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Stratigraphy and Structure of the Goajira Peninsula, Northwestern Venezuela and Northeastern Colombia

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University of Nebraska - Lincoln

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Part of the work was done as a field project for the Richmond Exploration Company. The rest of the study was completed, with certain financial aid from the company, while the writer was on educational leave of absence from the company. Several Richmond geologists, including P. B. McGrath, L. R. Cook, and J. B. Miller, furnished initial information on the area and also offered encouragement and suggestions. Mr. Miller reviewed the final manuscript. R. S. Jaroska and A. B. Whitman did the microfaunal determinations and prepared the zonation charts.

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Finally, the writer is deeply grateful to his wife, Constance Rollins, for her continuous help in the field and in the preparation of the manuscript.

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Introduction

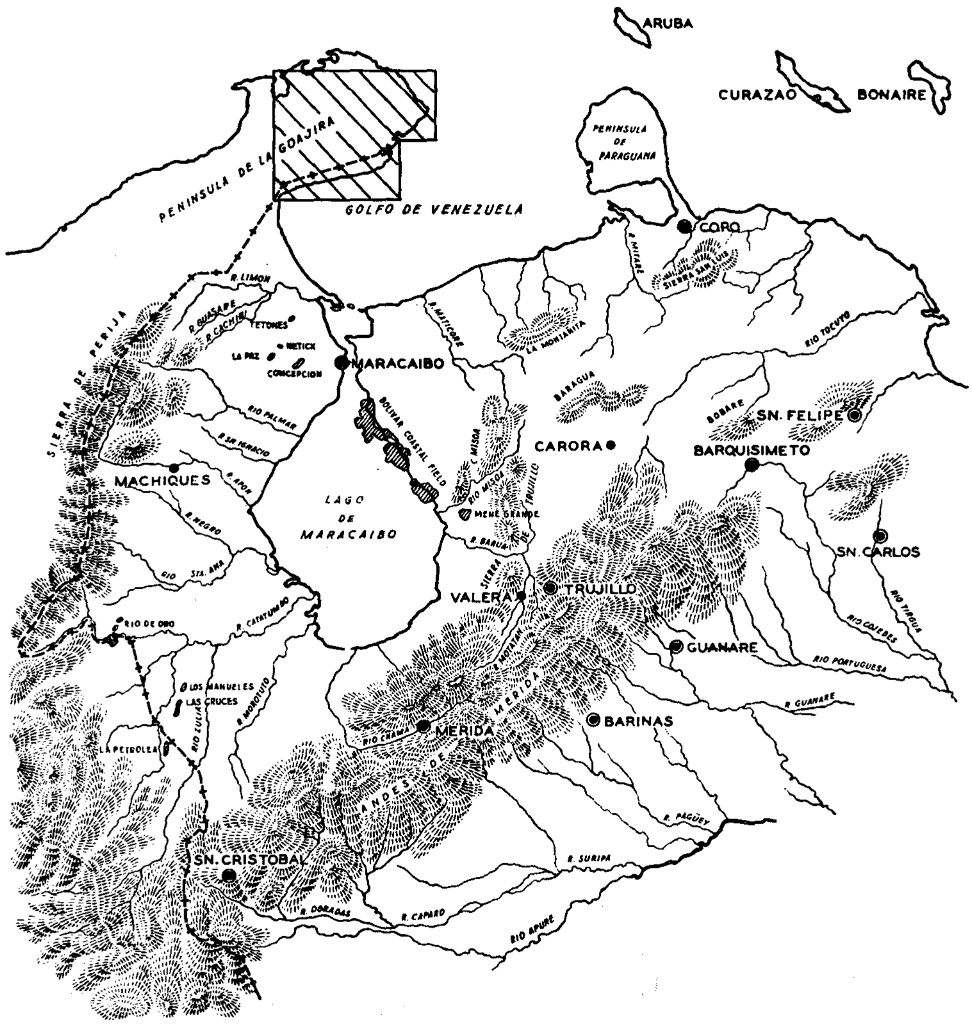
The Goajira Peninsula forms the northernmost extension of continental South America (*see* Fig. 1). Its lobate outer portion, the area of this geologic study, is a mountainous region about 75 kilometers wide at its widest part and juts 150 kilometers northeastward into the Caribbean Sea.

Although only about 110 kilometers north of the city of Maracaibo, Venezuela, the Peninsula is isolated and little known. Only a narrow coastal strip lies in Venezuela; the remainder is in Colombia; but the Peninsula is largely a desert wasteland not extensively entered by people other than its own sparse Indian population. Its remoteness has long led it to be called the "Forgotten Land of Colombia."

The exposures of Mesozoic and Cenozoic rocks on the Peninsula present a seldom equalled opportunity for fundamental study in stratigraphy, structure, and sedimentation. Probably few places in all of northern South America present a comparable area for the study of Cretaceous limestone lithology and deposition. Because of the arid nature of the region, the rocks are well exposed in most areas. As a result the outcrops can be studied in detail and lateral changes can be observed instead of surmised.

The sedimentary, metamorphic, and igneous rocks found in the Goajira indicate a long and varied geologic record. The sedimentary section is made up of a thick sequence of Mesozoic and Cenozoic strata. Of particular interest from a regional viewpoint is the succession of Cretaceous limestones, shales, and sandstones.

In addition, structural deformation of a complex nature clearly demonstrates some of the basic phenomena of the compressive deformation of rocks. On the southeastern part of the Peninsula compressive stresses have buckled the sediments of the Cocinas trough into an asymmetrically overturned and severely faulted anticlinal structure. Farther northward, the Serranías Jarara and Macuire have been uplifted into their present position after a much earlier period of severe crumpling. Metamorphism and igneous activity of several periods have further complicated the geology.



RELIEF MAP
MARACAIBO BASIN
(AFTER SUTTON)

SCALE

0 20 40 60 80 100

KILOMETERS

OIL FIELDS

FIG. —1 INDEX MAP

The five primary objectives of this research project were: (1) to study in detail the stratigraphic succession of both the Mesozoic and Cenozoic rocks, with special attention to the Cretaceous limestone sequence; (2) to correlate the formations of the Goajira with the stratigraphic succession elsewhere in western Venezuela; (3) to propose an areal synthesis of the orderly sequence of geologic events which occurred on the Goajira as interpreted from the field data; and (4) to reconcile and integrate observations made on aerial photographs with those made in the field.

Previous Work

Until comparatively recently, the Goajira Peninsula has remained as one of the last frontiers in Venezuelan and Colombian geology. The extent of the ignorance about the geology in this region before 1947 is summarized in the opening statement of Bucher's discussion of the Goajira:

> Not enough reliable information is available concerning the geology of the Goajira Peninsula to warrant an attempt at map presentation. (Bucher, 1952, p. 64.)

His comments are based upon Stutzer (1928), the only published study of the region prior to 1952. Primarily, the reason for a lack of interest in the Goajira was the universal belief that the entire Peninsula was composed of Paleozoic or older metamorphic and igneous rocks and therefore had no immediate interest for petroleum exploration. In addition, problems of transportation and the remoteness of the area from known production discouraged surface parties from exploring it in the early days.

Before the present study was made several geologists of the affiliate companies, Richmond Exploration Company (Venezuela) and Richmond Petroleum Company of Colombia, carried on reconnaissance work in the Goajira. Of particular importance were the measurement in 1948 and 1949 of Cretaceous limestone sections and some general mapping principally by W. E. Nygren, T. J. Newbill, and D. L. Conley. Presence of the Cretaceous outcrops in the outer Peninsula had not been noted until 1947.

Extensive work was done in the area by Shell and Creole (between 1953 and 1956?) but the discoveries have been kept confidential except for the publications by Renz (1956 International Geological Congress, 1960 Third Venezuelan Geological Congress) and brief reference by Dufour (1955) to the Goajira area.

Methods

In its early stages, all of the mapping was based principally on plane table work at scale of 1:20,000, supplemented by local traverses made by Brunton compass and chain. All of the stratigraphic sections, for example, were controlled by surveys of this type. The only aerial photographs initially available were for a narrow strip in Venezuelan territory along the shore of the Gulf of Venezuela.

The first field study commenced in January and ran through May, 1954. Further information was obtained by means of other field excursions that were carried on intermittently with photogeologic studies and other assignments from 1955 through 1958. Excellent vertical air photos of Colombian territory, on 1:40,000 scale, became available in April, 1954, through a project operated by the Concesionaria de Petroleo Shell-Condor and jointly financed by the Richmond and Shell oil interests in Colombia and Venezuela. Maps constructed from these photos by the Richmond Exploration Company, again at joint Richmond and Shell expense, are based on triangulation control received through courtesy of the Instituto Geográfico Militar Catastral (in Bogotá) and Cartografía Nacional (in Caracas) which are government agencies of Colombia and Venezuela. These maps form the final base sheets for compilation of the geologic data.

The use of aerial photographs proved to be indispensible to understanding the highly complex geology of the region. Indeed, it is doubtful that even the most detailed plane table work would ever have been adequate to solve the complex structural and stratigraphic problems that were encountered.

Microfaunal and macrofaunal collections were also studied intensively, and the results of these studies were used in the solution of many of the complex stratigraphic problems.

Geography and Physiography

The Goajira Peninsula can be subdivided into two physiographic provinces: (1) the Goajira plains and (2) the foothills and mountain region (*see* Fig. 2). The Goajira plains are a low, featureless desert area occupying the narrow southern portion of the Peninsula. The plains form the connecting link between the Sierra de Perijá to the south and the wider foothills and mountain region of the northern part of the Peninsula. The area of this study is confined to the northern region.

Within the northern part of the Peninsula, there are three mountain ranges: (1) Serranía de Macuire, the highest and northernmost; (2) Serranía de Jarara, lying in the interior; and (3) Serranía de Cocinas, a low range to the south. Broad lowlands separate the mountains and merge into low coastal plains which border most of the Peninsula.

The climate is dry throughout, and the region is typical desert brush country. All the drainage is intermittent. A strong northeast wind blows throughout the year, but is strongest (average 30-35 MPH) during the December to June trade wind season. The principal rainy season occurs during the month of October and is characterized by torrential downpours and resulting flash floods of short duration. A second minor rainy season usually occurs in early May. The rains fill the cañadas and lowlands, making travel about the region practically impossible.

The Goajira is inhabited by scattered tribes of seminomadic Indians whose economy is based mainly on their large herds of cattle, goats, horses, sheep, and burros. Small plots of land are farmed during the rainy season to provide food for family consumption.

The Goajiros have their own language and distinct culture. Their culture is more advanced than that of other Indian groups in northern South America but it is essentially the same today as it was before the Spaniards arrived on the continent.

Basement Complex

General Discussion.—A great variety of igneous and metamorphic rocks encompassing many different ages make up the basement complex on the Goajira. The basement rocks crop out in structural highs on either side of the Cocinas trough and also northward as the Serranía Jarara uplift and Serranía Macuire uplift. Since the basement rocks are outside of the intended scope of this paper, only a cursory examination of them was undertaken where there was a direct bearing upon the stratigraphic and structural problems or where the writer traversed the crystalline rocks in the studies of the sedimentary formations. Nevertheless, certain broad units were delineated in a general way on the maps in an effort to designate the major rock types. The results are of a reconnaissance nature and are far from being complete.

The basement complex of this report consists of all the igneous and metamorphic rocks considered to be of pre-Triassic age. These

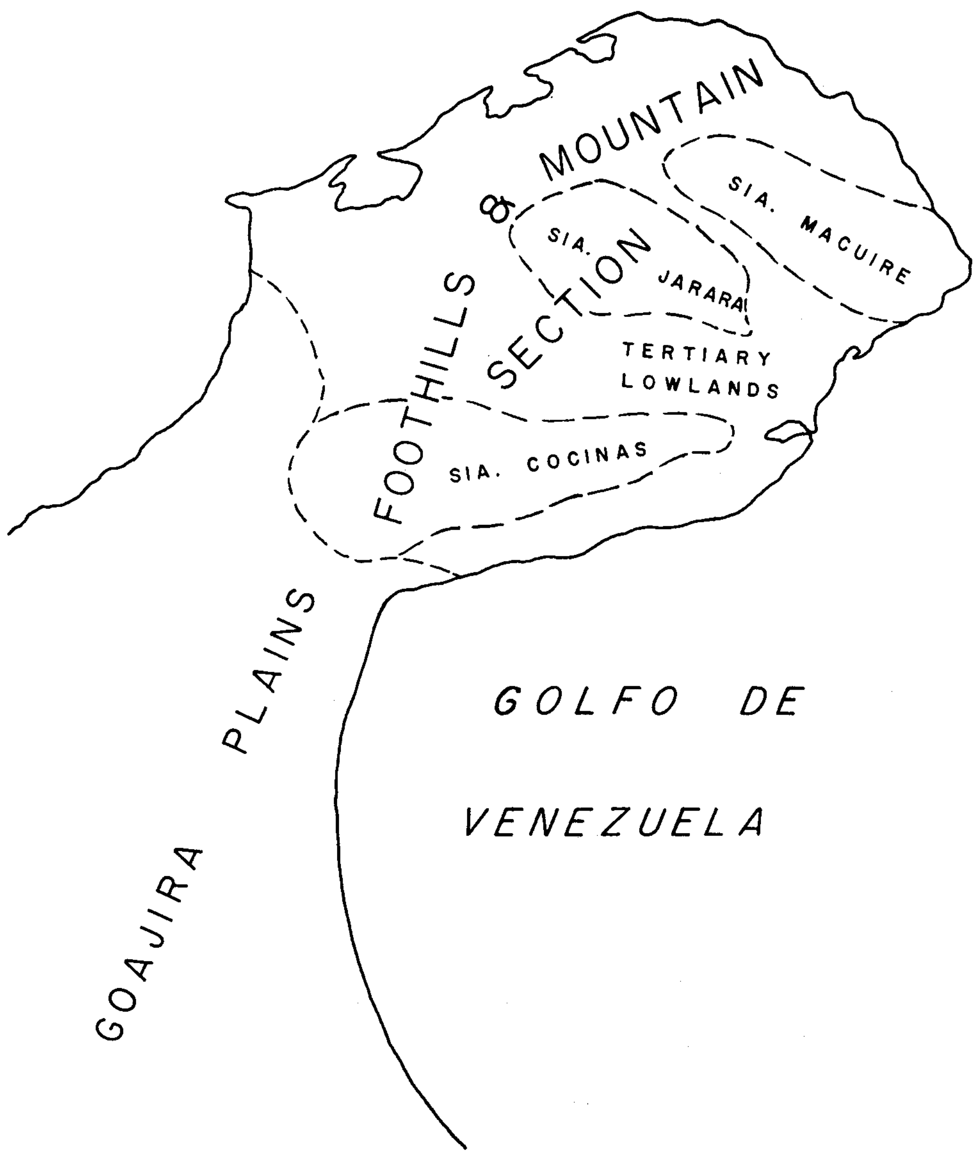


FIG. — 2 PHYSIOGRAPHIC SKETCH MAP GOAJIRA PENINSULA include granites and undifferentiated granitic type rocks, schists, gneisses, quarzites, and minor marbleized limestone.

The oldest rocks appear to be the metamorphics and are assumed to be Paleozoic or pre-Cambrian although no fossil evidence lends support to this idea. Bucher (1952, p. 64) suggested a Cretaceous age for these rocks based upon the descriptions of Stutzer (1928) and also noted the similarities with the Cretaceous metamorphic rocks in the Coastal and Interior ranges of the Andes, in the north-central part of Venezuela. However, on the Goajira Peninsula none of the Cretaceous rocks show a tendency towards metamorphism except locally where severe deformation along fault zones has altered the rocks through a low grade of metamorphism. Because the entire Cretaceous section is present and unmetamorphosed, there is no possibility that an intra-Cretaceous orogeny has resulted in a metamorphosed lower part found together with an unmetamorphosed upper part, as has been recorded regarding the mountains of north-central Venezuela. Further, there is no evidence of igneous activity in the Goajira during the Cretaceous period.

Similar reasoning regarding the Jurassic and Triassic rocks leads one to the conclusion that the age of the metamorphics is not only pre-Cretaceous but pre-Triassic as well. Although some extrusive rocks occur in the Triassic, field relationships show that important intrusive masses are all older. Thus, in the light of these new field data, it is felt that the metamorphic rocks and pre-Triassic igneous masses are at least as old as Paleozoic.

Local Description and Character.—The metamorphic rocks occur in three major outcrop areas: the northern and western parts of the Serranía Macuire; the Serranía Jarara, in the central Goajira; and a wide band of low relief north of the Cocinas trough (*see* Geologic Map).

Finely micaceous, gray to dark gray, thinly bedded schists and phyllites crop out in the northern areas of the Goajira. A few thin, bluish black marbleized limestones are intercalated with these schists and appear to be unfossiliferous. In addition to the schists and phyllites, granite gneiss occurs along the northern edge of the Cuisa fault which bounds the north side of the Cocinas trough. To the north the rocks become less gneissic and contain more remnants of the earlier rock. The sequence strongly suggests granitization. Just north of the triangulation stations of Tangare and GT-8 the gradation is complete, and only the gray micaceous schists can be found.

In the northwestern portion of the Serranía Jarara, ridges of slates and phyllites alternate with valleys eroded along bands of black, micaceous shales which form topographic valleys between the high strike ridges of slate and phyllite. Along the inner rim of the Serranía Jarara in a number of localities, unconformable remnants of bluish gray marbleized, apparently unfossiliferous, limestone can be observed overlying the other metamorphic rocks. Several of the remnants were seen also along the southern flanks of the Serranía Macuire. The most extensive outcrops of these limestones can be seen at the southernmost tip of the Jarara near Uitpa. These rocks were earlier considered by the writer to be altered Cretaceous limestone remnants; however, unaltered, fossiliferous Cretaceous limestone (Yúruma Group) was found in the hills northwest of Uitpa in close proximity to the marbleized limestones.

These marbleized limestones have been included in the metamorphic complex by the writer because they are definitely pre-Cretaceous and probably pre-Mesozoic. Their lithology and character are very similar to the outcrops of the Palmarito Series of Permian age in the Mérida Andes. Any actual relationship between the two cannot be demonstrated.

At least three large granitic masses are recognized in the Goajira. To the northeast a large part of the Serranía Macuire is composed of a light colored orthoclase granite which appears to be intruded into the metamorphic complex. The contact between the granite and metamorphic rocks was examined only in one locality but seems to be easily traced on the air photos.

At the northwestern extension of the Serranía Jarara, a smaller plutonic body can be observed. The rock is essentially a medium to coarsely crystalline, hornblendic diorite which is intruded into gray slates and mica schists. Xenoliths of country rock varying in shape from irregular blocks to long, thin "lenses" are fairly common along the outer edges of the intrusive. The contacts of the metamorphic with plutonic rocks are rather sharp and can be delineated on the air photos.

Farther to the southeast, in the vicinity of Cerros Cocinas and Cojoro, a third granitic mass crops out, forming a group of rounded hills (*see* Geologic Map). These rocks are coarse-grained pink orthoclase granite with many local variations. An occurrence of similar granite is found 30 kilometers farther east at the base of a high hill called Cerro Julanal.

Triassic Igneous Rocks

In the Cerro Cocinas-Cerro Cojoro area Triassic age rhyolite, rhyolite porphyry, and dacite porphyry, occur as sills, flows, and dikes in scattered outcrops. These rocks can be found intruded into the earlier granite mass, and occur both as intrusives and extrusives in the overlying sediments of the Cojoro Group.

The rhyolites appear to predate the Jurassic Cheterlo Formation, and their extrusion can be demonstrated as contemporaneous with deposition of the Triassic Cojoro Group. Recurring pulsations of igneous activity probably took place over a relatively short span of time and do not appear to have extended into either the Jurassic or Cretaceous periods.

Stratigraphy

The Goajira Peninsula presents an incomplete sedimentary record ranging from Triassic to Recent. The sediments have a total thickness in excess of 9,500 meters (31,000 feet) and represent a number of diverse rock types. They lie upon the older, complex assemblage of metamorphic and igneous rocks. Locally there are both intrusive and extrusive igneous rocks of Triassic age. Some parts of the sedimentary sequence are of considerable importance in understanding the regional geology of northern South America and especially western Venezuela.

The earliest known sediments are the Triassic Cojoro Group composed of continental sandstones and conglomerates below and overlain by shallow marine beach sands. More than 850 meters (2,800 feet) of Cojoro sediments are present.

A narrow, east-trending depositional basin called the Cocinas trough developed in the central part of the Goajira Peninsula during Jurassic time. This permitted the accumulation of at least 3,250 meters (10,660 feet) of sediments. These sediments have been subdivided into the Cheterlo Formation at the bottom, overlain successively by the Caju, Chinapa, and Cuisa formations.

The earliest Cretaceous is represented by the Palanz Formation, which (in the area of the Cocinas trough) lies on Jurassic sediments of the Cuisa Shale. On the adjacent shelf areas, however, the Palanz has overlapped the Jurassic succession and lies unconformably upon basement or with angularity upon the sediments of the Triassic.

A thick sequence of marine limestones interbedded with minor shales conformably overlies the Palanz. The deposits comprise the following from bottom to top: Yúruma Group; Cogollo Group; La Luna Formation; and the Guaralamai Formation. The entire Cretaceous section presents an aggregate thickness in excess of 3,000 meters (9,850 feet) and spans a time from Valanginian to Campanian.

At the close of the Cretaceous, strong orogenic movements folded and uplifted the sediments on the Goajira Peninsula, exposing them to erosion. Most of the Goajira appears to have been positive during early Tertiary, but by late Eocene time the seas occupied small localized embayments, at least at the southeastern corner of

PERIOD	AGE	GROUP	FORMATION
REC.	PLEISTOCENE - RECENT UNCONFORMITY		UNDIFFERENTIATED
TERTIARY	MIO - PLIOCENE		CASTILLETES
TERTIARY	MIOCENE		JIMOL
TERTIARY	(AQUITANIAN) LOCAL UNCONFORMITY		UITPA
TERTIARY	OLIGOCENE UNCONFORMITY		SIAMANA
TERTIARY	EOCENE ? UNCONFORMITY		MACARAO
CRETACEOUS	CAMPANIAN		GUARALAMAI
CRETACEOUS	SANTONIAN CONIACIAN TURONIAN		LA LUNA
CRETACEOUS	CENOMANIAN ALBIAN UPPER APTIAN	COGOLLO GP.	MARACA
CRETACEOUS	APTIAN	COGOLLO GP.	"LOWER COGOLLO"
CRETACEOUS	BARREMIAN	YURUMA GP.	"UPPER YURUMA"
CRETACEOUS	HAUTERIVIAN VALANGINIAN	YURUMA GP.	MOINA
CRETACEOUS	VALANGINIAN BERRIASIAN		PALANZ
JURASSIC	KIMMERIGIAN - PORT	COCINAS GROUP	CUISA SHALE
JURASSIC		COCINAS GROUP	CHINAPA
JURASSIC		COCINAS GROUP	CAJU
JURASSIC	UNCONFORMITY	COCINAS GROUP	CHETERLO
TRIASSIC			UIPANA
TRIASSIC	UNCONFORMITY		"RANCHO GRANDE"
PRE-R	UNCONFORMITY		BASEMENT-UNDIFF

FIG.-3 STRATIGRAPHIC CHART GOAJIRA PENINSULA the Peninsula. Shallow marine deposits of the Macarao Formation of late Eocene age represent the oldest known Tertiary sediments found in the region. They rest with sharp angularity upon the Cretaceous rocks.

After a second period of orogenic movements which folded the Macarao Formation, a broad, shallow marine basin developed over much of the interior of the Goajira. The Siamana Formation of Oligocene age was deposited overlapping the Macarao and older rocks. Subsequently the Uitpa, Jimol, and Castilletes formations were laid down in that order. These formations are considered to range from Acquitanian to late Miocene or possibly Pliocene age and in the main represent the gradual shallowing and retreat of the seas. An aggregate thickness of over 2,400 meters (7,875 feet) was deposited during the entire Tertiary. Alluvial deposits of recent age complete the stratigraphic sequence of the Peninsula.

TRIASSIC SYSTEM

Sediments of presumed Triassic age are found locally as erosional remnants in hills north of the coastal village of Cojoro. Two formations are recognized in this report: (1) the "Rancho Grande"; overlain by (2) the Uipana (*see* Strat. Sec. B-1, Cerro Cojoro). The former is composed of a continental sequence of coarse clastics with a characteristic dark reddish brown color. The latter is made up of a thick sequence of clean, light gray, cross-bedded beach sands. Collectively the entire sequence of Triassic sediments in the area comprises the Cojoro Group of Renz (1956, 1960). The Cojoro Group is considered by the present writer as equivalent to the La Quinta Formation in the Mérida Andes of western Venezuela and also equivalent to the Girón Formation of eastern Colombia.

The Uipana Formation is known only from the Goajira and may actually be a shallow marine facies equivalent of the upper part of the La Quinta.

"Rancho Grande" Formation

General Discussion.—Garner (1926) originally designated reddish brown conglomerates exposed in the hills northwest of the coastal village of Cojoro as the "Cojoro Sandstone." Renz (1956, 1960) elevated the term to group rank and subdivided the Cojoro Group into the following formations, from bottom to top: Guasasapa; Rancho Grande; and Uipana.

During the course of field work the present writer did not recognize a threefold subdivision, thus the "Rancho Grande" Formation of this report actually encompasses Renz' Guasasapa and Rancho Grande formations.

The writer's boundary between the "Rancho Grande" and the overlying Uipana Formation appears to coincide closely with that defined by Renz in his 1960 paper.

Local Description and Character.—The "Rancho Grande" redbeds in the Goajira are preserved as scattered erosional remnants at the Cerro Cocinas-Cerro Cojoro locale, north and northwest of the village of Cojoro (*see* Geologic Map). Here, the gently dipping beds lie directly upon a granitic basement.

A second occurrence, also thought to be "Rancho Grande," appears a few kilometers west of Punta Espada in the hills comprising the eastern extension of Serranía Macuire. Study was insufficient to enable the writer to determine whether the rocks in this second area are definitely "Rancho Grande," but their character strongly suggests that such is the case.

In the Cerro Cojoro area the "Rancho Grande" Formation is composed of massive, dark brown arkosic conglomerates; dark, brick red sandstones and interbedded, hard, clay-shales; olive drab shales; and buff to tan sandstones. Several very dense, finely crystalline, tan to gray limestones are found interbedded with the sands and shales. The limestones contain scattered bivalve remains suggesting a marine origin.

The sandstones are composed of fine to coarse-grained quartz and feldspar, silty in part, micaceous, generally well bedded and resistant. Some cross-bedding is present.

Hard shales and claystones are interbedded through much of the "Rancho Grande" Formation except in the lowest part. The shales are massive, micaceous, and silty or sandy. Their colors range from dark red to olive drab to buff, with the lighter colors predominating in the upper parts of the formation. In the Cojoro locality rhyolite sills, flows, and dikes are found at various levels in the "Rancho Grande."

A few kilometers west of Punta Espada, there are similar red beds which are composed mainly of interbedded, dark reddish, arkosic sandstones and hard, micaceous, dark red shales. A few conglomerate beds were observed in a reconnaissance of the locality. The similarities in lithology and the apparent stratigraphic position are suggestive of the "Rancho Grande," and the outcrops are mapped questionably as "Rancho Grande."

The "Rancho Grande" deposits were laid down essentially in a continental environment, but conditions apparently ranged during brief intervals to lagoonal and shallow marine. Stream bed and fresh water lake deposits are present, and there is evidence of the existence, at times, of considerable relief. A climate favorable for growth of vegetation is shown by the presence of silicified tree trunks.

Thickness.—The best available section of the "Rancho Grande" is at Cerro Cojoro where 327 meters (1,073 feet) of the sediments were measured. The base of the Formation is covered by alluvium. Although this section represents the maximum thickness seen in the Peninsula, it is obviously considerably less thick than the total present.

Stratigraphic Relations.—In the Cerro Cocinas-Cerro Cojoro area, the "Rancho Grande" Formation lies nonconformably upon a granitic basement and is overlain with apparent minor disconformity by the Uipana Formation. Elsewhere in the area, the "Rancho Grande" is overlain with considerable angularity by the Palanz Formation of the Lower Cretaceous.

Paleontology and Age.—Fossil evidence of the age of the "Rancho Grande" in the Goajira is lacking; thus the age assignment is made by inference dependent upon lithologic similarities and stratigraphic position compared with the La Quinta Formation in western Venezuela. The only organic remains found were a number of black petrified logs and tree stumps and a few indeterminable bivalves.

In the Mérida Andes, Kundig (1938, pp. 31–36) collected an assortment of fish material from exposures at the La Quinta type section. These were determined by A. S. Woodward as a "... genus of ganoid fishes which cannot be distinguished from the European Jurassic and Rhaetic Lepidotus."

He suggested a late Triassic to early Jurassic age. According to Sutton (1946, p. 1639), A. A. Olsson suggests a late Triassic age for the La Quinta on the basis of faunal evidence obtained in southern Mérida.

Based upon the stratigraphic position and lithologic similarities with the Mérida Andes section, a late Triassic age is suggested for the "Rancho Grande" Formation in the Goajira.

Correlation.—The exposures of the Cojoro Group in the Goajira are probably correlative with the La Quinta of the Mérida Andes and the Sierra de Perijá of Venezuela and with the Girón of eastern Colombia.

Uipana Formation

General Discussion.—For the thick sequence of clean quartzose sandstones which form the upper part of Cerro Cojoro, Renz (1960) designated the name Uipana Formation. These beds are exposed in a very limited area in the vicinity of the Cerro. The equivalent of this Formation is not known in western Venezuela although it may possibly be present somewhere in the Sierra de Perijá or perhaps in the César Valley of northeastern Colombia. The Uipana Formation may actually be a lateral, shallow, marine beach facies of the upper part of the La Quinta in western Venezuela.

A minor unconformity is present between the Uipana and the "Rancho Grande." This, together with the sharp change from a continental environment to that of an active marine beach, indicates a marine transgression following the continental deposition of the "Rancho Grande" Formation.

Local Description and Character.—The Uipana Formation is well exposed along the upper slopes of Cerro Cojoro and in a few scattered low outcrops a short distance to the north. The base of the Formation is considered to be the unconformable contact with the underlying "Rancho Grande." Here the contact is well marked with a persistent bed of limestone pebble conglomerate at the base of the Uipana. The top of the Formation is not exposed because it is truncated and overlapped with considerable angularity by the Cretaceous Palanz Formation.

The Uipana Formation is composed entirely of clean sandstones and conglomeratic sandstones except for small amounts of limestone conglomerate near the base. The sands consist of fine to very coarse-grained, clean white to gray and light buff quartz grains with irregular streaks of small pebble conglomerates. The pebbles are mostly subangular to subrounded white quartz. Individual sandstone beds vary from massive to cross-bedded and are well cemented.

At the base of the Formation, there is a zone of limestone conglomerate composed of subangular pebbles of dark gray, finely crystalline limestone in a somewhat poorly sorted matrix of sand. Two beds ranging from two to four feet in thickness are present and are separated by a massive, buff sandstone having a thickness of five to fifteen feet.

Renz (1960) considers the Uipana to have been deposited in a lagoonal or terrestrial environment. However, it is difficult to envision this type of environment for the Formation. The lithology of the Uipana is characteristic of a marine beach environment. Active shore currents kept the sands clean and well sorted. Shore currents of some intensity are indicated by the abundance of the coarser-grained sandstones and pebble conglomerates, especially in the upper parts of the Formation.

Thickness.—A maximum thickness of 532 meters (1,745 feet) was measured for the Uipana, but this is incomplete because the Formation top was not observed. True thickness may be considerably greater.

Stratigraphic Relations.—The Uipana Formation rests with apparent minor disconformity upon the underlying "Rancho Grande" Formation, and it is overlain with angularity by the Palanz Formation. This upper contact marks a major unconformity.

Paleontology and Age.—Lacking fossil evidence, an early Jurassic or late Triassic age is suggested on the basis of stratigraphic relationships. These quite distinctly confine the Uipana Formation to the interval between probable late Triassic beds of the underlying "Rancho Grande," and Lower Cretaceous beds of the overlying Palanz Formation. The angular unconformity between the Uipana and the Palanz is a further significant point, especially considering the presence, farther north, of the Cocinas Group of sediments which conformably underlies the Palanz and is of definite late Jurassic age. The basal part of the Cocinas Group (the Cheterlo unit) is possibly early or medial Jurassic. The stratigraphic position of the Uipana Formation appears to be below the Cheterlo.

No fossils whatsoever have been found in the Uipana sediments.

Correlation.—The Uipana Formation cannot be directly correlated with any specific section in the Maracaibo Basin. However, it is felt that the Formation may be related to the upper part of the La Quinta of the Mérida Andes although there is little direct evidence to support this idea.

JURASSIC SYSTEM

Rocks of known Jurassic age crop out along a narrow, east-west-trending belt in the southern interior of the Goajira called the Cocinas trough. The Cocinas trough originated as a depositional trough during the Jurassic period and resulted in the accumulation of a thick Jurassic and lowermost Cretaceous sedimentary sequence. The Jurassic rocks were originally defined and briefly described by Renz (1956). He designated the Cocinas Group for the entire system of rocks without further subdivision. His type section is about three kilometers north of the Indian village Ararieru (also Arunapas) in the south-central part of the Goajira (*see* Geologic Map) and is incomplete because of faulting.

In 1960 Renz designated two formational names and type sections for some of the sediments supposedly lying within the Cocinas Group. These are (1) the Cuisa Shale and (2) the Chinapa Formation. Both terms are unfortunate because they are defined in highly faulted localities. Renz (1960) himself moves the position of the Cuisa Shale from the Cocinas Group of Jurassic age to the overlying Cretaceous without apparent reason.

The Chinapa Formation, as defined by Renz, is actually the lower sandstone unit of the Cretaceous Palanz Formation. This unit is described in detail under the Cretaceous stratigraphy.

It becomes apparent in studying the Renz map of the Cocinas trough that he did not recognize the presence of a major anticlinal fold within the sediments of the Cocinas Group. Recognition of this structural feature has considerable bearing upon the true stratigraphic relationships within the Jurassic Cocinas Group.

In this report, the term Cocinas Group is retained and the rocks are subdivided into four formational units. These are from bottom to top: the Cheterlo, Caju, Chinapa, and Cuisa formations. The Chinapa and Cuisa formations are redefined and reference sections are given. Type localities and sections for the lower formations are defined and described in detail on subsequent pages.

In addition to the Cocinas trough exposures, a second outcrop locality is shown on the Geologic Map in the vicinity of Punta Espada as Jurassic? undifferentiated. It is thought by the writer that these rocks are probably Cocinas Group equivalents, but because the work done in this area was of a reconnaissance nature and no fossils were found, it is advisable to consider the identity and Jurassic age of the rocks as questionable.

The sediments of the Cocinas Group are not known in western Venezuela nor are they definitely known in eastern Colombia. There is a possibility that they might be present somewhere in the Sierra de Perijá or along the Cordillera Oriental of Colombia.

Cheterlo Formation

General Discussion.—The name Cheterlo is given by the writer to a sequence of drab to greenish gray and red shales and argillites and interbedded quartzites which crop out as a long narrow ridge in the center of the Cocinas anticline (*see* Strat. Sec. B-2). The ridge actually forms the core of the major east-west-trending fold. Intense deformation of the sediments has locally developed a low grade metamorphism resulting in a somewhat schistose character of the beds.

The type locality is along a road approximately 1.5 kilometers south of the village of Cheterlo on the southern flank of the Cocinas anticline. Here only a partial section was measured. The upper contact is at the top of a series of hard, quartzitic sandstones forming a rather sharp topographic break which lends itself nicely to air photo mapping.

From the top of the quartzitic sandstones the type section was measured stratigraphically downward through the overturned south limb of the anticline to the axis of the fold. A red and green argillite exposed along the axis represents the oldest rock visible in the fold. About 33 kilometers farther west, a thick section of Cheterlo crops out along the Quebrada Patamana and, although the section is faulted at the top and bottom, it is sufficiently exposed to allow study of the lower red and green argillite zone. Here, 800 to 1,000 meters of section are present and the base is not exposed.

Local Description and Character.—The Cheterlo Formation crops out along the core of the Cocinas anticline and in a fault block farther to the west (*see* Geologic Map). Lithologically, the Formation is made up of two rather distinct units—an upper unit composed of 30 to 40 percent sandstones interbedded with drab, silty shales and a lower unit composed of approximately 80 percent red and green argillites with 20 percent sandstone.

All of the sandstones are very dense, resistant, fine- to very fine-grained, and very quartzitic. They are well bedded and the bed thickness ranges from four inches to one foot. White quartz fracture filling is common. The sandstones are generally gray to greenish gray and less commonly light green. In the upper part of the Cheterlo, the sandstones are interbedded with soft, silty shales and shaley siltstones, all very micaceous and slightly carbonaceous. In the lower part of the Cheterlo, the drab colored shales grade downward to dark red argillites. Although red is the predominate color in this lower portion, there are alternating beds of light green argillites.

Environmentally, the Cheterlo is believed to have been deposited under near-shore marine conditions, perhaps even continental at times. Remains of *Ostrea* have been found only in one locality but their presence indicates a partial marine environment. It is suggested that greenish gray micaceous silts and silty shales, with some interbedded sands, were deposited in embayments. Later, eustatic changes in sea level exposed the muds to oxidation which possibly produced the red color.

Thickness.—At the type locality, approximately 485 meters (1,591 feet) were measured which included only the top of the "red bed zone." An additional 800 meters (2,625 feet) were measured on Quebrada Patamana. The base is not exposed in either section. The known thickness of the Cheterlo is at least 1,285 meters (4,216 feet) and the total may be considerably more.

Stratigraphic Relations.—The base of the Cheterlo is nowhere exposed. Probably the Formation rests unconformably on formations of the Cojoro Group, or perhaps even on basement rocks. At the top contact, the Formation grades into the overlying Caju shales.

Paleontology and Age.—No diagnostic fossils have been found in the Cheterlo. In a locality six kilometers east of Quebrada Patamana, at the junction of a northward draining arroyo called Quebrada Yoi, a number of poorly preserved *Ostrea* were collected.

On the basis of its stratigraphic position, in continuous sequence below rocks of known late Jurassic age, the Cheterlo is considered to be possibly medial to early Jurassic.

Correlation.—The Cheterlo Formation has no known equivalents in western Venezuela or eastern Colombia, therefore it cannot be correlated outside of the type region.

Caju Formation

General Discussion.—A thick sequence of dominantly olive drab shales forms a broad topographic low on both sides of the folded ridge of the Cheterlo Formation in the Cocinas anticline. For this distinctive lithologic unit, the writer designates the name Caju Formation (*see* Strat. Sec. B-3). The type locality is approximately 0.5 kilometers west of the Indian village of Caju on the road from Pulachi to Cuisa. Here the complete Formation is exposed and both upper and lower contacts are clearly visible. The top of the Formation is considered to be at the base of the persistent sandstones of the overlying Chinapa Formation. This contact is readily apparent and marks a sharp topographic break between the high ridge of the Chinapa sandstones and the low valley of the Caju shales. It is easily traceable on the air photos. The lower contact, as stated before, is at the top of the first series of quartzitic sandstones of the underlying Cheterlo.

Local Description and Character.—The Caju Formation in the type locality represents the overturned southern limb of the Cocinas anticline; the beds dip steeply to the north. The Caju is also exposed on the north limb of the anticline. Both outcrop areas are from one to four kilometers wide and trend east-west for about 50 kilometers.

Lithologically, the Caju Formation is composed principally of shales and siltstones with a few thin beds of sandstone and limestone. Throughout most of the outcrop, the shales are olive drab and they weather with a slight reddish staining. Near the top, the shales are gray, weathering to olive drab or light gray, and are micaceous and silty. Fine mica is so abundant in the middle of the formation that it gives a silvery gray color to the sediments. This in turn gives the appearance of a low grade mica schist.

Thinly bedded, fine-grained, quartzitic sandstones occur mainly in the upper part of the Caju. Several thin beds of very hard, sandy, dark gray limestones occur in the lower 300 meters of the Formation. Here and there throughout the Formation, thin layers of yellowish brown, impure dolomitic limestones are present in highly fractured beds from six inches to three feet in thickness. The fractures are filled with white quartz or calcite or both. Secondary vein quartz and calcite filling is very extensive in some zones, particularly in the vicinity of the larger shear faults.

In the lower 300 meters, hard, dark gray limestone nodules and concretions are abundant. The concretions are limonitic and weather to a drab to light brown color.

To the west along its outcrop band, there are reeflike structures of very dark gray, dense, sandy limestone in the upper 100 meters of the Formation. No coral or other organic debris has been observed in these structures.

On the basis of lithology and rather meager paleontological evidence, shallow marine conditions appear to be indicated as the depositional environment of the Caju Formation.

Thickness.—A total of 992 meters (3,255 feet) was measured at the type locality where the Formation is complete. In other localities, differences of up to several hundred meters probably exist.

Stratigraphic Relations.—The Caju Formation is gradational with both the underlying Cheterlo Formation and the overlying Chinapa Formation. As in the case of the lower contact, the upper contact was arbitrarily chosen. It was picked at the base of a predominantly sand sequence (Chinapa) for ease of mapping.

Paleontology and Age.—Fossils from the Caju are very scarce and those collected are nondiagnostic for dating. *Exogyra* or *Ostrea* remains were collected in several scattered localities and appear to be restricted to the upper part of the Formation. A fairly persistent zone containing *Astarte* and *Crassatella* was found approximately 450 meters below the top of the Caju. This zone is exposed on both limbs of the anticline. Two poorly preserved ammonites, both of which proved to be unidentifiable, were collected in the concretion zone near the base. Geologists from the Creole Petroleum Corporation collected a single ammonite which was tentatively identified by Fraunfelter (personal communication) as *Perisphinctes* cf. *biplex* Sowerby which is an Upper Jurassic form. From its stratigraphic position and more definite age data from overlying formations, it would seem that the age of the Caju is at least late Jurassic and possibly even medial Jurassic.

Correlation.—The Caju Formation has no known equivalents in western Venezuela or eastern Colombia and therefore cannot be correlated outside the type region.

Chinapa Formation

General Discussion.—The name Chinapa Formation was designated by Renz (1960) for a ridge of hard quartzitic sandstones exposed a few kilometers northeast of Cerro Iruan on the northern limb of the Cocinas anticline. His type section is located just north of the Indian settlement called Chinapa.

Unfortunately the choice is a poor one and as Renz himself states:

> The relationships of the Chinapa Formation to the upper part of the Cocinas Group are not yet known. (Renz, 1960)

Although Renz places the Chinapa within the Jurassic Cocinas Group below the Cuisa Shale, it can be clearly demonstrated in the field that his type section is in actuality the lower sandstone unit of the Palanz Formation. (*See* discussion of Palanz Formation.)

In this report the term Chinapa Formation is retained in order to simplify the stratigraphic nomenclature. The same position within the stratigraphic column, that is, below the Cuisa Shale and within the Cocinas Group, is maintained.

A reference section for the Chinapa is designated by the present writer in the vicinity of the hill called Cerro Pachepa located a short distance south of the Indian village of Caju (*see* Geologic

Map). The section encompasses a thick sequence of sandstones and conglomerates which are exposed as a high ridge along the southern limb of the Cocinas anticline. The reference section was measured along an Indian trail following two dry-wash valleys which drain the hill from either side approximately perpendicular to the strike of the ridge (*see* Strat. Sec. B-4). The top of the Chinapa Formation (so defined) was arbitrarily placed at the top of the first resistant, massive conglomerate beds which define a major topographic break. The base of the Formation is at the base of the sequence of thick sandstones and interbedded shales which overlie the Caju Formation. This contact likewise constitutes a sharp topographic break; thus both top and bottom are readily traceable on air photos.

Local Description and Character.—The Chinapa Formation (redefined) crops out along most of the southern limb of the Cocinas anticline as a high ridge. East of the village of Jipi, the ridge was worn down nearly to the level of the adjacent formations by a brief stage of late Pleistocene marine erosion. The outcrop band extends in an east-west direction for about forty kilometers in which the beds are consistently overturned steeply to the north. The Chinapa, as redefined, is not present along most of the northern flank of the fold because of faulting. However, near the westernmost end, seven kilometers north of Cerro Cocinas, the Formation is exposed for ten kilometers. This exposure constitutes a part of the north limb of the Cocinas anticline.

In the Punta Espada area east of Serranía Macuire are some sediments of unproved identity, suspected as Chinapa. These are mapped as questionable Jurassic.

Throughout the extent of outcrop, the Chinapa is composed principally of buff to tan sandstones and conglomerates with a few beds of dark gray shale and a few thin, yellowish brown limestones. The sandstones are generally medium- to coarse-grained, and only locally, in the lower part of the section, are they fine-grained. They are mostly arkosic, micaceous, and argillaceous. The beds are hard and resistant, evenly bedded, and bed thickness ranges from two to four inches and up to several feet.

The conglomerates consist of pebble to cobble-sized subangular to subrounded fragments of granite, metamorphic rocks, and pieces of reworked conglomerate attributed to "Rancho Grande." The conglomerates are well cemented within a poorly sorted sand matrix thus forming massive, resistant beds.

Numerous, hard, splintery, micaceous shales occur interbedded with the sandstones in the lower 100 meters. The shales are generally silty and thinly bedded. A few thin beds of yellowish brown dolomitic limestone, so characteristic of Jurassic sediments in the Goajira, occur in the middle and lower parts of the Chinapa Formation. The limestones are fine textured, very dense and hard, and occur in beds from six inches to two feet thick. The presence of these yellowish brown limestones and dolomitic limestones serves to distinguish the Jurassic sandstones from the Cretaceous sandstones (Palanz).

The depositional environment of the Chinapa Formation was probably continental to shallow marine. The coarseness of the clastics and the upward gradation from relatively fine to very coarse suggest a rapidly rising land mass nearby during the time of deposition.

Thickness.—Along its outcrop band, the Chinapa varies considerably in thickness. At the reference locality 1,177 meters (3,862 feet) were measured whereas to the east, near Jipi, only 664 meters (2,178 feet) were measured. West of the reference section, the Formation is even thicker. This pronounced thickening to the west takes place at the expense of the overlying Cuisa shale which thins rapidly in that direction.

Stratigraphic Relations.—The Chinapa Formation, as stated before, is gradational with the underlying Caju Formation and grades both laterally and vertically into the overlying Cuisa Formation.

Paleontology and Age.—Fossils are extremely rare in the Chinapa and no diagnostic fossils have been found. The dolomitic limestones locally contain shell fragments which appear to be pelecypod remains. Lack of fossils makes a definite age determination impossible; however, fossils of the lower Kimmeridgian (Upper Jurassic) have been collected in the overlying shales (Cuisa). This indicates a pre-Kimmeridgian age for the underlying Chinapa. A medial Jurassic age is suggested.

Correlation.—The Chinapa Formation cannot be correlated with any known formations in either western Venezuela or eastern Colombia.

Cuisa Shale

General Discussion.—The type section of the Cuisa Shale is designated by Renz as two kilometers south-southeast of the Indian houses called Kesima on the northern limb of the Cocinas anticline. A reference section is also given by Renz for the southern side of the Cocinas trough. In 1956 Renz included the Cuisa Shale interval as being within his Cocinas Group as an unnamed shale unit. Later Renz (1960) designated the name Cuisa Shale for this unnamed unit and included the Shale within the overlying Cretaceous age sediments or possibly as transitional between the Cretaceous and the Jurassic.

Because of problems arising from definite age dating as well as correlation, the present writer proposes to redefine the boundaries of the Cuisa Shale so as to include the entire unit within the Cocinas Group of Jurassic age. Thus, the redefined boundaries of the Cuisa Shale are, at the top, the contact with the overlying Palanz Formation of Cretaceous age and, at the base, the contact with the underlying Chinapa Formation (redefined) of Jurassic age. Redefined, the Cuisa Shale now constitutes a thick sequence of shales and interbedded sandstones which crop out in topographically low bands between the high ridges of the Chinapa and Palanz formations.

Two reference sections of the Cuisa Shale are given by the present writer: (1) a section exposed just south of Cerro Pachepa (*see* Strat. Sec. B-4), and (2) an excellent section exposed near the village of Jipi, just north of Cerro Julanal (*see* Strat. Sec. B-5). Both reference sections are located on the southern limb of the Cocinas anticline, east and west respectively, of Renz' type locality for the Cocinas Group.

At Jipi most of the Cuisa Shale is well exposed and the locality provides an excellent area for the study of the lithologic and stratigraphic relationships (*see* Strat. Sec. B-5). Unfortunately, the upper contact is faulted and does not permit a true total thickness to be measured, but the section is considered to be superior to other localities where the Formation is complete but only partially exposed. Also, an excellent faunal assemblage is available in the beds near Jipi, but only scattered fossils were found elsewhere.

Local Description and Character.—The Cuisa Shale, as redefined, crops out for over fifty kilometers on both limbs of the Cocinas anticline. It also occurs in a number of fault slices west of the anticline. These exposures trend in an east-west direction and coincide with the major structural trends. The beds on the south limb of the fold are overturned and consistently dip steeply to the north except where minor secondary folding produces a south dip.

The Cuisa Shale (redefined) is characterized by thinly bedded, silty, micaceous shales, varying amounts of interbedded sandstones, and minor quantities of siltstones. Also, there are minor amounts of dolomitic limestone, sandy limestone, and limestone; locally bioherms are well developed. There is a definite lateral increase in the sand content westward and northwestward until sand becomes the dominant lithology. The shales are hard, splintery, slightly carbonaceous, in part sandy, and dark gray to brown and drab. Tan to olive drab, finely micaceous siltstones are common near the top of the Formation. Fine- to medium-grained, hard sandstones occur in the middle and lower parts of the Cuisa Shale. These are platey, resistant, often very calcareous, and frequently contain macrofossil remains.

Throughout the more shaley interval of the Cuisa Shale there are numerous beds of distinctive yellowish brown, dolomitic limestone in layers from six inches to three feet thick. These are typically fractured and recemented with white vein quartz and/or calcite.

A series of biohermal reefs is exposed along the southern outcrop band, close to the Cocinas fault line. These reefs are in the uppermost beds of the Cuisa Shale and they apparently grew on the edges of a depositional hinge line (*see* Fig. 5). The bioherms are composed of very dense, dark gray to black coralline limestones with interfingering calcareous shales and sandstones. Locally, individual bioherms coalesce to form massive reef structures from 500 to 1,000 meters long and up to 100 meters thick. Recrystallization of the limestone has left little porosity except for a few sizable fissures cutting the rocks in haphazard directions.

Irregular calcareous sandstones containing abundant shell and coral debris between some of the reefs are thought to represent surge channels where swiftly moving sea waters flowed.

A fore-reef facies is composed of thinly bedded, hard, dark gray to black shales which are calcareous near the reef. These are interbedded with thin beds of calcareous sandstone. Close to the reef front these sediments contain coral and shell debris apparently washed off the face of the reef during deposition. Locally, from this fore-reef zone as well as in pockets between the bioherms, rich ammonite fauna were collected. The back-reef facies of the Cuisa Shale is not well exposed; however, a rapid sand pinch-out is suggested.

The sediments and macrofaunal assemblage of the Cuisa Shale indicate a shallow marine depositional environment.

Thickness.—At the Jipi locale the Cuisa Shale measures 1,008 meters (3,307 feet) in thickness. Because of faulting, the top could not be observed. It is estimated that the total thickness in this area might possibly be of the order of 1,200 meters (3,937 feet). It is probably the maximum in the region. Towards the west, the Cuisa Shale thins rapidly as the underlying Chinapa thickens. At the locality near Cerro Pachepa, only 549 meters (1,801 feet) of Cuisa were measured in a complete section.

Stratigraphic Relations.—The Cuisa Shale is conformable to the underlying Chinapa Formation, and within the trough area it is conformable to the overlying Palanz Formation. South of the Cocinas fault line the Cuisa pinches out and the Palanz rests upon basement rocks.

Paleontology and Age.—An excellent macrofaunal assemblage was obtained from the Cuisa whereas microfaunal collections are limited to a few indistinguishable arenaceous forms. The following macrofossils were collected and some preliminary identifications were made by the writer. Final identification was done by H. Bürgl.

Idoceras humboldti Burckhardt
Idoceras balderum Burckhardt
Idoceras cf. *neogaeum* Burckhardt
Idoceras cf. *santarosanum* Burckhardt
Idoceras cf. *mexicanum* Burckhardt
Idoceras sp.
Nebrodites cf. *niaclachani* Burckhardt
Parasenia zacatecana Burckhardt
Pseudosimoceras aquilerae Burckhardt
Nautilus cf. *perstriatus* Steuer
Meretrix quintucoensis Weaver
Perisphinctes sp.
Virgatites sp.
Aspidoceras sp.

The following fauna were collected by the writer and identified by G. H. Fraunfelter:

Elysastraea sp., cf. *moorei* Duncan
Apiocrinus sp., cf. *tehuantepec* Springer
Pentacrinus sp.
Trigonia sp.
Exogyra sp.
Ostrea sp.

Samples of coral were identified by J. A. Fagerstrom as *Montastrea* sp.

Renz (1956) reports the following ammonites identified by H. Bürgl:

Virgatites cf. *australis* Burckhardt
Idoceras sp.
Aspidoceras sp.
Perisphinctes cf. *densistriatus* Steuer

The ammonite collections above indicate a late Jurassic age (Kimmeridgian and Portlandian) for the Cuisa Shale (redefined).

Correlation.—The Cuisa has no known equivalents in either western Venezuela or the Cordillera Oriental of Colombia.

CRETACEOUS SYSTEM

Rocks of Cretaceous age crop out widely over large areas of the Goajira Peninsula. The sequence represents almost the entire Cretaceous Period and is one of the finest stratigraphic successions of this system in this part of northern South America. The Cretaceous sediments with all of their variations may be studied here in the most minute detail and a real insight into limestone deposition may be obtained. In addition, the profuse accumulation of macrofossils contained in some parts of the limestone beds makes the region an excellent one for study of the biostratigraphic relations of the Cretaceous System.

The terminology used for the Cretaceous formations in the Goajira was developed in part from the names used in the Maracaibo Basin of western Venezuela because a number of excellent stratigraphic ties can be made. Some terms are derived from type localities within the Goajira to accommodate formations distinctive to the Goajira.

In this report, the following terms are used from top to bottom, for designation of the stratigraphic sequence:

Guaralamai
La Luna
Cogollo Group
Yúruma Group
Palanz

The Guaralamai Formation of the Goajira Peninsula represents a lateral calcareous facies equivalent of the Colón Formation which is found along the Perijá mountain front in western Venezuela. The La Luna Formation maintains the characteristic western Venezuelan lithology. The Cogollo as a group is lithologically similar to the Cogollo Group of the Perijá mountain front, with only minor differences. The term Yúruma is given to the limestone sequence directly underlying the Cogollo in the Goajira and the name Palanz is used for the thick succession of sandstones found beneath the Yúruma.

Palanz Formation

General Discussion.—The name Palanz Formation was given by Renz (1960) for the thick succession of reddish brown sandstones and conglomerates which form prominent bluffs north of the road between Cojoro and Ranchería. Renz' type section is located approximately 11 kilometers northeast of the triangulation station on Cerro Guasasapa. Formerly Renz (1956) referred to these sandstones and conglomerates as the Río Negro Formation, a name given to similar appearing sandstones which are exposed in the foothills of the Sierra de Perijá in western Venezuela. In using the term Río Negro he appears to have used it for all of the clastics and intercalated biohermal limestones lying between the Yúruma above and basement rocks or Jurassic Cocinas Group or Triassic Cojoro Group sediments below.

In his 1960 paper, Renz discontinues the name Río Negro and subdivides the sequence into the Palanz above underlain by the Kesima Formation. The Kesima comprises a limestone and marl sequence which is found on the northern rim of the Cocinas trough. He apparently does not correlate the Kesima of the north rim with the well-developed biohermal limestones found along the southeastern rim. Yet it can be shown faunally and stratigraphically that they are equivalents. This writer believes that the confusion in correlation and terminology is due to Renz' failure to recognize the lower sandstone unit of the Palanz on the northern rim where he defines his Chinapa Formation, Cuisa Shale, and Kesima Formation. In actuality the total Palanz succession comprises (1) a lower buff sandstone, (2) a middle biohermal or marly limestone (Kesima), and (3) a reddish brown upper sandstone. This sequence is shown on Renz' geologic map as all Palanz Formation southeast of Cerro Gajararipa. However, here he shows the biohermal limestone as an unnamed member.

In attempting to resolve the difficulties, this writer proposes that the Palanz Formation include both the upper and lower sandstones (as mapped by Renz on the southern rim) and that the middle biohermal limestone (Kesima) be given a member rank. Thus the marly limestones in the type locality of the Kesima are considered

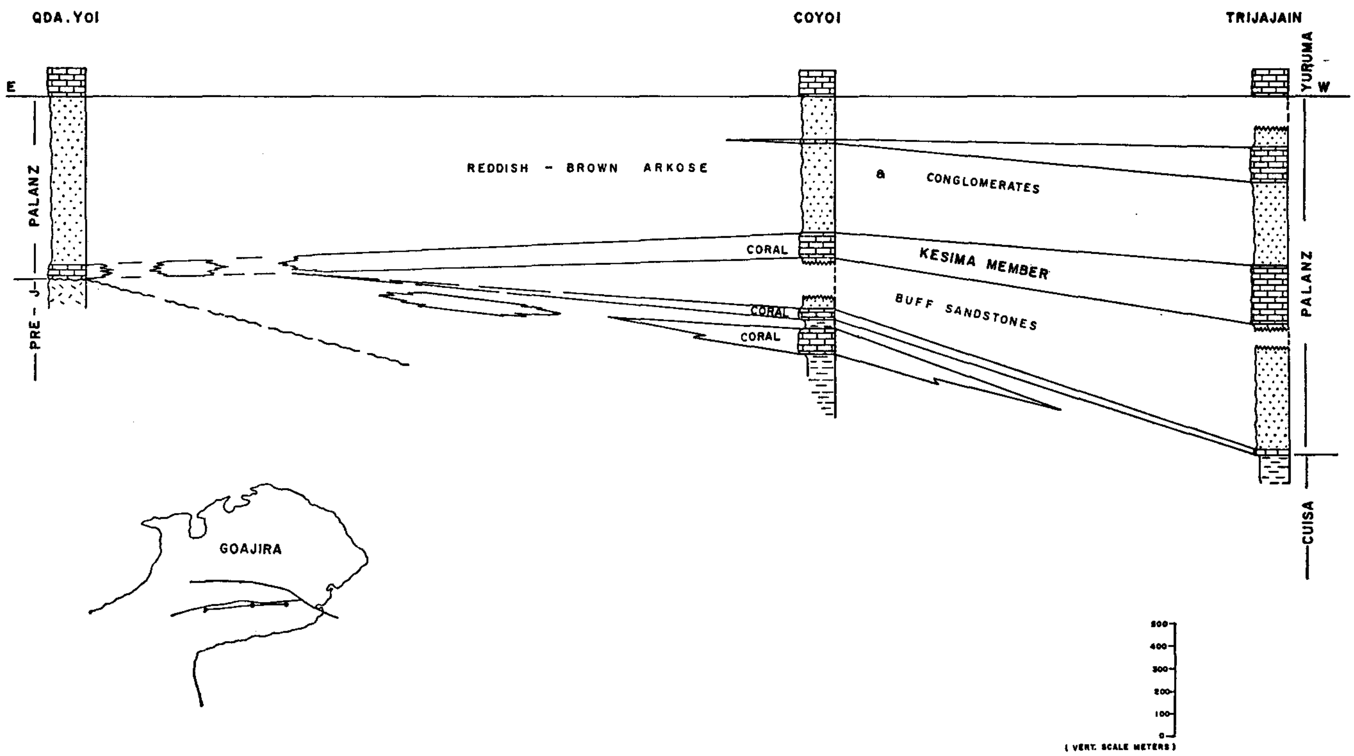


FIG. - 4 STRATIGRAPHIC DIAGRAM OF PALANZ FORMATION to equate with the more massive, biohermal limestones (unnamed by Renz) found on the shelf area south of the Cocinas fault.

Local Description and Character.—The Palanz Formation crops out as two more or less continuous bands on both sides of the Cocinas trough and extends for over fifty kilometers in an east-west direction (*see* Geologic Map). Complex faulting, together with rapid facies and thickness changes, have combined to make the unraveling of the true geologic picture of the Palanz rather difficult.

South of the Cocinas fault line, on the stable shelf area, the Palanz is relatively thin, nearly horizontal, and rests upon the basement rocks. A short distance to the north, in the trough area across the Cocinas fault, the Palanz Formation thickens three- and four-fold, and the dips are nearly vertical.

In the Punta Espada area, east of the Serranía Macuire, the Palanz, represented sometimes as the sandstone and sometimes as the limestone facies, crops out in several minor fault blocks.

The Palanz Formation is characterized lithologically by coarse-grained sandstones, conglomerates, minor beds of dark red, sandy, micaceous claystones, and some limestone (*see* Strat. Sec. B-6, B-7, B-8). In the southeast portion of the Goajira, closer to the source area, the sandstones are predominantly arkosic and are reddish brown.

The Palanz Formation within the Cocinas trough appears to be composed of two rather generalized sandstone types separated by a prominent reefal limestone (Kesima member). A lower unit is composed principally of coarse-grained, buff, quartzose sands, and an upper unit is composed of reddish brown, arkosic, conglomerates and conglomeratic sandstones with some quartzose sandstone (*see* Fig. 4). A relatively minor coralline limestone is also present locally at the base of the lower unit, but it is not delineated on the maps. As one approaches the shelf zone south of the Cocinas fault, the lower sand pinches out and the Kesima member lies directly upon basement rocks. At the type locality of the Palanz only the upper sandstone unit is present. Eastward, within the upper sand unit, a noncoralline limestone wedge appears and it thickens eastward.

Algal and coralline reef limestones (Kesima member) crop out in a narrow, more or less continuous band along the hinge line marked by the Cocinas fault. These limestones thicken eastward (*see* Geologic Map). The bioherms are composed of dense, massive, dark gray limestones which interfinger laterally with very sandy limestones, marls, and calcareous shales. To the west, near Cerro Cocinas, as a result of wedging out of the lower sandstone unit, individual

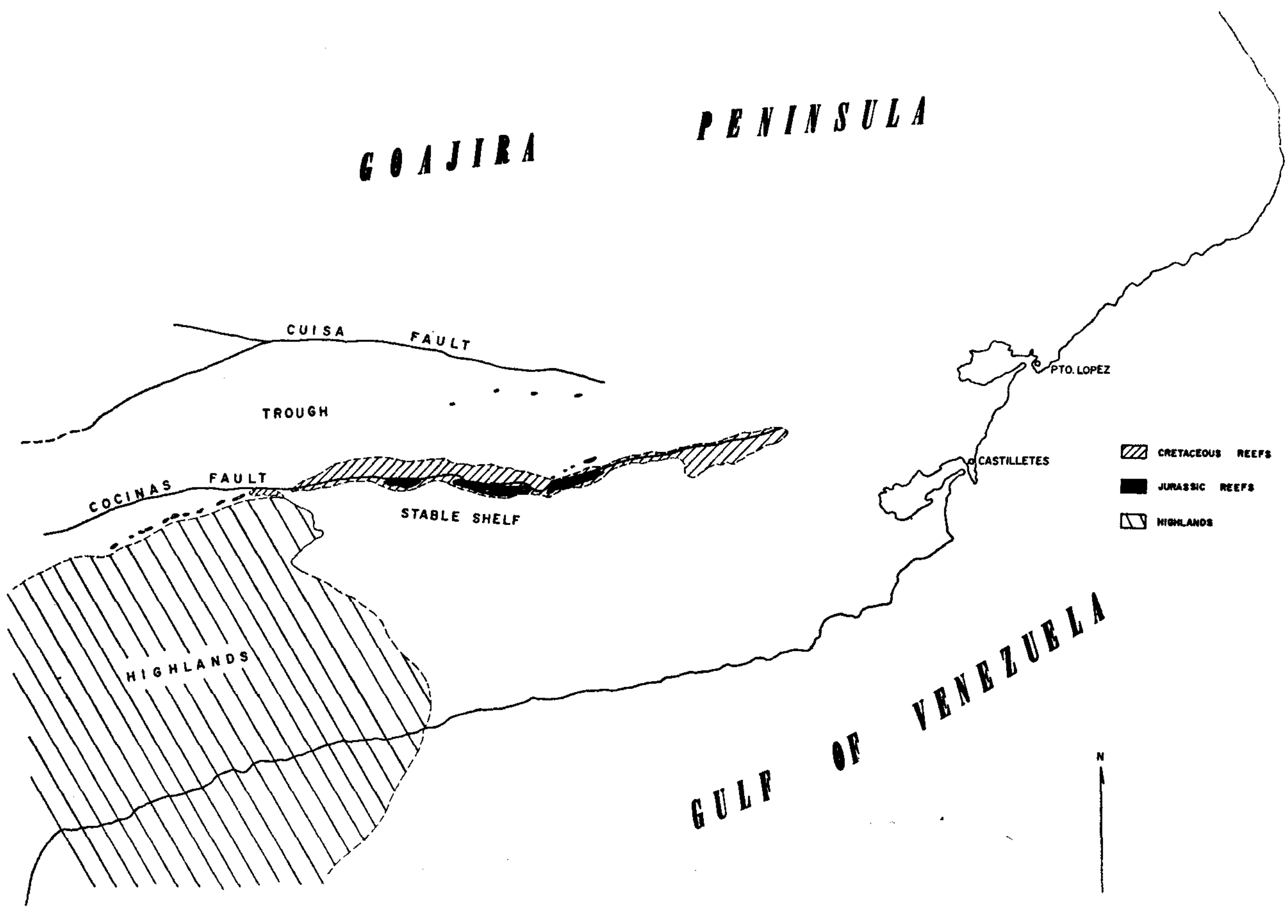


FIG. — 5 JURASSIC AND CRETACEOUS REEF DEVELOPMENT bioherms lie directly upon basement. These bioherms probably represent fringing reefs along the shoreline of a land mass which was present to the south (*see* Fig. 5). To the east, the bioherms thicken and coalesce along the Cocinas hinge line. They form a continuous unit of alternating coralline limestones and calcareous sandstones having a total thickness of up to 300 meters. The interfingering limestones are quite fossiliferous.

On the shelf, south of the area of reef development, the limestones grade laterally into a back-reef facies composed of light gray, calcareous beach sands.

Fore-reef sediments are well exposed in many places north of the Cocinas hinge line. These sediments consist mainly of marly, impure limestones and very calcareous shales which grade above and below into sandstones. This fore-reef facies outcrops in a continuous, narrow band along the northern outcrop locale near the village of Cuisa. The band is shown as the Kesima Formation of Renz. The reef facies thickens eastward to the vicinity of Porchina where it is overlapped by the beds of Oligocene age.

An upper limestone interval occurs in the Palanz near the Trijajain area (*see* Strat. Sec. B-7). This interval represents a marine intertonguing in the upper part of the Formation. The limes are highly fossiliferous but noncoralline. They are gray to black, argillaceous in part, thinly bedded, and contain interbedded gray, calcareous shales and reddish brown clay shales. At Trijajain, this interval is approximately 190 meters (623 feet) thick and thins rapidly to the west. Of these several limestone intervals within the Palanz, only the Kesima is delineated on the maps; however, the local stratigraphic relations of each are shown in the Palanz stratigraphic diagram (*see* Fig. 4).

The environment of the Palanz Formation varied from continental to shallow marine. To the east a shallow marine environment prevailed, becoming more continental farther west. During the deposition of the Kesima member, a shallow marine environment was quite widespread.

Thickness.—The thickness of the Palanz Formation ranges considerably. At Quebrada Yoi, about 12 kilometers northwest of Cerro Cocinas, 794 meters (2,605 feet) were measured. Farther to the east, near Cerro Coyoi, 592 meters (1,942 feet) were measured (incomplete), and at Trijajain, still farther to the east, in an incomplete section, 972 meters (3,189 feet) were measured. This last increase in thickness is due primarily to thickening of the Kesima member which measures 284 meters (932 feet); but a thick upper limestone and shale intertongue is also included. In contrast to the thick sections measured in the trough, the total thickness of the Palanz Formation on the platform areas, a short distance south of the Cocinas hinge line, is only 295 meters (968 feet).

An incomplete section of the Palanz measured at Quebrada Borochio on the northern side of the Cocinas trough is 371 meters (1,217 feet) thick. The total thickness is estimated at approximately 450 meters (1,476 feet) in this locality. Here the Kesima member is 104 meters (341 feet) thick. To the east along this same band of outcrop, near Porchina, the Kesima thickens to about 280 meters (919 feet).

Stratigraphic Relations.—The Palanz Formation conformably overlies the Jurassic Cuisa Formation within the Cocinas trough area. On the platform, south of the Cocinas fault line, the Palanz lies nonconformably upon basement rocks or lies with angularity upon the Triassic Cojoro Group. It is everywhere conformable with the overlying Yúruma Group.

Paleontology and Age.—Fossils have been recovered only from the limestone members of the Palanz Formation. The fore-reef facies of the Kesima member carries an abundant macrofauna in the marly limestones.

The following fossils were collected from several localities within the fore-reef facies of the Kesima member on its northern outcrop band (identification by H. Bürgl):

Isognomon cf. *ricordeana* d'Orbigny
Exogyra tamaulipana Imlay
Terebratuloid brachiopod
Trigonia n. sp.?
Ostrea sp.
Coral fragments

On the southern outcrop band in the area of reef development, near the settlement of Trijajain, the following macrofauna were collected from the Kesima member (identification by H. Bürgl):

Ostrea, sp.
Trigonia n. sp.?
Argentiniceras cf. *noduliferum* Steuer
Astrocoenia sp.
Algae

The *Trigonia* n.sp.? is a common form found in the marls of the Kesima along the northern rim of the Cocinas trough. The same form is found less commonly in the biohermal limestones on the southern rim. It is believed by this writer that this is the form referred to by Renz (1956, 1960) as *Trigonia lorentii* Dana. The true *T. lorentii* Dana is found much higher stratigraphically, in the lower part of the Moina Formation of the Yúruma Group.

The total aspect of the fauna is indicative of early Cretaceous and according to Bürgl (personal communication) *Argentiniceras* indicates a Berriasian to Valanginian age for the Palanz Formation. The base of the Formation, however, may actually extend down into the upper Jurassic.

Correlation.—The Palanz Formation, together with the overlying Yúruma limestones of the Goajira Peninsula, appears to correlate with the Río Negro in the type locality along the foothills of the Sierra de Perijá in western Venezuela. No fossils have been recorded from the Río Negro in the type locality.

In eastern Colombia, the Arcabuco and Caqueza quartzites have been suggested as equivalents to the Río Negro of the Maracaibo Basin by Sutton (1946, p. 1641). According to Sutton, the Caqueza contains beds of fossiliferous shales of Berriasian, Valanginian, and Hauterivian ages. Thus it appears that the Palanz of the Goajira Peninsula is, at least in part, equivalent to the Caqueza on the basis of paleontology.

Yúruma Group

General Discussion.—The name Yúruma Formation was used by Renz (1956) for the thick sequence of limestones and calcareous shales in the vicinity of Cerro Yúruma, a prominent limestone ridge located several kilometers north of the Indian village of Ranchería (*see* Geologic Map). At this time Renz indicated two units which he called "Upper Yúruma" Formation and "Lower Yúruma" Formation. In 1960 Renz redefined the term and designated the name Moina Formation for his "Lower Yúruma" and restricted the name Yúruma Formation to his "Upper Yúruma."

Although the term Yúruma was officially designated by Renz in 1956, reconnaissance geologists of the Richmond Exploration Company had independently recognized and used the name as early as 1947. The present writer measured and defined the type section in the early part of 1954. Therefore, the writer feels free to modify the position of the contacts as defined by Renz. The suggested modification is based upon both stratigraphic and paleontologic evidence.

In this report the term Yúruma is elevated to group rank and at the type locality the Yúruma Group has been subdivided into two units: the "Upper Yúruma" Formation and the Moina Formation (*see* Strat. Sec. B-9). The boundaries of the Moina Formation follow those defined by Renz (1960), that is, the lower boundary is at the contact with the reddish brown sandstones of the Palanz Formation and the upper boundary is at the top of the massive, dense limestone directly underlying a zone of soft marls and marly limestones.

The Yúruma Formation of Renz (1960) comprises the zone of marls, shales, and marly limestones extending from the contact with the massive limestones of the Moina, up the escarpment of the ridge to the base of the dense, black, capping limestones just below the top of the ridge. Thus by Renz' definition, the capping limestones are included in the overlying Cogollo Group.

In this report the "Upper Yúruma" Formation is redefined to include the dense black limestones at the top of Cerro Yúruma. The new boundary between the Yúruma Group and the overlying Cogollo Group is defined as the top of the massive, coarsely crystalline "oyster" limestone found near the base of Cerro Yúruma on the southeastern dip slope (*see* Strat. Sec. B-9). Redefined in this manner, the "Upper Yúruma" includes the "oyster" limestone and all of the dense black and gray limestones directly overlying the marl zone (considered by Renz as the lower part of the Cogollo Group). In the opinion of the writer, this redefinition has several desirable aspects.

From a biostratigraphic viewpoint the limestones in question belong with the marl section because both are Barremian in age. Two ammonites found within the massive "oyster" limestone are indicative of the Barremian and since the age of the overlying Cogollo Group is considered as Aptian and younger, it is more desirable to subdivide the section in order to restrict the Yúruma Group to pre-Aptian.

Field observations by the writer indicate that away from the type section, especially to the north near Cuisa, the marl zone changes facies downward and laterally, and thus becomes partially replaced by dense black limestones related to the Cerro Yúruma caprock. Mapping of the boundary as defined by Renz, away from the type locality, is therefore rather difficult. On the other hand, the upper contact as redefined in this report persists throughout the region. This is a reliable boundary for use in mapping.

Local Description and Character.—Rocks of the Yúruma Group crop out widely in the Goajira. They are exposed for about fifty kilometers along the Cocinas fault in addition to their occurrence on the adjacent platform to the south. They also form an east-trending outcrop band on the south side of the Cuisa fault. This is more or less continuous over a distance of approximately thirty kilometers. To the northeast, the Yúruma Group is exposed at the eastern end of the Serranía Macuire near Punta Espada. Also, a small but important formational remnant occurs near the village of Uitpa at the southern end of the Serranía Jarara (*see* Geologic Map).

The Yúruma is extensively faulted throughout most of its outcrop area, a circumstance that generally makes section measurement difficult. Fortunately, at the type section, the entire Group is present and unfaulted (*see* Strat. Sec. B-9). Elsewhere, a number of excellent partial sections were measured.

The Yúruma Group is composed principally of massive limestones with minor beds and zones of calcareous shale, marl, marly limestone, and some calcareous sandstone.

The Moina Formation at the type locality presents a threefold lithic subdivision: (1) a lower limestone and marly shale, (2) a middle marl and marly limestone, and (3) an upper massive limestone. With some variation, these three units persist throughout the area.

The lower limestones are dense, resistant, in part massive, tan to gray and black with interbedded soft, gray, marly, fossiliferous shales. In places, both the limestones and marls are sandy. The limestones range in texture from fine to coarse, and are generally fossiliferous.

The middle marl at the type locality is composed of tan to gray, marly, fossiliferous limestones. Farther north, between Porchina and Cuisa, the middle marl contains a prominent sandstone wedge with several thin beds of limestone. The sandstones are fine- to coarse-grained, calcareous, resistant, and range from gray to buff.

A relatively thick sequence of limestones characterizes the upper massive limestone interval of the Moina throughout the Goajira. The limestones are massive, very resistant, coarsely crystalline, and fossiliferous, containing especially abundant shell debris. They range from tan to dark gray. They are generally sandy; individual beds locally become very sandy, and are typified by coarse grains of white quartz.

The "Upper Yúruma" is broadly divisible into two lithic units which are not discernible everywhere: (1) a lower marl and shales; and (2) an upper limestone. At the type locality, the lower marl is composed of soft, tan to gray, nodular marls and marly limestones, and gray to black, thinly bedded shales. All are richly fossiliferous and contain many varieties of macrofossils. In the area between Cuisa and Porchina, the lower marls of the "Upper Yúruma" are represented in part by dense, black, bituminous limestones and black calcareous shales.

The upper limestone unit of the "Upper Yúruma" is everywhere composed of dense, evenly-bedded, bituminous limestone and lesser amounts of interbedded black, calcareous shales. The limestones are black but weather gray. They are commonly fine textured, and contain a few small shell fragments. Near the top of the "Upper Yúruma," the uppermost limestones are more massive, coarse textured, brownish gray to gray, and contain a thick-shelled molluscan fauna. At the contact with the Cogollo (following the writer's definition of the Yúruma Group), the limestone is massive, very resistant, and contains an abundant, distinctive fauna of large *Ostrea* and *Exogyra* and thus forms an "oyster-bank" limestone.

Although the environment of the Yúruma Group is shallow marine, there are considerable variations laterally and vertically throughout the Group. The Moina Formation was deposited mainly under a beach and near-shore shellbank environment. In "Upper Yúruma" time, the sea had spread farther inland to the southwest and a widespread reducing environment apparently prevailed which produced black, bituminous limestones.

Thickness.—At the type locality, 576 meters (1,890 feet) were measured including 269 meters (883 feet) for the "Upper Yúruma" and 307 meters (1,007 feet) for the Moina. This total thickness is considerably more than Renz' (1956) figure of 450 meters, but the difference is due to the redefinition of the upper boundary which adds considerably to the "Upper Yúruma."

In a northwestward direction, section measurements indicate rapid thinning of the Moina, and the entire Group appears to thin in response to this condition. At Quepsina, nine kilometers east of the village of Cuisa, 260 meters (853 feet) of Moina were measured, and at Quebrada Borochio, some four kilometers west of Cuisa, only 49 meters (161 feet) were measured. In this area, complete thicknesses for the "Upper Yúruma" are nowhere obtainable because of faulting, but it still appears to be quite thick. At least 228 meters (748 feet) are present at Quebrada Borochio.

Stratigraphic Relations.—The Yúruma Group rests conformably on Palanz sandstones, and is conformably overlain by sediments of the Cogollo Group.

Paleontology and Age.—A great many fossils were collected from all levels of the Yúruma Group. Preliminary studies were done by the writer and final identifications were done by H. Bürgl or G. Fraunfelter. The fossils were broadly subdivided into two working groups: (1) the ammonites, which were used for specific age determinations at the several levels and; (2) certain of the common molluscan faunas which the writer found extremely useful for local biostratigraphic zonations. Figure 6 summarizes the occurrence of those faunal zones in the "Upper Yúruma" and Moina Formation which indicate significant faunal zones and time stages.

The following fauna were collected from the Yúruma Group at the type locality:

"Upper Yúruma" (Barremian)
Upper Barremian

Ostrea spp.
Exogyra spp.
Exogyra couloni? Defrance
Pedioceras caquensense Karsten
Pseudohaploceras? cf. *incertum* Riedel
Ancyloceras? degenhardtii inflatum Karsten

Middle Barremian

Heinzia (Heinzia) provincialis d'Orbigny
Heinzia (Heinzia) colleti Bürgl
Heinzia (Gerhardtia) galeatoides galeatoides Karsten
Heinzia (Gerhardtia) veleziensis Hyatt
Pulchellia (Hettneria) sp.
Pulchellia (Hettneria) selecta Gerhardt
Pulchellia (Caicedia) fasciata Gerhardt
Pulchellia galeata aff. *ornata* Bürgl
Pulchellia multicostata Riedel
Pulchellia (Hettneria) hettneri Gerhardt
Ptychoceras beyrichi Karsten
Astarte cf. *sieversi* Gerhardt
Cucullaea cf. *gabrielis* Leym
Echinoid sp.
Perna sp.
Nautilus sp.
Antiptychina? mulleriedi Imlay
Rostellaria cf. *boussingaulti* d'Orbigny
Exogyra minor Coquand

Lower Barremian

Enallaster cf. *texanus* Roemer
Pseudohaploceras sp.
Nicklesia didayana didayana d'Orbigny
Nicklesia dumasiana dumasiana d'Orbigny

Nicklesia dumasiana retrocurvata Bürgl
Nicklesia alicantensis Hyatt
Nicklesia nodosa Bürgl
Pedioceras sp.
Exogyra boussingaulti d'Orbigny
Trigonia (Notoscabrotrigonia) tocaimaana Lea
Corbis sp.

Moina Formation (Valanginian-Hauterivian)

Choffatella sogamosae (Karsten)
Crioceras sp.
Simbirskites sp.
Olcostephanus sp.
Cucullaea sp.
Exogyra reedi Imlay
Exogyra couloni Defrance
Exogyra sp.
Lucina (Phacoides) porrecta Gerhardt
Clementia cf. *ricordeana* d'Orbigny
Trigonia sp.
Toxaster roulini Agassiz
Pseudoglauconia sp.

In addition to the above fossils, a number of *Trigonia lorentii* Dana, were collected from some sandy limestones on a circular knoll of Moina limestone four kilometers northwest of Cerro Queps, just above the contact with the Palanz. These indicate a Valanginian age for this part of the section.

Exogyra couloni Defrance is an excellent local stratigraphic marker for the lower limestone of the Moina, where they occur in profuse numbers. This is undoubtedly a local stratigraphic restriction since *E. couloni* extends from the Hauterivian to the Lower Cenomanian (personal communication, H. Bürgl).

Likewise, such fossils as *Trigonia tocaimaana, Cucullaea* cf. *gabrielis,* and others are known to range into the Aptian, but in the Goajira they appear to be restricted to the Barremian zones shown in Figure 6. Most of the forms collected at the Yúruma type locality are found in the same relative stratigraphic position wherever the Yúruma is exposed.

In the northern outcrop band at Quepsina, eight kilometers from the village of Cuisa, the following forms were collected from the "Upper Yúruma":

Pedioceras cf. *caquensense* Karsten
Colchidites apolinari Royo and Gomez
Colchidites sp.

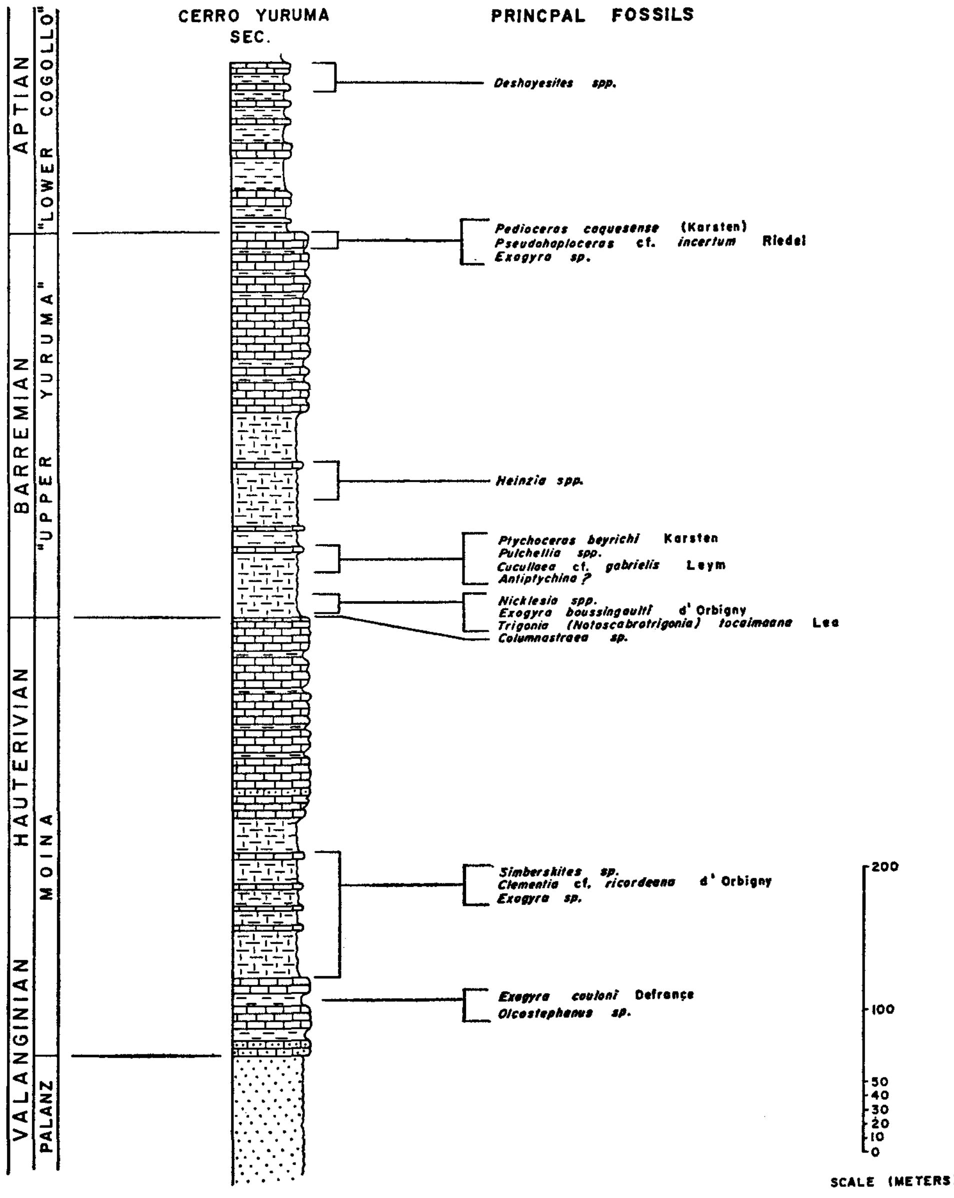


FIG. — 6 FAUNAL ZONES YURUMA GROUP

These are regarded by Bürgl (personal communication) as Upper Barremian? in age.

Also in the Cuisa area, Renz (1956) reports *Saynoceras, Crioceras,* and *Nautilus* cf. *peristriatus* Steuer from the Moina, indicating the Hauterivian.

In the Cerro Yúruma locale, Renz *(op. cit.)* lists the following fossils collected from the marl zone of the Moina:

Olcostephanus astierianus d'Orbigny
Exogyra reedi Imlay
Lucina porrecta Gerhardt
Trigonia hondaana Lea
Cucullaea sp.
Choffatella sogamosae (Karsten)

In summary, the age of the Yúruma Group ranges from the Valanginian through the Barremian. The Moina ranges from Valanginian through Hauterivian and the "Upper Yúruma" is entirely Barremian.

Correlation.—The Yúruma Group probably correlates in part with the Río Negro Formation of the Maracaibo Basin. It is believed to be a lateral facies equivalent of the upper part of the Río Negro in the Sierra de Perijá.

Cogollo Group

General Discussion.—Limestones of the Cogollo Group have been well known for many years in the Maracaibo Basin. Garner (1926, p. 679) first introduced the term to the literature, and since then the name Cogollo has been in general use in one form or another throughout western Venezuela. The type locality is on the Río Cogollo in the eastern foothills of the Sierra de Perijá. Here the Cogollo consists of massive limestones in the lower part, overlain by a middle black shale which is in turn overlain by upper limestones at the top.

Since Garner's paper was published, several authors have attempted to standardize the type Cogollo definition and resolve some of the problems associated with the Formation. Hedberg and Sass (1937, pp. 77–78) published the first complete and detailed definition of the type section. In 1946, Sutton (p. 1642) redefined the Cogollo elevating the term to group rank and subdividing the lithologic units into three formations in the following manner:

La Luna

Cogollo Group	Capacho Formation Aguardiente Formation Apon Formation

Río Negro

Rod and Maync (1954), in an excellently detailed discussion of the Lower Cretaceous in the Maracaibo Basin, subdivided the Cogollo Group even further:

La Luna

Cogollo Group	Maraca Formation Lisure Formation Upper Apon Member Middle Apon Member Lower Apon Member

Río Negro

Still a different method of Cogollo subdivision is locally used in the Mara-La Paz oil fields near Maracaibo, according to Smith (1953, pp. 58–59).

La Luna

Cogollo limestone	Upper Middle Lower

Río Negro

The nature of the Cogollo sediments in the Goajira Peninsula does not readily lend itself to any of the aforementioned systems of division; therefore, some compromise must be made. Since the outcrops in the Goajira represent a rather local mapping problem, it was decided by the writer to adopt tentatively the terms Maraca after Rod an Maync in the Maracaibo Basin and "Lower Cogollo."

The contact between the Maraca and "Lower Cogollo" in this paper is considered to be at the top of a rather thick sequence of massive, very sandy, gray to dark brown limestone containing thick-shelled *Ostrea*. The top of the limestone provides a very convenient contact on the air photos and is readily traced along the outcrop.

Local Description and Character.—Rocks of the Cogollo Group in the Goajira crop out in three different localities: (1) south and east of Cerro Yúruma; (2) along the Cuisa fault; and (3) the Punta Espada area at the northeastern end of the Peninsula.

Outcrops of Cogollo sediments extend from the south side of Cerro Yúruma eastward to the line of Oligocene onlap northwest of the trading post called Flor de Goajira (*see* Geologic Map). These outcrops provide excellent stratigraphic data, and although a composite section had to be used, a complete stratigraphic record was obtained. A complete section of the "Lower Cogollo" was measured at about 3.5 kilometers west of Tienda Monojoi (*see* Strat. Sec. B-11). This section also included about half of the Maraca with its important *Orbitolina concava texana* Roemer zone. The Maraca was measured also about 4.5 kilometers northwest of the Flor de Goajira (*see* Strat. Sec. B-12). This section also contains the *O. concava texana* zone.

To the north, along the Cuisa fault, the Cogollo crops out between two parallel faults which place granite gneiss next to the Cogollo on the north side and next to parts of the "Upper Yúruma" on the south side.

At the eastern end of Cerro Iruan, located a short distance south of the Cuisa fault, a wedge-shaped fault block brings to the surface shales and limestones of the "Lower Cogollo." Here a rich macrofauna was obtained.

Northeastward, in the Punta Espada area, Renz (1956) indicates a thick section of Cogollo limestones. Not enough work was done by the present writer in this area to differentiate the Cogollo from other Cretaceous limestones; thus, the map shows only "K undifferentiated."

Lithologically, the "Lower Cogollo" is composed mainly of silty shales and interbedded silty limestones; the Maraca is composed of massive limestones and a few thin beds of shale.

Most of the limestones of "Lower Cogollo" are characterized by the thin, platey bedding and dark brown to black color. Nearly all have a strong petroliferous odor when freshly broken. Most of the limestones contain fine silt laminations and are highly fossiliferous. Near the base, however, the limestones are more dense, bituminous, black, weathering to light gray. They occur in beds ranging from six inches to one foot thick. The limestones are more abundant toward the top of the "Lower Cogollo," and are more thinly bedded or even laminated. These are in turn overlain by moderately massive, sandy, limestones. Large, thick-shelled *Ostrea* are common in these upper sandy limes and a few coral remains are present. The colors of the limestones range from dark gray to dark brown.

The shales and siltstones of the "Lower Cogollo" are all soft, thinly bedded, calcareous, very fossiliferous, and grade imperceptibly from silty shales to shaley siltstones. Fresh samples have a slight petroliferous odor. Colors are generally dark brown to black and, upon weathering, become brown.

The Maraca Formation is characterized by massive, dense, tan to gray and bluish gray limestones with interbedded soft, gray, calcareous shale. The texture of the limestones ranges from microcrystalline to very coarsely crystalline. The microcrystalline rocks are generally buff to tan and light brown, and the more coarsely textured limestones are gray to dark bluish gray and occasionally buff. Most of the limestones are fossiliferous.

A massive *"Exogyra"* limestone bed marks the top of the Maraca. The limestone is dark, bluish gray, very resistant. It is also very fossilferous, containing abundant *Exogyra* and *Ostrea.*

Many of the Maraca limestones of the Goajira have the characteristic petroliferous odor of the Cogollo limestones in the Maracaibo Basin. The lighter colored microcrystalline beds are either barren of odor or only faintly petroliferous.

The depositional environment varied considerably in character. During "Lower Cogollo" deposition, a moderate marine depth with a slightly reducing condition prevailed. Clear, shallow marine waters characterized the environment during Maraca time. Towards the end of Cogollo time, massive "oyster bank" reefs flourished in a fashion typical of latest Cogollo time throughout western Venezuela.

Thickness.—A composite section thickness of the entire Cogollo Group is 818 meters (2,685 feet). This is based upon separate measurements for the Maraca Formation and "Lower Cogollo" in different localities.

It was not possible to measure a single complete Cogollo Group section anywhere on the Goajira Peninsula. However, several localities provided excellent partial sections. These, when combined by correlating key lithologic and paleontologic zones, provided a reasonable figure for the total.

About 3.5 kilometers west of the Indian settlement of Monojoi, on the Ipapure-Castilletes road, a well-exposed section of the "Lower Cogollo" and a portion of the Maraca were measured. Here, a thickness of 310 meters (1,018 feet) was determined for the "Lower Cogollo." Farther eastward, about four kilometers northwest of the trading post Flor de Goajira, an excellent outcrop of the Maraca Formation is present. At this locale a thickness of 508 meters (1,667 feet) was measured.

Stratigraphic Relations.—The Cogollo Group rests conformably upon the Yúruma Group and is in turn conformably overlain by the La Luna Formation.

Paleontology and Age.—The silty shales and interbedded limestones of the "Lower Cogollo" are very fossiliferous and contain a number of ammonites and abundant pelecypods. Several distinct biostratigraphic zones are useful for local mapping.

From the thinly laminated, platey, limestones in the lower part of the "Lower Cogollo," the following ammonites were collected from the Monojoi locality (identification by H. Bürgl):

Deshayesites stutzeri Riedel
Deshayesites sp.
Melchiorites? sp.

The following ammonites were collected from the middle shale member of the "Lower Cogollo" (identification by H. Bürgl):

Colombiceras sp.
Cheloniceras sp.
Uhligella sp.
Protocardia sp.
Protocardia elongatum Gerhardt
Lucina porrecta Gerhardt
Inoceramus sp.

In this interval, *Protocardia* and *Lucina* are especially abundant; they continue upwards into the laminated limestones of the top part of the "Lower Cogollo." Both fossils are useful here as a local biostratigraphic marker although they have a wide stratigraphic range in the Cretaceous.

In approximately the same "Lower Cogollo" interval, a large collection of ammonites and pelecypods was obtained at the east end of Cerro Iruan. The locality lies in a wedge-shaped fault block of the limestones. The following fossils were present (identified by H. Bürgl):

Melchiorites? sp.
Ancyloceras? cf. *degenhardtii inflatum* (Karsten)
Protocardia elongatum Gerhardt
Lucina porrecta Gerhardt
Neaera convergens Gerhardt
Inoceramus sp.

A zone in the upper limestones ranging from 50 meters to 90 meters below the top of the "Lower Cogollo" furnished the following fossils from the Monojoi locality (identification by H. Bürgl):

Parahoplites sp.
Acanthohoplites sp.
Protocardia sp.

The sandy limestone zone at the top of the "Lower Cogollo" contained abundant *Ostrea* sp. and several corals.

The Maraca limestones contain several fossiliferous zones of regional significance. Abundant *Orbitolina concava* var. *texana* Roemer occur in the section measured west of Monojoi. They occur in the dense, massive, tan colored limestone stratigraphically about 125 meters (410 feet) above the base of the Maraca. The *Orbitolina* zone is a well known stratigraphic marker throughout western Venezuela.

Another zone, in the Monojoi section 50 meters higher, contains beautifully preserved shells weathering out from a dense, massive limestone. The following fossils were identified (identification by G. Fraunfelter):

Trigonia (Quadratotrigonia) hondaana Lea
Trigonia (Notoscabrotrigonia) tocaimaana Lea
Ostrea sp.

These fossils are of little significance since they have a rather wide stratigraphic range within the Lower Cretaceous.

At the top of the Maraca Formation, a massive fossiliferous limestone yielded the following:

Ostrea scyphax Coquand
Exogyra n. sp.?

Although *Exogyra* n. sp.? has not been named, the form has been used for biostratigraphic correlation for some time by paleontologists of the Creole Petroleum Corporation, according to Fraunfelter (personal communication). Both the *Exogyra* n. sp.? and *Ostrea scyphax* Coquand are considered to be reliable index fossils of the uppermost limestones of the Cogollo Group in the Maracaibo Basin.

Renz (1956) lists the following Aptian ammonites which were collected from the Cogollo near Punta Espada:

Acanthohoplites interiectus Riedel
Cheloniceras sp.
Uhligella zurcheri Jakob and Tobler
Phylloceras cf. *morelianum* (d'Orbigny)

From the upper beds of the Cogollo at the same locality, Renz *(op. cit.)* also reports deformed specimens of *Venzoliceras* and *Peruvinquieria* from the upper beds of the Cogollo. These forms indicate that at least part of the Maraca is Albian.

The *Orbitolina concava* va. *texana* Roemer zone in western Venezuela is generally considered by Sutton (1946), Maync (1954), and others to be Upper Aptian although in other regions the *Orbitolina* is known to have a somewhat greater stratigraphic range according to Maync (1954, p. 269). Sutton (1946, p. 1648) indicates a Cenomanian age for *Ostrea scyphax* Coquand which, in both the Goajira and the Maracaibo Basin, is found in the uppermost beds of the Cogollo Group.

The age of the Cogollo Group, based on the fossil evidence and the stratigraphic position, ranges from Lower Aptian through the Cenomanian.

Correlation.—Salient features of the Cogollo correlation from the Goajira southward to the Maracaibo Basin (Mara-La Paz) are shown by a correlation diagram (Fig. 7). The top of the Cogollo Group of the Goajira probably correlates closely with the top of the Cogollo of the Mara-La Paz and with the top of the Maraca of the Perijá Mountain front. Likewise, the *Orbitolina* zone of the Goajira is correlative with the same zone in the Mara field.

The base of the Cogollo of the Goajira may not correlate exactly with that of the Maracaibo Basin. It is suggested that the Cogollo "shale break" of Smith (1951) in the Mara-La Paz oil fields thickens northward to the Goajira and extends downward stratigraphically as indicated on the correlation diagram. Thus, the "Lower Cogollo" of the Goajira is Lower Aptian in age whereas the section in the Mara-La Paz oil field is principally Upper Aptian and perhaps extends into the Lower Aptian.

It should be re-emphasized that the division between the Maraca Formation and the "Lower Cogollo" in the Goajira does not provide exact equivalents of any of the subdivisions in use in the Maracaibo Basin.

La Luna Formation

General Discussion.—The term La Luna has been used in western Venezuela for many years, and is well known. The type locality of the Formation is exposed at the Quebrada La Luna in the foothills of the Sierra de Perijá; it is composed of black petroliferous limestones, shales, cherts, and limestone concretions. The type section was first described by Garner (1926, p. 679).

The stratigraphic boundaries in the Goajira are similar to those of the Maracaibo basin. The lower contact of the Formation is at the base of a succession of finely crystalline foraminiferal limestones immediately above the massive, coarsely crystalline *"Exogyra"* limestones of the underlying Cogollo Group. The top of the La Luna is arbitrarily placed at the top of a 20 to 30 centimeter bed of limestone-pebble conglomerate which rests on typical La Luna limestones and lies below the shaley limestones of the Guaralamai Formation. This conglomerate bed is apparently unique to the Goajira since it has not been observed elsewhere in western Venezuela. In place of this conglomerate in most of western Venezuela there is a thin but very persistent glauconitic and phosphatic sandstone. Some geologists suggest that this glauconite bed indicates an interruption in the sedimentation.

Local Description and Character.—Outcrops of the La Luna Formation on the Goajira Peninsula are found four kilometers northwest of Flor de Goajira (*see* Geologic Map). Its narrow outcrop band begins at a fault-boundary with the Yúruma sediments at its westward end, and extends northeastward for about six kilometers. At its eastern end, the La Luna band is overlapped by Oligocene deposits. The nearly vertical attitude accounts partly for narrowness of the La Luna outcrop.

Renz (1956, 1960) reports exposures of the La Luna Formation between Punta Espada and Nazaret along the northern foothills of the Serranía Macuire. No other outcrops are known on the Peninsula.

Lithologically the La Luna on the Goajira Peninsula is characterized by the abundance of black cherts and petroliferous limestones. The Formation consists of a lower foraminiferal limestone overlain by a sequence of thinly bedded black cherts interlayered with a few beds of black limestone (*see* Strat. Sec. B-12). Within the limes, irregular discontinuous seams and nodules of chert also occur. The limestones are black, thinly bedded, laminated, bituminous, dense, pyritic, and finely crystalline. Thin sections show that they are composed in large part of foraminiferal tests in a black lime matrix.

Also present are a few discoidal concretions composed of very dense, black, resistant microcrystalline limestone. The occurrence of these concretions in the La Luna throughout western Venezuela is a well-known characteristic of the Formation.

The conditions of deposition of the La Luna are considered as rather complex, but are still not well understood. Deposition probably took place in a restricted or silled basin with stagnating bottom waters deficient in oxygen. The surface waters apparently were sufficiently clear for flourishing growth of pelagic foraminifera.

Thickness.—A thickness of 79 meters (259 feet) of La Luna sediments was measured northwest of Flor de Goajira. For this same area, Renz (1956) indicates a thickness of about 81 meters (266 feet). He gives a considerably thicker section, about 130 meters (437 feet) near Punta Espada, some 28–30 kilometers farther to the northeast.

Stratigraphic Relations.—The La Luna rests conformably upon the underlying Cogollo Group. It is overlain by the Guaralamai Formation. Although no structural discordance can be observed in the La Luna Guaralamai relationship, the presence of the thin conglomerate bed and its regional counterpart, the glauconitic sandstone, suggests some type of interruption in the sedimentation. The determination of the presence or absence of any significant unconformity at this boundary is precluded by incomplete or inconclusive paleontological data.

The conglomerate and its counterpart, the glauconitic sandstone, have been arbitrarily included in the La Luna but may be actually more closely related to the base of the overlying Guaralamai Formation.

Paleontology and Age.—No macrofossils were found in the La Luna beds, but the limestones contain a rich microfauna. The following forms were identified from samples taken northwest of the Flor de Goajira (identification by R. S. Jaroska):

Gümbelina sp.
Gümbelina striata Ehrenberg
Globigerina sp.
Globigerina cretacea d'Orbigny
Globotruncana fornicata Plummer
Globotruncana cf. *caniliculata* (Reuss)
Globotruncana lapparenti Brotzen
Globotruncana marginata (Reuss)

Based on the microfaunal assemblage, the La Luna ranges in age from Turonian to Santonian. According to Bürgl (1957), *Globigerina cretacea* and *Globotruncana marginata* are found in upper Turonian beds near Bogotá, Colombia. Renz (1956) suggests a Coniacian-Santonian age (in part) for the La Luna based on the presence of *Globotruncana fornicata*. The possible unconformity at the top of the La Luna may represent a portion of the Coniacian-Santonian interval.

Guaralamai Formation

General Discussion.—The term Guaralamai Formation has been given by Renz (1960) for a succession of thinly laminated limestones and calcareous shales which are exposed a few kilometers northwest of the Flor de Goajira. In his 1956 paper Renz referred to these exposures as the Colón Limestone, a term in common use in the Maracaibo Basin for the rather thin (generally 30 to 40 meters thick) shaley limestones found at the base of the Colón Formation. The type section of the Guaralamai Formation as defined by Renz is located 700 meters east of the Indian house called Guaralamai, which is approximately four kilometers northwest of the Flor de Goajira.

The Guaralamai Formation is of particular interest because it is believed to be a calcareous facies equivalent of the Colón Formation of the Maracaibo Basin. The typical Colón in the Basin is composed of massive, black foraminiferal shales usually with a thickness in excess of 400 meters. The facies-stratigraphic relationships are illustrated in the Cretaceous stratigraphic diagram (*see* Fig. 7).

Local Description and Character.—The Guaralamai Formation is represented by a considerable thickness of limestones and interbedded shales which are lithologically similar to the Colón Limestone facies in the northwestern part of the Maracaibo Basin. The Guaralamai is exposed in a small area some five to ten kilometers northwest of the Flor de Goajira, near the southeastern corner of the Goajira Peninsula (*see* Geologic Map). Renz (1956) also reports a partial section cropping out near the Punta Espada area.

Northwest of the "Flor," the Guaralamai is exposed in a north-dipping overturned fold between the La Luna Formation and beds of Eocene and Oligocene succession (*see* Strat. Sec. B-12). These younger beds overlap the Guaralamai with considerable angularity and therefore prevent observation of the upper portion of the Guaralamai sequence. Thus, it is impossible to determine if the true, deeper water Colón shales are present in the Goajira, or if the Formation is limited to only a limestone facies.

The limestones are shaley, silty, somewhat sandy, thinly bedded, platey, and brittle. They are finely crystalline, gray to dark brown, and weather brown to light buff. A few beds are fairly massive,

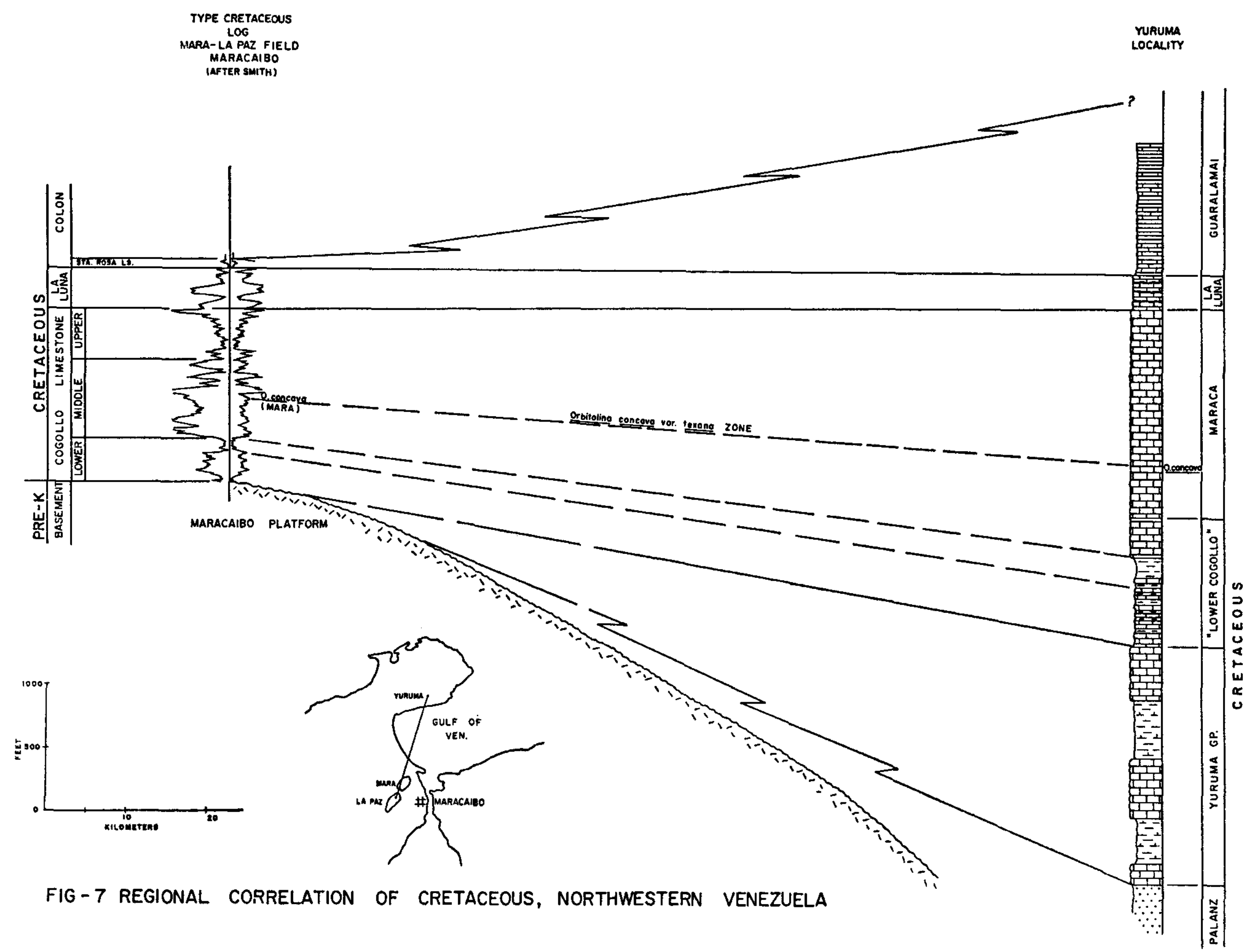


FIG-7 REGIONAL CORRELATION OF CRETACEOUS, NORTHWESTERN VENEZUELA dense, and black. Most of the limestones have a faint petroliferous odor when broken.

Thinly bedded, soft, brown to black calcareous shales are intercalated with the limestones. These shales weather to light buff. They are most common in the lower 200 meters of the Guaralamai and are estimated to constitute about forty percent of the unit.

The depositional environment of the Guaralamai is regarded as essentially shallow marine, and inclined toward the prevalence of argillaceous sediment. Sedimentation alternated, nevertheless, between a dominating calcareous condition (depositing argillaceous limestone) and clastic condition (depositing shale).

Thickness.—A thickness of 324 meters (1,063 feet) was measured for a partial section of the Guaralamai northwest of the Flor de Goajira. A short distance west of this exposure, the writer estimates that 500 meters (1,600 feet) may be present and the top is not evident. Renz (1956) reports approximately 490 meters (1,608 feet) for the Formation in this locality and 170 meters (558 feet) for a section measured in the Punta Espada area, also without reaching the top. There is no way of determining the total thickness of the Guaralamai Formation in this region from surface evidence.

Stratigraphic Relations.—As discussed previously, there may be an unconformity at the base of the Guaralamai. The time interval represented by the possible unconformity is unknown because of incomplete paleontological data. The Guaralamai is overlain with angular discordance by the Eocene Macarao Formation. In other places, the Guaralamai is overlapped with considerable angularity by the Oligocene Siamana Formation.

Paleontology and Age.—Several poorly preserved ammonite impressions and some pelecypod remains were collected from the Guaralamai. The following forms were collected from the platey limestones approximately 200 meters above the base of the Formation (identification by H. Bürgl):

Menabites sp.
Protexanites? sp.

Samples of the shales furnished the following microfauna (identification by R. S. Jaroska):

Nodosaria sp.
Gümbelina sp.
Globigerina sp.
Globigerina cretacea d'Orbigny

Based upon the ammonites, Bürgl (personal communication) indicates a Campanian age for the Guaralamai Formation.

Correlation.—The Guaralamai Formation correlates with the Colón Formation of the Maracaibo Basin.

TERTIARY SYSTEM

The beginning of the Tertiary Period marked a major change in the nature of the depositional trends on the Goajira Peninsula. These changes were brought about by strong, repeated orogenic movements on the Peninsula during the early Tertiary. Throughout this early Tertiary interval, most of the Goajira was positive except for the southeastern end where the shallow marine seas of the upper Eocene encroached upon a small portion of the land. Post-Eocene orogeny resulted in the formation of three mountain masses which have persisted until the present. These are the Serranías Cocinas, Jarara, and Macuire. Coincident with these uplifts, in the central part of the Goajira, a new depositional basin was formed which was totally unrelated to the depositional troughs of the earlier periods. The basin developed mainly between the uplifted Serranía Cocinas in the south and the mountain masses of the Serranía Jarara and Macuire to the north.

A thick marine Tertiary sequence is widely exposed in the interior as well as along the coast of the Goajira. Since the section lies within a different geologic province from the rocks of the Maracaibo Basin, lithologies and formational units differ considerably, thereby necessitating a different Tertiary nomenclature.

The following terminology, taken in part from Renz (1960), is proposed by the writer to designate the Tertiary units found on the Goajira Peninsula:

Pliocene?	Castilletes Formation
Miocene	Jimol Formation
Oligo-Miocene	Uitpa Formation
Oligocene	Siamana Formation
Eocene	Macarao Formation

In this report, the type localities are defined for the Macarao and Castilletes formations. Additionally the type sections of Renz' Siamana, Uitpa, and Jimol formations are described in detail. The ages of the Goajira Tertiary formations range from Eocene to the

Miocene, and probably include part of the Pliocene. Major unconformities separate the Eocene from the underlying Cretaceous beds and from the overlying Oligocene. A locally developed, somewhat minor unconformity occurs near the Oliogocene-Miocene boundary, and at the top of the succession a fourth unconformity exists.

Eocene Epoch—Macarao Formation

General Discussion.—Renz (1960) describes a sequence of sideritic limestones cropping out along the eastern plunge of the Serranía Cocinas which he called Guasare Formation of Paleocene age. The designation was based upon a supposed faunal and lithologic similarity with the Guasare Formation in the Maracaibo Basin. However, in the opinion of this writer the Guasare assumption is subject to considerable doubt both because of lithology and faunal characteristics.

The weight of the evidence strongly suggests that the exposures in the Goajira are not Guasare but represent a later sedimentation. For these reasons it was felt that a new name should be given to the rocks.

The name Macarao is proposed for the dark brown, platey sandstones, gray clays, and light colored limestones exposed a short distance to the north and northwest of the Indian trading post Flor de Goajira. The term Macarao is derived from the Indian name of the locality. The sediments of the Macarao are exposed in several small topographic depressions between the more resistant Cretaceous limestones and the overlapping Oligocene and Miocene beds (*see* Geologic Map).

Because of rather severe structural deformation and complications of overlap, the full stratigraphic relations cannot be ascertained; the type section is of limited value since neither the top nor the bottom of the Formation is exposed. However, analysis of the available data does give the age and some stratigraphic relations of the Formation.

The type section of the Macarao was measured approximately 1.5 kilometers northwest of the "Flor" where the Formation crops out between overlapping beds of the Oligocene limestones (*see* Strat. Sec. B-13). Here the Formation is little disturbed and possesses a fairly uniform dip towards the south.

Local Description and Character.—Glauconitic sandstones, selenitic clays, and massive limestones compose the Macarao Formation. The Formation is considerably deformed throughout most of its limited area of outcrop; dips are steep, and tight folding, faulting, and drag folding are characteristic.

At the base of the incomplete section are about 20 meters of tan to light gray, silty, slightly carbonaceous, selenitic clays. The clays are soft and weather rapidly. Overlying the clays are about 140 meters of sandstone and interbedded clays. The sandstones are fine grained, micaceous, thinly bedded, hard and platey. Glauconite is a common constituent and in fresh exposures the sands have a dark, brownish green color. However, the glauconite weathers rapidly, forming a very resistant limonite cement that gives the sandstone the characteristic brittle hardness and a dark brown color. The clays are interbedded with the sandstone, and are similar to the underlying clay sequence described previously. Above the sandstone and clay sequence are at least 90 meters of limestone. The limestones are mostly light buff to tan, dense, massive, and fossiliferous.

An important transition zone, about 10 to 20 meters thick, exists between the pure limestones and the platey sandstones. In this zone, the limes are very sandy, argillaceous, very limonitic, and of brown to dark brown color. They are very fossiliferous, containing *Ostrea* and *Venericardia.* Downward the sandy limes grade into sands and upward they pass into pure limestones.

The Macarao Formation was deposited under shallow marine embayment conditions. The limestones were probably deposited as off-shore shellbank reefs and the sands and clays were laid down in the back-reef lagoons. The limited extent of the Macarao on the Goajira Peninsula suggests the possibility that most of the Goajira was positive during Macarao time.

Thickness.—A true thickness for the Macarao Formation could not be obtained because of the previously mentioned stratigraphic and structural complications. A partial section of 253 meters (830 feet) was measured. This represents the maximum unfaulted exposure. However, if faulting in the area is assumed to be of small magnitude, about 400 to 600 meters of total section might reasonably be present.

Stratigraphic Relations.—The Macarao overlies the Guaralamai and all older formations with pronounced angularity. It is in turn overlapped with considerable angular discordance by either the Oligocene Siamana Formation or the Miocene-Pliocene Castilletes Formation.

Paleontology and Age.—The brownish, sandy limestone transition zone between the sandstones and limestones has been highly productive of macrofossils. Although the limestones are fairly hard, they weather quite rapidly, giving up their fauna.

The following pelecypods were collected from the sandy limestone transition zone of the Macarao (identification by G. Fraunfelter):

Turritella sp.
Ostrea n. sp.?
Venericardia (Venericor) n. sp.?
Venericardia sp.

The *Ostrea* n. sp.? is massive, up to 20 centimeters in length and 16 centimeters in width.

The *Venericardia (Venericor)* n. sp.? is very similar to the well-known *Venericardia (Venericor) planicosta* Lamark with only minor variations in the dentition. The exteriors of both species appear to be nearly identical. Both the *Ostrea* n. sp.? and the *Venericardia (Venericor)* n. sp.? are very abundant in the upper sandy limestones.

On the basis of stratigraphy alone, the Macarao can be shown to be definitely post-Guaralamai (Campanian) and pre-Siamana (Oligocene). Fraunfelter (personal communication) is of the opinion that the *Venericardia* is probably a new species and is of late Eocene (Jacksonian) age. This writer shares that opinion. However, Renz (1960) gives a Paleocene age (Guasare equivalent) for the sediments.

Numerous samples of the selenitic clays of the Macarao have so far proved to be barren of any diagnostic foraminifera; only a few undeterminable arenaceous forms have been present.

Correlation.—Correlation of the Macarao Formation with equivalents in the Macacaibo Basin is somewhat uncertain; but it may equate with the La Sierra Formation along the Perijá foothills.

Oligocene Epoch—Siamana Formation

General Discussion.—A major marine Tertiary transgression began in Oligocene time. In an extensive basin over the central and eastern parts of the Goajira Peninsula, reefal limestones, associated clay shales, and marly conglomerates were deposited.

For these light colored sediments, Renz (1960) proposed the name Siamana Formation. The type locality was designated as the Indian settlement of Siamana along the northern rim of the Serranía de Cocinas. Here the Siamana Formation overlaps Jurassic rocks, and an excellent stratigraphic sequence is exposed.

Local Description and Character.—Exposures of the Siamana Formation are found in two main areas: (1) along the northeastern edge of the Cocinas trough; and (2) along the flanks of the Serranía Jarara and Serranía Macuire. At the northwesternmost end of the Serranía Jarara, the Siamana disappears either by wedge-out or overlap, and the overlying Uitpa clays lie directly upon basement rocks. Overlap of a thin section is the more probable cause.

The Siamana is also exposed in a narrow pass between the Serranías Jarara and Macuire (*see* Geologic Map).

The Siamana Formation is composed of yellowish orange to buff, sandy limestones, reef limestones, marly limestones, marls and buff to light gray clay shales (*see* Strat. Sec. B-14, B-15). The limestones are generally fairly hard, resistant, and fine to coarse textured. They are commonly sandy and contain scattered pebbles. Some are pure and very dense. Most are fossiliferous; some are coquinoidal, with abundant *Pecten, Turritella,* and numerous other pelecypods and gastropods.

Gray to light buff, silty clay shales are interbedded with the limestones. The clay shales are selenitic in part.

The marls are soft, generally fossiliferous, sandy in part, and in the lower part of the Siamana they are quite conglomeratic. Locally, thin beds of calcareous or argillaceous sandstones are present. The sands range from fine- to coarse-grained and are buff to tan.

A basal conglomerate of irregular thickness represents the initial transgression of the Siamana seas. In the type area, a relatively thin, calcareous, sandy conglomerate is present. At Siamana, the basal conglomerate is very marly and thick. Along the southern flank of the Serranía Jarara, thick, conglomeratic outwash fans are evidence of former rivers draining from the highlands.

Over a large part of the Tertiary basin, Siamana coral-reef limestones are well developed. In places there are thick, massive buildups of reef material; elsewhere these reefs are much thinner or absent. On the line of traverse of the type section, corals are restricted to a single bed in the upper third of the Formation. The thick, massive reefs, which form perhaps 70 percent of the entire exposed Formation, crop out for several kilometers on either side of the line of section.

Reefal masses comprise a large part of the Siamana along the southern and western flanks of the Serranía Jarara. Along the southern rim of the Tertiary basin adjacent to the Cocinas structure, they are not so well developed. Here reefs are generally confined to the middle part of the Siamana and make up 20 to 30 percent of the Formation.

The corals grew as fringing reefs along the borders of the land masses. In places they are fairly continuous, but in other localities they are replaced by fan outwash or deltaic material, where an outpouring of clastic sediment from the land prevented the reef growth.

The Siamana Formation was deposited within a narrow basin, under shallow marine conditions. The clear, warm waters of this interval allowed coral reefs to grow and bottom dwelling mollusks to flourish. At least three land masses influenced, to differing degrees, the environment and resulting deposition. These positive areas supplied much of the clastic material found in the Siamana.

Thickness.—At the type locality of the Siamana Formation, the writer measured 302 meters (991 feet) of section and farther northeast, near Uitpa, 247 meters (810 feet) were measured. Renz (1960) gives 430 meters for the thickness at the type locality and states that considerable variation in thickness is present throughout the region.

Stratigraphic Relations.—The Siamana Formation is unconformable upon all older rocks. A sizable angular discordance is present where the Siamana overlaps the Eocene and Mesozoic sediments. The Formation is definitely unconformable with the overlying Uitpa sediments around the rim of the basin. However, in the central part of the basin the Siamana may be conformable with the overlying Uitpa.

Paleontology and Age.—The Siamana Formation contains an abundant macrofauna. It is characterized by the abundance of *Pecten* spp., corals, some *Turritella,* and a few echinoids. The following fossils were collected from the type locality and at the Uitpa locality (identification by H. Bürgl):

Pecten spp.
Ostrea sp.
Ostrea costaricensis Olsson
Pitaria sp.
Turritella sp.
Turritella chira? Olsson
Turritella olssoni? Clark
Coral
Balanus sp.

G. Fraunfelter identified *Pecten* cf. *macdonaldi* Olsson from the beds of the Siamana.

Microfaunal assemblages are represented principally by *Miogypsina* and *Amphistegina.* These larger Foraminifera indicate a shallow marine environment. At Uitpa, where the facies represent a slightly deeper water environment, the upper part of the Formation bears *Globigerina ciperoensis ciperoensis* Bolli.

Renz (1960) gives the following microforaminiferal assemblage from the type locality of the Siamana:

Miogypsina (Miogypsinoides) complanata Schlumberger
Miogypsina (Miogypsinoides) bermudezi Drooger
Miogypsina thalmanni Drooger
Amphistegina sp.
Operculinoides bullbrooki Vaughan and Cole
Operculinoides tamanensis Vaughan and Cole
Camerina sp.
Lepidocyclina canellei Lemoine and Douville

The faunal assemblage and, perhaps to a stronger degree, the stratigraphic position of the Siamana both indicate an Oligocene age.

Correlation.—The Siamana Formation is probably correlative in part with the Guacharaca Formation of eastern Falcón, Venezuela.

Oligo-Miocene Epoch—Uitpa Formation

General Discussion.—A mantle of soft, flat-lying clays and shales covers a large part of the interior of the Goajira. For these extensive deposits, Renz (1960) designated the term Uitpa Formation. This term comes from the Indian name for a spring located on the southeast plunge of Serranía Jarara.

The base of the Uitpa Formation is the contact between the soft marly clays and the more resistant limestones of the underlying Siamana Formation. The contact is also marked by a definite break in topography. The upper contact of the Uitpa is just below the massive calcareous sandstones of the overlying Jimol Formation. These resistant sandstones form a prominent ridge in contrast to the low-lying clays of the Uitpa.

Both contacts are readily traceable throughout the basin on the air photos.

Local Description and Character.—The Uitpa clays extend northwestward from the broad valley of Siamana almost to the northwest coast. Eastward, the outcrop band extends around the eastern end of the Serranía Jarara and thence northwestward through the narrow pass between the Serranías Jarara and Macuire.

The Uitpa Formation is composed principally of clay shale, shale, and minor beds of sandstone and sandy limestone (*see* Strat. Sec. B-14, B-15). The clay shales and shales are soft, silty in part,

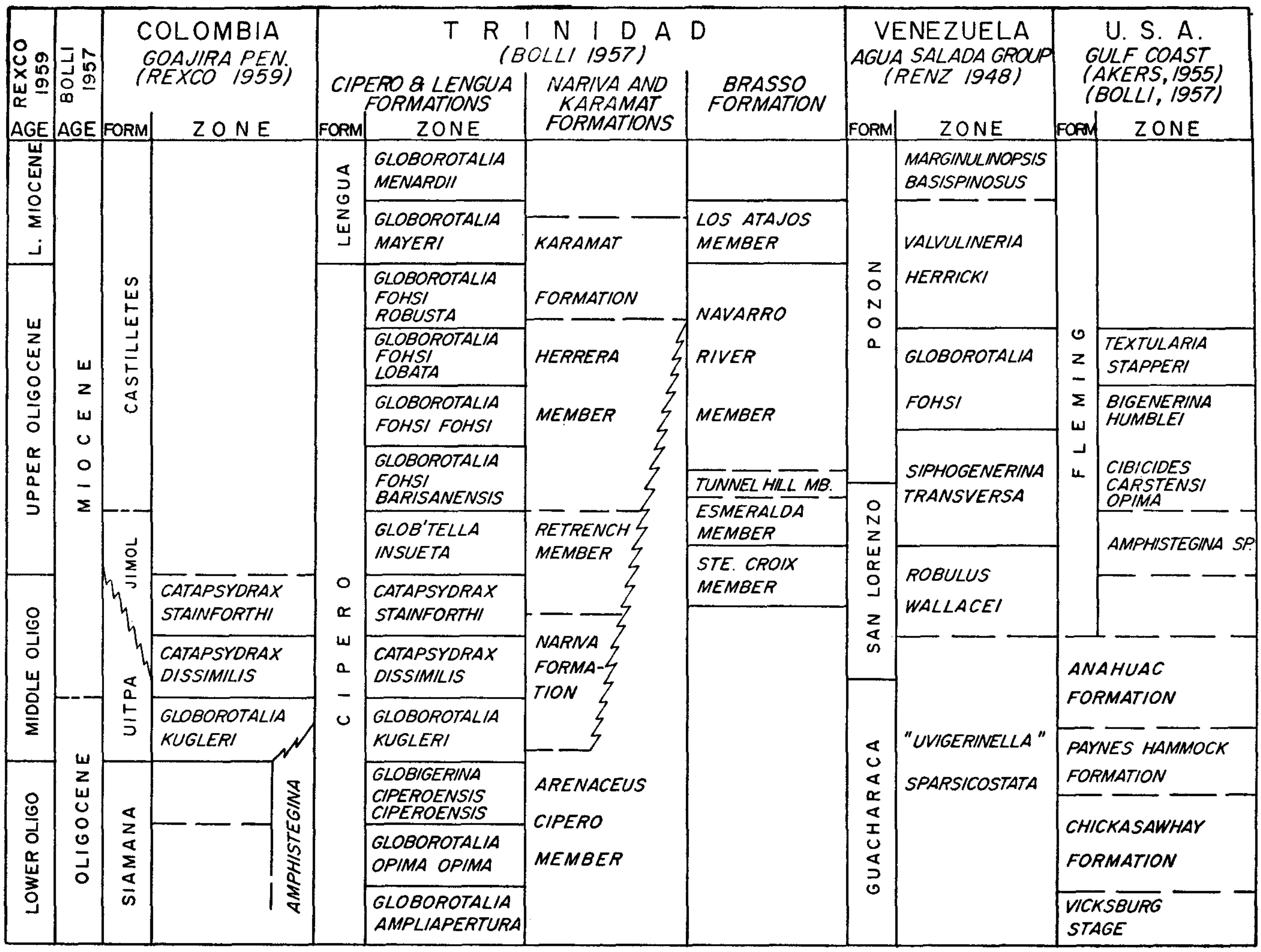


FIG. — 8 STRATIGRAPHIC CORRELATION OF THE SIAMANA, UITPA AND JIMOL FORMATIONS WITH VENEZUELA TRINIDAD AND THE U. S. A. GULF COAST and bear a few fine-grained sand lenses. The shales and clay shales range in color from tan to gray and chocolate brown, but weather to a rather uniform buff color. In many places alternating gray and chocolate brown colors result in a distinct banded appearance. The shales are usually selenitic.

A few thin beds of resistant, fine-grained, calcareous sandstone occur throughout the Formation but are more abundant in the lower part. The sandstones are generally fossiliferous, argillaceous, and range from tan to brown.

A few coarse-textured, porous limestones are also present. They are sandy or argillaceous and generally fossiliferous. Colors range from tan to orange buff and weather to dark brown. All are hard, resistant, and form low strike ridges.

East of the locality of the Siamana, sandy, coquinoidal limestone beds are quite numerous, and near the middle of the Formation, thick, biostromal limestones are well developed.

The depositional environment of the Uitpa was probably neritic to deeper marine. From limited sampling, Becker and Dusenbury (1958, p. 6) suggest a deposition of these sediments in waters of depth from 100 to 300 fathoms.

Thickness.—Near Uitpa, the writer measured a thickness of 342 meters (1,122 feet) for the Uitpa Formation. North of the settlement of Siamana a thickness of 201 meters (659 feet) was measured. In general, the Uitpa thickens to the east in the deeper parts of the basin and thins considerably to the northwest.

Stratigraphic Relations.—Along the edges of the Tertiary basin, the Uitpa lies unconformably upon the underlying Siamana Formation. In most places an angular discordance was observed and along the southern rim of the basin, between the settlements of Siamana and Porchina, several remnants of the Siamana, completely surrounded by the Uitpa clays, are exposed as knobs.

At the Uitpa locality, the lower contact of the Uitpa appears to be conformable with the underlying Siamana Formation. However, a short distance to the west along the southern flank of the Serranía Jarara, the contact is unconformable. In the central part of the basin, towards the east and southeast, the lower contact of the Uitpa is probably conformable with the Siamana.

The Uitpa grades conformably into the overlying Jimol Formation. Near the Laguna de Cocinetas, the Castilletes Formation overlaps the Jimol and lies with local unconformity upon the Uitpa deposits.

Paleontology and Age.—The macrofaunal content of the Uitpa Formation is less diagnostic than in the older formations, although a variety of fossils are present. The following macrofossils have been collected from the type locality (identification by H. Bürgl):

Pecten sp.
Flabelipecten fraterculus avaticus Combaluzier
Ostrea costaricensis Olsson
Ostrea alvarezii d'Orbigny
Turritella gatunensis Conrad
Scutelaster interlineatus (Stimpson)

Flabelipecten fraterculus avaticus Combaluzier is quite abundant throughout the Formation, especially in the sandy beds. Macrofossils are quite rare in the clay shales or shales with the exception of a few small gastropods.

The Uitpa clays and shales contain a rich microfaunal assemblage which has been studied in considerable detail by A. B. Whitman of the Richmond Exploration Company. Becker and Dusenbury (1958) published a detailed study of the microfauna obtained from a few random samples of the Uitpa Formation.

Whitman (personal communication) indicates three regionally recognized planktonic zones in the Uitpa Formation. These are:

Catapsydrax stainforthi (Bolli, Loeblich, and Tappan)
Catapsydrax dissimilis (Cushman and Bermudez)
Globorotalia kugleri (Bolli)

The correlative positions and ages of these zones are shown on the Stratigraphic Correlation Chart (Fig. 8) and the Goajira Correlation Section (Fig. 9).

The age of the Uitpa Formation is considered to be Aquitanian, based on the microfauna. The position of the Aquitanian is somewhat controversial. Some writers include it within the uppermost Oligocene while others place it within the lowermost Miocene. Becker and Dusenbury (1958, p. 6) consider it as Oligo-Miocene. On the basis of studies by Whitman (private company report), the writer considers the age of the Uitpa as extending from the Oligo-Miocene into the lower Miocene.

Correlation.—The Uitpa Formation probably correlates with the upper part of the Guacharaca and lower part of the San Lorenzo formations of eastern Falcón, Venezuela.

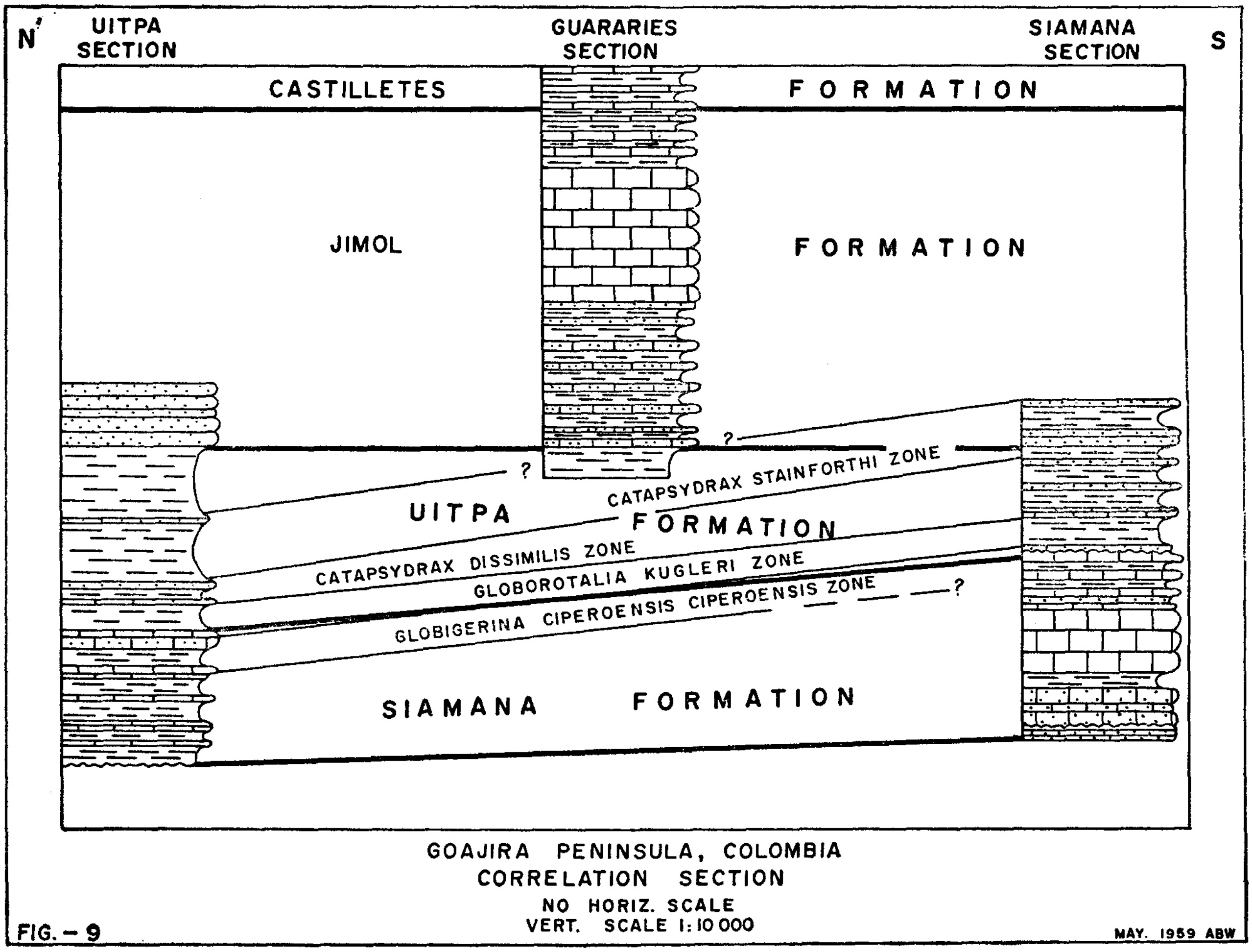


FIG. — 9

(This has been reduced 25% from the original art work.)

Miocene Epoch—Jimol Formation

General Discussion.—The term Jimol Formation was designated by Renz (1960) for a sequence of massive, brown, sandy limestones which are exposed in the central part of the Cocinetas embayment. Unfortunately the descriptions of the boundaries of the type section as given by Renz are not clear. Furthermore, his mapping in places appears to include sediments of the Siamana Formation. If the Renz interpretation of the position of the Jimol Formation is to be accepted, then the Jimol occupies a complex stratigraphic relationship—that of an overlapping depositional unit. This writer believes that by detailed mapping and analysis of the data a much simpler and more logical solution to the problem can be shown.

There is considerable doubt on the part of the present writer that the reference section given by Renz in the vicinity of Cerro Jimol actually includes rocks correlative with the Jimol in the central portion of the basin. The rocks near Cerro Jimol are believed to be Siamana Formation by this writer. Likewise the sediments of the Renz reference section at Quebrada Aischi are believed to be Siamana, and not Jimol. The overlying sediments in this area, which Renz shows as "Miocene Undifferentiated," are in actuality Uitpa clay shales in their normal position directly overlying rocks of the Siamana Formation.

On the southwest side of the narrow pass between Serranías Jarara and Macuire, Renz shows Siamana resting on basement and overlain by Uitpa. Yet on the northeast side of the pass, a few kilometers away, he shows Jimol sediments resting on basement and overlain by "Miocene Undifferentiated." Here again this writer believes that field mapping will support a much simpler relationship.

The lower contact of the Jimol Formation in the vicinity of Uitpa can be traced northward on the ground to the entrance of the pass, still resting upon Uitpa clay shales (*see* Geologic Map). It cannot be traced up into the pass itself. Thus the "Jimol" of Renz, which he shows resting upon basement on the northeast side of the pass, is actually Siamana and his "Miocene Undifferentiated" is actually Uitpa Formation. Paleontologic evidence from the Siamana and Uitpa formations in the pass area also supports this statement.

In an attempt to clarify the true stratigraphic position of the Jimol Formation, the writer has, in this report, redefined the stratigraphic boundaries of the Jimol Formation as follows:

The base of the Jimol Formation is at the base of the massive sandy limestone that makes a prominent ridge above the softer

Uitpa clays. This limestone grades laterally into a calcareous sandstone east of the settlement of Uitpa. Everywhere the beds are massive and the resistant scarp is easily recognizable.

The top of the Jimol Formation is between a soft sandy clay and an overlying argillaceous, *Ostrea*-bearing, limestone which forms the base of the Castilletes Formation. With a limited amount of ground control, both the upper and lower contacts are easily traceable on the air photos.

Local Description and Character.—Outcrops of the Jimol Formation extend from the middle part of the Siamana valley eastward towards the coastal plain, where the Formation dips below the Castilletes Formation (*see* Geologic Map).

The Jimol Formation is composed principally of sandy limestones, calcareous sandstones, and subordinate amounts of clay (*see* Strat. Sec. B-16). Scattered small, white quartz pebbles are found in most beds, and these help to distinguish the Formation from other Tertiary units. Two characteristics serving to distinguish the Formation are these white pebbles, and the presence of massive, resistant sandstones and sandy limestones which support a broad, dished plateau-like feature in the center of the basin.

The limestones are mostly massive, resistant, very sandy, and fossiliferous. They are orange to buff in color but weather dark brown. Generally they are coarse textured and dense.

Along the southern escarpment of the central plateau, there is a sequence of about ten meters of very dense, pure, algal, and reefal limestone containing coral heads and shell debris. This reef zone is limited to the southern side of the basin and extends towards the Laguna de Cocinetas.

Sandy limestones grade laterally into calcareous sandstones throughout the Formation. The sands are medium- to very coarse-grained, generally fairly well sorted, and contain scattered, white quartz pebbles. The sandstones range in color from buff to gray, and mostly weather brownish gray to brown. Calcareous cement makes the beds hard and resistant.

The more massive sandstones, especially those near the base of the Formation, weather with a characteristic spheroidal or discoidal shape, much like the "cannon ball" weathering except on a larger scale. The spheroids and discoids are commonly one to two meters in diameter.

Clays are soft, silty, commonly sandy, and range in color from tan to light gray to buff. The clays occur interbedded with the limestones and are more prominent in the lower part of the Formation.

The Jimol deposits were laid down in a shallow marine environment. Marine beach conditions prevailed during most of the interval.

Thickness.—At the reference locality the writer measured 614 meters (2,014 feet) of Jimol. The section thins rapidly to the west as the old shoreline is approached.

Stratigraphic Relations.—The Jimol is believed to be conformable with the underlying Uitpa Formation and is conformably overlain by the Castilletes.

Paleontology and Age.—The Jimol Formation contains a variety of pelecypods and gastropods. The following macrofossils were collected from the type locality (identification by H. Bürgl):

Clementia dariena Conrad
Cardium gatunense Toula
Arca chiriquiensis bolivari Weisbord
Arca grandis colombiensis Weisbord
Turritella aff. *supraconcava* Hanna and Israesky
Turritella sp.
Cardium sp.
Ostrea sp.
Pecten sp.

A middle Miocene age is suggested for the Jimol Formation based upon the macrofaunal assemblage and the stratigraphic position.

Correlation.—The Jimol is thought to correlate with part of the San Lorenzo Formation of the Agua Salada basin of Eastern Falcón, Venezuela.

Miocene-Pliocene? Epoch—Castilletes Formation

General Discussion.—In the last phases of the Tertiary regression, a thick sequence of *Ostrea*-bearing limestones and selenitic clays were deposited in the eastern portion of the Tertiary basin. For these sediments Renz (1960) proposed the name Tucacas Formation after Bahía de Tucacas (also known as Bahía de Tortugas). However, it is felt that the name Tucacas may lead to some confusion in Venezuelan-Colombian stratigraphic terminology since it may be confused with an eastern Falcón locality. The town of Tucacas in eastern Falcón, Venezuela, is old and widely known, and it is surrounded by late Tertiary marine deposits.

For this reason the writer proposes that the term Castilletes Formation be substituted for the name Tucacas. Castilletes is a well-known Venezuelan geographical name for a small settlement on the Goajira coastline on the Colombian-Venezuelan border (*see* Geologic Map).

The type locality remains unchanged and is eight or nine kilometers north of Castilletes near the Bahía de Tucacas. In this locality the Formation is exposed in an almost undisturbed condition. The top of the Castilletes Formation was not observed because the highest beds dip beneath the sea. Thus, the upper contact of the Formation cannot be defined.

The base of the Castilletes is the base of the lowest *Ostrea* limestone which forms a prominent escarpment immediately above the softer clays at the top of the Jimol Formation. The basal contact of the Castilletes is readily traceable on the air photos or on the ground.

Local Description and Character.—Sediments of the Castelletes Formation occupy most of the coastal area from the Laguna de Cocinetas at Castilletes to Quebrada Mauriru, several kilometers southwest of Punta Médanos (*see* Geologic Map).

Southwest of Castilletes, along the low coastal lands towards Cojoro, the Castilletes Formation is exposed in nearly horizontal beds covering all the older Tertiary. The Castilletes in the vicinity of Cojoro is covered by alluviam, except for a small outcrop which is exposed in Quebrada Patamana just west of the settlement.

The Castilletes Formation is undoubtedly present on the northern and northeastern coast of the Goajira Peninsula as shown on the Geologic Map. However, it has not been examined in the field by the writer and therefore is indicated as questionable Castilletes.

The Castilletes Formation is characterized by soft, buff to tan colored marly limestones and clays. There is a two-fold lithologic subdivision of the Formation in the type locality, namely: (1) a lower, predominantly limestone division and (2) an upper, predominantly clay division. However, since the division appears to be rather local, both units have been included as one formation (*see* Strat. Sec. B-17).

The limestones are coarse textured, marly, argillaceous, sandy, fossiliferous, and fairly hard. They are buff colored but weather to gray. Although the limestones are generally of only medium hardness, they are resistant to weathering, and all form the caprock of long strike ridges. A few beds of coarse-grained, calcareous sandstone were found. These are very hard and resistant because of the carbonate cement.

The clays are silty, with some sandy zones, and have colors ranging from brown to buff, gray, and greenish gray. Some reddish mottling, which may be secondary, was observed.

The Castilletes Formation was deposited in a very shallow marine environment probably much like the shallow water conditions that exist today just off shore from the Goajira Peninsula.

Thickness.—At the type locality of the Castilletes Formation, a thickness of 692 meters (2,270 feet) was measured. Renz (1960) gives 850 to 900 meters for the thickness at the type locality. South of the Flor de Goajira locale and westward, the Formation is considerably thinner, possibly not more than 100 meters thick.

Stratigraphic Relations.—The Castilletes rests conformably upon the underlying Jimol Formation. The top of the Castilletes is not exposed but is probably unconformable with the Pleistocene and Recent sediments. This is a regional relationship in all of western Venezuela.

Paleontology and Age.—The best "index" fossils for differentiation of the Castilletes from other Tertiary formations are the very abundant *Ostrea*. None of the macrofossils collected are diagnostic for age determination. The following macrofauna were collected from the Castilletes type locality (identification by H. Bürgl):

Ostrea pulchana d'Orbigny
Ostrea sp.
Chlamys (Aequipecten) plurinominis morantensis Woodring
Pecten bowdenensis Dall
Chione sp.
Cardium sp.

The microfauna consists of arenaceous forms and appears to be nondiagnostic of age.

The age of the Castilletes is considered to be Miocene and probably Pliocene, based upon its stratigraphic position.

Correlation.—The Castilletes is believed to correlate with the Pozón Formation of eastern Falcón, Venezuela.

Pleistocene (Including Recent)—(Undifferentiated)

General Discussion.—A thin mantle of sand, gravel, and minor clay covers wide areas of the Goajira. Part of these deposits resulted from a short-lived marine transgression which covered much of the lowland. Alluvial valley fill, outwash fans, and dune sands constitute continental deposition. No attempt has been made to differentiate any of these deposits; all are mapped simply as Quarternary alluvium.

Résumé of the Biostratigraphy

A number of useful faunal zones have been recognized in the Mesozoic and Tertiary sediments of the Goajira Peninsula. Some of these zones are important only locally for use in solving the stratigraphic and structural problems inherent in the Goajira. However, others, especially the ammonite zones of the Cretaceous, and the foraminiferal zones of the Tertiary, are of regional significance and are important in solving long range stratigraphic correlations. The faunal zones are summarized, for simplicity, in this section on stratigraphy.

JURASSIC

Crassatella Zone.—The oldest significant faunal zone in the Goajira is the *Crassatella* zone of possible medial Jurassic age. It occurs approximately 550 meters above the base of Caju Formation and is characterized by abundant *Crassatella* and *Astarte*. The zone is approximately ten to twenty meters thick and persists throughout the outcrop of the Caju.

In the Cuisa Formation of Late Jurassic age, two rather thick faunal zones were observed in the Jipi locale.

Perisphinctes Zone.—This lower zone, situated approximately 500 to 600 meters up from the base of the Cuisa carries *Perisphinctes* and *Idoceras* species.

Virgatites Zone.—An upper zone, coinciding with the reef development near the top of the Cuisa, it is characterized by the occurrence of *Virgatites, Idoceras,* and *Parasenia* species.

CRETACEOUS

Trigonia Zone.—The lowermost faunal zone of the Cretaceous period is in the Kesima member of the Palanz Formation. This is the Trigonia zone and is characterized chiefly by Trigonia, a terebratuloid brachiopod, and coral. Renz (1956) called this zone, along the northern edge of the Cocinas trough, the *Trigonia* aff. *lorenti* Dana horizon of the Río Negro. However, it appears that the fossil is probably a new species. The age of the zone is Berriasian, based upon the ammonite *Argentiniceras.*

Within the Yúruma Group several excellent faunal zones have been determined.

Period	Age	Group	Formation	Fossil Zones
TERTIARY	MIO. - PLIO ?		CASTILLETES	*Ostrea pulchana*
TERTIARY	MIOCENE		JIMOL	
TERTIARY	(AQUITANIAN)		UITPA	*Catapsydrax stainforthi* *Catapsydrax dissimilis* *Globorotalia kugleri*
			LOC. UNCONF.	
TERTIARY	OLIGOCENE		SIAMANA	*Globigerina ciperoensis ciperoensis*
			UNCONF.	
TERTIARY	EOCENE ?		MACARAO	*Venericardia (Venericor)* n. sp. ?
			UNCONF.	
CRETACEOUS	CAMPANIAN | TURONIAN		GUARALAMAI	
			UNCONF. ?	
CRETACEOUS			LA LUNA	*Globigerina*; *Globotruncana*
CRETACEOUS	CENOMANIAN	COGOLLO GP.	MARACA	*Exogyra* n. sp. ? *Ostrea scyphax*
CRETACEOUS	U. APT. – ALBIAN	COGOLLO GP.	MARACA	*Orbitolina concava* var. *texana*
CRETACEOUS	U. APTIAN	COGOLLO GP.	"LOWER COGOLLO"	*Parahoplites*; *Acanthohoplites*
CRETACEOUS	L. APTIAN	COGOLLO GP.	"LOWER COGOLLO"	*Cheloniceras*; *Ancyloceras ?* *Uhligella*; *Protocardia*; *Lucina* *Deshayesites*
CRETACEOUS	U. BARREMIAN	YURUMA GROUP	"UPPER YURUMA"	*Pedioceras*; *Exogyra*; *Ostrea*
CRETACEOUS	M. BARREMIAN	YURUMA GROUP	"UPPER YURUMA"	*Heinzia* *Pulchellia*
CRETACEOUS	L. BARREMIAN	YURUMA GROUP	"UPPER YURUMA"	*Nicklesia*; *Exogyra boussingaulti* *Trigonia (Notoscabrotrigonia) tocaimaana*
CRETACEOUS	HAUTERIVIAN VALANGINIAN	YURUMA GROUP	MOINA	*Simberskites*; *Choffatella* *Clementia*; *Pseudoglauconia* *Olcostephanus*; *Exogyra couloni*
CRETACEOUS	BERRIASIAN		PALANZ	*Trigonia* n. sp.; Terebratuloid brach. *Argentiniceras* Coral
			LOC. UNCONF.	
JURASSIC	KIMM. — PORT.		CUISA SHALE	*Idoceras*; *Parasenia*; *Virgatites* *Perisphinctes*; *Idoceras*
JURASSIC			CHINAPA	
JURASSIC			CAJU	*Crassatella*; *Astarte*
JURASSIC			CHETERLO	
			UNCONF.	
TRIAS			UIPANA	
			UNCONF.	
TRIAS			"RANCHO GRANDE"	

FIG.- 10 CHART OF PRINCIPAL BIOSTRATIGRAPHIC ZONES
GOAJIRA PENINSULA

Exogyra couloni Zone.—In the basal 50 meters of the Moina Formation (Valanginian), *Exogyra couloni* DeFrance is abundant. Although *E. couloni* has a much greater stratigraphic range in other regions, it appears to be narrowly confined on the Goajira Peninsula.

Clementia Zone.—Higher up (Hauterivian), in the middle marl of the Moina, the *Clementia* zone is prominent along with the Foraminifera *Choffatella sogamosae* Karsten.

Nicklesia Zone.—Just above the base of the "Upper Yúruma," in a sequence of marls and limestones, is a zone of Nicklesia together with *Trigonia (Notoscabrotrigonia) tocaimaana* Lea and *Exogyra boussingaulti* d'Orbigny. *Nicklesia* is a well-known marker for the lower Barremian in many regions.

Pulchellia Zone.—About 50 meters higher is a zone of abundant *Pulchellia.*

Heinzia Zone.—Still another 50 meters higher a zone occurs with abundant species of *Heinzia.* Both *Puchellia* and *Heinzia* are middle Barremian in age.

Ostrea Zone.—The top of the Yúruma Group (Upper Barremian) is marked by a very prominent limestone containing *Ostrea, Exogyra,* and *Pedioceras.*

The Cogollo Group has several important zones of regional significance.

Deshaysites Zone.—Just below the middle shale of the "Lower Cogollo" a zone of *Deshaysites* (thickness 50 meters) occurs in thinly bedded, platey limestones.

Lucina Zone.—Above this, encompassing all of the middle shale and extending up into the overlying silty limestones, is a zone containing the abundant *Lucina* and *Protocardia.* The *Protocardia* and *Lucina* are quite useful for solving local field relationships in the Goajira. Here also are found the *Cheloniceras, Uhligella,* and *Ancyloceras?* ammonites. Both of the aforementioned zones are of lower Aptian age.

Parahoplites Zone.—In a sequence of silty limestones extending from 50 meters to 90 meters below the top of the "Lower Cogollo," there is a zone of *Parahoplites* and *Acanthohoplites* ammonites (upper Aptian).

In the Maraca Formation two important regional zones are present.

Orbitolina concava Zone.—Approximately 125 meters up from the base of the Formation (upper Aptian-lower Albian) there is a thin zone of abundant *Orbitolina* occurring in two meters of dense, tan limestone. This is a well known zone in the Cogollo Group of the Maracaibo Basin.

Ostrea scyphax Zone.—At the top of the Maraca (Cenomanian), in a massive limestone, there is a zone containing *Ostrea scyphax* and *Exogyra* n. sp.? This zone is also a regional marker in the Maracaibo Basin.

Globigerina Zone.—The La Luna Formation (Turonian) is well known for its abundant *Globigerina* fauna in the Maracaibo Basin and there they have been intensively studied and zoned. However, in this report, the La Luna has not been zoned and is recognized as a complete unit, namely the *Globigerina* zone.

The zones discussed above represent the most important faunal zones of the Mesozoic sedimentary succession on the Goajira Peninsula.

TERTIARY

Venericardia (Venericor) Zone.—The Macarao Formation (late Eocene) contains a single zone characterized by the occurrence of *Venericardia (Venericor)* n. sp.? and *Ostrea* n. sp.? The actual stratigraphic position of the zone is not completely understood because neither the top nor the bottom of the Formation has been observed. However, it is of considerable importance from a regional viewpoint with regard to age determination.

The Siamana Formation (Oligocene) is characterized by a number of distinctive macrofossil forms but it is without any discernable zones. Lithofacies changes control the vertical and horizontal dispersion of the forms within the Formation.

Miogypsina complanta Zone.—Microfaunally, Drooger (1952) indicates a zone of *Miogypsina complanta* within the upper beds of the Siamana.

Globigerina ciperoensis ciperoensis Zone.—In the Uitpa locality the *Globigerina ciperoensis ciperoensis* zone occurs near the top of the Siamana. It is of regional significance.

Three regionally recognized microfaunal zones are present in the overlying Uitpa Formation of Oligocene-Miocene age. These are from top to bottom:

Catapsydrax stainforthi Zone
Catapsydrax dissimilies Zone
Globorotalia kugleri Zone

Post-Uitpa sediments do not appear to contain any sharply defined faunal zones of importance.

Structural Geology

REGIONAL TECTONIC FRAMEWORK

The structural geology of the Goajira Peninsula comprises a number of highly complex features. Regionally, the Goajira tectonic block now appears to be unrelated to adjoining structural systems to the south in western Venezuela and eastern Colombia (*see* Fig. 11). However, in contrast to the present day dissimilarities between the Goajira structures and those to the south, there is evidence of several Mesozoic trends which regionally relate the older structural features between these areas. These trends, reaching into the Goajira, are continuous with the major Mesozoic structural elements of western Venezuela and eastern Colombia (*see* Fig. 12). They indicate existence of structural unity at one time.

At the present time, the Goajira displays a dominant east-west and northwest trend parallel to the prominent Oca fault which is located approximately 60 kilometers to the south. Most of the structural trends of the Goajira are in marked contrast to the major tectonic trends south and southeast of the Oca fault zone.

The predominant structural trend in eastern Colombia and western Venezuela is north-northeast. The Sierra de Perijá, a dominant feature on the west side of the Maracaibo Basin, is a northward continuation of the Cordillera Oriental of Colombia. The trend is terminated by the east-west Oca fault which cuts across the entire system.

The relationship between the Goajira and the Sierra de Perijá to the south is not clearly known. The two areas are today separated by the Oca fault along which the Goajira block has moved relatively eastward. Furthermore, the lack of exposures on the broad area of the featureless Goajira plains north of the Oca fault effectively guards, in the subsurface, the secrets of the structural ties between the two regions.

GOAJIRA STRUCTURAL FRAMEWORK

General Considerations.—The basement framework over a large part of the Goajira is characterized by the presence of metamorphic and igneous rocks either at the surface or at a relatively shallow

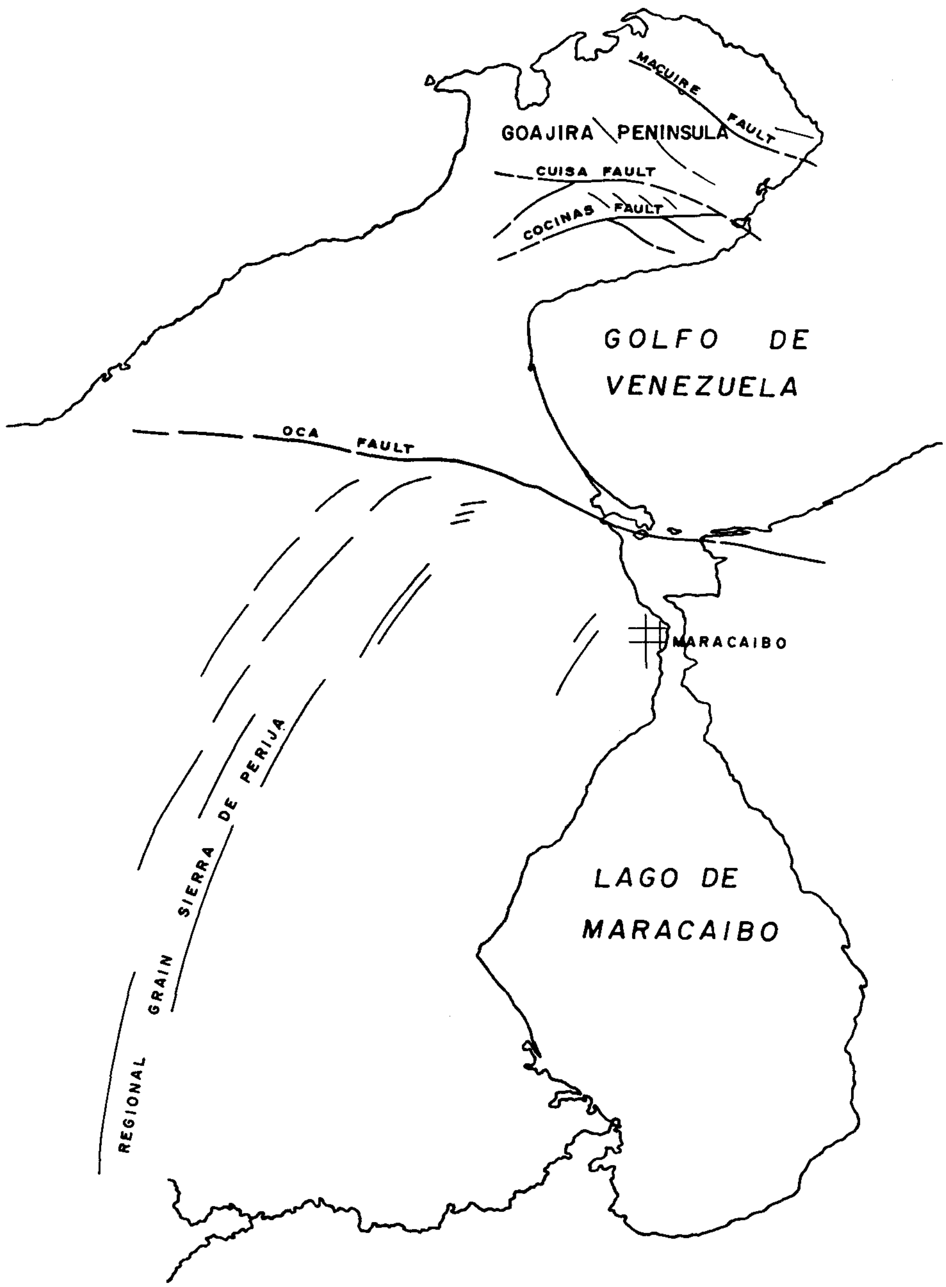


FIG.-11 REGIONAL TECTONIC FRAMEWORK WESTERN VENEZUELA

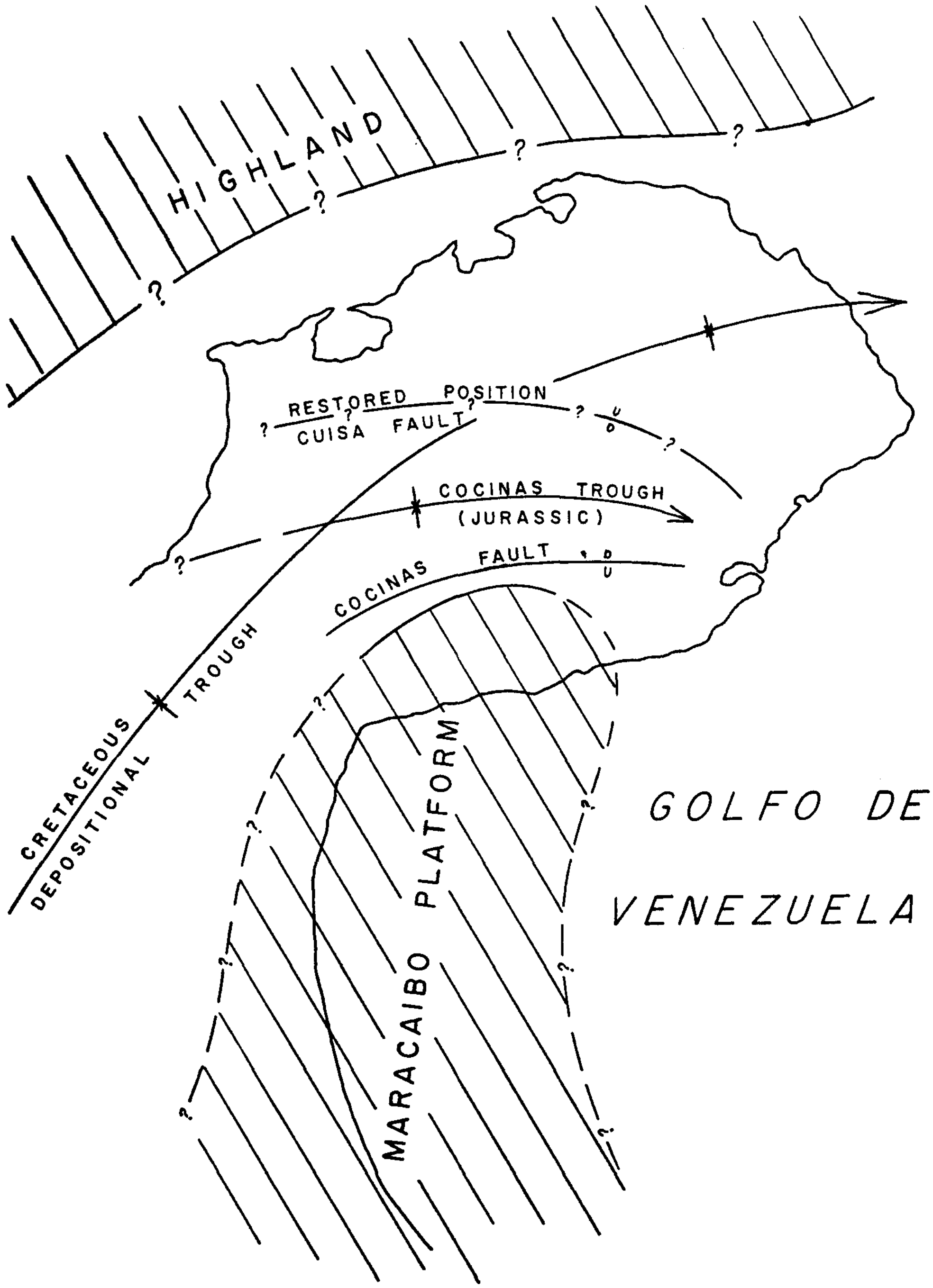


FIG.—12 MESOZOIC TECTONIC FRAMEWORK OF GOAJIRA depth. The metamorphic rocks, in their broad pattern, have a prominent northeasterly grain, although in the northernmost part of the Peninsula this tends to swing toward the southeast. An extensive granitic batholith is associated with the metamorphics in the north (Macuire uplift), and a smaller pluton occurs at the northwestern end of the Jarara uplift. Neither the older metamorphic grain nor the presence of the intrusives appears in any way to influence later structural development of the Goajira. The present day structure is superimposed at a distinctly different angle upon the older basement grain.

The most dominant feature of the Goajira Peninsula is the presence of the deep, narrow, structural, and depositional Cocinas trough trending generally east-west across the southern part of the region. This trough profoundly influenced sedimentation and later structural development within and adjacent to its trend. It is along this trough that the structural makeup of the region can be best analyzed.

From the field evidence it becomes clear that the structural pattern results from a dominant influence of compressional stresses, and although the pattern is complex, the relationships are logical and stem from an orderly sequence of geological phenomena and events. As will be described, the Goajira is composed of five, well-defined structural elements (*see* Fig. 13). These are (1) the stable platform area, lying to the south; (2) the Cocinas trough, lying northward and adjacent to the platform area; (3) the Serranía Jarara uplift, lying in the interior; (4) the Serranía Macuire uplift, located in the northwestern Goajira; and (5) the Tertiary basin structures, extending across the central part of the Goajira.

Each of these elements is an asymmetrical structural feature with the steeper side towards the south or southwest. The structural elements are closely related to one another in the pattern, although there is a divergence of trend between them. Three dominant fault trends are present within each structural element. The older set of longitudinal faults is cut by two sets of later-formed oblique faults, most of them having strike-slip character. The fault pattern and much of the deformation of the sediments strongly suggests that the deforming forces were compressional.

STABLE PLATFORM AREA

The stable platform area is defined as the region lying between the Cocinas fault system and the Gulf of Venezuela coastline. Its

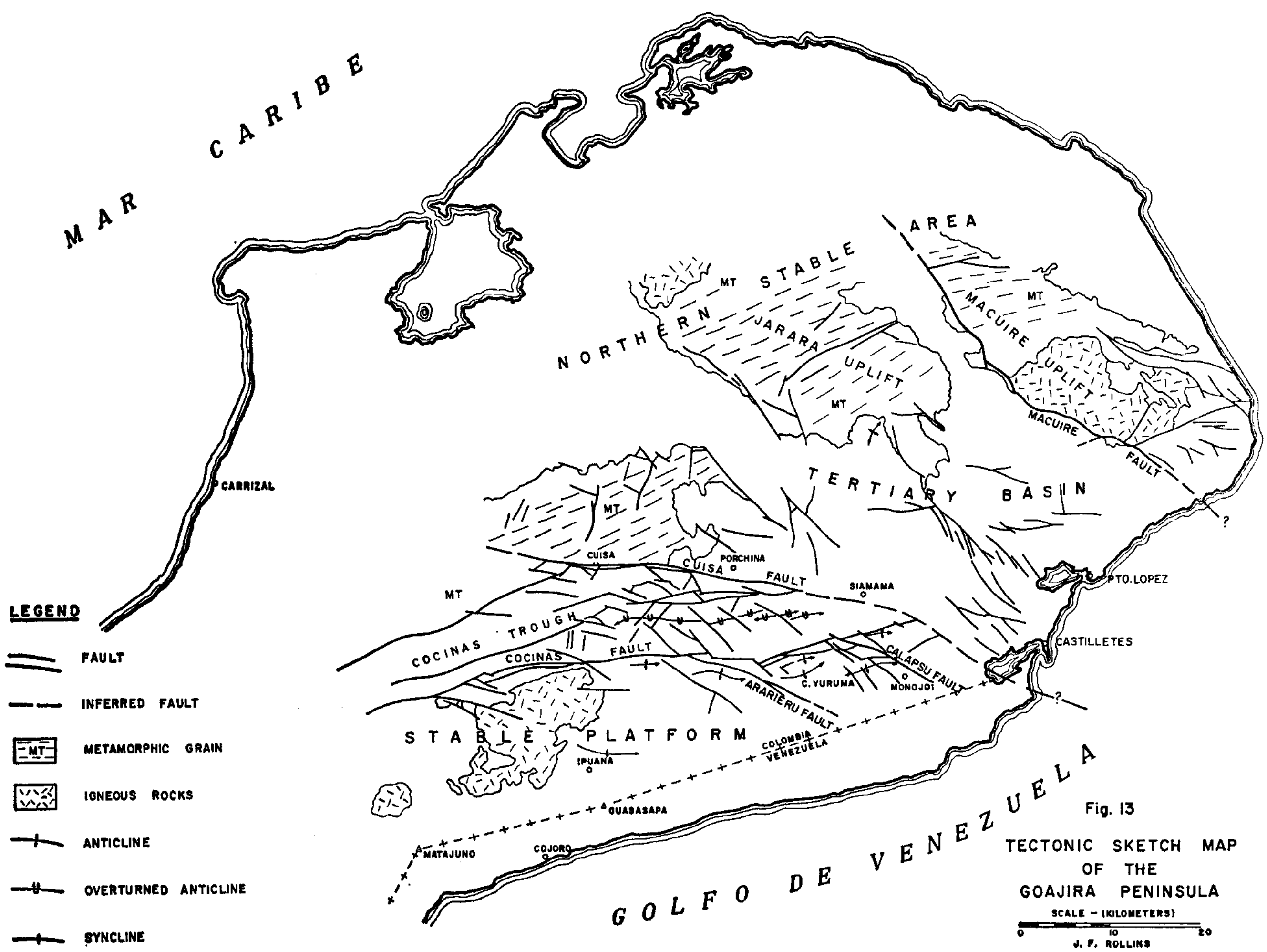


Fig. 13

TECTONIC SKETCH MAP
OF THE
GOAJIRA PENINSULA

eastern end is terminated by the hinge line of the Tertiary basin edge just east of the Indian trading post of Flor de Goajira. The western end is somewhat indefinite, but the Cerro la Teta locality, just off the west edge of the Geologic Map, is definitely within the platform.

The stable platform area is characterized by a relatively thin sequence of sediments which dip gently southward. Most of the formations known elsewhere on the Goajira are present but are typically thinner on the platform. The relatively thin sediments and moderate south dip contrast sharply to the great thickness and strong, north dip of the beds in the Cocinas trough north of the Cocinas fault system.

A granitic mass that underlies the Cretaceous (and Triassic) is considered to be the stabilizing element of the platform. The basement is well exposed towards the west end of the region in the vicinity of Cerro Cocinas and Quebrada Patamana. From the outcrop area, the basement is thought to plunge gently eastward beneath the cover of Cretaceous deposits. This is suggested by the gentle east plunge of the syncline developed in the Palanz Formation.

Faulting.—The sediments lying on the platform are cut by three types of faults: (1) east-trending longitudinal faults which are probably high angle thrust faults, downthrown on the south; (2) east- and southeast-trending longitudinal strike-slip faults; (3) southeast-trending obligue faults, most of which appear to be right-lateral movements. The intensity of faulting increases in an eastward direction along the platform area, and is matched by the increasing intensity of deformation in the Cocinas trough.

(1) *Longitudinal Thrust Faults.*—Only two major longitudinal thrust faults are found on the stable platform (*see* Geologic Map). The first is a high angle thrust fault, dipping northward from 40 to 60 degrees, which passes along the southern flank of Cerro Julanal. This thrust actually represents a branch fault of the main Cocinas system which passes along the north side of Cerro Julanal.

The hard sandstones of the Palanz Formation probably were deposited at a relatively steep angle across the hinge line between the Cocinas trough and the stable platform. The hinge movement formed an initial, sharp monoclinal fold. Later, during periods of orogeny, the compressional stresses finally ruptured the rock, and the sandstones were thrust southward over the Moina limestones and the granitic knob. This fault represents the only sizeable known thrust in the Goajira.

The second major high angle thrust fault of the stable platform trends in an east or east-northeast direction, south of the locality of Trijajain. This major trend can be traced westward for about nine kilometers where it separates the Palanz sandstones from limestones of the Yúruma Group. The fault apparently dies out in sediments of the Palanz Formation. Although the actual fault plane was never observed, the nature of the drag folding adjacent to the fault suggests that the feature is probably a high-angle northward dipping thrust. Other longitudinal faults are quite small, but also appear to be thrusts.

(2) *Longitudinal Strike-slip Faults.*—Two major strike-slip fault zones also align with the eastward longitudinal structural trend. These two zones, named by Renz (1960), are the Ararieru and the Calapsu fault zones. Each consists of multiple faults and associated features.

The Ararieru fault zone originates in the Cocinas longitudinal system just north of the settlement of Aruanapas. It trends obliquely across the strike of the bedding in a southeastward direction to the vicinity of Ranchería (*see* Geologic Map, also Tectonic Sketch Map). It has a known length of approximately 14 kilometers, and probably continues for some distance beneath the alluvial cover. Towards the southeast, the main fault divides into two subsidiary faults. Adjacent to the main fault are numerous smaller faults and joints which contribute to a general disorientation of bedding. The entire zone is extensively shattered.

The Calapsu fault zone trends from the Cocinas system southwestward, and passes underneath the Castilletes Formation southeast of Monojoi. It has a known length of about 11 kilometers, and consists of several similarly-trending strike-slip faults. Total deformation is less severe along this zone than in the Ararieru fault zone. Of interest is the observation that the Calapsu fault cuts the Oligocene and older beds but not the Miocene; thus the age of the faulting is established as pre-Castilletes and post-Siamana.

(3) *Oblique Faults.*—The third group of faults consists of numerous oblique faults. Numerous examples of such features, mostly trending southeastward, comprise one of the most prominant aspects of the stable-platform geology. They are interpreted as strike-slip faults because of horizontal offset and drag of adjacent beds, and also because of their apparent genetic association with faults, in the Cocinas trough farther to the north. Also steep and sometimes even vertical or overturned folds are horizontally offset. The offsets on these features are almost universally of right-lateral character,

and range from 50 to 500 meters, or occasionally even more. A few of the obliques are normal faults, which occur on anticlines and are epianticlinal features. A minor group of oblique faults is oriented in northeast and northward direction. These are classified also as strike-slip displacements.

Along northwest-trending strike-slip faults, almost without exception the east fault block is displaced southward relative to the west block. Along the north-trending faults, with few exceptions, the west block has moved southward. This is in keeping with some of the fundamental ideas of shear movements caused by compression (*see* Fig. 14).

The average strike of the southeast trending faults is S60E, and the average strike of the north-trending faults is N2W west. From this information is inferred or resolved, a principal stress axis aligning S31E. Because one set of faults (the southeast set) predominates so clearly, there is inference that the deformation was caused by a stress couple.

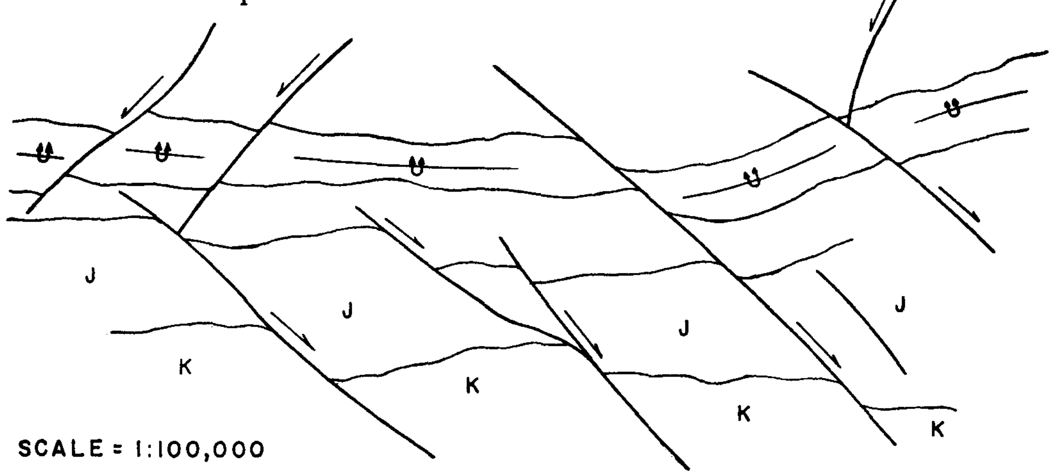


FIG.—14 ILLUSTRATIONS OF STRIKE-SLIP FAULT PATTERN DUE TO COMPRESSION. (Reduced 10% from original art work.)

Folding.—A number of folds of eastward trend were developed upon the stable platform. Along the northern edge of the platform, near and parallel to the Cocinas fault system, are six narrow, asymmetrical anticlines with consistently steep north flanks. The folds range from two to six kilometers in length. The north flanks dip from 10 to 30 degrees, but locally have dips of 50 to 60 degrees. All these folds are probably the result of regional north-south compressional movements within the Cocinas trough.

In contrast to the narrow folds on the platform edge, several broad, gentle folds are located farther to the south. These have the same eastward trend, and differ from folds of the platform rim only in broader character.

A broad anticlinal fold is developed in the Palanz and Moina sediments north of the village of Ranchería. The fold plunges gently towards the northeast and is terminated at its west end by the Ararieru fault zone. Dips are of the order of 7 to 20 degrees and the anticline is essentially symmetrical despite localized drag-folding along the Ranchería fault. A number of small faults are present along the Palanz-Moina contact on both flanks of the plunging nose. This fault pattern is an example of de Sitter's (1956, p. 208) "peri-anticlinal faulting" in which stretching has been accompanied by a series of small shear faults (*see* Fig. 15).

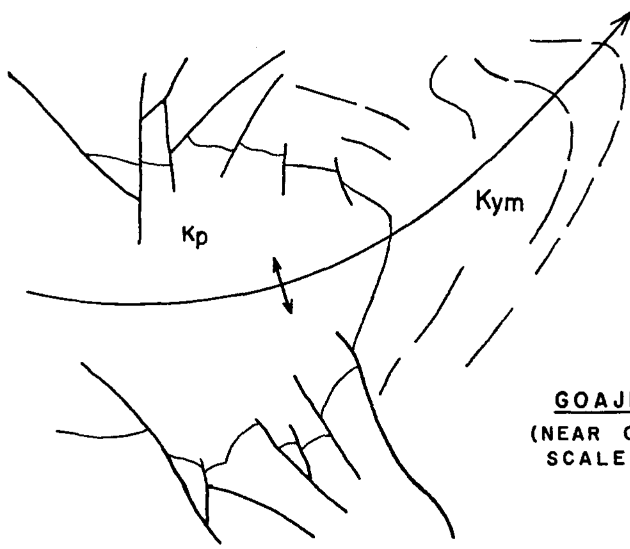
An anticline with form of an elongate dome, trending in east-northeast direction, is located in the vicinity of Monojoi. The fold is expressed in the surface by the "Upper Yúruma" and "Lower Cogollo" limestones and marls, and it has a length on the surface of about six kilometers. The fold is essentially symmetrical. The average dips are 25 to 30 degrees. An east-trending strike fault cuts the north flank of the fold and brings the Palanz sandstones against "Upper Yúruma" limestones. The east end of the anticline is terminated against the Calapsu fault zone and the west end of the fold dies out in "Upper Yúruma" limestones. A number of northwest-trending relief faults cut diagonally across the anticline suggesting epi-anticlinal faults.

On the southern side of Cerro Yúruma, a narrow syncline is developed in "Lower Cogollo" shales and limestones. This relatively minor feature is the largest of several folds in this locality.

A broad, shallow syncline developed in the Palanz sandstones is located a few kilometers east of Cerro Cocinas. The syncline has a length of approximately 12 kilometers, and plunges gently to the east. Dips on both limbs average four to eight degrees. The syncline is probably a depositional feature resulting from a broad, shallow depression in the basement, rather than being truly folded by organic movements.

COCINAS TROUGH

The Cocinas trough is a large structural depression bounded on the south by the Cocinas fault system and on the north by the Cuisa fault system (*see* Geologic Map). The trough trends in an



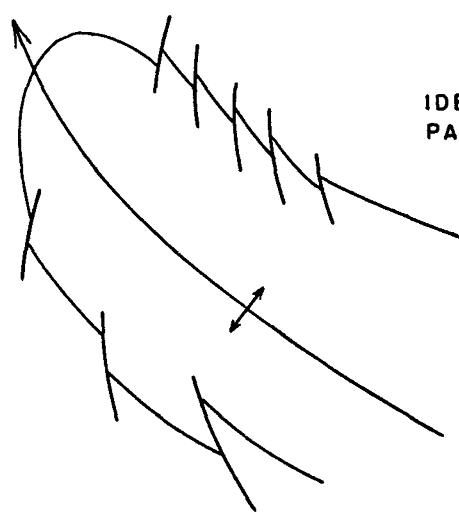


FIG.—15 PERI-ANTICLINAL FAULT PATTERNS

(Reduced 18% from original art work.)

easterly direction. It has a length of at least 70 kilometers and a present day width of nine kilometers.

Originally much wider during Jurassic and early Cretaceous sedimentation, the width of the Cocinas trough has undergone considerable narrowing due to compressive deformation that occurred near the close of the Cretaceous Period and again near the end of Eocene time. The results of these movements have produced folding and severe faulting of the sediments within the trough area. A major anticlinal fold and an intricate system of faults have developed; these classically illustrate the phenomena of compressive deformation of rocks.

Faulting.—Faulting represents one of the most striking features in the structural make-up of the Cocinas trough. Three sets of faults, similar in character to those on the platform to the south, are dominant throughout the region. These are: (1) an older set of longitudinal faults trending generally in an east-west direction; (2) a group of northwest-trending strike-slip faults, all of which cut the earlier longitudinals; and (3) a minor set of northeast-trending strike-slip faults that also cut the longitudinal system but are terminated by the northwest-trending set.

Only the Cuisa and Cocinas faults, which are the boundary features limiting the Cocinas trough, have entered in an important way into the development of the main, regional structure. Each of these features may most properly be called fault systems because each comprises a series of closely related parallel fault wedges and slices rather than two simple displacements. There is an arcuate shape to each of the systems conforming to axial curvature associated with the trough.

The Cocinas fault system is composed of a number of nearly parallel faults which bound narrow wedges of highly disturbed rocks. Later-formed oblique strike-slip faults have cut the faults of the Cocinas system in many places offsetting the fault or fault zone up to one kilometer. The Cocinas fault system is at least 60 kilometers in length, and trends generally eastward, or slightly north of east. At its western end, the Cocinas system is buried under alluvial gravels. At the eastern end, it is overlapped by Oligocene limestones. The Cocinas fault may actually be terminated near this point by a suspected southeastward extension of the Cuisa fault system under the Oligocene cover. The dips of the faults which comprise the Cocinas system have never been observed, but they have been arbitrarily represented as nearly vertical on the structural cross-section (*see* Structural Cross-section).

Although Renz (1956) indicates that the Cocinas fault system is a transcurrent fault, the bulk of the field evidence suggests that strike-slip movements are rather minor, and that they occurred during the final phases of deformation. It is the opinion of this writer that the major movements of the Cocinas system are dip-slip.

The Cuisa fault arcs around the north rim of the Cocinas trough, and divides metamorphic rocks and onlapping Tertiary sediments of the stable northern (general Jarara) area from the Mesozoic sediments of the trough. From an indefinite western origin which is mantled by alluvial material, it trends northeastward for about 25 kilometers to the vicinity of Borrochio and Cuisa. A subsidiary branch, entering from the metamorphic rocks to the west, joins the main fault at this point. The fault then continues eastward, and curves somewhat toward the southeast before disappearing beneath the Oligocene limestones. Its known length is nearly 60 kilometers; its total length is probably considerably greater.

At its eastern end, a few kilometers east of the village of Porchina, the Cuisa fault is overlapped by Oligocene sediments. However, there is evidence that the fault continues its trend for at least an additional 25 kilometers, and follows along the approximate edge of the Oligocene contact. The fault probably passes along the southwestern edge of the Laguna de Cocinetas and on out into the ocean. The evidence for the fault extension is threefold: (1) the Oligocene contact defines a sharp depositional hinge line which was present during the medial Tertiary; (2) there is a minor flexing of the Tertiary sediments all along the hinge line; (3) a pronounced topographic "hinge line," existent in present topography, coincides with the structural and depositional alignment as well as with the line of Oligocene overlap. The flexing of the Tertiary sediments is most pronounced near Flor de Goajira, where there is an abrupt change from the thin, gently-dipping Tertiary strata south of the hinge to the thicker, disturbed Tertiary beds along its northern side.

The Cuisa fault, like the Cocinas fault, is generally composed of several narrow, parallel elements. It also tends to be cut, with its trend slightly offset, where it is crossed by the minor, oblique displacements. The subsidiary westward branch in the Cuisa-Borrochio locality is an important element of the fault system, but probably dies out westward within the metamorphic rocks found in this direction.

Raasveldt (1956, pp. 21–22) suggests that the Cuisa fault is essentially a strike-slip fault, based on photogeological interpretation. Alberding (1957, p. 788) assumes a strike-slip displacement of up to 15 kilometers along this fault, based on the data of Raasveldt (1956, pp. 21–22). In actuality, the field evidence indicates that the principal movement of the Cuisa fault system has been dip-slip, with only minor lateral displacement.

The lateral movements of the Cuisa system probably took place during a second stage of the deformation concurrent with the development of the oblique-trending strike-slip faults throughout the entire region. The drag-folding of the Yúruma limestones in the Quepsina area is suggestive of deformation due to strike-slip movement. However, the lateral movements along the Cuisa fault are believed to be on the order of less than one kilometer rather than the 15 kilometers as suggested by Alberding (1957).

Another complex longitudinal fault system is located several kilometers south of the Cuisa system and has the same general east-west trend. Here the fault pattern has enveloped a wedge of "Upper Yúruma" limestones bounded on the south of the Jurassic Cuisa Formation and bounded on the north by either Palanz sandstones or thin slivers of Cuisa. This wedge has been called the Chinapa wedge by Renz (1956). Horizontal drag-folding along the northern edge of the limestone in the wedge is indicative of at least a small amount of right-lateral movement along this fault (*see* Geologic Map). Evidence along the southern boundary fault suggests only a slight right-lateral movement. The main displacement of the Chinapa wedge was a dip-slip movement.

Immediately south of the Chinapa wedge there is a long sinuous wedge of Cuisa Formation. It is bounded on the north by the Chinapa wedge and on the south by a fault which juxtaposes the Caju Formation against the Cuisa. In contrast with the faults bounding the Chinapa wedge, the fault on the south side of the Cuisa wedge does not show any evidence for strike-slip movement. Although the fault planes were not observed, it is believed that these are predominantly dip-slip faults, but direction of the dip is problematical.

Renz (1960) shows a major longitudinal fault approximately 40 kilometers long in the central portions of the Cocinas trough. This is his Parasipo fault. However, field evidence does not support the presence of this fault except at the western end where there is a longitudinal fault approximately 8 kilometers long in this position.

A number of other longitudinal faults of lesser importance are also present in the Cocinas trough, and have broken up the normal succession of the beds, producing considerable repetition of the strata. These, too, appear to be dip-slip faults, although the actual direction of the dip has not been observed.

West of Cerro Iruan, the east-west trend of all the longitudinal faults, as well as the general strike of the formation bedding, swings to a southwestward alignment (*see* Geologic Map). This southwestward trend continues until the entire sequence of rocks becomes covered by alluvium west of the Quebrada Patamana.

Numerous oblique strike-slip faults, similar to those described on the stable platform, are present throughout the Cocinas trough. Most of these faults are one to two kilometers in length. There are, however, a number of major obliques up to six to eight kilometers long. The longest, and most dominant ones, trend in a northwest direction. In contrast, a northeast set is consistently shorter, never greater than four kilometers. Both sets cut across all previously formed structures. Offsets along the faults vary from several hundred meters up to approximately 1.5 kilometers. About 0.5 kilometers is the average offset. The east block of any northwest oblique is consistently offset to the south, whereas on a northeast oblique the east block generally moves northward. West of Cerro Iruan, as the structural grain swings to the southwest, the trend of the two sets of oblique faults changes from N58°W and N26°E, to N81°W and N1°E, respectively.

Folding.—A major anticlinal fold occupies most of the central portion of the Cocinas trough. The anticline trends easterly over its entire length of 20 kilometers. The north limb of the fold dips from 50 to 70 degrees. The south limb is overturned, and dips more steeply northward, generally at an angle of 60 to 80 degrees.

A small but complex fold is present in severely faulted Cretaceous beds (*see* Geologic Map), at Cerro Iruan. The axis of the anticline strikes in a northeastward direction and plunges steeply to the northeast. Each flank of the fold is cut by a high angle, northeastward-trending longitudinal fault, and these in turn are cut by a set of northwest strike-slip dislocations. Movement of the Cerro Iruan block relatively eastward has resulted in intense deformation accompanied by faulting of "Lower Cogollo" against "Upper Yúruma" sediments at the eastern end of the block.

THE SERRANÍA JARARA UPLIFT

The Serranía Jarara is a range of hills in the interior of the Goajira Peninsula, rising to summit altitudes of 600 to 700 meters (1,900 to 2,300 feet). Essentially, the Serranía represents a broad northwestward-trending arch with the axis of uplift approximately perpendicular to the grain of the pre-Mesozoic metamorphic rocks (*see* Geologic Map). Except for one small exposure of Yúruma limestone at the southeast end of the Jarara, the uplift consists of an extensive exposure of basement rocks surrounded by outwardly dipping Siamana and Uitpa sediments.

The core of the structure is composed of uniformly northeastward-trending strike ridges of metamorphic rocks characterized by steep dips to the north. At the northern end of the uplift, near a dioritic intrusive, the metamorphic rocks dip steeply to the south. Locally, near the eastern corner of the Serranía Jarara, the grain of the metamorphic rocks swings eastward and southeastward.

A number of prominent strike faults trending northeastward are evident in the interior of the Serranía. A major southeast-trending fault on the southeast flank of the uplift cuts the metamorphic grain close to the present contact with the Oligocene beds. This fault transversely crosses the gneissoid grain of the basement rock but is a longitudinal feature with respect to the form of Tertiary uplift of the Serranía. The fault begins in the metamorphic rocks a short distance west of the village of Uitpa and continues southeastward into the Tertiary strata of the adjoining basin. Minor transverse and oblique faults also are present in several localities.

At its eastern end, an extension of the Jarara uplift is believed to plunge southeastward in the subsurface of the Tertiary basin. Basement movements on this extension of the uplift are believed to be responsible for faulting seen in the overlying sediments.

MACUIRE UPLIFT

The Serranía Macuire is located a short distance to the northeast of the Jarara uplift, and it is nearly parallel to it. A narrow structural and depositional trough separates the two uplifts. The Serranía Macuire is essentially a northward-tilted fault block of pre-Mesozoic metamorphic rocks and granite, but it includes, at its eastern end, a segment of Mesozoic (Cretaceous, Jurassic?, and Triassic?) sediments (*see* Geologic Map). The Macuire uplift trends generally southeast. Air photo studies and very limited ground control of the metamorphic complex suggest an east-west grain, with some northeast grain at the northwestern end of the Serranía. Along the northern and eastern sides of the complex, most of the grain appears to swing southeastward.

In the southeastern portion of the uplift, the metamorphic rocks were apparently intruded by a very coarsely-crystalline, light buff colored, orthoclase granite. The contact with the metamorphics was examined in only one locality, near the western limit of the mass. Here the contact indicates an intrusive relationship. The contact was traced around its periphery using air photo control only; thus it may be subject to some later revision. The granite mass is of batholithic proportion, and it is definitely younger than the metamorphic rocks which adjoin it.

Along the entire southwestern flank of the Serranía Macuire there is an apparent normal fault, downthrown on the southwest side. This is named the Macuire fault. The fault is at least 35 kilometers long, and trends southeasterly. Although the fault plane has been seen in only two places, it appears to be a south-dipping, high-angle, gravity fault. The amount of vertical displacement is uncertain, although it apparently is large. The northern termination of the fault is not known to the writer, but its southeastern termination appears to be in the Jurassic? sandstones near the coastline. The fault may well extend out into the Gulf of Venezuela under an overlapping cover of Oligocene deposits.

Even though the fault plane indicates a normal or gravity relationship, the feature may actually be a ramp thrust developed by compressional movements. The regional relationships of the Goajira suggest a compressional origin for the Macuire fault.

Along the northeastern flank of the Serranía Macuire no evidence of faulting could be observed, and the metamorphic rocks appear to slope gradually under a cover of Tertiary sediments and alluvium. At the southeastern end of the Macuire uplift, rocks of questionable Triassic and Jurassic age are exposed, as well as rocks of known Cretaceous age. They dip steeply and are extensively faulted. The Mesozoic sediments and the crystalline rocks of the core are overlapped by outwardly dipping Siamana and younger sediments.

At the southeastern end of the Macuire uplift, near Punta Espada, faulting caused a mass of Cretaceous limestones to be downdropped into the surrounding older rocks. Thus, it remains preserved today while the rest of the Cretaceous has been removed by erosion. The faults on both sides of the limestones parallel the southeast trend of the Macuire uplift. A later set of southeast-trending oblique faults has cut the former faults. The offset is due apparently to vertical rather than lateral movements.

TERTIARY BASIN STRUCTURES

The Tertiary basin is a northwest-southeast-trending structural and depositional basin partially bounded on the north by Serranía Macuire and on the south by Serranía Cocinas. The basin is structurally divided into two parts: (1) the long, narrow, and shallow structural and depositional trench between the Serranías Jarara and Macuire; and (2) the wider, main basin between the Serranía Jarara and the Cocinas structural complex (*see* Geologic Map). The deeper part of the basin is in this southern sector with the depositional axis passing approximately through the Guararies locality and plunging southeasterly into the Gulf of Venezuela (*see* Tectonic Sketch Map).

Towards the coast, eastward from Serranía Jarara, the two parts of the basin probably continue to be separated in the subsurface. It is postulated that a southeastward extension of the Jarara structure projects as a basement arch for some distance into the subsurface. This is suggested by the fault pattern and deformation of the overlying Tertiary sediments along this hypothetical trend.

Faulting.—The northern part of the Tertiary basin, including the narrow tectonic trench, is virtually undisturbed, other than for the gentle upwarping of its edges. In the central part of the basin, however, faulting is fairly prominent over the subsurface extension, or nose, of the Serranía Jarara uplift. Two trends are present: (1) an eastward-trending set of faults and (2) a northwest-trending set of faults. The east-west faults cut the strike of the Tertiary beds obliquely, and although some are up to six kilometers in length, they appear to have little displacement at the surface.

More important is the group of northwest-trending en echelon faults associated with the major longitudinal fault line described earlier in connection with the structure of the Serranía Jarara. The longitudinal fault originates in the metamorphic rocks west of the village of Uitpa and extends outward into the sedimentary basin. As pointed out earlier, this fault is considered "longitudinal" with respect to the axis of the Jarara uplift, even though it is transverse with respect to the rocks of the Tertiary basin. This major fault has a total length of approximately 18 kilometers, and follows a southeast direction across the Tertiary beds. Its principal displacement has been vertical, with the downthrown block to the south. There is some right-lateral movement which has deformed the soft Tertiary sediments and produced the en echelon faults. The series of shorter en echelon faults branch from the main transverse fault on the south side at an angle of about 30 degrees. These en echelon faults probably developed as a group of tension features reflecting right-lateral movement along the main fault. The surface expression of this entire zone is probably a weaker reflection of stronger movements in basement rocks of the subsurface.

In the Sillamana valley farther west, a small group of basement controlled faults exist. These faults generally display the regional southeast trend common throughout the Goajira. The largest of these is located approximately eight kilometers north of the village of Porchina. Here the surface outcrop of the basement complex is terminated by the fault, and Uitpa clays are brought in contact with the metamorphics.

In the west-central part of the Sillamana valley, in the vicinity of Cerro Alopana, post-Siamana-pre-Uitpa fault movements are evident (*see* Geologic Map). A small, tilted horst structure, widening to the southeast, has been developed between two branching faults. The triangular-shaped horst has been forced upward between the two faults and tilted gently to the southeast. The basement metamorphic rocks are brought to the surface along with the overlying Siamana limestones. The movements occurred prior to the deposition of the overlying Uitpa Formation.

Most, if not all, of the Tertiary faulting probably is a reflection of the underlying basement movements.

STRUCTURAL SYNTHESIS

Structural Analysis of the Cocinas Trough.—Consideration of the major structural trends in the Cocinas trough may shed some light on the action of forces which were responsible for developing the fault patterns throughout the Goajira. In the central and eastern portion of the Cocinas trough, the average trend of the longitudinal faults is N84°E, parallel to the fold axis in the trough. A dominant set of somewhat younger right-lateral strike-slip faults has an average trend of N58°W, and an associated minor set of left-lateral strike-slip faults has an average trend of N26°E. The pattern indicates an axis of maximum stress trending N16°W (see Fig. 16).

Since both sets of strike-slip faults cut the longitudinal faults, a two-phase period of faulting is apparent (*see* Fig. 17). The longitudinal faults were developed during the early phase, contemporaneously with the buckling of the sediments within the Cocinas trough. Several of these longitudinals are definitely high-angle thrusts or reverse faults. Since they all are presumed to be genetically

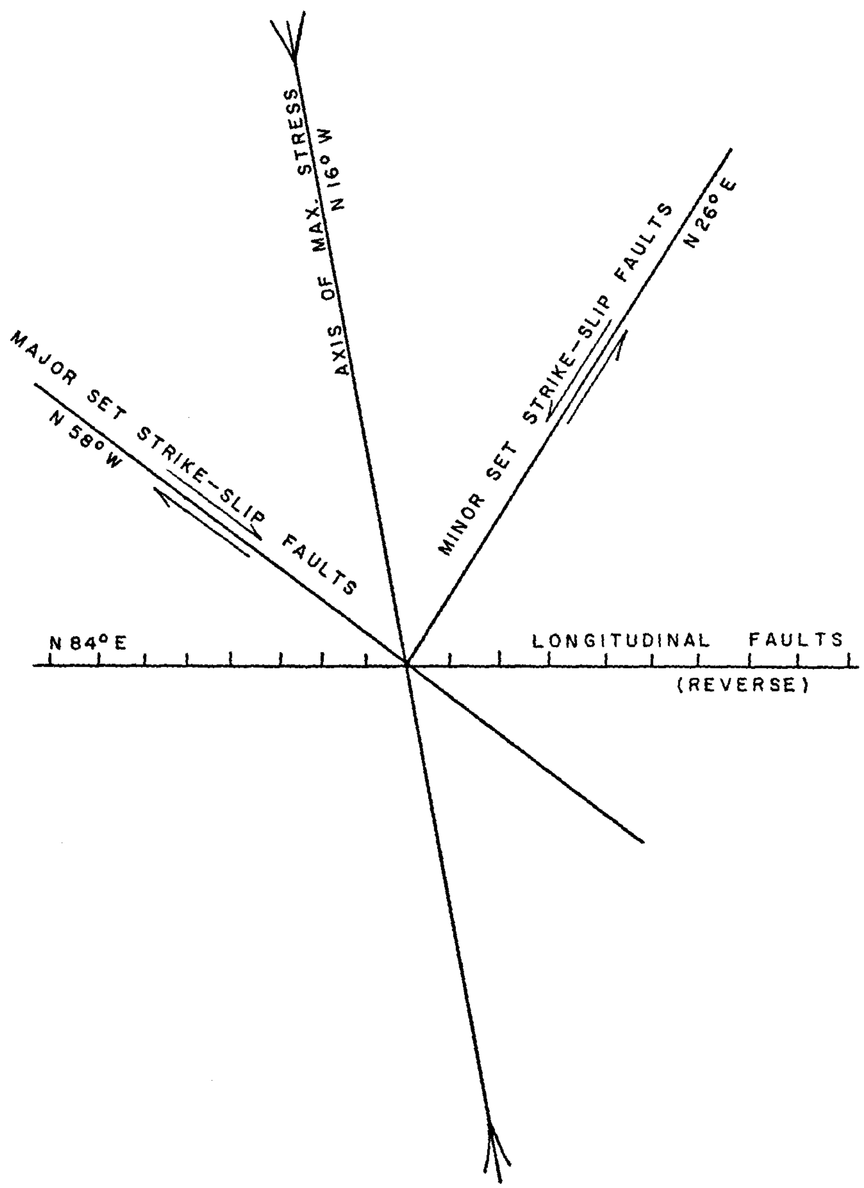


FIG.—16 RELATION OF AXIS OF MAXIMUM COMPRESSION TO AVERAGE TRENDS OF FAULT SETS IN PART OF COCINAS TROUGH

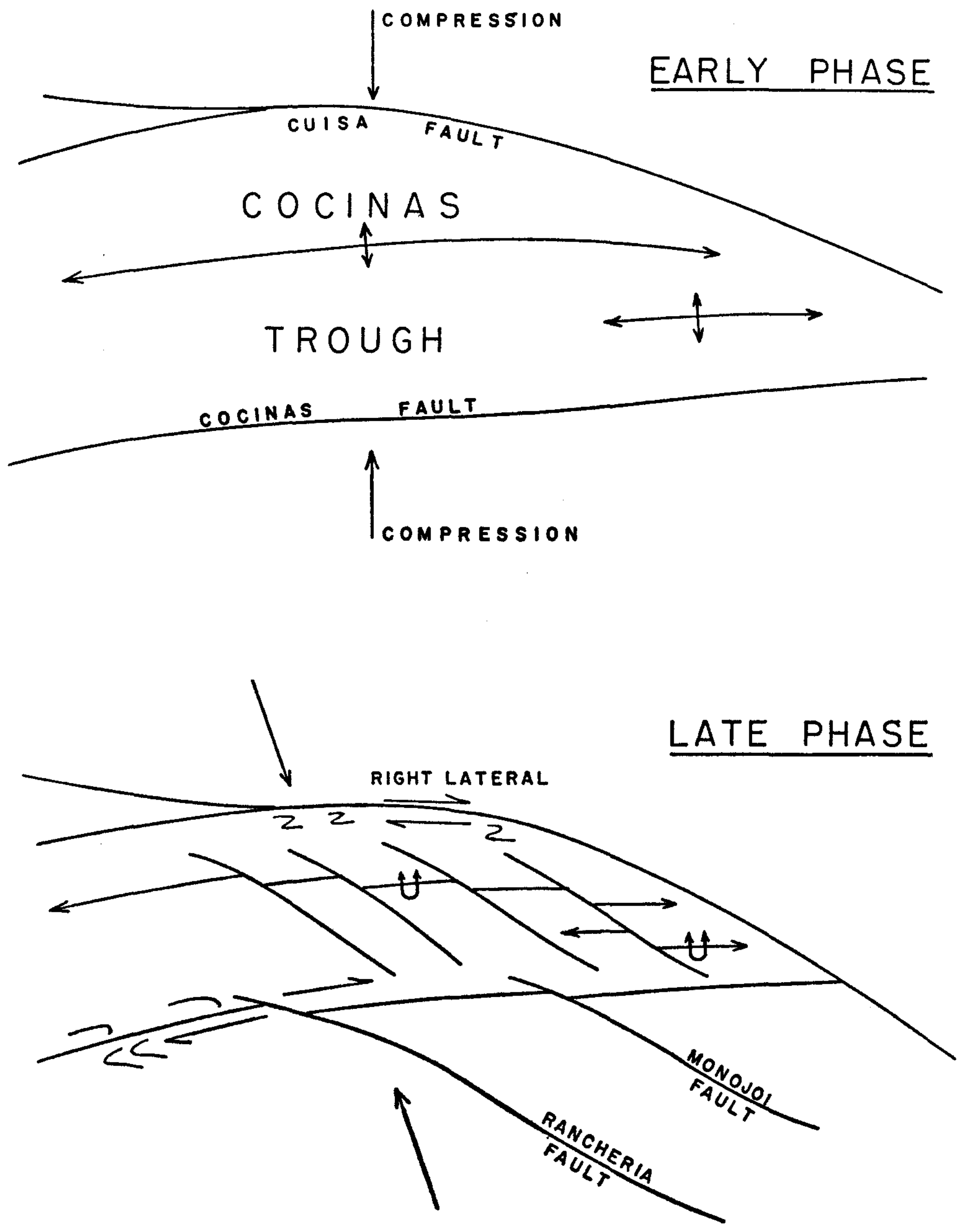


FIG.—17 GENESIS OF COCINAS STRUCTURAL PATTERNS related, it is assumed that all the longitudinal faults are high-angle thrusts. However, the actual dips of the fault planes of the Cuisa and Cocinas fault systems have not been observed. Because the Cocinas system and possibly the Cuisa system appear to be the delimiting features of a depositional trough, the possibility that they have a long history, and were originally normal faults prior to or during part of the depositional interval, is not ruled out. On the other hand, later structural relations suggest that they are either ramp thrusts, or that they may be high-angle reverse faults at the surface which recurve at depth into low-angle thrusts.

In any case, early compressional movements resulted in a group of linear structural features whose strike was perpendicular to the axis of maximum stress. Perhaps in a later phase of the deformation, or in a later episode, further compressional movements resulted in a host of oblique strike-slip faults which trend northwest and northeast. The predominance of the northwest-trending fault set, in addition to definite evidence of some small amount of right lateral movement along the boundary faults of the Cocinas trough, strongly suggests a southeast clockwise-acting couple.

Towards the west end of the Cocinas trough, all of the trends systematically rotate so that the longitudinal faults trend southwestward. The two groups of strike-slip faults also rotate, but maintain their angular relationships to the longitudinal faults.

Consideration of the Regional Structural Trends.—From detailed studies of the relatively local Cocinas trough, some interesting structural relationships applicable to the region as a whole can be observed.

In the stable platform south of the trough, the dips of the Mesozoic and Tertiary sediments are gentle, and the nature of the movements of some of the faults is not so clear. Nevertheless, the dominant trends of the fault pattern in the trough persist on the shelf. Where the relationships can be observed, they are correlative between the two areas. It is reasonable to assume that all of this faulting is of similar nature.

Faults are less numerous in the area north of the Cocinas trough, but there appears to be again a persistence of the same fault pattern. There is again a systematic rotation of the trends into a southeast alignment. The longitudinal faults parallel the axes of the Tertiary basin, the Jarara uplift, and the Macuire uplift. The Tectonic Map shows the relationship of these fault trends to the major structural elements. In the Tertiary basin and in the Jarara and Macuire uplifts, the complexity of the basement rocks and flatness of dips and softness of the Tertiary rocks prevents a definite determination of the nature of the movement along many of the faults. But it seems reasonable to surmise that if the fault trends persist throughout the Goajira, the nature of movement along the faults may also persist. On the basis of this observation and similarities throughout the Goajira in prevailing trends, it is concluded that the faulting in general can be divided into three groups or types: (1) longitudinal high-angle thrust or reverse faults, with some right-lateral movement; (2) younger dominant right-lateral strike-slip faults of oblique southeasterly trend; (3) left-lateral strike-slip faults of oblique, north, or northeastward trend. In addition to these there are undoubtedly some faults which do not conform to these three major trends.

It is significant to note that throughout the Goajira, in each of the structural elements, the intensity of faulting and deformation is greater towards the east where the individual elements are crowded together. Compression was apparently more intense in the east, where the structural elements are closely spaced, and less intense in the west and northwest, where they are farther apart.

The character of the Macuire fault in the northern part of the Goajira remains somewhat problematical and deserves further comment here. Although inconclusive field evidence suggests a southwest-dipping gravity fault, such a feature would require tensional rather than compressional stresses. As suggested earlier, the fault may, in reality, be a ramp thrust which at depth recurves to dip northeastward beneath the Macuire uplift. If this should be true, then this area would conform to the remainder of the Goajira structural pattern. However, if the fault is actually a normal fault, then the origin of the Macuire uplift is different from the compressional origin of the Cocinas trough. Thus it would be difficult to resolve the Macuire into the regional structural synthesis. Since the field data are at present inconclusive, the writer prefers to consider the fault as some type of compressional feature. Thus, an already complex structural situation is not made more so by injecting the possibility of a totally unrelated element.

Effect of Thickness and Competence of the Sedimentary Cover.— The effects of thickness and character of the sedimentary cover each play an important role in the development of the surface structural features on the Goajira Peninsula. There are three areas where these effects are paramount: (1) the Cocinas trough, an area of very thick sediments; (2) the adjacent, structurally high, stable platform; and

(3) the Tertiary basin. On both the latter two areas, the sedimentary cover is either lacking or relatively thin.

The thickness of the pre-Quaternary sedimentary cover on the stable platform ranges from zero in the west to 2,500 meters in the east. To the north, within the Cocinas trough, the aggregate thickness is at least 5,000 meters and perhaps more. Still farther north, in the Tertiary basin, the sedimentary cover ranges from zero in the western area to a maximum of 1,200 meters near the east end of the main Tertiary embayment.

The relative thinness of the sedimentary cover that is associated with the stable platform and Tertiary basin is probably characteristic of the remainder of the Goajira. Thus, all of the Goajira excepting the Cocinas trough is relatively high, structurally, and the sedimentary cover is relatively thin. The Cocinas trough, with its very thick sedimentary accumulation, is unique.

Although the faults and the deforming forces are possibly of uniform character throughout the Goajira, the folding in the Cocinas trough is distinct from folding observed elsewhere in the area. The asymmetrical major folds in the Cocinas trough are typical of compressional folds developed in areas of thick sediments and are at least somewhat independent of the basement rocks. On the other hand, the folds and uplifts on the remainder of the Goajira probably reflect basement deformation to a large degree.

Summary of Stages of Structural Development.—Three major stages of post-Triassic structural growth are apparent on the Goajira. These are (1) the post-Cretaceous-pre-upper Eocene orogeny, (2) the post-Eocene-pre-Oligocene orogeny, and (3) the late Pliocene orogeny. Evidence is also present for several periods of minor movements.

The major crustal movement near the close of the Cretaceous Period and during earliest phases of the Tertiary probably coincided with a similar but less active stage of orogenesis which has been observed over most of western Venezuela. The longitudinal faults and associated folds were developed during this earlier phase of Goajira movement. As deformation continued, the oblique faults were formed which cut and offset the longitudinal trends.

A second phase of orogenesis took place at the end of Eocene time. Without a doubt this also coincided with crustal movements in the Maracaibo Basin. Judging from the Goajira relationships, this was an important and perhaps even a maximum period of deformation in the Goajira. Evidence in determining its relative importance is not entirely conclusive.

Some crustal movement occurred in post-Miocene time, and this probably coincided with the late Pliocene orogeny, which was a period of major mountain building in western Venezuela. The post-Miocene movements appear to be considerably less profound in the Goajira than in western Venezuela.

Summary of Geologic History

The geologic history of the Goajira Peninsula, since Triassic time, is recorded in fairly good order by features of the stratigraphy and geologic structure. The record is not yet entirely understood and lacks important details. Nevertheless it adds considerably to information available in other areas of western Venezuela and northern Colombia, and therefore is of great regional as well as local interest.

Paleozoic and Earlier History.—Only a little is known concerning the pre-Mesozoic geologic history of the Goajira Peninsula. This early period probably involves a complex history of both marine and continental sedimentation and probably several periods of diastrophism, metamorphism, and igneous intrusion. At least two periods of erosion are clearly evident, and undoubtedly there are others.

Mesozoic History.—The details of the geologic history become somewhat better known with the beginning of the Triassic period in the Goajira, even though there are still wide gaps in the record. Apparently most of western Venezuela and a large part of Colombia, including the Goajira, were eroded extensively prior to the deposition of the Triassic sediments.

The recorded Mesozoic history of the Goajira begins late in the Triassic with deposition of the "Rancho Grande" redbeds on the eroded, uneven surface of older metamorphic and crystalline rocks. Sedimentation appears to have been contemporaneous with redbed deposition over a wide region in western Venezuela and northeastern Colombia.

The "Rancho Grande" Formation was deposited under continental and fluviatile conditions. The sediments of the Goajira area were supplied from a source nearby, perhaps from a source area lying to the northwest in an ancestral extension of the Santa Marta range of Colombia. Several stages of igneous activity are indicated by the distribution of sills and flows.

Towards the end of "Rancho Grande" time, a local incursion of the sea resulted in the accumulation of clean, white beach sands which constitutes the Uipana Formation. It is postulated that the beach deposits of the Uipana are marine equivalents of the upper

La Quinta continental beds occurring in the Maracaibo Basin in Venezuela.

The Jurassic period in the Goajira was one of shallow marine sedimentation which resulted in accumulations to a thickness of 4,000 to 5,000 meters in an east-west-trending tectonic depression called the Cocinas trough. A time interval of uncertain proportions spans the gap between the underlying "Rancho Grande"-Uipana formations and the oldest formations of Jurassic age. During this interval, some orogenesis took place in which the Triassic beds were gently folded.

Throughout the depositional history of the Cocinas trough, from late Jurassic time into the early Cretaceous, gradual subsidence seems to have occurred, although at times it appears that depositional infilling was greater than the rate of subsidence.

The earliest known Jurassic deposits in the trough are carbonates and siltstones of the Cheterlo Formation. These were overlain by the shales and silts of the Caju Formation. Towards the end of Caju time, rejuvenation of nearby land masses began to take place, and the shales graded upwards into interbedded sandstones until finally sand deposition became dominant.

During Chinapa time the rising land masses apparently reached their maximum elevation, and coarse sandstones followed by massive conglomerates were laid down in the trough. A few thin beds of dolomitic limestone containing scattered shell fragments suggest that shallow marine conditions existed during at least part of this phase.

By late Jurassic time, the land masses gradually became worn down and the conglomerates of the Chinapa Formation were replaced upwards by the standstones of the lower part of the Cuisa Shale. As the trough deepened, these in turn graded vertically into interbedded sands and shales and finally into siliceous shales. Coral and algal reefs began to flourish along the southern shelf edge of the Cocinas trough contemporaneously with the deeper water shales. The presence of numerous ammonites within the shales and reef-limestones provides us with the first definite age determinants of the Jurassic sequence.

Early Cretaceous time witnesses only a gradual change of conditions in the Goajira region as the first sands and shales of the Palanz Formation were deposited in the trough. After this stage an interval of reef development occurred along the shelf edge of the Cocinas fault line. Marls and marly limestones (Kesima member) accumulated in the deeper portions of the trough. Fringing reefs growing on the basement rocks were fairly abundant along the edges of a Maracaibo-Goajira area highland.

Once again rejuvenation of land masses brought in a heavy influx of sands followed by conglomerates, which covered the reefs and apparently extended over the entire Goajira Peninsula. At the eastern end of the trough, marine limestones and marl intertongues persisted throughout much of the upper Palanz sedimentation, while to the west and southwest the Palanz sediments graded laterally into near shore and continental deposits. By the close of Palanz time, the Cocinas trough had been obliterated as a depositional feature.

A broad encroachment of the seas took place on the Goajira at the beginning of Yúruma time (about Valanginian). Sedimentation conditions changed from a primarily clastic deposition to a carbonate deposition. Clear, shallow waters prevailed and an abundant marine fauna flourished. Some sand was brought into the western and northwestern part of the area from a highland farther to the northwest. The depth of the seas fluctuated several times during Yúruma and Cogollo sedimentation as evidenced by alternating changes in the rocks from shales and marls to massive limestones. At the end of Cogollo time a massive oyster-bank reef limestone was deposited. This limestone is known throughout a wide region including the Maracaibo Basin.

The conditions of sedimentation of the La Luna Formation are subject to considerable controversy and opposing ideas. In any event conditions changed abruptly from those of Cogollo time. A silled basin with restricted intake of marine water is thought to have prevailed over most of western Venezuela and northern Colombia, the Goajira included. Stagnant bottom conditions allowed the deposition of thinly bedded, black, bituminous lime muds and interbedded black cherts. That there was at least partial access to the open seas is indicated by the abundance of globigerinal tests in the limestones.

In the Goajira, the end of La Luna time is marked by a thin bed of limestone-pebble conglomerate. It is postulated that a barrier reef to the north, which was responsible for restricting the basin, was briefly exposed to subaerial erosion. This permitted the pebbles to pour off the barrier and accumulate in the deeper parts of the basin. On the other hand, the conglomerate may actually represent a basal transgressive phase of the overlying Guaralamai Formation.

Guaralamai sedimentation in the Goajira is characterized by thinly bedded lime muds and shaley limestones thought to have been deposited under subneritic bottom conditions. Elsewhere in western Venezuela, after a brief shallow water transitional period, the Guaralamai equivalent (Colón Formation) was deposited as open ocean deep marine muds. In contrast, it would appear that the Goajira existed as a shelf of moderate depth on the edge of the deeper Colón basin. The complete Colón-Guaralamai relation is obscured in the Goajira by the overlap of younger sediments.

A long history of sedimentation which began in the Jurassic Period was brought to a close at the end of the Cretaceous Period. Orogeny may actually have been initiated in Late Cretaceous time and then continued through much of the Eocene and into later stages of the Tertiary, or it may not have begun until the early Tertiary. The exact timing of these movements is not clearly understood.

Tertiary and Quaternary History.—Early Tertiary geologic history is imperfectly known on the Goajira because of wide gaps in the depositional sequence. However, a generalized understanding can be assembled from the basic data which will contribute to the regional Tertiary geologic history of western Venezuela.

The Goajira region was folded and faulted during a main stage of orogenic movements, beginning probably at the close of the Cretaceous Period and continuing into the early Tertiary. The Peninsula was uplifted, and it is quite possible, but not certain, that the major structural features of the Goajira were developed at this time. Erosion stripped off a large part of its sedimentary cover. Thousands of feet of sediments were removed during this interval. The Mesozoic record is preserved only in the down-dropped block of the Cocinas structure.

By late Eocene time the Goajira was probably worn down to a relatively low land mass. During the late Eocene interval the Macarao Formation was deposited in shallow, shoreline embayments along the southeast end of the Goajira. These sediments must have been deposited all along the submerged edges of the Peninsula. However, the unkown effects of later erosion, in addition to overlap by younger sediments, obscure the true extent of the Macarao basin.

A second major period of orogenesis was initiated in the Goajira at the close of the Eocene epoch. This coincided with regional, but less pronounced, post-Eocene movements throughout western Venezuela.

By Oligocene time the major structural elements of the Goajira were formed. Although the major structural elements may have been

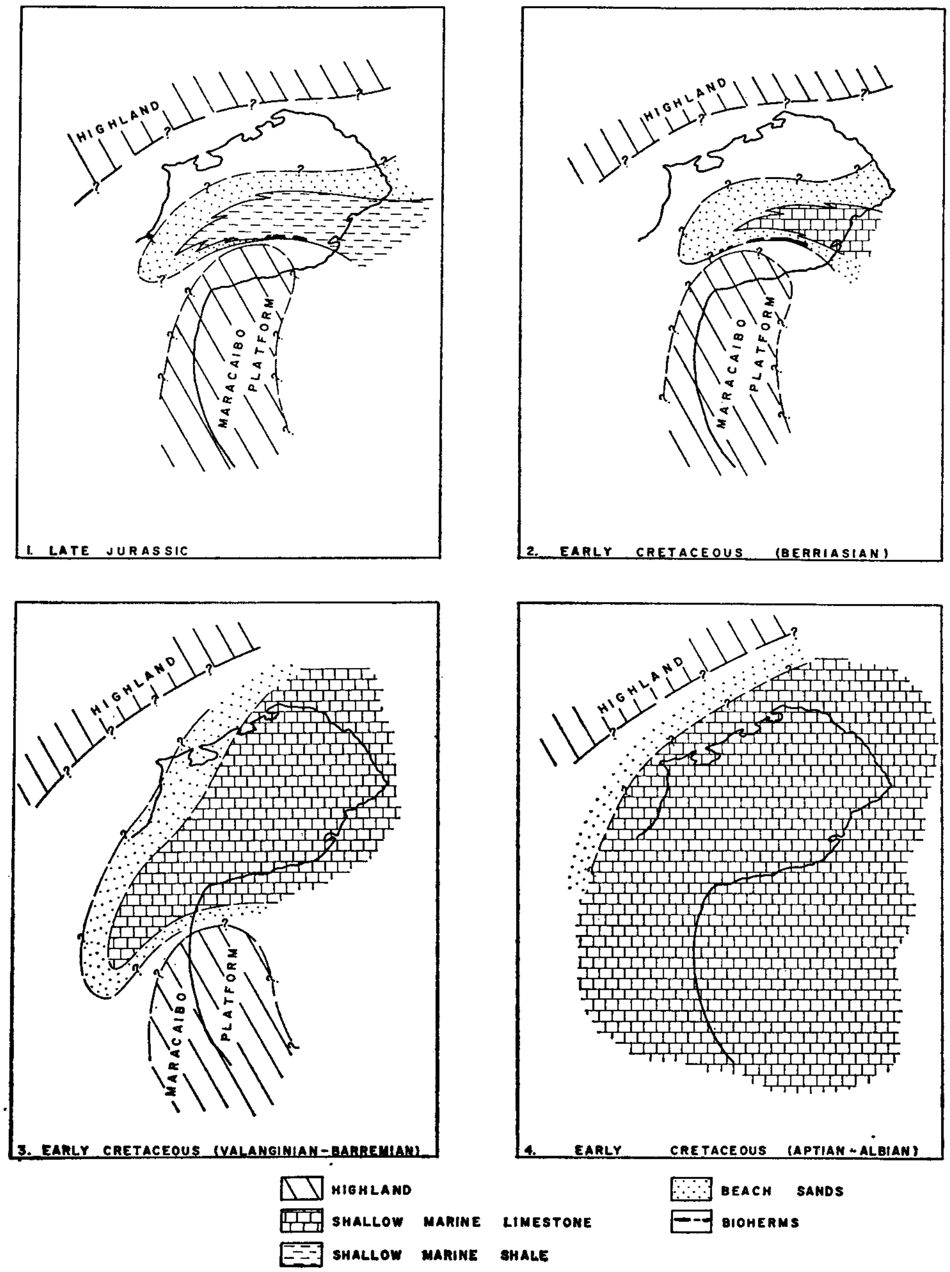


FIG.— 18 PALEOGEOGRAPHIC & LITHOFACIES SKETCH MAPS SHOWING SEDIMENTARY DEVELOPMENT OF THE GOAJIRA

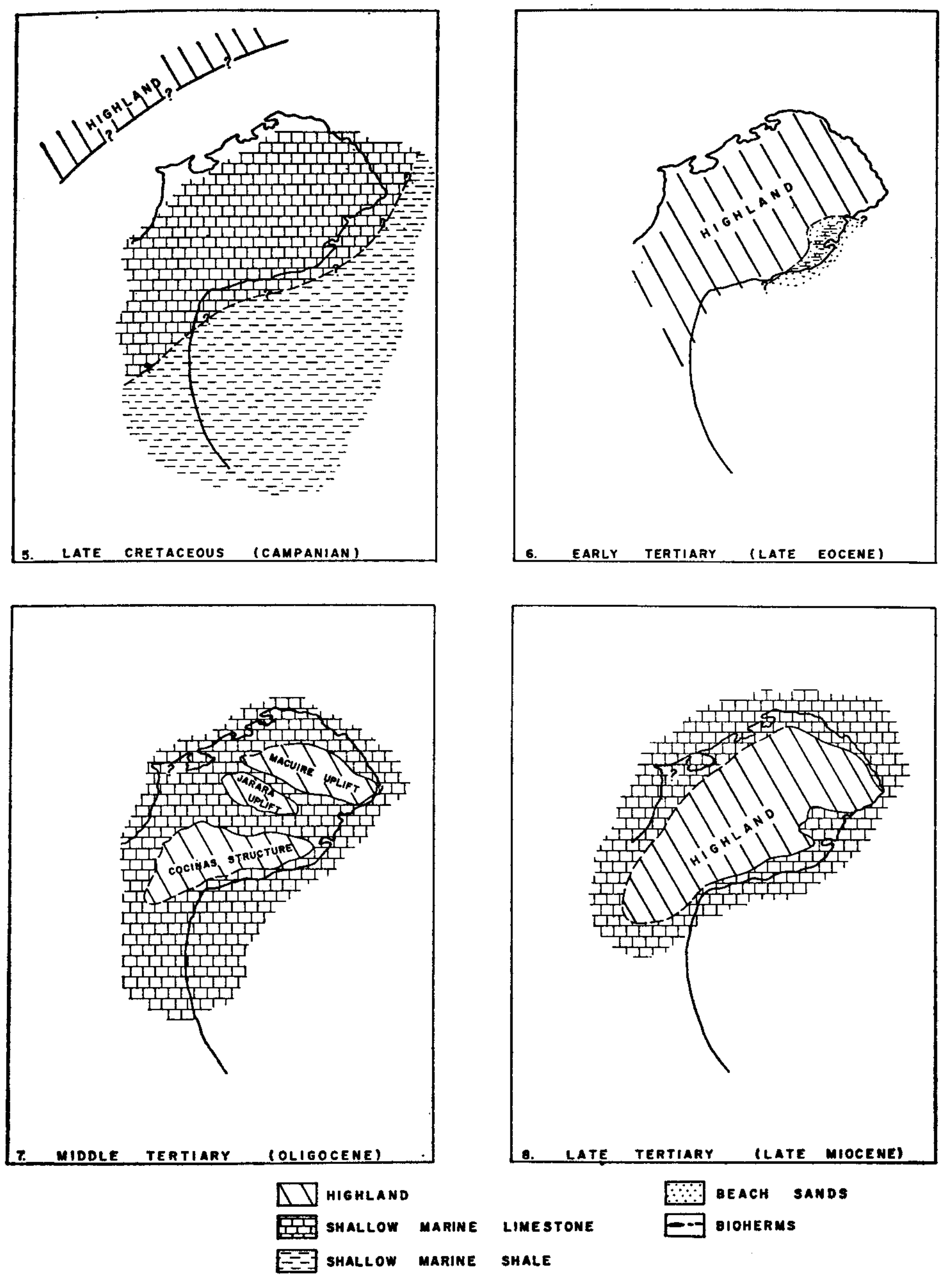


FIG. — 19 PALEOGEOGRAPHIC & LITHOFACIES SKETCH MAPS SHOWING SEDIMENTARY DEVELOPMENT OF THE GOAJIRA formed prior to the deposition of the Macarao, they undoubtedly were re-emphasized by the post-Eocene-pre-Oligocene movements. The Oligocene sea transgressed over a considerable portion of the interior of the Goajira as well as the outer edges. This transgression initiated, within the region, the major depositional cycle of the Tertiary period. The Serranías Jarara and Macuire existed as islands upon a submerged shelf. The Cocinas structural element also formed an island, or perhaps a narrow promontory from the south; the record is not sufficient for this distinction.

A warm water reefing condition persisted, with abundant reef growths fringing the borders of the three land masses or islands. Active long shore currents are clearly indicated by the record of distinctive rock fragments found in the Oligocene deposits. Black chert pebbles, known only from outcrops of the La Luna Formation near Flor de Goajira, can be traced northwestward in the Siamana Formation along the northern edge of the Cocinas structure. Here they can be traced towards Porchina and thence north of the village to the point where the Formation is overlapped by the Uitpa clays.

A number of outwash fans, composed of pebble and cobble conglomerates, are found in the Siamana sediments on the flanks of the Oligocene "islands." These fans were deposited by sizeable streams which washed down from the highlands during Oligocene time. A fan located just northwest of a trading post called Siamana is composed of Cretaceous limestone and Jurassic sandstone cobbles. Fans along the Serranía Jarara consist of granite and schist fragments.

After the deposition of the Siamana sediments, there was gentle uplift of the positive elements. The result was the upwarping of the basin edges and exposures of the sediments to subaerial erosion. Eastward, in the deeper parts of the Tertiary basin, sedimentation was probably continuous while the rim of the basin was undergoing erosion.

During the Aquitanian interval, following this relatively short interruption of the Tertiary cycle, the seas deepened. The richly foraminiferal clays of the Uitpa Formation were deposited, according to Becker and Dusenbury (1958, p. 6), in waters of between 100 and 300 fathoms. This is the maximum depth attained by the Tertiary seas in the Goajira Peninsula.

Regression was already in progress before the close of Uitpa time as evidenced by the change in the microfaunal assemblages near the top of the Formation. By approximately mid-Miocene time the seas in the Tertiary basin had shallowed sufficiently to permit the deposition of calcareous sandstones and sandy limestones of the Jimol Formation.

Emergence of the Goajira Tertiary basin resulted in continued offlap of the Tertiary formations. Shallow marine sediments of the Castilletes Formation were deposited beginning about late Miocene time and probably extending through the Pliocene.

The late Tertiary sedimentary cycle was interrupted by the effects of Pliocene orogeny. This event is well known throughout western Venezuela. Whereas elsewhere it is marked by the final push and culmination of mountain building movements and large agglomerations of coarse-grained sediments, the effects on the Goajira were relatively minor. The seas transgressed over a large part of the Goajira, including a considerable portion of the Cocinas structure. The inundation was one of very short duration, but it accounts for limited beveling of older sediments and deposition of a thin mantle of gravels and some marly clay.

Subsequent to the Pleistocene, the Goajira became once again emergent and arrived at its present form. Alluvial valley filling and some wind-blown sands complete the major Tertiary and Quaternary sedimentary cycle which began in Oligocene time.

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Appendix 1

REVISION OF STRATIGRAPHIC NOMENCLATURE FOR THE GOAJIRA PENINSULA

The terminology used in this report is the result of several revisions, both published (Renz 1956, 1960) and unpublished (Rollins 1960). The evolution of the terminology from 1956 to the present, 1963, is illustrated in Figure 20 for the purpose of clarifying the use and stratigraphic position of each formational name. The author was guided by suggestions made by a "committee on nomenclature" composed of operating company geologists in the Maracaibo area. During 1961–1962 the committee revised and updated a correlation chart for all of Venezuela and Trinidad including the Goajira.

The terminology used in this report adheres very closely to the Goajira nomenclature shown on the latest Correlation Chart of Lithostratigraphic Units in Venezuela and Trinidad. This chart was submitted to the Committee of the Venezuelan Petroleum Congress in 1962 after careful review by all the operating companies as well as the Ministry of Mines and Hydrocarbons.

	RECENT	RENZ (1956)	RENZ (1960)	ROLLINS (1960)	ROLLINS (1963)
TERTIARY	MIO.- PLIO	Not Reported	Tucacas	Castilletes	Castilletes
	MIOCENE		Jimol	Guararies	Jimol
	(AQUITAN)		Uitpa	Sillamana	Uitpa
	OLIGOCENE		Siamana	Uitpa	Siamana
	EOCENE		Unamed	Macarao	Macarao
	PALEOCENE		Guasare		
CRETACEOUS		Colón Ls.	Guaralamai	Colón	Guaralamai
		La Luna	La Luna	La Luna	La Luna
		Cogollo	Cogollo	Cogollo Gp.: Upper Cogollo	Cogollo Gp.: Maraca
				Cogollo Gp.: Lower Cogollo	Cogollo Gp.: Lower Cogollo
		Upper Yúruma	Yúruma	Yúruma Gp.: Upper Yúruma	Yúruma Gp.: Upper Yúruma
		Lower Yúruma	Moina	Yúruma Gp.: Lower Yúruma	Yúruma Gp.: Moina
		Rio Negro	Palanz	Rio Negro	Palanz
			Kesima	Cuisa Mem.	Kesima Mem.
				Rio Negro	Palanz
			Cuiza		
JURASSIC		Cocinas Group: No Name	Cocinas Group: Chinapa	Cocinas Group: Jipi	Cocinas Group: Cuisa
				Cocinas Group: Pachepa	Cocinas Group: Chinapa
			Cocinas Group: No Name	Cocinas Group: Caju	Cocinas Group: Caju
				Cocinas Group: Cheterlo	Cocinas Group: Cheterlo
TRIASSIC			Cojoro Group: Uipana	Cojoro	Uipana
			Cojoro Group: Rancho Grande	La Quinta	"Rancho Grande"
			Cojoro Group: Guasasapa		
	PALEOZOIC	Cojoro Group			

FIG. 20 EVOLUTION OF STRATIGRAPHIC TERMINOLOGY FOR GOAJIRA PENINSULA

Appendix 2

DETAILED STRATIGRAPHIC SECTIONS

B-1 THROUGH B-17

(The Detailed Stratigraphic Sections are in the pocket inside the back cover. They have been reduced 40% from the original art work.)

A NOTE ABOUT THE AUTHOR

John Rollins received his B.S. degree in geology from the University of New Hampshire and his M.S. and Ph.D. degrees in geology from the University of Nebraska. From 1952 to 1959 he was employed by the Richmond Exploration Company in Venezuela as an exploration geologist. Since 1960 he has been employed with American Overseas Petroleum, Ltd., in various company operations in the Philippines, Australia, and Sumatra.