone, yellowish- and brownish-gray, hard, fine-grained, argillaceous, in beds 0.9-2.2 m thick,
N. 14° W., vertical .......................... 19.5

Total thickness of Mercedes Formation 339.7

Tibú Formation:

Limestone, dark-gray, hard, fine-crystalline, fossiliferous, N. 14° W., vertical .................. 24.0
Sandstone, light-yellowish-gray, hard, fine-grained, argillaceous, micaceous, slightly calcareous ... 1.7
Limestone, dark-gray, hard, fine-crystalline, fossiliferous, N. 14° W., vertical .................. 50.6
Covered ........................................ 28.7
Sandstone, light-yellowish-brown, hard, fine-grained, argillaceous, micaceous, N. 10° W., vertical ... 9.4
Covered ........................................ 66.7
Sandstone, light-yellowish-white, very hard, fine- to medium-grained, micaceous, in beds 1-3 m thick,
N. 10° W., vertical .............................. 26.0
Covered ........................................ 15.0

Total thickness of Tibú Formation 222.1

Covered ........................................ 30.07

Granite, white, medium- to coarse-grained, weathered ...........................................
The Tibú and Mercedes rarely produce a prominent outcrop. The contact between them, and the contact of the Tibú with underlying metamorphic and igneous rocks, are obscured by colluvium and are seldom definable on aerial photographs. In contrast, the boundary between the Mercedes shales and the massive sandstone section of the Aguardiente is usually well-defined. As a result of these circumstances, it has not been found possible or practical to map the Tibú and Mercedes as separate units. They are mapped as one unit between the underlying pre-Cretaceous rocks and the overlying Aguardiente.

In the measured section, the 222 meters thickness of the Tibú Formation compares with 107-166 meters in the type locality, and the 340 meters of the Mercedes compares with 149-201 meters in the type locality (Notestein et al., 1944, p. 1177). The larger figures in the Pamplona area are more typical for these formations farther to the south in quadrangle H-13.
The thin basal sandstone section of the Tibú Formation is equivalent to the Río Negro Formation of western Venezuela where it is much thicker and where fossils ranging in age from Hauterivian to Aptian have been collected from thin sandy limestones in the state of Táchira (Trump and Salvador, 1964, p. 5). With regard to its position at the base of the Cretaceous section, as well as lithologically, it is correlative with the Tambor Formation of the Magdalena Valley section, although it may be somewhat younger than the Tambor (fig. 9). In similar manner, the limestone section of the Tibú may be correlated with the Rosa Blanca and the Mercedes with the Paja and Tablazo formations in terms of lithology and stratigraphic sequence if not in age. Except for the basal sandstone, the Tibú and Mercedes correspond to the Apón Formation of western Venezuela where the distinction between the two units disappears toward the northeast (Trump and Salvador, 1964, p. 4).

Unpublished reports of early studies of molluscs and echinoids from the Tibú Formation south of Sardinata (quadrangle G-13) indicate a late Aptian to early Albian age (Notestein et al, 1944, p. 1178). In western Venezuela, more extensive faunal studies of the Apón Formation, including ammonites, indicate a late Aptian to middle Albian age according to Sutton (1946, p. 1643) or Aptian to early Albian according to Trump and Salvador (1964, p. 5). The Tibú and Mercedes may be assigned a similar age range except for the basal sandstone of the Tibú which probably extends the range of that formation into the Barremian.
Oil is produced from the Tibú and Mercedes Formations in the Tibú and Socuavó fields of the Barco Concession in places where fracturing provides permeability (Notestein et al, 1944, p. 1177).

Aguardiente Formation (Kia).--This formation is named for Filo del Aguardiente (Aguardiente Ridge) in the north central part of quadrangle G-13 (Notestein et al, 1944, p. 1177). There is consists of more than 200 meters of extremely hard and calcareous, gray or light-green, coarse-grained, cross-bedded glauconitic sandstone. Black, micaceous, carbonaceous shale is present in thin beds and laminae, and there are a few thin limestone beds in the lower part. It is considered conformable with both the underlying Mercedes and the overlying Capacho Formations in Colombia, but a disconformity is postulated with the underlying Apón Formation in Venezuela (Sutton, 1946, p. 1646).

A section of the Aguardiente exposed along the Bucaramanga-Cúcuta highway immediately east of Pamplona is described below. The formation is well-exposed, but dips to the west indicate that the beds are locally overturned. This section is much thicker (440 m) than that of the type locality (200 m) 75 kilometers to the north, the sandstones are not calcareous or glauconitic, and no limestone beds are present. The character and thickness of the Aguardiente in the Pamplona area continues southward in quadrangle H-13. A section measured in Quebrada Lisgurá south of San Andrés (planchita 121-III-D, H-3, H-4) is 388 meters thick, has no limestone beds, and contains glauconite only near the base.
Stratigraphic section of the Aguadiente Formation
along the highway east of Pamplona (planchita 110 II-C, C-9 and C-10), Municipality of Pamplona, Department of North Santander.
(Measured and described by F. Montero, October, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacho Formation (lower beds only):</td>
</tr>
<tr>
<td>Shale, black, brittle to fissile, micaceous, with</td>
</tr>
<tr>
<td>interbeds of fine-grained, micaceous, glauconitic,</td>
</tr>
<tr>
<td>brownish- to yellowish-gray sandstone that is</td>
</tr>
<tr>
<td>partly conglomeratic with pebbles of quartz; two</td>
</tr>
<tr>
<td>15-cm beds of hard conglomerate .................. 6.0</td>
</tr>
<tr>
<td>Aguadiente Formation:</td>
</tr>
<tr>
<td>Sandstone, yellowish-white to light-yellowish-gray,</td>
</tr>
<tr>
<td>hard, fine- to medium-grained, feldspathic, micaceous, glauconitic, in beds 1.2-2.6 m thick, N. 21° E., 48° NW. ................... 22.0</td>
</tr>
<tr>
<td>Sandstone, light-yellowish-gray, hard, medium-grained</td>
</tr>
<tr>
<td>to coarse-grained at the base, conglomeratic, micaceous, with lenses of carbonaceous, micaceous,</td>
</tr>
<tr>
<td>brittle black shale up to 70 cm thick that are more</td>
</tr>
<tr>
<td>numerous at the top, N. 27° E., 53° NW. ........... 150.0</td>
</tr>
<tr>
<td>Sandstone, light-yellowish-gray, hard, medium-grained,</td>
</tr>
<tr>
<td>conglomeratic, micaceous, with numerous lenses of</td>
</tr>
<tr>
<td>carbonaceous, micaceous, brittle black shale,</td>
</tr>
<tr>
<td>N. 26° E., 51° NW. .......................... 180.0</td>
</tr>
<tr>
<td>Shale, black, brittle to fissile, micaceous,</td>
</tr>
<tr>
<td>N. 26° E., 37° NW. .......................... 8.5</td>
</tr>
</tbody>
</table>
Sandstone, yellowish-white to yellowish-gray, hard, micaceous, feldspathic, with numerous interbeds of black shale 0.3-1.6 m thick, N. 15° E., 76° NW. .............................. 20.0

Sandstone, yellowish-white to yellowish-gray, hard, micaceous, feldspathic, with few interbeds of black shale 10-30 cm thick .............................. 60.0

Total thickness of Aguardiente Formation 440.5

Mercedes Formation (upper beds only):

Shale, black and dark-gray, brittle to fissile, calcareous in part, with interbeds of fine-grained, micaceous, argillaceous, yellowish- and brownish-gray, fairly soft, sandstone .......................... 30.5
The thick and resistant nature of the massive sandstone beds of the Aguardiente Formation makes it an easily distinguishable map unit both in the field and on aerial photographs. Structural complexities do not usually obliterate this character as is often the case with the thinner or less competent units.

Fossil molluscs, *Exogyra aff. boussingaulti*, have been reported from the Aguardiente near Gramalote in quadrangle G-13 (Notestein et al., 1944, p. 1178). In the more calcareous phase of the formation, the foraminifer *Orbitolina lenticularis* (equivalent of *O. concava texana*) is characteristic of the Aguardiente of northern Táchira (Trump and Salvador, 1964, p. 5), and on this basis the formation is assigned to the early and middle Albian when it was deposited under very shallow marine conditions.

The Aguardiente is recognized also in western Venezuela where it is the middle member of the Cogollo Group (Sutton, 1946, p. 1630). Westward from the Colombian-Venezuelan border area, sandstone of the Aguardiente very gradually phases into shales, and in the Middle Magdalena Valley the lower part of the Simití is the lateral equivalent of the Aguardiente.

Capacho Formation

The name for this formation dates back to 1888 when Wilhelm Sievers first used it for limestone exposures near the village of Capacho Viejo in western Táchira, Venezuela. The village has since been re-named Libertad. The Capacho is the upper formation of the Cogollo Group in Venezuela which includes the Apon at the base and the Aguardiente in the middle (Sutton, 1946, p. 1630). A fourth formation is now recognized in western Venezuela, the Maraca, between the Aguardiente and the Capacho (Trump and Salvador, 1964, p. 5). It is only a few meters thick in some places and has not been found in the area of this report.

In their report on the Barco Concession of northeastern Colombia, Notestein et al (1944) apparently thought that their Cogollo Formation was the equivalent of the undivided Cogollo in the type locality. It has since been established that the Cogollo Formation of the Barco Concession is equivalent to only the Capacho Formation of the type locality of the Cogollo Group (Trump and Salvador, 1964, p. 4).

In the area of the Barco Concession, two divisions and sometimes three are recognizable in the Capacho according to Notestein et al (1944, p. 1179):

Guayacán Member - Limestone, brownish-gray, abundantly fossiliferous, in massive beds with interbedded, non-calcareous, partly silty and micaceous, dark-gray to black shale.

Middle Member - shale, dark-gray to black, non-calcareous, with few beds of siltstone and argillaceous, fossiliferous gray limestone.
Lower Member - shale, black, thin-bedded, very calcareous, organic, bituminous, foraminiferal, and foraminiferal dark gray limestone.

The limestones of the Guayacán Member are not widespread, and the uppermost part of the Capacho is usually shale. Thickness of the formation ranges from 175-435 meters, increasing from north to south.

Along the highway and Río Pamplonita east of Pamplona, in quadrangle H-13, the Capacho Formation is well exposed, and a section measured there is described below. Beds in the lower part of the section are overturned, as are those of the underlying Aguardiente. A regional strike fault apparently passes through the Capacho in this area, so that the accuracy of the measured thickness of 475 meters is open to question. Limestone is most abundant near the middle of the section.

The base and top of the Capacho are conformable and usually well-defined with the underlying Aguardiente and overlying La Luna Formations, and the unit tends to form a belt of lower topography between the two more resistant formations.

Late Albian fossils have been found in the sandy limestone of the underlying Maraca Formation in western Venezuela, and rare ammonites in the Guayacán Member of the Capacho (Trump and Salvador, 1964, p. 5, 6). Based on this evidence, the age of the Capacho probably ranges from Cenomanian to late Turonian. According to these same authors (ibid., p. 4), the Capacho grades laterally northward into the lower part of the La Luna Formation in the foothills of the central part of the Serranía de Perijá.
Stratigraphic section of the Capacho Formation
along the highway east of Pamplona (planchita 110 II-C, C-10), Municipality of Pamplona, Department of North Santander.
(Measured and described by F. Montero, October, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
<th>Strata Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>178.0</td>
<td>La Luna Formation (lower beds only): Chert, black to gray, hard, brittle, calcareous, in plane uniform beds 4-20 cm thick, with numerous beds of micaceous, laminar black shale up to 2.6 m thick near the base</td>
</tr>
<tr>
<td>141.5</td>
<td>Capacho Formation: Shale, black and dark-gray, brittle to fissile, micaceous, with few interbeds of hard, crystalline, fossiliferous, bluish- to dark-gray limestone 1.1-1.4 m thick, N. 5° E., vertical</td>
</tr>
<tr>
<td>6.0</td>
<td>Limestone, bluish- and dark-gray, hard, crystalline, fossiliferous, in beds 10-80 cm thick, with thin interbeds of brittle to fissile, black and dark-gray shale, N. 7° E., vertical</td>
</tr>
<tr>
<td>26.0</td>
<td>Shale, black and dark-gray, brittle to fissile, micaceous</td>
</tr>
<tr>
<td>4.0</td>
<td>Limestone, bluish- and dark-gray, hard, crystalline, fossiliferous, with thin interbeds of black shale</td>
</tr>
<tr>
<td>30.0</td>
<td>Shale, black and dark-gray, brittle and fissile, micaceous</td>
</tr>
</tbody>
</table>
Limestone, bluish- and dark-gray, hard, crystalline, fossiliferous, in beds 10-60 cm thick, with thin interbeds of brittle to fissile, dark-gray to black shale

<table>
<thead>
<tr>
<th>Shale, black and dark-gray, brittle to fissile, micaceous</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.2</td>
</tr>
</tbody>
</table>

Limestone, bluish- and dark-gray, hard, crystalline, fossiliferous, in beds 10-60 cm thick, with thin interbeds of brittle to fissile, black and dark-gray shale, N. 10° E., 45° NW.

<table>
<thead>
<tr>
<th>Shale, black, brittle to fissile, micaceous, with scattered interbeds of hard, crystalline, fossiliferous, bluish- to dark-gray limestone in beds 10-30 cm thick</th>
</tr>
</thead>
<tbody>
<tr>
<td>38.0</td>
</tr>
</tbody>
</table>

Limestone, bluish-gray, very hard, massive, nodular at the base, highly fossiliferous, with veinlets of calcite perpendicular to the bedding, N. 9° E., 54° NW.

<table>
<thead>
<tr>
<th>Sandstone, yellowish-gray, friable, very fine grained, argillaceous</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
</tr>
</tbody>
</table>

Shale, black, brittle to fissile, micaceous, N. 10° E., 36° NW.
Sandstone, brownish-gray, hard, fine- to medium-grained, argillaceous, micaceous, with carbon fragments and grains of pyrite ........................................ 4.0

Shale, black, brittle to fissile, micaceous, with interbeds of fine-grained, highly glauconitic, micaceous, brownish- to yellowish-gray sandstone, partly conglomeratic with pebbles of quartz; two 15-cm beds of hard conglomerate .................................. 6.0

Total thickness of Capacho Formation ................................ 474.8

Aguardiente Formation (upper beds only):

Sandstone, yellowish-white to light-yellowish-gray, hard, fine- to medium-grained, feldspathic, micaceous, glauconitic, in beds 1.2-2.6 m thick, N. 21° E., 48° NW. .................................................. 22.0
The Capacho correlates with the upper part of the Simití Formation of the middle Magdalena Valley section and is similar to the Simití in the predominance of dark gray shales.

Oil is produced from all three members of the Capacho on the Petrolea anticline of the Barco Concession and is controlled by fracturing (Notestein et al., 1944, p. 1181 and fig. 5). The beds contain much organic material, and the oil could well have originated within the formation.

La Luna Formation

The formation is named for Quebrada La Luna in the eastern foothills of Serranía de Perijá, about 16 kilometers northwest of La Villa del Rosario, Zulia, Venezuela (Notestein et al., 1944, p. 1182). There the formation contains hard, dark-gray to black, carbonaceous and bituminous limestone in plane, uniform beds up to 20 centimeters thick with interbedded black calcareous shale (Sutton, 1946, p. 1648). Hard, fine-grained, dark-gray calcareous sandstone and seams and nodules of chert are present in subordinate amounts. Discoidal concretions of hard, black limestone from a few centimeters to more than one meter in diameter are characteristic of the formation. Megafossils, including ammonites, are common in these concretions. Fresh surfaces of the limestone generally have a gassy odor.
Southward from the type locality, and in the eastern part of the present report area, the La Luna assumes a two-member character with chert or porcelanite as the main constituent of the upper part and limestone and calcareous shale with concretions in the lower part. A well-exposed section that clearly shows these members was measured north of the report area near Lourdes in quadrangle G-13 by J. Abozaglo (see below). The main phosphorite beds are near the middle of the upper member which is 63 meters thick. The lower member is 37 meters thick. The term porcelanite is an oversimplified description of the beds which contain also true chert and siliceous shale.

Another section of the La Luna exposed along the highway southeast of Pamplona in quadrangle H-13 follows. This section contains black chert with interbedded black shale near the base and top, but no section of limestone and calcareous shale with concretions is present. Thin beds of phosphatic black sandstone are present near the base of the formation.
Stratigraphic section of the La Luna Formation

in Quebrada El Portigo (planchita 87 III-B, H-2 NW).

Municipality of Lourdes, Department of North Santander.
(Measured and described by J. Abozaglo, 1968)

Colón Formation (lower beds only):

Sandstone, gray, thick-bedded, hard, fine-grained, calcareous; at the base are abundant phosphatic black grains and nodules up to 25 mm in diameter and a few grains of glauconite; weathered surface contains small cavities

Phosphorite, dark-brown, hard, granular, calcareous, in uniform bed with abundant phosphatic black grains and nodules up to 15 mm in diameter; weathers with rough, earthy texture

Shale, gray to dark-brown, soft, finely laminated, calcareous, with few phosphatic grains; basal sandy calcareous phosphorite in irregular bed up to 4 cm thick contains lenses of fine-crystalline gray limestone up to 8 cm thick

La Luna Formation (strike N. 10° E., dip 26° NW.):

Porcelanite Member:

Porcelanite, dark-gray, hard, calcareous, in beds 5-8 cm thick, with veinlets of calcite

Meters

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone</td>
<td>0.20</td>
</tr>
<tr>
<td>Phosphorite</td>
<td>3.00</td>
</tr>
<tr>
<td>Shale</td>
<td>0.35</td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Porcelanite</td>
<td>3.00</td>
</tr>
</tbody>
</table>
Limestone, gray, hard, fine-crystalline, lenticular ............. 0.35 Meters

Porcelanite, dark-gray, hard, calcareous, in beds 5-8 cm thick with interbeds of yellowish-brown claystone up to 3 cm thick; 5-cm bed of hard, dark-gray limestone at the base contains phosphatic grains and fish scales ........ 1.30

Shale, dark-gray, hard, calcareous, with phosphatic grains near the base and top ............. 0.15

Limestone, gray, hard, argillaceous, with scattered black phosphatic grains and nodules up to 2 mm in diameter, and weathered yellowish-brown claystone at the base ............. 0.25

Porcelanite, dark-gray, hard, calcareous, with veinlets of calcite, in irregular to lenticular thin beds; hard, lenticular, dark-gray, limestone near the middle, up to 30 cm thick, contains scattered foraminifers ............. 7.00

Limestone, gray, hard, fine-crystalline, lenticular grades laterally to porcelanite containing poorly preserved foraminifers ............. 0.50
Porcelainite, dark-gray, hard, calcareous, in irregular beds 7-10 cm thick with calcite veinlets and poorly preserved foraminifers ... 2.30

Limestone, gray, hard, fine-crystalline, grading laterally to dark-gray porcelainite with poorly preserved foraminifers ... 0.30

Porcelainite, dark-gray, hard, calcareous, in irregular to lenticular beds with section of hard, lenticular dark-gray limestone above the middle ... 0.85

Limestone, gray, hard, fine-crystalline, lenticular ... 0.55

Porcelainite, dark-gray, hard, calcareous, in irregular thin beds ... 2.00

Limestone, gray, hard, fine-crystalline, lenticular ... 0.20

Porcelainite, dark-gray, hard, calcareous, in irregular thin to thick beds ... 0.30

Limestone, gray, hard, fine-crystalline, lenticular ... 0.20

Porcelainite, dark-gray, hard, calcareous, in irregular thin beds that change laterally to dark-gray limestone; contains detrital quartz grains and abundant siliceous-calcareous black lenses distributed at random ... 2.60
Limestone, gray, hard, fine-crystalline, in thin beds containing grains of quartz and apatite; soft, dark-brownish-gray calcareous shale at the base contains abundant phosphatic grains ... 0.25

Phosphorite, dark-brown to black, hard, granular, calcareous, in a uniform bed with black phosphatic grains; 19.08 percent P$_2$O$_5$ in channel sample ... 0.45

Limestone, gray, hard, fine-crystalline, with phosphatic black grains and small nodules; 1.78 percent P$_2$O$_5$ in channel sample .... 0.20

Phosphorite, dark-brown to black, hard, granular, calcareous, in a uniform thick bed with smooth, ovoid, phosphatic black grains; siliceous-calcareous lenses near the base are up to 6 cm thick and contain phosphatic grains; weathers dark-brown with rough earthy texture, N.-S., 35° W.; 19.23 percent P$_2$O$_5$ in channel sample .... 1.70

Porcellanite, dark-gray, hard, calcareous, in irregular thin beds with siliceous-calcareous black lenses and lenticular beds of fine-crystalline gray limestone up to 50 cm thick above the base and near the top ... 1.30
Limestone, gray, hard, fine-crystalline, with
veinlets of calcite and phosphatic grains;
siliceous-calcareous black lenses up to 10 cm
thick near the middle; 10.27 percent \(P_2O_5\) in
channel sample ......................... 0.50

Porcelanite, dark-gray, hard, calcareous, in irregular
thin beds with phosphatic grains near the top ... 0.35

Limestone, gray, hard, medium-crystalline, with
calcite veinlets, in irregular thin beds with
few phosphatic grains near the top; gray,
calcareous concretions near the base are up to
30 cm in diameter ..................... 0.55

Porcelanite, dark-gray, hard, calcareous, in
irregular thin beds ..................... 1.00

Limestone, gray, hard, fine-crystalline,
lenticular ............................. 0.40

Porcelanite, dark-gray, hard, calcareous, in irregular
thin beds ............................ 0.75

Limestone, gray, hard, fine-crystalline, lenticular,
siliceous near the top .................. 0.45

Porcelanite, dark-gray, hard, calcareous, in irregular
to lenticular thin beds .................. 2.60
Porcelanite, dark-gray, hard, calcareous, with
8-cm beds of dark-brown limestone at the top
and base containing abundant phosphatic grains
and bone fragments .................................. 1.00

Porcelanite, dark-gray, hard, calcareous, in
irregular to lenticular thin beds, with lenticular
beds of hard, fine-crystalline, gray limestone
20-40 cm thick at the middle and top .......... 2.80

Porcelanite, dark-gray, hard, calcareous, with inter-
beds 1-15 cm thick of soft, plastic, yellowish-
brown to light-greenish-gray claystone and one
20-cm bed of hard, fine-crystalline gray limestone
in the upper half .................................. 2.45

Limestone, gray to black, hard, fine-crystalline,
siliceous, in thin to thick beds with interbedded
soft, plastic, light-greenish-gray claystone up
to 40 cm thick and few beds of hard calcareous
dark-gray porcelanite ............................. 2.80

Porcelanite, dark-gray, hard, calcareous, in thin beds
with veinlets of calcite; calcareous concretions
near the middle are up to 35 cm in diameter; fine-
crystalline, lenticular, gray limestone up to 50 cm
thick near base .................................. 5.50
<table>
<thead>
<tr>
<th>Limestone, gray, hard, somewhat lenticular, with few phosphatic grains</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procelanite, dark-gray, hard, calcareous, in irregular to lenticular beds</td>
<td>2.00</td>
</tr>
<tr>
<td>Limestone, gray, hard, fine-crystalline, lenticular</td>
<td>0.45</td>
</tr>
<tr>
<td>Procelanite, dark-gray, hard, calcareous, in irregular to lenticular thin beds; calcareous concretions up to 25 cm in diameter in a zone 70 cm above the base</td>
<td>3.60</td>
</tr>
<tr>
<td>Porcelanite, dark-gray, hard, calcareous, with thin zones of soft, plastic, yellowish-brown claystone and gray, calcareous concretions up to 37 cm in diameter at the base and top</td>
<td>3.55</td>
</tr>
<tr>
<td>Porcelanite, dark-gray, hard, calcareous, in irregular beds with zones of gray calcareous concretions up to 25 cm in diameter near the top and up to 1.1 m in diameter near the base</td>
<td>4.00</td>
</tr>
<tr>
<td>Covered</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Total thickness of Porcelanite Member 62.70
Limestone Member:

Limestone, dark-gray, hard, in alternating thin and thick beds, with abundant scattered gray calcareous concretions up to 20 cm in diameter .......... 5.50

Limestone, gray, hard, fine-crystalline, in alternating, irregular to lenticular, thin and thick beds with laminar-bedded, dark-gray to light-brown calcareous shale; abundant scattered gray calcareous concretions up to 80 cm in diameter; 2-cm bed of weathered, soft, yellowish-brown claystone 8.1 m above the base .............. 19.60

Shale, dark-gray, hard, calcareous, in laminar beds with lenticular, fine-crystalline limestone up to 5 cm thick in the upper part and a zone of gray calcareous concretions up to 45 cm in diameter 60 cm above the base ....................... 1.80

Limestone, gray, hard, fine-crystalline, in single thick bed with soft, yellowish-gray weathered claystone at base ..................... 0.45
Meters

Shale, dark-gray, hard, calcareous, in laminae
beds with hard lenticular beds of fine-crystalline
gray limestone up to 50 cm thick near the base and
middle and gray calcareous concretions up to 30 cm
in diameter near the top ........................................ 2.60

Limestone, gray, hard, fine-crystalline, in irregular
to lenticular beds with abundant scattered gray
calcareous concretions up to 50 cm in diameter .......... 4.00

Covered ..................................................................... 1.30

Porcelanite, dark-gray, hard, calcareous, with inter-
beds of soft, yellowish-brown weathered claystone ..... 0.95

Limestone, gray, hard, fine-crystalline, in irregular
thin beds with interbeds of soft, yellowish-brown
weathered claystone .............................................. 0.75

Limestone, gray, hard, in irregular to lenticular
beds with scattered phosphatic grains and
nodules .................................................................... 0.45

Total thickness of Limestone Member 37.40

Total thickness of La Luna Formation 100.10

Capacho Formation (upper beds only):

Siltstone, dark-gray, soft, fissile, calcareous, with
small crystals of gypsum on bedding planes; 15-cm
bed of hard, argillaceous, gray limestone near the
middle contains few scattered phosphatic grains ........ 4.15
Limestone, gray, hard, fine- to coarse-textured,

in massive beds with abundant fossil pelecypods .. 3.50

Siltstone, dark-gray, soft, slightly calcareous .. 4.00
Stratigraphic section of the La Luna Formation along the Pamplona-Chitaga highway (planchita 110, D10 and D-11), Municipality of Pamplona, Department of North Santander.
(Measured and described by F. Montero, October, 1968)

Colón Formation (lower beds only):
Shale, dark-gray, brittle to fissile, with thin beds of yellowish-brown ironstone up to 10 cm thick; interbeds of hard, very fine grained, argillaceous, partly glauconitic, dark-gray sandstone in beds 0.9-1.5 m thick...........

...unconformity...

La Luna Formation:
Chert, black, dark-gray, and white, highly fractured and folded, with interbeds of black shale, N. 23° W., 26° NE. ................. 39.0
Covered ...
Chert, black, dark-gray and gray, hard, brittle, calcareous, in uniform plane beds from 4-20 cm thick; numerous interbeds of micaceous, siliceous, laminar black shale up to 2.6 m thick near the base, and a few beds 5-10 cm thick of black phosphatic sandstone, N. 26° W., 48° NE. ....... 178.0
Total thickness of La Luna Formation 243.0
Capacho Formation (upper beds only):

Shale, black and dark-gray, brittle to fissile, micaceous, with few interbeds of hard, crystalline, fossiliferous, bluish- to dark-gray limestone

1.1-1.4 m thick, N. 5° E., vertical  . . . . . . . 141.5
The La Luna shows large variations in thickness. From 300 meters at the type section, it thins southward to 43-56 meters in the Tibú area of the Barco Concession of quadrangle F-13 (Notestein et al., 1944, p. 1182). Southward from Tibú, it thickens to 100 meters near Lourdes in quadrangle G-13 and to 243 meters at Pamplona.

A study of the La Luna Formation by E. K. Maughan and others (written commun.) made in connection with the formation's phosphorite resources, has indicated probable erosional periods between the members and at the top of the formation which apparently account for the large variations in thickness. In places where the section is thickest, it forms a characteristically sharp topographic ridge between the less resistant, shaly Capacho and Colon and Mito Juan Formations. But where the La Luna Formation is thin, the ridge is seldom well defined.

Abundant fossils in the La Luna include numerous ammonites, pelecypods, pelagic foraminifers and fish remains. At the type locality, early and late Turonian and early Coniacian fossils have been identified (Sutton, 1946, p. 1650).
The lower, concretionary limestone-shale member correlates with the Salada and Pujamana Members of the La Luna in the middle Magdalena Valley, whereas the upper chert member correlates with the Calembo Member. In western Venezuela, the upper chert member is called the Táchira Chert (Trump and Salvador, 1964, p. 6), but the lower, concretionary limestone-shale section is unnamed.

Oil is produced from shallow wells that penetrate fractured beds of the La Luna near the crest of the Petrólea North Dome of the Barco Concession (Notestein et al, 1944, p. 1182). The bituminous nature and abundant organic remains in the La Luna are considered by Hedberg (1931) to indicate sources of petroleum.
Colon and Mito Juan Formations

Because of the similarities in lithology and weathering characteristics, the boundary between these formations cannot be mapped with certainty, and they have therefore been mapped as a single unit. The type section of the Colon is in the District of Ayacucho north of the town of Colon in western Táchira, Venezuela. There the formation consists almost entirely of dark-gray to black, hard, locally pyritic, conchoidal- to irregular-fracturing shale (Sutton, 1946, p. 1651). A few very thin beds of gray, hard, dense limestone are present in the upper part in some places.

Foraminifers are abundant. In the Barco Concession area of northeastern Colombia (quadrangle F-13), the formation consists of gray to dark-gray, slightly calcareous, fissile, moderately foraminiferal shale with thin nodules and lenses of brown clay-ironstone (Notestein et al., 1944, p. 1183). At the base, overlying the La Luna, is a zone of several meters of sandy glauconite, re-worked foraminifers, abundant fish remains and nodules and pellets of phosphorite.

The Mito Juan Formation is named for Quebrada Mito Juan on the east flank of the Petrolea North Dome in the Barco Concession, quadrangle F-13, where it consists of greenish-gray shales, with silty to sandy shales increasing upward to siltstone and very fine-grained sandstone near the top (Notestein et al., 1944, p. 1184). Thin lenses and small nodular masses of brown clay-ironstone are common. A few thin beds of glauconitic, sandy, fossiliferous, ferruginous limestone occur in the upper part of the formation.
The Catatumbo Formation, which overlies the Mito Juan Formation in the Rio Catatumbo area of the northern part of the Barco Concession (quadrangle F-13), is composed predominantly of dark-gray shales and claystones that are commonly somewhat carbonaceous and contain small nodules and thin lenses of brown clay-ironstone (Kotestein et al, 1944, p. 1186). Interbedded and interlaminated dark-gray, argillaceous, very fine- to fine-grained sandstones that are present in the type locality are less common farther south, and the formation cannot be mapped as a unit distinct from the Colón-Mito Juan section. In western Táchira, the Catatumbo is mappable only locally and is therefore regarded as a member of the Mito Juan Formation (Trump and Salvador, 1964, p. 7). In the area of this report, the Catatumbo is not a distinct unit between the underlying Mito Juan and the overlying Barco Formation and is therefore regarded as a member of the former (fig. 9).

Although structural discordance has not been reported between the Colón and La Luna Formations, a break in sedimentation occurred during all or part of the Santonian stage according to Sutton (1946, p. 1652) or an erosional interval occurred according to Maughan et al (written commun.). The Colón-Mito Juan boundary is conformable and gradational lithologically but is more sharply defined in foraminiferal zones. According to Notestein et al (1944, p. 1189), the Catatumbo is apparently conformable with the underlying Mito Juan and the overlying Barco Formations, but Sutton (1946, p. 1656) expresses doubt about this because of thinning of the Catatumbo and Barco Formations over anticlines and thickening in synclines.
The Colon Formation at the type location is 900 meters thick. On the Barco Concession it varies from 215 to 460 meters (Notestein et al., 1944, p. 1183). The Mito Juan is 275 to 420 meters thick in the type locality, and the Catatumbo from 106 to 208 meters thick. In the area of this report, no section has been found well enough exposed for measurement and description, but estimates of thickness of the Colon and Mito Juan together, based on average dips and width of outcrop belt, range from 325 to 600 meters.

According to Trump and Salvador (1964, p. 7), the Colon-Mito Juan sequence contains the most prolific microfauna known in Táchira. It ranges from Santonian to Maestrichtian. The carbonaceous beds of the Catatumbo Member contain Paleocene pollen which extends the age range of the sequence above the Cretaceous-Tertiary boundary.

In the Barco Concession area of northeastern Colombia, Notestein et al. (1944, p. 1184) report a Campanian-Maestrichtian age for the Colon Formation based on microfossil studies by Cushman and Hedberg (1941). Ammonites and pelecypods have also been reported from this area. The Mito Juan is assigned to the Maestrichtian, likewise on the basis of microfossils, ammonites, and pelecypods. On the basis of pelecypods and the upward extension of a foraminiferal zone from the Mito Juan into the Catatumbo, the age of the latter is at least Maestrichtian and possibly younger. The upper part of the Catatumbo is of brackish-water to non-marine origin, and fossils are lacking. Pollen studies are not reported for this area.
The Colón-Mito Juan sequence correlates well with the Umir Formation of the middle Magdalena Valley section (fig. 9), and the uppermost part probably is equivalent to the lowermost part of the Lisama Formation. The correlation with the Umir applies to the lithology and topographic expression as well as to the age.

In the Río de Oro anticline in the northern part of the Barco Concession, a thin sandstone near the top of the Mito Juan produces oil (Notestein et al, 1944, p. 1185). The main production is from the sandstones of the Catatumbo which are also productive on the Sardinata anticline.
Tertiary and Quaternary, Middle Magdalena Valley section

In the western part of the report area, the Tertiary sedimentary rocks have been mapped in accordance with the standard nomenclature adopted by representatives of the Colombian petroleum industry (Morales et al., 1958, p. 647). In the eastern part, the nomenclature of the Maracaibo Basin of northeastern Colombia and western Venezuela are used (Notestein et al., 1944; Trump and Salvador, 1964). The nomenclature of the two regions is shown in figure 9.

Marine deposition came to an end near the close of the Cretaceous Period as the Cordillera Oriental began to rise and became a source of Tertiary continental sediments deposited along its flanks. Along the west flank, these sediments may exceed 8000 meters in thickness according to Morales et al. (1958, fig. 7). They vary greatly in thickness and lithologic character. Much coarser material was deposited in the upper half of the Tertiary than in the lower half.

Compared with the marine Cretaceous section, the Tertiary Formations have few fossils. Age determinations are based on fresh water pelecypods and gastropods, pollen grains, plant, and vertebrate remains.
Lisama Formation

The type section of the Lisama is in the Quebrada Lisama which is just to the south of the Río Sogamoso where the river crosses the western boundary of quadrangle H-12. It was defined by T. A. Link in an unpublished report in 1925 (Morales et al, 1958, p. 656).

The Lisama beds are transitional in nature, following the end of marine Cretaceous deposition of the Umir Formation. They are principally mottled shales with colors of reddish-brown, brown and gray with interbedded gray, greenish-gray and brown sandstones of medium-to fine-grain. Towards the top of the formation the sandstones are coarser grained. Scattered coal seams are present but are thinner than those of the upper Umir.

The contact with the Umir is conformable and gradational and is usually placed at the first well-developed sandstone above the shales of the Umir. The contact with the overlying La Paz Formation is unconformable with pronounced angular discordance locally (Taborda, 1965, p. 11).

Because of the predominance of shales in the Lisama, the formation tends to form valleys in the topography, and only the more resistant beds are well exposed. This is true of the section described below which was measured along the new highway from Bucaramanga to Barrancabermeja where this highway crosses the Lisama on the north slope of the canyon of Río Sogamoso.
The thickness of 1090 meters (see section) compares with a maximum of 1225 reported by Morales et al (1958, p. 657). In the de Mares Concession of quadrangle H-11, Taborda (1965, p. 11) reports a maximum of 1100 meters, and states that the formation is often missing due to erosion during post-Lisama uplift.

Palynological studies indicate a Paleocene age for the Lisama according to Taborda (1965, p. 11). The lithologic character suggests depositional conditions ranging from lagoonal to deltaic.

Chorro Group

Wheeler first used the name "Chorro series" (Pilsbry and Olsson, 1935) for beds now recognized as the La Paz and Esmeraldas Formations (Morales et al, 1958, p. 658) in the Chorro Group.

La Paz Formation

--The prominent La Paz ridge in the western part of quadrangle H-12, between the Ríos Lebrija and Sogamoso, is the source of the name for this formation. It was originally used in the Río Sogamoso area of the de Mares Concession (Taborda, 1965, p. 11). The unit consists principally of massive, cross-bedded, light-gray conglomeratic sandstones. In the lower part and near the top are interbeds of rather soft gray claystone. A section measured along the new Bucaramanga-Barrancabermeja highway along the north slope of the canyon of Río Sogamoso follows:
-Stratigraphic section of the Lisama Formation along the new Bucaramanga-Barrancabermeja highway (planchita 120 I-B, S-2, D-2 and D-1), Municipality of Girón, Department of Santander.

(Measured and described by F. Montero, September, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Paz Formation (lower beds only):</td>
</tr>
<tr>
<td>Sandstone, gray, hard, fine-grained, conglomeratic with quartz pebbles, in beds 0.8-2.0 m thick; interbeds of soft gray claystone 10-40 cm thick... 11.7</td>
</tr>
<tr>
<td>Lisama Formation:</td>
</tr>
<tr>
<td>Claystone, brown, soft, with interbeds of brown, fine-grained, hard, micaceous sandstone ........ 6.3</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained, micaceous, slightly argillaceous, medium-hard, crossbedded ........ 4.6</td>
</tr>
<tr>
<td>Claystone, violet-gray, soft, micaceous ........ 3.8</td>
</tr>
<tr>
<td>Sandstone, greenish-gray to violet, hard, very fine grained, micaceous, crossbedded, in beds 0.9-2.1 m thick .................. 12.1</td>
</tr>
<tr>
<td>Claystone, violet, soft, micaceous ................. 8.2</td>
</tr>
<tr>
<td>Sandstone, violet, hard, very fine-grained, micaceous, feldspathic, argillaceous, crossbedded ........ 6.5</td>
</tr>
<tr>
<td>Claystone, violet, sandy, soft ....................... 3.5</td>
</tr>
<tr>
<td>Sandstone, brown and violet, very fine grained, argillaceous, medium-hard ....................... 9.5</td>
</tr>
<tr>
<td>Claystone, gray and violet, micaceous, soft, in beds 1.0-3.2 m thick .................. 28.0</td>
</tr>
</tbody>
</table>
Meters

Covered ........................................ 370.4

Claystone, brown, soft, with numerous thin beds of
  white gypsum 2-8 mm thick, N. 25° E., 45° NW. .... 1.7

Claystone, brown, soft, with thin beds of coal,
  N. 26° E., 52° NW. .................................................. 3.4

Claystone, brown, soft, with thin beds of white
gypsum .......................................................... 1.2

Covered ........................................ 230.0

Sandstone, greenish-gray, very fine grained, hard,
  conglomeratic, crossbedded .............................. 4.2

Claystone, gray, soft, slightly micaceous .............. 6.8

Sandstone, greenish-gray, very fine grained,
  conglomeratic, crossbedded, very hard; interbedded
  with hard, argillaceous, micaceous, slightly calca-
  careous, dark-gray sandstone, N. 25° E., 48° NW. .... 22.5

Covered ........................................ 151.2

Sandstone, greenish-gray, very fine grained, hard,
  micaceous, crossbedded in some parts; interbeds of
  soft, micaceous, gray and black claystone 0.8-4.0 m
  thick, and fine-grained, medium-hard, micaceous,
  argillaceous, gray and brown sandstone in beds
  1.2-4.5 m thick, N. 40° E., 80° NW. .................. 74.5
Covered .................................................................. 40.0

Sandstone, dark- and light-gray, very fine grained, hard, argillaceous and micaceous, with interbeds of gray, green, and black claystone .......................... 8.0

Claystone, violet-gray, black, and yellow, hard to soft, micaceous, slightly sandy in parts .................................. 58.8

Claystone, gray, shaly, slightly concretionary; interbeds of fine-grained, slightly hard, argillaceous gray sandstone 20-75 cm thick ........................................ 34.5

Total thickness of Lisama Formation 1039.7

Umira Formation (upper beds only):

Shale, dark-gray, brittle, micaceous, with thin beds and lenses of brown clay ironstone and thin seams of coal ................................................................. 142.0

Sandstone, light-gray, fine-grained, hard, micaceous .......................... 5.0

Shale, dark-gray, brittle, micaceous, with thin beds and lenses of brown clay ironstone ........................................ 151.0
Type stratigraphic section of the La Paz Formation along the new Bucaramanga-Barrancabermeja highway on the north side of the canyon of the Rio Sogamoso (planchitas 120 I-A, C-15 and 120 I-B, C-1 and D-1), Municipality of Giron, Department of Santander. (Measured and described by F. Montero, September, 1968)

<table>
<thead>
<tr>
<th>Meters</th>
<th>Esmeraldas Formation (lower beds only):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sandstone, light-brown, fine-grained, very hard, slightly micaceous, in four beds of about 1.1 m each, with interbedded light-gray to reddish-gray soft claystone, N. 44° E., 27° NW.</td>
</tr>
<tr>
<td></td>
<td>Conglomerate, light-gray, with pebbles of white quartz and sandy claystone up to 5 cm in diameter in matrix of light-gray clay</td>
</tr>
<tr>
<td></td>
<td>Claystone, greenish- and violet-gray, soft</td>
</tr>
<tr>
<td></td>
<td>Sandstone, light-gray, fine-grained, hard</td>
</tr>
<tr>
<td></td>
<td>Sandstone, light-gray, fine-grained, hard, conglomeratic with pebbles of white quartz and chert up to 2 cm in diameter</td>
</tr>
<tr>
<td></td>
<td>Sandstone, gray and violet, fine-grained, argillaceous, slightly hard, N. 75° E., 32° NW.</td>
</tr>
<tr>
<td></td>
<td>Claystone, greenish- and violet-gray, soft, with sandy claystone concretions and lenses of argillaceous, fine-grained sandstone at the base</td>
</tr>
</tbody>
</table>
La Paz Formation:

Sandstone, very light yellowish gray, fine-grained, hard, conglomeratic with quartz pebbles up to 4 cm in diameter .................................................. 12.4

Claystone, greenish- and violet-gray, soft .................................. 6.7

Sandstone, brown, fine-grained, hard, in beds up to 10 cm thick, interbedded with slightly hard, brown claystone in beds up to 1/4 cm thick .................................. 3.6

Sandstone, very light yellowish gray, hard, conglomeratic with quartz pebbles .................................................. 2.3

Claystone, dark-gray, soft, nodular ........................................ 16.8

Sandstone, greenish-gray, fine-grained, hard, micaceous and argillaceous .................................................. 1.9

Claystone, greenish- and dark-gray, soft, micaceous, conglomeratic, with interbedded greenish-gray, fine-grained sandstone .................................................. 1.1

Sandstone, very light gray, fine-grained, hard, argillaceous, reddish on weathered surface; contains abundant dark grains .................................................. 17.6

Sandstone, light-gray, hard, argillaceous, conglomeratic with quartz pebbles up to 3 cm in diameter, N. 40° E., 32° NW. .................................................. 5.8
Meters

Sandstone, light-gray, hard, argillaceous, conglomeratic, with few interbeds of dark-gray, soft, carbonaceous claystone up to 1.2 m thick in the upper part; contains carbonized plant remains, N. 35° E., 32° NW. 42.0

Sandstone, very light yellowish gray, fine-grained, very hard, micaceous, crossbedded, in beds up to 80 cm thick; scattered conglomeratic beds up to 2.6 m thick and claystone beds are more numerous at the base and top, N. 25° E., 40° NW. 202.0

Sandstone, very light yellowish gray, fine-grained, very hard, micaceous, crossbedded, conglomeratic and argillaceous at the top, middle, and base 346.0

Sandstone, brown to pink, fine-grained, slightly hard, crossbedded, with interbedded greenish-gray, soft, nodular claystone 3.2

Sandstone, pink and greenish- and yellowish-gray, very fine grained, hard, micaceous, crossbedded, N. 42° E., 32° NW. 39.5

Sandstone, light-gray, fine-grained, slightly hard, micaceous, carbonaceous, interbedded with soft, dark-gray claystone in beds up to 10 cm thick 3.6
<table>
<thead>
<tr>
<th>Claystone, dark-gray, soft, slightly micaceous</th>
<th>16.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, light-gray, fine-grained, slightly hard,</td>
<td></td>
</tr>
<tr>
<td>micaceous, carbonaceous, interbedded with soft,</td>
<td></td>
</tr>
<tr>
<td>dark-gray claystone</td>
<td>39.0</td>
</tr>
<tr>
<td>Sandstone, greenish-gray, fine-grained, hard,</td>
<td></td>
</tr>
<tr>
<td>micaceous, carbonaceous, N. 30° E., 46° NW.</td>
<td>24.0</td>
</tr>
<tr>
<td>Covered</td>
<td>120.0</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained, hard, micaceous;</td>
<td></td>
</tr>
<tr>
<td>carbonaceous, in beds up to 1.8 m thick, interbedded with micaceous, soft, gray claystone in beds up to 1.1 m thick</td>
<td>7.6</td>
</tr>
<tr>
<td>Sandstone, greenish- and yellowish-gray, very fine grained, very hard, silty, micaceous, carbonaceous, conglomeratic with pebbles up to 3 cm in diameter</td>
<td>10.0</td>
</tr>
<tr>
<td>Claystone, violet-gray, micaceous, slightly hard</td>
<td>2.0</td>
</tr>
<tr>
<td>Sandstone, greenish- and yellowish-gray, very fine grained, very hard, silty, micaceous, carbonaceous, conglomeratic with pebbles up to 3 cm in diameter</td>
<td>11.0</td>
</tr>
<tr>
<td>Claystone, reddish-brown, slightly hard, micaceous</td>
<td>44.5</td>
</tr>
<tr>
<td>Sandstone, greenish- and yellowish-gray, very hard, very fine grained, silty, micaceous, carbonaceous, crossbedded, conglomeratic with pebbles up to 3 cm in diameter, N. 27° E., 42° NW.</td>
<td>21.7</td>
</tr>
<tr>
<td>Description</td>
<td>Meters</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Claystone, violet-gray, soft, micaceous</td>
<td>34.4</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained, very porous, conglomeratic with pebbles up to 4 cm in diameter</td>
<td>2.1</td>
</tr>
<tr>
<td>Claystone, light-gray and greenish-gray, soft, micaceous</td>
<td>17.3</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained, very porous, conglomeratic, with pebbles up to 4 cm in diameter</td>
<td>4.8</td>
</tr>
<tr>
<td>Conglomerate, gray, very hard, with pebbles of quartz and nodules of pink and gray sandy claystone up to 6 cm in diameter in fine sandy matrix</td>
<td>4.6</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained, conglomeratic with pebbles up to 4 cm in diameter</td>
<td>2.0</td>
</tr>
<tr>
<td>Conglomerate, gray, hard, with pebbles of quartz, feldspar, flint, and agate up to 6 cm in diameter</td>
<td>7.1</td>
</tr>
<tr>
<td>Claystone, gray, soft</td>
<td>3.8</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained, hard, slightly conglomeratic</td>
<td>5.1</td>
</tr>
<tr>
<td>Claystone, gray and violet, soft</td>
<td>9.2</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained, hard, conglomeratic, in beds up to 2 m thick, with interbeds of soft, gray claystone up to 40 cm thick</td>
<td>11.7</td>
</tr>
<tr>
<td>Total thickness of La Paz Formation</td>
<td>1102.4</td>
</tr>
</tbody>
</table>

---unconformity---
Lisama Formation (upper beds only):

Claystone, brown, soft, with interbeds of hard,

micaceous, fine-grained, brown sandstone  . . . . . . 6.3
The La Paz attains its maximum thickness in the Río Sogamoso area. Taborda (1965, p. 12) mentions 1280 meters measured along the river, but only 460 meters in Quebrada Putana about 14 kilometers to the southwest. Farther to the west, in oil fields of quadrangle H-11, the La Paz is only 170-210 meters thick.

At the base of the La Paz in some places, a hard, dense, grayish-pink to cream-colored shale about 30 meters thick was originally referred to as the "altered shale" but is now termed the "Toro Member" (Taborda, 1965, p. 12).

The lower boundary of the La Paz is one of regional unconformity and angular discordance. This is less apparent in the outcrops of the western part of quadrangle H-12 than in the subsurface in quadrangle H-11 where, in the La Cira oil field, it overlies the truncated edges of all the Cretaceous formations and part of the Giron Formation (Taborda, 1965, fig. 7). The contact with the overlying Esmeraldas Formation is conformable. The formation yields oil in some of the smaller fields of the middle Magdalena Valley.

No fossils have been found with which to date the continental La Paz, but its position with respect to dated formations above and below indicates an Eocene age.
Esmeraldas Formation.--This upper formation of the Chorro Group was named for the hamlet of La Esmeralda on Río Sogamoso where the type section is exposed in the western part of quadrangle H-12. A description of this section was published by Wheeler (Pilsbry and Olsson, 1935). The formation consists of light gray to greenish-gray, thin-bedded to laminated, fine-grained sandstone and siltstone with interbedded dark-gray shale locally mottled brown, red, and purple. Scattered seams of lignite are present. The formation is conformable with the underlying La Paz Formation but is unconformable with the overlying Mugrosa Formation. It generally forms very low topography.

The lower beds of the Esmeraldas Formation in the area of the type section are described with the La Paz Formation. A section measured along the Río Lebrija about 27 kilometers north northeast of the type section is shown below. The thickness of 575 meters is less than half the 1200 meters reported at the type section. The formation is thinner also to the south and west of the type section.

Brackish- to fresh-water gastropods and pelecypods from the Los Corros fossil horizon, which occurs locally at the top of the formation, have been identified as late Eocene forms (Pilsbry and Olsson, 1935). Studies of pollen also indicate a late Eocene age on the basis of correlation with pollen of the late Eocene (lower part of the Carbonera Formation) of the Maracaibo Basin (Morales et al, 1958, p. 659). A deltaic and lagoonal origin is indicated for the formation.
Stratigraphic section of the Esmeraldas Formation  
along the Bucaramanga-Puerto Wilches railroad on the south  
side of the Rio Lebrija, (planchita 109 I-D, H-8 and H-7),  
Municipality of Lebrija, Department of Santander.  
(Measured and described by A. Castro, September, 1968)

Meters

Mugrosa Formation (lower beds only)

Sandstone, light-gray, fine- to medium-grained,  
argillaceous, micaceous, in beds 0.5-1.0 m thick;  
interbedded yellowish-gray claystone in the  
upper part ........................................ 19.7  
Covered ........................................... 92.0

Esmeraldas Formation:

Claystone (60 percent), gray, soft, laminar, with  
yellowish-gray, medium-grained, crossbedded, crumbly  
sandstone (40 percent) at the base and middle,  
N. 3° E., 62° NW. ................................ 27.6  
Covered ........................................... 10.7

Sandstone (50 percent), yellowish-gray, medium-grained,  
crumbly, micaceous, crossbedded, thin-bedded to  
laminar; interbedded with gray claystone (50 percent)  
Covered ........................................... 91.8

Sandstone (80 percent), yellowish-gray, medium-grained,  
crumbly, micaceous, crossbedded, thin-bedded to  
massive in the middle; contains abundant dark grains;  
interbedded with gray claystone (20 percent) in the  
upper half, N. 4° W., 56° SW. ....................... 46.0
Covered ........................................ 127.6

Sandstone (70 percent), yellowish-brown, medium- to
coarse-grained, crumbly, argillaceous, micaceous,
crossbedded and thin-bedded; contains abundant
dark grains; interbedded with laminar gray clay-
stone (30 percent) in the upper part, N. 6° W.,
49° SW. ........................................ 27.8

Covered ........................................ 117.5

Sandstone (60 percent), yellowish-brown to yellowish-
gray, fine-grained in lower part, medium-grained in
upper part, crumbly, argillaceous, micaceous, cross-
bedded, in beds 0.2-0.8 m thick; interbedded with
yellowish-gray claystone (40 percent) ........ 80.6

Total thickness of Esmeraldas Formation 575.3

La Paz Formation (upper beds only):

Sandstone, light-gray, medium- to very coarse
grained, hard, micaceous, argillaceous; contains
small clay nodules and carbonaceous films on
bedding planes, N. 5° W., 64° SW. .......... 64.0

Meters
Chuspas Group

The beds above the Los Corros fossil horizon and below the coarse clastic strata of the Real Formation were originally called the Chuspas Formation. The section was later divided into the Mugrosa and Colorado Formations by Wheeler (Pilsbry and Olsson, 1935) on the basis of the Mugrosa fossil horizon at the top of the Mugrosa Formation.

Mugrosa Formation ——The type section is in the Quebrada Mugrosa in the area of the Mugrosa anticline in quadrangle H-11. In this general area, the lower part consists of gray to grayish-green, fine- to medium-grained, rarely coarse and pebbly sandstone with interbedded gray and blue shale (Taborda, 1965, p. 13). The middle part contains dull blue and brown, massive, mottled shales with few thin interbeds of fine-grained sandstone and light green sandy shales. The upper part includes gray, fine- to coarse-grained, rarely pebbly sandstone with minor interbeds of green and mottled shale. The proportion of sand to shale increases eastward in the lower part (Tomi), whereas in the upper part (Toms) the proportion of shale to sand increases (Morales et al, 1958, p. 660). A little oolitic glauconite is present. The formation weathers to low topographic relief.

The boundary with the underlying Esmeraldas is one of regional unconformity according to Morales et al (1958, p. 660), but Taborda (1965, p. 13) states that the unconformity has not been found in the Río Sogamoso area and oil fields of quadrangle H-11. It is conformable with the overlying Colorado Formation.
A partially exposed section of the Mugrosa in quebradas south of
the Rio Lebrija and Bucaramanga-Puerto Wilches railroad is described
below. The thickness of this section, 843 meters, is similar to
the 820 meters in the Colorado oil field about 10 kilometers north of
the type section. Southward from the described section the
formation thickens and may reach 2000 meters.

The Mugrosa fossil horizon that occurs locally at the top of the
formation contains fresh-water gastropods, a few fish bones and plates
of turtles. On the basis of these fossils the age of the formation
ranges from Early to Middle Oligocene. Oil is produced from the
Mugrosa in the fields of quadrangle H-11.

Colorado Formation---This formation receives its name from
Rio Colorado in quadrangle H-11 where the type section is located.
The lower boundary is the top of the fossiliferous zone at the
top of the Mugrosa Formation. The formation consists of tough, massive,
light-gray, purple and red mottled shales with interbeds of fine-to
coarse-grained, white, gray and yellowish-brown cross-bedded sandstone
(Morales et al, 1958, p. 660). The shales are more reddish in color
and the sandstones are coarser and more conglomeratic than those of the
Mugrosa Formation. The La Cira fossil zone marks the top of the
Colorado which is unconformable with the overlying Real Group. Total
thickness at the type section is 1250 meters. Elsewhere it ranges up
to 2500 meters.
Stratigraphic section of the Mucrosa Formation south
of the Bucaramanga-Puerto Wilches railroad in the area of
Quebradas Arenosa and Vega de Pato (planchita 109-I-D, H-7
and H-6), Municipality of Lebrija, Department of Santander.
(Measured and described by A. Castro, September, 1968)

Colorado Formation (lower beds only):

Conglomerate, yellowish-gray, hard, well-cemented,
slightly calcareous, in beds 0.8-1.2 m thick;
pebbles up to 12 cm in diameter of sandstone,
limestone, quartz, and very few of metamorphic
and igneous rocks, N. 3° E., 62° NW. 73.8

Covered 172.6

Mucrosa Formation (upper member):

Claystone, yellowish-brown, medium-hard; in upper
part are a few beds of coarse- to very coarse
grained, argillaceous, feldspathic, conglomeratic
sandstone in beds 20-40 cm thick 30.0

Sandstone, yellowish-brown, medium-hard, very coarse
grained, slightly conglomeratic with rounded
pebbles up to 2 cm in diameter, in beds 0.7-1.0 m
thick; interbeds of yellowish-gray argillaceous
sandstone at the base and pinkish-gray claystone
near the top, N. 3° E., 56° NW. 32.0

Covered 22.0
<table>
<thead>
<tr>
<th>Meters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.0</td>
<td>Conglomerate, poorly consolidated, with subangular pebbles of quartz and feldspar up to 4 cm in diameter, fewer smaller pebbles of metamorphic rock; interbeds of coarse-grained, argillaceous sandstone, N. 4° E., 64° NW.</td>
</tr>
<tr>
<td>17.0</td>
<td>Claystone, greenish- to violet-gray, 8 m at the base and 6 m at the top, separated by coarse-grained, argillaceous, feldspathic, yellowish-gray sandstone in beds up to 2 m thick</td>
</tr>
<tr>
<td>28.0</td>
<td>Covered</td>
</tr>
<tr>
<td>30.0</td>
<td>Sandstone (50 percent), yellowish-gray, coarse- to very coarse grained, argillaceous, with few beds of conglomerate containing pebbles of quartz and feldspar up to 2 cm in diameter; interbedded with yellowish-gray claystone (50 percent), N.-S., 60° W.</td>
</tr>
<tr>
<td>8.0</td>
<td>Covered</td>
</tr>
<tr>
<td>12.0</td>
<td>Claystone, yellowish-pink, with interbedded argillaceous conglomeratic, coarse-grained, yellowish-gray sandstone</td>
</tr>
<tr>
<td>11.0</td>
<td>Covered</td>
</tr>
</tbody>
</table>
Mugrosa Formation (lower member, Tmi)

<table>
<thead>
<tr>
<th>Description</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covered</td>
<td>82.0</td>
</tr>
<tr>
<td>Siltstone, yellowish-gray, medium-hard, with few beds of argillaceous, micaceous, yellowish-white sandstone in beds 20-50 cm thick</td>
<td>46.0</td>
</tr>
<tr>
<td>Covered</td>
<td>36.0</td>
</tr>
<tr>
<td>Siltstone, greenish- to violet-gray, medium-hard, with few beds of argillaceous, yellowish-white sandstone in beds 5-10 cm thick</td>
<td>60.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-white, poorly consolidated, argillaceous, micaceous, with interbedded yellowish-gray siltstone, N.-S., 51° W.</td>
<td>42.0</td>
</tr>
<tr>
<td>Covered</td>
<td>96.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-white, poorly consolidated, argillaceous, micaceous, with interbedded violet-green siltstone, N. 4° E., 66° NW.</td>
<td>36.0</td>
</tr>
<tr>
<td>Siltstone, yellowish-green to yellowish-gray, medium-hard, with few interbeds 15-20 cm thick of medium-grained, argillaceous, micaceous, crumbly, yellowish-red sandstone</td>
<td>63.3</td>
</tr>
<tr>
<td>Covered</td>
<td>50.0</td>
</tr>
</tbody>
</table>
Sandstone, light-gray, crumbly, fine- to medium-grained, argillaceous, micaceous, in beds 0.5-1.0 m thick, with interbeds of yellowish-gray claystone near the top .................................. 19.7 Covered ........................................... 92.0

Total thickness of the Mugrosa Formation 843.0

---unconformity---

Esmeraldas Formation (upper beds only):

Claystone (60 percent), gray, soft, laminar, with yellowish-gray, medium-grained, crossbedded, crumbly sandstone (40 percent) at the base and middle, N. 3° E., 62° NW. ..................... 27.6
A section of the Colorado Formation exposed along and near the Bucaramanga-Puerto Wilches railroad is described below. The formation there is 1379 meters thick and is composed mostly of coarse conglomerates with abundant pebbles and boulders of sandstone and limestone, fewer of quartz, chert, and metamorphic and igneous rocks, in a coarse-grained, sandy, calcareous matrix. Pebbles, cobbles, and boulders range up to 45 cm in diameter, but most are less than 12 cm. The beds in the lower part of the formation are hard and form a prominent ridge in contrast to the low topography over the Mugrosa Formation. The upper beds of the Colorado are poorly consolidated and do not form prominent topography.

In the La Cira shale zone at the top of the Colorado, a freshwater gastropod, genus *Hemisinus*, is the most characteristic fossil (Taborda, 1965, p. 14). Other fossils include lignitic material, fish scales and teeth, vertebrae, bone fragments, and small pelecypods. The latter were described by Pilsbry and Olsson (1935). On the basis of these fossils and those in the fossiliferous zone at the top of the Mugrosa, the Colorado is placed in the Late Oligocene and Early Miocene and is of continental origin. It is an important oil reservoir in some of the oil fields in quadrangle H-11.
Stratigraphic section of the Colorado Formation along the Bucaramanga-Puerto Wilches railroad (planchita 109 I-D, C-5) and in Quebrada Kilometro 72, west of the railroad (planchita 109 I-D, F-6), Municipality of Lebrija, Department of Santander.

(Measured and described by A. Castro, September, 1968)

<table>
<thead>
<tr>
<th>Real Formation (lower beds only):</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conglomerate, sandstone, and claystone, interbedded</td>
<td>84.7</td>
</tr>
<tr>
<td>Covered</td>
<td>101.3</td>
</tr>
</tbody>
</table>

- - - - - - - - - - - - unconformity - - - - - - - - - - - -

Colorado Formation (measured along the railroad from post number km 67/10-68/5):

| Conglomerate, yellowish-gray, poorly consolidated, in beds 1.5-2.5 m thick, with interbeds of purplish-gray, sandy claystone up to 1.0 m thick and yellowish-gray, medium-grained, argillaceous, lenticular sandstone beds up to 1.5 m thick. Pebbles and boulders in the conglomerate range up to 25 cm in diameter, most are from 6-12 cm, and include fine- to medium-grained, yellowish-gray, hard sandstone, argillaceous and micaceous friable sandstone, and few scattered pebbles of chert and metamorphic rocks, N. 90° E., 590 NW. | Covered (railroad tunnel) |
| | 78.4 | 79.1 |

Covered (railroad tunnel) | 79.1 |
Conglomerate, similar to that described above,
with pebbles up to 16 cm in diameter, in beds 3-4 m thick; interbeds of purplish-gray, sandy claystone, N. 6° NE., 56° NW. ........................ 75.9
Covered ........................................... 51.4

Conglomerate, yellowish-gray, poorly consolidated, in beds 1.5-2.5 m thick, with interbeds of purplish-gray siltstone and lenticular beds of argillaceous, fine- to medium-grained, crumbly, yellowish-purple sandstone up to 1.5 m thick. Pebbles are of hard to friable, yellowish-gray sandstone up to 10 cm in diameter and a few are of chert and metamorphic rocks .................................................. 60.4
Covered ........................................... 45.1
Sandstone, yellowish-purple, coarse- to very coarse grained, argillaceous, conglomeratic with pebbles of quartz and sandstone up to 6 mm in diameter. At the base these beds have scattered pebbles of quartz, sandstone, and chert up to 10 cm in diameter, mostly 2-5 cm, and alternate with beds of purplish-gray claystone. In the middle part, the beds are more conglomeratic and pebbles are larger. In the upper part, pebbles and cobbles up to 13 cm in diameter are mostly of sandstone, some are of quartz, few are of chert. Thin inter-beds are of claystone and lenticular sandstone ... 246.2

(Measured in Quebrada Kilometro 72, west of the railroad)

Covered ............... 82.4

Conglomerate, hard, calcareous, with pebbles 3-12 cm in diameter, in beds up to 1.0 m thick; pebbles are mostly of sandstone, others are of quartz, limestone, chert, and few are of metamorphic and igneous rocks, N. 2° E., 62° NW. ............... 74.5
Conglomerate, yellowish-gray, with rounded pebbles of limestone and sandstone 6-18 cm in diameter, few smaller ones of chert; calcareous matrix of coarse- to very coarse grained sand; at the top, pebbles are mostly medium-grained, micaceous, hard, yellowish-gray sandstone 4-22 cm in diameter, N.-S., 63° W. .............. 109.6

Sandstone, brownish-gray, coarse-grained, hard, calcareous, conglomeratic, with interbeds of conglomerate with pebbles of limestone and yellowish- to pinkish-gray sandstone, N. 2° E., 62° NW. ........... 66.0

Conglomerate, gray, hard, with pebbles 12-24 cm in diameter of limestone, sandstone, quartz, few of chert and very few of metamorphic rocks in sandy, calcareous matrix; pebbles decrease in size to 6-10 mm in diameter at the top and beds are thinner .... 48.7
Conglomerate, gray, hard, with pebbles of limestone and sandstone in sandy, calcareous matrix; the lower beds have mostly limestone pebbles up to 15 cm in diameter and few sandstone pebbles 5-8 cm; at the top, sandstone and light- and dark-gray limestone pebbles are about equal in numbers, mostly 10-15 cm in diameter with some boulders 30-45 cm, N. 4° E., 58° NW. ................................. 80.6

Covered ................................................................. 34.0

Conglomerate, gray, hard, in beds 0.8-1.2 m thick, with pebbles up to 12 cm in diameter of sandstone, limestone, quartz, very few of metamorphic and igneous rocks, in slightly calcareous, coarse- to very coarse grained sandy matrix ............................... 73.8

Covered ................................................................. 172.6

Total thickness of Colorado Formation 1378.7

Mugrosa Formation (upper beds only):

Claystone, yellowish-brown, medium hard; in upper part are a few beds of coarse- to very coarse grained, argillaceous, feldspathic, conglomeratic sandstone in beds 20-40 cm thick .............................. 30.0
Real Group

The type section of the Real is in quadrangle I-11 on the north side of Rio Opon and two kilometers west of Quebrada Real. A description of these rocks as the "Real Series" was first published by Wheeler (Pilsbry and Olsson, 1935). Attempts to divide the thick section into units have been successful only locally according to Taborda (1965, p. 14). In quadrangle H-12, it is divided into three unnamed units, lower (Tmri), Middle (Tmrn), and upper (Tmrn). The contacts with the underlying Colorado Formation and overlying Mesa Group are unconformable.

At the type section along the Rio Opon, the following description of the Real is given by Taborda (1965, p. 14) and Morales et al (1958, p. 661):

Mesa Group

---unconformity---

Real Group

Sandstone, blue-gray, hard, fine- to coarse-grained
with interbeds of laminated dark-gray shale 747
Shale, gray, with few thin interbeds of coarse-grained, friable, grayish-white sandstone 457
Conglomerate, massive, with pebbles of brown and black chert, clay ironstone and quartz, and fragments of coal; interbeds of massive, coarse-grained sandstone with thin shale partings 1067
Shale, gray with red mottling, with scattered interbeds of fine- to coarse-grained sandstone 1295
Sandstone, massive, cross-bedded, friable to hard, with streaks of blue clay and small coal fragments 453

Conglomerate, massive, with pebbles of brown and black chert, clay ironstone and quartz, and fragments of coal 35

Total thickness 4054

-------------unconformity-------------

Colorado Formation

A partly exposed section of the Real Group along the Bucaramanga-Puerto Wilches railroad follows, below. Only the lower and middle divisions are present, and the 1732 meters measured is less than half the thickness of the type section.

Vertebrate fossils ranging from Late Oligocene to Late Miocene, and plant leaves and gastropods of Miocene age have been reported from the Real (Morales et al, 1958, p. 661) and indicate a continental origin.

Mesa Group

In the Magdalena Valley, all beds above the Late Miocene are included in the Mesa Group (Morales et al, 1958, p. 662). Earlier, the name Mesa Formation was used by Weiske (1926) and by Butler (1942) for beds in the lower part of the group in the Honda area in the upper Magdalena Valley. Various names have been used locally by different oil companies in the middle Magdalena Valley, some recognizing two members, others a single unit. The Mesa is unconformable over the Real Group.
Stratigraphic section of the Real Group along the Bucaramanga-Puerto Wilches railroad from kilometer 67/8 to 64/0 (planchita 109 I-D, C-5, C-4 and C-3), Municipality of Lebrija, Department of Santander.

(Measured and described by A. Castro, September, 1968).

Meters

Mesa Formation (lower beds only):

Sandstone, light-gray to white, medium- to coarse-grained, argillaceous, friable; contains cross-bedded lenses of poorly consolidated conglomerate up to 45 cm thick with pebbles of sandstone and quartz up to 4 cm in diameter, N. 6° E., 12° NW. ...

- - - - - - - - unconformity - - - - - - - -

Real Group (middle part):

Covered (Quebrada Dorada) .................. 114.2

Sandstone, white to light-gray, coarse- to very coarse grained, conglomeratic, feldspatic, crossbedded, in massive beds 4-6 m thick; lenticular beds of conglomerate contain pebbles of quartz and sandstone up to 3 cm in diameter, N. 16° E., 24° NW. .. 64.8

Covered ...................................... 88.1

Conglomerate, yellowish-white and light-gray, poorly consolidated, with pebbles of sandstone and quartz up to 4 cm in diameter; interbedded medium- to coarse-grained, argillaceous, micaceous, light-yellowish-gray sandstone in the upper and lower parts and sandy, micaceous, massive white claystone in the middle, N. 12° E., 36° NW. .................. 79.3
Covered ........................................ 121.1

Sandstone, white to light-gray, medium- to coarse-grained, feldspathic, friable, in massive beds up to 2 m thick, with conglomeratic zones and interbeds of sandy, grayish-green claystone up to 40 cm thick; coarser grained and more conglomeratic at the top where interbeds are fine- to medium-grained, dark-green argillaceous sandstone, N. 9° E., 45° NW. ........................................ 115.6

Sandstone, white to light-gray, medium- to coarse-grained, feldspathic, friable, in beds up to 2 m thick, with alternate beds of sandy, greenish-gray claystone up to 4.5 m thick. Poorly consolidated basal conglomerate 1.2 m thick contains pebbles of quartz and sandstone up to 4 cm in diameter, N. 12° E., 38° NW. ........................................ 37.8

- - - - - - - - - unconformity- - - - - - - -

Real Group (lower part):

Sandstone (poorly exposed), yellowish-gray, coarse- to very coarse grained, crumbly, feldspathic, conglomeratic, with interbedded conglomerate and greenish-gray, sandy to conglomeratic claystone; claystone predominant in upper part, N. 11° E., 52° NW. ........................................ 34.9
<table>
<thead>
<tr>
<th>Covered</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conglomerate (poorly exposed), yellowish-gray, crumbly, with pebbles of sandstone and metamorphic and igneous rocks 10-15 cm in diameter</td>
<td>20.0</td>
</tr>
<tr>
<td>Sandstone (poorly exposed), light-yellowish-gray, coarse-grained, alternating with conglomerate with pebbles of sandstone and metamorphic and igneous rocks up to 15 cm in diameter and dark-violet-green, sandy to conglomeratic claystone; sandstones predominate in middle part, N. 30° E., 58° NW.</td>
<td>87.7</td>
</tr>
<tr>
<td>Conglomerate, coarse, crumbly, with pebbles of sandstone, siltstone, metamorphic and igneous rocks, few of chert and very few of volcanic rocks up to 18 cm in diameter, in beds up to 2 m thick, with lenticular sandstone beds, N. 10° E., 56° NW.</td>
<td>27.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-gray, coarse-grained to conglomeratic, crumbly, highly feldspathic, in beds up to 1.5 m thick, alternating with coarse conglomerate beds up to 2 m thick and violet-gray sandy claystone</td>
<td>57.7</td>
</tr>
</tbody>
</table>
Covered ...................................... 101.3

Total thickness of Real Group 1731.9

- - - - - - - - unconformity - - - - - - - -

Colorado Formation (upper beds only):

Conglomerate, yellowish-gray, poorly consolidated,

with pebbles of fine- to medium-grained, hard,

yellowish-gray sandstone, argillaceous and

micaceous friable sandstone, and few of chert

and metamorphic rock up to 25 cm in diameter,

in beds up to 2.5 m thick ................................ 44.0
At the type locality, Alto de Gigante northwest of Honda, the lower part of the Mesa consists of well-bedded sands and andesitic tuffs which contain beds of coarse-grained sandstone, grits, agglomerates, clay, silt, conglomerates and pyroclastics. In the pyroclastics are fragments of andesite, dacite, pumice and ash and small fragments of quartz and flakes of phyllite. The upper part contains gravel, boulders, sandstone and interbedded silts. The group ranges up to 575 meters in thickness.

In the de Mares Concession (quadrangle H-11 and I-11), where the Capote and Magdalena Formations are recognized, the Mesa consists of massive black shales, friable sandstones, poorly consolidated conglomerates, and terrace gravels and sands (Taborda, 1965, p. 15). Some of the sandstones contain abundant carbonized plant material. The dark bluish-gray conglomerates contain pebbles of quartz, chert and igneous rocks. In the uppermost part are unconsolidated, poorly bedded gravels in sandy matrix, with local interbeds of yellowish-to reddish-gray clayey sand and sandy clay. The thickness ranges up to 250 meters.

In the northwest corner of quadrangle H-12, the Mesa occurs over a wide area. Exposures occur along the Bucaramanga-Puerto Wilches railroad between kilometers 53 and 64 from Puerto Wilches. The section consists of alternating sandstones and thinner claystones and a few beds of conglomerate. The following descriptions list the lithologies in order of abundance:
No fossils have been reported on which to base an age determination for the Mesa Group. The lower part was considered to be of Pliocene age by Wheeler (Pilsbry and Olsson, 1935). On this assumption, the upper part is placed in the Pleistocene.
Upper part

- thickness ?

Sandstone, yellowish-gray to reddish-brown, very coarse-to fine-grained, poorly consolidated; conglomeratic in some beds with pebbles of quartz and sandstone and few of metamorphic rocks up to 5 cm in diameter

Claystone, reddish-gray, soft, sandy

Lower part

- estimated thickness 1100 meters

Sandstone, light yellowish-gray to yellowish-gray, coarse-to very coarse-grained, poorly consolidated, cross-bedded, conglomeratic in most beds with pebbles of sandstone and quartz and few of igneous, metamorphic, and volcanic rocks up to 5 cm in diameter, mostly 1-2 cm

Claystone, light yellowish- to greenish-gray, sandy and conglomeratic

Conglomerate, light yellowish- to brownish-gray, poorly consolidated, in scattered beds and lenses with pebbles of quartz and sandstone and few of igneous, metamorphic and volcanic rocks up to 15 cm in diameter

Because of the low dips of the beds and the intermittent nature of the exposures, accurate measurements of thickness of individual exposures could not be made. An estimate has been made of the thickness of the lower member based on an average dip of 12°. In the upper member, dips are only a few degrees to horizontal and no estimate of thickness has been made.
Tertiary and Quaternary, Maracaibo Basin, Colombia

Barco Formation

The type section for this formation is the prominent East Barco Ridge of the Petrolea anticline on the Barco Concession, quadrangle F-13 (Notestein et al., 1944, p. 1190 and fig. 8). There the formation is composed of 215 meters of interbedded sandstone, shale, and claystone. The sandstone, which commonly comprises one-half to two-thirds of the section, is in beds ranging from 0.3-20 meters thick and is mostly gray, argillaceous, very fine-to medium-grained, well-sorted, cross-bedded, with locally abundant micaceous-carbonaceous partings and shale laminae. Secondary growth of quartz on sand grains is a common occurrence, and the resulting crystal faces produce the "sparkling sandstones" of the Barco. The interbedded shales and claystones are gray to dark-gray, partly silty, micaceous, and carbonaceous. Thin lenses and small nodules of brown clay-ironstone are common, and one or more thin beds of coal are usually present in the upper part of the formation.

In the eastern part of quadrangle H-13 of this report, the Barco is very similar in character to that of the type locality and is conformable with the underlying Mito Juan Formation. Estimates of the thickness in various places vary from 160-275 meters. This is similar to the range of 150-278 meters found in outcrops in the Barco Concession area (Notestein et al., 1944, p. 1191). In wells of that area, the thickness ranges from 76-198 meters.
A few non-diagnostic arenaceous foraminifers have been found in the Barco Formation (Trump and Salvador, 1964, p. 8), but an early Paleocene age is assigned to it on the basis of Paleocene pollen described by Van der Hammen (1958, p. 94). A fluvial to brackish-water origin is indicated for the unit. It correlates with the lower part of the Lisama Formation of the middle Magdalena Valley (fig. 9) and with the lower parts of the Angostura, Marcelina, and Trujillo Formations of Venezuela (Sutton, 1946, p. 1630).

Oil is produced from sandstones of the Barco in the Petrólea and Tibú-Socuavó fields of the Barco Concession (Notestein et al., 1944, p. 1191), and it contains gas on the Sardinata anticline. Production is mainly from the "sparkling sandstones."
The type section of this formation is in Quebrada Los Cuervos that drains into Río Catatumbo in the northern part of the Barco Concession, quadrangle F-13 (Notestein et al, 1944, p. 1192). There the formation is mostly claystone and shale with scattered sandstone beds. The lower 75 meters contain dark-gray carbonaceous shale and claystone interbedded with micaceous, carbonaceous siltstone, fine-grained sandstone and coal. There are usually 8 to 10 coal beds ranging from 0.1 to 2.5 meters thick. Above the coal-bearing section, the Los Cuervos is mostly gray and greenish-gray, partly silty, usually sideritic claystone with scattered beds of argillaceous sandstone. The lower part of the section contains dark-gray carbonaceous shales, and the claystones are slightly mottled. Mottling is more pronounced in the upper half of the formation, with colors of red, yellow, and purple. The Los Cuervos is conformable with the underlying Barco Formation.

The Los Cuervos is part of the Tertiary section that crops out in the eastern part of quadrangle H-13 of this report. It is quite similar to the section in the type locality. It tends to weather as a slight valley between the more resistant Barco and Mirador Formations. Coal beds in the lower part of the section are mined on a small scale in various places. The estimated thickness varies from 265 to 420 meters as compared to 245 to 490 in outcrops in the area of the type locality. In wells of the type locality the Los Cuervos varies from 249 to 426 meters (Notestein et al, 1944, p. 1192). In western Táchira, Venezuela, Trump and Salvador (1964, p. 8 and fig. 6) report thicknesses varying from 320 to 500 meters.
The only fauna reported from the Los Cuervos includes a few marine or brackish-water pelecypods from a thin black shale near the base of the formation in the type locality (Notestein et al., 1944, p. 1194). Their age is Cretaceous or Tertiary. Paleocene pollen reported from carbonaceous beds in western Táchira (Trump and Salvador, 1964, p. 8) dates the formation more closely. According to Van der Hammen (1958, p. 94) the age range indicated by pollen is from middle Paleocene to early Eocene. The presence of coal indicates a paludal environment.

The Los Cuervos correlates with the upper part of the Lisama Formation of the middle Magdalena Valley section (fig. 9), and with the upper parts of the Angostura, Marcelina, and Trujillo Formations of Venezuela (Sutton, 1946, p. 1630).

Oil is produced from two sandstones of the Los Cuervos in the Carbonera field of the Barco Concession and in the Tarra field of Venezuela (Notestein et al., 1944, p. 1192, 1194). The oil is presumed to have migrated from lower source beds along faults to the present reservoirs where permeability is controlled by fracturing.
This formation is named for Cerro Mirador on the Tarra anticline of the Colón district in southwestern Zulia, Venezuela (Sutton, 1946, p. 1669). It is predominantly light colored, clean, massive, fine- to coarse-grained sandstone with conglomeratic beds containing quartz pebbles. In the lower part, the sandstone is less clean and thinner bedded. Cross-bedding and ripple-marks are common. Interbeds of purplish-gray shale and siltstone are few and thin. A persistent shale break occurs near the middle of the formation in some areas, but has not been found in the area of this report where the Mirador is limited to the southeastern part of quadrangle H-13.

Topographically, the Mirador forms a persistent ridge that is similar to but somewhat more prominent than that of the Barco Formation. The contact with the underlying Los Cuervos is unconformable, at least locally, in the area north of quadrangle H-13 (Notestine et al, 1944, p. 1195), but no unconformity has been noted in the area of this report.

In the eastern part of quadrangle H-13, several estimates of the thickness of the Mirador range from 210 to 235 meters. Notestine et al (1944, p. 1195) report 160-400 meters in surface sections of the Barco Concession in quadrangle F-13, and 251-448 meters in wells of that area. Thicknesses of 80-190 meters are reported from western Táchira, Venezuela (Trump and Salvador, 1964, p. 9).
Diagnostic fossils are lacking, and rare pollen remains are not conclusive as to the age of the Mirador according to Trump and Salvador (1964, p. 9). According to Van der Hammen (1958, p. 94, 95), palynological evidence indicates an early Eocene age for most of the formation and a middle Eocene age for the upper part.

The Mirador correlates with the La Paz Formation of the middle Magdalena Valley section (fig. 9). In western Venezuela, it has been traced around the southern end of the Maracaibo Basin into the Misoa Formation on the eastern side (Sutton, 1946, p. 1669).

Oil seeps have been found in outcrops of the Mirador, but no oil has been produced from this formation in Colombia. However, it has important producing zones in the Tarra field in western Venezuela (Notestein et al, 1944, p. 1195).
The formation name is taken from the Quebrada La Carbonera on the eastern flank of the Petrólea anticline in the Barco Concession in quadrangle F-13 (Notestein et al, 1944, p. 1196 and fig. 10). There the formation is a thick series of gray to greenish-gray and brown claystone and associated sandstone with lignitic coals in the lower and upper parts. A few thin limestone beds occur in the coal-bearing intervals and rare glauconitic zones of limited lateral extent have been found in various parts of the section. In western Táchira, the section is described by Trump and Salvador (1964, p. 9) as an alternating sequence of sandstones, siltstones, claystones, shales and coals with occasional fossiliferous sandy limestones. The fine- to medium-grained brown sandstone contains carbonaceous laminae, and carbonized plant remains are common throughout the section, although coal beds are limited to the lower two-thirds. Sandstone is more abundant in the lower part of the section, and beds are more massive than in the upper part where shale is more abundant. Sections of the Carbonera in the Barco Concession and western Táchira range from 410 to 560 meters thick. The contact with the underlying Mirador is conformable and gradational.
The Carbonera is the youngest Tertiary formation of the Maracaibo Basin section in the area of this report where it crops out in the southeastern part of quadrangle H-13. The upper part and all younger Tertiary beds have been eroded away. The part of the Carbonera that remains is not well exposed, and its maximum thickness is estimated at 375 meters in planchita 121 II-C, C-8 and C-9. The coal beds are thinner and of poorer quality than those of the Los Cuervos Formation, and no instance of mining development of the coals of the Carbonera is known.

Although the widespread occurrence of coal beds and plant fossils indicate a generally non-marine origin for the Carbonera, marine beds are present from which molluscan faunas have been collected and reported from the type locality and from north and west of Cúcuta in Colombia (Notestein et al., 1944, p. 1199) and from southeast of San Antonio in western Táchira, Venezuela (Trump and Salvador, 1964, p. 9). The collections from Colombia have been dated as late Eocene and middle Oligocene, and those from Táchira as late Eocene. On the basis of palynological studies, Van der Hammen (1958, p. 95) assigns the lower part of the Carbonera to the late Eocene and the upper part to the early Oligocene.

The Carbonera may be correlated with the Esmeraldas Formation and the lower part of the Mugrosa Formation of the middle Magdalena Valley section (fig. 9).
Oil is produced from the Carbonera on the Socuavo anticline of the Barco Concession (quadrangle H-13), but it is not a major reservoir (Roberts et al, 1959, p. 27). It is of greater importance as a reservoir in the Tarra field of western Venezuela.
Surficial deposits

Glacial deposits

Deposits of bouldery till are present on the flanks and floors of some of the valleys above 3200 meters altitude in the northern, central, and southeastern parts of quadrangle H-13. These deposits are typically linear to crescentic in form and occur as lateral moraines along the sides of valleys or as lateral and terminal moraines which flank and cross the valleys. In some places glaciofluvial valley-train deposits cover the floors of the valleys. In many places the terminal moraines have been partly to wholly removed by glaciofluvial or modern streams and only the lateral moraines remain. However, well-formed terminal moraines are preserved in some places as in Quebrada El Salado north of Vetas (H-13, a-2 SE.) and in Quebrada Ramírez east of Cachiri (H-13, a-1 NC.). Moraine deposits are well displayed and readily accessible north of Berlin on the road to Vetas. Another extensive but less accessible morainal deposit lies about 7 kilometers north of El Portillo (H-13, b-5 NW.). A large deposit of till and valley-train sediments is located south of Presidente and north of Páramo de Almorzadero (H-13, c-6 NW.).
The glacial deposits were formed by cirque glaciers which formerly occupied favorably situated valley heads. The moraines rarely reach below 3200 meters altitude. Above this altitude glacial erosion is common, and extensive areas of fresh rock stripped of weathered material are exposed, particularly above 3600 meters, as on Morro Nevado (H-13, b-2 NW.). Tarn lakes are common throughout much of the high country.

The glacial deposits are simple and as far as can be determined are of only one age. Four successive parallel moraines, each representing a stage in the retreat of the terminus of a glacier that formerly occupied the site, project into the valley of Quebrada Los Salados where it makes a right-angle bend southeast of Morro Nevado (H-13, b-2 SW.). Nowhere else were multiple moraines seen.
Valley-train glaciofluvial deposits downstream from the former sites of the glaciers are common. These deposits can be recognized by their association with moraines, and that close to their heads the deposits contain boulders far larger than those being moved by the present streams. The valley-train deposits appear to be graded to terrace deposits farther down the valleys. This was noted in Quebrada Ramírez east of Cachirí, and in Quebradas Honda and Los Salados west of Mutiscua. Large terraces in the valleys north of El Portillo in the headwaters of the Río Mataperros (H-13, b-5 W.) appear to be deposits of meltwater streams that issued from former nearby glaciers. Terrace deposits over much of the area are discontinuous and fragmentary owing to steep gradients of the narrow valleys of some of the mountain streams. However, it is reasonable to infer that most, if not all, the terraces in the larger stream valleys in the high country were deposited concomitantly with glaciation. The glaciation was probably accompanied by increased precipitation (Van der Hammen and Gonzalez, 1963) which resulted in increased erosion and transportation by streams in the high country. This appears to have been accompanied by aggradation at somewhat lower altitudes.
Terrace and alluvial fan deposits

Terrace and alluvial fan deposits are widely distributed in the southern half of the report area. Many of the larger stream valleys have terraces or terrace remnants with surfaces well above the modern flood-plain surface. The terraces tend to be widest, most extensive, and least dissected in the upper reaches of valleys. Examples can be seen at Mogotes, on the páramo near Berlín and in the valleys of Río Guaca and Perchiquez. Downstream, particularly in the deeper canyons, the terrace deposits are dissected and quite fragmentary. They appear to be remnants of more extensive alluvial deposits that once may have filled most of the large valleys in the zone but are now undergoing erosion. In places, one or two smaller and lower fragmentary terraces are present with surfaces not far above the modern flood plain. These were noted in places along the Río Chicamocha near Cepita and in the Bucaramanga area along the Río de Oro and its tributaries.

Extensive coalescing alluvial fans at and south of Bucaramanga partly fill the basin west of the mountain front. These deposits are being dissected by the modern drainage. Near Bucaramanga the Río de Oro flows about 150 meters and the Río Suratá flows about 350 meters below the surface of the fans. South toward Floridablanca and Piedecuesta, the coalescing fans are less dissected and form a fairly continuous, westward-sloping surface. The apex of each fan coincides with, but lies at a considerably higher elevation than, the mouth of a modern stream valley issuing from the mountain front.
The Bucaramanga terrace, on which the city of Bucaramanga is located, has been described by de Forta (1959, p. 5-13) and Julivert (1963, p. 41-59). The lower part of the terrace is composed of fluvial gravel, sand, silt, and minor clayey beds. The upper part is composed of unsorted bouldery materials interpreted by us as colluvial deposits. The colluvial deposits thin away from the mountain front, have a greater surface gradient than that of the underlying stream deposits, and are restricted to a zone along the valley sides.

The gradient of the upper surface of the fluvial deposits appears to be more gentle than that of the surface of the terrace on the overlying colluvial deposits. The top of the stream deposits on the edge of the Bucaramanga terrace overlooking the gorge of the Río Surate is at about 700 meters. To the north, the top of the stream deposits lies at about 825 meters. Towards Girón, flat surfaces on remnants of the dissected terrace lie at about 850 to 825 meters. The surface may have been graded to a divide to the Río Sogamoso at about 900 meters elevation on the west side of Mesa de Los Santos. However, the present axis along the lowest part of the surface of the deposits seems to plunge northward rather than southward in the direction of the present drainage. The terrace deposits appear to have completely filled the valley of Bucaramanga and Girón for they abut against the west wall of the valley near Girón where they are tilted up at the Suárez fault (Julivert, 1963, figs. 6, 7, laminas II, III). Here landslide debris from slopes to the west unconformably cover the upturned terrace deposits here.
The lower fluvial deposits appear to be derived chiefly from Jurassic and Cretaceous sandstones. This is particularly true south of Girón and suggests a source in that direction. Julivert (1958, p. 34-36) proposed that the deposits were laid down by the ancestral Río Chicamocha-Sogamoso before capture from the west by streams north of Zapatoca.

Remnants of terraces, apparently formerly continuous with the fluvial deposits of the Bucaramanga terrace, flank the sides of the Ríos Suratá and Tona in the mountains east of Bucaramanga.

The wedge of colluvium at the top of the Bucaramanga terrace has a somewhat uneven surface. Features such as the Lagos de Florida and the Lagos del Cacique south of Bucaramanga may be natural depressions on an irregular initial surface. The boulders in the material range from hard quartzite (Tambor Formation) through white to purple, soft, crumbly arkosic sandstone (Girón Formation) to very soft, punky, almost saprolitic feldspathic gneiss (Bucaramanga Gneiss) and quartz monzonite (La Corcova Quartz Monzonite). The color of the matrix is a deep red in most places, but in others it is brown or even yellow gray. The latter material seems to be derived entirely from areas underlain by La Corcova Quartz Monzonite, as can be seen in a road cut on the highway near Floridablanca. The material making up the colluvial deposits must have been derived from deeply weathered parent material, such as is found today on the mountains east of Bucaramanga. In some places materials of unlike color and texture are in sharp contact with one another. This relationship suggests that the colluvial deposits are composite; the individual deposits are derived from a broad range of source material.
Modern landslide deposits are found throughout Zone III, but nowhere today are colluvial deposits as extensive as those on the Bucaramanga terrace being laid down. Some large inactive landslide deposits, such as those at Lago de Ortices (I-13, a-1 SE.), are contemporaneous with the colluvial deposits on the Bucaramanga terrace. Julivert (1963, p. 55) comments on the widespread presence of this type of deposit in the Cordillera Oriental.

Small terraces whose surfaces lie at lower elevations than that of the terrace and fan deposits of the Bucaramanga type are present in the Bucaramanga area, near Mogotes, and near Cepita on Río Chicamocha. The surfaces of these terraces are nearer to the elevations of the adjacent modern flood plain than to the elevations of the overlooking fan and terrace deposits.

The terrace and fan deposits are so widespread throughout the zone and everywhere show such similar characteristics, that they are considered to represent a single time-stratigraphic deposit. Their widespread distribution suggests that they were formed in response to a change in climatic conditions rather than to changes in base level of streams due to local tectonism (Prof. Roy J. Shlemon, oral commun., 1968). In the section on glacial deposits, we indicated that the terrace and fan deposits can be related to glacial deposits by tracing of surfaces of terrace deposits into outwash deposits. This has not been done systematically, but it is reasonable to infer that they were formed contemporaneously. The small lower terraces, of course, are younger and represent pauses in postglacial down-cutting due to climatic fluctuations or possibly to tectonic events.
Colluvial deposits

Areas of thick landslide, talus, mud flow, and other colluvial deposits have been combined in a single unit on the geologic maps. Landslide deposits are most common on steep slopes, particularly where a more resistant rock overlies a less resistant rock. The age of these deposits, as suggested in the previous section, probably ranges from Pleistocene to Holocene. Landsliding is an active process throughout the zone.

Landslides form a larger part of this map unit in the eastern part of quadrangle H-13 than they do elsewhere. In c-4-W., an area of 4 to 5 square kilometers of sandstone of the Aguardiente Formation has crumbled and slid down-dip southeastward toward Río Chitagá. In c-7-E., landslides in a cirquelike basin in the Aguardiente and Capacho Formations are funneling down through the narrow Quebrada Agua Sucio toward Río Servita. In c-7-SE., a large slide has occurred in the Barco, Colón, and Mito Juan Formations which has moved northeastward toward Quebrada El Oso. On the surfaces of these slides, features can be seen on aerial photographs which are similar to those seen on the surfaces of glaciers, including crevasses and pressure ridges transverse to the direction of movement.
Alluvium

The most extensive areas of alluvium flank major streams, such as the Ríos Lebrija and Sogamoso, where they flow on the floor of the Magdalena Valley in the western part of quadrangle H-12.

In the mountainous areas alluvial deposits are sparse. Some of the deposits mapped as alluvium in the high paramo are possibly in part or entirely correlative with the terrace and fan deposits and are possibly Pleistocene.
The pattern of regional metamorphism in the southern half of Zone III is complicated by post-metamorphic batholiths, by the presence of at least two periods of regional metamorphism, and by extensive faulting that has juxtaposed at the present level of exposure huge blocks of the massif which were metamorphosed at different depths in the crust. Accordingly, metamorphic isograds commonly follow stratigraphic boundaries, the contacts of intrusive masses, or faults. Where isograds follow faults or stratigraphic boundaries, the rock units themselves act as metamorphic zones delimited by the faults or stratigraphic contacts. The isograds drawn indicate the first appearance of certain index minerals that formed at the peak of regional metamorphism.

Isograds in the Bucaramanga Gneiss and the Silgara Formation appear to form a single simple pattern even though it is likely that more than one period of metamorphism has affected the older rocks. The distribution of the isograds is not influenced by the Jurassic-Triassic batholiths of the Santander Plutonic Group.

Isograds in the Floresta Formation do not coincide with those in the underlying rocks. Except locally for the Diamante Formation, rock units younger than the Floresta Formation are not metamorphosed. However, the Diamante Formation of Permian-Carboniferous age is noticeably recrystallized in areas where the Floresta Formation shows the most metamorphism.
Bucaramanga Gneiss

The Bucaramanga Gneiss is composed of rocks of high metamorphic grade, entirely within the sillimanite isograd, that belong to the upper amphibolite facies. Mineral assemblages indicate metamorphism of the Bosost type because of the complete lack of kyanite, the general lack of garnet, and the prevalence of andalusite and cordierite (Winkler, 1967, table 7). Typical assemblages are shown in table 3.

The gneiss has undergone varying degrees of retrograde metamorphism in which aluminum silicates have been sericitized and cordierite has been pinitized. Because of the difficulty in distinguishing primary from secondary muscovite in the field, only the first sillimanite isograd marking the beginning of the sillimanite-cordierite-muscovite-(almandine) subfacies of the cordierite-amphibolite facies (Winkler, 1967, p. 121-122) has been shown. An examination of the mineral assemblages (table 3) shows that the sillimanite-cordierite-orthoclase-(almandine) subfacies has also been reached. Rocks of this subfacies are in fact fairly widespread. The presence of andalusite and sillimanite in one assemblage should be noted. Discussion of this association will be deferred to the section on the Silgará Formation.

<table>
<thead>
<tr>
<th>Mineral Assemblage</th>
<th>Proportion</th>
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<tbody>
<tr>
<td>Quartz + Plagioclase + Biotite</td>
<td>40.0%</td>
</tr>
<tr>
<td>Quartz + Plagioclase + Chlorite</td>
<td>40.0%</td>
</tr>
<tr>
<td>Quartz + Plagioclase</td>
<td>20.0%</td>
</tr>
</tbody>
</table>

Note: Proportions are given in percentage of the total volume of the mineral assemblage in each sample.
In the belt of Bucaramanga Gneiss east of Bucaramanga, garnet is extremely rare; a trace of garnet was seen in only one specimen. The composition of this garnet is unknown. Aluminum silicates are andalusite and sillimanite with cordierite, indicating low pressure-high temperature assemblages. No orthopyroxenes have been observed and biotite is universally present indicating that none of the rocks belong to the granulite facies. No wollastonite was found in calcareous rocks.

The same assemblages prevail in the Bucaramanga Gneiss in the Berlín-Vetas belt of Gneiss. A trace of garnet was noted in the Tona area, but it is typically lacking in the main part of this belt. Only in paragneisses in the Río Carabá area northeast of Berlín near the Silgará Formation is garnet abundant. Interestingly enough, some of the layers of granitic gneiss contain traces of garnet.

The Bucaramanga Gneiss in the Chitaga-Pamplona area has assemblages similar to those observed elsewhere. East of Chitaga, the bulk of the rocks appear to be in the sillimanite-cordierite-orthoclase (almandine) subfacies.
These rocks were metamorphosed within the range of temperatures at which migmatitic gneiss forms through anatexis of rocks of appropriate composition. The migmatitic character of much of the Bucaramanga Gneiss is in keeping with the degree of metamorphism involved. As discussed under the description of the Bucaramanga Gneiss, some layers are too thick and too obviously discordant in composition and structure to have formed by anatexis in situ. However, many of the small features of the migmatitic gneiss could well be of local anatectic origin. The fluidal structures in some of these gneisses indicate extreme plasticity during deformation. Some layers of meta-arenite are quite granitoid in appearance.
The Silgará Formation is typically low or medium grade. Its mineral assemblages are those of the greenschist or lower amphibolite facies, although locally assemblages diagnostic of the upper amphibolite facies occur. Like the Bucaramanga Gneiss, the Silgará has been affected to varying degrees by retrograde metamorphism.

The range of facies series in which the Silgará Formation has undergone metamorphism is more apparent than in the Bucaramanga Gneiss. In the northern part of the Quebrada Silgará belt, the rocks are within the greenschist facies, but to the south they pass into the amphibolite facies. Chloritoid, staurolite, and garnet, except for rare traces, are lacking. In the higher grade rocks to the south, pelitic rocks contain andalusite, cordierite, and sillimanite (table 3). These assemblages are typical of the Abukuma or Bosost-type facies series. In the Tona area garnet and staurolite are present although not in great abundance. In the remainder of the belts of the Silgará Formation, typical assemblages in the upper greenschist and lower amphibolite facies contain garnet and staurolite, and with increasing metamorphism they contain andalusite, cordierite, and sillimanite. The presence of garnet and staurolite in low- to middle-grade rocks in this area could be interpreted as evidence that the Silgará Formation may have metamorphosed in a somewhat higher pressure series than elsewhere. Chlorite persists into the amphibolite facies in some rocks in the Silos and Pescadero areas probably due to an unusual bulk composition of these rocks.
Mineral parageneses in the Silgará Formation as well as those in the Bucaramanga Gneiss suggest a complex metamorphic history. Early muscovite, chlorite, biotite, and sillimanite, particularly fibrolite, are generally oriented parallel to the foliation or to a cleavage. Long axes of andalusite and staurolite crystals tend to lie in the plane of foliation, but tend to be randomly oriented within that plane. The orientation of these two minerals may be mimetic or controlled by narrow zones of suitable composition. Garnet in some specimens shows a spiral structure. On the other hand, some biotite and chlorite porphyroblasts have grown athwart the foliation. Late muscovite forms mats of fine flakes or groups of large poikiloblastic flakes without preferred orientation. These muscovites may be related to the widespread retrograde metamorphism. Many porphyroblasts of cordierite and some of andalusite contain needles of sillimanite whose long axes lie in the plane of foliation. This relationship suggests post-kinematic growth of the andalusite and cordierite and further demonstrates the non-contemporaneity of individual minerals in the reported assemblages (table 3). Metamorphic crystallization, which may have been either continuous or have taken place in steps, occurred under changing conditions of pressure and temperature. Petrographic relationships described briefly above were seen throughout the Bucaramanga Gneiss and Silgará Formations and suggest that an earlier phase of metamorphism with a strong dynamic element was followed by a later more static phase. The apparent typomorphic minerals of the Abukuma facies series in these rocks may be in part the overprint of
static-thermal conditions of metamorphism on an earlier assemblage possibly formed in a different facies series. The change from crystallization under dynamic conditions to crystallization under static conditions could have occurred during a single continuous period of metamorphism.
The Floresta Formation locally has been metamorphosed within the greenschist facies to form argillitic slates to phyllites. Quartz, chlorite, and muscovite constitute the usual mineral assemblage. Porphyroblasts of garnet, chloritoid, and biotite are present only in the area south of Berlín at the north end of the Covarachia-Silos belt of the Floresta Formation, but some of these rocks may actually belong to the Silgará Formation.

Structures and minerals of the rocks of the Floresta Formation are products of dynamothermal metamorphism. In the Mogotes area, for example, three sets of S planes can be distinguished readily bedding - $S_1$, primary foliation - $S_2$, and a slip cleavage - $S_3$. Metamorphic minerals are oriented parallel to $S_2$ which is not everywhere coincident with $S_1$, and some reorientation and recrystallization of minerals accompanied the development of $S_3$. No late postkinematic porphyroblasts have been observed in this area.
Orthogneiss

Mineral assemblages of the different types of orthogneiss are stable over a wide range of middle- to high-grade metamorphic conditions. However, where the metamorphic grade of the enclosing rocks is low (greenschist facies), the orthogneiss contains more chlorite and epidote, has more thoroughly altered plagioclase, and shows less annealing of cataclastic texture than orthogneiss enclosed in rocks of higher metamorphic grade. These features are well displayed in the orthogneiss around Coverachia and Capitanejo where the surrounding rocks are of low metamorphic grade as contrasted with orthogneiss in rocks of high metamorphic grade north of Berlín.

The concordance of foliation and lineation in the orthogneiss with these structures in adjacent rocks of the Bucaramanga Gneiss and Silgará Formation are interpreted as indicating that all three rocks have undergone the same dynamothermal metamorphism. Whether the orthogneiss was emplaced as magma during metamorphism, or is plutonic rock emplaced and solidified prior to metamorphism is not certain.

Radiometric age determinations (table 2) and the observation in many parts of the world that emplacement of batholiths and regional high-grade metamorphism are spatially related form the basis for believing that the orthogneiss was emplaced more or less synchronously with the regional progressive metamorphism of the Bucaramanga Gneiss and Silgará Formation. Details of the internal textures and structures of the orthogneiss have been given earlier in the section on the description of the unit.
Retrograde metamorphism

Many features indicating a widespread retrograde metamorphism have been mentioned in the preceding sections. These features are most pronounced in the Bucaramanga Gneiss and in certain areas of the Silgará Formation. The Floresta Formation does not show retrograde effects.

In the Bucaramanga Gneiss the most prominent retrograde features are pinitized cordierite, saussuritized plagioclase, and sericitized sillimanite and andalusite. Potassium feldspar is generally unaffected, although it may be kaolinized or sericitized in some places. Hornblende is little affected, although clusters of epidote, biotite, and chlorite with sphene and iron oxide in some rocks may be relics of the complete alteration of hornblende. Widespread and pervasive muscovitization is characteristic of much of the retrograde metamorphism. In places it is difficult to distinguish this muscovitization from that caused by dynamic metamorphism produced by local shearing and faulting. In some rocks the muscovitization has produced only mats of sericite; in other places the sericite appears to have coalesced to form large, nonoriented, commonly poikiloblastic muscovite flakes that have replaced aluminum silicates or cordierite. Fibrolite is pseudomorphed by muscovite in many rocks, but in other rocks oriented sillimanite needles are preserved in muscovite porphyroblasts. In some rocks coupled reactions have taken place in which biotite altered to chlorite providing potassium for the sericitization of aluminum silicates.
Retrograde metamorphism in the Silgará Formation, particularly in rocks in the greenschist facies, is less evident than that in the Bucaramanga Gneiss. This is because these low-grade mineral assemblages were more or less stable under the conditions of the retrograde metamorphism. In rocks in the lower amphibolite facies, particularly in the Pescadero-Aratoca belt, garnet has in part been chloritized and staurolite has been to some extent altered to sericite and chlorite. Otherwise reactions are similar to those in the Bucaramanga Gneiss. Retrograde chlorite can be distinguished from prograde chlorite by the usually anomalous interference colors of the former and by its inclusions of exsolved iron oxide and in some cases leucoxene.

In the orthogneiss similar retrograde effects are observed. However the restricted mineral assemblages of these rocks limit the effects to biotite and plagioclase, which may be partly chloritized and saussuritized, respectively.

The retrograde metamorphism was accompanied by appreciable activity of water and potassium. Temperatures were apparently those of the greenschist facies. The time of this metamorphism in relation to the prograde metamorphisms, beyond that it is younger than the metamorphism of the Silgará Formation, is unknown.
Contact metamorphism

Contact metamorphic effects of the batholiths of the Santander Plutonic Group are minor. No hornfels has been observed. The only effect noticed in the field was a coarsening of grain size of muscovite in certain rocks of the Silgará Formation at their contacts with the intrusives. For example, large round plates of poikiloblastic muscovite are prominent near the contact with the Pescadero Granite south of the bridge over Río Chicamocha at Pescadero. Probably, however, more effects took place in the wall rocks than has been noticed.

Contamination of the plutonic rocks by the meta-sediments, however, is usually more prominent. Muscovite and garnet are common in granite and quartz monzonite near contacts with meta-sediments. This was noticed along the east side of the Río Negro batholith and in some of the La Corcova Quartz Monzonite. The Durania Granite is liberally contaminated by the schists it intrudes. The Santa Bárbara Quartz Monzonite is in places more biotitic and contains hornblende adjacent to hornblendic rocks.
Summary and discussion

The regional dynamothermal metamorphism of the Bucaramanga Gneiss and the Silgará Formation is of the Bosost type facies series in the belt of metamorphic rocks on the west side of the massif, east of the Bucaramanga fault and possibly of the Eastern Pyrenees-type facies series along the east side of the massif and in the Silgará Formation west of the Bucaramanga fault south of Bucaramanga. These facies series may be considered variants of the Abukuma-type facies series.

On the basis of the mineral assemblages, it is estimated that the maximum temperatures of the metamorphism were at 600 to 700°C and the maximum depths of burial were about 10 km for the rocks on the east side of the massif and perhaps 15 km for those on the western side of the massif.

However it should be pointed out that the rocks on the eastern side of the massif that show evidence of belonging to a somewhat higher pressure facies series than those to the west are restricted to the middle- and low-grade zones of the Silgará Formation. It is possible that whereas the temperature-pressure curve of Abukuma-type metamorphism was relatively straight in the western belt, the curve was concave in the eastern belt with lower than normal temperatures at the shallow depths and standard temperatures for this type of metamorphism at greater depth. It is the Silgará Formation that shows more clearly the difference in metamorphic facies series from place to place and not the Bucaramanga Gneiss. This could be interpreted as having resulted from the Bucaramanga Gneiss having been metamorphosed under different conditions and at an earlier time than the Silgará Formation. However there is no concrete evidence for such interpretation.
A static phase of thermal recrystallization appears to have followed an earlier dynamic phase in both the Eucaramanga Gneiss and Silgará Formation.

The major regional dynamothermal metamorphism occurred prior to the deposition of the Floresta Formation, which rests unconformably and with metamorphic discontinuity on rocks of the Silgará Formation and on orthogneiss. Radiometric Rb-Sr whole rock determination on orthogneiss and meta-diorite indicates an upper Ordovician age for the metamorphism of these rocks. Because Precambrian gneisses of high metamorphic grade are involved, however, a period of Precambrian metamorphism may have occurred prior to the Ordovician event. An alternative explanation is that the Ordovician ages are actually, Precambrian ages partially made younger during the post-Devonian metamorphism. This would be possible if the Silgará Formation were Precambrian also and not Cambro-Ordovician as believed. Radiometric dates that support the Ordovician age of the orthogneiss are found in the nearby Cordillera de Merida of Venezuela where Bass and Shagam (1960, p. 381) report Rb-Sr ages of $410 \pm 40$ and $420 \pm 105$ m.y. on muscovite from phyllite and whole rock (schist) respectively. To the south, in the Serranía de la Macarena, Pinson and others (1962, p. 907-960) report ages of about $436$ and $484$ m.y. from pegmatites. These widely distributed radiometric ages suggest a regional plutonic-metamorphic event in northwestern South America during the lower Silurian-upper Ordovician.
The metamorphism of the Floresta Formation is regional prograde dynamothermal and everywhere of low grade. This metamorphism also affected the Permo-Carboniferous Diamante Formation, but it predates the deposition of the continental deposits of Bocas Formation of Triassic age. A phyllite in the Silgará Formation between Sardinata and Ocaña in the north part of Zone III gives a K-Ar age of 221±8 m.y. (table 2) or lower Triassic although this date may reflect some resetting by the nearby Aguablanca batholith from which 196±7 m.y. (table 2) age was obtained. Radiometric dating of metamorphic rocks in the nearby Cordillera de Merida of Venezuela has given similar ages ranging from 230 to 280 m.y. (Bass and Shagam, 1960, p. 381).

Retrograde metamorphism characterized by high water and potassium activity affected rocks of the Bucaramanga Gneiss and Silgará Formation over most of Zone III. The time of this metamorphism is uncertain. It could be related to the regional progressive low-grade metamorphism of the Floresta Formation. The retrograde metamorphism appears to be too widespread to be related to the emplacement of the batholiths of the Santander Plutonic Group, all of which have negligible contact metamorphic effects but might be related to the initial rise of magma.
STRUCTURE

Structural features of the metamorphic rocks

Primary minor structural features are well preserved in many of the metamorphic rocks, although they are frequently distorted. In the Floresta and Silgará Formations, small-scale features such as lamination, graded bedding, fine-scale cross-bedding, channeling, and intraformational conglomerate are present in many rocks, particularly in meta-siltstones and meta-sandstones of the greenschist facies of metamorphism. In rocks of higher metamorphic grade these features are less evident. In the highest grade rocks, such as the Bucaramanga Gneiss, only gross compositional layering reflecting the original sedimentary bedding is preserved.

Foliation in the Bucaramanga Gneiss is in most places parallel to compositional layering, both on large and small scales, so that foliation symbols on the map normally indicate the attitude of the layering or relict bedding as well. In the Silgará and Floresta Formations, however, foliation and bedding are commonly discordant to one another; only in the more arenaceous thin-bedded rocks are they generally parallel. In some places foliation and bedding are grossly discordant, particularly in the axial zones of folds. This relationship is best seen in the thicker pelitic beds. Foliation symbols in the Silgará and Floresta Formations therefore cannot be relied upon to depict the attitude of layering or bedding.
Slip cleavage is the most prominent structural feature in rocks of the Floresta Formation in the Mogotes area and the Coverachia-San Andrés belt. The slip cleavage generally is at a high angle to layering and foliation. Many of the foliation symbols in the Floresta Formation were actually measured on this cleavage and cannot be used to interpret attitudes of beds and foliation. In areas where cleavage and foliation were distinguished and cleavage symbols are present, the foliation and bedding symbols may be relied upon. Cleavage in the Silgara Formation parallels axial surfaces of crinkles, chevron, or drag folds in schist.

Attitudes of minor folds, the strike and dip of their axial surfaces, and more commonly the strike and plunge of their axes, are indicated in some places. Although the mapping of these features was rather spotty, they help to interpret the gross structure of the rocks and the orientation of the stress field that prevailed during folding and metamorphism. Where attitudes of fold axes range widely over small areas, folds of several generations have been measured, or faulting has disrupted the pattern. In the latter situation, attitudes within any one fault block should be consistent, but may be at variance with attitudes in adjacent blocks. Where folds of several generations are present, axes with different orientations may be measured in single outcrops. This situation is not uncommon in the Santander Massif, and indicates a rather complex history of deformation.
Two sets of folds seem to be present. One set is characterized by tight to isoclinal folds with foliation tending to be non-parallel areas. The other set is characterized by more open folding of both layering and foliation with the development of slip cleavage parallel to axial surfaces. The two types are not distinguished on the geologic maps.

Minor folds in the Bucaramanga Gneiss are less conspicuous, although tight isoclinal folds are present. Broadly folded foliation and layering are common. In the migmatitic rocks, folds tend to be disharmonic and reflect the high degree of plasticity of the rocks during deformation.
Structural trends and major structural features

Structural attitudes measured in the metamorphic rocks are sufficient to indicate the general trend of these rocks but are insufficient to more than suggest locally their internal pattern of folding. The trends of foliation and orientation of folds are more or less similar in the Bucaramanga Gneiss, the Silgará Formation, the Floresta Formation, and the orthogneiss. Regionally, trends are north-south and parallel the grain of the Cordillera Oriental with only local departures. The continuity of the trends in the basement rocks of the massif is broken by the batholiths and where covered by sedimentary rocks.
Bucaramanga-Silgará-Cepita belt.—The Bucaramanga Gneiss in the belt east of Bucaramanga has a general north to northwest trend, but the rocks are so intensely folded and sheared that little can be said about overall structural patterns within the belt. Fold axes are subparallel to or strike into the Bucaramanga fault and are clearly much older than it. There is a suggestion of a syncline in the gneiss from the Bucaramanga area to the Piedecuesta area between the Bucaramanga fault and the La Corcova Quartz Monzonite. The axis plunges northwesterly. Axes of minor folds plunge fairly consistently to the northwest in the gneiss from Bucaramanga to the Tona area. They bear more to the west than the strike of the Bucaramanga fault. Dips of foliation in the gneiss between the La Corcova pluton and the Santa Bárbara batholith in the Sevilla area and south to the Cepita-Umpala area are relatively gentle. Further south it is noteworthy that dips in the gneiss are to the east on the east side of the Bucaramanga fault and to the west in the roof pendants in the Mogotes batholith west of the fault. In the Silgará Formation east of the Río Negro batholith the general trend of foliation is north-south. The rocks are apparently highly folded to the north with no clear pattern. Near the southern end of the Silgará belt, the Silgará Formation appears to lie in a northward plunging syncline.

South of Matanzas and northwest of Tona, the Silgará Formation trends east-west and dips of layering and plunges of fold axes are to the northwest, off the underlying Bucaramanga Gneiss. Here and near Tona, and in the patches of Silgará to the south, the attitudes and outcrop pattern suggest that the Silgará is fairly flat-lying.
Piedecuesta-Aratoca-Mogotes belt. -- The metamorphic rocks in the belt from Piedecuesta to Mogotes all lie west of the Bucaramanga fault and, except for the roof pendants of Bucaramanga Gneiss in the Mogotes batholith along the fault in I-13, consist of the Silgará Formation and, in the Mogotes area, the Floresta Formation. In the Pescadero-Aratoca area the trends are north to northwesterly. Axial planes of folds were measured only in one area south of Pescadero where the attitudes suggest vergence of folding toward the northeast. Here, axes of minor folds plunge to the southwest. However, north of Pescadero plunges are to the northeast, and to the south in the Aratoca area, plunges of folds are to the southeast. This distribution of plunges is domical. Near Mogotes cleavage and foliation strike generally northerly whereas layering strikes generally east-west. The area of Silgará Formation southeast of San Joaquín and northwest of Onzaga is synclinal if the foliation and layering are parallel. Trends of planar features in the Floresta Formation in this area tend to follow trends in the older rocks. Slip cleavage is prominent in the Floresta here and strikes northerly.
Berlín-Vetas-Páramo Santurban area. — The most prominent structural feature in the Páramo de Santurban area is the incomplete dome in the Río Caraba area. This dome plunges moderately southward near the Río Caraba and gently northward in the Morro Nevado and Vetas areas. The Silgará Formation dips off the dome on the east side and wraps around the Bucaramanga Gneiss and orthogneiss on the south side. The map pattern of the orthogneiss and Silgará Formation west of Mutiscua suggests the presence of gently plunging isoclinal folds within the major feature. The orthogneiss appears to represent the core of an anticline and the Silgará to the west a complementary syncline. These folds must be refolded near the Río Caraba. Further west, toward Vetas and California, the patterns are less clear. Trends are northward and foliation and layering, at least in the western part, dip west. Near Morro Nevado some outcrops show reverse drag folds with westward dipping axial planes indicating overturning to the east. Several large isoclinal folds can be seen in the excellent exposures of Bucaramanga Gneiss in this area. However observations are lacking elsewhere so that the complete fold pattern of this belt cannot be determined. East of Cachiri, the distribution of rock types in the Bucaramanga Gneiss suggests either a westward dipping homoclinal or isoclinally folded sequence. South of this area toward California there is no clear pattern.
Pamplona-Chitagá area.—The metamorphic rocks near Pamplona and Chitagá lie in fault-bounded blocks and little can be said about their structural pattern. Trends of foliation and layering are generally northward as elsewhere. At Pamplona the orthogneiss is greatly sheared with vertical shear planes. The Silgará Formation in the area southwest of Pamplona, near Morro Negro, appears to dip off the Bucaramanga Gneiss east of the intervening Durania Granite. The Bucaramanga Gneiss near Chitagá, on the other hand, dips gently to moderately eastward, but the Silgará Formation further east appears to be folded with asymmetry to the west. Information is scanty in the southern part of this belt.

Baraya-Guaca-San Andrés belt.—Trends in the metamorphic rocks of the belt east of the Santa Bárbara batholith are also northerly. Westward-dipping cleavage and axial planes of minor folds suggest that minor folds in the Floresta Formation are asymmetrically overturned to the east. Plunge of minor fold axes near Baraya and San Andrés are south-southeastward as in the Aratoca area. There is a general northwest trend to layering and foliation in the area from San Andrés south. East-west trends are recorded in the Bucaramanga Gneiss west of the Bucaramanga fault in this area.
Summary.—The prevailing structural trends in the metamorphic rocks of the southern half of Zone III are northerly with north-northwest strikes somewhat predominant over north-south and north-northeast strikes. Complexity of deformation seems to decrease from the older to the younger rocks. Where the trends of later deformations departed from those of earlier ones, the imprints of the earlier deformations are blurred. The complex folding seen in some outcrops of Bucaramanga Gneiss cannot be adequately depicted on the geologic maps. Retrograde features in the pre-Devonian metamorphic rocks, local shearing and mylonitization, and lineation in much of the orthogneiss, all attest to a history of repeated deformations, the chronology of which is somewhat obscure. It appears, however, that the orientations of the stress fields of the successive deformations were somewhat similar and that this resulted in folds, foliation, and lineation that trend roughly north-south in all the rocks.
Lineaments

Lineaments mapped on aerial photographs were interpreted as faults where this interpretation best fitted the map pattern. Elsewhere the lineaments could be either faults or joints. Most of the lineaments shown in the Río Negro batholith in northeastern H-12 are joints that reflect a regional fracture pattern in the uniform rock of the batholith. These joints probably formed in connection with movements on the Bucaramanga fault. Such lineaments are less evident in the other batholiths.

Drainage channels commonly develop along faults and joints because of the fractured and generally weakened condition of the rocks in such places. As a consequence, many linear drainage channels are indicated as lineaments on the geologic maps even though little or no relative displacement can be detected. In flat-lying or nearly horizontal beds, such as on the Mesa de Los Santos, numerous linear drainage channels are apparent on the aerial photographs, some with relative vertical displacement and others without.
Mylonite

Zones of mylonite, phyllonite, mylonitic gneiss, and cataclasite are encountered in many places. Many of these zones lie east of the Bucaramanga fault both near and several kilometers from it. They are not, however, clearly related to it. Dips of some of these zones are gentle in contrast with the apparent steep dip of the Bucaramanga fault. Near Piedecuesta mylonite strikes into the fault, but it could be argued that mylonite, formed during early movements on the fault, could have been rotated by later movements on the fault. Northeast of Pescadero, near Umpala, mylonite dips gently away from the fault. Mylonite can be traced for about 10 kilometers northeast of Los Curos along the contact of the Bucaramanga Gneiss with the La Corcova Quartz Monzonite. This mylonite dips westward, in places gently, into the Bucaramanga fault. It is exposed along the road about a kilometer east of Los Curos (120 IV-B, C-14 SE). Another narrow zone further east within the La Corcova is vertical but also strikes northerly. Even further east and exposed on this same road near the east contact of the La Corcova with the Bucaramanga Gneiss is another mylonite zone within the Bucaramanga Gneiss that dips gently to moderately westward into the adjacent more steeply-dipping intrusive contact.
Sheared rock dipping gently west was encountered at places along the Río Sevilla to the north. A very narrow zone, less than a meter wide and dipping gently east, crops out at the contact of the Silgará Formation with Bucaramanga Gneiss and La Corcova Quartz Monzonite west of Alto El Picacho on the Bucaramanga-Pamplona highway. One or the other of these zones may connect with the zone on the east side of the La Corcova Quartz Monzonite on the Los Curos-Guaca road to the south.

Narrow zones of mylonite crop out in the Bucaramanga Gneiss on the Bucaramanga-Pamplona highway a few kilometers air-line east of Bucaramanga. On strike and further north, westward-dipping, mylonite and phyllonite crop out along the west side of the Río Suratá and in places in the block of Bucaramanga Gneiss east of the Río Suratá where moderate dips both to the east and west are encountered. With more detailed work it might be possible to trace out zones of mylonite and to connect some of the outcrops described above. Zones of mylonite are not readily seen on aerial photographs because of the relatively competent character of the rock and are often overlooked in rapid reconnaissance mapping in the field.

Elsewhere in the zone, mylonite crops out in dioritic orthogneiss southwest of Babega (110 IV-C, E-1 NW). The orthogneiss near Pamplona is markedly sheared. Mylonite dips westward in orthogneiss near the contact with the Floresta Formation south of Covarachía.
Some of the mylonite may be related to late high-angled faults. However such faults are generally more typically characterized by breccia with open voids and discrete surfaces with slickensides and in some cases by hydrothermal alteration. The broad range of attitudes of the mylonite and the commonly moderate or gentle dips, as well as its tight, competent character indicate that it represents an older generation of faulting that took place deep in the crust. A detailed study of the mylonite zones and their distribution might reveal that the Santander massif at one time underwent appreciable low-angle thrusting. These zones, like some of the rock units, have been perhaps folded and dislocated by later faults. The antiquity of some mylonite is indicated by the presence of pebbles of mylonite in conglomerate of the Bocas Formation of Triassic age found north of Bucaramanga and west of the Bucaramanga fault. The presence of these clasts of mylonite indicated fault movements in Triassic or pre-Triassic time.

Some mylonite could be as old as the proposed late Ordovician Orogeny that metamorphosed the Silgará Formation. That some mylonite is related to the Bucaramanga fault cannot be ruled out. Some mylonite zones may mark local thrusts contemporaneous with lateral movement on the Bucaramanga fault.
Faults of pre-Cretaceous age

A thrust fault system older than the emplacement of the tonalite and granodiorite of Paramo Rico pluton has been postulated around the south end of the Río Caraba dome as described in the section on northerly-trending faults below.

The outcrop pattern of the continental deposits of Triassic and Jurassic age suggests deposition in north-trending basins separated by positive areas or it suggests post-deposition differential uplift and erosion with north-south central in pre-Cretaceous time. In either case faulting may have played a part. Conglomerates in the Bocas Formation near the hydro-electric plant on the Río Suratá northeast of Bucaramanga (109 IV-D, G-2 SW) contain pebbles of mylonite and granite of a type present in the massif to the east. This shows that part of the massif was exposed in Triassic time. Faulting may have contributed to the uplift.

Julivert and Tellez (1963, p. 9-15) have presented estimates that the Aratoca and Suratá faults were active in pre-Cretaceous time and that the Suratá fault had a sense of movement opposite to that which it has had since the Cretaceous.
The structural control for the emplacement of the batholiths was discussed in an earlier section. The strong north-south control evident in the distribution of the batholiths and in the linearity of their eastern and western margins suggests prebatholith or penecontemporaneous fault control. The age of these faults would be no younger than early Triassic to Jurassic. They probably are younger than the marine deposits of Permian and Carboniferous age.
The Bucaramanga fault dominates the fault pattern in the southern half of Zone III (fig. 11). It is a fault of regional extent that can be traced from near the southern end of the Santander massif to the Caribbean coast west of Santa Marta where it is called the Santa Marta fault. The name Santa Marta fault has been applied to the fault in the Bucaramanga area as well. We prefer to keep the name Bucaramanga fault for that part of the Santa Marta-Bucaramanga fault system in Zone III, at least for that part south of Ocaña, because the fault is not a single straight lineament but appears to be a system of some complexity (fig. 11). Clear topographic expression of the fault system is limited to the area south of the Río César valley (all of fig. 11). To the north, the Santa Marta fault is expressed chiefly in the sub-surface (Tschanz, written commun., 1968).
The most prominent feature of the Bucaramanga fault in the Santander massif is its topographic expression, although there are some areas where this is obscure. Throughout most of its extent it presents a remarkably straight lineament expressed by aligned valleys and differences in rock units on either side, observations consistent with the view that the fault has a steep dip. The apparent steep dip of the fault and the long distance through which the lineaments can be traced suggest that the fault is a major wrench fault as discussed by Raasveldt (1956), Rod (1956), Young (1956), Alberding (1960), Moody and Hill (1956), and Campbell (1965). Campbell calculates a left lateral strike-slip displacement of 110 km for the fault. On different evidence, Tschanz (oral commun.) calculates a similar strike-slip displacement of about 100 km. Julivert (1956, 1961, 1970), however, looking at the evidence in the Bucaramanga area, stresses the importance of the vertical component. He visualizes the Bucaramanga fault to be a bounding fault of an uplifted mountain block with primarily vertical displacement. A full discussion of the Bucaramanga-Santa Marta fault system and its relation to the tectonics of northern South America is beyond the scope of this report and the following discussion will relate to the fault as it appears in the report area.
In detail the Bucaramanga fault appears to be a zone of faulting in which one particular fault carries the major displacement. Zones of parallel faults have been observed in some places as near Bucaramanga, and lineaments parallel to the main fault have been observed in other places, particularly north of Bucaramanga. There is no great crush or breccia zone comparable to that reported by Feininger (1970, p. 1203) along the Palestina fault in eastern Antioquia, nor any widespread mylonitization. The fault zone contains much fractured and locally sheared rock and numerous slickensided surfaces oriented in different directions. No systematic study has been made of orientations of slickensided surfaces or striae. Individual fault surfaces that have formed during the latest movement dip steeply. As mentioned in a previous section, mylonite zones, probably in part older than the Bucaramanga fault, dip moderately to gently into it or away from it. The mylonite zones are, in some places, cut by the steeper faults.
The Bucaramanga fault has a fairly straight southeasterly trace with a few fault slices from the north edge of quadrangle H-12 (c-1) to the Río Manco near Los Curos (d-7 NE). This trace is interrupted only where the fault has been offset by northeast-striking faults. The fault assumes a nearly south strike from Los Curos south to near Cepitá (I-13, a-1 NW) where its strike once again is southeasterly but less distinct. Although several lineaments exist in this sector, the rocks on either side of the fault are somewhat similar, and it is difficult to tell which lineament corresponds with the major fault, particularly near Capitanejo in quadrangle I-13. Possibly the fault splays out in this area.

Julivert (1961a, b) shows the Bucaramanga fault as one of a series of high-angle reverse faults with the east block upthrown that formed during the development of the present Magdalena Valley and the concomitant rise of the Santander massif. Present observations seem to support this interpretation. Lower Mesozoic and Upper Paleozoic strata are vertical to overturned in places near Bucaramanga fault on the west block in the Piedecuesta and Floridablanca areas (H-12, d-6, d-5) indicating that here relative movement of the east block was upward and westward. North of Bucaramanga the attitudes of beds near the fault are inconsistent. Immediately north of Bucaramanga along the Río Suratá, a block of sedimentary rocks in normal sequence dips into the fault. This is in an angle or reentrant where the Bucaramanga fault is offset and this block may have been rotated.
From the north edge of the geologic map (pi. 1) to the Umpalá-Cepita area (H-13, a-8 NW; I-13, a-1 NW), rocks are older and topography is higher northeast of the Bucaramanga fault than to the southwest. Southeast of Cepita the age relationships of the rocks on the two sides of the Bucaramanga fault are reversed. The relatively older rocks are in the west block. In this sector the fault passes between the Mogotes and Santa Bárbara batholiths, and lithologic contrast between the two blocks is lost. In this sector too, little difference in elevation exists between the two blocks.

Topography on either side of the fault is not a consistent indicator of throw on the fault, nor is age of bedrock in the two blocks a consistent criterion. The observations suggest that appreciable erosion has taken place since any major fault movements occurred and also suggest that movement along the fault is primarily lateral.

Although Campbell (1965) showed illustrations indicating left-lateral displacement of streams flowing across the trace of the Bucaramanga fault in the Bucaramanga area, no apparent systematic offset of streams exists along the fault in the length from Bucaramanga to the northern edge of the zone. For example, Río Santa Cruz is deflected southward along the fault before turning east to the Magdalena Valley, but Río Cachira north of the map area is deflected northward.
Several features in the southern half of Zone III support the interpretation that the Bucaramanga fault is a major wrench fault of considerable displacement. The elongate, thin south end of the Río Negro batholith could be interpreted as a "drag tail" along a fault of left lateral displacement, as might the little mass of quartz monzonite at Bucaramanga be a "drag slice." Equally as suggestive is the similarity of the Río Negro and Mogotes batholiths with their quartz monzonite phases and their granodiorite phases in similar relative positions. However, geologic control on either side of the fault is not good enough to demonstrate convincingly the amount of strike-slip movement, if any, that occurred on the Bucaramanga fault.
The linearity and length of the Bucaramanga fault suggest that it is primarily a strike-slip fault of major proportions. The presence of features that could be interpreted as drag tails and drag slices would support this concept. It is also possible to match in a crude way displaced rock units on either side of the fault. Yet near Bucaramanga, the fault clearly has vertical displacement with movement of the east block up and to the west and regionally it seems to be part of a system of faults involving the development of the Magdalena Valley and the rise of the Santander massif. It is quite possible that the Bucaramanga fault has been the locus of movements of different styles and at different times. The latest movements appear to be those related to uplift of the massif. The Bucaramanga fault is probably a very old fault that has a long and complex history.
Structural features east of the Bucaramanga fault

The Bucaramanga fault divides the report area into two large structural provinces, the Santander massif to the east and the mesa-plateau-basin region to the west.

In the northern part of the Santander massif, sedimentary rocks which once covered the massif have been preserved in long belt-like remnants bounded on one side by north- or northwest-trending faults (pl. 1 and sections A-A', B-B'). On the west flank of the massif, the uplifted blocks within the massif are on the west sides of the faults, whereas on the eastern flank the uplifted blocks are on the east sides. This gives the impression that during post-Cretaceous faulting the central part of the massif has collapsed or settled relative to the flank areas.

In the southern part of the Santander massif, north- and northwest-trending faults are prominent. Here two large areas of sedimentary rocks are preserved in what appear to be structural basins or complexly faulted areas that subsided prior to elevation to their present positions.
Western flank of the Santander massif

Northeast-trending faults are prominent in the southern half of Zone III, particularly in the area immediately to the east of the Bucaramanga fault. They are younger or penecontemporaneous with the Bucaramanga fault, for where they intersect it they appear to offset it with a general right-lateral, and rarely left-lateral sense of horizontal displacement. Faults with right-lateral displacement are near El Playón (H-12, c-1 NW) and several small faults are to the south, one being at Río Negro (H-12, c-3 SE). The largest offset, at least 750 meters, is along the Suratá fault at Bucaramanga. Other northeast-trending faults with right-lateral displacement are near Piedecuesta (H-12, d-6 NE) and near Cepitá on the Río Perchique fault (H-13, a-8 SW). The displacement is less certain at other places such as along the Río Manco fault (H-12, d-7 NE) and the Río Umpalá fault (H-13, a-8 NW). Left-lateral movement of small displacement occurred on the Sevilla fault just north of Los Curos (H-12, d-7 NE). Left-lateral movement may also have occurred on two faults between Río Negro and El Playón, but the presence of alluvial cover at the critical places renders this unproved.

Vertical movement is apparently also involved in some of these faults. The fault north of Piedecuesta (H-12, d-6 NE) offsets the La Corcova Quartz Monzonite in the opposite sense than it does the Bucaramanga fault.
Suratá fault.—This fault, which extends northeastward from Bucaramanga approximately parallel to Río Suratá, is the largest of the northeast-trending faults on the east side of the Bucaramanga fault. Near Suratá (H-13, a-2 NW), where the Upper Cretaceous Umir Formation is in contact with the Silgará Formation of pre-Devonian age, the throw of the fault is estimated to be at least 2100 meters (assuming a thickness for the Cretaceous section of 1000 meters).

Near the northern edge of H-13, where the fault has a northerly trend, the Giron Formation overlies the Silgará on the western side of the fault. The narrow belt of Cretaceous rocks ends about one kilometer north of the map boundary, but the fault continues to the north through a synclinal area containing rocks of the Giron and Bocas Formations.

In the Cretaceous rocks east of the fault, strike faults cause repetition of the lower part of the section as can be seen along the road from Suratá to California. The faults appear to be concentrated in the shales of the Paja and Tablazo Formations. Higher in the section there is considerable small-scale folding and contortion of the beds that is difficult to recognize in the lower black shales but which is readily seen in the distinct thin beds of the La Luna Formation.
One kilometer southwest of Suratá is a small angular fault block of Lower Cretaceous rocks adjacent to the Suratá fault on the west and apparently in fault contact with the Umir shales on the north, south and east. Inasmuch as the Cretaceous rocks are progressively younger from the normal contact along the east margin of the belt toward the Suratá fault on the west, the only probable explanation for the anomalous presence of this block is that it somehow failed to undergo the full displacement that is indicated elsewhere along the fault.

Julivert and Tellez (1963, p. 9-15) point out that the Suratá fault has a history of pre-Cretaceous as well as post-Cretaceous movement. To the southwest of the belt of Cretaceous rocks, pre-Cretaceous rocks of the Bocas, Jordán, and Girón Formations are present in blocks that are bounded by faults which separate them nearly everywhere from the Cretaceous rocks (H-12, d-3 E). These blocks were apparently saved from pre-Cretaceous erosion by being downfaulted into the pre-Devonian metamorphic rocks.

The Suratá fault splays out at its southern end where, as mentioned before, it offsets the Bucaramanga fault.
Cristalina fault.--This fault of north-northwest trend (H-13, a-2, a-3, and a-4) places Lower to Upper Cretaceous sedimentary rocks on the east in contact with pre-Devonian orthogneiss and the Silgará Formation on the west. About one-half kilometer west of Charta (a-3 NW), the fault is exposed in a cut on the north side of the road where the Tablazo Formation is in contact with orthogneiss. At its southern end, the fault makes a broad curve toward the east and dies out in the orthogneiss west of Berlín (a-4 NC). It is apparently offset by cross faults in several places. North of Quebrada La Rinconada, where it is offset to the northeast by a northeast-trending fault along this quebrada (H-13, a-3 NW), the Cristalina fault apparently dies out in the Cretaceous sedimentary rocks east of the Surata fault. The maximum throw of the fault is estimated to be at least 1400 meters.

Tona fault.--This fault extends from the Cristalina fault (H-13, a-3 SW) on a south to south-southwesterly trend through the town of Tona to the Sevilla fault north of Sevilla (H-12, d-6 NE). It extends through pre-Devonian metamorphic rocks except for a three-kilometer segment near the middle where the Girón and Tambor Formations of the Picacho syncline on the east are in contact with the Silgará Formation and quartz monzonite on the upthrown west side. The southern boundary of this block of sedimentary rocks is an east-trending fault which is upthrown on the south side. On the south side of this fault the Tona fault is displaced slightly toward the west. The estimated minimum throw of the Tona fault is 300 meters.
Picacho syncline.--This indistinctly synclinal area which includes sedimentary rocks of the Girón, Tambor and Rosa Blanca Formations (H-13, a-4 SW and a-5 NW), is about 12 kilometers from north to south and less than five kilometers in maximum width. Only a thin section of the Girón Formation is present in the northern and western parts where the underlying rocks are mostly pre-Devonian orthogneiss and Silgará Formation. In the east, where the Girón is absent, the Tambor overlies the Santa Bárbara Quartz Monzonite. The normal contact of sedimentary with metamorphic rocks along most of the western boundary contrasts with the areas of sedimentary rocks to the north where the Suratá and Charta faults mark the western boundaries of the belts of sedimentary rocks.

Picacho and Sevilla faults.--These parallel south-southwest-trending faults extend across the middle of the Picacho syncline from its northeastern boundary into the pre-Devonian Silgará Formation and Bucaramanga Gneiss. The Picacho fault ends against the Tona fault near the boundary between H-12 and H-13, whereas the Sevilla fault extends on to the Bucaramanga fault and produces a slight offset in that fault north of Los Curos (H-12, d-7 NE). The upthrown sides of both faults are to the west. Near Alto El Picacho (H-13, a-5 NW), where the Picacho fault is well-exposed on the Bucaramanga-Pamplona highway, the vertical displacement on this fault appears to be 400-500 meters. The displacement on the Sevilla fault may be even greater.
Río Manco, Río Urrupa, and Río Perchimina Faults.—These faults of northeast trend extend from the Bucaramanga fault across the igneous and metamorphic rocks for long distances in the southwestern part of H-13. Where they intersect the Bucaramanga fault they produce right-lateral displacements.
Eastern flank of the Santander massif

Major north-trending faults extend from the northern edge of H-13 in the Pamplona and Mutís cua areas south to the Soatá area in I-13. Most appear to be normal faults, some of which have quite large displacements that bring rocks of Early Paleozoic or Precambrian age against rocks as young as Tertiary. In places the faulting displays imbricate patterns with criss-crossing north- and northwest-trending segments. The pattern of the post-Cretaceous faults in the Pamplona-Mutís cua area is to bring up older rocks on the north and east sides. In the northern part of H-13, some of these faults are interpreted as thrusts. Pre-Cretaceous faulting occurred north of Mutís cua on the Mutís cua and Sulasquilla faults and southeast of Chitaga on the Chitaga fault. On the Mutís cua and Chitaga faults, the pre-Cretaceous movement was opposite to that on the post-Cretaceous faults, placing strata of Devonian and Permian to Carboniferous age on the east side in contact with rocks of pre-Devonian age on the west.
Mutiscua and Río Sulasquilla faults.—The presence of rocks of the Floresta and Diamante Formations between these two north-trending faults (H-13, b-1 E and b-2 E) suggests that the two formations occur in a graben and thereby escaped pre-Cretaceous erosion. The presence of a generally synclinal area of Cretaceous rocks overlying the Floresta in the northern part of the graben indicates that there was further movement on these faults in post-Cretaceous times. In the area of these Cretaceous rocks, vertical displacement by the post-Cretaceous faulting is estimated at a minimum of 1000 meters on the Mutiscua fault and 1500 meters on the Río Sulasquilla fault. The amount of pre-Cretaceous displacement cannot be estimated.

The Mutiscua fault extends from the northern boundary of H-13 (b-1 NE) southward to Mutiscua near where it is offset by two cross faults (b-2 SE). It may continue southward from Mutiscua in the Silgará Formation along Quebradas La Laguna (Río La Plata) and La Honda to terminate at another fault northwest of Silos (b-4 NE), but this is not clear. The continuation of Río Sulasquilla fault is unclear also. It apparently dies out beneath the long belt of Cretaceous rocks that lie west of Morro Negro fault.
Laguna fault.--This fault trends south and south-southwest from east of Mutiscua (H-13, b-3 E) and has Cretaceous rocks on the east side in contact with pre-Cretaceous rocks on the west. The fault dies out south of the village of La Laguna (Monteagrande on topographic maps) beyond which the Cretaceous rocks overlie the Silgará in depositional contact. The thick section of sandstone of the Aguardiente Formation forms a prominent high ridge in this block of Cretaceous rocks.

Socotá and Angosturas faults.--Except for the northern part of the Socotá fault, these two generally south-trending parallel faults define a narrow graben in which mostly Jurassic and Lower Cretaceous rocks are exposed (H-13, b-4 E and b-5 E). The Socotá fault on the east extends from its intersection with the Laguna fault southward along the western slope of Cuchilla Socotá. South of Río Caraña it crosses from the west side to the east side of the canyon of Río Angosturas and continues parallel to that stream toward the central ridge of the massif. The north end of the Angosturas fault is east of Silos from where it extends southward at distances varying from 0.3-1.3 kilometers west of Socotá fault. The two faults may join and continue on into the southeastern part of H-13, but this is not clear.

In b-5 E, where Rosa Blanca limestone of the graben is in contact with Silgará Formation on the east side of Socotá fault, the minimum vertical displacement of the fault is estimated at 1500 meters. On the Angosturas fault to the west, a throw of 1200 meters is estimated, based on the presence of an isolated remnant of the Tenbor Formation lying on the Girón Formation in a synclinal area about two kilometers west of the fault (b-5 SE).
Morro Negro fault and Carbonera syncline.--This fault traces a broad arc from the northern boundary of H-13 southward to the Mutiscua area and then southeastward to where it intersects and offsets the Chitaga fault (H-13, c-1 W to c-4 NW). The belt of sedimentary rocks on the west side of the fault contains Cretaceous and Tertiary formations, possibly including the Mirador. The outcrop of the Aguardiente Formation makes a prominent ridge in the northern and southern parts of the belt but is less prominent in the central part. The Tertiary rocks form the narrow, sharply-defined Carbonera syncline with its axis along Quebrada La Carbonera which parallels the fault about 400 meters to the west (c-3 W).

Along the northern half of the fault, overthrusting is indicated by the trace of the fault with respect to the topography. Where it was observed on a farm road west of the unfinished road from Pamplona to Cucutilla (110-II-A, J-2 SW), the fault dips eastward at a low angle. In the southeast-trending southern half of the fault, left lateral movement is indicated by an offset of about one kilometer in the Chitaga fault. However, the offset in the southeastward-dipping Cretaceous formations across the fault in this locality is the opposite of that in the Chitaga fault, suggesting that the Chitaga fault may dip to the northwest and that the offsets across the Morro Negro fault are mostly apparent offsets due to vertical displacement of dipping components rather than true offsets due to lateral displacement. The trace of the fault is generally well-defined by breaks and irregularities in the topography than can be seen on aerial photographs except where it crosses the Durania Granite (c-3 SW).
The belt of sedimentary rocks west of the Morro Negro fault ends abruptly against the north northeast-trending Babega fault (c-3 NW) which terminates at the Morro Negro fault where the vertical displacement on the latter is probably at a maximum. The minimum displacement on the Morro Negro fault is estimated to be 2300 meters.

Babega fault.—From its termination at the Morro Negro fault, the Babega fault extends south southwestward to Babega and beyond, and, as shown on plate 1, possibly continues to a termination at the Socotá fault in Quebrada El Oso (H-13, c-3 SW to b-5 NE). Assuming that the fault is continuous as indicated, rotational movement has occurred about an axis normal to the fault in the central area where orthogneiss (pDo) on the southeast side of the fault is in contact with orthogneiss (pDod) on the northwest. Northeast of this axis, older rocks are on the southeastern side of the fault, whereas to the southwest the older rocks are on the northwestern side, and relative displacement increases from zero at the axis to maximums at the ends of the fault. Such an explanation of the present structure appears quite possible for the northeastern part of the fault but is not as applicable in the southwestern part. There the irregular trace of the fault on the eastern slope of Río Angosturas indicates a strong east dip on the fault plane. The minimum vertical displacement at the northern end of the Babega fault equals the 2300 meters estimated for the Morro Negro fault in this locality where Tertiary rocks are in contact with pre-Devonian rocks and Durania Granite.
Parapona fault.--This fault extends into the report area from the north and continues with south to south-southwest trend west of Pamplona to terminate at the Morro Negro fault (H-13, c-1 W to c-3 W). Along most of its northern half, pre-Devonian orthogneiss on the east is in contact with a narrow belt of Cretaceous rocks on the west, up to and including the La Luna Formation. Sandstone of the Aguardiente Formation forms a prominent central ridge throughout the length of this belt. Beyond the southern end of the belt, the fault cuts across the pluton of Durania Granite and then becomes the boundary between this granite and the Silgará Formation to the west. South of a northwest-trending fault that offsets it slightly to the east (c-3 W), the Pamplona fault again cuts through Durania Granite to its termination at the Morro Negro fault.

Northwest of Pamplona, where the Tibú, Mercedes, Aguardiente, and Capacho Formations are present west of the fault, the vertical displacement is estimated to be 2000-2500 meters. Near the north boundary of H-13, where the La Luna Formation is present, the displacement may be even greater.

Chitaga fault.--This is the largest and longest fault on the eastern flank of the Santander massif in the report area. From a southerly trend in the northeastern part of H-13 (c-1 and c-2), it curves south-westward to Río Chitaga and follows the broad arc of that river around a wide area of pre-Devonian and Devonian rocks in the eastern part of the quadrangle (H-13, c-3 to c-6).
In the area east and northeast of Pamplona, the Pamplonita syncline borders the fault on the west, and thrust faults are included in the highly complex fault pattern of that area. Girón Formation rocks have been thrust westward over Cretaceous and Tertiary rocks, and the Bocas Formation in turn has been thrust westward over the Girón. The section of Bocas shales, orthoquartzites, and feldspathic sandstones is estimated to be 2700 meters thick. Southwest of Pamplona, a small pluton of quartz monzonite (cg) appears to be thrust westward locally over Cretaceous and Tertiary rocks (c-2 E), although this is not clearly evident in the field.

South of the Pamplonita syncline, the trace of the Chitagá fault is much more regular where Bucaramanga gneiss has been brought up on the eastern side for a long distance. About 4 kilometers south of the offset caused by the intersecting Morro Negro fault (c-4), another intersecting fault that causes approximately equal displacement, but of opposite direction, restores the fault trace to its original course.

South of Chitagá the fault changes trend to southeasterly and follows Quebradas Sorotana and El Quemado where the Floresta Formation is on the upthrown northeast side. In Quebrada El Quemado and southeasterly to the boundary of the quadrangle, Bucaramanga Gneiss is on the southwestern side of the fault, indicating that pre-Cretaceous movement occurred on the fault opposite in direction to that of the post-Cretaceous faulting.
Vertical displacement along the northern part of the Chitaga fault is difficult to estimate with confidence because of complicating lesser faults and the uncertain nature of the eastern limb of the Pamplonita syncline. East of Pamplonita where the syncline is widest, the minimum displacement is estimated to be 2300 meters. South of Chitaga, near the westernmost point of the fault, estimated minimum displacement is 2200 meters.

Pamplonita syncline.—This syncline in the belt of sedimentary rocks west of the Chitaga fault includes Jurassic, Cretaceous, and Tertiary rocks up to and including the Los Cuervos Formation (H-13, c-1, c-2). Because of complicated faulting, the axis is not clearly defined except in the Tertiary rocks near Pamplonita. Although Cretaceous formations are exposed east of the axis, most are highly faulted and the attitudes of the beds seem to indicate structure unrelated to that of the syncline. The Aguardiente Formation crops out along most of the western limb as a prominent ridge with small breaks due to cross faults in the vicinity of Pamplona. Long strike faults cut the black shale sections of formations above the Aguardiente and can be detected in the resulting offsets and repetitions in the La Luna Formation.
Central area of the Santander massif

In this area where altitudes range from 3,000-4,500 meters, extending across H-13 from northwest to southeast, rocks are less weathered and better exposed, and as a consequence the structure is better defined in most places than in the flank areas.

In the northern part of the massif, where pre-Devonian metamorphic rocks predominate, fault trends vary from northeast to northwest, with north-northeast trends somewhat more common than others. In the southern half, an area with mostly sedimentary rocks ranging from Devonian to Tertiary, strikes of folds and most major faults fall within a narrow range of north to north-northeast. Short cross faults of northeast to east trend are numerous in the eastern part of this area but do not represent major movements.

River Cucutilla fault.—The River Cucutilla fault forms a marked lineament more prominent north of the map area than within it. It enters the map area in north-central H-13 (b-1 NW), but immediately becomes indistinct and branches. What appears to be the main branch trends southward to cross River Vetás and Páramo Rico where it intersects the Charita fault (H-13, a-2 E, a-3 E). A branch of the fault may connect with a probable fault along River Baja. The mineralization in the River Baja area may have some connection with the River Cucutilla fault, if not directly on the fault itself, then in satellite faults at an angle to the main fault. Displacement on the fault is undetermined for the rocks on either side are similar and no displacement is evident.
Río Charta fault.—A remarkable arc-like northwest- to west-trending fault southeast and east of Charta (H-13, a-3) shows little apparent vertical displacement but appreciable left-lateral horizontal displacement. This fault extends from the Charta area across the southern part of the Páramo de Santurban to Río Caraba. East of the Berlín-Vetas road this fault is no more than a lineament, but in Río Caraba it appears to cut the nose of the Río Caraba dome and postulated thrust faults between orthogneiss and the Silgará Formation in the Río Caraba area.

Ventanas fault.—The west contact of the mass of orthogneiss west of Mutiscua (H-13, b-3 C) that passes near Morro de Ventanas north of the Río Caraba is shown as a fault which has placed the orthogneiss over the Silgará Formation. The inference is that this mass of orthogneiss is an anticline with the west limb overturned and faulted. Near Río Caraba two faults are indicated. One with gentle dip has been offset by the other which has a steeper dip (pl. 1, sec. B-B'). The gently-dipping fault is interpreted as a thrust on the quadrangle map of H-13 (pl. 1) and is shown as having been cut by the normal fault along the Río Caraba. The continuation of the postulated thrust on the block south of Río Caraba is drawn in the area between Volcán Amarillo and Cerro El Albedri north of Berlín (H-13, a-35E). This thrust predates the intrusion of the tonalite and granodiorite of the Páramo Rico pluton. A discordance in attitudes in the gneisses on either side of this thrust is not matched by any possibly related feature in the adjacent tonalite and granodiorite.
Servita fault.—From its termination at the Babega fault, the Servita fault trends southward with slight deviations and becomes the boundary between the Malaga structural basin to the west and the Cerrito structural basin to the east (H-13, c-4 W to c-8 W). The Giron Formation is exposed along most of the western side of the fault in H-13 where it is in contact with mostly Upper Cretaceous and Paleocene rocks on the east. The largest vertical displacement is in the northern part (c-5 W) where the Servita and Chitaga faults define a short graben-like area about four kilometers wide that appears to be a northern extension of the Delgado syncline. Inasmuch as the older Tertiary beds on the west limb of the syncline are overturned and dip westward, an asymmetrical syncline probably lies at depth, and the vertical displacement of the fault may exceed 3000 meters. The fault dies out rapidly to the north where orthogneiss occurs on both sides at the north end. Displacement decreases gradually to the south, and the fault splays out in the Cretaceous formations in the southern part of H-13.
Malaga structural basin.--This portion of the central region of the massif is a roughly elliptical synclinal area with long axis trending north-south. It is defined on the west by the boundary of the Floresta Formation with pre-Devonian metamorphic rocks and the Santa Barbara batholith and on the east by the Servita fault. It extends from the central part of H-13 southward into I-13. Within this large area the sharply defined Angosturas syncline is the dominant feature of the eastern part of the basin, whereas north- to northeast-trending faults are dominant in the west. Pre-Devonian rocks crop out only in a small area in the northeast (H-13, b-5 SE) where they have been raised on the eastern side of the Socota fault. Santa Bárbara Quartz Monzonite is present in the same area and in a small outcrop about five kilometers to the southwest. A few masses of basic igneous rock intruded the Giron Formation of which the most notable is a sill of andesite about 75 meters thick that was found near the Giron-Tambor contact about 10 kilometers east northeast of Guaca (121 III-B, E-10 W). Similar rock, possibly the same sill but thinner, was found in similar stratigraphic position one and one-half kilometers to the northeast (D-11 SE).
Although the basin appears to result from tectonic rather than depositional activity, the thick sections of coarse sediments of the Jordán and Girón Formation suggest that it was also the site of a rather narrowly defined depositional basin during Jurassic time, complementary to the thick deposition west of the Bucaramanga fault and derived from the intervening Santa Bárbara batholith and the older rocks that originally covered it and that flank it on the east and west. The Cretaceous rocks, of which the youngest is the small area of La Luna Formation a few kilometers southeast of Guaca (H-13, b-7 SW), are quite similar in character and thickness to the Cretaceous elsewhere in the region of the massif, and they do not suggest that there was any localized basin of deposition in this area during Cretaceous time. Isolated remnants of Tambor sandstone at the base of the Cretaceous section, lying on pre-Cretaceous rocks of various ages, are indicative of the continuous and uniform nature of the Cretaceous deposition. The lithologic variation of the pre-Cretaceous surface is strikingly revealed in the western half of the basin. Along the western limb, Cretaceous rocks lie directly over beds of Devonian age, whereas a few kilometers to the east a thick section of the Bocas, Jordán, and Girón Formations is exposed along the east sides of the major faults. Possibly some of these rocks were saved from pre-Cretaceous erosion as down-faulted blocks that have since been raised by reverse movements.
Baraya fault.--This north-trending fault on the west side of the basin has brought pre-Cretaceous rocks up on the east side of the fault into contact with Cretaceous rocks on the west (H-13, b-6 W to b-8 W). South of the Río Listará fault, it is offset one-half kilometer to the east, beyond which it continues southward into I-13. East of Guaca, where rocks as old as the Floresta Formation are in contact with the Upper Cretaceous La Luna, the minimum displacement is estimated to be not less than 2000 meters. Locally in this area the fault plane has a low angle of dip to the east where the Bocas Formation has been thrust westward over the La Luna. Northward from this area the displacement decreases gradually and the fault splays out north of Baraya in the El Portillo area.

Alto de Guaca fault.--This north-trending fault is approximately parallel to the Baraya fault and 2 to 4 kilometers to the east (H-13, c-6 to c-8). In the ridge east of Alto de Guaca (c-7 SC) and on the slope southward to Río Listará, the fault is well-exposed, with gray shales of the Bocas Formation on the east in contact with Jordan red beds to the west. Elsewhere also, older rocks are exposed on the east side of the fault except for a downfaulted anticlinal block of the Giron a short distance north of Alto de Guaca.
There is no clear extension of the fault south of the Río Listara fault. In its northern part, it is offset to the east by an intersecting northeast-trending fault, and it then swings toward the northeast and dies out near the Angosturas fault. Vertical displacement across the fault cannot be estimated, but considering the smaller differences in rock ages on the opposite sides as compared with the Baraya fault, the displacement must be considerably less than that of the Baraya fault.

Morro Las Penas fault.--This north-trending fault is approximately parallel to the Baraya and Alto de Guaca faults and about 4 kilometers east of the latter (H-13, b-6 E to b-8 E). It has similar relative displacement, with older rocks upthrown on the east side. From its termination at the Río Listara fault, it extends northward on the east side of Morro Las Penas (b-7 SE) with Girón rocks on the east in contact with Cretaceous rocks on the west. Farther north it continues as a well-defined lineament through the thick Girón section and possibly extends to the junction of the Angosturas and Socotá faults (H-13, b-6 NE), although this is not clear.

Maximum vertical displacement along the Morro Las Penas fault occurs northeast of Morro Las Penas where Aguardiente sandstone is in contact with Girón beds. The displacement there is estimated to be 1,600 meters.
Río Listará Fault.--This fault trends approximately N. 60°-65° E. from San Andrés along Río Listará and is the only major fault that cuts more or less directly across the dominant north-south structural trend of the area (H-13, b-8 N). At the northeast end it changes trend to east and then southeast before dying out in Cretaceous rocks. It produces an offset in the Baraya fault, and the Alto de Guaca and Morro Las Peñas faults terminate against it. Age differences of the rocks across the fault vary greatly because of the displacements across the north-trending faults. Rocks north of the fault range from the Floresta to the Aguardiente and on the south from Giron to Capacho. Vertical displacement in the Cretaceous rocks across the Río Listará fault is estimated to be 200-300 meters.

Angosturas syncline.--This sharp trough-like feature that dominates the eastern side of the Malaga structural basin is for the most part relatively uncomplicated by faulting and minor folding. Because of the high altitudes, the rocks are relatively unweathered and vegetation is very sparse, with the result that the Cretaceous formations can be easily defined on aerial photographs in most places. In its northern part (H-13, b-6 and b-7, c-6 and c-7), it is quite symmetrical, and the axis, which is possibly a fault in the south, is distinctly a sharp fold in the north where it changes trend to north-northeast. The axis continues well-defined in the Giron Formation to the graben between the Socotá and Angosturas faults. North of the graben, it continues in the Giron and Bocas Formations, although not so sharply defined.
In the southern part of H-13, the syncline loses its symmetrical appearance rather abruptly south of an east-trending cross fault on the east limb (c-7 SW). The Giron is no longer exposed on the east limb which is obscured by local folding, and the main axis is shifted toward the west.

Cerrito structural basin.--This large feature, bounded by the Servita fault on the west and the Chitaga fault on the east, is somewhat similar in shape to the Malaga structural basin but with axial trend of north-northwest (H-13, c-5 to c-8). The contrast in stratigraphy is very great however. The Tertiary and Upper Cretaceous rocks that are the most commonly exposed in the Cerrito basin are absent in the Malaga basin, whereas the Giron and older rocks that are the most widespread in the Malaga basin are not exposed anywhere in the Cerrito basin. The structures of the area are well displayed on aerial photographs by the outcrops of the thick sandstone sections of the Barco and Mirador Formations.
Although faults are numerous, folding is the more striking structural feature. The Delgadito syncline is the largest and longest in the basin, and its axis corresponds to the long axis of the basin, trending N. 15°-20° W. and extending northward, beyond a highly faulted area, into the graben between the Servita and Chitaga faults.

To the southwest of and parallel to the Delgadito syncline are the Vado Ancho anticline, La Arena syncline, and Pescaditos anticline, of which the axis of the last named corresponds to the long, curving Pescaditos fault. West of the Pescaditos fault is the Almorzadero syncline with axis trending south-southwest and changing to south-southeast. This axis, if projected on to the southeast, nearly coincides with the axis of the El Coronel syncline southeast of Cerrito (c-8 W).

Westward from the Delgadito syncline, folding is progressively sharper until the limbs are nearly parallel in the Almorzadero syncline. The coal in beds near the base of the Los Cuervos Formation is very hard and has apparently been compressed to about half the thickness that is found in mines 20 kilometers to the north.

Numerous cross faults offset the axes of the synclines and anticlines. The trend of these faults varies from east to northeast, and in the northern part of the basin (c-6 W) there are also short cross faults of northwest trend.
In the eastern part of the basin, where a full section of Cretaceous rocks is exposed above Bucaramanga Gneiss, folding and faulting complicate the structure of the Upper Cretaceous formations as revealed in the outcrop pattern of the La Luna Formation. A strike fault in the northern part of this area (c-6 SE, c-7 NE) has raised the southwestern side, resulting in repetition there of the Upper Cretaceous section that is exposed northeast of the fault.
Structural features west of the Bucaramanga fault

This part of the report area is divided into three areas with differences in structural character. The Suárez fault separates the topographically lower mesa area south of Bucaramanga from a higher plateau belt to the west. Westward from the plateau belt, all formations ranging from the Girón to those of the Tertiary and Quaternary dip westward into the geosynclinal area of the middle Magdalena basin.

Suárez fault

This fault extends into quadrangle H-13 from near the middle of its southern boundary and traces a rather sinuous course northward to its termination at the Bucaramanga fault north of Bucaramanga. In the southern part of H-12 it is closely parallel to the course of Río Sogamoso and 2 to 3 kilometers to the west. Where the river changes course from north to northwest, the fault changes trend to northeast and crosses the river at right angles. Other faults are present in this area that complicate the structural pattern, and the net effect suggests an offset to the northeast, beyond which the fault continues its northward trend.
In the southern part of H-12, where the fault is west of Río Sogamoso, red beds of the Giron Formation on the west side are in contact with Cretaceous formations up to and including the Paja on the east. Estimates of vertical displacement of the Tambor-Rosa Blanca contact across the fault in this area range from 1700 to 2300 meters, with displacement decreasing toward the north. North of the offset area and about 10 kilometers south of the town of Giron, the vertical displacement of the Tambor-Giron contact across the fault is estimated to be 1000 meters. In this area and continuing to the north, the trace of the fault is covered by Quaternary beds.

West of Giron and continuing to the north, an eroded fault scarp lies west of the fault, and older Quaternary beds of the Bucaramanga terrace have been dragged up to a vertical position on the east side of the fault by later Quaternary movements (Julivert, 1963, fig. 7 and pls. II and III). These beds are well exposed where the highway from Giron to Lebrija crosses the fault (120 II-A, F-9). Beds of the Giron Formation underlie the terrace deposits, and a few small exposures of them lie east of Río de Oro along the road from Giron to the railroad terminus at Cafe Madrid. Inasmuch as Giron rocks lie on both sides of the fault in this area, a good estimate of the vertical displacement cannot be made. However, the height of the fault scarp to the west makes a throw of 400-500 meters quite possible.
Near its termination at the Bucaramanga fault, the Suárez fault cuts Devonian and Permian-Carboniferous beds of the Floresta and Diamante Formations in a narrow belt of these rocks that parallels the Bucaramanga fault on the west side. The structure in this area is complicated by other faults, but apparently the vertical displacement along the Suárez fault is not very large.
Mesa area

The wedge-shaped fault block between the Bucaramanga and Suárez faults is down-dropped and tilted slightly toward the west. It is the site of the present mesas of Barichara (I-12 NE) and Los Santos and Ruitoque (H-12 SE). Mesa areas in the middle of this block are capped by sandstone of the Tambor Formation where it has not been eroded to expose older beds of the Girón and Jordán Formations. To the south, Mesa Barichara and part of Mesa Los Santos retain a cover of younger Cretaceous rocks up to the Tablazo and possibly higher (Téllez, 1964, p. 17). Pre-Devonian rocks of the Silgará Formation crop out on the eastern slopes of these mesas below the cap rocks.

The present surface of the fault block is lowest at the northern end, reached not in a uniform gradient from south to north but probably in steps related to northeast-trending faults along the northern edges of Mesas Los Santos and Ruitoque. At the narrow north end of the block, the thick Quaternary deposits of the Bucaramanga terrace accumulated in the basin between the Suárez and Bucaramanga faults. In his morphotectonic study of the mesa area, Julivert (1958, p. 37 and fig. 13) postulates that the stream-derived lower beds of the terrace were deposited when Río Sogamoso earlier flowed northward along the Suárez fault to Río Lebrija before it was captured by a northwestward-flowing stream that is the present channel of the river.
On Mesa Los Santos a network of faults is indicated by the lineaments that can be seen in the drainage pattern on aerial photographs. They apparently have little vertical displacement. The Los Santos fault, which trends northwestward along Quebrada Los Santos from the southern slope of the mesa, dies out northwest of the village of Los Santos. It probably has greater displacement than any other fault in the mesa surface, but near Los Santos this is probably not more than 100 meters. The flexure with which this fault is associated probably results from a fault in the pre-Cretaceous rocks and extends on to the northwest beyond the end of the fault. Northeast of this fault, sandstone of the Tambor Formation which caps the mesa dips gently southwestward toward the fault, with dip increasing rather abruptly near the fault. The southwest side is downthrown, and there the Rosa Blanca Formation overlies the Tambor, with the Paja and Tablazo Formations also present farther to the southwest. The combined and reinforcing effects of the fault, the flexure, and the regional dip make the mesa area to the southwest of the fault 400-500 meters lower than that to the northeast.

If projected toward the southeast, the Los Santos fault coincides with the Aratoca fault that extends northwestward from Aratoca along Quebrada La Playa to Río Chicamocha. However, landslides and colluvium on the lower slopes of Mesa Los Santos in this locality make this extension of the Los Santos fault unclear.
Plateau area west of the Suárez fault

This area includes a belt lying west of the Suárez fault that narrows gradually northward from the south central part of H-12 and terminates at the Bucaramanga fault. It differs from the lower mesa area to the east in that gentle folding has resulted in an uneven surface as compared to the gentle and regular westward slopes of the mesas. Cretaceous rocks up to and including the Tablazo Formation overlie the thick Giron Formation in the Zapatoca syncline (H-12, b-8, c-7, c-8), and Tambor Formation sandstone is present north of Río Sogamoso, but the northern half of the plateau area has only Giron Formation exposed. Compared with the Zapatoca syncline that trends parallel to the belt, all other anticlinal and synclinal structures are minor in extent and rather variable in trend.

Lineaments traced on aerial photographs generally show a rather random orientation. A long, winding lineament has been traced in the Giron Formation west of the Suárez fault (c-7, c-8) that corresponds to a sharp change in strike and dip of beds as seen on aerial photographs. The absence of indicated lineaments and fold axes in the southwestern part of the plateau belt (b-5 E, b-6 E and b-7 E) is due to lack of full photo coverage rather than to absence of these features in the rocks.

The western boundary of the plateau belt is not sharply defined but is where the undulations of the beds of the Giron are succeeded by strong and sustained dips toward the west. Julivert (1958, p. 16) has called this the "flexion del Chucuri."
El Espino fault. --This north-trending fault lies west of and roughly parallel to the Bucaramanga fault from the western slope of Quebrada El Espino in the south nearly to La Ceiba in the north (H-12, c-1 to c-4). Along most of this distance, from Bocas northward to Portachuelo, the trace of the fault is along the upper west slope of Río Negro. The position of the fault in eastward-draining quebradas and on adjacent ridges indicates a west dip in the fault plane. Dips in the Bocas Formation east of the fault are mostly toward the east. Those in the Girón Formation on the west are toward the west.

At Portachuelo El Espino fault is only a few meters east of the Bucaramanga fault. To the north it is exposed in several places on the lower west slope of Quebrada San Francisco. It terminates at a northeast-trending fault that intersects and offsets the Bucaramanga fault at La Ceiba (c-1 S).
La Plata and Río Negro faults.--These two relatively short, north-trending faults lie between the Bucaramanga and El Espino faults west and east of the town of Rionegro (H-12, c-3). They are the boundaries of a narrow downfaulted block of reddish-brown siltstone and sandstone of the Jordán Formation. West of Rionegro, fractured light-colored quartzites of the Bocas Formation are west of the La Plata fault. North of an offsetting cross fault, dips in the Jordán are toward the west; those in the Bocas are toward the east. Similar to the El Espino fault, the La Plata fault lies along the slope west of Río Negro, but in this case fault positions in eastward-draining quebradas and on adjacent ridges indicate an eastward dip in the fault plane. The fault terminates at El Espino fault to the south and apparently terminates at a small spur fault west of the Bucaramanga fault to the north.

The Río Negro fault extends northeastward from near the confluence of Río Negro and Río Lebrija and then curves northward to a position tangent to the Bucaramanga fault north of the town of Rionegro. The fault is exposed in a road cut along the highway to Rionegro (109 IV-A, I-13 NE). North of this exposure, beds of the Bocas Formation are highly fractured in the narrow belt between the Río Negro and Bucaramanga faults.
Middle Magdalena basin

West of the plateau area, approximately half of quadrangle H-12 lies on the eastern side of the middle Magdalena basin. The belt of westward-dipping Jurassic and Cretaceous formations display more complicated structure than does the Nuevo Mundo syncline with its Tertiary rocks to the west. The western boundary of this syncline is the La Salina fault.

Pre-Tertiary belt.—From a north-northeast trend in the southwestern part of H-12, this belt changes rather abruptly to a northwest trend near the northern boundary in an area of rather complex folding and faulting. The Cretaceous rocks of the belt are only a few kilometers west of the Bucaramanga fault at this change of trend. The broad area of Giron Formation exposed in the plateau area ends here and is succeeded to the north by a rapidly widening area where the Bocas Formation is exposed. This latter area is somewhat similar structurally to the plateau area, at least in the western part. In the eastern part, faults are prominent features and dips of beds are steep to vertical, possibly as a result of the intrusion of a long body of rhyolite which trends parallel to the Bucaramanga fault.
Solferino fault.--In the north central part of H-12, the Girón Formation has apparently been thrust slightly westward over Cretaceous formations over a distance of 5 or 6 kilometers along this fault (pl. 1, sec. A-A'). West of the fault, the Cretaceous beds have responded to the deformation by gradually reaching an overturned position from their normal westward dips to the north and south. An intersecting fault of northwest trend causes offset in the Solferino fault near the place of maximum thrust.

The Solferino fault dies out rapidly toward the south as a strike fault. Northeastward its oblique truncation of the Cretaceous formations dies out gradually. A lineament on aerial photographs indicates that the fault continues northward in the Bocas Formation with trend curving to the north and northwest where it parallels the west boundary of the long rhyolite intrusion. It terminates at the Río Cachira fault. Another lineament branches to the left and extends approximately parallel to the Girón-Bocas boundary.
Sardina fault.--This fault is closely parallel to the eastern boundary of the rhyolite intrusion in the Bocas Formation south of the Río Cachira fault (H-12, c-1 SW, c-2 NW). It terminates at the Solferino fault in the south and at the Río Cachira fault in the north. Beds of the Girón and Tambor Formations are on the east side of the fault over most of its length. A thick zone of cemented coarse fault breccia is exposed in several places in Quebrada Sardina and in tributary quebradas to the east. Blocks of breccia have been found also in the quebrada that marks the course of the fault south of Río Salamanca.

The narrow, curving fault block between the Solferino and Sardina faults suggests that the rhyolite intrusion has pushed this block upward.

Río Cachira fault.--Along the valley of Río Cachira, this fault cuts almost directly across the structural trend and strike of formations in the north central part of H-12 (c-1 W, c-2 NW). Right lateral movement has apparently occurred to cause the large offsets across the fault. The rhyolite intrusion is displaced about 2.5 kilometers and the Girón Formation about 1.5 kilometers. The fault is thought to curve northwestward to a position parallel to the Bucaramanga fault near the northern boundary of H-12. A northeast-trending branch, or possibly a different fault, continues the northeast trend and intersects and offsets the Bucaramanga fault with right lateral displacement of less than 500 meters.
After cutting across the strike of much of the Cretaceous section along its southern half, the Río Cachíra fault trends nearly due south but cannot be traced where alluvium of Río Lebrija covers the Umir Formation.

The vertical displacement across the fault is large whether produced by lateral or vertical movement or both. Surface dips and strikes in the Giron and Tambor Formations on the north side of the fault indicate that the Tambor-Giron contact there would project in the fault plane to a depth of 1600 meters vertically below the Tambor-Giron contact on the south side of the fault.

**Lebrija fault.**—Near the northern boundary of H-12, the Bocas Formation and northwest-striking Giron and Lower Crétaceous formations end at the Lebrija fault (b-1). On the west side of the fault are Lower Tertiary beds. The fault continues northward into G-12 where Cretaceous formations again appear east of the fault. In its southern part it apparently dies out as a strike fault in the shales of the Umir Formation.

West of the fault, dips in the Lisama Formation are steep to the east, and east of the fault in the Bocas Formation they are somewhat less steep toward the east (b-1 NW). On the basis of this information and an estimation of 3000 meters for the thickness of the Jurassic-Cretaceous section, a minimum vertical displacement of 4600 meters is estimated where the Lisama and Bocas Formations are in contact across the fault.
Vanegas structural embayment.---This area of northeast- to northwest-striking Cretaceous and pre-Cretaceous formations is bounded on the east by the Solferino fault and on the west by the Lebrija fault (H-12, b-1 E, b-2 E, c-1 W, c-2 W). The embayment appears to result from the movements on the Solferino fault and uplift to the north where the Bocas Formation is widely exposed and is intruded by a long body of rhyolite that has probably been a factor in the uplift.

Numerous faults and folds cross the embayment with trends varying from northwest to northeast. They extend into the Umir Formation in the southern part of the embayment where they are covered by widespread Quaternary deposits or die out in the Umir Formation shales. Undoubtedly some of them continue south of the embayment because the thickness of the Umir is much less than the width of the outcrop belt seems to indicate (see section A-A'' of pl. 1).

Vanegas anticline.---The somewhat winding and gently plunging axis of this structure can be traced for about 14 kilometers from the Giron Formation in the north to the La Luna Formation in the south (H-12, b-1 SE, b-2 E). In view of this length and persistence, the anticline probably continues southward in the Umir Formation (see section A-A''', pl. 1), although this is not clear.
Vanegas syncline and Cuestarica fault.--The eastern limb of the Vanegas anticline adjoins the Vanegas syncline which plunges gently southward and disappears under the alluvium of Río Lebrija. The synclinal axis is well-defined northward to the Cuestarica fault, which then traces the approximate axis of the syncline to the northwest. In the Bocas Formation near the northern boundary of H-12, dips and strikes of beds indicate a syncline of northwest trend that is in approximate alignment with the Vanegas syncline, but there is no clear continuity. In its northwestern part, the Cuestarica fault intersects the Lebrija fault and offsets it slightly to the northwest. Beyond this offset it dies out in Tertiary beds west of the Lebrija fault. A vertical displacement of 400 meters is estimated in the Tambor-Girón contact across the fault where the Vanegas anticline is sharply defined in the Girón Formation (H-12, B-1 SE).

Arevalo syncline.--This sharp, north northeast-trending syncline near the eastern side of the Vanegas structural embayment is the best defined of several folds that occur east of the Río Cachira fault. All of them plunge gently southward and disappear under Quaternary deposits.
**Rio Sucio anticline and Naranjo syncline.**—These features lie within the wide outcrop belt of the Umir Formation southwest of the Vanegas structural embayment (H-12, b-4). Two elongate areas of the Lisama Formation containing thick sandstone beds overlie the Umir Formation east of the axis of the Rio Sucio anticline and are isolated from the main westward-dipping outcrop of the Lisama along the west limb of the anticline. In its southern part, the anticlinal axis is represented by a fault with the eastern side downthrown.

The northern isolated area of the Lisama Formation, and part of the southern one, lie in the trough of the Naranjo syncline. The syncline is in a downfaulted position between parallel strike faults to the east and west.

**San Vicente faulted and folded area.**—Folding and faulting that are confined mostly to the Umir Formation south of the Vanegas structural embayment extend into some of the older Cretaceous rocks in the San Vicente area (H-12, a-6 SE, a-7 E, b-6 W, b-7 W). The Girón, Tambor, and Rosa Blanca Formations remain relatively unaffected.

The San Vicente syncline (not labeled on pl. 1) plunges very gently northward along the east side of the disturbed area and apparently terminates at both ends against the San Vicente fault. This fault is downthrown on the west side and cuts obliquely across the section from the Umir Formation at the north end to the Paja Formation in the south.
West of the San Vicente fault, several strike faults with down-thrown sides on the east result in repetition of the section that is well-shown in the La Luna Formation. The Chucurí anticline is a well-defined, narrow structure in the La Luna that plunges northward and is bounded by strike faults.

The Tertiary rocks to the west of the San Vicente area of faulting and folding are relatively unaffected.

Nuevo Mundo syncline and La Salina fault.—This large synclinal area that covers most of the western part of H-12 is only the small, easternmost part of a much larger geosynclinal area that has been referred to structurally as a "half-ramp" because of the extensive faulting near and parallel to the eastern margin. The Tertiary section (and probably also the Cretaceous) reaches its greatest thickness along this side of the geosyncline and may exceed 6000 meters in the Nuevo Mundo syncline (Morales et al., 1958, fig. 7).

The north-trending La Salina fault, which is immediately to the west of the boundary of H-12 with H-11, forms the western boundary of the Nuevo Mundo syncline in its southern part. The fault extends briefly into H-12 (a-7 W) and dies out farther north in the northeastward plunge of Las Monas anticline (a-3 W). It is an eastward-dipping, high-angle reverse fault along which the eastern side is thrust up and westward, bringing the Umir Formation on the east side into contact with rocks as young as the Real Formation on the west. The fault is present in the subsurface at the west end of section A-A' of plate 1. A throw of about 1200 meters is indicated in the Umir-Lisama contact in this locality.
At the surface, the axis of the Mundo Nuevo syncline is close to the west limb, probably as a result of the strong uplift along the east side of La Salina fault. In the subsurface the axis probably moves eastward as depth increases (see section A-A" of pl. 1). In the southwestern part of H-12, the axis of the syncline in the Umir Formation corresponds to the northeast-trending Putana fault. This fault extends from La Salina fault in H-11 and produces a large offset in the Umir-Lisama contact. North of this offset, the axis of the syncline diverges northward from the Putana fault. North of Río Sogamoso, the axis of the syncline is offset 4 to 5 kilometers to the west of its position south of the river. A similar offset occurs in the La Salina fault. The offsets suggest that a fault of west-northwest trend, and with strong left lateral displacement, is present along the course of Río Sogamoso beneath the cover of alluvium.

The position of the axis of the Mundo Nuevo syncline becomes unclear in the northwestern part of H-12 where the youngest Tertiary beds are nearly horizontal.

Las Monas anticline. --This nose-like feature plunges to the northeast beyond the end of La Salina fault and possibly reflects the dying out of the fault at depth.

Provincia fault. --This fault diverges northward from the axis of the Nuevo Mundo syncline and corresponds to the western boundary of the Provincia oil field at its south end. There is slight uplift on the eastern side.
Provincia anticline.--In outcrops, the axis of this structure diverges northeastward from the trend at the producing level of the Provincia oil field. In the southern part of the field, there is no well-defined position of the axis at the surface, although the field is bordered on the east by the Mundo Nuevo syncline and on the west by a sharp syncline in the Mesa Formation.
GEOLOGIC HISTORY

The geologic history of the southern half of Zone III and by extension the Santander massif is summarized in table 4. Discussion of age and correlation already presented at the end of the description of each unit are here summarized, and additional remarks intended to clarify or amplify specific events or to show areas of uncertainty are also given. The geologic history is presented below in 18 events whose numbering corresponds to that on table 4.

1) The Bucaramanga Gneiss became part of the Precambrian Guayana shield probably in late Precambrian time, about 950 m.y. ago. The 945 m.y. age from the Santander massif, the oldest reported from the Cordillera Oriental, is supported by a 940 m.y. age from the Sierra Nevada de Santa Marta (Tschanz, 1969). The 680 m.y. age from the Santander massif is interpreted as retrograded. Older ages of 1300 to 1400 m.y. are reported by Tschanz from the Sierra Nevada, and ages of 1200 to 1300 m.y. are reported by Pinson and others (1962) to the east of the Cordillera Oriental in the Guayana Shield in the Río Guaviare region, and by Kalliokoski (1965) in central Venezuela. These ages apparently date an older orogeny to the east of that in the Santander massif. The rocks that give the 1300 to 1400 m.y. ages in the Sierra Nevada de Santa Marta are granulite facies rocks, whereas the Bucaramanga Gneiss is no higher grade than the upper amphibolite facies.
The rocks in the two areas could be stratigraphically equivalent but metamorphosed under somewhat different conditions of temperature and pressure. The sample that gave the 940 m.y. age in the Sierra Nevada de Santa Marta is also of the granulite facies. In this case the 940 m.y. ages both in the Sierra Nevada and the Santander massif could be retrograde 1300 m.y. ages. However, the fact that two similar age figures come from such widely separated areas suggests the presence of an extensive metamorphic-plutonic event round 950 m.y. Strongly retrograded granulite facies rocks crop out in a structurally isolated area on the east flank of the Cordillera Central (Feininger, written commun., 1968), but these have not been dated. They underlie phyllite of Ordovician age. Some phases of the Bucaramanga Gneiss resemble phases of the Nus Gneiss and related rocks in the eastern Cordillera Central.

2) The geosyncline in which sediments of the Silgará Formation were deposited was apparently of considerable extent and received an appreciable thickness of sediment along the site of the present Cordillera Oriental and possibly the Cordillera de Merida in nearby Venezuela. The Silgará Formation east of the Bucaramanga fault in the Pescadero-Aratoca area projects westward with undiminished thickness under the Mesozoic sedimentary cover. The Silgará may have been fairly thick beneath the Magdalena Valley, but its present subsurface distribution is speculative because of intervening large wrench faults. (Feininger, 1970) between the Cordilleras Central and Oriental. The Ordovician rocks at Cristalina station on the Antioquean railroad are probably correlatable with the Silgará. These may be the remnants of a once thick section, but it is equally likely that the thickness of the Ordovician rocks never was great.
The thickness of the Silgará is uncertain. The Silgará in the
Pescadero-Aratoca area may be 3700 meters thick and there is probably
a similar amount, if not greater thickness, in the Quebrada Silgará
area. Hubach (1957, p. 162) notes that the equivalent Guéjar series
thickens appreciably in the Cordillera Oriental westward from the
Serranía de la Macarena. Renz reports 2000 meters of the Guéjar on
the trail to Uribe. C. J. Campbell (1965, enclosure 1 and p. 11)
calculates the Quetame Group east of Bogota and correlative of the
Guéjar series is 2750 meters thick. Christ (1927, p. 404) estimates
the total thickness of the possibly correlative Bella Vista and
Caparo Formations in the Cordillera de Mérida as 3000 meters.

No evidence has been seen that the Precambrian rocks in the
Santander massif were exposed during the time of deposition of the
Silgará Formation. The source area for the thin-bedded fine-grained
primarily siliceous sediments may be the Guayana shield to the east.
The thickness of the formation in different areas and its degree of
metamorphism give some clue as to the limits of the Ordovician-
Cambrian Basin. The Ordovician-Cambrian Guéjar Group in the Serranía
de la Macarena is thin, very lightly metamorphosed, and contains
appreciable amounts of quartz sandstone (Hubach, 1957, p. 161-162).
Further north, the Caparo Formation of Ordovician age between the
Cordillera de Mérida and the Barinas Basin to the south is 700 meters
thick and little metamorphosed. The nonfossiliferous Bella Vista
Formation which crops out in the same area and is of presumed
Cambrian age is more strongly metamorphosed.
and much thicker. The two formations appear to be separated by a major fault (Pierce, 1960, p. 220), and the Bella-Vista may represent metamorphosed deposits of a deeper part of the geosyncline than the Caparo Formation. The Macarena area and the Barinas basin area may be near the limits of the Ordovician-Cambrian basin. In the Serranía de Perijá, the Ordovician and Cambrian strata also appear to be thin and little metamorphosed. Hea and Whitman (1960, p. 354) indicate about 1000 meters thickness in northwest Venezuela for their revised definition of the Perijá Series, which they consider to be Ordovician and Cambrian rather than Lower Devonian. Trumpy (1943, p. 1292) indicates about 700 meters of thickness for pre-Devonian beds south of San Isabel in the southwestern Perijá and these are little metamorphosed. Possibly the Serranía de Perijá represents the site of the western or northern margin of the Early Paleozoic geosyncline. No rocks of Ordovician-Cambrian age are known from the Sierra Nevada de Santa Marta (Tschanz, written commun., 1969).
3) The degree and extent of the Late Ordovician-Early Silurian
metamorphism and plutonism is somewhat uncertain, and without a better
knowledge of the stratigraphic boundary between the Bucaramanga Gneiss
and the Silgará Formation no definite statement can be made. Some of
the coarse-grained mica schists and the meta-wackes assigned to the
Silgará Formation may actually be less metamorphosed Bucaramanga
Gneiss. The true base of the Ordovician(?) and Cambrian(?) rocks may
be somewhat higher than we have indicated on our map. The principal
evidence for an Ordovician-Silurian orogeny lies in the fact that
metamorphosed rocks with radiometric ages of 450 m.y. and 410 m.y.
are unconformably overlain by unmetamorphosed rocks of Devonian age.
Similar ages have been obtained elsewhere in eastern Colombia and
western Venezuela (table 4). It is unlikely that these closely-
spaced ages are retrograded Precambrian ages. The Ordovician-Silurian
metamorphism however was too weak to entirely eradicate radiometric
evidence for the Precambrian age of the Bucaramanga Gneiss. It is
puzzling, however, that the distribution of isograds and orthogneiss
in the Silgará Formation and Bucaramanga Gneiss suggest but a single
metamorphic-plutonic event rather than the two events indicated by the
radiometric ages. A more detailed study of the stratigraphic relation
of the Silgará Formation to the Bucaramanga Gneiss and of the spatial
relations of the rocks mapped as orthogneiss in the Santander massif
is needed.
4) No fossil or other evidence exists for the presence of strata of Silurian and lower Devonian in the Santander massif; presumably this was a time of uplift and erosion. However, Mencher (1963) cites Boucot as stating that fossils in the Cordillera de Merida of Venezuela previously thought to be Devonian are in reality Silurian in age, implying the presence of Silurian strata in that region.
The basin of deposition of the Floresta Formation and other Devonian rocks in the Cordillera Oriental and Cordillera de Mérida was apparently a widespread shallow sea. In most places the Devonian section is thin and unmetamorphosed or only slightly metamorphosed. The Cachiri Group of the eastern flank of the Serranía de Perijá is about 2600 meters thick (Sutton, 1946, p.1635) and is considered to be the maximum thickness for the Devonian system in Venezuela. Pierce (1960, p. 223-225) indicates a thickness of 1800 meters for two formations of the Mucachuchi Group of Devonian age in the Cordillera de Mérida. At Floresta, the thickness of the type Floresta Formation is 600 to 700 meters (Botero, 1950, p. 259). Patches of completely unmetamorphosed Devonian strata occur in the Acuavio, Medina, and Villariconcio quadrangles in central Colombia, east of Bogota. According to Campbell (1965, enclosure 1 and p. 11) these strata are about 600 meters thick. Near Bucaramanga, the thickness of the Floresta is estimated also to be 600 to 700 meters by us. Near the center of the Santander massif, where the Devonian rocks are more metamorphosed than elsewhere, the section appears to be thicker, but folding makes accurate measurement of the section impossible. This area may be coincident with the axis of the Devonian miogeosyncline. As with the Ordovician-Cambrian geosyncline, the probable site of the axis of the geosyncline and the most intense metamorphism are nearly coincident with the axis of the Cordillera Oriental where are now exposed the oldest and most metamorphosed rocks.
6) The metamorphism of the Floresta Formation in the Santander massif may have taken place between the Middle Devonian and the Middle Pennsylvanian, a span in which no fossil or sedimentary record is known to be preserved. However, no appreciable angular discordance between the Floresta Formation and the overlying Carboniferous beds is evident in most places, nor are there any radiometric ages within this time span. We also observed in the Berlin and Mutiscua areas that the Diamante Formation of Middle Pennsylvanian to Permian age was affected by the metamorphism of the Floresta Formation. Although the recrystallization of the limestone of the Diamante could be attributed to thermal metamorphism related to emplacement of the Jurassic-Triassic batholiths, the phyllitic rocks associated with the recrystallized limestone in the Mutiscua area are not the product of simple thermal metamorphism. Either the limestone and associated phyllite are not Diamante, but possibly Floresta Formation, or the metamorphism of the Devonian and Pennsylvanian rocks occurred later, in Late Permian to Early Triassic time (see event 9).

7-8) From the Late Permian event (8) to the Late Triassic event (11) was apparently a time of progressively increasing orogenic activity whose initial pulse is registered in the mild discordance between the Diamante Formation and the overlying Tiburon Formation.
9) The metamorphism of the Floresta Formation in the Santander massif is most intense in the east central part of the massif and, except for the Mogotes area, is confined to a rather restricted belt from Capitanejo to the Mutiscua area. Metamorphosed Devonian rocks are present in the Cordillera de Mérida, but Devonian beds are not metamorphosed in the Serranía de Perijá nor in the Convención region of the Department of Norte de Santander. The axis of most intense metamorphism of the Devonian rocks thus appears to lie on the east flank of the Santander massif and to swing off northeastward into the Cordillera de Mérida of Venezuela.

The existence of radiometric ages ranging from Latest Pennsylvanian to Early Triassic in the Cordillera de Mérida, Sierra Nevada, and Santander massif (table 4), and the presence of metamorphosed Pennsylvanian rocks in the Santander massif support the interpretation of a plutonic-metamorphic event during Late Permian to Triassic time. Radiometric ages in this time span have also been reported from the Cordillera Central. This event appears to have been marked in most places mainly by plutonic intrusion without attendant regional metamorphism except in the Santander massif and the Cordillera de Mérida. Possibly the spread in the radiometric ages is apparently the combined result of different methods of dating and the effect of heating during the major episode of batholithic intrusion in the Jurassic and Late Triassic in the Cordillera Oriental and Sierra Nevada de Santa Marta.
10) For the first time there is definite evidence that the massif was once a positive area. The evidence is that the Bocas Formation contains detritus derived from older rocks of the massif. The deposition of the continental sediments of the Bocas Formation followed the Late Permian-Early Triassic orogeny and marks the beginning of a new phase in the history of the massif.

11) The Late Paleozoic-Early Mesozoic orogenesis and uplift culminated in widespread postkinematic emplacement of calc-alkaline batholiths in the Santander massif (the Santander Plutonic Group), the Sierra Nevada de Santa Marta (Tschanz, written commun., 1969), and probably in the Merida Andes. The oldest batholiths were emplaced near the Jurassic-Triassic boundary in the Santander massif. The nearby Palmar Granite of northwest Venezuela, however, appears to be somewhat older (Mencher, 1963, p. 75). Emplacement of the batholiths continued well into the Jurassic period both in the Sierra Nevada de Santa Marta (Tschanz, written commun., 1969) and in the Santander massif.
Continental and marine red beds containing volcanic debris interlayered with volcanic rocks are widely distributed in the Santander massif, Cordillera de Mérida, Serranía de Perija and Sierra Nevada de Santa Marta, and on the east flank of the Cordillera Central. Their age ranges from Triassic through Jurassic and in some places even into the Early Cretaceous. In the Santander massif, the Jordán Formation contains less igneous material than do equivalent beds in the Perija and Sierra Nevada de Santa Marta and Cordillera de Mérida. The Jordán is quite variable in thickness, in part due to later differential uplift and erosion and probably also due to original deposition in basins of limited width and depth.

Renewed orogenesis in Late Jurassic time is recorded by the angular unconformity between the Jordán and Giron Formations. The present distribution and thicknesses of the Giron also suggest deposition in rather limited basins. Clasts derived from the Triassic-Jurassic batholiths show that these were de-roofed by the time of deposition of the Giron Formation.

Deposition of the Giron Formation was followed by a period of quiescence and marine transgression during the Cretaceous. On the west flank of the Santander massif, marine deposition began in the Early Cretaceous, but on the east flank it did not begin until the Middle Cretaceous. The Giron Formation on the east side of the massif may be in part of Early Cretaceous age, equivalent to the Río Negro Formation of western Venezuela.
Perphyry dikes that cut Lower Cretaceous rocks northeast of Bucaramanga as well as rhyolite in the Ocaña area north of the area of the geologic maps with a radiometric age of 127 m.y. show that igneous activity in the Santander massif continued into the Early Cretaceous. Radiometric ages of 129 and 131 m.y. have been obtained from rhyolite ignimbrite and granodiorite respectively in the Sierra Nevada de Santa Marta (Tschanz, written commun., 1963). A period of mineralization affecting rocks of Middle Cretaceous age in the Santander massif occurred at some later date.

15) In the Late Cretaceous, marine deposition continued in the area of the Santander massif but was interrupted by three periods of mild uplift and erosion of varying extent (Maughan, personal commun.). These uplifts occurred prior to, during, and following the black shale-chert-phosphorite deposition of the La Luna Formation which covered a very large area of Colombia and western Venezuela. In the last and most far-reaching of these periods, much of the La Luna was eroded in some places, including the main phosphorite beds. A thin but widespread conglomeratic and glauconitic sandstone at the base of the overlying Umir Formation contains varying amounts of phosphatic pellets and nodules derived from the eroded beds of the La Luna. Seas became gradually shallower during the deposition of the shales of the Umir, and of the Colón and Mito Juan Formations.
16) By the end of Cretaceous time, s^as had withdrawn to the extent that sedimentation was taking on a continental character, with coal beds in the upper Umir and in the Paleocene Lisama Formations. The Santander massif in the area of the present report probably became again a positive area during this period (see also Young et al, 1956, fig. 6).

17) The Tertiary period was one of continued uplift and diastrophism. In the absence of any remnants of Tertiary formations in the large area between the western part of H-12 and the eastern part of H-13, it is difficult to estimate the original extent of the Tertiary deposition in most of the area of the massif as well as in the mesa and plateau area west of the Bucaramanga fault. The deposition was undoubtedly of continental nature and similar to that which is present in the western and eastern areas at the present time. According to Morales et al (1958, p. 664), the sedimentary record in the middle Magdalena Valley gives evidence of uplifts there at the end of the Paleocene, at the end of the Eocene, at the close of the Oligocene, in the Middle Miocene, and during the Pliocene. There may have been two other uplifts, although the evidence is less clear (Julivert, 1961b, p. 41). During the Oligocene, the middle Magdalena Valley was flooded by the most widespread transgression of the Tertiary, but deposition remained essentially continental in character (Morales et al, 1958, p. 664).
The discordances in the section of the middle Magdalena Valley are known in the oil-producing area west of the La Salina fault where the Tertiary section is probably only half as thick as that in the Nuevo Mundo syncline to the east of the fault. The thicker section in the syncline represents a more nearly continuous accumulation of sediments derived from the rising area to the east that included not only the massif but the mesa and plateau area west of the Bucaramanga fault as well. The increasing coarseness of the material deposited during the Oligocene and Miocene reflects the increase in the rate of uplift as the Tertiary period progressed.

On the eastern flank of the massif, remnants of Tertiary formations that are present in fault blocks and in the Cerrito structural basin are limited to the Paleocene, Eocene, and lower Oligocene. These rocks are mostly similar in lithology to those of the same age in the middle Magdalena Valley but are only about half as thick, indicating a slower rate of deposition or possibly less deposition to the east of the massif during this part of the Tertiary.

18) The deposits in the vicinity of Bucaramanga record the latest events in the geologic history of the area. No fossils have been found with which to fix the age of these deposits, but they are generally regarded as of Quaternary age. Julivert (1963) has recognized four stages which we have modified somewhat:
1. Very coarse to fine fluvial materials of the present Bucaramanga terrace were deposited in a sinking block between the Suárez and Bucaramanga faults to a depth of 250-300 meters. The sinking was further localized south of a connecting fault along Río Suratá (de Porta, 1959, fig. 2).

2. During a period of regional uplift that followed, unsorted colluvial material derived from deeply weathered rock was deposited over much of the terrace. Similar colluvial deposits in the mesa area and throughout the Cordillera Oriental are thought to have been formed at the same time.

3. Locally in the highest parts of the Bucaramanga terrace, a sequence of interbedded gray silts and peaty material up to five or six meters thick accumulated over the colluvial deposits.

4. Small terraces below the level of the Bucaramanga terrace do not have its cover of colluvial material. These terraces are therefore of more recent origin, and indicate stages in the dissection of the valley fill.
The Suárez and probably the Bucaramanga faults were active during the accumulation of the sediments of the present Bucaramanga terrace but probably not since that time. Remnants of the colluvial material that overlies the Suárez fault have not been disturbed by any later movements on the fault (Julivert, 1963, fig. 7).

The alpine glaciation that occurred in the highest parts of the Santander massif probably developed during one of the major glacial periods of the Pleistocene. The surfaces of glacio-fluvial deposits seem to be graded to the surfaces of terraced remnants of valley fill such as the Bucaramanga terrace.

Diastrophism and uplift in the Cordillera Oriental continue actively at the present time. Within the report area, erosion is proceeding in the massif at elevations up to 4500 meters while material is being deposited in the northern part of the Nuevo Mundo syncline at elevations of less than 100 meters. Erosion processes can be observed very strikingly in such areas as that of Río Umpalá where it cuts the Santa Bárbara batholith. Here the deeply weathered rock crumbles and slides down long steep slopes to the river which carries the material away like a conveyor belt.
REFERENCES CITED


5. Botero, R. Gilberto, 1945a., Estudio preliminar sobre las pegmatitas que contienen mica, en el Departamento de Norte de Santander, in Compilación de los estudios geológicos oficiales en Colombia: Servicio Geológico Nacional (Colombia), Tomo VI, p. 263-305.


Christ, Peter, 1927, La coupe geologique le long du chemin de Mucuchachi a Santa Barbara dans les Andes venezueliennes: Eclog. Geol. Helv.


De Porta, J., 1959, La terraza de Bucaramanga: Univ. Indus. de Santander (Colombia), Bol. de Geologico, no. 3, p. 3-13.


Etayo, F., 1964, Posicion de las faunas en los depositos cretacicos colombianos y su valor en la subdivision cronologica de los mismos: Univ. Indus. de Santander (Colombia), Bol. de Geologia, nos. 16, 17, p. 1-142.


1957, Contribucion a las unidades estratigraficas de Colombia: Servicio Geologico Nacional (Colombia), Informe 1212, 166 p.


Julivert, I. de, 1963, Estudio petrográfico de las calizas de la formación Rosablanca de la región de la Mesa de Los Santos: Univ. Indus. de Santander (Colombia) Bol. de Geología, no. 15, p. 5-34.

Julivert, M., 1958, La morfoestructura de la zona de mesas al SW. de Bucaramanga: Univ. Indus. de Santander (Colombia) Bol. de Geología, no. 1, p. 7-44.

1959, Geología de la vertiente W del macizo de Santander en el sector de Bucaramanga: Univ. Indus. de Santander (Colombia) Bol. de Geología, no. 3, p. 15-34.

1961a, Las estructuras del valle medio del Magdalena y su significación: Univ. Indus. de Santander (Colombia) Bol. de Geología, no. 6, p. 33-52.

1961b, Geología de la vertiente W de la Cordillera Oriental en el sector de Bucaramanga: Univ. Indus. de Santander (Colombia) Bol. de Geología, no. 8, p. 39-42.

1963, Nuevas observaciones sobre la estratigrafía y tectónica del Quaternario de los alrededores de Bucaramanga: Univ. Indus. de Santander (Colombia) Bol. de Geología, no. 15, p. 41-56.
Julivert, M., Barrero, D. y Navas, G., 1964, Geología de la Mesa de Los Santos: Univ. Indus. de Santander (Colombia) Bol. de Geologia, no. 18, p. 5-11.

Julivert, M., and Tellez, N., 1963, Sobre la presencia de fallas de edad precretaciá y post-Giron (Jura-Triásico) en el flanco W del macizo de Santander (Cordillera Oriental, Colombia): Univ. Indus. de Santander (Colombia) Bol. de Geologia, no. 12, p. 5-17.

Julivert, Manuel, 1970, Cover and basement tectonics in the Cordillera Oriental of Colombia, South America, and a comparison with some other folded chains: Geol. Soc. America Bull., v. 81, p. 3623-3646.


Langenheim, J. H., 1959, Preliminary notes on plant fossils from Late Paleozoic and Early Mesozoic rocks in the Cordillera Oriental of Colombia: Univ. Indus. de Santander (Colombia) Bol. de Geologia, no. 3, p. 51-53.


Martinez, L. E., 1962, Investigacion de unos yacimientos de yeso, barita, y cobre en el Municipio de Zapatoca, Departamento de Santander: Servicio Geologico Nacional (Colombia), Informe 1127, 17 p.


Navas, J., 1962, Geologia del Carbonifero al N de Bucaramanga: Univ. Indus. de Santander (Colombia) Bol. de Geologia, no. 11, p. 23-34.

1963, Estudio estratigrafico del Giron al W del macizo de Santander (Cordillera Oriental, Colombia): Univ. Indus. de Santander (Colombia) Bol. de Geologia, no. 12, p. 19-33.


Paba, F., 1946, Carbones del Municipio de San Vicente de Chucuri, Departamento de Santander: Servicio Geologica Nacional (Colombia), Informe 525, 8 p.
Paba, F., 1948, Segundo informe de los carbones del Municipio de San Vicente de Chucuri, Departamento de Santander: Servicio Geológico Nacional (Colombia), Informe 627, 23 p.


Restrepo, V., 1937, Estudio sobre las minas de oro y plata de Colombia: Annales Escuela Nac. Minas de Medellin (Colombia), no. 43.


Scheibe, E. A., 1933, Estudios geologicos y paleontologicos sobre la Cordillera Oriental de Colombia, parte 1: Dept. de Minas y Petroleo (Colombia), 58 p.


Servicio Geologico Nacional (Colombia), 1961, Mapa geologico de Colombia.

1962, Mapa geologico de Colombia.


Tellez, N., 1964, Geologia de la Mesa de Barichara: Univ. Indus. de Santander (Colombia), Bol. de Geologia, no. 18, p. 12-21.


Wokittel, R., 1953, Yacimientos del Municipio de Molagavita, Departamento de Santander: Servicio Geologico Nacional (Colombia), Informe 972, 21 p.

1954, Recursos Minerales de los zonas Alta, Baja, y Vetas en el Municipio de California, departamento de Santander: Servicio Geologico Nacional (Colombia), Informe 1030.

1957, Yacimientos minerales en el Municipio de Barichara, Departamento de Santander (Barita, yeso, cobre): Inst. Geol. Nac. (Colombia), Informe 1169, 10 p.


Van der Hammen, T. y Gonzales, E., 1963, Historia de clima y
vegetacion del Pleistoceno superior y del Holoceno de la Sabana
de Bogota: Servicio Geologico Nacioinal (Colombia) Bol. Geol.,
v. XI, p. 189-260.

Ward, D. E., Goldsmith, Richard, Jimeno, V. A., Cruz, B. J., Gomez, R.
E., 1969, Mapa geologico del cuadrangulo H-12, "Bucaramanga,"
Colombia: Colombia Ministerio de Minas y Petroleos, Inst. Nac.
Inv. Geologico-Mineras.

Ward, D. E., Goldsmith, Richard, Cruz, B. J., Jaramillo, C. L., Vaugas,
I. R., 1970a, Mapa geologico del cuadrangulo H-13, Pamplona:
Colombia Ministerio de Minas y Petroleos, Inst. Nac. Inv. Geologico-
Mineras.

Ward, D. E., Goldsmith, Richard, Cruz, B. J., Tellez, I. N., Jaramillo,
C. L., 1970b, Mapa geologico de parte de los cuadrangulos I-12
(San Gil) I-13 (Malaga): Colombia Ministerio de Minas y petroleos,

Mineral resources of the southern half of zone III, Santander,
Norte de Santander, and Bayaca, Colombia: U.S. Geol. Survey open-

Risko, F., 1926, Memoria detallada de los estudios del Rio Magdalena:
Obras proyectadas para su arreglo y resumen del presupuesto:
Ministerio de Obras Publicas (Colombia) Editorial Minerva.