Preliminary report on the stratigraphy of the Giron formation in Santander and Boyaca

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RESUMEN.—Se estudian los afloramientos de la "formación Girón" en la Sierra de Arcabuco (Duitama) y en la plataforma de Lebrija y zonas vecinas, en Santander. La sección del río Lebrija es la más interesante y la que puede considerarse como sección tipo; en ella se reconocen 3.500 metros de Girón con tres niveles, entre los que existe un paso gradual. El nivel inferior es de arenisca que contiene cantos de cuarzo o de rocas ígneas; su espesor es de 750 metros. El nivel medio es de "shales"; su potencia es de 1.250 metros. El nivel superior está formado nuevamente por areniscas de grano medio a grueso con cantos de cuarzo o rocas ígneas; tiene alrededor de 1.500 metros de espesor. Girón se encuentra discordante sobre rocas de edad carbonífera en Bucaramanga y sobre un complejo metamórfico algo más al S. Se apoya sobre una superficie arrasada, si bien el depósito debió empezar más precozmente en algunos puntos, probablemente durante el pensilvaniense superior; no obstante la mayor parte de la formación debe ser de edad Rhetiense-Liásico. Existen intrusiones ígneas truncadas por la formación Tambor que se superpone discordante sobre Girón. Son característicos también en Girón los frecuentes cambios de facies; el origen del aporte para la zona de Lebrija hay que buscarlo al N de Bucaramanga. Existen mineralizaciones, especialmente de cobre.

RESUME.—La formation Girón est étudiée dans les secteurs "Sierra de Arcabuco" (Duitama) et Lebrija et ses environs. La coupe du río Lebrija est la plus intéressante ainsi que la plus complète. On reconnait trois niveaux parmi lesquels n'existe pas une limite bien nette et dont l'épaisseur atteint les 3.500 m. A la base des grès avec des galets de quartz et des roches eruptives, avec une puissance de 750 m. Le niveau moyen de 1.250 m. d'épaisseur constitué par des "shales" et le niveau supérieur representé aussi par des grès avec des galets quartzeux et de roches eruptives, la puissance est de 1.500 m. Girón s'est déposé sur une surface érodé discordant sur le carbonifère, à Bucaramanga et plus au Sud sur des roches métamorphiques d'âge plus ancienne. Dans certains endroits le dépôt de sediments a commencé pendant le Pennsylvanien supérieur, mais la plupart du Girón doit être d'âge Rhétien-Liasique. Des intrusions eruptives sont découpées par la formation Tambor qui surmonte discordante le Girón. Il faut remarquer les changements de faciès, très typiques de la formation Girón; l'apport de sediments pour la région de Lebrija proviendrait du Nord de Bucaramanga.

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INTRODUCTION

The Giron formation includes many different kinds of non-marine clastic rocks and is widely distributed in the Cordillera Oriental of Colombia and the Venezuelan Andes. Other outcrops occur on the flanks of the Sierra Santa Marta and in the Cordillera Central. Only exposures in the core of the Arcabuco Range at Duitama, on the Lebrija Highland of eastern Santander and in adjacent areas, however, are considered here.

The Giron formation is sparsely fossiliferous and the few known plants, fish and non-marine invertebrates are mostly undescribed. Wherever the upper contact is exposed the Giron formation is succeeded by Cretaceous rocks that are generally considered Hauterivian or younger. The base of the formation is less widely exposed, but rocks as young as Pennsylvanian occur unconformably beneath the Giron formation. Therefore the stratigraphic position of the formation restricts it to an age between Pennsylvanian and Hauterivian. Most of the fossils so far reported appear to be of Triassic or Jurassic age.

The present study was undertaken in an effort to discover the age of the Giron formation in its type region, to adequately describe the formation in this area, and to interpret the geologic history of the area. The study has economic significance in addition to its importance in filling an important gap in our knowledge of the geologic history of Colombia. The Giron formation is a record of events immediately preceeding deposition of Cretaceous rocks. Thus full understanding of the Giron formation is necessary to effective interpretation of the conditions under which early Cretaceous rocks were deposited. These conditions, of course, determined the possible distribution of petroleum in the Cretaceous rocks. The Giron formation also includes potential reservoir rocks and may contain oil derived from older or younger strata although it is probably not a source of petroleum. The Giron formation also contains widespread small-scale copper mineralization.

Field work was carried out between June 10 and September 1, 1953. The writer, Dr. Jean H. Langenheim, paleobotanist, Mr. Alberto Ronderos, geologist, Mr. William D. Meyers, geologist and Mr. Daniel Valenzuela, assistant, were in the field during the entire investigation. In addition, Mr. Jaime González, civil engineer, and several field assistants joined the party for a few days in order to survey the Arcabuco Range traverse. Dr. Enrique Hubach, Director of the Instituto Geológico Nacional, selected the problem and guided the course of research throughout. Mr. Herbert Belding and Mr. James Doreen, International Petroleum Corp., Colombia, arranged for cooperation by Intercol and took an active interest in the progress and success of the investigation. In addition, many other individuals and organizations in Bogotá, Duitama, San Gil and Bucaramanga contributed to successful completion of field work. This paper is a contribution from the Museum of Paleontology of the University of California, Berkeley, California, U. S. A.

STRATIGRAPHIC NOMENCLATURE

Giron Formation.—Hettner (1892), in his original description, did not designate a type section and failed to clearly define the stratigraphic limits of the Giron formation. His discussion of the formation includes a description of the Carboniferous rocks at Bucaramanga and does not exclude redbeds of the basal Cretaceous. Schuchert (1935), Oppenheim (1940), Dickey (1941), Trumpy (1943) and others have subsequently recognized the problems arising from Hettner's incomplete description and broad formation concept, but have also failed to clearly define the formation or select a type section. For this reason the Lebrija Gorge section is here designated as the type section of the Giron formation. At this locality the Giron formation consists entirely of non-marine, clastic rocks and is unconformably separated from both the underlying Carboniferous Bocas formation (Alvarado and Del Río, 1947) and overlying Cretaceous rocks. The name "Giron" should be applied only to rocks physically correlative with those of the type section.

Tambor or Arcabuco Formation. A sequence of conglomerate, redbeds and sandstone lies between the restricted Giron formation and the lowest black shale and limestone of the Cretaceous. These Early Cretaceous rocks have formerly been included in the Giron formation (Dickey, 1941; Trumpy, 1943), correlated with the Cocuy quartzite (Oppenheim, 1940), or described separately. They are here considered physically correlative with the cliff-forming sandstone of the Arcabuco area and are therefore equivalent to the Arcabuco sandstone in the restricted sense. The name, "Arcabuco" has, however, been applied to the upper part of the restricted Giron formation as well as to the restricted Arcabuco sandstone thus producing much confusion. Therefore the name, "Tambor formation", (Morales and others 1958) will be employed in this paper although the Tambor formation is considered a facies equivalent of the restricted Arcabuco sandstone. The type section of the Tambor formation is located in the Lebrija Gorge (Morales and others, 1958) in geographic continuity with the type section of the Giron formation.

No attempt has been made to judge the validity of correlations between the Cocuy quartzite and the Arcabuco or Tambor formation.

MEASURED SECTIONS

Columnar sections were measured at Jordan, Mesa de Ruitoque, Lebrija Gorge, Quebrada Pujamanes and on the Arcabuco Range near Duitama (fig. 1).

Jordan.—The section at Jordan was measured up the east flank of the Cuchilla del Peñón at the mouth of Quebrada Monte Grande about three and one-quarter kilometers southwest of Jordan, Santander. 417 meters of Giron formation are exposed at this point (figs. 1 & 2). At the base of the section red arkose alternates with brick-red mudstone in beds up to two meters thick. Higher in the section arkose beds are thinner and less abundant. All of the rock above

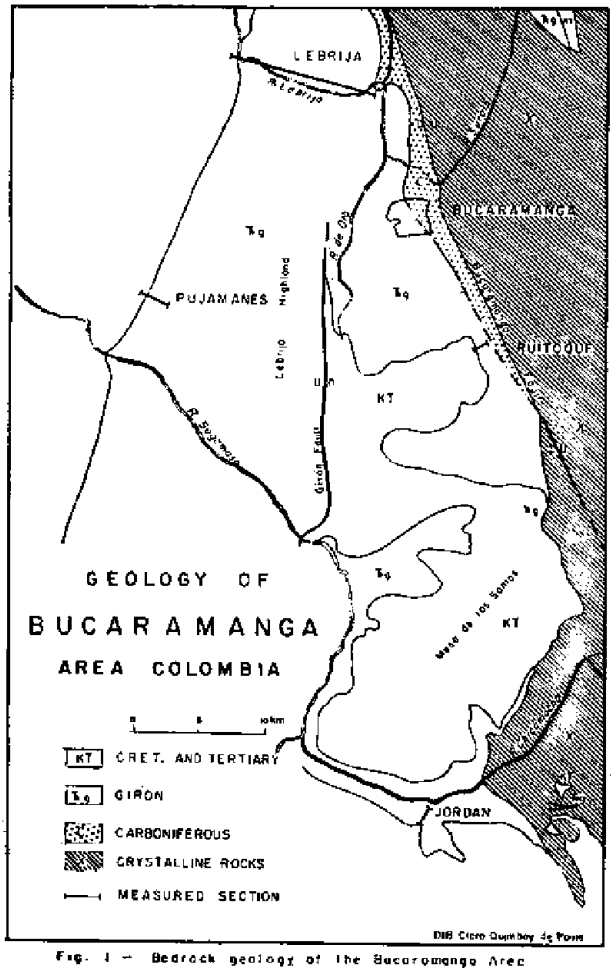

Fig. 1 — Bedrock geology of the Bucaramanga Area

the basal 100 meters is composed of thick to thin-bedded, brick-red mudstone and silty mudstone.

A prominent white arkosic conglomerate about two or three meters thick occurs at the base of the Tambor formation in this section. The contact with the Giron mudstone is sharp, but there are no reworked mudstone fragments within the conglomerate. Pebbles and cobbles in the conglomerate are chiefly composed of white quartz with lesser quantities of igneous and metamorphic rocks. The conglomerate is succeeded by buff sandstone alternating with red sandy shale and siltstone. Sandstone is, however, most abundant and forms an impressive cliff above a bench eroded in ten or twenty meters of interbedded sandstone, siltstone and shale. The massive, cliff-forming sandstone comprises the top of the Tambor formation and is succeeded by Cretaceous black shale and limestone containing marine fossils.

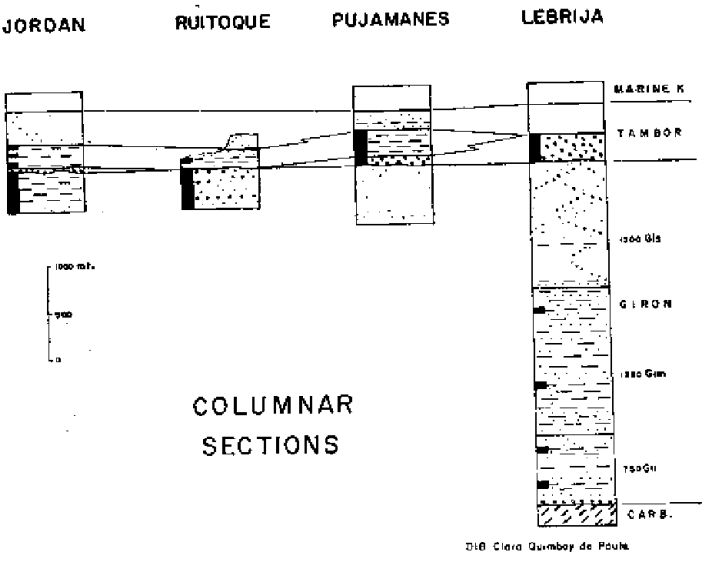

Fig. 2 — Columnar sections in the Bucaramanga Area. The Tambor formation is shown diagrammatically and does not conform to the indicated scale. The black band on the left side of the columns indicates the presence of redbeds

Mesa de Ruitoque.—This section was measured by tape and compass on the south wall of the third prominent quebrada on the east face of the Mesa de Ruitoque about three kilometers south of Floridablanca, Santander (Figs. 1 & 2). Here only 400 meters of Giron formation are exposed below the Tambor formation. Medium to coarse red arkose is most prominent but is interbedded with an approximately equal amount of brick-red mudstone or siltstone. In addition, there are many beds of arkosic conglomerate scattered throughout the exposed four hundred meters of Giron formation.

There is no conglomerate at the base of the Tambor formation and the contact is arbitrarily placed at the base of the first well-washed, buff sandstone. This horizon is also marked by the occurrence of numerous springs. Layers of dark red, massive mudstone are interbedded with white sandstone in the basal fifteen meters of the Tambor formation and are succeeded by thick-bedded, white, cliff-forming sandstone capping the mesa.

Quebrada Pujamanes.—The Quebrada Pujamanes section was measured by tape and compass in the bottom of the quebrada between the top of the Tambor sandstone and the second high waterfall in the south branch of Quebrada Pujamanes, sometimes called Quebrada Volcan (figuras 1 & 2). Quebrada Pujamanes is the first quebrada north of the Rio Sogamoso on the west side of the Lebrija Highland.

All of the 90 meters of Giron measured here are composed of white, cross-bedded, medium to coarse arkose. Igneous and metamorphic rock pebbles occur as thin lenses and layers in the cross-

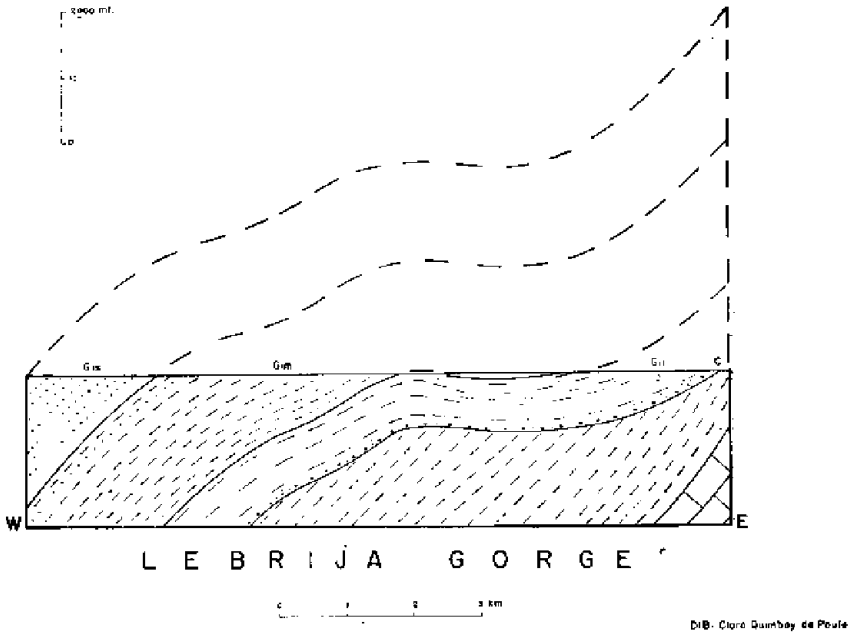

Fig. 3 - Structure section along the Lebrija Gorge showing the Giron formation and the Bucaramanga Carboniferous

lamination. Pebbles are not, however, sufficiently abundant to classify the rock as a conglomerate.

Two layers of red, boulder-conglomerate, separated by coarse arkose, occur at the base of the Tambor formation in Quebrada Volcan. One-half kilometer north in Quebrada Pujamanes the basal conglomerate thickens to approximately four meters in a single stratum. There is no conglomerate, however, at the base of the Tambor formation three kilometers south in the gorge of the Sogamoso River. The remainder of the Tambor formation at these three localities consists of interbedded deep red, massive mudstone, green mudstone and fine gray sandstone. The contact with the black marine shale and limestone above is poorly exposed, and there is no prominent, ledge-forming sandstone at the top of the formation.

Lebrija Gorge.—The Lebrija Gorge section was measured along the line of the railroad between kilometer 108 + 371.96 just below Las Bocas and kilometer 93-00 between Las Palmas and Conchal (Figs. 1 & 3). Measurements were made by reference to railroad survey monuments and maps of the F. C. Central del Norte, Sec. Primera prepared by H. Barrera Soler in 1954. These maps were made available through the courtesy of the railroad administration in Bucaramanga. A supplementary tape and compass traverse in Quebrada Piedra Azul provides data from better exposed outcrops of uppermost Giron and a second supplementary tape and compass traverse in Quebrada Honda establishes the stratigraphic position of a bed containing abundant plant fossils.

The Lebrija Gorge section was selected as the type section of the Giron formation because both the top and base of the formation are exposed, and because the traverse is within the original outcrop area described by Hettner (1892). Also, outcrops are relatively continuous, and the traverse is reasonably accessible. Here the Giron formation is exposed in a terraced monocline over a distance of about seven kilometers. The Giron formation is apparently conformable with the underlying Carboniferous Bocas formation at the dam below Las Bocas, but truncates the Carboniferous at almost right angles one-half kilometer upstream from Las Bocas. There is no basal conglomerate at these localities and gray quartzite of the Giron formation rests directly upon interbedded black shale and carbonaceous sandstone in the Bocas formation. Basal conglomerate does, however occur in the Giron formation in Quebrada San Ignacio between Las Bocas and Bucaramanga and at Cemento Diamante. This conglomerate is only a few meters thick, but contains cobbles of carboniferous limestone and fragments of reworked shale from the Bocas formation.

The Giron formation is approximately 3,500 meters thick in the Lebrija Gorge and includes three members separated by gradational contacts. The lower sandstone member, approximately 750 meters thick, is composed of alternating medium to coarse, gray, quartzitic, arkosic or feldspathic sandstone and massive, thin to thick-bedded, gray, green, or red mudstone. Some of the sandstone is conglomeratic but the pebbles are less than five centimeters in diameter. Pebbles are of igneous rock or quartz. Much of the sandstone is thick-bedded and it is generally cross-bedded.

The middle shaly member, approximately 1,250 meters thick, dominated by mudstone and siltstone with lesser amounts of arkosic or feldspathic sandstone. Most of the mudstone and siltstone is dark gray or black but some is red or green. One bed of black shale in Quebrada Honda contains abundant fern fossils which are probably of Late Pennsylvanian age (Langenheim, 1959).

The upper sandstone member, approximately 1,500 meters thick, is composed almost entirely of gray arkosic or feldspathic sandstone Near the base there is some interbedded shale and fine sandstone, similar to rocks of the middle shaly members, but the remainder contains only a very few isolated thin shaly beds separated by hundreds of meters of uninterrupted thick beds of massive sandstone. The sandstone is medium to coarse and cross-bedded and pebbles of igneous rock and quartz, 1-2 centimeters in diameter form thin layers in the cross-laminae. Isolated chips of black shale up to 10 centimeters in diameter are scattered through the sandstone along with fragments of carbonized wood.

The top of the Giron formation is poorly exposed in the Lebrija Gorge. Near kilometer 93.00, however, approximately 100 meters, of boulder conglomerate prominently crop out near the base of the type section of the Tambor formation. The conglomerate is bright red and boulders of quartzite from the Giron formation are abundant. Similar conglomerate also occurs very close to the base of the Tambor formation in Quebrada Piedra Azul, but only a few meters are exposed. Bright red shale is associated with the conglo-

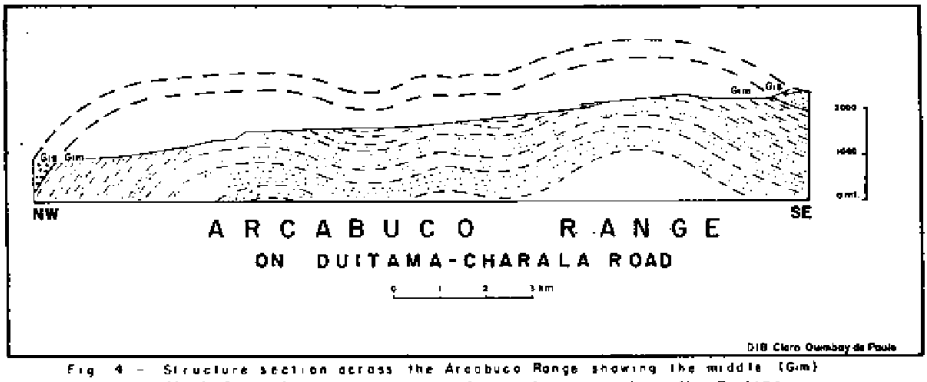

Fig. 4 — Structure section across the Arcabuco Range showing the middle (Gm) and upper (Giv) Giron formation as exposed on a traverse along the Duitama — Charala road and on the ridge west of the Rio Surba

merate and near kilometer 92 on the railroad these rocks are succeeded by white medium to fine quartzitic sandstone similar to the upper sandstone at Mesa de Ruitoque and Jordan. This sandstone is succeeded by dark marine shale and limestone containing Cretaceous marine fossils.

Arcabuco Range.—The Arcabuco Range section was measured by means of a plane table traverse along the Duitama-Charalá road between the Boyacá fault on the southeast and the base of the Tambor formation on the northwest (Fig. 4). A side traverse was also made on the ridge-top northwest of the Rio Surba Valley between the base of the Tambor formation and the highway. Rocks of the Giron formation exposed in the northernmost quebrada at the head of Rio Palermo were examined but were not measured. No formations older than the Giron formation were observed in the head of this canyon at what appeared to be the lowest stratigraphic horizon exposed in the range.

The lowest exposed part of the Giron formation consists of interbedded steel-gray arkose and micaceous mudstone. These rocks are similar to those of the lower unit in the Lebrija Gorge and are tentatively assigned to the lower sandstone member. Rocks of the lower sandstone member are gradationally succeeded by dark gray to black mudstone interbedded with fine sandstone and siltstone in the middle shaly member. Approximately 1,000 meters of the middle member were measured on the traverse and approximately 400 meters more are exposed in the headwaters of Rio Palermo. The mudstone and shale contains widely disseminated plant debris including, cycadeoids, conifers, ginkgos and other plant remains. The plant fossils appear to be Rhaetic or Jurassic in age (Langenheim, 1959). Estherids, ostracods and freshwater mollusca are also abundant. In addition, black sandy limestone, known from float fragments in the head of Rio Palermo, contains fresh or brackish-water pelecypods.

The middle shaly member is succeeded by approximately 400 meters of medium to coarse red arkose and arkosic conglomerate interbedded with micaceous red siltstone and mudstone. The contact between the middle shaly member and upper sandstone member is transitional but the first interbedded arkose in the middle shaly mem-

ber is only a few meters below the base of the dominantly arkosic upper sandstone member. The upper sandstone member is well-exposed in the Rio Surba Valley which parallels the strike of these beds over much of its length. The upper sandstone member is also well-exposed in the higher peaks of the range and beneath the Tambor formation high on the northwest side of the range north of the road. It is not, however, exposed where the highway passes over steeply dipping, deeply weathered beds immediately beneath the Tambor formation on the northwest side of the range. Its apparent absence here seems to be a result of poor exposure and a local increase in the proportion of interbedded siltstone and mudstone.

The Giron formation is succeeded by massive, white, feldspathic or arkosic, cliff-forming sandstone in the Tambor formation on the northwest side of the range. Interbedded green or red silty and shaly beds up to two meters thick occur near the base of the Tambor formation but are relatively inconspicuous. Thin erosional remnants of the Tambor formation cap some of the higher spurs on the southeast side of the range and the regional aspect of the Tambor formation suggests that it was also thinner here.

STRATIGRAPHY AND GEOLOGIC HISTORY

Metamorphic Rocks.—At the Mesa de Los Santos the Giron formation rests directly on metamorphic rocks which form the core of the Santander massif and is overlapped by the Tambor formation which also rests on metamorphic rocks at the east end of the Mesa (Fig. 1). Metamorphic rocks intruded by a quartz porphyry stock are well-exposed along the road between Los Curos and the top of the Mesa de Los Santos. The stock, at the Los Curos end of the road, is unmetamorphosed, though deeply weathered. It is also similar in composition to the rhyolite stock intruding the Giron formation at Jordan and is probably much younger than the surrounding metamorphic rocks. Its contact with the metamorphic rocks is sharp and no evidence of contact metamorphism was observed. Phyllite is the most abundant rock along the road between the stock and the Tambor formation, but is accompanied by garnet schist, mica schist and quartzite. Quartz veins and pegmatite dikes are also present. A careful search for fossils in the phyllite was unsuccessful.

Nearly horizontal and less intensely metamorphosed quartzite, quartzite conglomerate and phyllite are in fault contact with the Giron formation at San Rafael. Farther west highly metamorphosed mica-schist occurs in contact with the Giron formation at Alto de Pedregal. Coarse granitgneiss and magnesian rocks are prominent at El Picacho near Aratoca.

Presence of much less highly metamorphosed Carboniferous and Devonian rocks in this general area indicates that the metamorphic rocks are probably at least Early Paleozoic in age. Complete absence of fossils suggests that they may be Pre-Cambrian, but the complex record of their deposition and subsequent history is beyond the scope of this investigation.

Floresta Formation.—The Floresta formation is composed of mudstone, siltstone and fine sandstone which is, in most exposures, weathered to massive, soft, buff clay. Abundant brachiopods, bryozoa

and molluscs are preserved as molds in distinct fossiliferous layers. The formation is a record of shallow marine deposition in an area of weak current action during the Devonian period.

Bucaramanga Carboniferous.—The Carboniferous rocks at Bucaramanga include marine limestone, shale and sandstone; redbeds; and black shale and muddy sandstone of swamp or flood plain origin. Interbedded marine rocks and redbeds in the lower portion of the section are a record of oscillation between marine and non-marine environments during latest Mississipian and/or earliest Pennsylvanian time. These rocks are succeeded by black shale and interbedded limestone which grade upward into interbedded carbonaceous shale and sandstone of the Bocas formation. The lower portion of this sequence is at least partially marine in origin but the upper portion contains estherids, fresh water molluscs and plant remains. Plant fossils include *Mesocalamites* and *Cordaites* (Langenheim, 1959) indicating a shift to non-marine environments of deposition in this area probably in Pennsylvanian time.

Giron Formation.—The Giron formation rests in angular unconformity on Carboniferous rocks at the type section and elsewhere in the Bucaramanga area. In the Chicamocha canyon it rests nonconformably upon metamorphic rocks. Thus deposition of the Giron formation was preceded by deformation of Pennsilvanian and older rocks followed by formation of an erosion surface. These events may have occurred at any time after the earliest Pennsylvanian. The plant fossils at Quebrada Honda, however, indicate that deposition of the Giron formation probably began during the Late Pennsylvanian. The coarse, non-marine sediments at the base of the Giron, however, indicate that rapid erosion was in progress at the time of their deposition. This, in turn, suggests that the erosion surface beneath the Giron was probably formed shortly before its deposition, perhaps synchronously with the deposition of part of the Giron formation itself. Thus, although Late Paleozoic rocks may occur in the deeper and older parts of the Giron basin, the bulk of the Giron formation may be of Rhaetic-Liassic age.

The following rock types are abundantly represented in the Giron formation: arkosic conglomerate, fine to coarse red arkose, fine to coarse gray arkose or feldspathic sandstone, micaceous red or green siltstone, black, green or red shale, and black, green or red mudstone. The only carbonate rocks noted are black medium-grained fossiliferous limestone observed as float fragments in the core of the Arcabuco Anticline, and limestone nodules and lenses in red mudstone at Jordan.

Igneous rocks intrude the Giron formation but are truncated by the overlying Tambor formation near Jordan (Fig. 1). The trail between Los Santos and Jordan crosses outcrops of a small stock which yielded samples identified by Nelson (1953) as rhyolite and rhyolite tuff. Several dikes and sills also crop out in the vicinity, but no other igneous rocks were observed intruding the Giron formation in the area studied. Widespread association of extrusive igneous rock with the Giron formation in other areas suggests, however, that the intrusions at Jordan were probably emplaced shortly after the deposition of the Giron formation.

Abrupt facies change characterizes the Giron formation. Between the Giron and Bucaramanga faults (Fig. 1) the rock is red and cobble and boulder conglomerate is abundant. The rocks of the Lebrija Highland and the Arcabuco Range are, however, mostly buff or black sandstone and shale and coarse conglomerate is generally rare. East of the Giron fault the Giron formation is relatively thin in contrast to sections over 1,000 meters thick wherever the formation is completely exposed to the west. Thus it is convenient to refer to the thick, gray and buff Giron formation of the Arcabuco-Lebrija area as the western facies and the thinner redbeds of the Bucaramanga-Los Santos areas as the eastern facies.

Furthermore the distribution of the two facies suggests that the source of Giron sediments in the area studied was located east and possibly north of Bucaramanga. The basal sandy member of the western facies is best exposed in the Lebrija Gorge. Here it is dominated by steel-gray, massive, cross-bedded feldspathic or arkosic sandstone. Almost all of the interbedded micaceous siltstone and mudstone is gray or green. South of Las Bocas, however, these rocks become more red in what appears to be a transitional change to conditions typical of the eastern facies. The basal sandy member of the Giron is also exposed in the head waters of Palermo Canyon in the Arcabuco Range where it is similar to its exposures in the Lebrija Gorge.

The lower sandy member apparently was deposited by rapidly flowing streams draining an area of eroding crystalline rocks. The depositional surface was probably submerged or saturated most of the time as indicated by the generally unoxidized sediments.

The middle shaly member is chiefly composed of dark green or black micaceous siltstone in the Lebrija Gorge. This material is interbedded with less abundant layers of fine to medium, buff to gray arkose or feldspathic sandstone. In the Arcabuco Range the middle shaly member is generally finer grained. Black mudstone is predominant and black limestone apparently occurs near the base of the member in Palermo Canyon. Redbeds are almost completely absent in all exposures of the middle shaly member examined in the western facies.

The middle shaly member is the most abundantly fossiliferous portion of the Giron formation. It includes the probably Late Pennsylvanian at Quebrada Honda on the Rio Lebrija (Langenheim, 1959). It also contains the plant fossils of the Arcabuco Range which are probably Rhaetic or Jurasic in age (Langenheim, 1959). The Arcabuco Range plants, however, are accompanied by abundant estherids described as *Howellisaura colombianus* by Bock (1953, a, b). In addition small pelecypods, gastropods and ostracods are present in the mudstone and larger pelecypods occur in the limestone. Bock (1953, a) assigned his fossils to the Rhaetic and none of the other invertebrates or plants furnish incontrovertible evidence to the contrary for the Arcabuco collections (Letter to R. L. Langenheim, Jan. 29, 1957). Bock has also stated, however, that *Howellisaura colombianus* is not stratigraphically comparable to any Triassic estherid and that his age assignment is based on a type of ostracod which he considers to be abundant in the Triassic. Furthermore he states

that he is certain only that the rocks from which his fossils came, middle shaly member of the Giron formation on the Arcabuco Range, are not older than the late Triassic and that he is inclined to assign them to a somewhat younger age.

The middle shaly member of the western facies, therefore, represents floodplain, lake, swamp and/or coastal plain deposits. Here sediments were laid down in slowly moving or ponded water and a non-oxidizing environment was maintained, probably by continuous water cover. In the Arcabuco Range fewer deposits require deposition by rapidly flowing water. Also the pelecypod bearing limestone near Palermo is the only possible marine rock noted in the Giron formation during this study. Thus the middle shaly member seems to represent slackening of erosion in the source area of the sediments.

The upper sandy member of the western facies in the Lebrija Gorge is composed almost entirely of medium to coarse, gray to buff, cross-bedded, massive, extremely thick-bedded feldspathic or arkosic sandstone. Thin layers of gray-green shale or siltstone occur at intervals of several hundred meters. This unit includes all of the Giron formation measured at Quebrada Pujamanes and forms the top of the Lebrija Highland along the roads between Giron, Portugal and Motoso. It is also prominent on the road between San Vicente and Zapatoca. To the east outcrops along the road from Giron to Lebrija appear to include substantial amounts of interbedded, fine, red sediments near the base of the member. In the Arcabuco Range the upper sandy member is composed of red arkose, conglomerate and siltstone similar to the eastern facies.

The upper sandy member of the western facies represents deposition in rapidly flowing water. The sediments were derived from an area of crystalline rock. Relatively well-sorted, evenly bedded rocks in the Lebrija Gorge indicate more sorting and reworking of sediments there than in the Arcabuco Range. Reappearance of coarse sediments indicates renewed uplift in the source area.

The eastern facies of the middle shaly member of the Giron formation is well represented by approximately 300 meters of bright red mudstone resting on coarse arkose below Jordan in the southeast wall of the Chicamocha Canyon (Fig. 1). The contact between the arkose and mudstone is gradational although it takes place over a very few meters. The basal coarse sandy member rests nonconformably on Pre-Cambrian in Quebrada Aratoca east of Jordan. Here the Giron formation is abruptly folded upward toward the east and is truncated between the Tambor formation and Pre-Cambrian rocks. A small wedge of redbeds is preserved in a down-faulted block farther east on the Aratoca-Pescadero road.

On the northwest wall of the canyon the Giron formation gradually thins northeastward between the Tambor formation and Pre-Cambrian crystalline rocks. It is finally truncated by a nearly vertical fault immediately below the trail from the top of the Mesa to San Rafael. Coarse arkose exposed at the base of the Giron formation between Jordan and Aratoca, however, is not uniformly present in the northeast wall of the canyon. Coarse rocks occur at San Rafael but only mudstone was observed below Alto de Pedregal.

The Tambor formation rests directly upon Pre-Cambrian rocks at the northeast end of the Mesa de Los Santos between San Rafael and a point approximately one kilometer north of the Los Curos road. Here the Giron formation appears and thicken abruptly toward the north. The formation, however, is truncated less than one kilometer farther north by a nearly vertical fault which does not affect the overlying Tambor formation. Giron rocks reappear a few hundred meters beyond and again thicken sharply toward the west.

The Giron formation of the upper Rio de Oro Valley and the Piedecuesta Valley between Bucaramanga and the Mesa de Los Santos is chiefly composed of coarse, red, arkosic sediments including much conglomerate. The Mesa de Ruitoque section is a good sample of this interbedded coarse arkose, pebble and boulder conglomerate and micaceous red mudstone. A lens of micaceous mudstone located in a conglomerate ledge beneath the highway bridge at Quebrada Mensuli just south of Floridablanca contains abundant cycadeoid fronds of probable Jurassic age (Langenheim, 1959).

Rocks of the eastern facies of the Giron formation are also exposed between Bucaramanga and Matanza where a thick section of red arkose and mudstone is thrust eastward over marine Cretaceous rocks.

Truncation of the Giron formation by the Tambor formation at the east end of the Mesa de Los Santos indicates that the thinner sections of the eastern facies result in part from uplift and erosion rather than non-deposition. The thin section resting directly on the Pre-Cambrian and the fine-grained redbeds at Jordan further suggest that the eastern facies is probably physically correlative to the lower and middle members of the western facies. This, however, has not yet been demonstrated by tracing beds or by recognition of key beds in both facies.

Rocks of the eastern facies were deposited for the most part by rapidly moving waters draining a nearly source of crystalline rocks. Oxidizing conditions prevailed and it seems probable these sediments were deposited on piedmont alluvial fans. The surface of the fans probably sloped westward into the floodplains and swamps in which the western facies was deposited.

Tambor Formation.—The Tambor formation was studied in order to establish the upper limit of the Giron formation. Thus recognition of the basal angular unconformity in the Chicamocha Canyon was most important. This relationship is conclusively demonstrated by angular contact, post-Giron and pre-Tambor faulting, post-Giron and pre-Tambor intrusion, sporadic basal conglomerate in the Tambor, and by overlap of the Tambor formation on older rocks. This unconformity is apparently widespread through the area studied. A sharply angular contact between the basal Tambor conglomerate and Giron redbeds was also observed three kilometers southeast of Duitama on the road to Sogamoso. On the Floresta-Santa Rosa road, however, buff Devonian Floresta mudstone is gradationally succeeded by over 100 meters of red mudstone. This red mudstone is succeeded in conformity or disconformity by conglomerate containing abundant quartzite pebbles. Interbedded arkose and micaceous red siltstone

above the conglomerate grades upward into buff sandstone and shale containing Cretaceous fossils. It thus seems likely that the Giron formation is absent here and the Tambor formation rests paraconformably on mudstone of the Floresta formation. In addition, the basal Tambor conglomerate contains boulders of arkose from the Giron formation on the west side of the Lebrija Highland.

When the formations are nearly conformable, however, and there is no basal conglomerate in the Tambor formation, the top of the Giron formation is difficult to separate from the base of the Tambor formation. Redbeds in the lower Tambor formation further complicate the problem. Red mudstone in the Tambor formation on the west side of the Lebrija Highland and on the Mesa de Ruitoque was at first confused with the red mudstone of the Giron formation. Miscorrelations based on such confusion have occurred many times in the past. The red mudstone of the Tambor formation, however, is associated with medium-fine, well-sorted, gray or buff sandstone which here seems to occur only in the Tambor formation.

The Tambor formation of this area is divisible into a basal conglomerate member, a middle member of interbedded gray sandstone and red shale or siltstone, and an upper cliff-forming sandstone member. These three members range widely in thickness and character within the area studied. The basal conglomerate is absent on the east side of the Mesa de Ruitoque, in the Sogamoso Gorge, and on the Duitama-Charalá road. It is relatively thin (1–5 meters) between Sogamoso and Duitama, between Santa Rosa and Floresta, in the Chicamocha Canyon and at Quebrada Pujamanes. At the type section of the Tambor formation in the Lebrija Gorge, however, it is at least 100 meters thick. Quartz and crystalline rock fragments dominate on the Duitama-Sogamoso road and in the Jordan area, but pebbles and cobbles of Giron arkose are prominent between Floresta and Santa Rosa and on the west side of the Lebrija Highland.

The middle member of interbedded red shale or siltstone and buff or gray sandstone is thickest and finer grained on the west side of the Lebrija Highland. Here thick beds of massive dark red mudstone characterize this unit and are interbedded with medium to fine, steel-gray sandstone. This member is thinner on the Mesa de Ruitoque and in the north end of the Mesa de Los Santos but still includes much red mudstone. In the Chicamocha Canyon there is little red mudstone and the member is composed of interbedded medium to coarse buff sandstone and red siltstone or sandstone. Farther south, on the Duitama-Charalá road this member loses its identity and is represented only by isolated, thin (less than one meter) beds of red siltstone in the lower Tambor formation. Three kilometers southeast of Duitama on the road to Sogamoso, however, red and buff rocks are interbedded in a member ten to twenty meters thick above the basal conglomerate. Also on the Santa Rosa-Floresta road, a few kilometers east, redbeds dominate the lower half of the basal Cretaceous formation.

The upper, thick-bedded, cliff-forming sandstone member is well developed on the Duitama-Charalá road where it is very similar to the Arcabuco sandstone at Arcabuco. To the east, on the Duitama-Sogamoso road and on the Santa Rosa-Floresta road there is

no thick-beddded cliff-forming sandstone and much finer grained sandstone with marine fossils occupies its place. The cliff-forming sandstone thins gradually northward but still forms an impressive cliff girdling the Mesa de Los Santos. On the Mesa de Ruitoque it is markedly finer and thinner and on the west side of the Lebrija Highland sandstone is almost absent and is fine grained.

The Tambor formation presumably represents continental and beach deposition at the beginning of the Cretaceous cycle of marine deposition. The redbeds of the lower and middle member probably derive their color from reworked Giron rocks. This is suggested by the parallel distribution of such redbeds and Giron quartzite in the basal conglomerate.

ECONOMIC GEOLOGY

Copper.—Copper mineralization is widespread in redbeds of the Giron formation. A mudstone layer near the Rio Surba bridge on the Duitama-Charalá road contains abundant nodules of pyrite and chalcocite with associated crusts and stains of malachite and azurite. Similar occurrences were noted elsewhere in this area. The plant bearing lens of mudstone at Floridablanca also is stained by crusts of malachite. The green color of many mudstone lenses, however, is chiefly a result of ferrous iron reduced in the presence of abundant plant material. This mineralization is probably supergene and is characteristic of redbeds the world over. Copper deposits of this sort, however, have never been of major economic importance in modern times in Colombia although some copper was produced during the colonial epoch.

More extensive copper mineralization west of Jordan may, however, be hydrothermal. Here chalcocite, malachite and azurite occur along minor fractures and in porous layers connected with the fractures. These deposits seem more abundant near the Los Santos-Jordan rhyolite stock and may be associated with the intrusive. If this is so, flows and intrusions so widespread in the Giron formation elsewhere might also be expected to bear copper deposits. The Jordan deposits, however, are not large enough for economic explotation.

Petroleum.—Redbeds similar to those of the eastern facies of the Giron formation are not outstanding petroleum producers. They are a product of an oxidizing environment in which organic matter is destroyed rather than preserved. Furthermore the upland environment in which they were deposited probably did not support abundant living things that might be converted to hydrocarbons. Finally the sediments are poorly sorted and thus do not form porous reservoir rocks.

The rocks of the eastern facies, however, were deposited in swamps and on floodplains in a non-oxidizing environment. They may, in addition, include or intertongue with marine rocks in the Arcabuco range. Thus the possibility of accumulation and preservation of petroleum is increased. Also the better sorted sandstones, similar to the upper sandy member in the Lebrija Gorge, might serve as reservoir rocks. It is therefore suggested that suitable structures or lensing sandstone southwest of the area studied might contain pe-

troleum. Pre-Cretaceous and Tertiary deformation of these rocks, however, renders existence of such deposits most doubtful.

The Tambor formation is intimately associated with organic marine shale and, as a transgressive sand body, should be well sorted and porous. It, therefore, should be tested wherever structural conditions are favor petroleum accumulation.

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