# IX
# CONGRESO
# LATINOAMERICANO DE GEOLOGIA
## CARACAS, VENEZUELA

**COORDINATION**
CARLOS SANCHEZ- LAGOVEN S.A.

**ORGANIZATION**
LAGOVEN S.A.
Subsidiary of PETROLEOS DE VENEZUELA

**GUIDES:**
YVES CHEVALIER
EDUARDO ALVAREZ
GUSTAVO HERNANDEZ

**ENGLISH TRANSLATION**
VIRGIL WINKLER

# A TRANSVERSE SECTION FROM THE ORINOCO OIL BELT TO THE EL PILAR FAULT SYSTEM

## Tectonics and Stratigraphy

# IX

# CONGRESO LATINOAMERICANO

FIELD TRIP
NOV. 9-10, 1995

By
Yves Chevalier

# CONTENTS

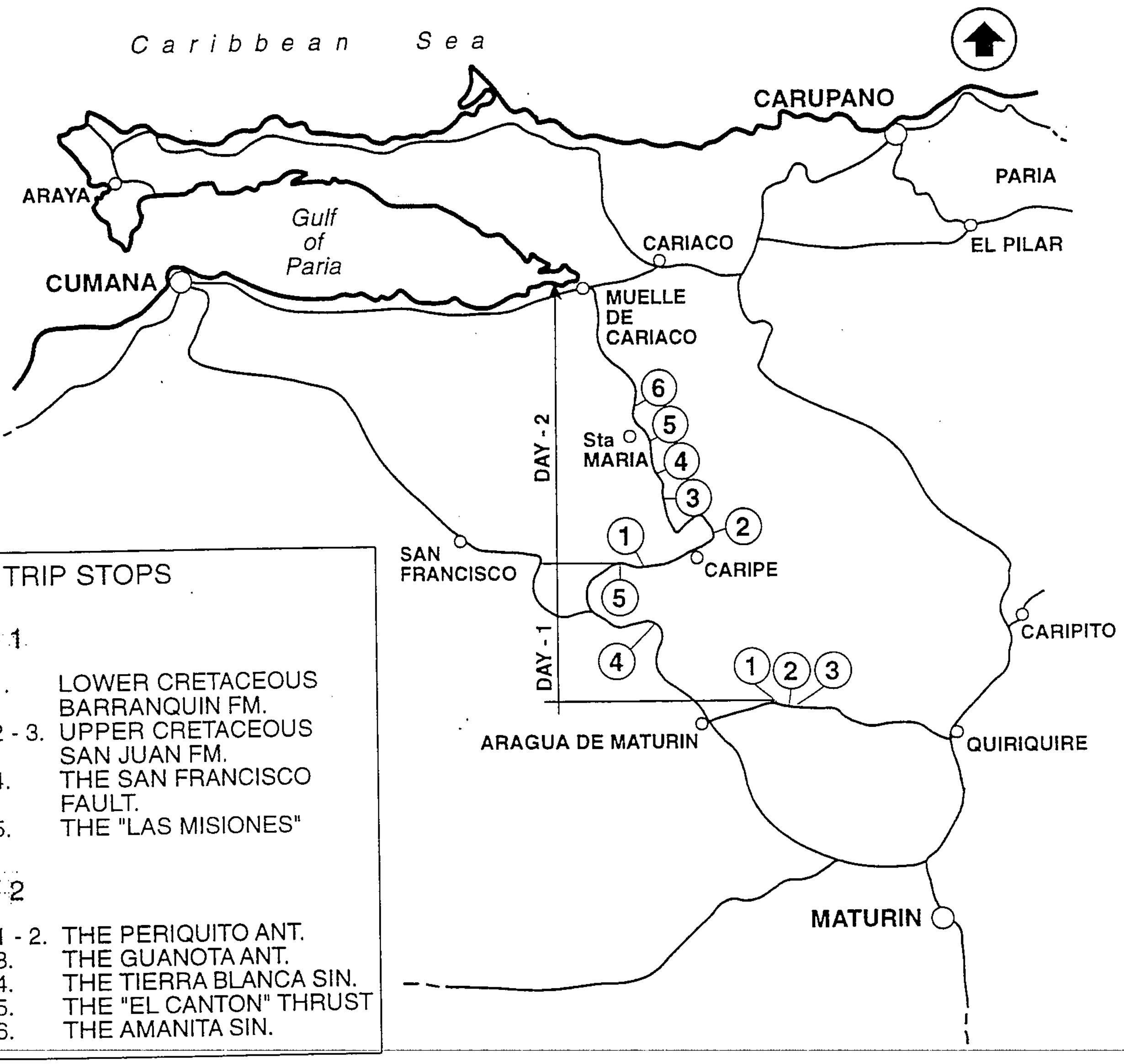
PAG.

IX CONGRESO LATINOAMERICANO DE GEOLOGIA

FIELD TRIP
NOV. 9 - 10, 1995

# A TRANSVERSE SECTION FROM THE ORINOCO OIL BELT TO THE EL PILAR FAULT SYSTEM

# UNA SECCION TRANSVERSAL DESDE LA FAJA DEL ORINOCO HASTA EL SISTEMA DE LA FALLA DE EL PILAR




FIELD TRIP STOPS

DAY - 1

| | |
|---|---|
| STOP 1. | LOWER CRETACEOUS BARRANQUIN FM. |
| STOP 2 - 3. | UPPER CRETACEOUS SAN JUAN FM. |
| STOP 4. | THE SAN FRANCISCO FAULT. |
| STOP 5. | THE "LAS MISIONES" |

DAY - 2

| | |
|---|---|
| STOP 1 - 2. | THE PERIQUITO ANT. |
| STOP 3. | THE GUANOTA ANT. |
| STOP 4. | THE TIERRA BLANCA SIN. |
| STOP 5. | THE "EL CANTON" THRUST |
| STOP 6. | THE AMANITA SIN. |

# THE EASTERN VENEZUELA BASIN

The Eastern Venezuela basin, with a surface area of 165.000 $Km^2$ underlying 5 states, is limited on the North by the Caribbean Mountain system, on the South by the course of the Orinoco River which approximately follows the northern border of the outcropping Guayana craton, on the west by the "El Baúl" high and toward the East by the Atlantic Ocean ( Fig. 1 ) .
After the Maracaibo Basin, the Eastern Venezuela Basin occupies second place in hydrocarbonm resources in all of South America (without counting the Orinoco heavy and Extra-Heavy Oil Belt). The well, Babaui-1, drilled in 1913 in the Guanoco area, initiated the petroleum industry in the Eastern Venezuela Basin.
Total acumulated production, to the end of 1990, reached the figure of 10 billion barrels. Before the discovery of the deep Musipan-El Furrial-Boquerón trend, Martínez in 1976 mentioned the presence in this basin of 32 oil fields, each with more than 100 million barrels. The best known of these fields are: Guara, Mata, Jusepín, Oficina and Quiriquire.

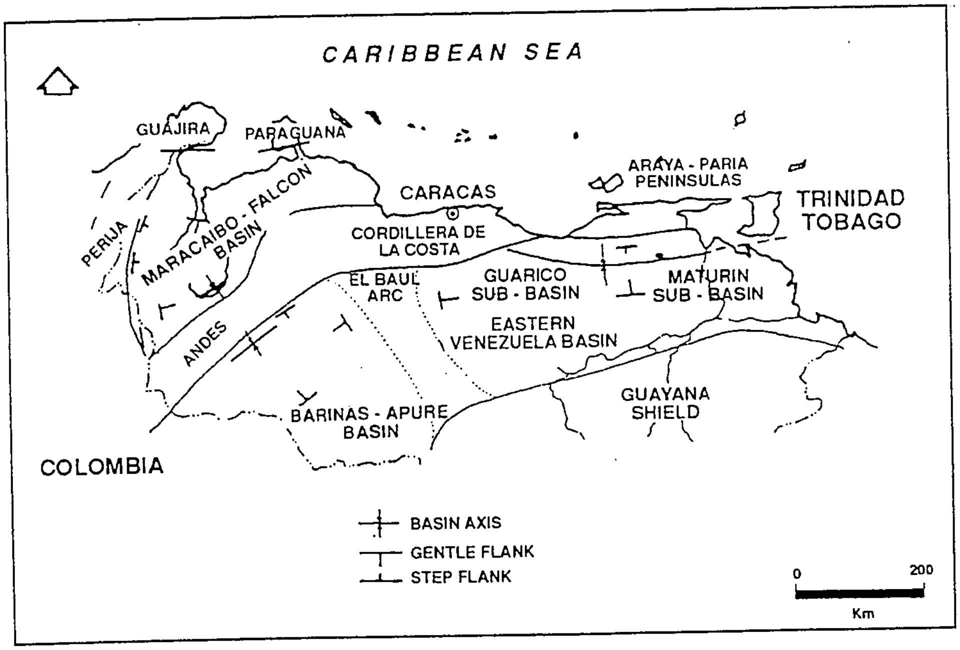



Fig. 1. Northern Venezuela tectonic elements.
( From Lilliu .1990 ).

A North-South cross section of the basin passing through Maturín can be divided into three distinct zones which are, from South to North:

1. **The Orinoco Belt**
2. **The Maturín sub-basin**
3. **The Interior Mountain Range**

The northern border of the Eastern Venezuela Basin is delineated by the "El Pilar" zone of faulting which is the present limit between the South American and Caribbean plates.

# THE ORINOCO BELT

Located along the southern margin of the Eastern Venezuela Basin, parallel to the course of the Orinoco River, The Orinoco Belt covers an area on the order of 52.000 $Km^2$. It is divided, from West to East, into four distinct production zones: Machete, Zuata, Hamaca and Cerro Negro (Fig.2 ) .

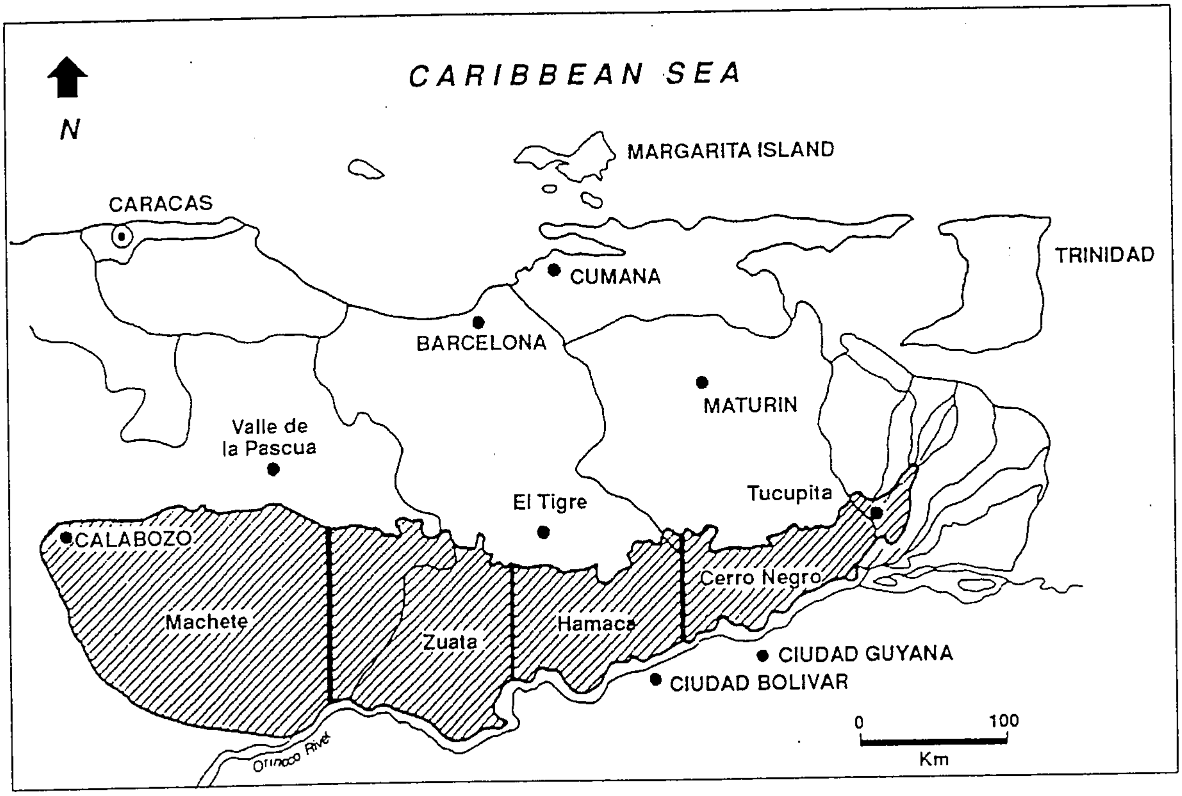



Fig. 2 : The Orinoco Belt.
(From Audemard et Al. ,1985 ).

This belt represents the highest concentration of heavy and extra-heavy oil in the world, with reserves of 150 x $10^9$ barrels. These hydrocarbons, discovered in 1936 by the well La Canoa N° 2, do not possess oil lighter than 15° API.

# THE ORINOCO BELT, ITS STRATIGRAPHY

Discordant upon the igneous-metamorphic Precambrian basement, or upon the Cretaceous series, the Tertiary column of the Belt was divides by Audemard et al (1985) into three transgressive-regressive sedimentary cycles, in addition to the Las Piedras (Pliocene) and Mesa (Pleistocene) formations (Fig.3, A and B). The Paleocene and Eocene series known to the North of the Belt were not deposited, or preserved, on the southern flank of the Eastern Venezuela Basin.

The first sedimentary cycle, known only in the Machete and Zuata zones, West of the Hato Viejo fault (Fig.4 ), corresponds to the Oligocene. In these western areas the Oligocene cycle is made up by the La Pascua, Roblecito and Chaguaramas Formations.

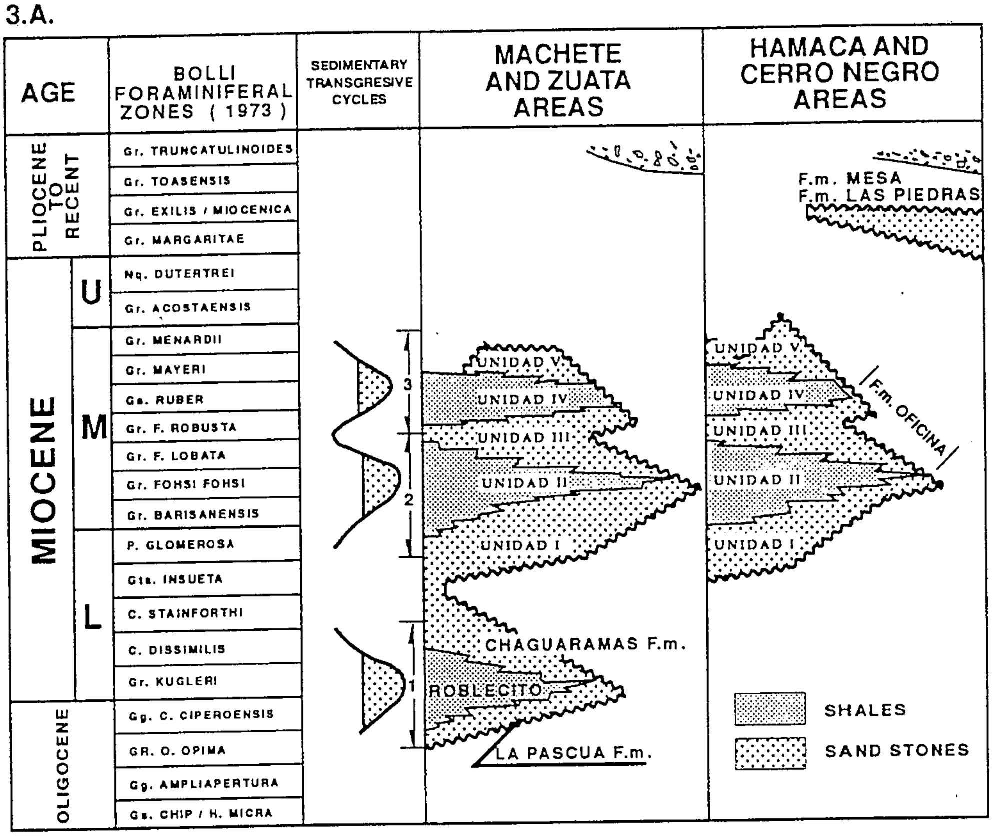
This transgressive.regressive cycle rests discordantly upon the Cretaceous series, which, in turn, rest discordantly upon a Lower Paleozoic series (Di Giacomo; 1985, Benedetto and Puig; 1985). The regressive facies of the Chaguaramas Formation is limited at its top by a possible erosion surface. The maximun transgression of the Oligocene is represented by the states of the Roblecito Formation.

The second cycle rests discordantly on the igneous-metamorphic basement in the eastern part of the Belt and corresponds to the major part of the Oficina Formation. This cycle was divided by Audemard et al. (1985) into three units which are: 1) Sandy transgressive, II) Shaly in the maximun transgression and III) Sandy regressive. Detailed study of unit I has permited differentiation of two subunits in the western sector, of which the first, lower, is composed of massive, prograding sandstones deposited in a deltaic environment. One cannot rule out the presence of a discordant surface between these two subunits. This sedimentary cycle has its maximum transgressive peak during the early part of the Middle Miocene, foraminiferal zone of **Globoratalia foshi foshi**, which is marked by the El Yabo Member of the Oficina Formation in the Cerro Negreo area, equivalent to the Unit II described by Audemard et Al. (op.cit) (Fig.5 ). Unit III is separated into two parts by an internal discordance which constitutes the limit between cycles 2 and 3 of Miocene age.

The third cycle, composed of the upper part of Unit III plus Units Iv and V corresponds to the upper part of the Oficina Formation plus the Freites Formation. Unit IV, represented principally by shales corresponds to the maximum of the transgression, which has been dated as the later part of the Middle Miocene (foraminiferal zone of **Globigerinoides ruber** of Bolli, 1977). From the formational point of view this Unit IV is equivalent to the Freites Formation (Fig.5).

The Post-Miocene deposits correspond essentially to the Las Piedras Formation and are composed principally of sand of continental character.

3.A.




3.B.

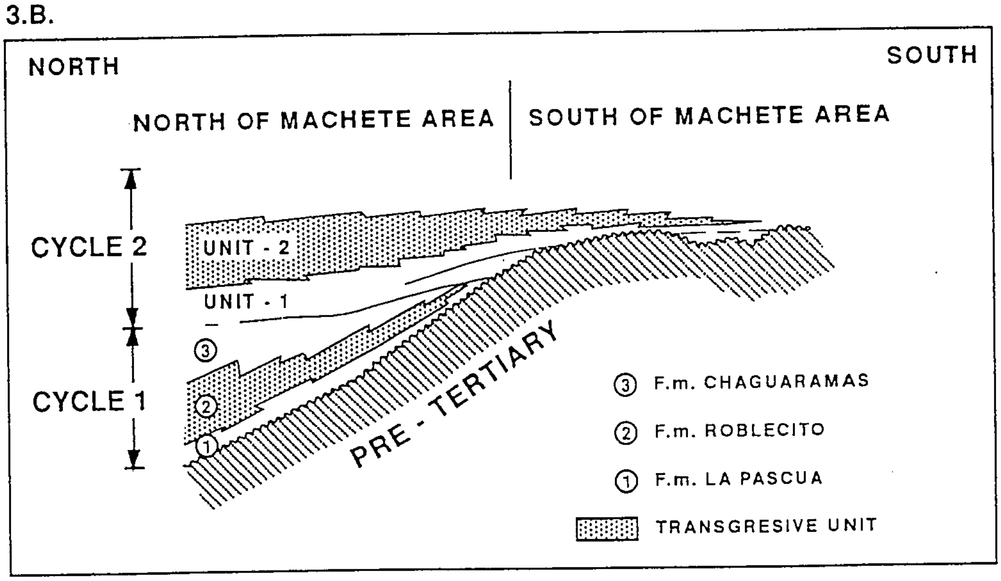



Fig.3 : Age of different transgressive cycles ( Fig.3A ) and schematic section of Machete area (Fig.3B).

(From Audemard et Al; 1985 )

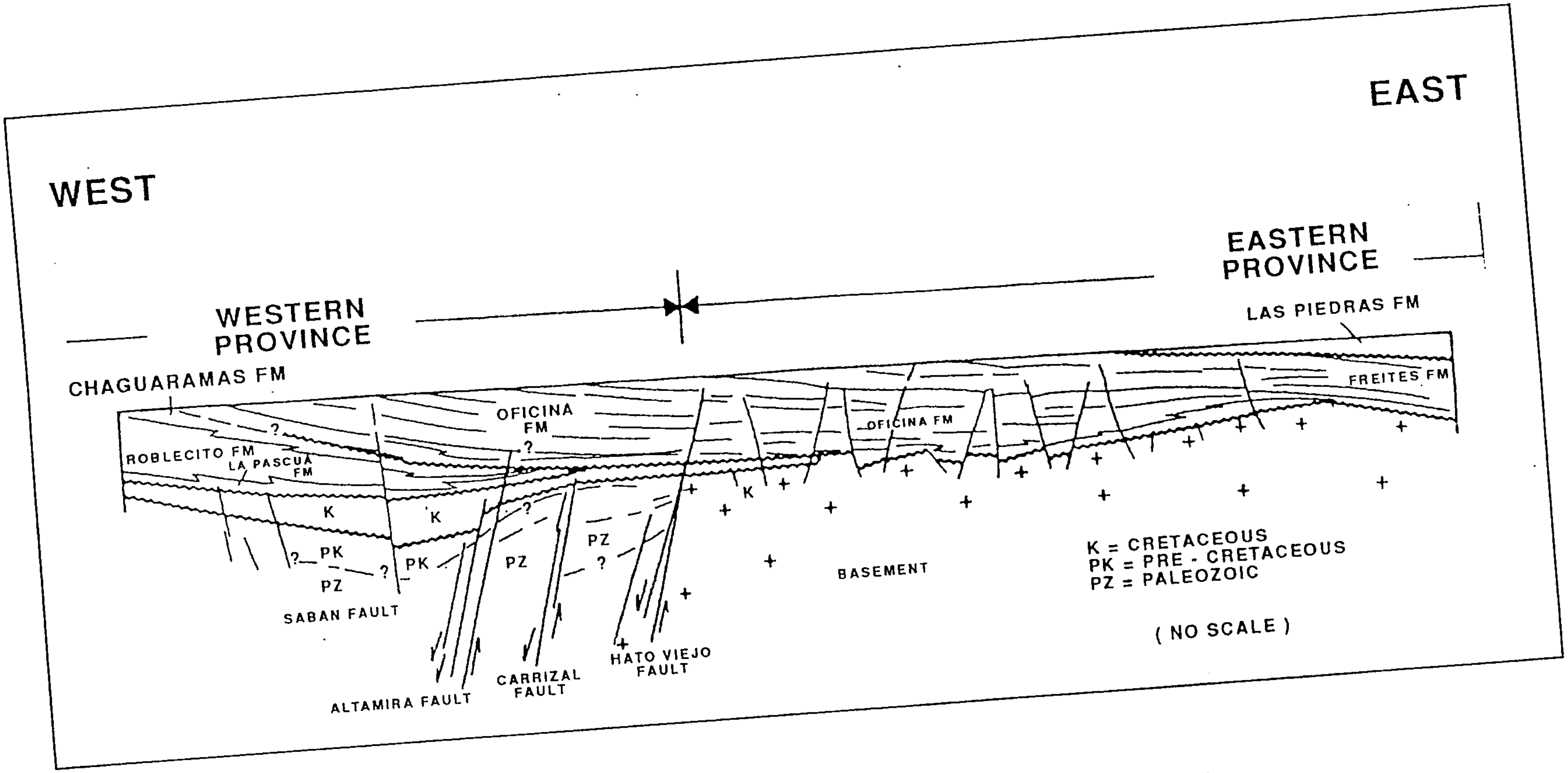



Fig.4 : Schematic structural configuration of the Orinoco Tar Belt.
(From Audemard et Al ;1985 )

# THE ORINOCO BELT: STRUCTURAL STYLE

The pinchout of the Tertiary sediments above the Cretaceous series and, especially above the igneous-metamorphic Precambrian basement, is affected by numerous East-West normal faults with a vertical throw generally less than 150 feet (Fig.4).

Based upon the depth of the Precambrian basement two provinces have been defined, separated by the Hato Viejo fault (Audemard et al, 1985). In the areas of Hamaca and Cerro Negro both the basement and the Tertiary rocks are cut by numerous faults while in the Machete and Zuata zones two generations of faulting can be differentiated. The first cuts only the Paleozoic or Cretaceous sediments, as the case may be, without affecting the Tertiary cover. The second shows the reactivation of the older faults during the Tertiary, as is the case of the Hato Viejo fault, and demonstrate extension tectonics during Oficina time.

These movements took place before the end of the Oficina time since the Oficina top is not affected which indicates an Early Middle to Middle Miocene age for the vertical movements which took place in this sector of the Eastern Venezuela Basin.

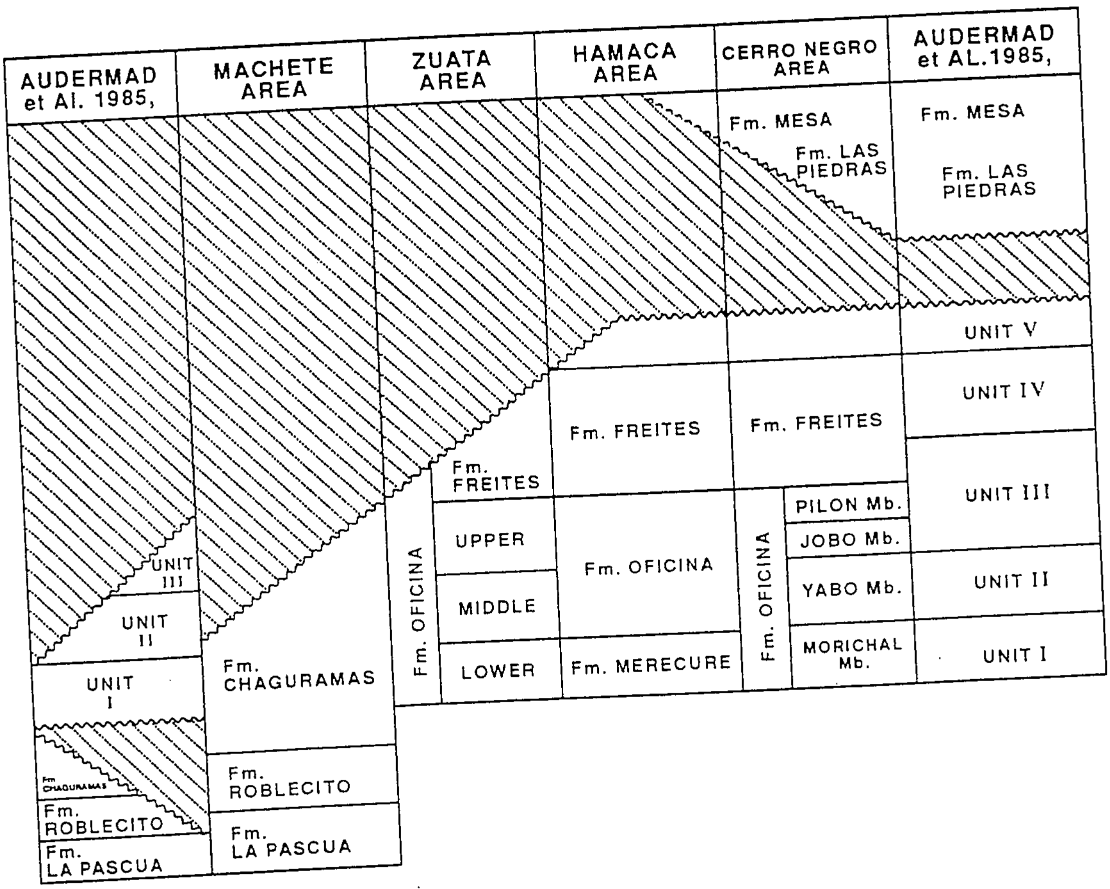



Fig.5: Relation between the transgressive cycles and the formationnal division of the tertiary sediments of the Orinoco Belt.
(From Audemard et Al ,1985 )

# THE MATURIN SUB-BASIN

Separated only by a limit on crude variation from the Orinoco Belt, the Maturin sub-basin,, of Tertiary to Recent age, has a tectonized northern flank, corresponding to the first pulsations toward the South of the Interior Range.

Due to the presence of numerous oil seepages along the mountain front, the northern flank of the Maturin sub-basin was the object of an important hunt for hydrocarbons from the beginning of this century. This led to the discovery of the fields of Quiriquire (1928), Orocual (1933), Jusepin (1938), Manresa (1954) (González de Juana et al., 1980), where the reservoirs are less than 9,000' deep; since then ,deeper and deeper wells have been drilled. After a first successful campaign of deeper drilling in Orocual in 1985, Lagoven, S.A. discovered the giant Furrial-Musipan trend.

The Maturin subbasin can be divided structurally, as well or stratigraphically, into two tectonic provinces and into three sedimentary megasequences all of which are associated with the geodynamic evolution of this "foreland" basin.

## THE MATURIN SUB-BASIN: TECTONIC CHARACTERISTICS

Under the Plio-Pleistocene sediments which fill the basin, two tectonic provinces have been recognized by seismic data: a southern, extensional province and a northern, compressional province which correspond to the compressional front of the Interior Range.

1. The Extensional Province

Two types of structures can be recognized. The first type is characterized by the presence of numerous normal faults which cut the Precambrian igneous-metamorphic basement as well as the Cretaceous and Tertiary sedimentary cover. These structures, which are very frequent in the Orinoco Oil Belt permitted the entrapment of the oil migrating along the unconformity of Mesozoic and Cenozoic beds upon the basement, (See the regional section ,annex, plate 1 ).

The second family of faults is observed only in the Miocene sediments associated with "Roll Over" structures. These listric faults are dated as middle Miocene due to the presence of an unconformity surface of late Miocene age (Lilliu, 1990; Daza and Prieto, 1990, Fig.6). However, certain seismic lines show a reactivation of growth faults during the Plio-Pleistocene (Daza and Prieto, op. cit.).

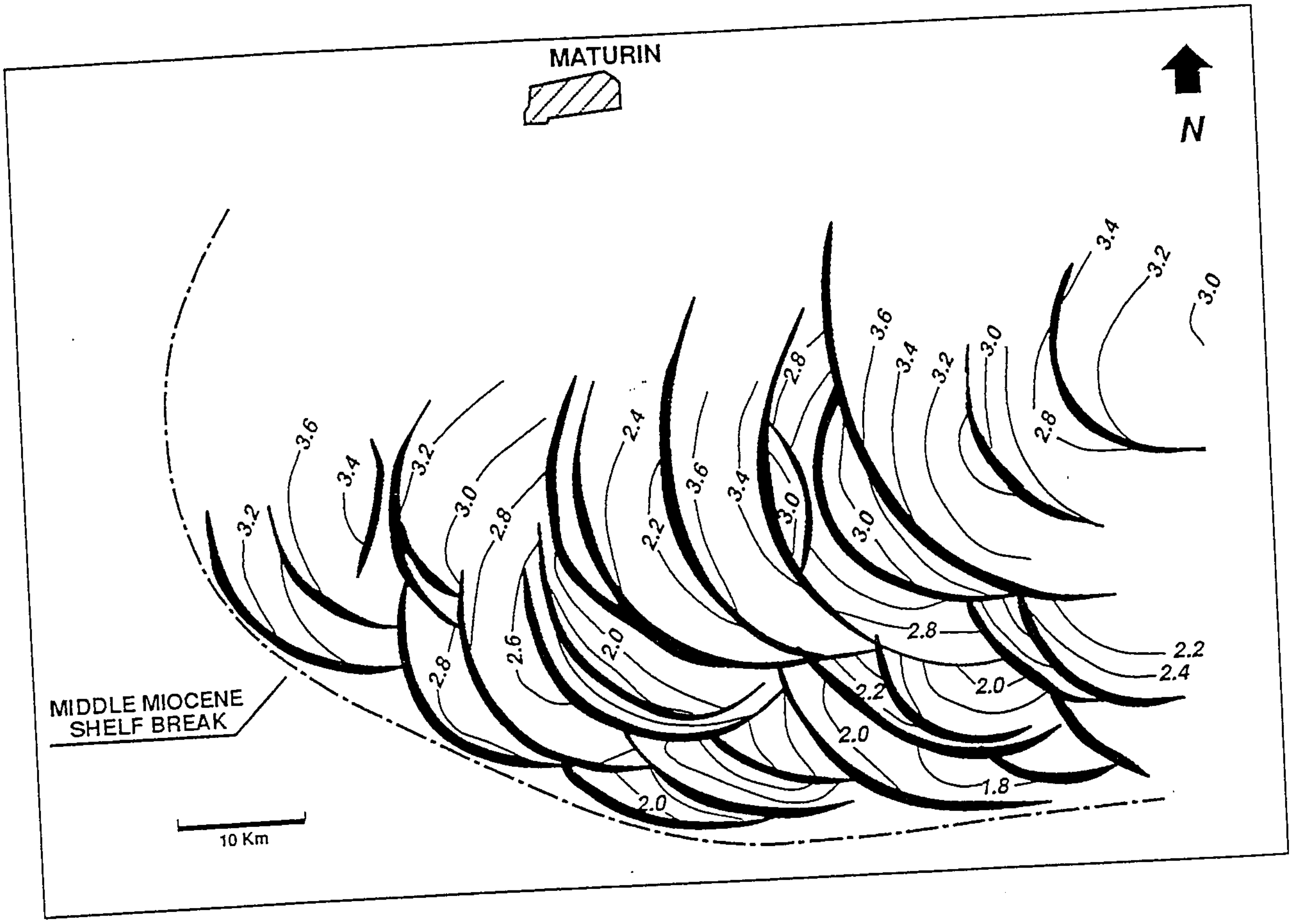



Fig. 6: Generalized map of the growth faults in the Mapirito-Soledad-Casma Area. Top of Freites Formation. ( From Daza and Prieto, 1990 ).

## 2. The Allochthonous Province

This province corresponds to the zone of frontal sheets developed during the sedimentation of the shales of the Carapita Formation. The order of appearance of each sheet is normal, with the youngest to the south, due to tectonic transport from the northwest toward the southeast. A schematic North-South section from southwest of Maturin northward to the mountain front in the vicinity of Manresa permits one to observe the following geometries (See regional section, plate 1).

1. The Frontal backthrust:

The development of the thrust sheets of well-consolidated pre-Lower Miocene material under an important thickness of shales of the Carapita formation involved the creation of a triangular zone as a frontal effect of the deformation ( Chevalier and Alvarez 1991;Gonzalez et Al 1992 ).

2. The frontal imbrications of the shales of the Carapita Formation:

A series of duplications in the shales, due to plastic behavior, has been interpreted in the triangular area in the Carapita formation (Chevalier and Alvarez, Op Cit.-Lilliu and Cabanach, 1992).

3. The Amarilis Sheet:

Due to limitation to the South by the Amana thrust (Lilliu, 1990) the Amarilis sheet is composed primarily of Carapita shales with productive levels of turbidites.

4. The Furrial Sheet:

Located between the thrust sheets of Maturin, to the south, and Masacua to the north, (La Toscana thrust sheet according to Lilliu, 1990), the Furrial sheet corresponds to an asymmetrical ramp-type mega-anticline, 5 to 8 kilometers wide and 50 Km long. The axis of the structure dips gently to the East and is cut by several tear-faults, which separate the giant reservoirs of Carito-Musipan-El Furrial and Boquerón (Gutiérrez, 1988; Carnevali, 1991).

5. The Orocual Sheet:

In the deep Orocual field the geometry of this sheet, limited to the north by the complex Pirital thrust, corresponds to a ramp type mega-anticline with several backthrusts on the northern side of its hinge. (Matesco S., 1989).

6. The Manresa Sheet:

This last northern most sheet of the Maturin sub-basin represents the subsurface prolongation of the structures cropping out in the mountain front. In the front of this sheet one observes a tectonic thickening of the Carapita shales affected by late-stage clay flowage, the conglomerates of the Morichito Formation lie upon this sheet and represent a tilting of the strata to the North. Several explanations for this complex geometrical configuration have been advanced. At present, the most commonly suggested hypothesis is the presence of a "piggy back" basin North of the present Pirital High (Lilliu, 1990; Carnevali, 1991). To explain the curved geographic form of the trace of the Pirital thrust in the subsurface, Carnevali (op.cit.) has a proposed that this sheet is an out-of-sequence thrust.New studies indicate that the sediments of Morichito Formation represent the proximal facies of a more extensive sequence ,that extends to the South of the actual Pirital High;this discards the piggy-back hypothesis ( Gonzales G. and Mata S. ,report in progress 1991; Linares L.M. 1992 ).

One suspects that there are several levels of detachment in order to create the structures observed in the deformation model. This presumes a plane of detachment in an unknown stratigraphic level of pre-Barranquin age in the Early Cretaceous.

A second level of detachment, even greater, according to Lilliu (1990), developed in the black shales and limestones of the Querecual Formation of Cenomanian-Turonian age. However several shear zones occur in the shales of the Carapita Formation, giving rise to more flowage over the underlying thrust sheets.

The age of the tangential deformation in the Maturin sub-basin is contemporaneous with the sedimentation of the Carapita Formation of Early to Middle Miocene age. A chronology of the different pulsations was proposed by Potié (1989).

The first indication of compression in this sub-basin, basal Lower Miocene in age, was that responsible for the unconformity described by Lamb and Sulek (1968) between the C. dissimilis zone and the G. ampliapertura zone of foraminifera in the Quiriquire area.

The second pulsation was reported by Rossi (1985) and is of latest Lower Miocene age.

The third, and most outstanding in the Quiriquire area, is responsible for the turbidites of the Chapapotal member of middle Miocene age, G. Fohsi zone (Lamb and Sulek, 1968; Rossi, 1985), and the tectonic phases of the early Middle Miocene near the top of the G. Fohsi peripheronda zone.

These wide-spread pulsations were responsible for the migration to the South of the Carapita Formation depocenters and, as a result, for the progressive migration of the "Onlap" toward the South over the basin foredeep. During the post-tectonic phases of the filling of the Maturin Sub-basin with sediments of the La Pica, Las Piedras and Mesa formations, because of the lithostatic pressures clay flowage was developed to such an extent that diapirs were formed. These clay and mud domes are aligned in belts which follow the trace of the underlying thrust zones.

## THE MATURIN SUB-BASIN: ITS STRATIGRAPHY

Three periods of sedimentary evolution of the Maturin subbasin can be differentiated, The first period corresponds to a passive margin stage during which all the sediments were derived from the South and Southwest, The second stage is characterized by the uplift of present Interior Range and by sedimentation from the North. During this stage, of Early to Middle Miocene age a foreland basin was developed. The third period consists of the infill of the basin by post-tectonic sediments.

### 1. The Passive Margin Stage

The Cretaceous history of the subbasin is little known due to the slight amount of drilling to these levels. For Northern Monagas it is believed that the Cretaceous and Paleocene sequence is equivalent to that of the Interior Range (see the next chapter - Chiock M. 1985). Farther to the south, in Central Monagas, the known Cretaceous facies are more sandy and near-shore (Canoa and Tigre Formations, (Fig.7).

Before the start of the Neogene cycle there was an important regressive phase which produced a regional unconformity with a hiatus of 38 million years in the El Furrial field (Fasola and Paredes, 1990).

The transgressive sands of Oligocene age in Northern Monagas are excellent reservoir rocks with an average of 15% porosity and a permeability of 500 md (Salazar, 1990; Aguado et al., 1990; Isea et al., 1990).

### 2. The syntectonic facies of Lower to Middle Miocene (Carapita and Oficina Formations)

This second stage in the history of the Basin constitutes a brusque change in sedimentary dynamics. One encounters for the first time

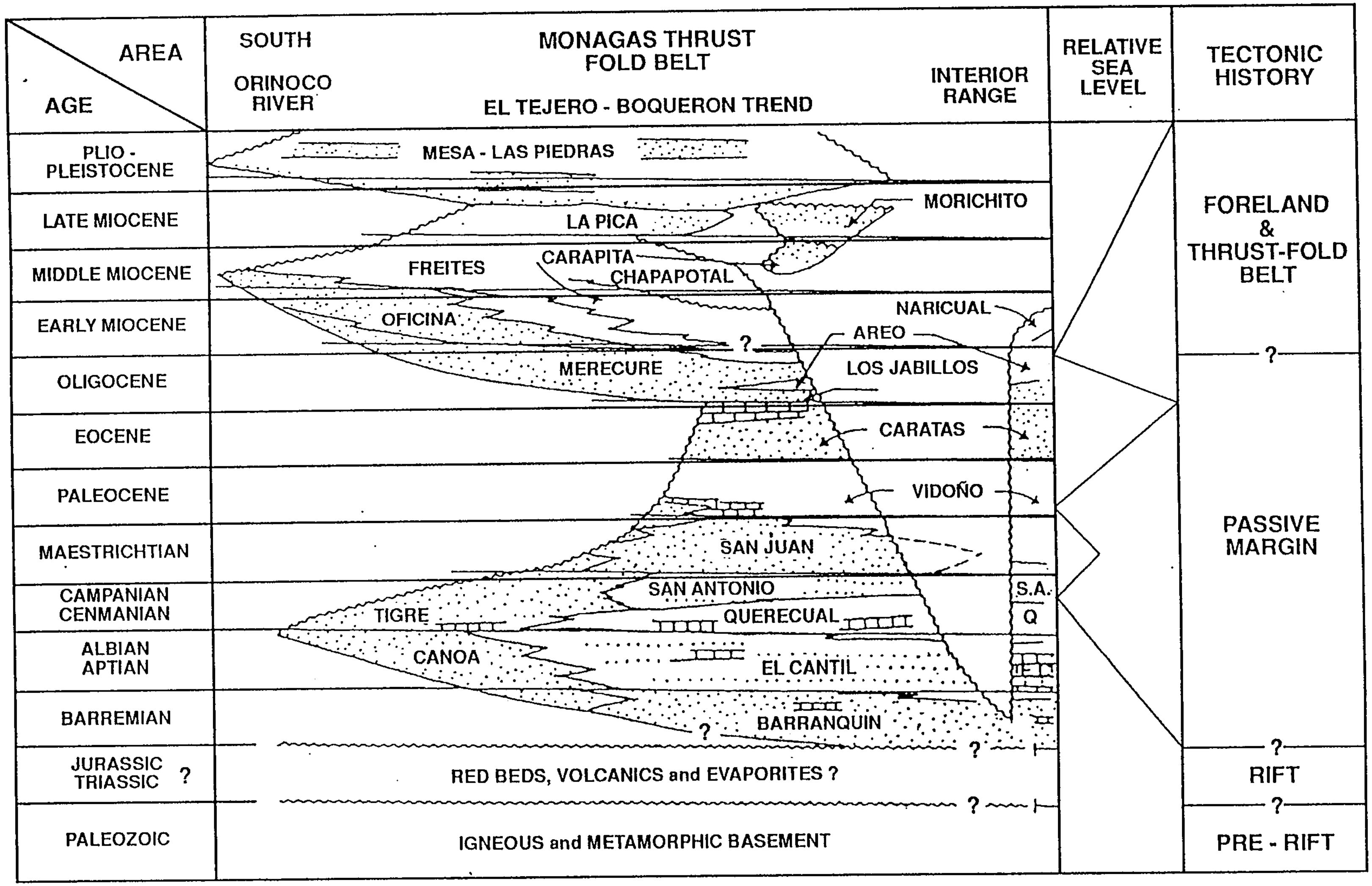



Fig. 7 : Generalized tectono- stratigraphy diagram in the Maturin Sub-Basin.
( From Carnevalli ,1990 ).

in the pelitic basin fill, in the process of basin sinking, the arrival of turbiditic material indicating the erosion of the Interior Range.

The conglomeratic levels of Chapapotal and Cachipo (Lamb and Sulek, 1968; Sulek and Stainforth, 1965) and the turbidites of Amarilis ( Barrios F. and Sams R. H.1992 ) are an indication of the inversion of polarity of sediment entry into the Basin. The important quantity of pelites rich in foraminifera of the Carapita Formation can be correlated with the outlet of the paleo-Orinoco river into the foreland basin in process of formation.

Farther to the South the Carapita Formation passes laterally into the Oficina Formation (See previous chapter). Toward the East the turbiditic and conglomeratic lenses, such as the Chapapotal member, correlate with the Herrera and Retrench of the Cipero Formation of Trinidad (Lamb and Sulek, op. cit.).

Of a thickness of 6000 feet in the basin the Carapita Formation crops out in the stream with the same name with a thickness of only 1000 meters. (Stainforth, 1971-see chapter on stratigraphy of the Interior Range).

## 3. The Mio-Pliocene post-tectonic series: The Formations La Pica, Morichito, Las Piedras, Quiriquire and Mesa

The upper Miocene and Pliocene correspond to the progressive filling of the basin, still subsiding, with, first, marine, and later, continental sediments.

### 3.1. The Upper Miocene: Morichito and La Pica Formations

After a last compressive pulse which formed a high to the North of the Pirital thrust, followed by a period of erosion two chronologically equivalent sequences were deposited:

- the Morichito Formation located North of Pirital is characterized by sandy and conglomeratic deposits with a thickness of at least 1500 meters (Lamb and De Sisto, 1964).

- The La Pica Formation was deposited toward the South over the Carapita

Formation, which was deformed and partially eroded in the zone of thrust sheets, or concordantly over the Middle Miocene under formed series of the foreland area, With 800 to 2000 meters of thickness this Formation, made up of sandy-pelitic materials was subdivided by De Sisto (1960) into zones designated A to F, in the Jusepin area. The La Pica Formation grades laterally toward the South into the upper third of the Freites Formation (Gonzalez de Juana et al., 1960).

## 3.2 The Pliocene Formation Las Piedras and Quiriquire

Described first in the well Las Piedras-1 (González de Juana op. cit.), the Las Piedras Formation consists principally of clay shales, clays and siltstones (González de Juana et al., 1980). This formation is composed of two members in the Northwestern part of the Maturin Subbasin: Prespuntal Member (below) and Caicaito Member (above) separated by an unconformity. In this area these lie discordantly upon the Quiamare Formation (see chapter on the stratigraphy of the Interior Range); but in the greater part of the basin the Las Piedras Formation is concordant upon the La Pica or Freites formation. The mollusca, characteristic of fresh-water, fluvial environments suggest a Pliocene age.

In the Quiriquire field, the stratigraphic interval of the Las Piedras Formation is composed principally of conglomerate beds which are grouped together as the Quiriquire Formation. This Formation, which is discordant on the older beds, is 1500 meters thick in the type well, but forms a wedge which thins towards the North and thickens toward the South, grading into finer materials (González de Juana, op. cit.).

## 4. The Pleistocene

The Mesa Formation is recognized along the mountain front where it rests in angular unconformity upon all the previous formations. It is made up mainly by conglomerates and clays. Although the stratigraphy of the quaternary is well-known, González de Juana (1946), suggested a double source for the Formation, one deltaic and the other alluvial fans.

# THE INTERIOR RANGE: ITS STRATIGRAPHY

The stratigraphic column of the Interior Range begins with the Barranquin Formation of Early Cretaceous age and ends with the Pleistocene Mesa Formation (Fig.8 ). The base of the sedimentary column is unknown. It is believed that there exists a sedimentary series of Jurassic-Paleozoic rocks upon an igneous-metamorphic basement.

## THE EARLY CRETACEOUS

During this period, the sedimentation corresponds to a continental platform area. The Barranquin, El Cantil and Chimana Formations were deposited. The known thickness of this Early Cretaceous series is 3000 meters, with the following succession.

1. The Neocomian Barremian-Aptian:

At the South of the Interior Range, near Pico Garcia, a thick terrigenous series of 2400 meters, characterized by facies deposited in a littoral to continental environment crops out.

To the North, in the Rio Grande area, near the Gulf of Cariaco two horizons of limestones interdigitate with the terrigenous facies, constituting the 800 meters of Lower Cretaceous known.

- The lower level, named the Morro Blanco Member of the Barranquin Formation, is composed of meters-thick beds of bioclastic and calcareous pelites containing Nannoplancton (Nannoconus colomii, det. C. Muller) and benthic foraminifera (Choffatella decipiens, det. M. Furrer) of Barremian age.

- The upper level, of late Aptian age (Bedoulian) corresponds to the Taguarumo Member of the Barranquin Formation.

The top of the neritic limestones is characterized by the presence of Rudistids (Caprina sp and Amphitricoelus sp gr waringi; det. J.P.Masse), The algal flora found is clearly Mesogene (Macsotay, 1980, J.P. Masse in Rossi, 1985).
The southern extension of the Bedoulian rudist-containing limestones is found in the mountain front with a very reduced thickness.

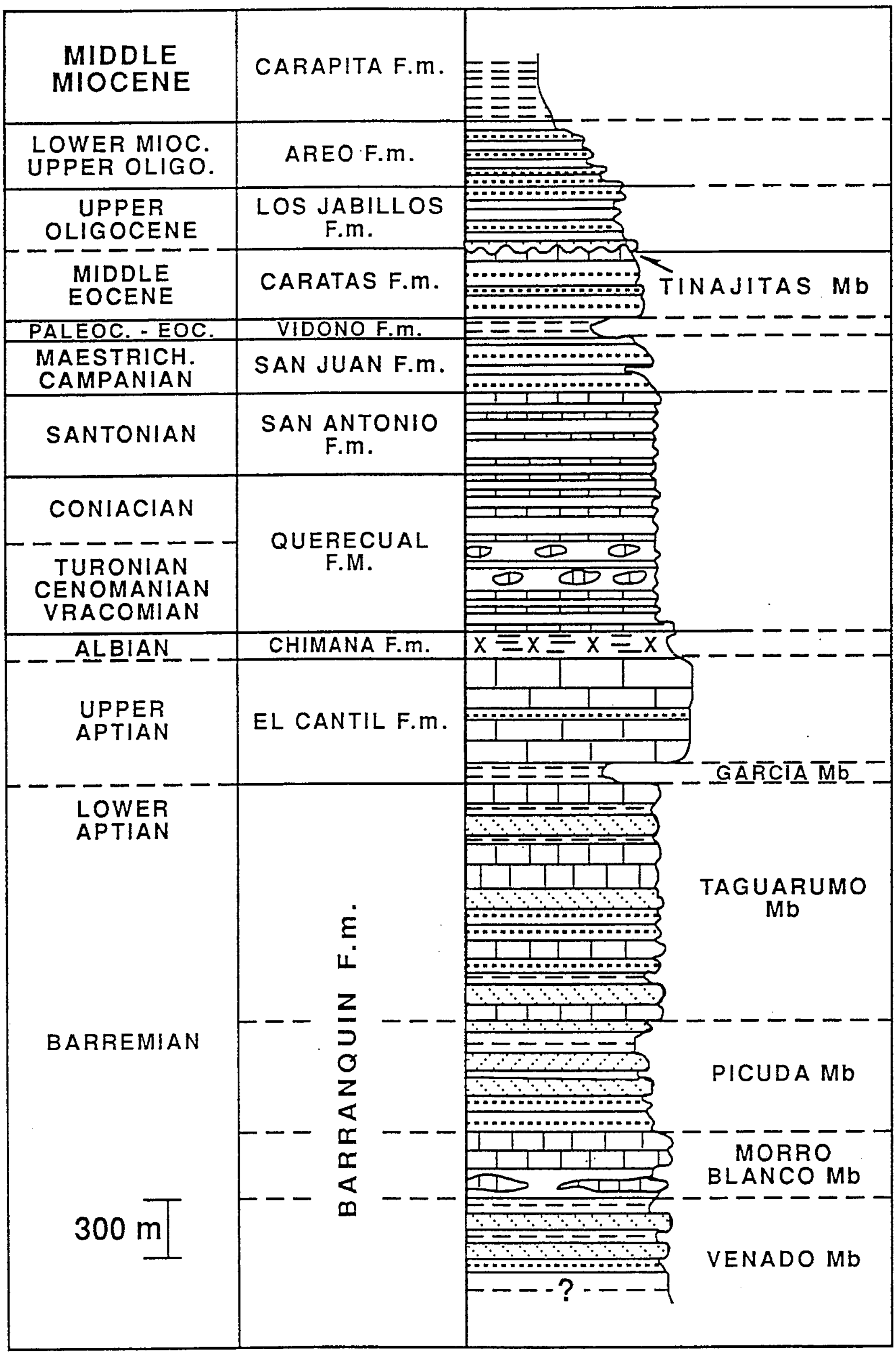



Fig. 8 : Schematic stratigraphic column of the Interior Range.

## 2. The Basal Upper Aptian

El Cantil Formation, Garcia Member: The sedimentation of a clayey series with levels of glauconite covers the entire area. With a thickness of 60 to 100 meters maximum these clayey beds correspond to the Garcia Member of the El Cantil Formation, or to the base of the Chimana Formation when the pelitic beds are persistent.
The study of its fossil content (planctonic foraminifera, ammonites and pollen) has given an age of late part of the Early Aptian in the planctonic foraminiferal zone of Chakoina cabri (Odehnal and Falcon, 1989), while its content of ammonites yield an age of earliest Late Aptian (Zone A. Nisus of Lower Gargasian, det. J.P. Thieuloy in Rossi et al, 1987) (Fig. 9 ).

## 3. Upper Aptian-Lower Albian

The sedimentation of this time is characterized by great lateral variations, among which it was possible to distinguish four isopachous domains in the transect Cariaco-Aragua de Maturin (Fig. 9 , Rossi, 1985).
From South to North one observes:

3.1. A southern platform area

This first area extends northward in the El Canton sector. Two sub-provinces were differentiated:

- A sub-province where an alternation of neritic limestones, pellites and quartz clays with a thickness of 800 meters were deposited.

  This thick series corresponds to the El Cantil Formation sensu stricto (Rosales, 1959, Guillaume et al, 1972).

This alternation passes progressively toward the North into two distinct lithological sequences:

- A lower, sandy sequence 20 meters thick in the Caripe sector and of 100 meters thickness in the El Canton sector, which corresponds to the Mapurite Member of the El Cantil Formation (Guillaume et al, op. cit.)

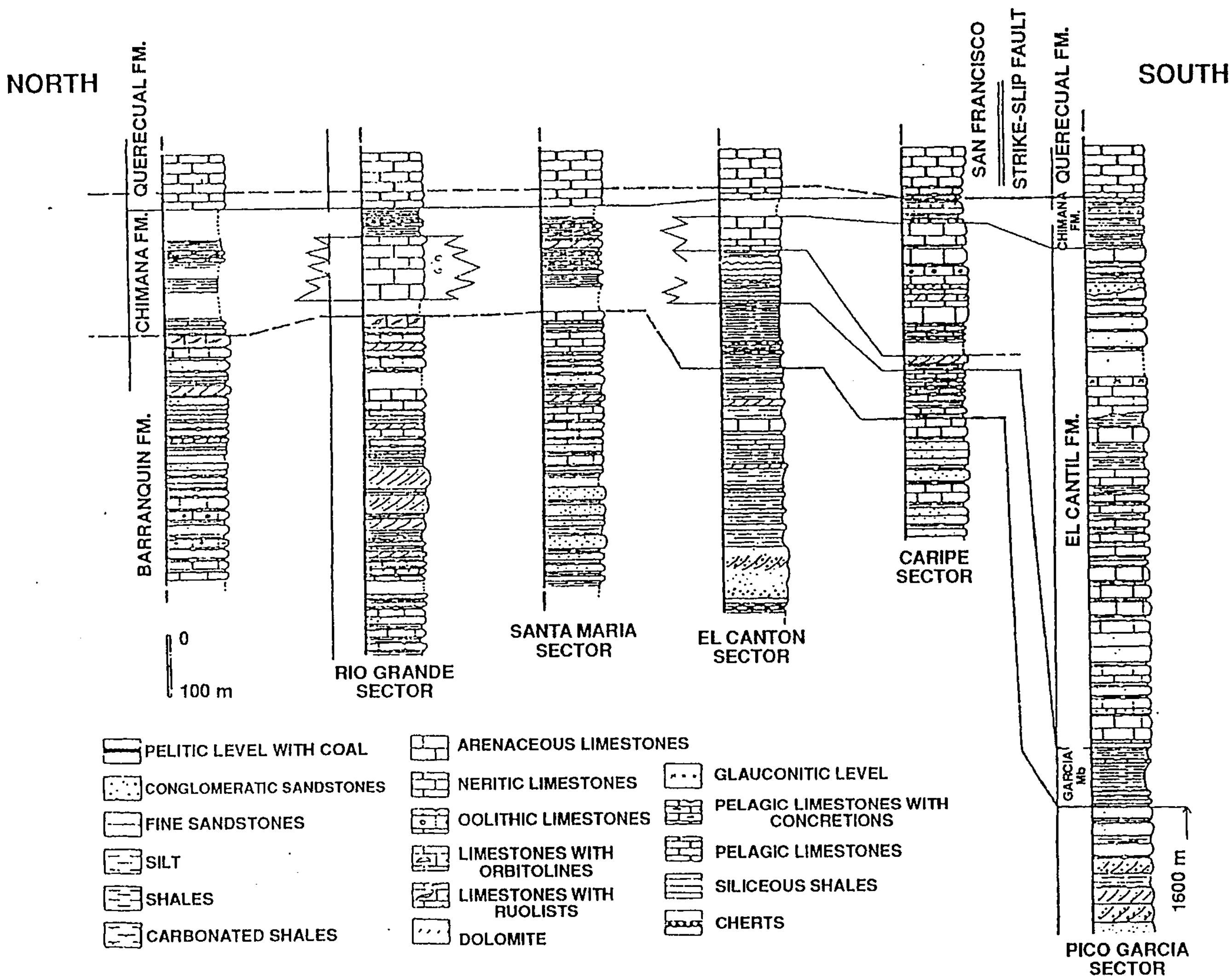



Fig. 9 : Lower cretaceous stratigraphic columns along the Aragua de Maturin --Cariaco transversal section.

(From Rossi ,1985).

- An upper carbonate sequence made up of thick limestone beds of outer platform character, with variable thickness, being 400 meters thick in the El Canton sector. These massive limestones constitute the Guacharo facies of the El Cantil Formation. The limestones of this formation member are characterized by the development at their top by levels of Orbitolina (Mesorbitolina) texana which indicates an age in Venezuela of Late Aptian-Early Albian (Rossi et al, op. cit.).

3.2 A central dominion; in Santa Maria-Santa Cruz area

This area is characterized by the absence of massive beds of limestone. One notes the persistence of pelitic and calcareous sedimentation with a planctonic fauna. These facies are grouped under the term Chimana Formation, Valle Grande Facies. Rossi (1985) included under this designation the Cutacual Formation described by Metz in 1968.

3.3 A northern shallow water dominion

In the northern part of the Cariaco-Aragua de Maturin transect one encounters again the Valle Grande facies of the Chimana Formation; The pelitic series is characterized by the abundance of pelagic fauna (ammonites, belemnites, foraminifera and nannoplancton) of Late Aptian-Early Albian age (Rod and Maync, 1954, Guillaume et al, 1972).

3.4 The upper and Middle Albian (Chimana Formation)

The Middle Albian is characterized by pelitic deposits with ammonites, especially in the area of the Interior Range. These sediments, deposited under nearshore conditions, are relatively thin on the order of 50 meters.

The Upper Albian presents a variation in facies, indicating a relative lowering of sea level. Although pelitic sedimentation continued in the northern part of the Interior Range, to the South near the mountain front a sandy series, locally with microconglomerates, rests directly upon the pelitic levels of Middle Albian age.

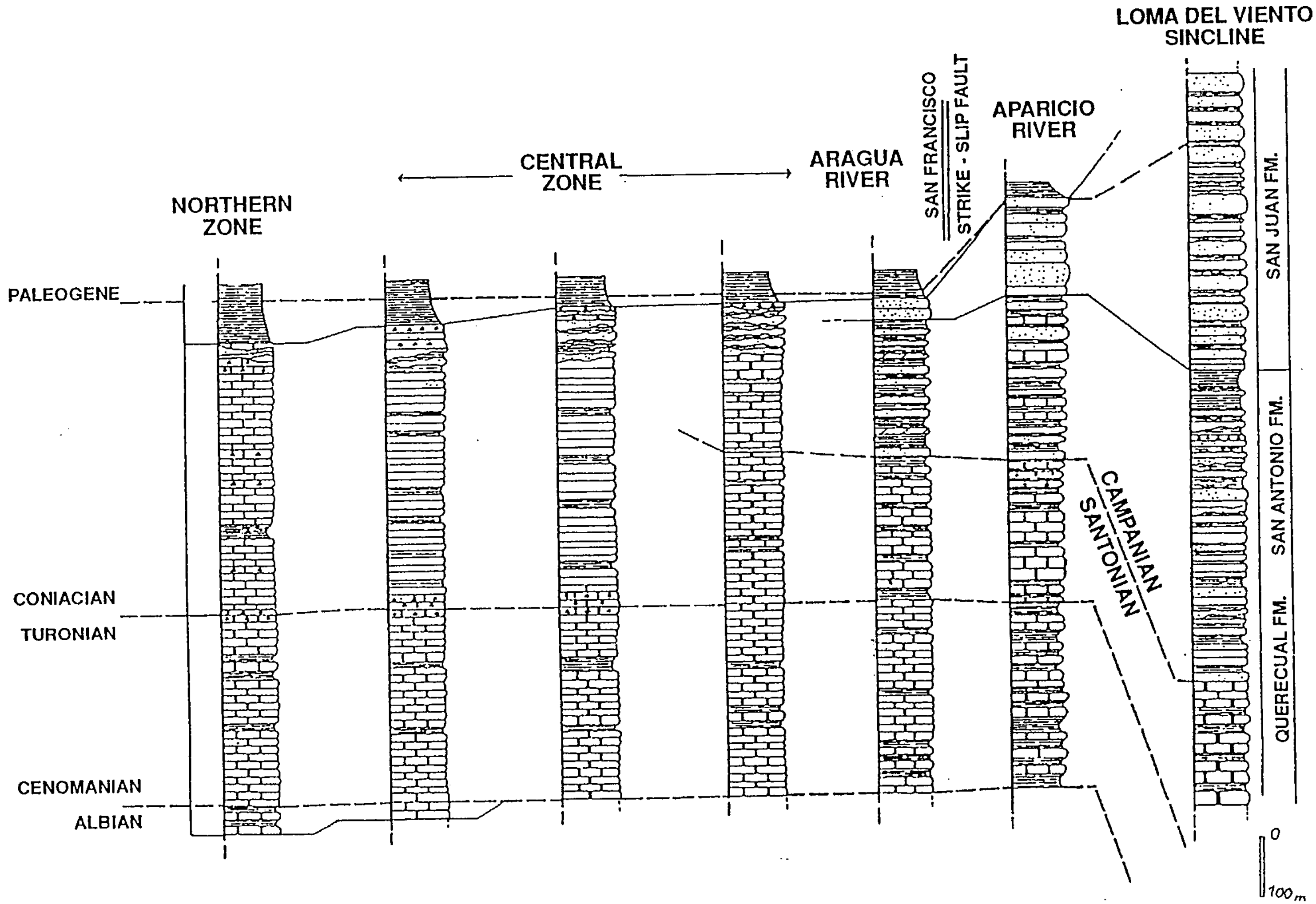



Fig. 10 : Upper cretaceous schematic stratigraphic columns along the Aragua de Maturin -- Cariaco transversal section.

(From Rossi ,1985 ).

Terminal Albian (Vraconian) (Querecual Formation). The Vraconian is recognized world-wide as the initiation of the Cenomanian transgression. Over this entire area of the Interior Range there began pelagic sedimentation. The contact between this series and the underlying ones appears to be diachronic toward the South. The facies of this period belong to the Querecual Formation, which continues during the Upper Cretaceous.

## THE LATE CRETACEOUS

The Late Cretaceous is made up of the Guayuta Group, which in composed of the Querecual and San Antonio Formations. This stratigraphic level includes also all or part of the San Juan Formation to the South and the base of the Vidoño Formation to the North. The Guayuta Group represents the principal source rock for the hydrocarbons found in the Maturin Subbasin, including the Orinoco Oil Belt.
Three big periods of time correspond over the area to the deposition of the large lithologic groups (Fig.10).

1. The Cenomanian-Turonian (Querecual Formation)

The pelagic and sapropelic sediments deposited during this period are micritic limestones and black pelites, laminated black shales in which one finds concretions and nodules of micrite and pyrite of different sizes.
These beds are rich in pelagic microfauna. The thickness of the Querecual Formation, which is mainly of Cenomanian-Turonian age, is 600 to 650 meters in the type section in Rio Querecual (Vivas, 1986). At the position of the Cariaco-Aragua de Maturin transect its thickness is on the order of 250 meters.
The basal contact corresponds to the Albian-Cenomanian contact in the central part of the mountain chain, but is Vraconian in the North. In the Santa Maria-Santa Cruz trench it is presumed to be Early Albian in age (Rossi, 1985) .

2. The lower Senonian (San Antonio Formation)

In the type section of Rio Querecual, The Lower Santonian sediments correspond to the San Antonio Formation and have a thickness of 300 meters (Vivas, 1986). The depositional systems are equivalent to that of the Querecual Formation, but less anoxic.

Along the Cariaco-Aragua de Maturin section, the fossils found indicate an age of Santonian-Maestrichtian. The stratigraphic contact between the Turonian and Coniacian still is hypothetical. In this regional North-South section, the Lower Senonian corresponds to the development of two provinces with different sedimentary environments.

In these sectors, central and northern, the sediments are composed of cherts with clays, of cream color, sometimes calcareous and are characterized by the presence of centimeter-thick zones of black cherts which are lenticular to well-stratified. These phases indicate sedimentation rich in silica and well-oxygenated.

The southern province is characterized by the sedimentation of a pelitic and calcareous series with a very rich concentration of organic matter. These sediments are very hard to separate from those of the Querecual Formation even though they have less parallel-lamination sedimentary structures and have some dolomitic beds.

3. The Upper Senonian (San Juan or sandy San Antonio)

The Upper Senonian is characterized by a diachronic interdigitation from South to North by stratified or lenticular sandstones in the biogenous sedimentation mentioned previously as characterizing the Upper Senonian. The abundance of sandy material and sedimentary structures permits the differentiation of the two formations: the sandy San Antonio Formation and the overlying San Juan Formation.

1. The sandy San Antonio (or lower unit) is characterized by the presence of an important pelagic sedimentary unit (calcareous and siliceous), by the lenticular form of the sandstones and the frequent presence of clastic dikes. The sedimentary environment was bathyal. The existence of Haplophragmoides of shallow waters together with Cyclammina of deep waters points to the presence of reworked sandy materials (Rossi et al, 1987). The arrival of these sands are essentially of Late Senonian age to the South but, to the North, these thin sand units contain radiolaria of latest Campanian age.

2. The San Juan Formation (or upper group) in which one observes the disappearance of the biogenous sedimentary units, has well-stratified and quite thick sandstones (Di Croce, 1989). The thickness to the South, at the mountain front, is 450 meters, but these diminish in thickness very rapidly to the North of Guanaguana. Their age changes with position in the mountain chain; Late Senonian-Paleocene, to the South, Middle to Late Maestrichtian in the Rio Amana Syncline, and Late Maestrichtian in the sector North of Rio Aragua.

## PALEOGENE (VIDOÑO, CARATAS, LOS JABILLOS, AREO AND NARICUAL FORMATIONS).

Due to the near-absence of the Tertiary sediments in the Aragua de Maturin-Cariaco transect, in order to complete the stratigraphy of the Interior Range. We propose a synthesis of the outcropping Tertiary formations along the western border of the chain. The data presented here are taken, mainly, from the doctoral thesis of Victor Vivas (1986) covering the sector Santa Ines-Bergantin, following an ample study by the author of the zones of Piritu-Kilometer 52; Cumana-Turimiquire Range and Barcelona (Vivas, V., 1980-1981, Vivas, V. et.al. 1985;Fig.11 and Fig.12 ).

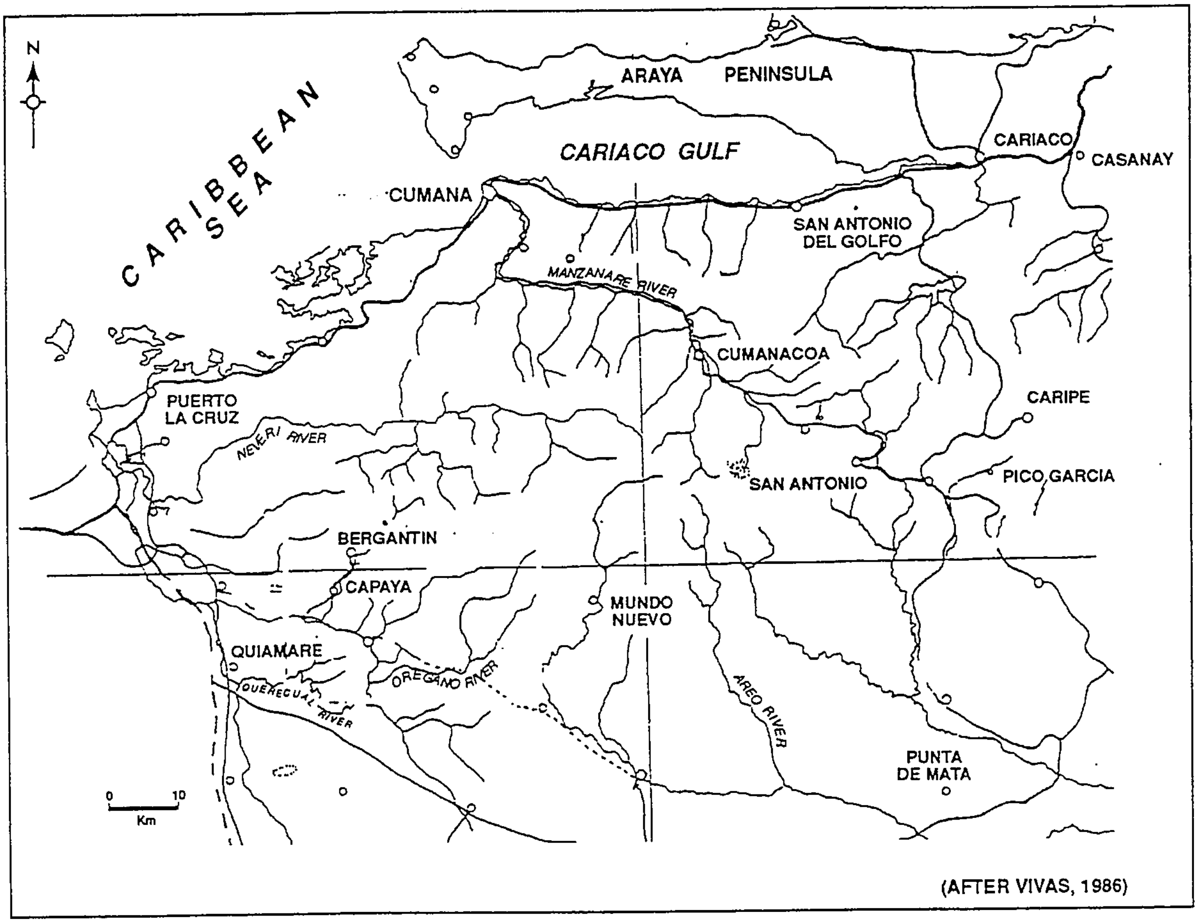



Fig. 11 : Index map that includes locations of type -sections for various Neogene Formations.

( After Vivas ,1986)

1. The Upper Maestrichtian-terminal Paleocene: Vidoño Formation

The Vidoño Formation, deposited in a sedimentary environment of deep water, is made up, essentially, by a pyritic pelitic-glauconitic facies. Of variable thickness, its age is Late Maestrichtian-Paleocene (Vivas, 1986; Hedberg and Pyre, 1944 and Pyre, 1944). Even though Renz (1962) indicated that the black shales in the type section of Rio Querecual contained foraminifera found in the Globotruncana Gansseri zone of the late Maestrichtian to the Globorotalia rex (G. edgari) of terminal Early Eocene age.

2. The Eocene: Caratas Formation

The Eocene facies vary from the West to East. In the Bergantin-Santa Ines sector the Caratas Formation is composed of a detrital-pelitic facies, calcareous, frequently glauconitic, which forms a massive, arenaceous unit. Renz (op.cit.) in his study of the type section in Rio Querecual (315 meters thick) found Globigerina linaperta (Finlay), Globorotalia bronnimann; and Globorotalia Wilcoxensis (Cushman and Ponton) in the lower and middle part of the section, this association indicates a Lower Eocene age.

In this sector, the Caratas Formation has in the top an essentially calcareous sequence which is very fossiliferous which is designated the Tinajitas Member (Salvador, 1964), of late Middle Eocene age, of the zones P13-P14 of planctonic foraminifera, belonging to the zones: Orbulinoides beckmanni and Truncorotaloides rohri to the East. In the Rio Amana area a pelitic-sandy section 350 meters thick is found with interbedded glauconite beds in the basal part. In its upper part this formation is locally coaly. Foraminifera and Nannoplancton permit an age determination of Early to Middle Eocene in this facies (Lamb, 1964; Rossi, 1985). However in the upper part some foraminifera of younger age have been identified: Globorotalia cerroazulensis of Late Eocene age (Contreras and Hernandez, 1982) and at the top Globigerina ampliapertura of the terminal Eocene-Early Oligocene.

3. The Lower Oligocene (upper part)- basal Middle Oligocene: Los Jabillos Formation

Lithologically the Los Jabillos Formation corresponds to an arenaceous sequence, subdivided into centimeter-to meter-thick beds of quartz sandstones, locally glauconitic, fine- to coarse-grained with a variable thickness (150 meters in the Rio Querecual, 327 meters in Rio Oregano, 340 meters in Rio Amana). The sandstones of the Los Jabillos Formation were deposited over a large area in shallow waters upon a near-shore platform (littoral to sub-littoral). No fossils are found in the lower part of the formation but in the middle and upper part it contains benthic foraminifera, ostracods, bivalve and gastropod levels which indicate an Early Oligocene age.

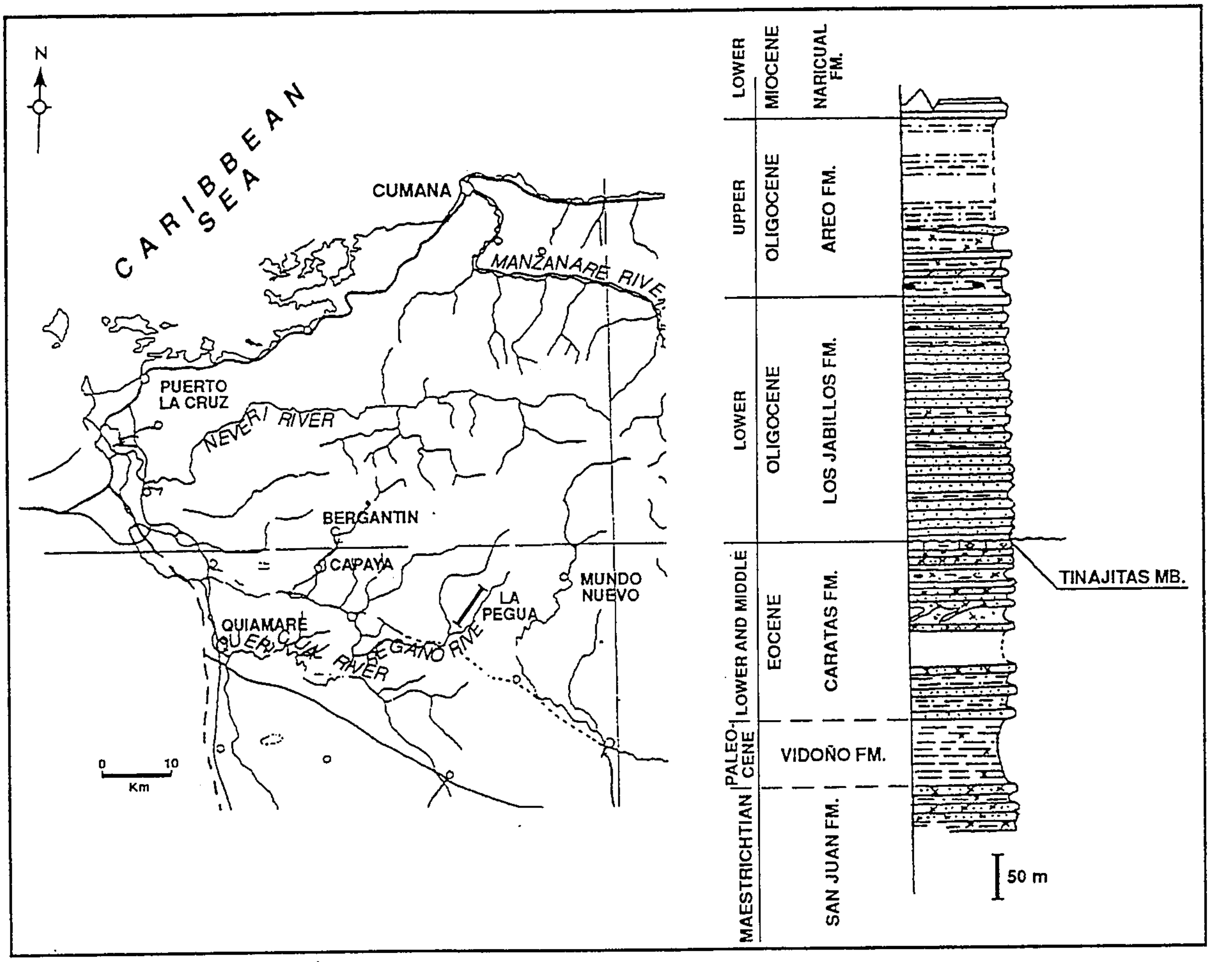



Fig. 12 :The Paleogene along the La Pegua section.
(From Vivas ,1986)

According to Gonzalez de Juana et al. (1980) the unconformity at the base of the Merecure Formation, where it lies upon the Temblador Group in the subsurface, can be correlated with the basal contact of the sandstones of the Los Jabillos above the Middle Eocene formations.

## THE NEOGENE: NARICUAL, CAPAYA, CARAPITA, UCHIRITO AND QUIAMARE FORMATIONS

Those sediments corresponding to the Neogene are found principally in the foothills of the Western part of the Interior Range. The maximum thickness estimated for the Neogene sediments is 7470 meters (Vivas, op. cit;Fig.13 and Fig.14 ).

### 1. The Terminal Oligocene-basal Lower Miocene, Naricual Formation

Made up of a detrital-pelitic carbonaceous facies, the Naricual Formation increases in thickness toward the Northwest in the area of Bergantin-Santa Ines (1500 meters Vivas, 1986; 1800 meters Hedberg and Pyre, 1944). The formation thins toward the East and Southeast so that it is only 44 meters thick at Rio Aragua (Lamb, 1964). The lithology, ichnofauna and sedimentary structures of the Naricual Formation suggest an environment of massive sedimentation on an unstable shelf which is sinking rapidly and repetitively, with a high rate of sedimentation and evidence of turbidite facies (Vivas, op. cit.), Lamb (1964), Peirson (1965), Campos and Gomez (1983), among others assign an age of Late Oligocene-Early Miocene zone of Globorotalia Kugleri to the Naricual Formation.

### 2. The Lower Miocene: Capaya and Carapita Formations

Concordant and transitional upon the Naricual Formation in the Carapita ravine, the Capaya Formation (425 meters) was laid down in an outer shelf environment during its basal part and on an inner shelf during its upper part. Toward the Southeast it shows evidence of turbidite facies (Vivas, op. cit; Macsotay, 1978). By comparison with the overlying and underlying formations an Early Miocene age has been proposed for the Capaya Formation, between the zones of Globorotalia Lingleri and Catapsydrax dissimilis.

The Carapita Formation is represented in the region of Bergantin-Santa Ines by a monotonous sequence of dark gray to black, calcareous, microfossiliferous shales. In concordant and transitional contact with the Capaya Formation, the base of the Carapita Formation presents intercalations of thin beds of fine-grained sandstones. In the type section of the Quebrada Carapita this has a thickness of 750 meters, which increases toward the Southeast and decreases toward the Northwest through interdigitation with the Capaya and Uchirito Formations.

The abundance at benthonic foraminifera indicate sedimentation on the outer edge of the continental platform down to the upper part of the lower continental slope for the basal part of the formation. (Vivas, 1986). The abundance of Catapsydrax dissimilis (Cushman and Bermudez) and the presence of the benthonic foramifer Siphogenerina transversa (Cushman) suggest an age of early Miocene (Vivas, op. cit.).

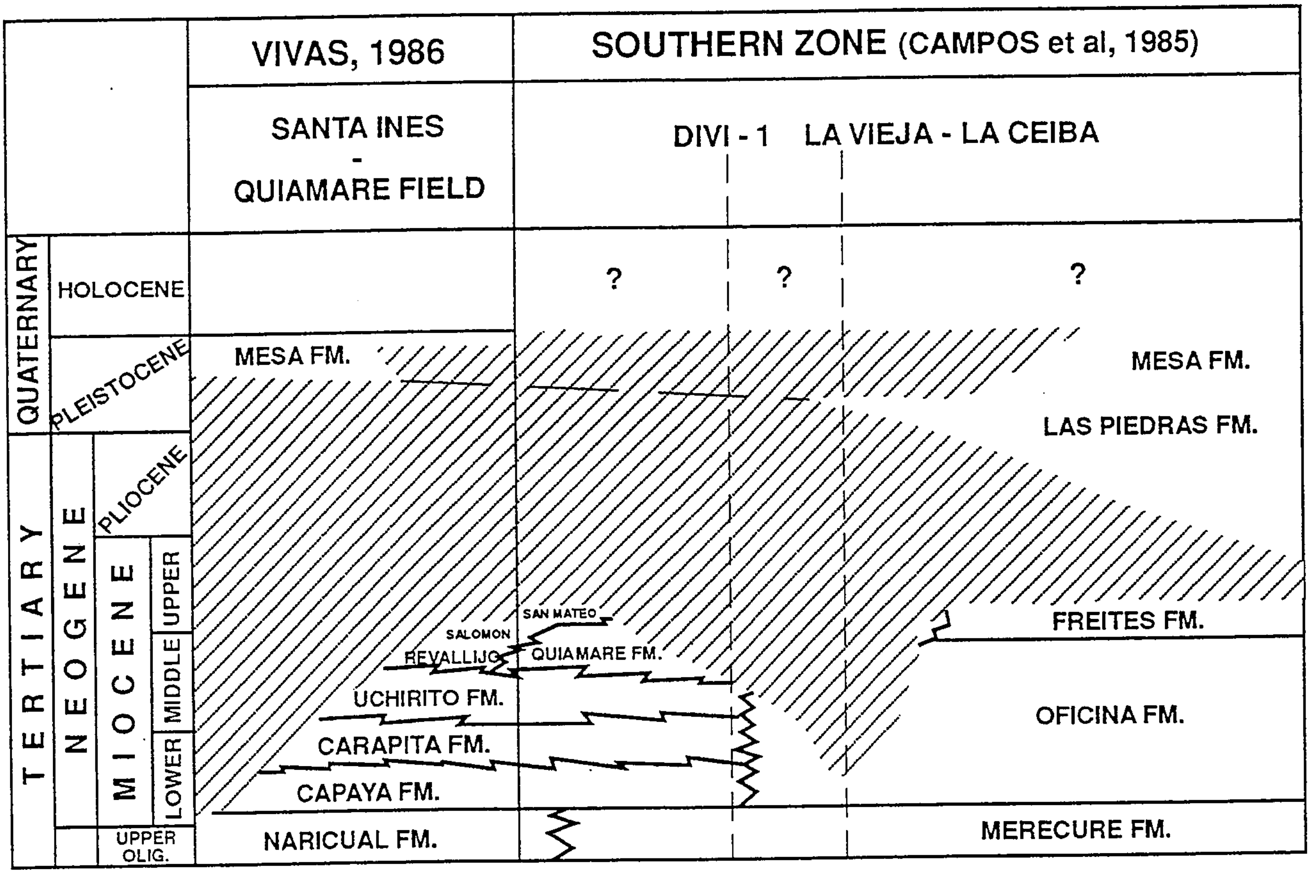



Fig. 13 : The Neogene Formations in the South -West flank of the Interior Range .
(After Vivas 1986)

3. The Middle Miocene base of Upper Miocene: Uchirito and Quiamare Formations

With a thickness at 1320 meters in the type locality, the Uchirito Formation is composed essentially of sandy, calcareous, dark gray shales (80%) and beds of fine-to medium-grained sandstones of 10 to

15 meters thickness; with shales and beds of subconglomerates. These molassic type deposits contain numerous mollusca, indicating a littoral to sub-littoral environment of sedimentation and lower to middle Mid-Miocene age (Hedberg, 1937; Macsotay in Vivas, 1986).

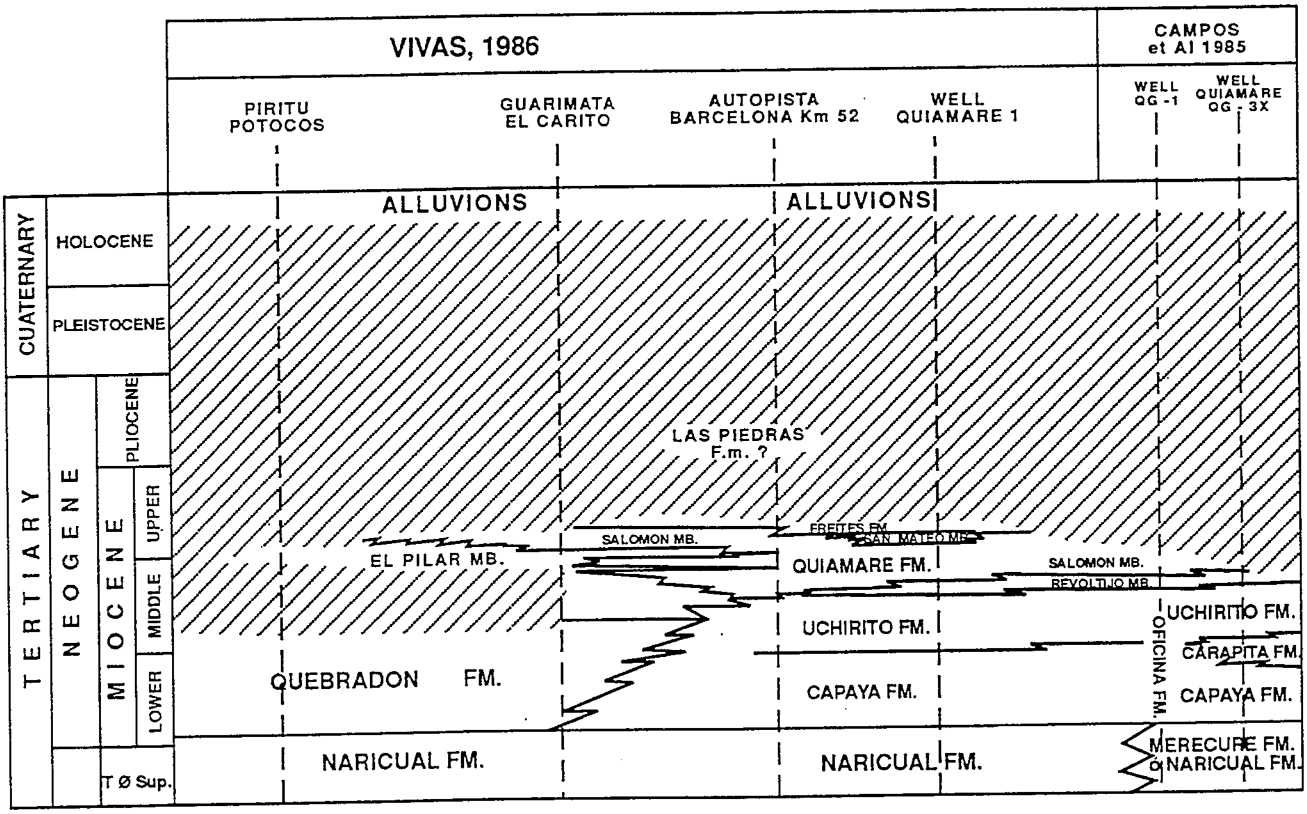



Fig. 14 : The Neogene Formations and their stratigraphic correlation. (From Vivas 1986 ).

Clear evidence for sedimentation from the North to Northwest reflects a stage in the uplift of the Interior Range. In the area of Bergantin-Santa Ines, the Uchirito Formation maintains a concordant and transitional contact with both the overlying Quiamare Formation (basal Revoltijo Member) and the underlying Carapita Formation. West of Barcelona the Uchirito Formation passes into the Quebradon Formation of saltier waters and toward the South into the Oficina Formation in the subsurface (Fig.13) (Vivas, 1986).

On the Western border of the Interior Range the Quiamare Formation is divided into two members:

The Revoltijo Member (1000 meters) is composed of sandy and carbonaceous shales. The presence of bivalves and small poorly-preserved gastropods indicate conditions of deposition in very shallow marine waters (littoral environment). Because of its relative stratigraphic position, an age of middle to upper part of the Middle Miocene has been proposed for it.
The Salomon Member (1300 meters) in concordant and transitional contact with the Revoltijo Member is characterized by gray clays which are locally sandy. It has been assigned an age of late Middle Miocene to basal Late Miocene (Vivas, 1986). Towards the West the Revoltijo and Salomon Members interdigitate with the conglomerates of the El Pilar Member (terminal Middle Miocene basal Late Miocene), considered to be post-orogenic molasse. These overlie the Quebradon Formation (Early Miocene-lower Middle Miocene). Towards the South the Quiamare Formation passes by concordant and transitional contact into the Freites Formation (Campos and Gomes, 1984) of possible Middle to Late Miocene age (Gonzalez de Juana et. al, 1980).

4. The Quaternary: Mesa Formation

The conglomeratic sediments, in clear angular unconformity over the Early and Middle Miocene Formations represent the Mesa Formation of Pleistocene age (Hedberg and Pyre, 1944).

# THE INTERIOR RANGE: ITS TECTONIC EXPRESSION

## Introduction

Limited on the North by the "El Pilar" zone of transcurrent faults, the Interior Range extends from the zone of faults of Urica on the West, to the Gulf of Paria to the East. Its southern flank is covered by the sediments of the Maturin subbasin. (Fig.15).

Upon examining briefly air photographs and SLAR, one notes the obliquity of orientation of fold axes of the range to the trace of the El Pilar fault zone. This leads to an interpretation of the lack of parallelism between the North-South shortening of the chain and the tectonic transport in a Northwest-Southeast direction as a consequence of a regimen of deformation during dextral transpression associated with the relative movement of the Caribbean and South American plates.

## Trancurrent Movements

The horizontal displacement of the Urica Fault, according to Salvador and Stainforth (1968), oscillates between eight (8) and ten (10) kilometers and the age of movement was early Pliocene. Its last activity was after the formation of the range.

Aeromagnetic data indicate clearly the base of this dextral transcurrent fault (Feo Codecido et al, 1984). Present interpretation is that the Urica Fault, of Tertiary age, followed an older structural direction of the basement (paleofracture), according to Potié, (1989) and its present structural expression can be seen to the area of Aguasay, where its surface trace disappears.

The San Francisco-Quiriquire system of faults, which divides the range into two blocks; the Bergantin Block to the West and the Caripe Block toward the East was described in detail by Salvador and Rosales, (1960) and Rosales (1962). This fault starts in the Cumanacoa Valley, follows a N 130 E direction and curves toward the East, becoming E-W in the area of Guanaguana. Rosales (1972) suggests that the displacement and folding along the fault are synchronous. The Buena Vista syncline (Bergantin Block) was correlated by Rosales (op. cit.) with the syncline La Laguna (Caripe Block), which would indicate a displacement of 18 Km.

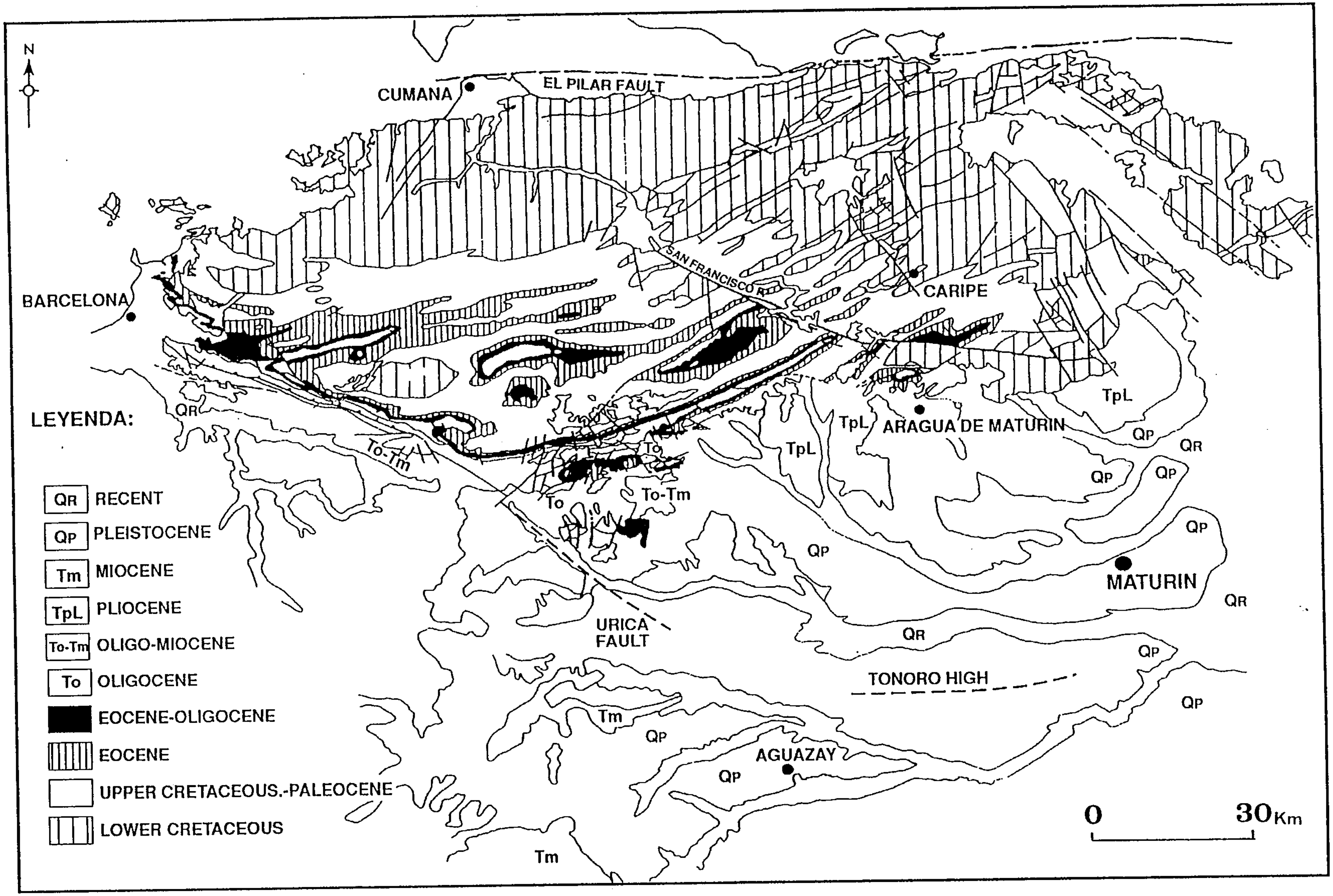



Fig. 15 : Schematic geological map of the Interior Range.
(Modified from Bellizzia et Al 1976 ,in Chevalier and Alvarez 1990).

Later, Rosales (1972), taking into account the 100 and 200 meter isopachs of the San Juan Formation on both sides of the fault, proposed a displacement on the order of 30 to 40 kilometers.
Rossi, 1985, summarizing the different criteria concluded that the dextral displacement of the San Francisco-Quiriquire fault was on the order of 15 to 20 kilometers. Its eastward prolongation in the subsurface was detected by aerogravimetric methods by Martin and Espinoza, (1990). The geometric configuration obtained indicates that the Pirital thrust and the faults which delimit the Rio San Juan depression unite in a single feature to the south of Guariquen, which could be the eastward prolongation of the San Francisco-Quiriquire fault system (Martin-Espinoza op. cit.).

## Folding

The cartographic scheme, obtained from a general examination of the D-10 and D-11 geologic maps of the Creole Petroleum Corporation, allows one to map the Interior Range as a huge anticlinorium with its axis N 80 E and slight axial dip toward the Southwest. Due to erosion, Tertiary rocks crop out in the Western zone while the older nuclei of the structures do so toward the East.

Folding is the form of elongated folds, reaching, in places, a length of 50 Km with a wave-length oscillating between five (5) and seven (7) kilometers, showing a frontal shortening of structures (Subieta et al., 1988).

The structural pattern is characterized by large anticlines and small synclines (Box Folds), sheared, with an upthrusted style. Vivas, in 1986, was the first to propose and illustrate on a regional section, a basal thrust level, comparing the style of deformation of the Interior Range with the French-Swiss chain of the Jura. Potie (1989) continued by developing this same hypothesis by placing emphasis on the tectonic cover of the chain without including the igneous-metamorphic basement in the deformation, contrary to the model presented by Rossi (1985) and Rossi et al. (1987).

## Tangential Shears

In addition to the probable basal shearing (Vivas op. cit.) the folds are associated with synthetic and antithetic faults with an overall tectonic vergence toward the Southeast.

In the Bergantin Block the large thrusts of "El Culon" and "Mundo Nuevo" are representative of the synthetic movements while the fault of "Tentenocaigas" (Vivas, 1986) located to the south of Cumana is antithetic and affects the north flank of the Mochima anticline.

The true mountain front, made up by a series of imbricated sheets, is covered by the Mio-Pleistocene molasse fill, which extends, at first (Mio-Pliocene), only along the tectonic flexure of the foreland but later extends (Plio-Pleistocene) over both sides of the initial Foreland-type basin.

# THE TRANSECT CARIACO-ARAGUA DE MATURIN

## I General

This North-South transect is located, mainly, in the Caripe Block, with the exception of the southern part which cuts the eastern wedge of the Bergantin Block (Fig.16)( see Annex ,Plate 2 ).

After the work done in the zone by the Creole geologists (Pantin, Rosales, Claxton), three more transects were made: two in the Bergantin Block (V.Vivas, 1986 and G. Potié, 1989) and one in the Caripe Block, (Rossi, 1985). This latter author divided the transect into three parts.

I.1. Northern Block: Located between the Gulf of Cariaco and the zone of Santa Maria it presents a subdued topography morphology due to the lithological character of the Lower Cretaceous (Barranquin Formation) which crops out in this sector. The structural style of this block is dominated by the tendency for box folding with axes N 70°N 80° E associated with a double vergence of the folds. The presence of disharmonic levels, due to the alternation of competent and incompetent beds, causes minor parasitic folds associated with the large structures, which can change into tangential shears, such as the thrusts of Vuelta Larga and La Blascoa or into regional backthrusts like Rio Grande. This geometry is affected by faults trending N 20°-N 130°-N 150° E which have small horizontal and vertical displacement. Upon this older structure, the effects of more recent tectonics are superimposed, which generated the "Pull Apart" Pleistocene basin of the Gulf of Cariaco (Rossi op. cit., Bladier and Macsotay, 1977).

I.2. Central Range: It can be divided into two asymmetric flanks: the first extending from Santa Maria to the axis of the "El Purgatorio" anticline; the second from the before-mentioned anticline to the depression of the San Francisco-Quiriquire system of faults.

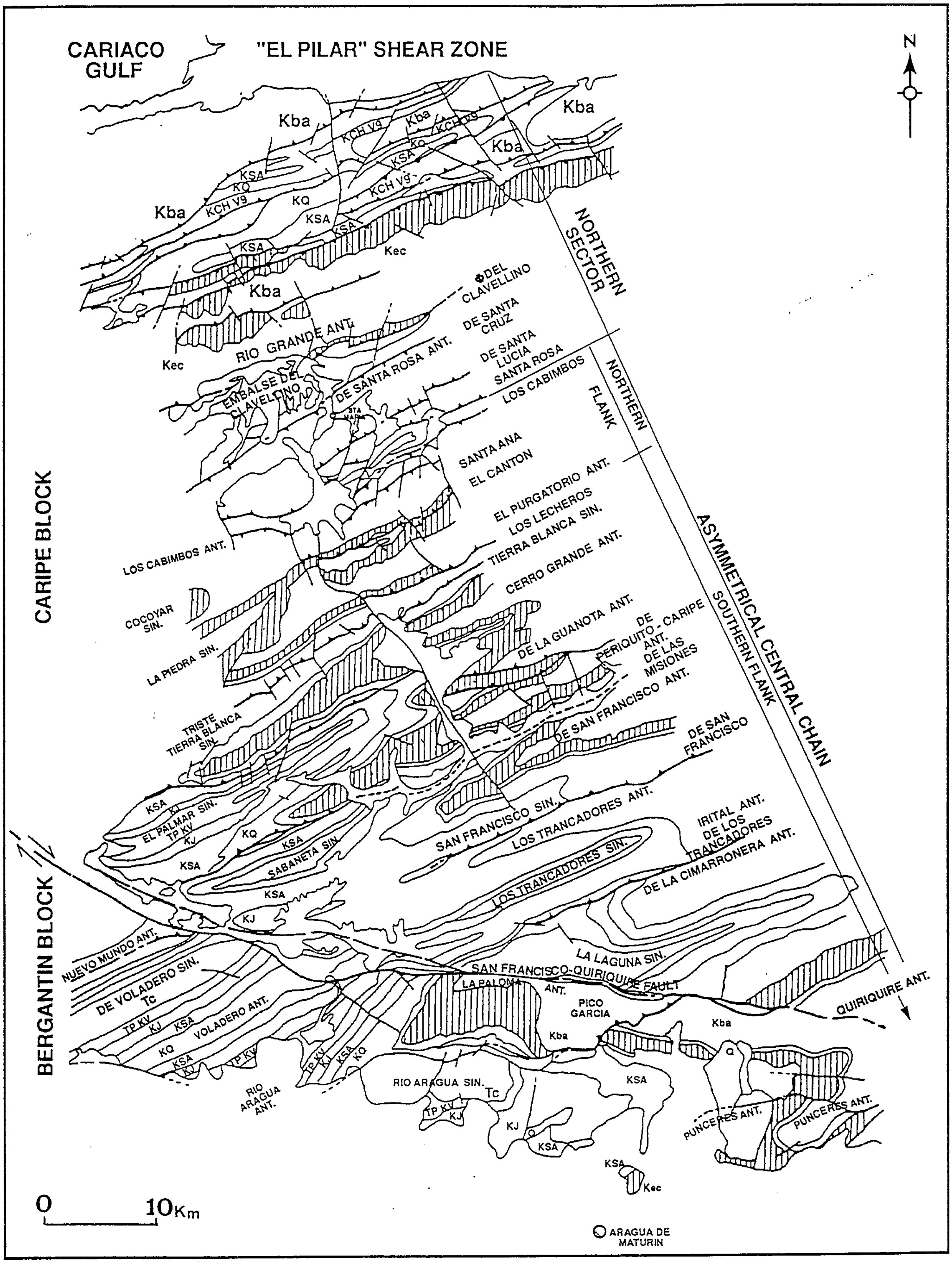



Fig. 16 : Schematic geological map of Cariaco -Aragua de Maturin transect. (modified from Rossi ,1985 ,in Chevalier and Alvarez ,1990)

The northern flank of the central anticlinorium on this transect consists of, from North to South, the Amanita syncline and the Los Cabimbos anticline. The Amanita syncline is bounded to the North by the Santa Rosa thrust and to the South by the backthrust of Los Cabimbos which unites toward the west with the backthrust of Santa Ana. The deformation observed in the bed of the San Antonio Formation, which form the syncline, is characterized by important internal shears with South vergence. The beds of the Barranquin Formation form the anticline of "Los Cabimbos" and have been affected by two types of tectonics: compression which has formed a fold with double vergence associated with tangential shears and gravity tectonics which cause decametric to hectometric collapses.

The southern flank of the Central Range is limited topographically by a range formed by the limestones of the El Cantil Formation, of which Cerro Papelón is a part. From this limit, the large structures step down with gentle south dip until they reach the depression formed by the San Francisco-Quiriquire fault system. This low dip contrasts sharply with that of the North zone of the Central Range.

The geological limit of the southern segment of the Central Range is marked by the trace of the "El Canton" thrust. This shearing places the southern overturned flank of the Los Cabimbos anticline upon the northern flank of the "El Purgatorio" anticline which dips 30° N. The shortening causes nearly complete disappearance of the "La Piedra" syncline. It has not been possible to accurately measure the displacement which occurred along this tangential shear plane.

Continuing the section toward the South one finds the thrust of "Los Lecheros" which shears the nearly vertical southern flank of the knee fold of the Purgatorio anticline over the box fold syncline of Tierra Blanca-Triste (Day 2 stop 4 ). This is followed by the gently southwest dipping anticline of Cerro Grande which overturns on the "El

Palmar" syncline accompanied on one flank by tangential shearing.

Farther to the East the "El Palmar" syncline closes to form a parasite anticlinal nose (La Guanota anticline) which crops out on both sides of the Caripe fault. This fold is affected by shears which permit it to override the Periquito-Caripe anticline toward the Southeast, which, in turn, overrides the Sabaneta syncline along the thrust planes of Las Misiones. Immediately to the South of the town of Caripe one finds the San Francisco anticline which overrides the contiguous structure formed by the Los Trancadores and Irital anticlines, both separated by the Los Trancadores syncline. This structural pattern is repeated until the San Francisco-Quiriquire zone of transcurrent faulting is reached affecting the "La Cimarronera" and Quiriquire" anticlines and the overturned syncline of "La Laguna".

In the Central Range one recognizes a major fault which cuts the structures from the Amanita syncline to the San Francisco Anticline; this fault is known as the Caripe Fault.

The branch of this fault has a dominantly vertical component, with displacement oscillating between 250 and 300 meters, with the eastern block downthrown. In the same direction, on a lesser scale, one finds a series of tear faults cutting the structures perpendicularly.

In most cases these faults are found between two important shears, affecting only the folds, as can be seen on the Periquito Anticline.

## I.3. Southern Belt

This belt, located in the Bergantin Block south of the San Francisco-Quiriquire system of faults, presents two principal structural directions which come together and are superposed.

The first structural direction, W 70° E, maintains the general structural grain of the range and characterizes the western sector of the southern belt of the transect. The second direction, oriented E-W is parallel to the trace of the San Francisco-Quiriquire fault system.

The structural style of the western sector is similar to that described in the Central Chain with an axial direction N 70° E and asymmetric folding, frequently overturned and sheared toward the Southeast.

The thrust associated with the overturned anticline of Mundo Nuevo changes strike as it nears the San Francisco fault, which is an indication of the transcurrent character of the fault.

A transition zone marks the passage between the N 70° E structures (The Buena Vista syncline, Mundo Nuevo and Voladero anticlines) and the structures oriented E-W (Cerro Aragua syncline and Punceres, Quebrada Seca and Azagua anticlines). The overturned syncline of Rio Aragua and the Paloma or Pico Garcia anticline with a N 50° E axial direction form part of this zone of change of structural pattern. Together with the complex folding of this sector, one observes several transcurrent faults associated with the San Francisco-Quiriquire system of faults (D-11 Map, Creole, 1962). A preliminary cartographic analysis of the Southern Belt indicates a close relation between the structural style of the area and the dextral transcurrent regime of the San Francisco-Quiriquire system of faults.

## DAY 1: THE INTERIOR RANGE

STOP 1: Foot of the mountains in the Pico Garcia sector. Structural characteristics

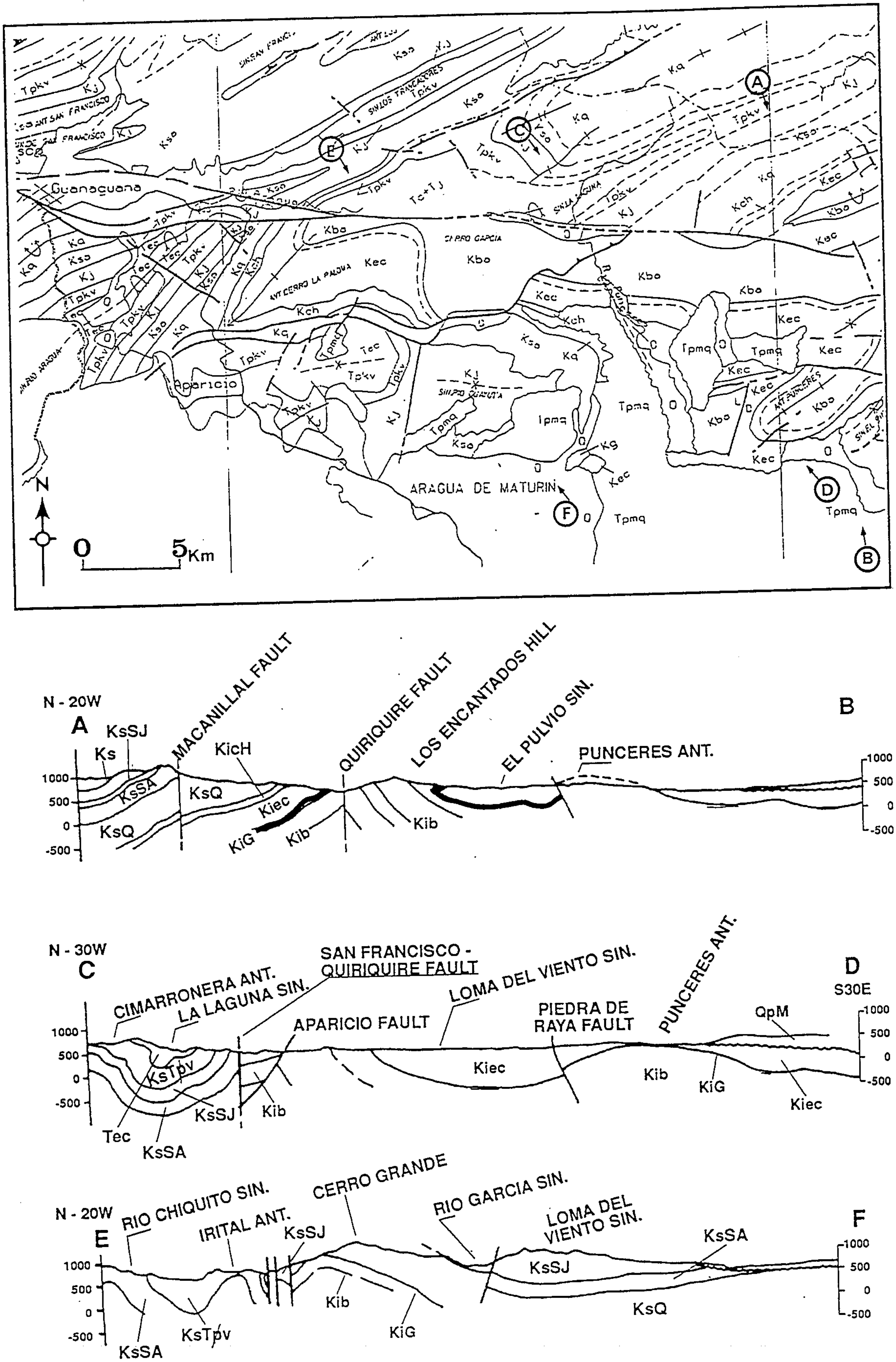
Located South of the trace of the San Francisco Fault, in the Bergantin Block; the Pico Garcia sector is formed essentially by sediments of the Barranquin and El Cantil Formations (See the Stratigraphy Chapter); which make up on map, a huge conic fold dipping toward the Southwest, called the La Paloma Anticline (Fig.16).

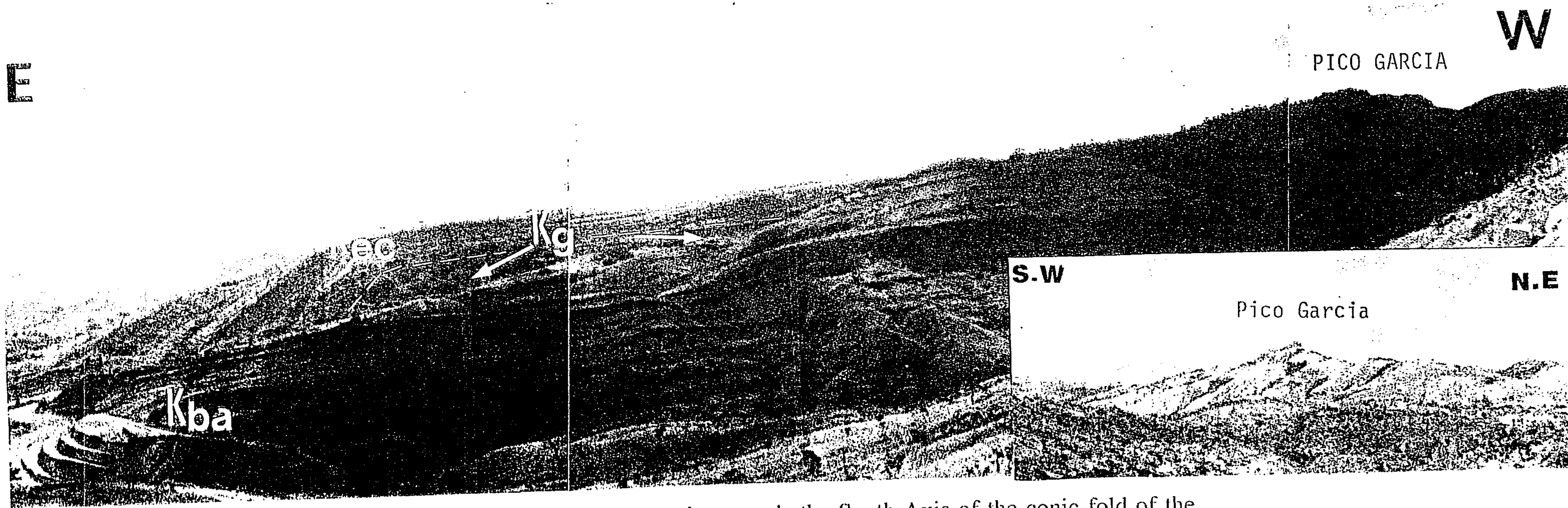
The structure, which indicates a large horizontal movement correlatable with the San Francisco fault, is limited toward the South by the Aparicio Fault, which, in this sector, separates the Albian beds of the El Cantil Formation from the Campanian-Maestrichtian beds of the San Juan Formation. The beds of the Upper Cretaceous are deformed and form a huge open syncline toward the East-Northeast (Guayuta Syncline-Map of Creole Petroleum Corporation).

The north flank of this multi-kilometric structure shows a collapse-type of gravitational deformation (Fig.17).

The panorama of the first stop allows understanding on a grand scale of the structures located on both sides of the Aparicio Fault.

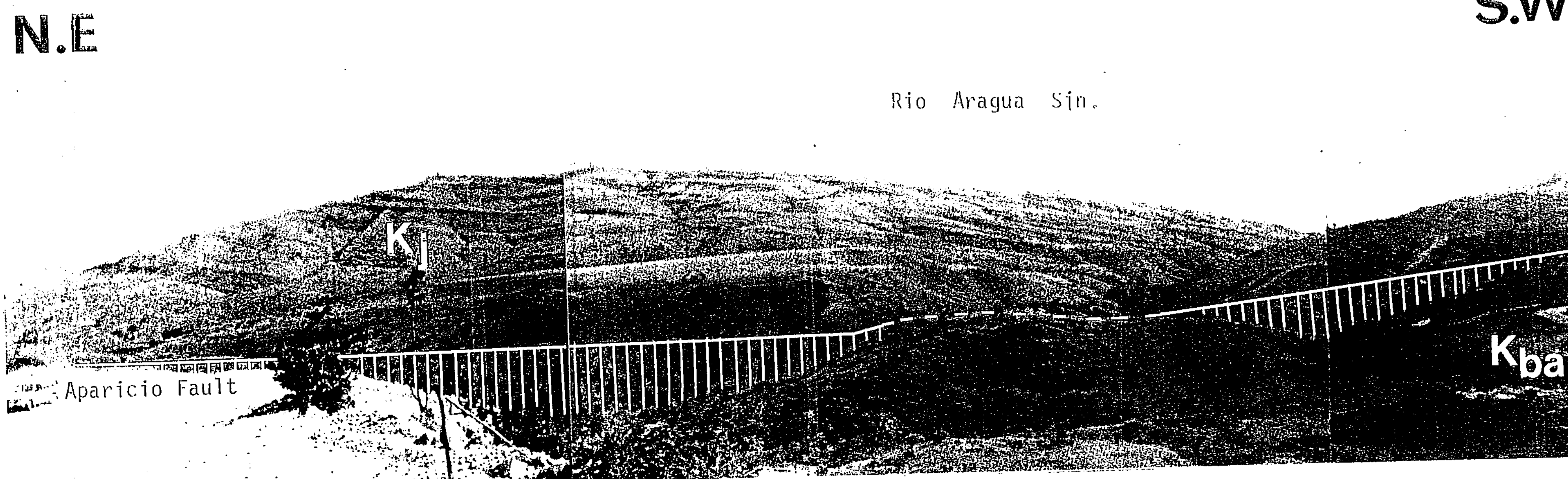
Fig. 17 : Cross-sections in the foothills near Pico Garcia Mount.
(From Aguasuelos,1992, simplified ).






<u>Photograph 1</u>: Panoramic from Pico Garcia towards the South Axis of the conic fold of the La Paloma anticline.






<u>Photograph 2</u>: Panoramic view of the Guayuta Syncline toward the Southeast.

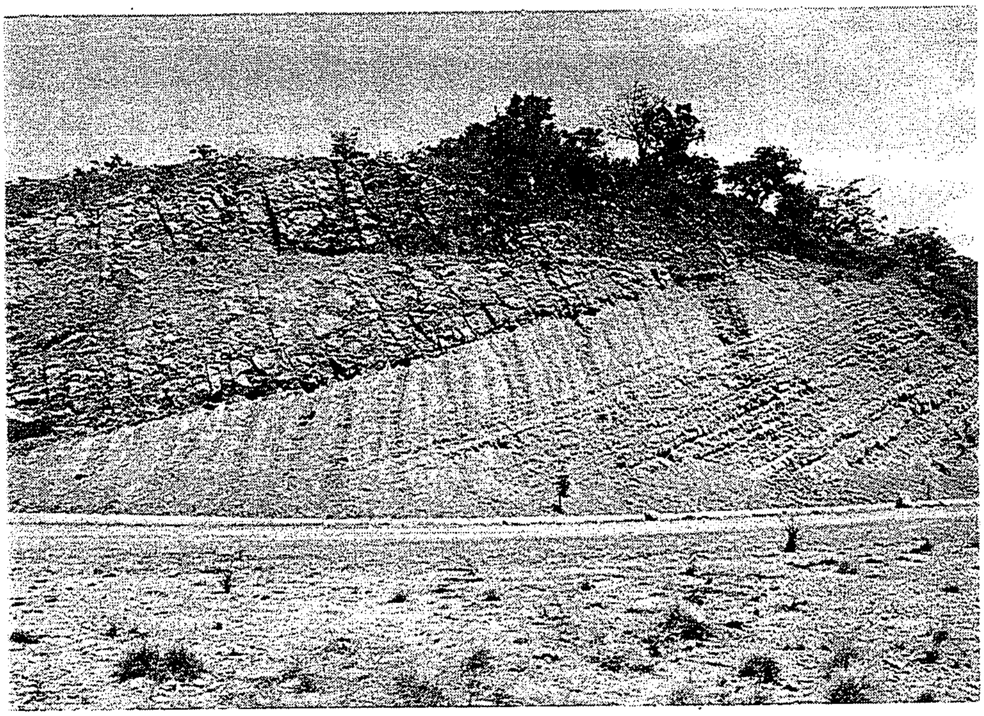
## DAY 1: THE INTERIOR RANGE

Stop 2: Campanian-Maestrichtian Sandstones.

Two outcrops allow us to observe in detail one of the subsurface reservoir rocks of the Maturin Subbasin: The sandstones of the San Juan Formation.

Very thick in the Pico Garcia area, these sandy beds of the San Juan Formation thin rapidly toward the North (see Chapter on Stratigraphy Rosales, 1972).

According to several authors, the environment of sedimentation of these sands is fluvio-deltaic and progradational. One recognizes easily the different cycles in which one observes the massive basal beds, composed of canals. The successive arrivals of quartz-arenites of fine-to-medium grain, with little clay content, interdigitate with deep pelitic sediments, which predominate at the end of each cycle. The fauna found in these beds allows dating of this deep pelagic rain to the Campanian Maestrichtian. The top of the San Juan Formation contains several levels of glauconite.



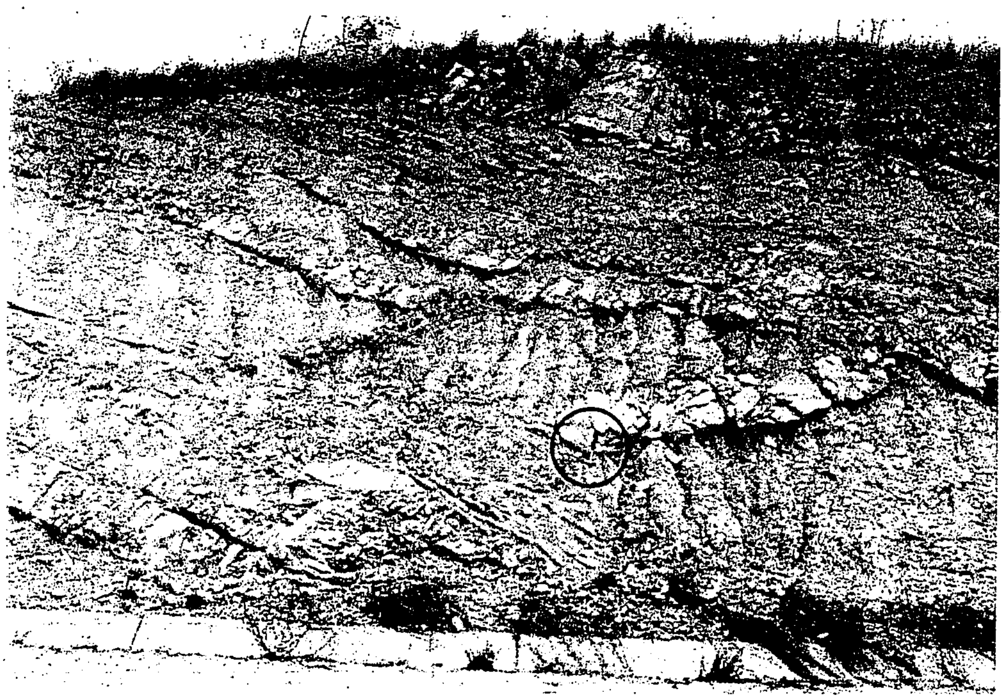
Photograph 3: Contact between two sedimentary cycles in the San Juan Formation of Late Cretaceous age.

Stop 3: Clastic "dikes" in the San Juan Formation

The presence of numerous clastic "dikes" or Injectites in the sands of the Upper Cretaceous (Sandy San Antonio and San Juan Formations) were described in great detail by Vivas et Al. (1988) in the Bergantin-Santa Ines sector, in the western sector of the Interior Range.

The genesis of these veins of sandy material requires levels of unconsolidated sand rich in interstitial water plus the effects of lithostatic pressure. As an hypothesis Rossi (1985) proposed that the rapid and progressive arrivals of sands in great quantities were produced by a rapid subsidence of the slightly consolidated, sandy levels. With the consequent effects of the increasing pressure conditions, the interstitial fluids, rich in quartz-arenite particles, migrated, in part, upward and, in part, downward.

The presence of vertical tectonic movements could have favored the vertical, or lateral migration of these clastic veins as has been suggested in a recent study (Aguasuelos, 1992).



Photograph 4: Clastic "dikes" in the San Juan Formation Pico Garcia sector Guayuta Syncline.

## DAY 1: THE INTERIOR RANGE

Stop 4: The San Francisco Fault. Its geomorphological expression.

The San Francisco-Quiriquire Fault system was described in detail by Salvador and Rosales (1960), Rosales (1962) and Rossi (1985) (See chapter on Tectonic Expression).
The fault starts in the Cumanacoa valley and extends to near the town of San Francisco in a direction N 115° E. After making a curve this fault continues in a N 95° E direction until it disappears under recent sediments Northeast of Quiriquire. The geomorphological expression of this fault is very variable (Fig.18). In the zone of the Cumanacoa valley it appears to develop a small basin of the "Pull Apart" type. In the sector from Guanaguana to North of Pico Garcia its horizontal displacement is marked by narrow deformation zones. Farther East the San Francisco-Quiriquire fault is marked by the valley of Rio Quiriquire.

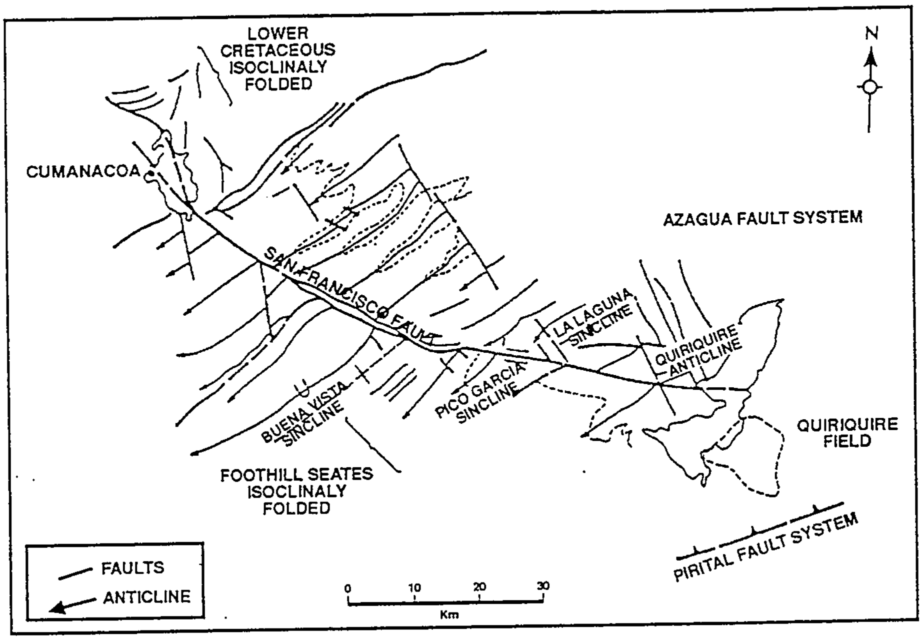



Fig.18 :The San Francisco Fault and associated folding.
(After Rosales,1972).

A microtectonic study of the borders of this zone of horizontal displacement near the Guamo dam, shows two families of striations; one, sub-horizontal with 5° to 15° of inclination and the second with very variable inclinations. These data seem to corroborate the idea of synchronous development of the San Francisco-Quiriquire Fault with the regional folding. Associated with these sub-vertical planes of faulting one observes an increase in fracture-type cleavage near the zones of major lateral displacement.
A dextral displacement of 18 Km of the San Francisco-Quiriquire fault was proposed by Rosales (1972) on the basis of a possible correlation of the major structures. According to this same author using the isopach values of the San Juan Formation on both sides of the fault zone a movement of 6 to 8 Km is shown by the 100 to 200 meter curves and 30 to 40 km along the length of the San Francisco-Quiriquire fault.

# THE "EL PILAR SYSTEM OF FAULTS"

Observed in 1820 by the explorer A. Von Humbolt, the "El Pilar" fault zone was defined in 1946 by Liddle. The East-West fault system of "El Pilar", which constitutes a major geological feature in Northeastern Venezuela, allows the juxtaposition of two different dominions. To the North, a dominion made up principally of metamorphic terranes belonging to the Caribbean Plate and, to the South, a dominion composed of a series of deformed sedimentary rocks, the Interior Range, the Cretaceous and Tertiary cover of the South American craton (Fig. 21 ).

This shear zone, three-fourths under water, is seismically active (Molnar and Sykes, 1969; Perez and Aggarwal 1981). It extends from Cabo Codera (to the West, near Caracas), to the extreme eastern area East of Trinidad, where the deformation is translated by a succession of en echelon discontinuities trending N 80° E affecting the southern flank of the Barbados Prism. (Fontas et al., 1985). The morpho-structural configuration of its trace, 450 Km long, is marked by "Pull apart" or "Push up" structures. The rhombohedral morphology of the grabens (Schubert, 1979, 1982) and the seismo-tectonic data (Perez and Aggarwal, 1981) indicate an eastward displacement of the northern side.

From the West toward the East different structures were recognized along this shear zone.

1. The Cariaco Basin, 200 Km long, must be formed by the change from the Moron Fault to the North, to the El Pilar to the South, with an estimated displacement of 25 Km (Schubert, 1982,1985). An age of late Miocene was proposed for the opening of this "pull-apart" basin (Biju Duval et al., 1982):

2. The Humboldt Graben, The present Gulf of Cariaco presents, on both sides, Mio-Pliocene series affected by different periods of North-South or Northwest-Southeast compression. (Bladier and Macsotay, 1977). On the southern border of the Gulf of Cariaco in the Cumana area, the opening of this graben was registered in the Plio-Quaternary sediments. The facies of the lower part of these deposits are composed of pebbles of metamorphic rocks originating in the Araya Peninsula, located at present to the North of the "El Pilar" fault system; while in the sediments of the upper part, discordant and of Pleistocene age, one finds fragments and blocks coming only from the Interior Range (Macsotay and Blanchet in Stephan, 1982).

3. The zone of Casanay-El Pilar, is the only place where one can study the contact of the metamorphic terrane of the Araya-Paria Peninsula with the sedimentary series of the Interior Range. 5 to 6 Km wide this "shear zone" presents in this place a series of scales of metamorphic rocks, sedimentaries, and lenses of serpentinites. Between the towns of Casanay and El Pilar, the Chuparipal fault causes the juxtaposition of metamorphic and sedimentary rocks. Described first in 1964 by Metz, this contact was restudied by Alvarez et al (1985). This fault is sealed by a turbiditic series, dating from Middle Miocene (Middle part, zone of G. Fohsi Los Amoyos Formation).

## REFERENCES

Audemard,F.;Azpiritxaga,I.;Bauman,P.;Isea,A.;Latreille,M.1985
Marco geologico del terciario de la Faja Petrolifera del Orinoco de Venezuela
VI Congr.,Geof.,Venez.; tomo I ,p. 70 - 109

Aguado B, Ghost. S., Isea A. 1990
Diagenis and Reservoir Characterization of the Cretaceous-Tertiary Sequence, Eastern Venezuela
AAPG 1990, Abstracto Pág. 43

Aguasuelos Ing. 1992
Estudio Geológico de la Serranía del Interior. Partes Central y Oriental.
Trabajo en progreso

Alvarez, E., Macsotay, O., Rivas, D., Vivas, V. 1985
Formación Los Arroyos: turbiditas de edad Mioceno medio de la región de El Pilar
VI Cong. Geol. Venez. Mem. T.I., Caracas

Barrios F.,Sams R.H. 1992
Analisis sismoestratigrafico en el area de Amarillis, Norte de Monagas.
Mem. VI Congr. Venez. de Geofi.; p.62 -69.

Benedetto ,J.L. ; Puig,E.R. 1985
La secuencia sedimentaria precambrica-paleozoico inferior pericratonico del extremo norte de suramerica y sus relaciones con las cuencas del norte de Africa
VI Congr. Geof. Venez. tomo I ,p.140-156.

Biju-Duval, B., Mascle, A. Rosales, H., Young, G.1982
Episutural Oligo-Miocene basins and resent subduction processes along the north Venezuelan margin
I.F.P. Synthesis Geologiques et géologiques

Bladier Y.; Macsotay O.1977
Direcciones de acortamiento cortical en rocas Plio-Cuaternarias aflorantes alrededor del Golfo de Cariaco-Venezuela
Report interne, mem. Caracas

Carnevali, J.O. 1991
Monagas Thrust Fold Belt in the Eastern Venezuela basin: Anatomy of a grant discovery of the 1980 s.
Thirteenth World Petroleum Congress, Buenos Aires

Chevalier, Y. 1987
Contribution a l'etude géologique de la frontieré Sud-Est de la plaque Caraibe: Les zones internes de la chaine Sud-Caraibe sur le transect ile de Margarita-Peninsule d'Araya (Venezuela).
Ph.D. Brest 464 p. 189 fig. 2 pl

Chevalier Y, Alvarez E. 1991
Consideraciones estructurales del transecto Cariaco-Maturin (Geología superficie-subsuelo)
Informe inedito Lagoven N° 3000-115-9. Caracas. Pág. 56

Chiock M. 1985
Cretaceo y Paleogeno en el subsuelo del Norte de Monagas
VI Congr. .Geol., Venez., p350-383.

Contreras, B., Hernández Y. 1980
Historia sedimentaria del Eoceno y del Oligoceno de la Serranía del Interior. Norte de Monagas
Trabajo Especial de Grado. U.C.V. Escuela de Geología. Caracas. Inedito. Pág. 462

Creole Pretroleum Corporation 1962
Corte geologique de la Creole Petroleum Corporation D10-D11. La Serranía del Interior

Daza J., Prieto R. 1990
Fallas de crecimiento en el area de Mapirito-Monagas Central
V. Congreso Venezolano de Geofisica
Caracas. 21-25 Oct. Pág. 142-149

De Sisto. J 1960
A Supplementary type section for the La Pica Formation
Asoc. Ven. Geol. Min. y Pet. Bol. Inf. 3 (7). Pág. 186-198

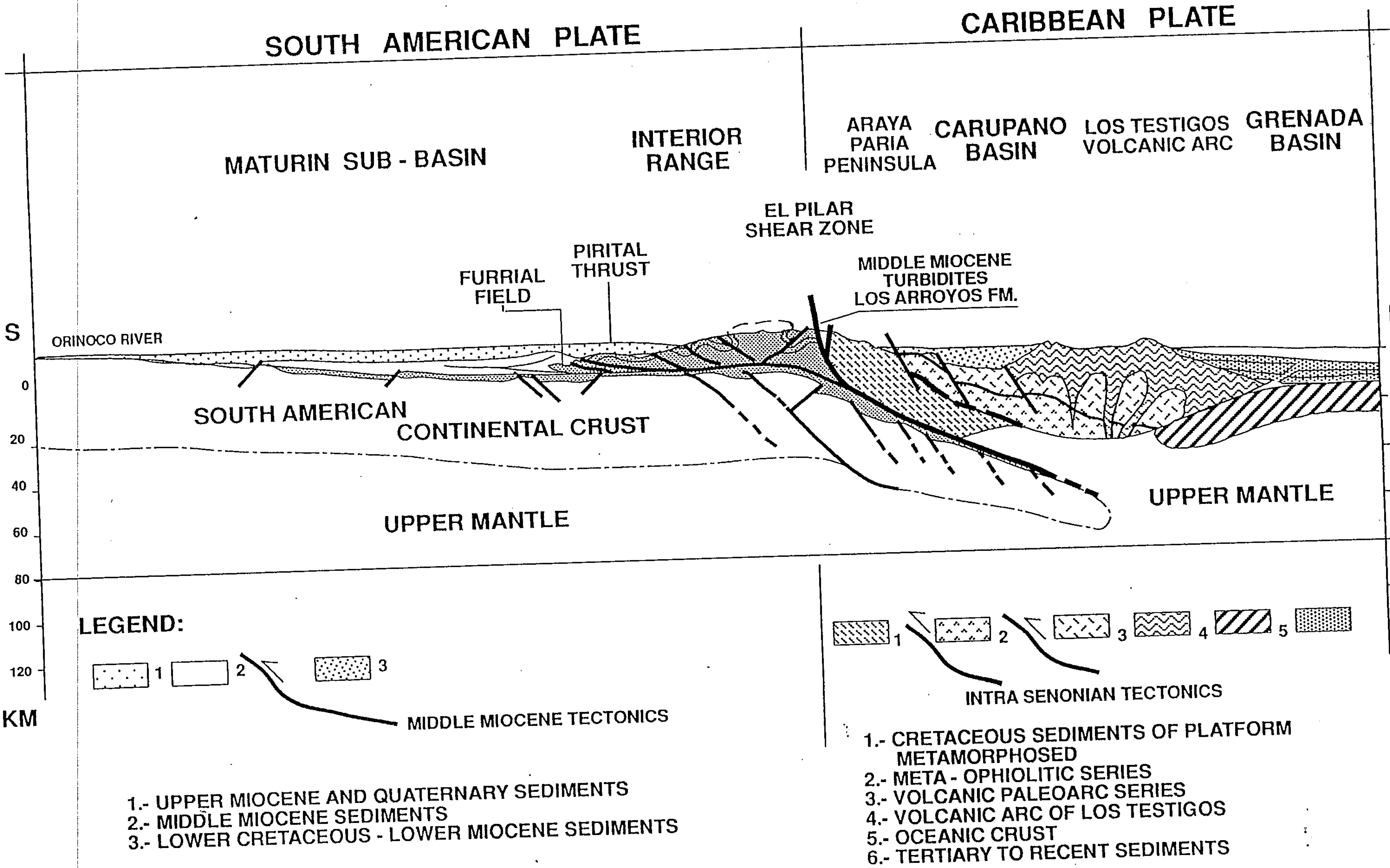



Fig. 21 : Esquematic section from Grenada Basin to Orinoco river.
( from Chevalier ,1987, modified ).

Farther to the South this Neogene series is affected by reverse faults with a N 50° E direction and by a branch of the "El Pilar" fault, with a N 60° E strike. In this sector numerous normal to transcurrent faults, with a N 140° E direction cut the feature previously described. These recent faults are marked by several hydrothermal springs. The "El Pilar" fault, sensu stricto, active to the South of the Chuparipal fault continues to the East under the name of the Casanay fault. Vierbuchen (1978-1984) after a study of this sector and the examination of gravimetric data, proposed a vertical relief of the tectonic contacts to a depth of 5 km before they become horizontal.

4. The Casanay Fault is not located exactly at the foot of the metamorphic range of Paria. Toward the East this fault continues across the Island of Trinidad where it represents the limit between the metamorphics of the "Northern Range" and the sedimentary Caroni Basin. The central segment of this fault forms the northern border of the Yaguaraparo depression.

5. The Yaguaraparo Basin is limited to the East by the Los Bajos Fault, with dextral, horizontal movement, N 110° E, and the normal Bohordal Fault with a direction of N 130° E. This depression contains a very thick sedimentary section of more than 3000 meters of Plio-Quaternary sediments (Perez de Mejia and Tarache, 1985).

Di Croce J. 1987
Análisis sedimentológico de la Formación San Juan en la Cuenca Oriental de Venezuela (Estado Anzoátegui y Monagas)
Trabajo de Grado. Magister Scientiarum en Ciencias Geológicas. U.C.V.

Di Giacomo ,E. 1985
Acritarcos de la Formacion Carrizal ,area de Zuata, Faja Petrolifera del Orinoco, Venezuela Oriental .
VI Cong.,Geol.,Venez., tomo I, p.503-536.

Fasola A, Paredes I. 1990
Late Cretaceous and Mid-Tertiary Palynological Assemblages from the "El Furrial" Area wells, Venezuela
AAPG 1990. Abstract. Pág. 107

Feo Codecido G. 1984
Smith J.,Aboud N,Di Giacomo E.
Basement and paleozoic rocks of the Venezuelan Llanos basin
G.S.A. Mem. 162. Pág. 175-187

Fontas, P., Griboulard, R., Prud'Momme, R. 1985
Morphogénese d'un prisme d'accretion et variabilité de style des deformations sur une marge active. Apports et specificités des resultats d'une analyse cartographique interpretative sur la Ride de la Barbade
Symposium Geodynamique des Caraibes. Paris-Fevier edt. Technip Pág. 221-233

Gonzalez A. ,Fuentes J., Navarro J., Lander R. 1992
Estilos estructurales de las areas Norte de Monagas y Norte de Oficina .(Venezuela ).
Mem. VI Congr. Venez. de Geofi. p.70 -77.

González de Juana, C. 1946
Estudios sobre aguas subterráneas en los Llanos de Venezuela.
Revista de Fomento. Caracas. 8 (69) Pág. 9-59

González de Juana, C.,Arrozena J., Picard Cadillat X,1990
Geología de Venezuela y de sus cuencas petrolíferas
Foninves Ed., Caracas. 2 Vol., Pág. 1031

Guillaume, H.A.,Bolli, N.M.,Beckmann, J.P.,1972
Estratigrafía del cretáceo inferior en la Serranìa del Interior, Oriente de Venezuela
IV. Cong. Geol., Caracas, Bol. Geol. T. III, Vol. 5, Pág. 1619-1655. Public. Esp.

Guillet Ph., Cannat M., 1984
Cinematique en place del unite ultrabasique du cerro Matasiete, Ile de Margarita, Venezuela
C.R. Acad., Sci. París, t. 299, serie II, 3, p.133-138

Gutiérrez R. 1988
Nuevas Expectativas en la subcuenca de Maturín
Cuenca Oriental de Venezuela
Bol., Soc. Venezolana Geol., Pág. 33-43 (1988)

Hedberg, H. D. 1937
Stratigraphy of the Rio Querecual section of mertheastern Venezuela
Geol. Soc. Amer. Bull. 48 (12), Pág. 1971-2024

Hedberg, H.D., Pyre A. 1944
Stratigraphy of northeastern Anzoategui, Venezuela
Amer. Asoc. Petrol. Geol. Bull. 28 (1) Pág. 1-28

Isea A; Ghost S., Aguado B. 1990
Facies Distribution and Reservoir Potential of the Oligocene Sequence El Furrial, Musipan. Giant Field, Venezuela
AAPG 1990. Abstract, Pág. 108

Lamb, J.L. 1964
The Geology and paleontology of Rio Aragua surface section. Serranía del interior, State of Monagas, Venezuela
Asoc. Venez. Geol. Min y Petro. 7 (4) Pág. 111-123

Lamb J.L; de Sisto J. 1964
The Morichito Formation of Northern Monagas
Asoc. Ven. Geol. Min y Petr., Bol. Inf., 6 (9)
Pág. 269-376

Lamb J. L., Sulek J.A. 1968
Miocene turbiditas in the Carapita
Formation of Eastern Venezuela
Cong. Geol. Carib. IV, Trinidad 1965. Pág. 111-119

Liddle, R.A. 1946
The geology of Venezuela and Trinidad
2nd ed. Paleon. Res. Inst. Ithaca, New York, Pág. 890

Lilliu, A. 1990
Geophysical interpretation of Maturin foreland
Northeastern Venezuela
Tesis de la Universidad de Houston. Pág. 129

Lilliu, A., Cabanach, A. 1992
Análisis de calidad de la data sismica en la zona del frente deformación de
la subcuenca de Maturín
VI Cong. Venez. de Geofisica in press.

Linares M .L. 1992
Sequence stratigraphy of late Miocene -Pleistocene of Northern Monagas,
Eastern Venezuela Basin.
Thesis de la Universidad de Texas ,Austin .Pag.82.

Macsotay, O. 1978
Formación Naricual: un yacimiento carbonífero de origen turbiditco proximal del
Mioceno de Venezuela Oriental.
Bol. Geol. Mem., XII (24), Pág. 263-300

Macsotay, O.1980
Mollusques benthiques du cretace inferior: une methode de correlation entre la Tethys
mesogéenne et le domaine paleo-caraibe (Venezuela)
Thése d'Universite-Université Claude Bernard Lyon.

Martin, N., Espinoza E.1990
Integración de la información gravimetrica del flanco Noreste de la cuenca oriental de
Venezuela
V. Cong. Venez. de Geofisica Pág. 78-85

Martinez, A. 1976
Cronologia del Petroleo Venezolano.
Foninves ,Ed.,Ciencia y Petroleo ,Caracas 349 p.

Matesco S. 1989
Interpretacion sismo-geologica de la sub-cuenca de Maturin; Cuenca Oriental de Venezuela (Norte de Monagas).
Informe interno Lagoven S.A.; N·3000-228-99.

Metz, H. L. 1964
Geology of the El Pilar fault zone, state of Sucre, Venezuela
Ph. D. Tesis University of Princeton
New Jersey, U.S.A. Pág. 102

Metz, H.L. 1968
Geology of the El Pilar Fault Zone, State of Sucre, Venezuela.
4th Caribb. Geol. Conf., Trinidad 1965 Pág. 193-198

Molnar, P., Sykes, L.R. 1969
Tectonics of the Caribbean and Middle America regions from focal mechanisms and seismicity
Geol. Soc. Am. Bull. 80 p. Pág. 1639-1684

Murany, E.E. 1972
Tectonic basis for the Anaco fault
Amer. Assoc. Petrol. Geol. Bull.,(56) (5).Pág.860-870

Odehnal, M., Falcón R.1989
La zona de Schackoina Cabri en Venezuela
VII Cong. Geol. Venez. Barquisimeto

Peirson, A. 1965
Geology of the north Central Venezuela
Doc. Lagoven, S.A. inedito
N° 3000-11-5 Caracas Pág. 337

Perez, O. J. Aggarwal, Y.P. 1981
Present day tectonics of the South-Eastern Caribbean and Northeastern Venezuela
J. Geol. Res., 86, B.11, Pág. 10791-10804

Pérez de Mejia, D., Tarache, C. 1985
Síntesis Geológica del Golfo de Paria
VI Cong. Geol. Venez., Mem. V, Caracas, Pág. 3243-3277

Potie G. 1989
Contribution á l'etude geologique de la frontiere sud-est de la plaque Caraibes: La Serranía del Interior Oriental su le transect Cumana-Urica et le bassin de Maturin-Venezuela
Thése Brest 95 fig. Pág. 240

Renz, H. H.1962
Stratigraphy and paleontology of the type section of the Santa Anita group.
Asoc. Venez. Geol. Min y Pet. 5 (4). Pág. 89-108

Rod, E, Maync. W. 1954
Revision of Lower Cretaceous stratigraphy of Venezuela
Amer. Assoc. Petrol. Geol. Bull 38(2). Pág. 193-283

Rosales, H. 1959
Discusión sobre la Formación El Cantil del noreste de Venezuela
Bol. Geol. 5 (10)

Rosales, H. 1972
La falla de San Francisco en el Oriente de Venezuela
IV. Cong. Geol. Venez. Caracas. Bol. Geol., 3 (v). Pág. 2332-2336. Publ. Esp.

Rossi, T. 1985
Contribution á e'etude géologique de la frontieré subd-Est de la plaque Caraibe: La Serranía del Interior Oriental (Venezuela) sur le transect Cariaco-Maturin
Thése, Brest, 338. Pág. 122 Fig. 2 pl

Rossi, T. Stephan, J.F.Blanchet, R. Hernández, G.1987
Etude geologique de la Serranía del interior oriental (Venezuela) le transect Cariaco-Maturin
Revue de R.I.F.P. 42 (1) Pág. 3-30

Salazar, M. 1990
Development of the El Furrial Field, Eastern Venezuela
AAPG-1990. Abstracts. Pág. 160

Salvador, A. 1964
Proposed redefinition of the Tinajitas in northeastern Venezuela
Asoc. Venez. Geol. Min. y Pet., 7 (2) Pág. 53-64

Salvador, A., Rosales, H. 1960
Guia de excursión A.3. Jusepín-Cumaná
III Cong. Geol. Venez. Mem. T.I..
Bol. Geolg., Caracas, Publ. Esp. 3., Pág. 63-74

Salvador A., Stainforth R.M. 1968
Clubes in Venezuela to the Geology of Trinidad and vice-versa.
4th. Caribb. Geol. Conf. Trinidad 1965. Pág. 31-40

Schubert, C., 1979
El Pilar fault zone, northeastern Venezuela: brief review
Tectonophynics, S2. (1-4) Pág. 447-455

Schubert, C., 1979
Origin of Cariaco Basin-Southern Caribbean Sea
Marine Geology, 47. Pág. 345-360

Schubert, C., 1985
Cuencas Cenozoicas tardías de Venezuela
VI Cong. Geolg. Venez. Caracas 1985,
T. IV. Pág. 2663-2679

Soccas, Mercedes, 1991,
Estudio Sedimentológico de la Formación Naricual. Estado Anzoátegui. Tesis de grado U.C.V. Pág. 287

Stainforth, R.H. 1971
La Formación Carapita de Venezuela Oriental
Cong. Geol. Venez. IV Caracas. Nov. 1969
Memoria Bol. Geolg. Caracas. Pub. Esp. S.I: Pág. 433-463

Sulek, J.A; Stainforth R.M. 1965
Chapapotal Member, new name for Cachipo Member of Carapita Formation
Asoc. Ven. Geol. Min y Petr. Bol. Inform. 8 (9). Pág. 281-282

Subieta, T.,Carnevali, J.,Hunter, V., 1988
Evolución tectono-estratigráfica de la Serranía del interior y de la subcuenca de Maturin
III Simp. Bolivariano. Cuencas Subandinas

Tribovillard N. P.; Cotillon P.; Jautee E., Stephan J.F. 1991
Les nodules carbonates des formations riches en matiere organique du Cretace Superieur des plates-formes venezueliennes.
Bull. Soc. .Geol.. France -t 162 - p. 859-866.

Vierbuchen, R.C. 1978
The Tectonics of Northeastern Venezuela and southeastern Caribbean sea.
Ph. D. Thesis. Princenton Univ.. Pág. 175

Vierbuchen, R.C. 1984
The geology of the El Pilar fault-zone and adjacent areas in the northeastern Venezuela
In: The Caribbean-South America plate boundary and regional tectonics Bonini. W.E. Hargraves R. B. et Shagan R.. eds.

Vivas, V. 1980
Geología de la región de Píritu-Naricual. Km. 52. Estado Anzoátegui (Venezuela)
Informe interno. Ministerio de Energia y Minas. Caracas