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A Cross Section From The Oil-Rich Maturín Sub-Basin to Margarita Island The Geodynamic Relations Between South American and Caribbean Plates

LAGOVEN
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Field Trip N° 1

II AAPG/SVG INTERNATIONAL CONGRESS AND EXHIBITION

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ORGANIZATION AND COORDINATION
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Subsidiary of
PETROLEOS DE VENEZUELA, S.A.

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ENGLISH TRANSLATION

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ABOUT THIS FIELDTRIP BOOK......

In this excursion guide, we present a regional section from the Orinoco River to the Island of Margarita.

Instead of a division of the chapters in terms of pasive margin, foreland stage or molassic fill, which do not permit one to illustrate clearly the two dominant geological dominions located on the two sides of the El Pilar shear zone; we have prefered to use a description of each orogenic segment encountered in order to present the complexity of this sector of northeastern Venezuela.

In order to cover totally the proposed section; the first part deals with the Maturin sub-basin with its southern flank composed of the Orinoco Heavy Oil belt; whose special characteristics have induced us to differenciate and emphasize it in the framework of the Eastern Venezuela Basin.

The second part constitutes the basic elements of the field trip. There in, we present successively the stratigraphy and the tectonics of the Interior Mountain Range and of the internal zones of the South Caribbean Chain as exhibited in the Island of Margarita.

The reader will find a list of references utilized at the end of this excursion guide, which could constitute a first aproach for a more detailed study.

Yves Chevalier

CONTENTS

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.

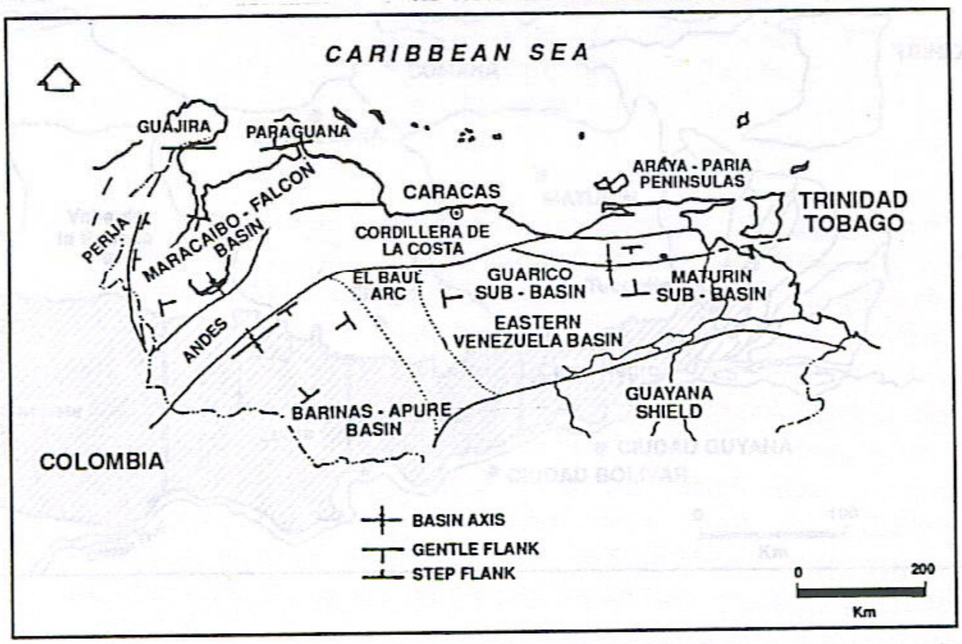


Fig. 1. Northern Venezuela tectonic elements.
(From Lilliu .1990).

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) .

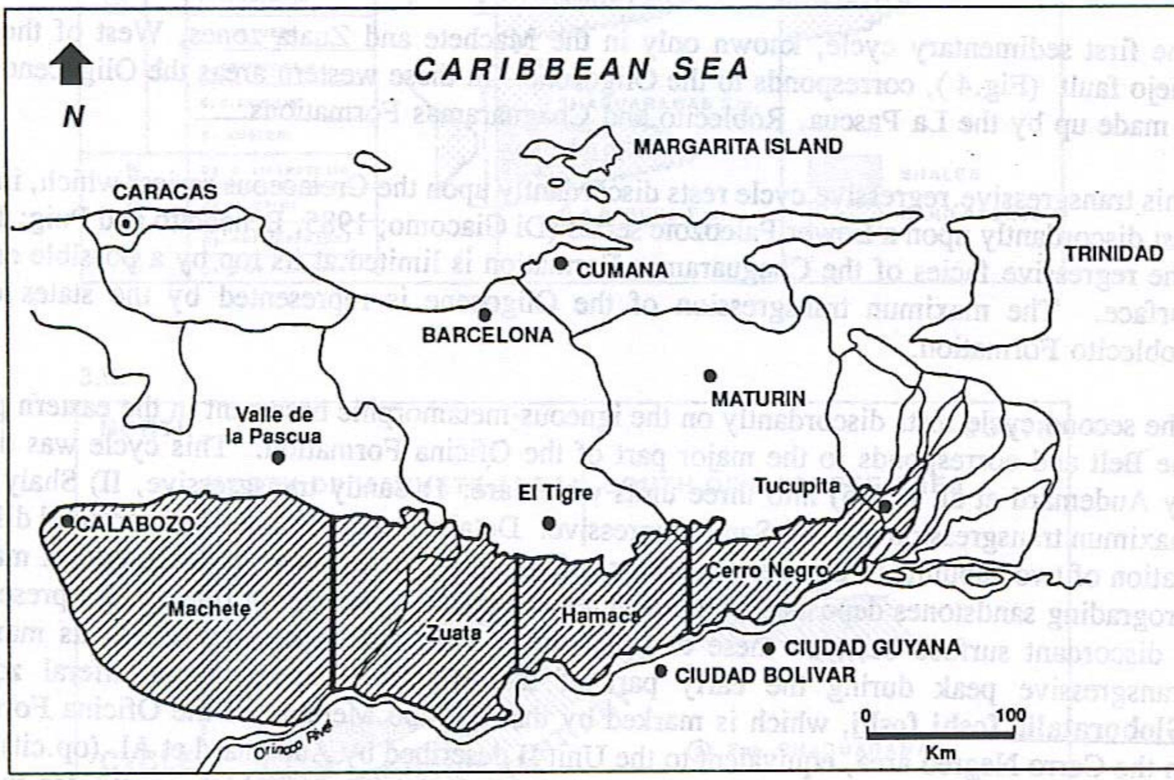


Fig. 2 : The Orinoco Belt.
(From Audemard et Al. ,1985).

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.

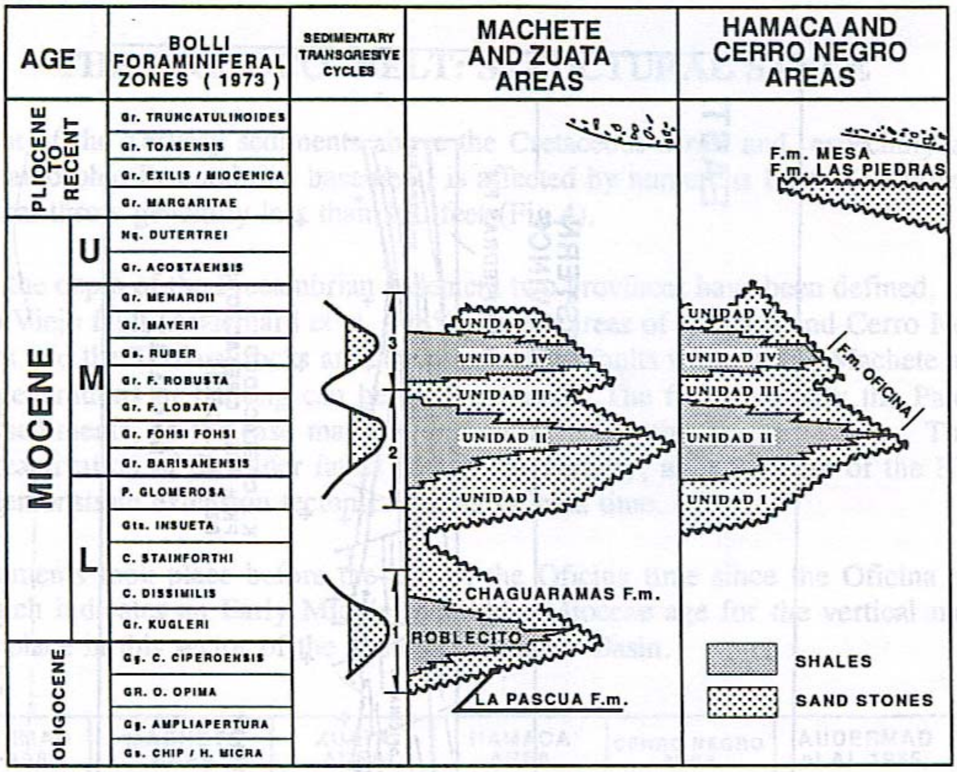
This transgressive.regressive cycle rests discordantly upon the Cretaceous series, which, in turn, rest discordantly upon a Lower Paleozoic series (Di Giacomo; 1985, Benedetto and Puig; 1985). The regressive facies of the Chaguaramas Formation is limited at its top by a possible erosion surface. The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



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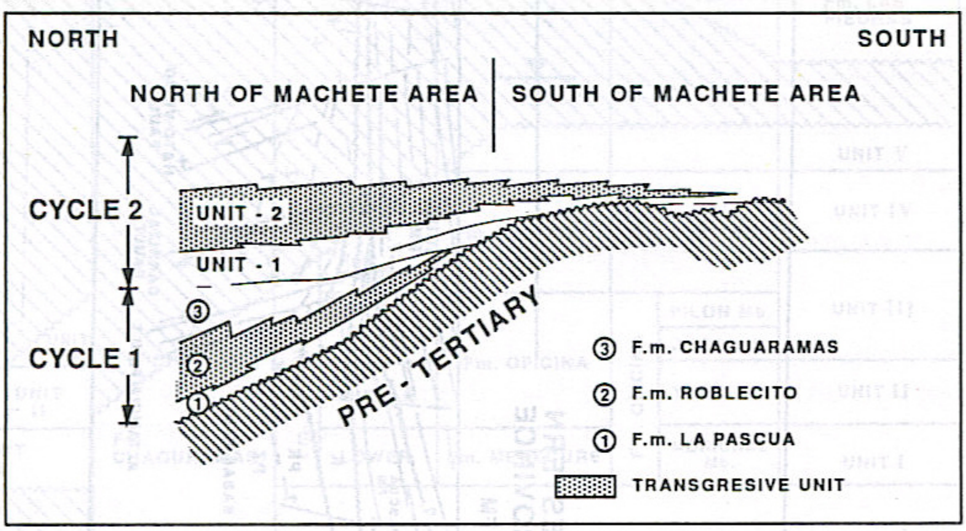


Fig.3 : Age of different transgressive cycles (Fig.3A) and schematic section of Machete area (Fig.3B).

(From Audemard et Al; 1985)

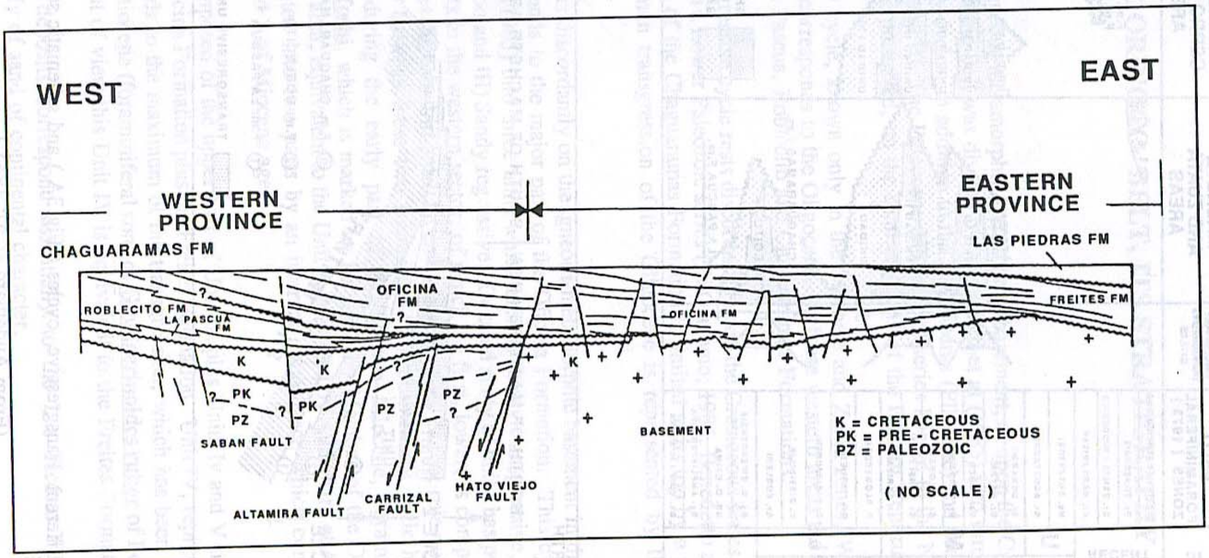


Fig.4 : Schematic structural configuration of the Orinoco Tar Belt.
(From Audemard et Al ;1985)

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.

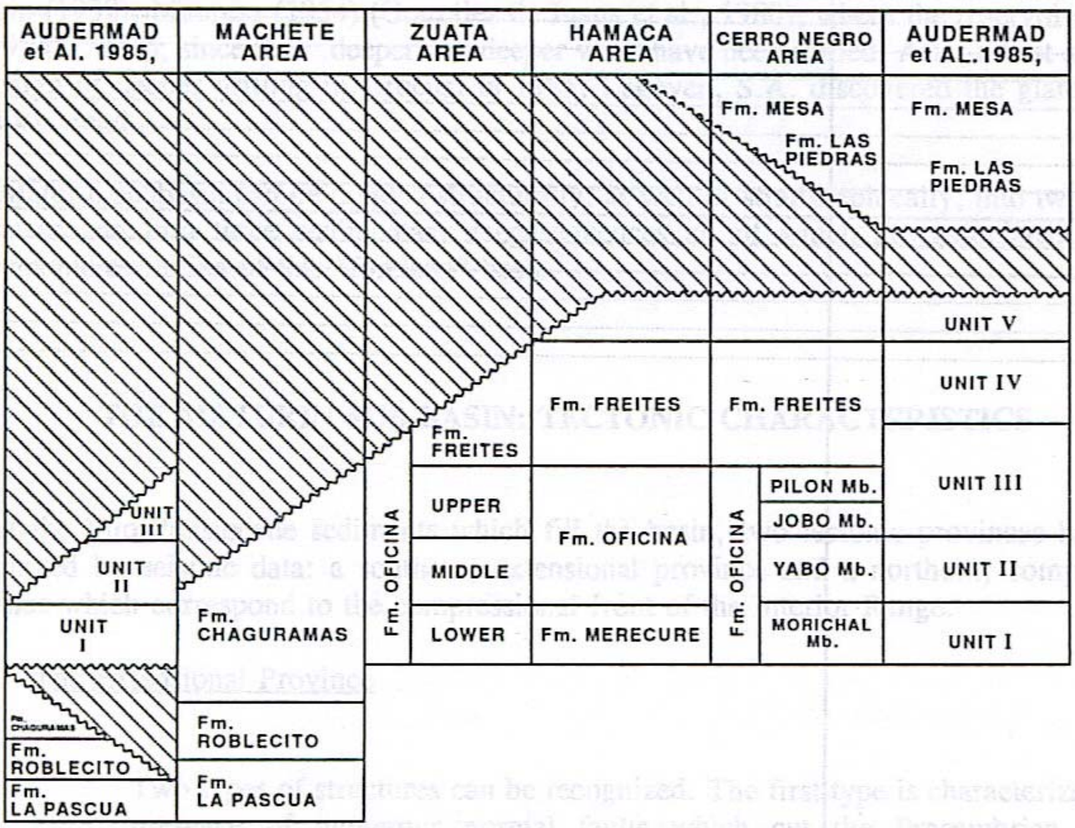


Fig.5: Relation between the transgressive cycles and the formationnal division of the tertiary sediments of the Orinoco Belt.

(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.).

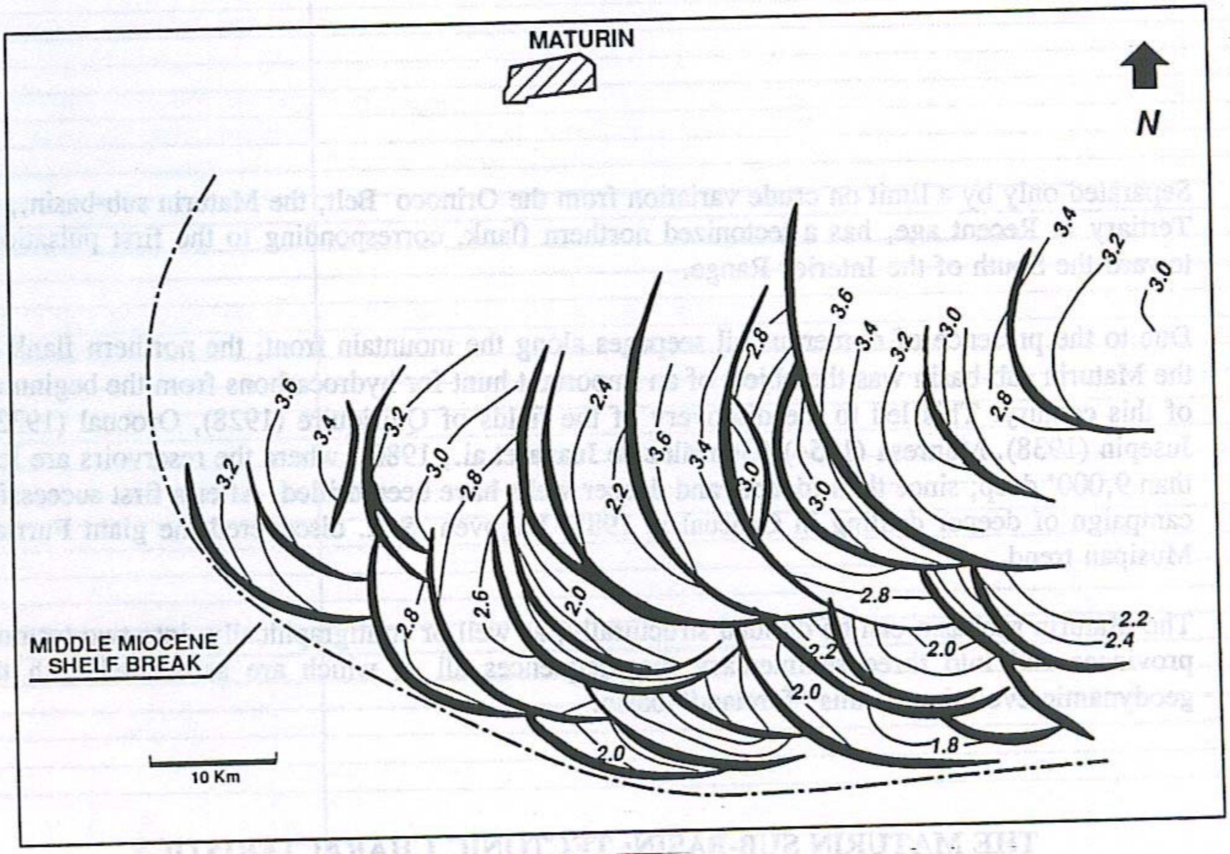


Fig. 6: Generalized map of the growth faults
in the Mapirito-Soledad-Casma Area.
Top of Freites Formation.
(From Daza and Prieto, 1990).

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. <u>The Passive Margin Stage</u>

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. <u>The syntectonic facies of Lower to Middle Miocene (Carapita and Oficina Formations)</u>

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

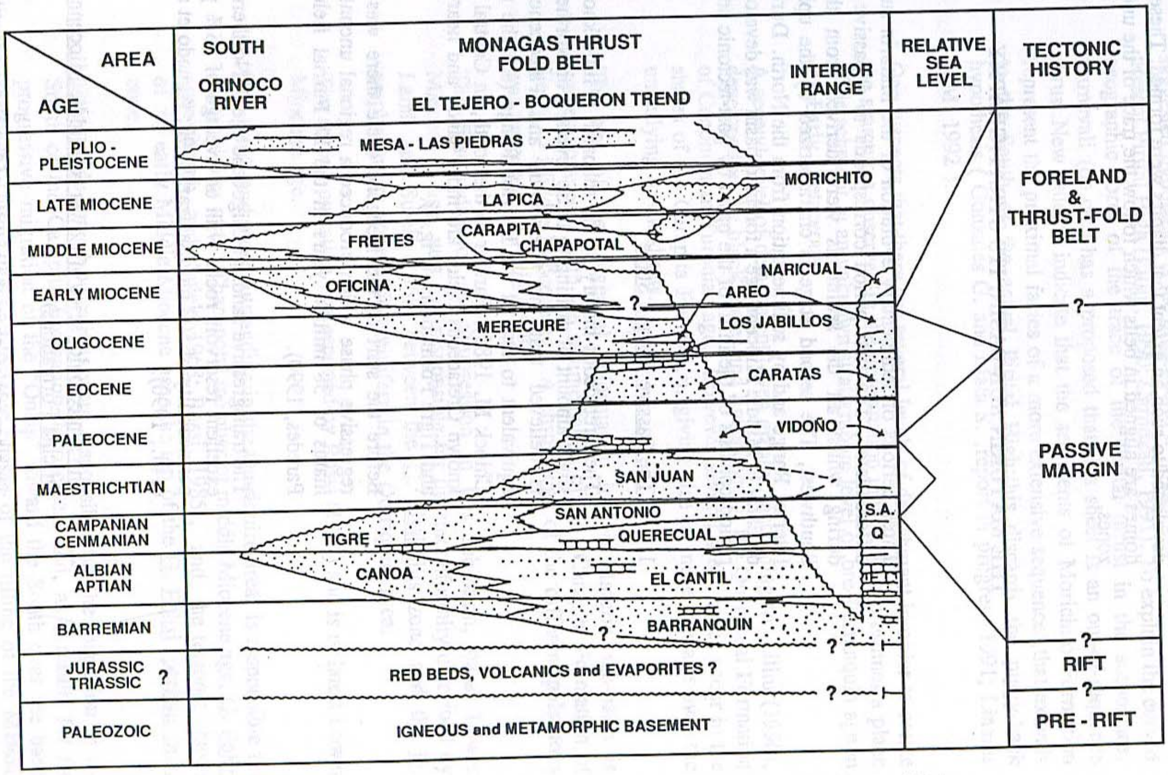


Fig. 7 : Generalized tectono- stratigraphy diagram in the Maturin Sub-Basin.
(From Carnevalli, 1990).

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. <u>The Neocomian Barremian-Aptian</u>:

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 (<u>Nannoconus</u> <u>colomii</u>, det. C. Muller) and benthic foraminifera (<u>Choffatella</u> <u>decipiens</u>, 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 (<u>Caprina</u> sp and <u>Amphitricoelus</u> 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.

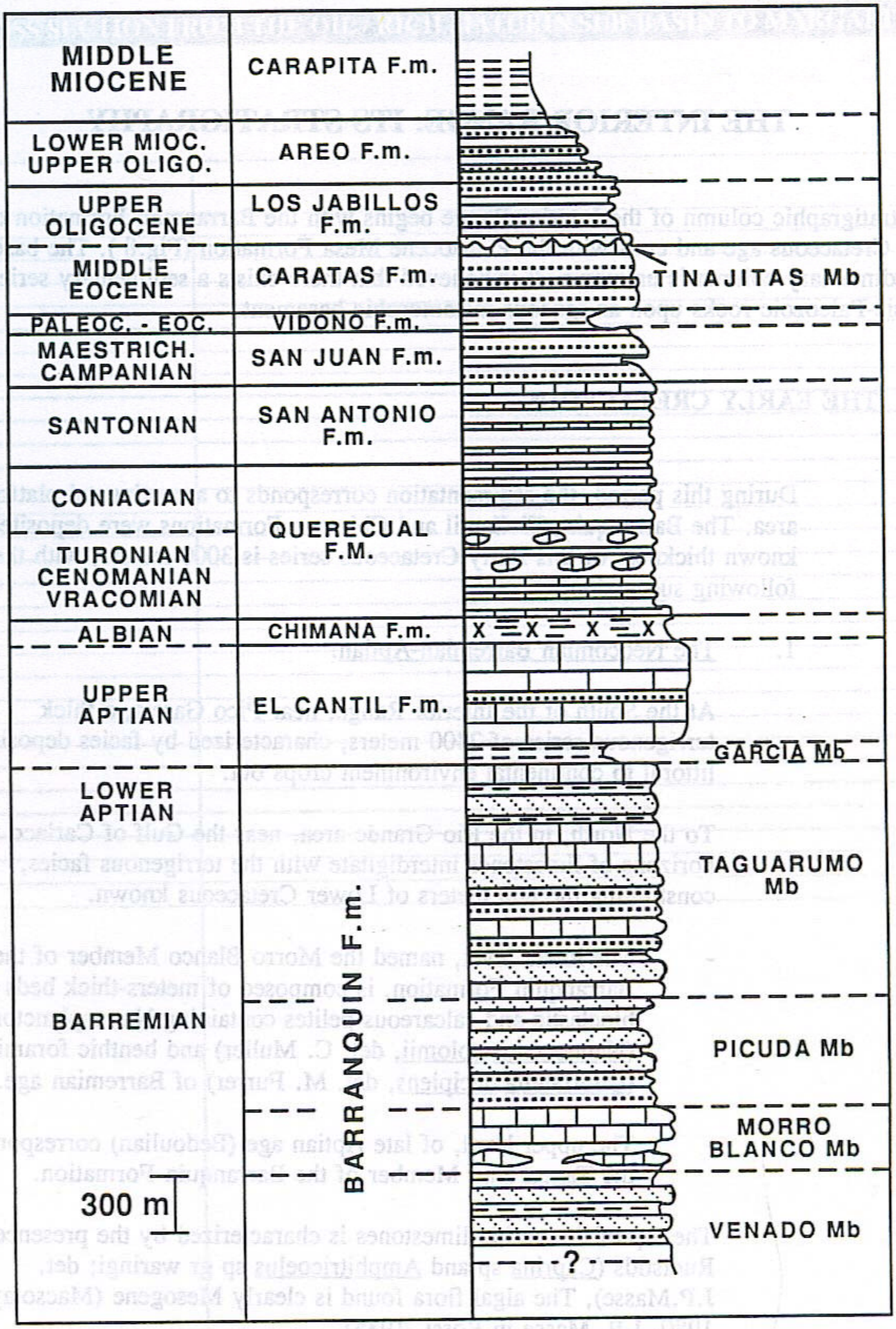


Fig. 8 : Schematic stratigraphic column of the Interior Range.

2. <u>The Basal Upper Aptian</u>

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 <u>Chakoina</u> <u>cabri</u> (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. <u>Upper Aptian-Lower Albian</u>

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.)

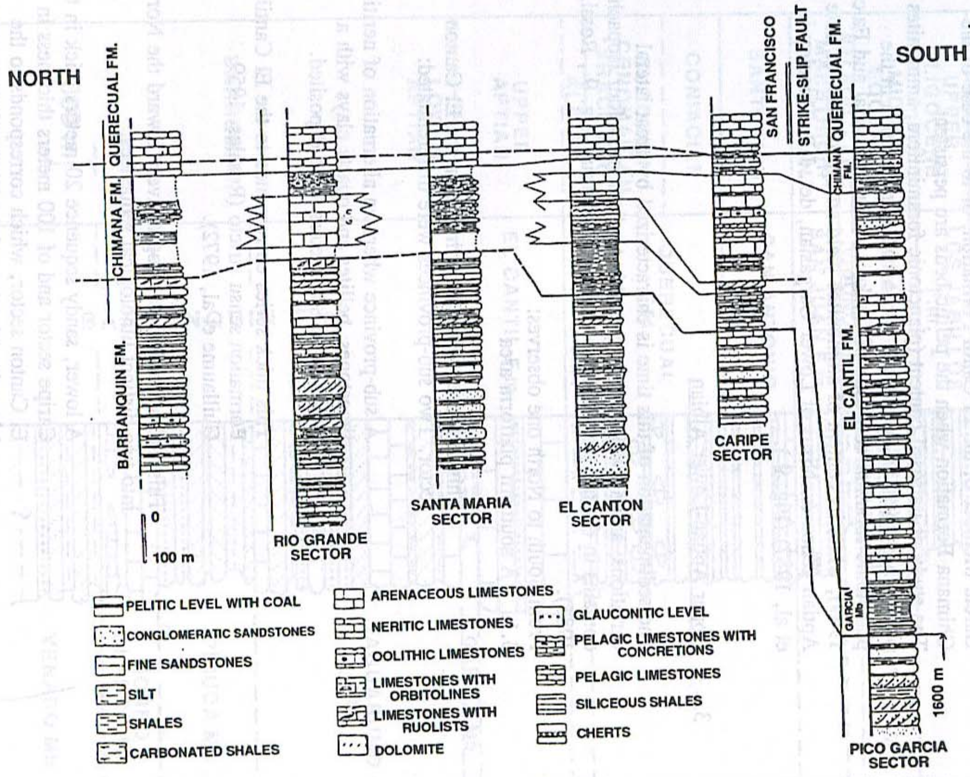


Fig. 9 : Lower cretaceous stratigraphic columns along the Aragua de Maturin --Cariaco transversal section.

(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.

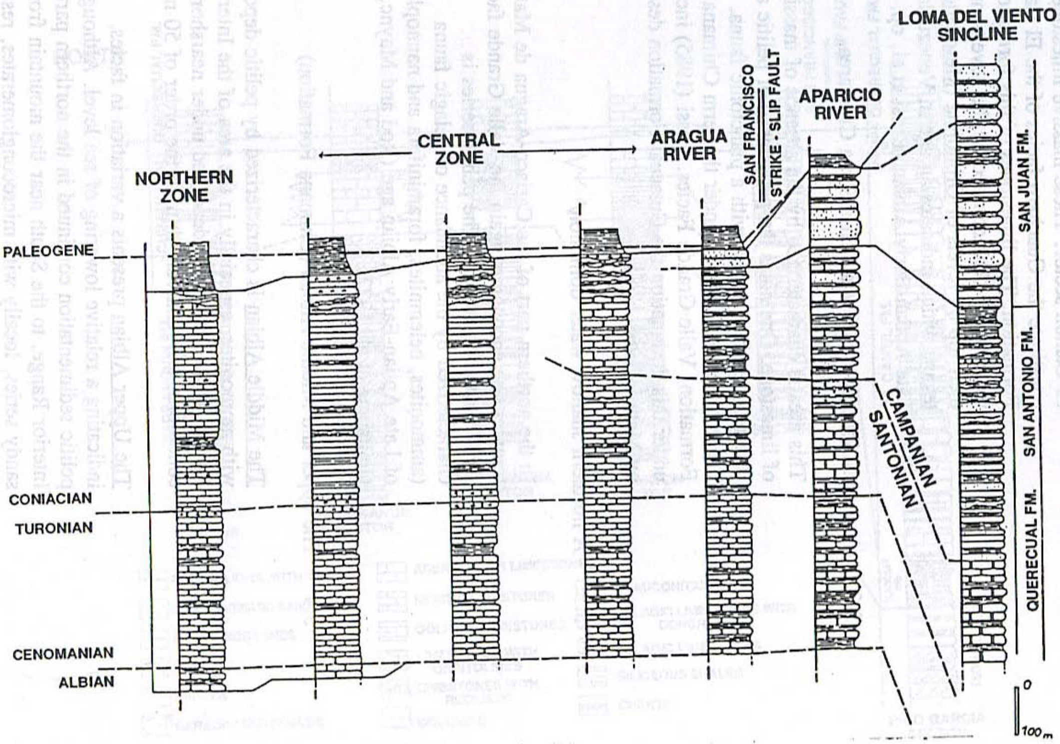


Fig. 10 : Upper cretaceous schematic stratigraphic columns along the Aragua de Maturin -- Cariaco transversal section.

(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. <u>The Upper Senonian</u> (<u>San Juan</u> or <u>sandy San Antonio</u>)

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 <u>Haplophragmoides</u> of shallow waters together with <u>Cyclammina</u> 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).

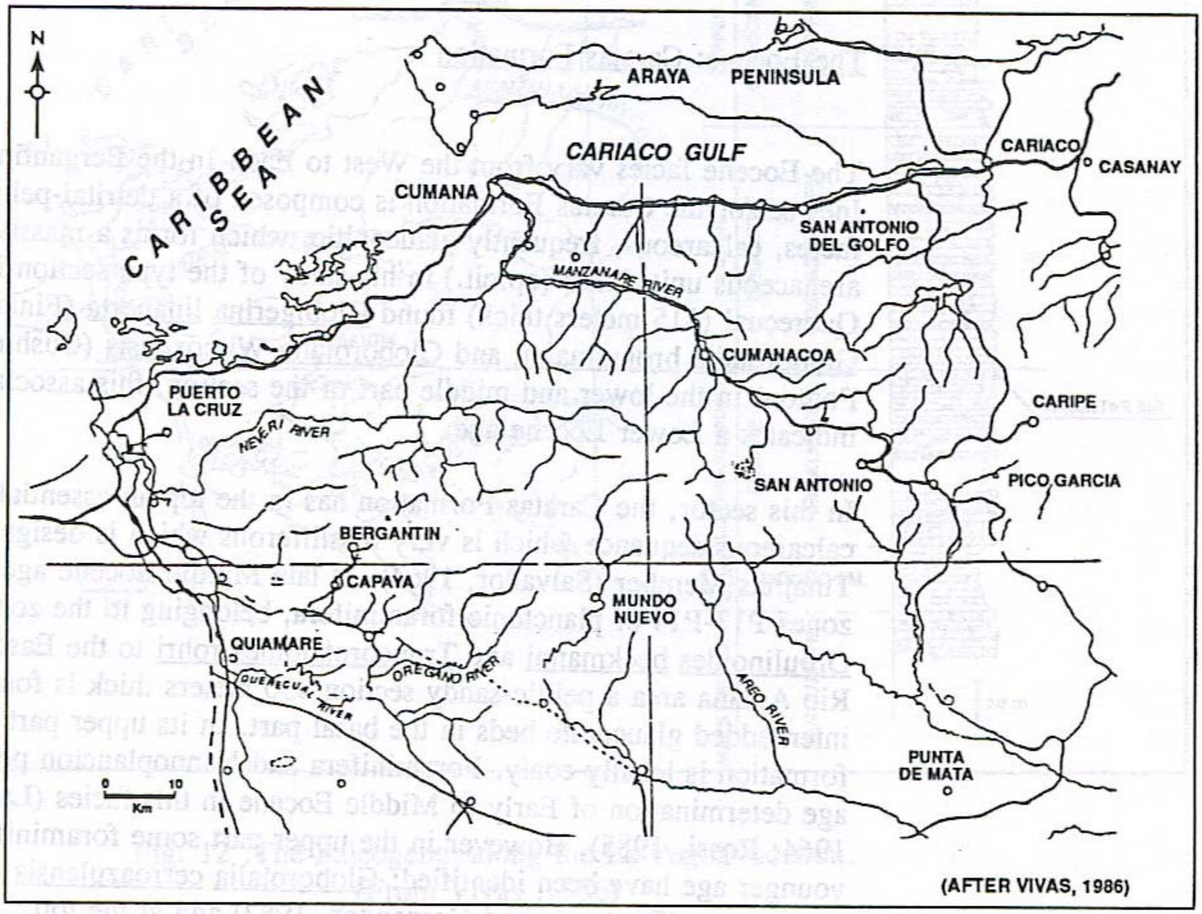


Fig. 11 : Index map that includes locations of type -sections for various Neogene Formations.

(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.

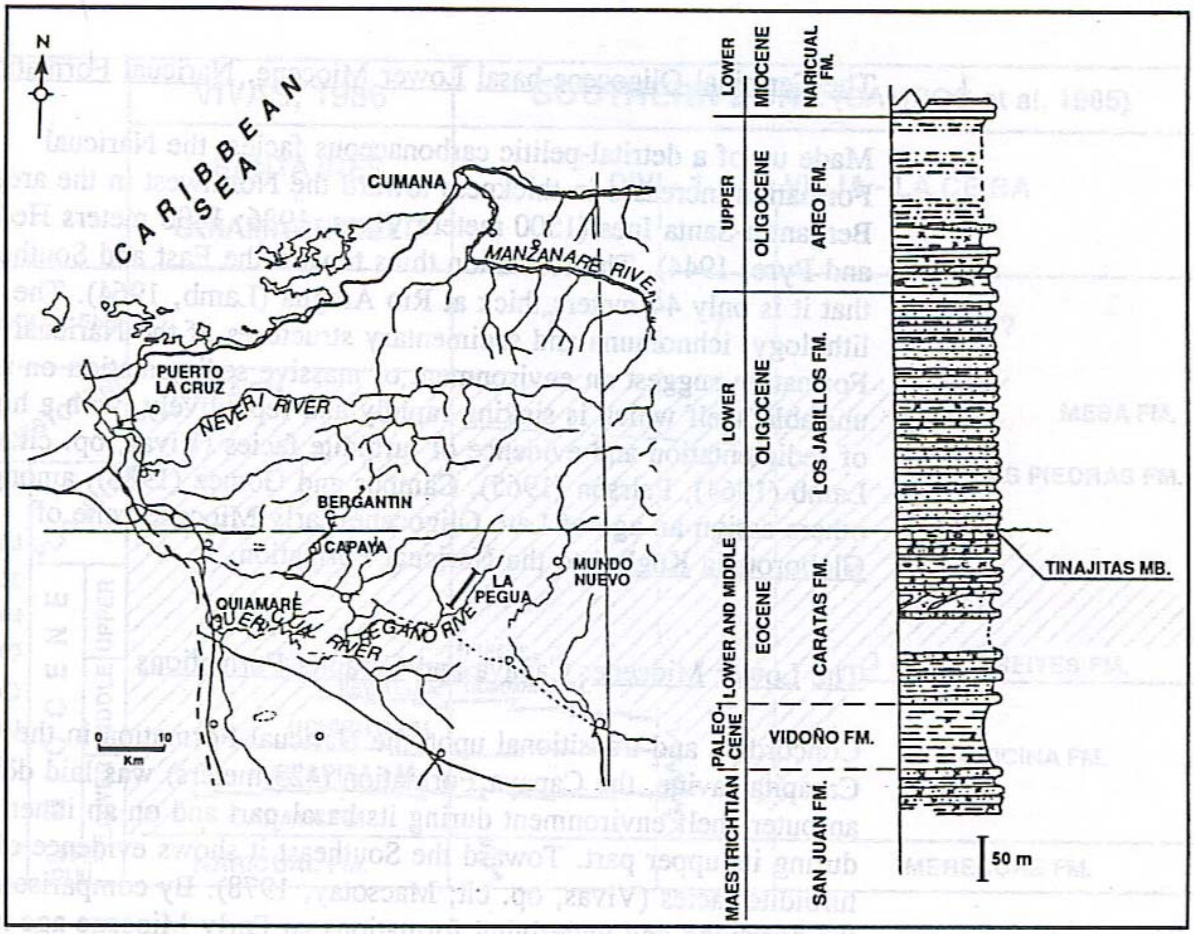


Fig. 12 :The Paleogene along the La Pegua section.
(From Vivas ,1986)

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.).

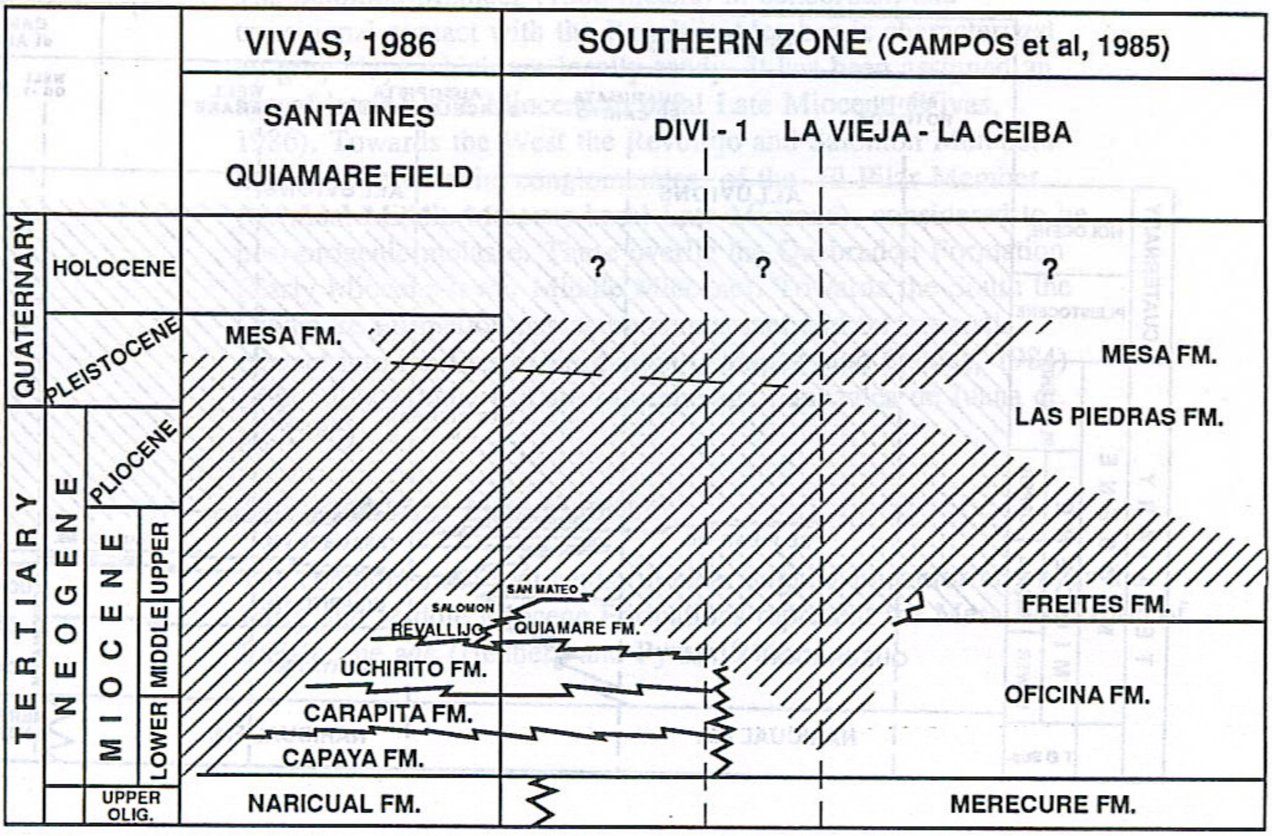


Fig. 13 : The Neogene Formations in the South -West flank of the Interior Range .

(After Vivas 1986)

3. <u>The Middle Miocene base of Upper Miocene: Uchirito and Quiamare Formations</u>

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).

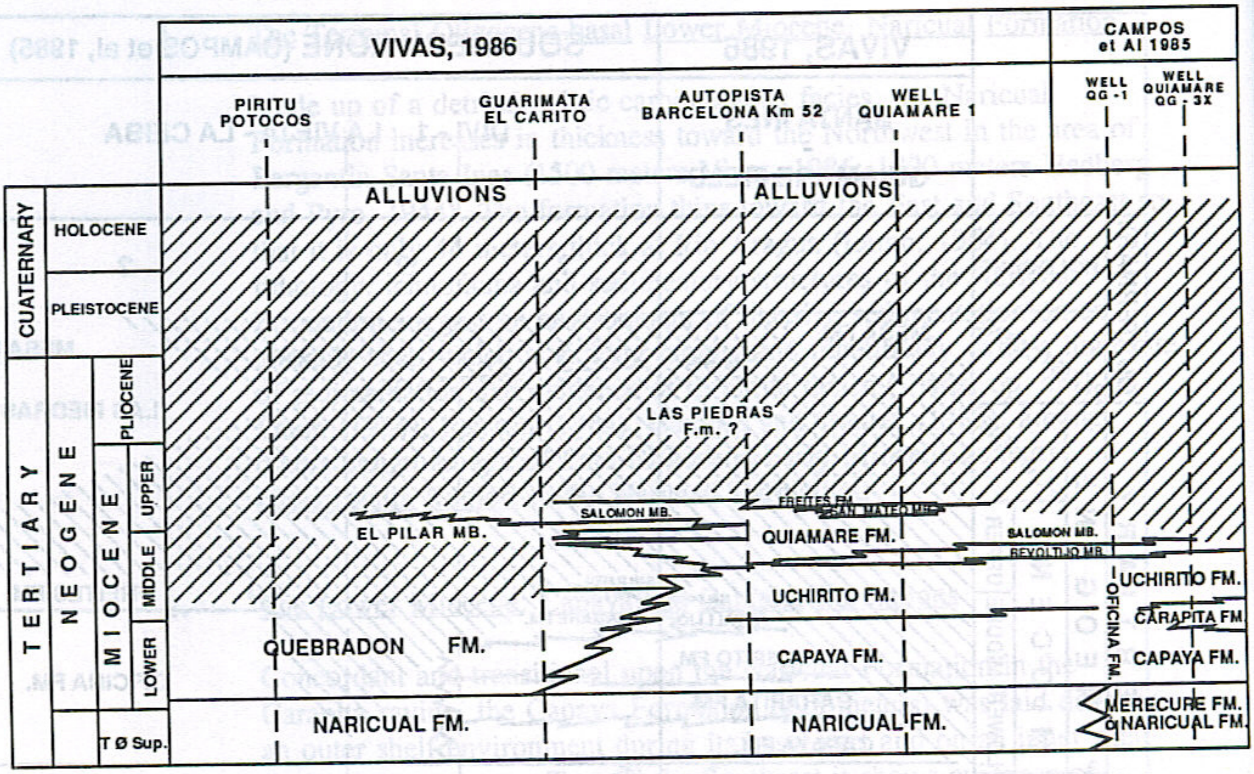


Fig. 14 : The Neogene Formations and their stratigraphic correlation. (From Vivas 1986).

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:

<u>The Revoltijo Member</u> (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.
<u>The Salomon Member</u> (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. <u>The Quaternary</u>: <u>Mesa Formation</u>

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.

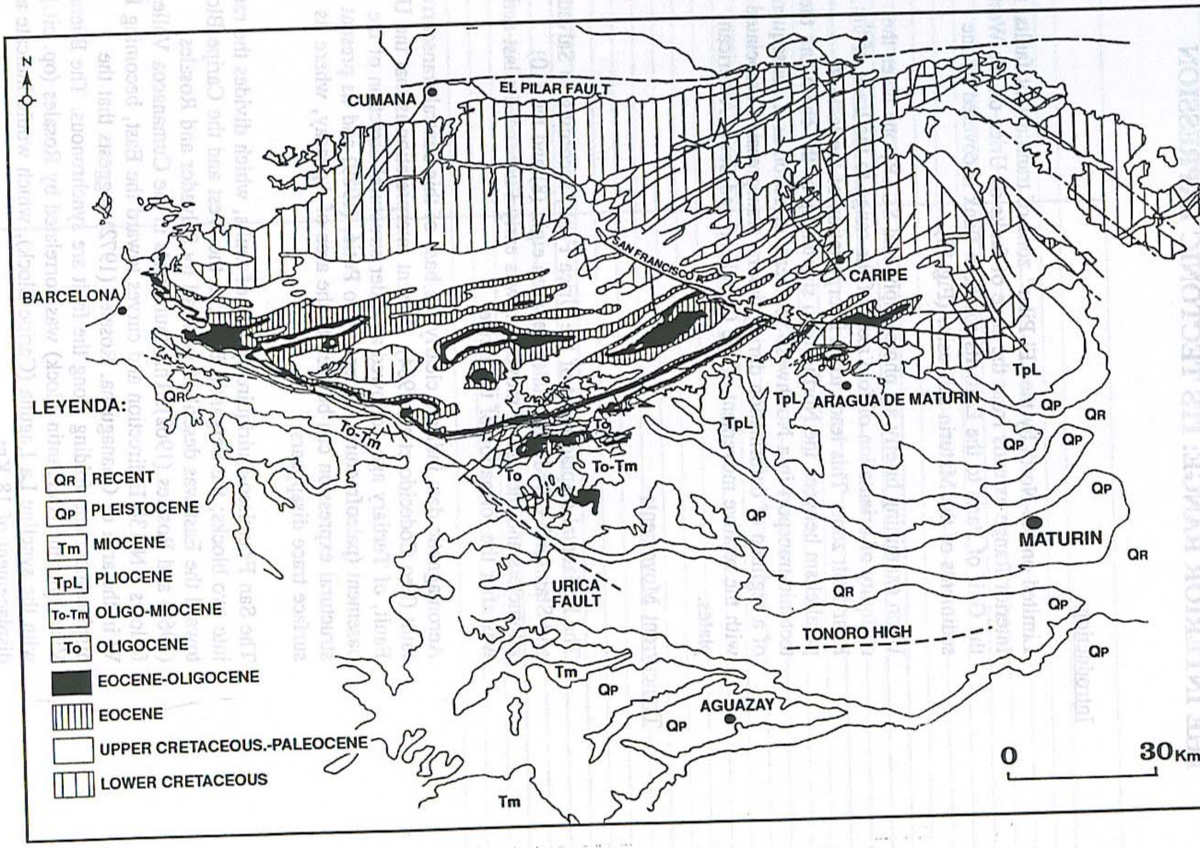


Fig. 15 : Schematic geological map of the Interior Range.
(Modified from Bellizzia et Al 1976 ,in Chevalier and Alvarez 1990).

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.

FIELD TRIP

THE TRANSECT

CARIACO - ARAGUA DE MATURIN

THE INTERIOR - RANGE

DAYS 1 AND 2

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.

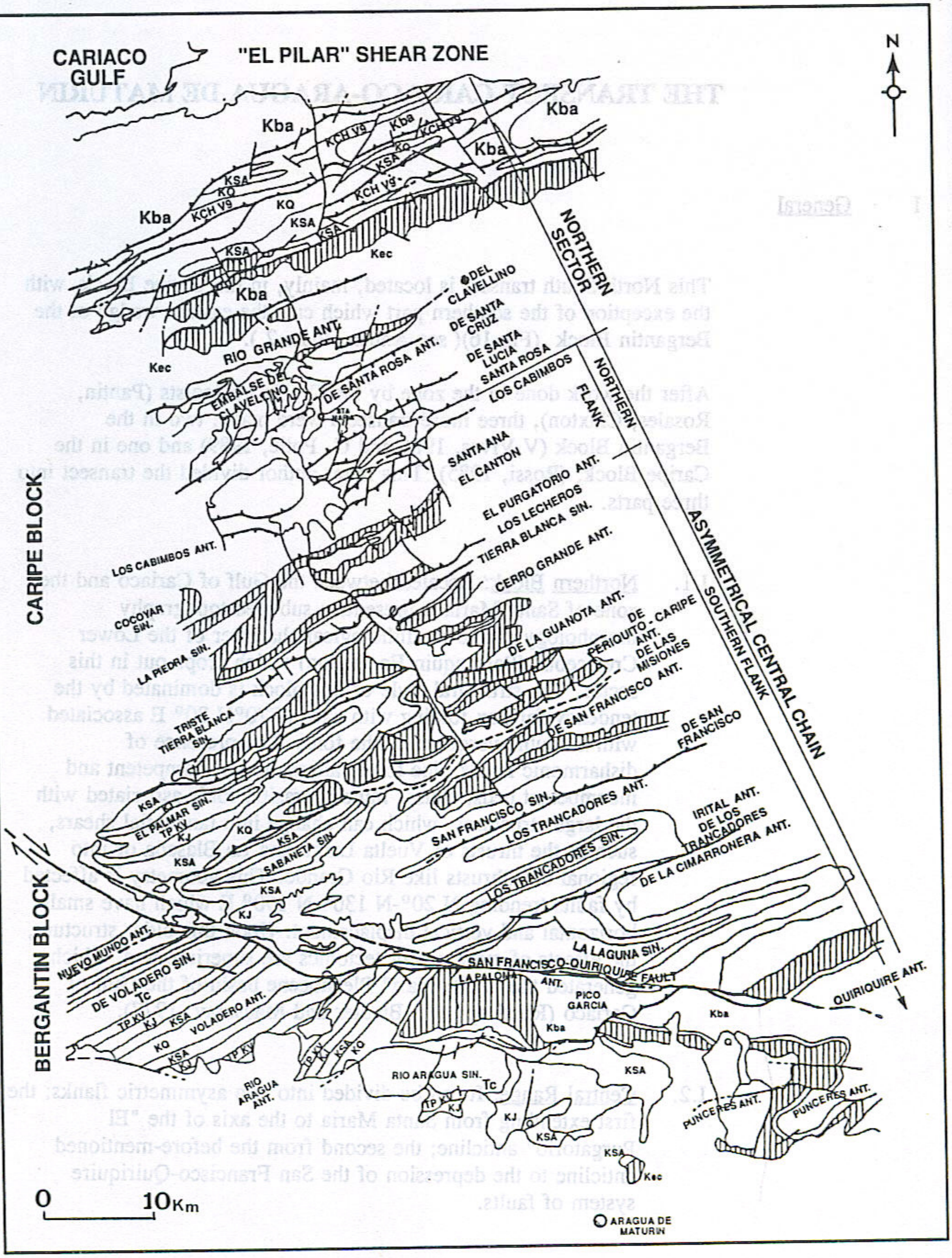


Fig. 16 : Schematic geological map of Cariaco -Aragua de Maturin transect. (modified from Rossi ,1985 ,in Chevalier and Alvarez ,1990)

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

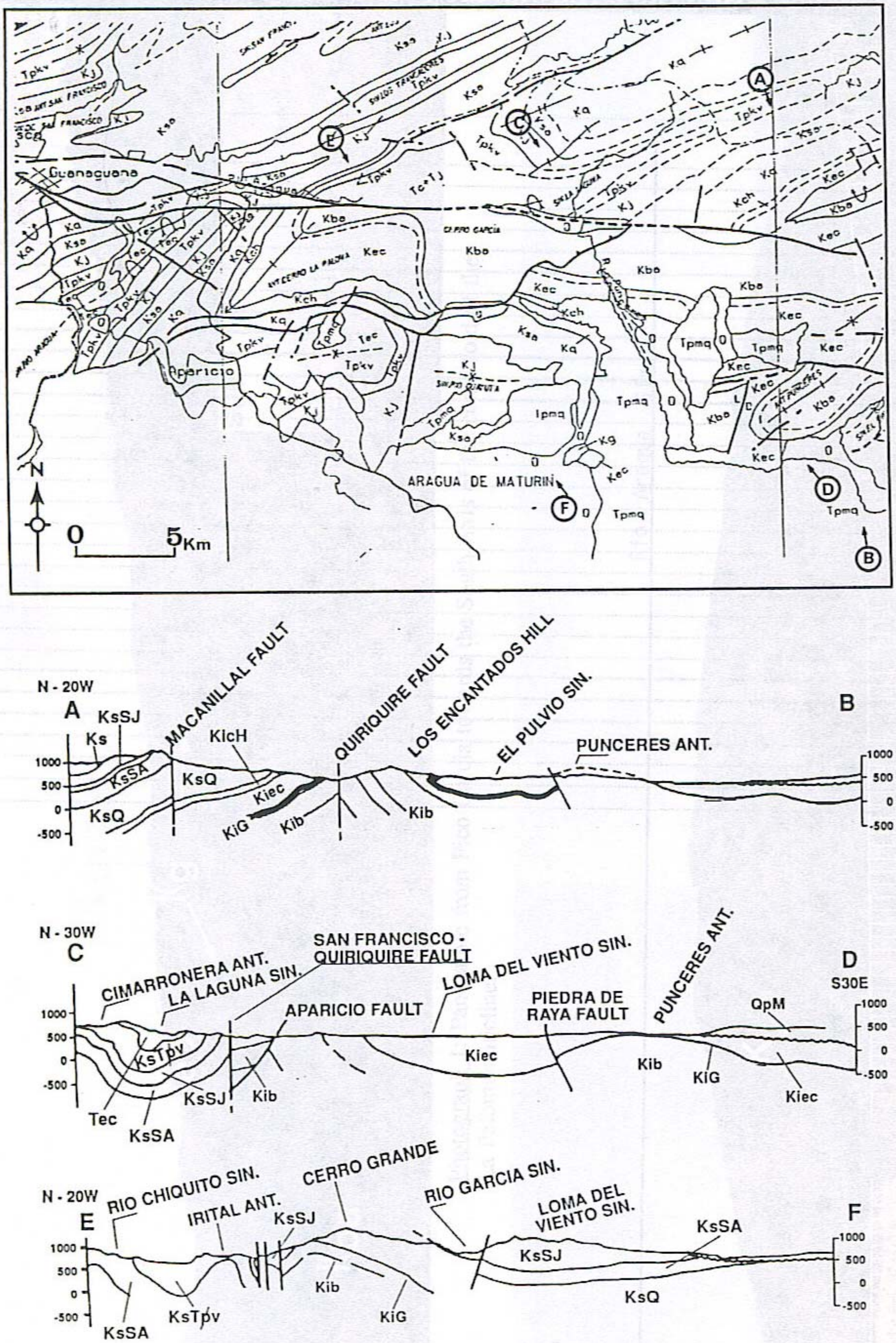
Located South of the trace of the San Francisco Fault, in the Bergantin Block; the Pico Garcia sector is formed essentially by sediments of the Barranquin and El Cantil Formations (See the Stratigraphy Chapter); which make up on map, a huge conic fold dipping toward the Southwest, called the La Paloma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

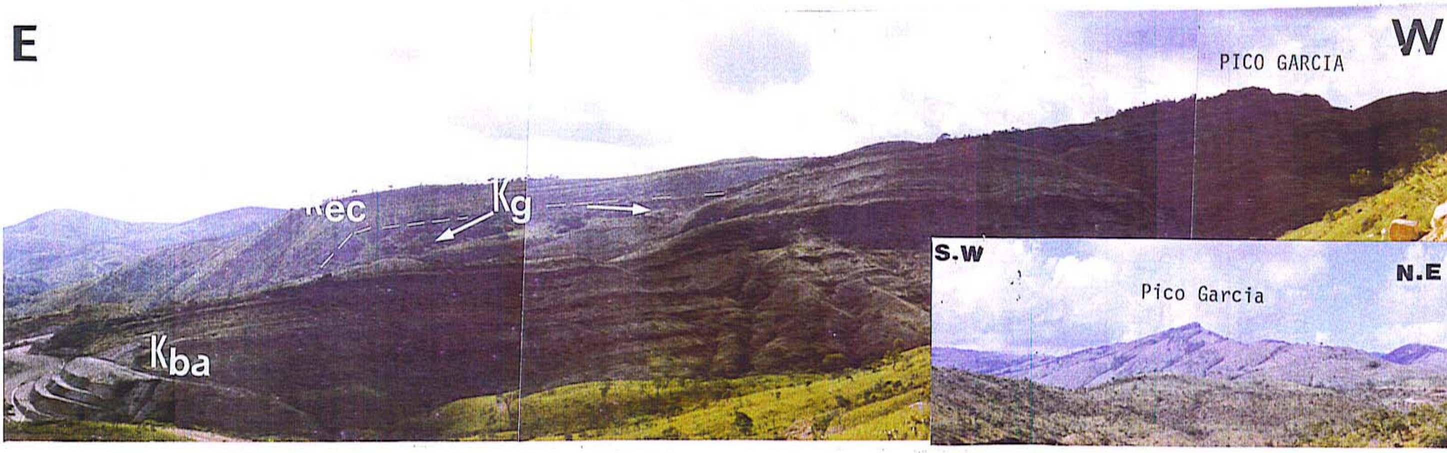
The structure, which indicates a large horizontal movement correlatable with the San Francisco fault, is limited toward the South by the Aparicio Fault, which, in this sector, separates the Albian beds of the El Cantil Formation from the Campanian-Maestrichtian beds of the San Juan Formation. The beds 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).

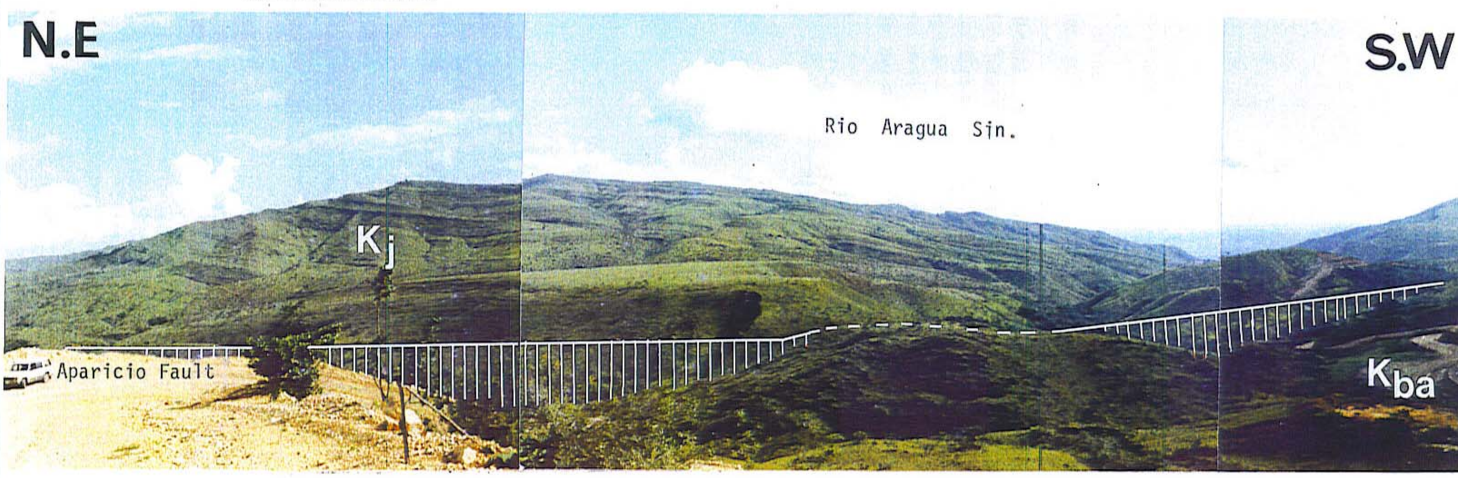
The panorama of the first stop allows understanding on a grand scale of the structures located on both sides of the Aparicio Fault.

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





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



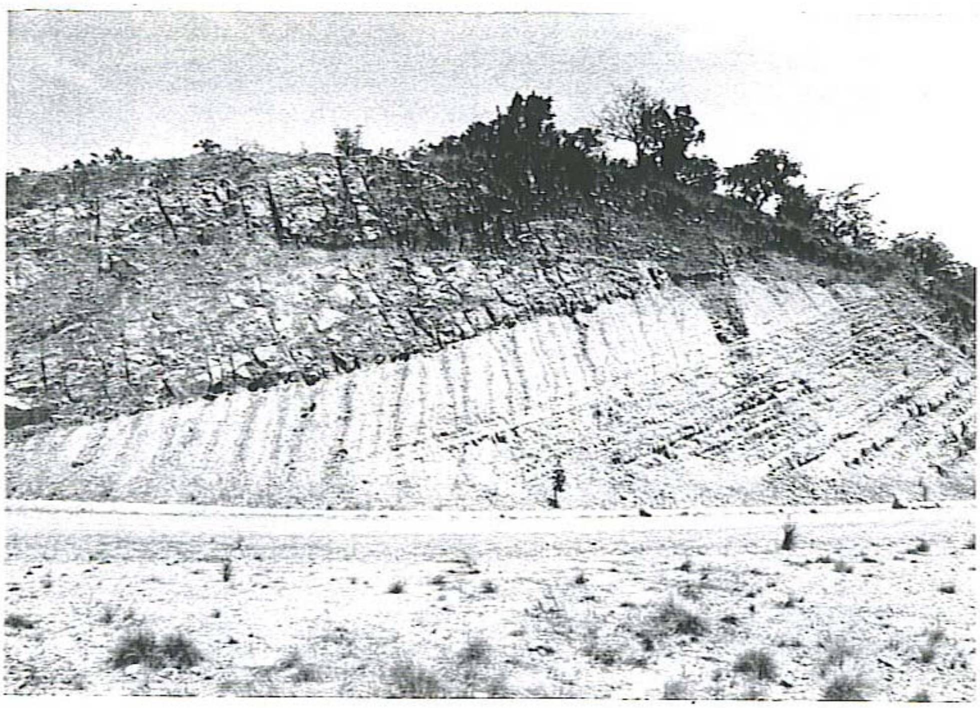
DAY 1: THE INTERIOR RANGE

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.

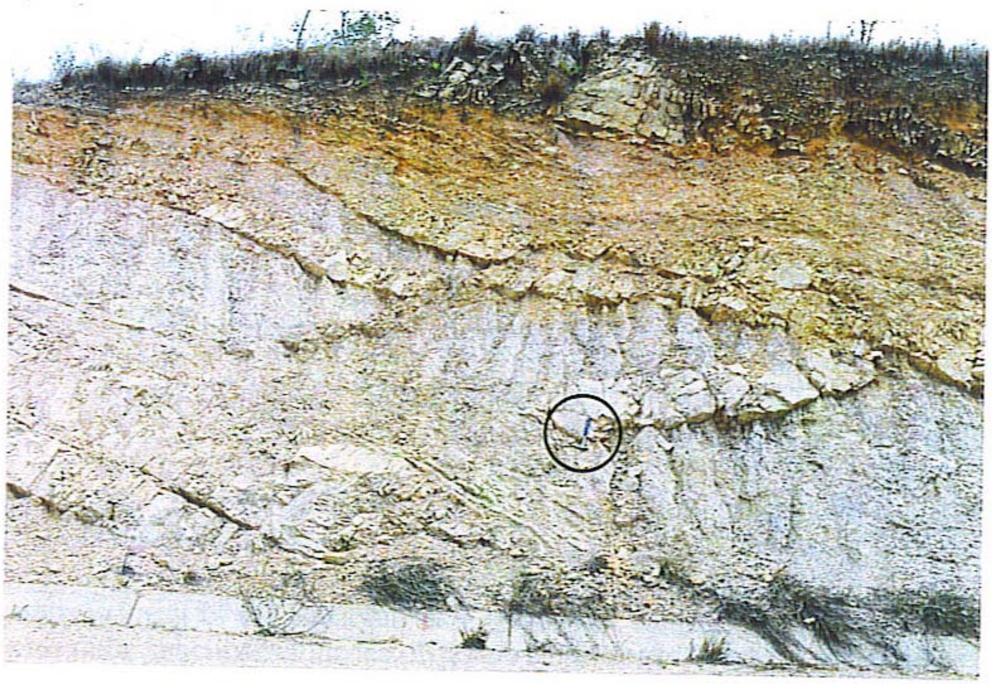
DAY 1: THE INTERIOR RANGE

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.

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.

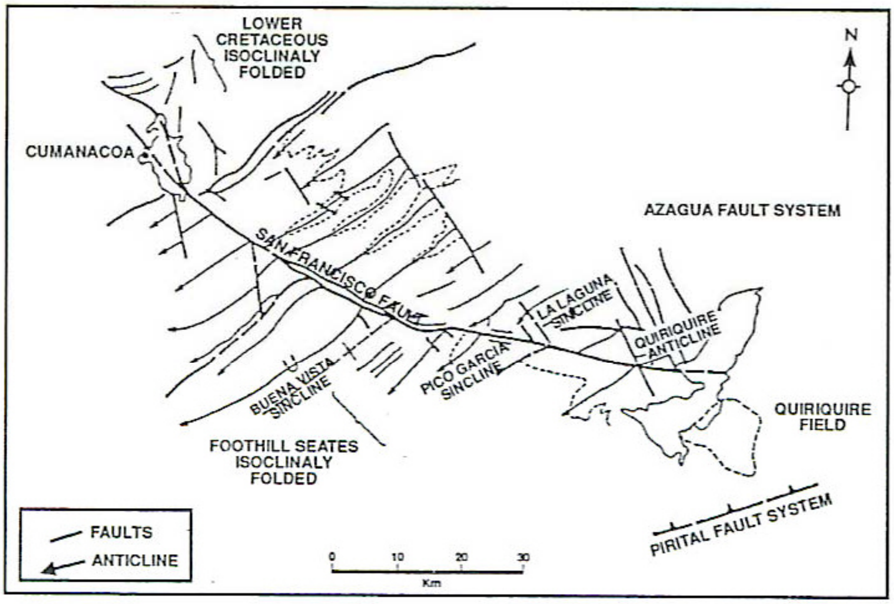
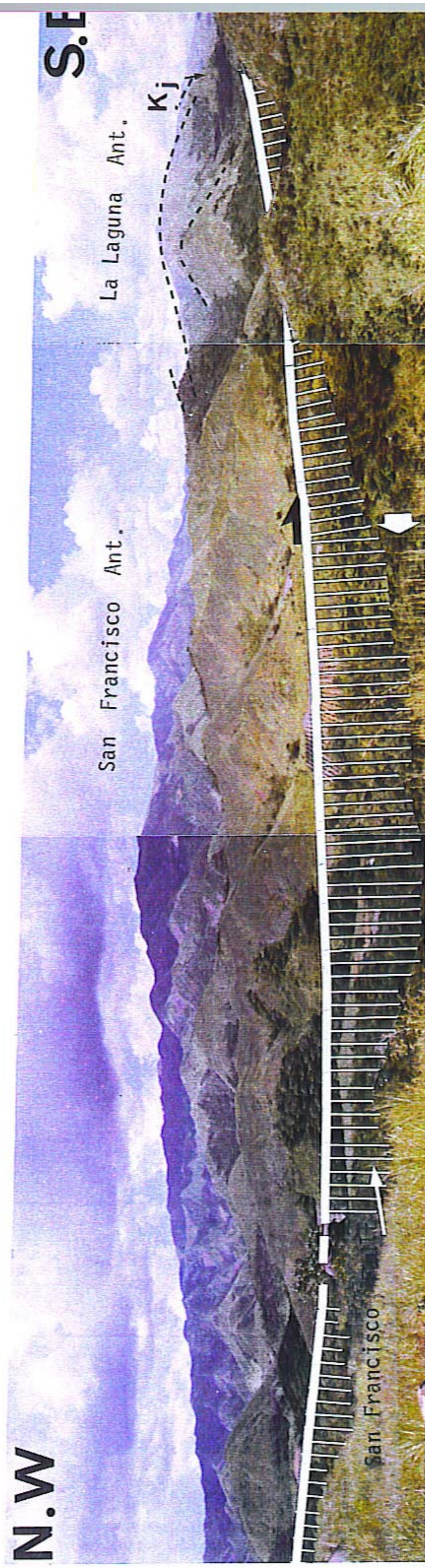


Fig.18 :The San Francisco Fault and associated folding.
(After Rosales,1972).

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.



Photograph 5: Panoramic view illustrating the geomorphologic expression of the San Francisco-Quiriquire fault in the Guanaguana sector.

DAY 1: THE INTERIOR RANGE

Stop 5: Road to Las Misiones. Gravitational Structures

Located on the South flank of the Periquito Anticline, the cuts along the Road to Las Misiones allow one to observe the transition between the facies of the Querecual and San Antonio Formations of early to basal middle Turonian age in this area. In addition to this litho-stratigraphic aspect one can study the structural behavior of these rocks during the deformation of the South flank of the Periquito Anticline.

In a thickness of 50 to 60 meters the transition facies between the two formations is characterized by the increasing presence of lenses and thin beds of chert and by an inversely proportional decrease of micritic concretions.

From the structural point of view, this section presents, from North to South (Fig.19).

1. A major level of a tangential shear marked by the recrystallization of calcite and accompanied by various levels of satellite over thrusts.

2. Farther to the South, toward the syncline, collapse type gravitational structures are developed associated with some normal faults of gravity-slide origin.

DAY 2 - STOP 1. LAS MISIONES SECTION

<u>Photograph 6</u>:Collapse- structures-Road to Las Misiones. South flank of the Periquito Anticline.

<u>Photograph 7</u>: Compressional structures -Road to Las Misiones.

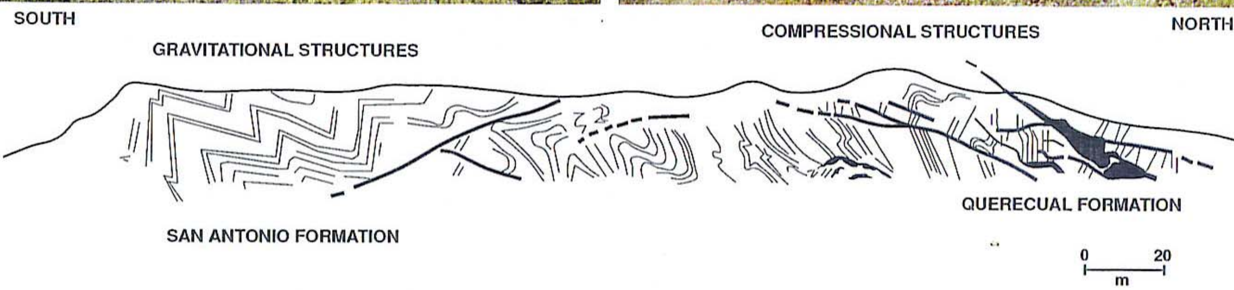


Fig.19: A section along the South flank of the Periquito Anticline.

The source rock of the hydrocarbons of the Eastern Venezuela Basin. The Querecual Formation.

The pelagic and sapropelic deposits of the Cenomanian-Turonian (See Stratigraphy) known from Lake Maracaibo to Trinidad crop out under the name Querecual in the Eastern Venezuela Basin. Although the outcrops in the Interior Range give a slightly high vitrinite reflectance value, indicating over-maturity of the rock, some analyses indicate a T.O.C. (Total organic Carbon) of the order of 5%.
The black facies of these sediments, finely laminated, are subject to an intense deformation with folds which are generally cylindrical and uniform equidimensional, when they are not the preferred levels of detachment during the development of the tangential tectonics during the Miocene.
Numerous concretions, or nodules, can be observed in the strata of the Querecual Formation. Two types of concretions can be differentiated. The first are of large size, up to more than 1 meter in diameter. The second have a maximum diameter of 30 cm and represent nodules richer in pyrite. The genesis of these concretions is attributed to early diagenetic phenomena, controlled according to Hayes (1964) by the liberation of CO_2 gas produced by the decomposition of the organic matter in an anaerobic environment. During the exchange of interstitial fluids the influence of variations of PH of the water is preponderant. (New et al, 1967 in Rossi, 1985,Tribovillard N.P. et Al 1991).

Photograph 8: Levels of calcareous nodules in the black. micritic limestones of the Querecual Formation. Río Aragua-Aparicio area.

Photography 9: Levels of pyritic nodules in the Querecual Formation Rio Aragua Aparicio area.

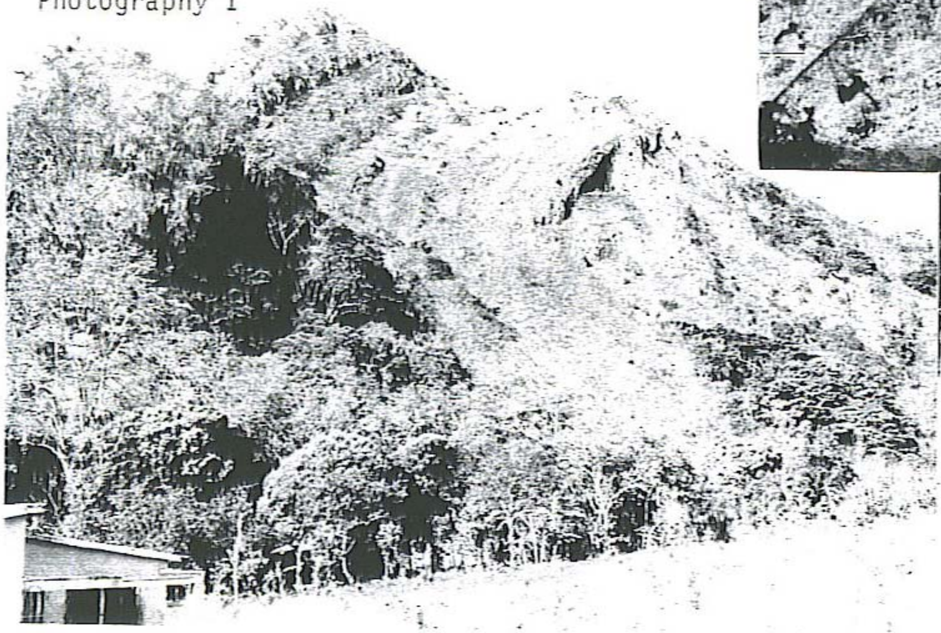
DAY 2: THE INTERIOR RANGE

Stop 1: La Placeta, Periquito Anticline

Cut by the Maturin-Caripe road, at La Placeta, the Periquito Anticline shows a geometrical evolution controlled by tear folds with a N 130° E direction.
This stop allows one to observe on both sides of the road the hinge attitude exhibited by the massive limestones of the El Cantil Formation.

Photography 2

Photography 1



Photograph 1: Hinge of the Periquito Anticline near La Placeta Fold formed in the limestones of the El Cantil Formation of Late Aptian-Early Albian age.

Photograph 2: Vertical South flank in limestones of the El Cantil Formation, seen from the town of Periquito.

Stop 2: El Mirador, The Caripe Fault and the Periquito Anticline.

This second stop presents another angle of observation of the Periquito Anticline, here North of the town of Caripe. The hinge of the anticline is completely overturned toward the South. Its center is occupied by the sandstones of the Barranquin Formation of Barremian-Aptian age and its flanks essentially formed by the massive carbonates of the El Cantil Formation (Guacharo Facies). In the panoramic view of its South flank one can see the Chimana and Querecual Formations. On the other side of the Caripe valley, where the Las Misiones thrust passes, one observes the North Flank of the box-anticline of San Francisco.

Perpendicular to the axis of the Periquito Anticline and near to one is the Caripe Fault with a southerly direction. Mapwise this normal fault continues for a distance on the order of 20 km across the central chain of the Interior Range (See chapter on Tectonic Expression).

This fault is clearly visible on satellite radar images and can be traced to the location of the Clavellino dam. The fault throw, estimated in the Sabana Piedra valley, is 300 to 400 meters with the upthrown side to the West. This vertical displacement permits a good panoramic view of the structures. Although the movement on the Caripe Fault is nearly vertical, we have observed horizontal and oblique, as well as vertical, striations on small slicken-side surfaces.

Photograph 3: Panoramic view of the Periquito and San Francisco anticlines cut by the North-South Caripe normal fault. View toward the West.

DAY 2: THE INTERIOR RANGE

Stop 3: Panoramic view of the La Guanota and Cerro Grande anticlines.

An observation on the road between the Guacharo cave and Sabana Piedra, permits one to differentiate in the eastern panorama, and from South toward the North, the La Guanota Anticline, the rounded end of the El Palmar Syncline and the near vertical South flank of the Cerro Grande (or Cerro Negro) Anticline. Located to the East of the Caripe Fault, the structures can be differentiated due to the presence of the limestones of the El Cantil Formation, South of the near vertical flank of the La Guanota Anticline there exists a plane of this structure over the long North flank of overthrusting which permits the overlapping of the North flank of the overturned Periquito Anticline.

A panoramic view of the structures located on the Western side of the Caripe Fault (Fig.20) shows the superposition of the folds in this section of the chain.

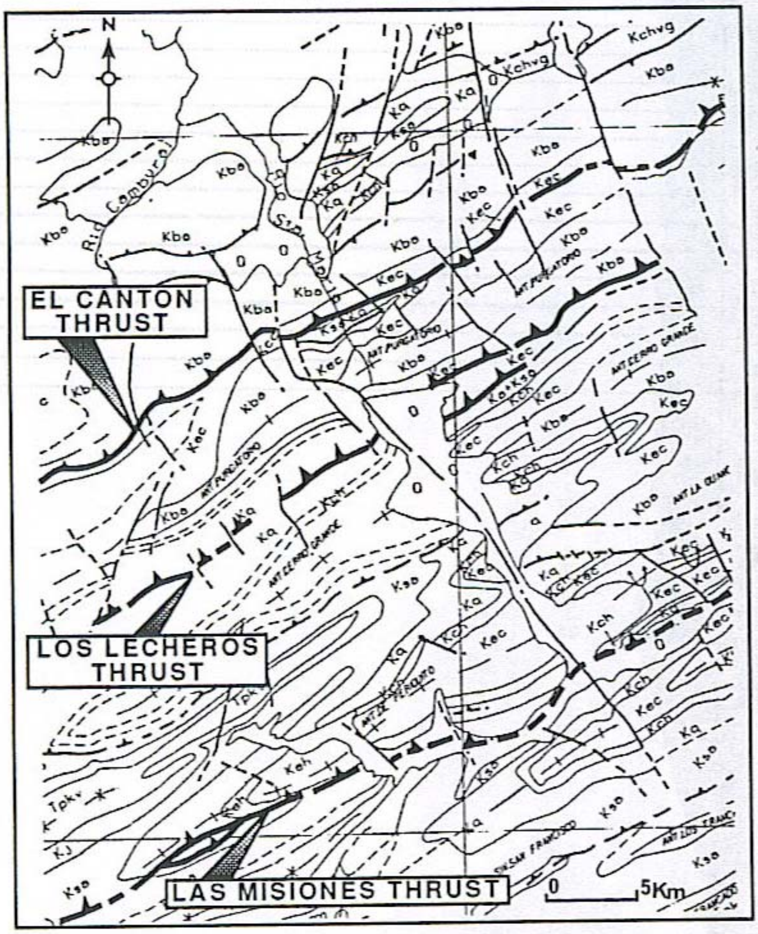
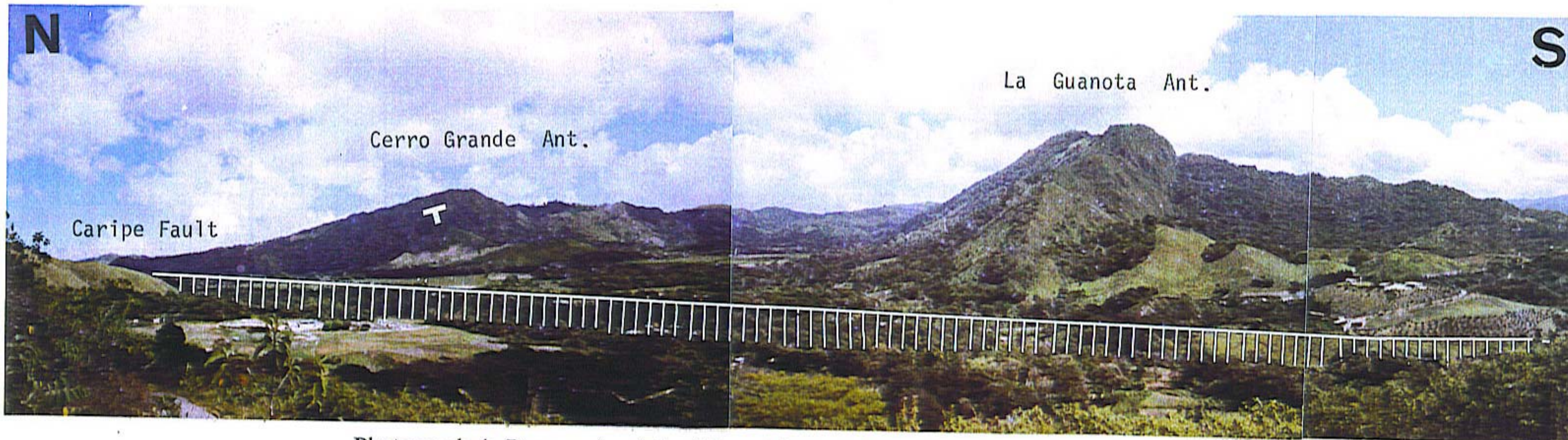


Fig.20: Simplified geological map in the La Guanota area.



Photograph 4: Panoramic of the Sabana Piedra valley toward the East, illustrating the structural style of the large box folds overlapping to their axes.

DAY 2: THE INTERIOR RANGE

Stop 4: Box syncline of Tierra Blanca

Located on the flank of the Cerro Grande (Cerro Negro) Anticline the Tierra Blanca-Triste syncline is sheared in its to differentiate in its western part by the Los Lecheros overthrust. In this panorama one can differentiate by their coffee-color the cherts of the San Antonio Formation of Santonian-Campanian age.

The characteristic box geometry of the Tierra Blanca syncline at this stop illustrates the tectonic style of the central chain of the Interior Range. The near absence of box synclines, and of small size leads us to propose an up-thrust structure for this part of the chain and to interpret the structures described previously as complications of box-type mega-anticlines affected at the level of their axes by inverse faults to overthrusts which destroy many of the kilometric box structures.

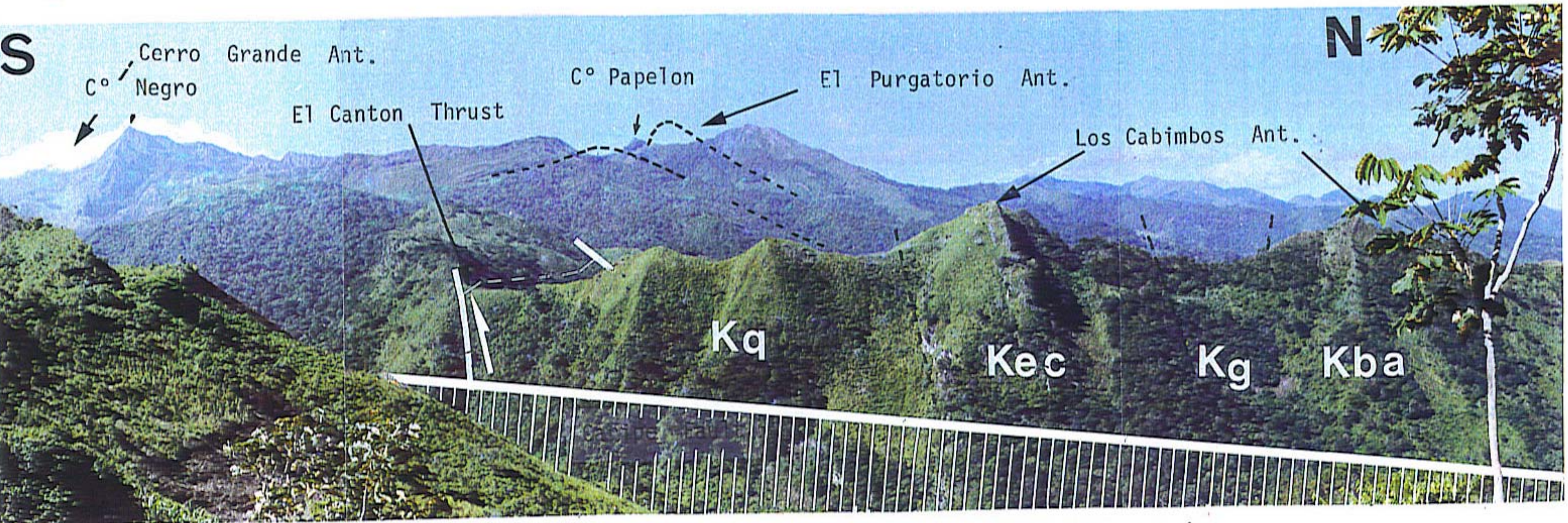
Photograph 5: Box syncline of Tierra Blanca deforming the white cherts of the San Antonio Formation. Syncline located between the Cerro Grande Cerro Negro Anticline to the South and El Purgatorio to the North.

DAY 2: THE INTERIOR RANGE

Stop 5: The "El Canton" Overthrust

Located on the North flank of the central chain of the Interior Range the near-vertical southern flank of the "Los Cabimbos" Anticline rests by reason of the "El Canton" overthrust upon the large North flank of the Purgatorio Anticline made up of massive limestone beds of the El Cantil Formation. The amount of shortening is unknown.

From this selected stop one can appreciate the character of the completely vertical, graded beds of the southern flank of the Los Cabimbos Anticline on the Barranquin Formation, El Cantil, with its basal shaly Garcia Member, Chimana and Querecual; while the northern flank of the Purgatorio Anticline dips 20° toward the North under the shear plane of "El Canton". The beds of the Querecual Formation show several metric-size folds associated with disharmonic levels in the pelitic beds.

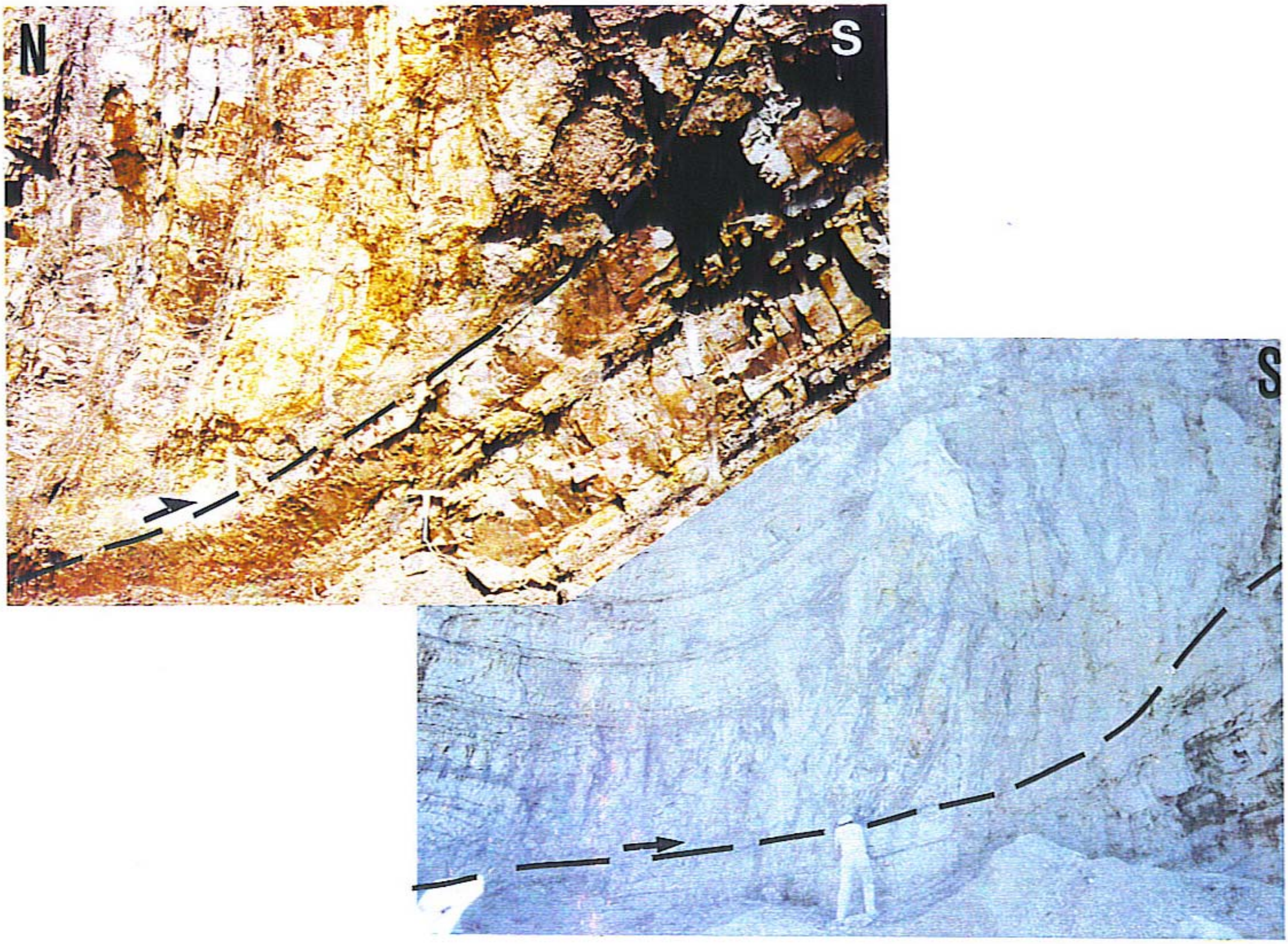


Photograph 6: Panoramic view of the contact of the north flank of the El Purgatorio Anticline and the near-vertical South flank of the eroded Anticline of Los Cabimbos Scene toward the Southwest. Structures cut by the Caripe Fault and its associated branches.

DAY 2: THE INTERIOR RANGE

Stop 6: The Amanita syncline and its deformations

The Amanita Syncline, formed in the cherts of the San Antonio Formation is located North of the Los Cabimbos Anticline, which is affected by several movements toward the North. Its northern flank is limited by the Santa Rosa thrust which, together with the Santa Lucia thrust, affect the southern flank of the box mega-anticline of Santa Rosa, made up of the sandstones and limestones of the Barranquin Formation (See Tectonic Expression Fig. 16). The beds of the Amanita Syncline form cylindrical folds separated from each other by tangential shears. Observation of one of these contact shows us a geometric disposition very similar to those observed on a larger scale in the preceding panoramas.



Photograph 7(A and B): Amanita Syncline. Quarry located East of the town of Santa Maria, on one side of the road to Caripe. Presence of a small shear plane showing on a reduced scale the structural style of the central chain of the Interior Range.

DAY 2: THE INTERIOR RANGE

The El Pilar fault zone

The outcrops located North of the Clavellino Dam up to the Gulf of Cariaco indicate a succession of small synclines and very large anticlines, ordered in a typical upthrust style accompanied by box folding of the constituent formations (See Fig.21 Schematic Section).

The point of major structural interest in this northern part of the Interior Range is the backthrust of Rio Grande.

This inverse fault of notable vertical displacement causes the juxtaposition of the Campanian-Santonian series of beds with the limestones of Aptian age. This tectonic feature, parallel to the structural grain of the chain, extends for a distance of 50 km and its trace on the radar images is easy to identify.

North of the back thrust of Rio Grande, which limits the northern extension of the box-type mega anticline of the same name, we find the pelitic beds of the Valle Grande Facies of the Chimana Formation. The northern border of the Interior Range is an anticlinorium made up of the sandstones and limestones of the Barranquin Formation.

Stop 7: The road between Caripe and Carupano passes through a depression 5 to 7 km wide. On both sides of this topographic feature in an East-West direction the rocks which crop out are different in age and evolution, those to the north, of the metamorphic range of Araya-Paria, belonging to the Caribbean Plate and to the South those of the Interior Range correspond to the tectonization of the sedimentary cover of the Guayana craton of the South American Continent. This limit between the two plates is formed by "El Pilar" fault system, a long which the Caribbean Plate moves toward the East deforming the northern border of the South American Plate during its migration. (See following chapter).

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).

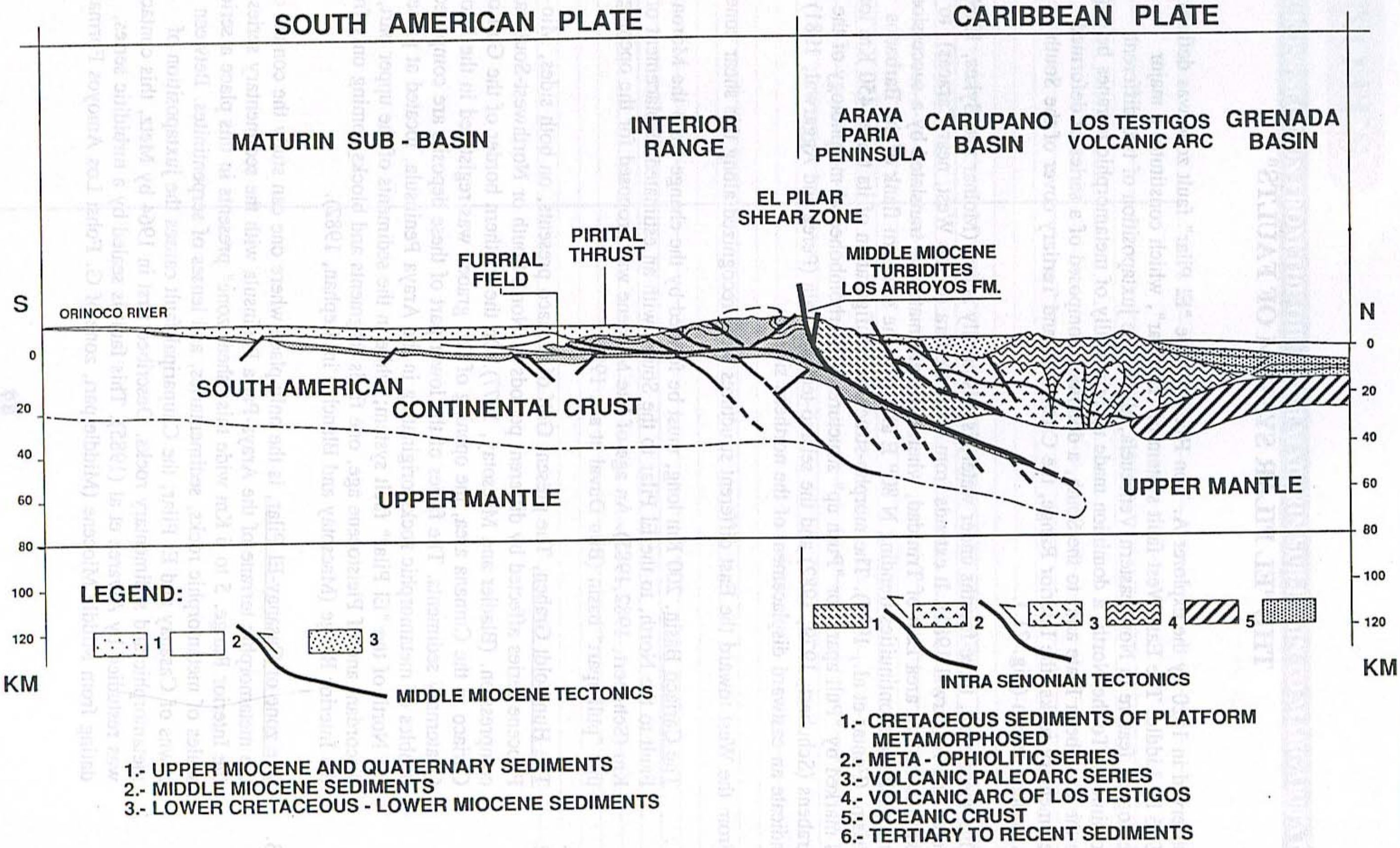


Fig. 21 : Esquematic section from Grenada Basin to Orinoco river.
(from Chevalier ,1987, modified).

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).

FIELD TRIP

THE MARGARITA ISLAND

DAYS 3 AND 4

THE TECTONO-METAMORPHIC EVOLUTION OF THE INTERNAL ZONES OF THE SOUTH CARIBBEAN CHAIN AT THE LEVEL OF THE ISLAND OF MARGARITA

INTRODUCTION

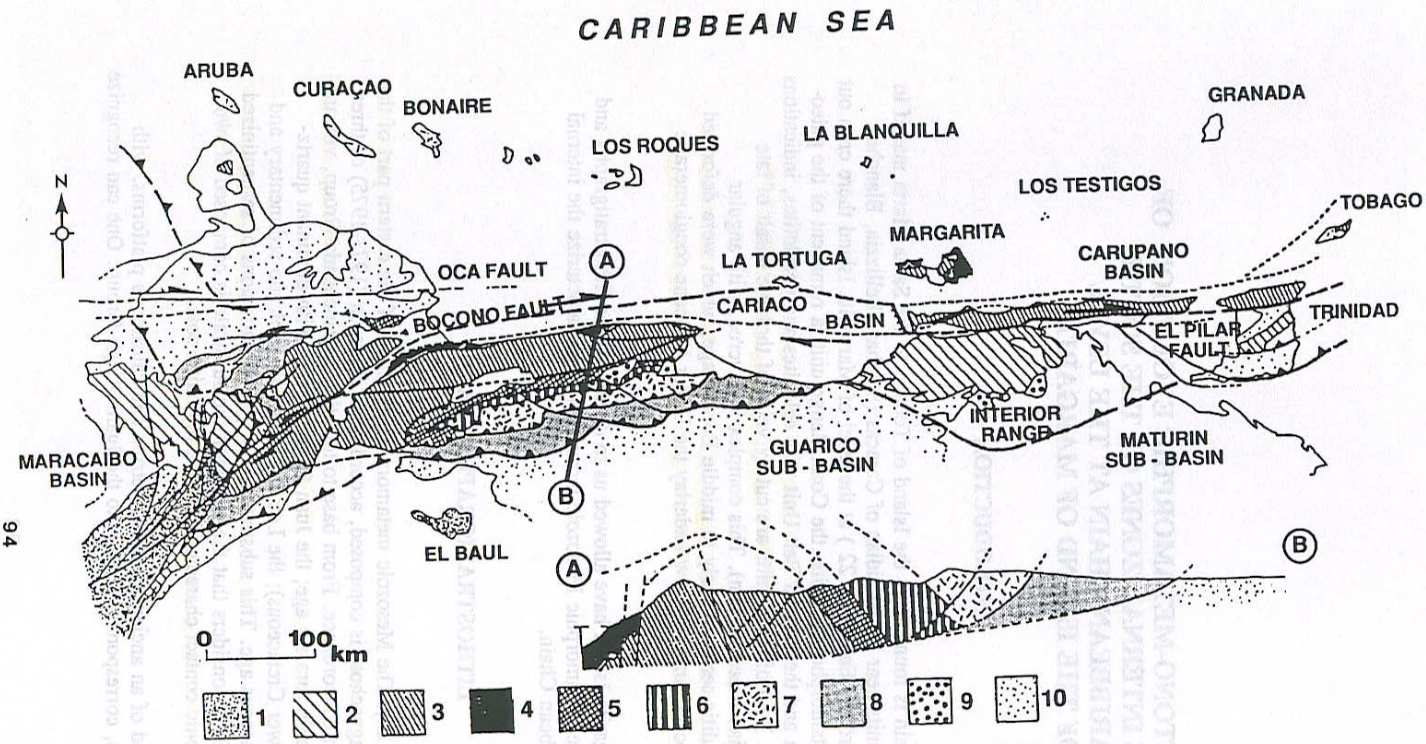
The South Caribbean Chain is found from the Island of Tobago to the Santa Marta massif in Colombia with five big units near the meridian of Caracas (Stephan, Bellizzia, Blanchet, 1980; Beck,1985). Toward the East (Fig. 22) at the level of Margarita Island there crop out only the lower, more metamorphosed, units ,the Coast Range unit, a remanent of the paleo-margin of South America and the Coastal Belt Unit with eclogites and peridotites, indications of an ophiolitic complex. Both of these units are cut by veins of tholeitic basalt of late Cretaceous age (Campanian-Maestrichtian). This complex is covered, with angular discordance, by the turbiditic series of early to middle Eocene age, which were deformed during late Eocene-Oligocene time and now underlay the Upper Miocene conglomeratic series (Fig. 23).

Detailed studies on Margarita Island have allowed us to determine the lithostratigraphy and structural evolution of the metamorphic Mesozoic terranes which characterize the internal zones of the South Caribbean Chain.

LITHOSTRATIGRAPHIC DATA

Island of Margarita (Fig.23): The Mesozoic metamorphic substrate of the eastern part of the Island of Margarita (Paraguachoa) is composed, according to Maresch (1973-1975) of three stratigraphic groupings in concordance. From base to top: the La Rinconada Group, volcano-sedimentary and of probable Jurassic age; the Juan Griego Group with dominant quartz-feldspathic sequence (Lower Cretaceous); the Los Robles Group, volcano-sedimentary and calcareous, of Late Cretaceous age. This substrate is cut by cold intrusions of serpentinized peridotites. Chevalier (1987) considers that the metamorphic substrate is composed of two units separated by a tectonic contact characterized by a mylonitic sole.

The lower unit, composed of an ancient series of detritic and calcareous platforms. with some levels of volcanites, corresponds, in part, to the Juan Griego Group. One can recognize



1. Precambrian and Paleozoic series (Los Andes and the El Baul massif).
2. Mesozoic and Middle Eocene coverage of the Guayana Shield.
3. Map of the Coastal Cordillera.
4. Nappe of the coastal belt of Margarita.
5. Nappe of Caucagua-El Tinaco.
6. Nappe of Loma de Hierro.
7. Nappe of Villa de Cura-Tobago and the volcanic arc of Curaca
8. Nappe of the foothills belt with flysch.
9. Oligo-Mio-Pliocene undifferentiated.
10. Upper Miocene-Pliocene.

Fig.22 : Schematic map of the Caribbean Range.
(After Stephan,1982 and Beck,1985; simplified).

three terrigenous, pelitic sequences and two of carbonates which are organized from base to top in the following manner :

1. A quartz-feldspathic sequence composed of an alternation of paragneiss, quartzites and graphitic schists. The transition to the overlying sequence is marked by a lenticular level of meta-conglomerates made up of ancient pebbles of sedimentary rocks of sandstone and wacke types.

2. The first level with marble, lenticular, with a thickness which is metric to decametric constitutes the first carbonate sequence. Based on regional correlation with the Zenda Member of the Caracas Group (Urbani, 1969) a Late Jurassic age has been attributed to these marble lenses in this study.

3. Two meta-pelitic sequences of mica schists and graphitic schists.

4. The massive marbles of Piache, located in nappes in the tectonic structure, represent the latest sequence of the Juan Griego Group. These levels have been correlated with the limestones of the Guinimita Formation which crop out on the Araya Peninsula and which contain a fauna of Barremian-Early Aptian age (Macsotay in Campos, 1981).

The uppermost unit corresponds to a very deformed meta-ophiolitic complex and its metasedimentary cover.

The meta-ophiolitic complex contains different aspects of the La Rinconada Group (flaser-gabbros, amphibolites and eclogites as well as all the ultrabasic bodies. This meta-ophiolitic series is believed to be of Jurassic-Early Cretaceous age. The presence of dunite, pyroxenolites and gabbros remanents in these materials, indicate the plutonic character of the protoliths. These basic and ultrabasic rocks are, in addition, associated with orthogneisses which represent ancient granodiorite intrusives into the ophiolitic complex.

This complex, of plutonic nature, is discordantly covered by old sands and gravels which resulted, according to circumstances, from the erosion of the ophiolitic complex or of the acid plutons or, more frequently, of metatuffites covered by thin metamorphosed limestones. The deposition of these sediments was contemporaneous with outpourings of alkaline pillow basalts. The different terms for this supra-ophiolitic cover correspond, in part, to the Los Robles Group. An early Cretaceous to Turonian age is proposed for these meta-sediments.

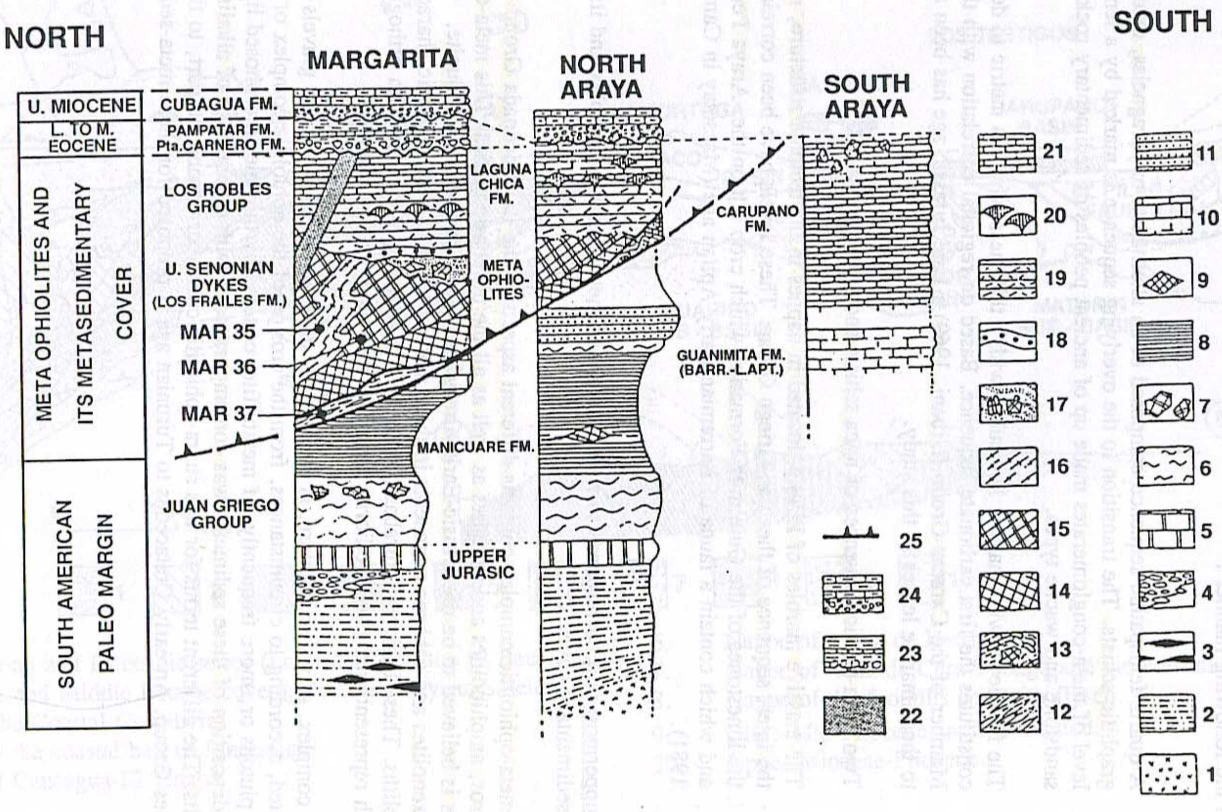


Fig.23 : Stratigraphic columns of Margarita-Araya Transect.
(From Chevalier et Al.,1988).

Figure N° 23

Synthetic Stratigraphic Columns of the Margarita Araya Transect.

Lithofacies of the South American Paleomargin

1. Leptinites
2. Quartz Feldpathic Sequence
3. Metabasalts
4. Metaconglomerates with natural sedimentary elements
5. Lenticular marbles of probable Late Jurassic age
6. Mica-schists with garnets
7. Olistoliths of gabbroic character
8. Graphitic schists
9. Serpentinite Olistoliths
10. Massive marbles of probable Barremian-Early Aptian age (El Piache in Margarita Guinimita Formation on the South flank of the Araya Peninsula
11. Massive metaquartzites (Araya).

LITHOFACIES OF THE META-OPHIOLITES OF MARGARITA, OF THE ORTHOGNEISSES AND OF THE META-SEDIMENTARY COVER

12. Mylonitic sole
13. Series with blocks of tectono-sedimentary origin
14. Basic sequence (eclogites, amphiboles, meta-gabbros)
16. Orthogneisses (Former granites and granodiorites)
17. Metamorphosed sands and gravels of ophiolitic nature (ophiolitic detritus).
18 Meta-sandstones (result of erosion of the granites and granodiorites
19. Metatuffites
20 Alkaline meta-basalts in pillow form
21. Thin recrystallized limestones (Carúpano Fm)

Lithofacies of the cover of the Mesozoic metamorphic substratum

22. Veins of tholeitic basalts
23. Wildflysch biocalcarenites, turbidites (Pampatar and Punta Carnero Formations)
24. Conglomerates and limestones (Cubagua Formation)

Symbols

25. Regional overthrust

MAR 199-MAR 36, MAR 35: Location of the samples dated by the 40 AR-40K method

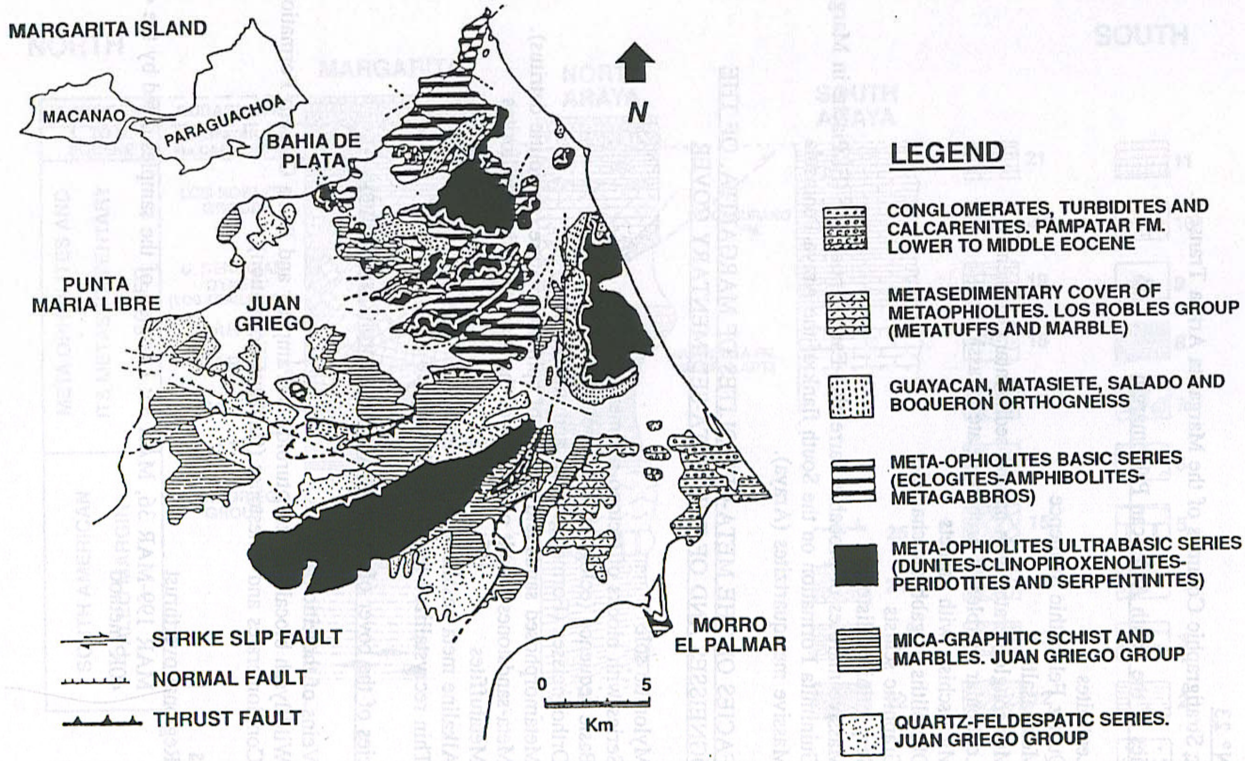


Fig.24 : Geological map of Eastern Margarita (Paraguachoa).
(after Chevalier ,1987).

THE STRUCTURAL DATA

A detailed analysis of the two great metamorphic units has permitted us to differentiate two major compressive events.

The first is marked by the local presence of an old series with blocks (with olistoliths of gabbroic character) in the top of the platform metasediments of the Juan Griego Group (Margarita), Manicuare Formation (Araya)(Fig.24 ;Fig.25 and Fig.26). The development of a stretching lineation has been associated with this series, identified by Guillet and Cannat (1984) in the nucleus of the peridotites of the Cerro Matasiete nappe, generated, according to these authors, by a deformation of high temperatures (T>1000° C).

This first event is related to the obduction probably during early Cretaceous, of a part of the oceanic crust over the South American paleomargin. This obducted ophiolitic block was later intruded by granodiorite plutons.

The second event, preponderant for regional tectonics, is quite marked in the group of terms of the two metamorphic units. The development of the folds, of the schistosities and of the lineations in these two units result in a complex evolution where one can distinguish, however, an early phase (D1 S1) and a later stage (D2 S2).

1. <u>The early phase D1 S1</u>

This early phase is characterized by the acquisition of the regional foliation S1, in a regime of non-metamorphic tangential deformation with a vergence toward the NE or E-ME. This foliation carries a mineral lineation (L1) which passes from an E-NE direction in the Western Margarita sectors (Macanao), to a N-NE direction in Eastern Margarita (Paraguachoa) (Fig.27).

Fig.25:SECTIONS ACROSS THE PARAGUACHOA PENINSULA EASTERN MARGARITA

LEGEND

In terms of facies

1. Quartz-Feldspar Sequence (Juan Griego Group)
2. Mica Schists (Juan Griego Group)
3. Marbles
4. Graphitic schists (Juan Griego Group)
5. Ultra-basic sequence (Dunites, clino-pyroxenolites, peridotites, serpentinites) (Meta-ophiolites of Margarita)
6. Basic sequence (Eclogites amphibolites, meta-gabbros) (Meta-ophiolites of Margarita
7. Orthogneisses (of Guayacan, of Matasiete, of El Salado)
8. Meta-volcano-sedimentary series (Meta-tuffites and thin marbles) Supra-ophiolitic cover-Los Robles Group
9. Lower and Middle Eocene conglomerates and turbidites

In terms of nappes

A. Relative autochthon
B. Santa Ana nappe
C. La Rinconada nappe
D. El Salado nappe
E. Cerro Grande nappe
F. El Piache nappe
G. Los Robles nappe
H. Cerro Chico nappe
I. Matasiete-Guayamuri nappe

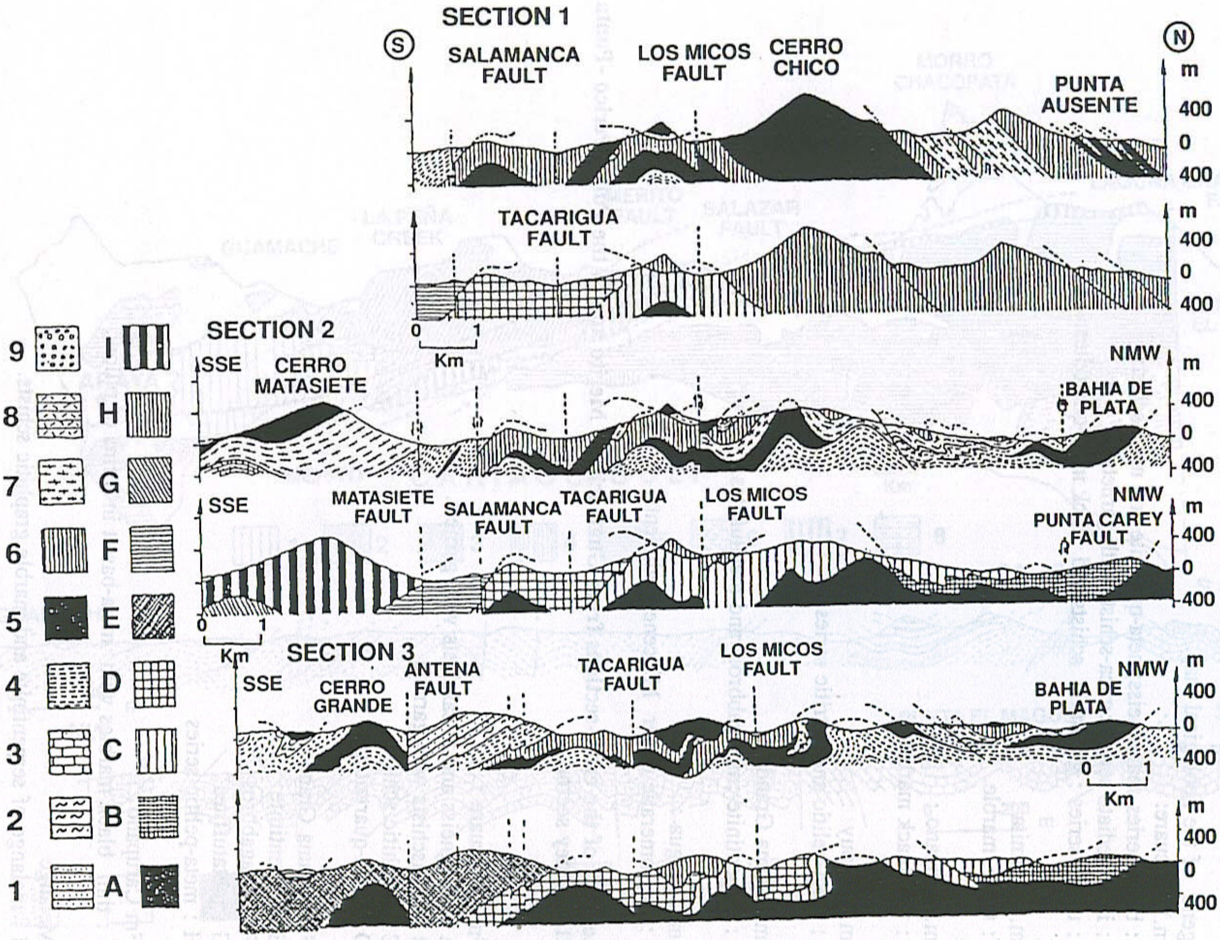


Fig.25 : Cross-sections through Paraguachoa Island (Eastern part of Margarita Island)-(After Chevalier,1987).

Fig. 26 : Schematic geological map and cross-sections of Araya Peninsula.

legend of the geological map.

Fm.Manicuare:

1 : basal series :paragneiss;meta-quartzite and mica-schists.

2 : intermediate series :mica-schists with garnets.

3 : upper series : graphitic schists and thick meta-quartzites.

Fm.Guinimita :

4 : thick marble.

Fm.Carupano :

5 : thin black marbles.

Fm.Tunapuy :

6 : meta-pelitic and detritic series.

Fm.Laguna Grande :

7 : serpentinite ;metagabbros and metatuffites.

Fm Cubagua :

8 :conglomeratic upper Miocene sediments.

Legend of the cross-sections from Guamache to Merito and in the Punta Perico -Punta El Maguey sector.

Fm.Manicuare :

A : paragneiss and micaschists with garnets.

B : micaschists with garnets

C : graphitic schists

D : meta-quartzites

Fm Laguna Grande :

E : serpentinite

F : metagabbros

G : metatuffites

H : meta-pelitic series

Fm Carupano :

I : thin black marbles with meta-basalt in forms of pillow.

Melange

J : melange of serpentinite and marble,graphitic schists.

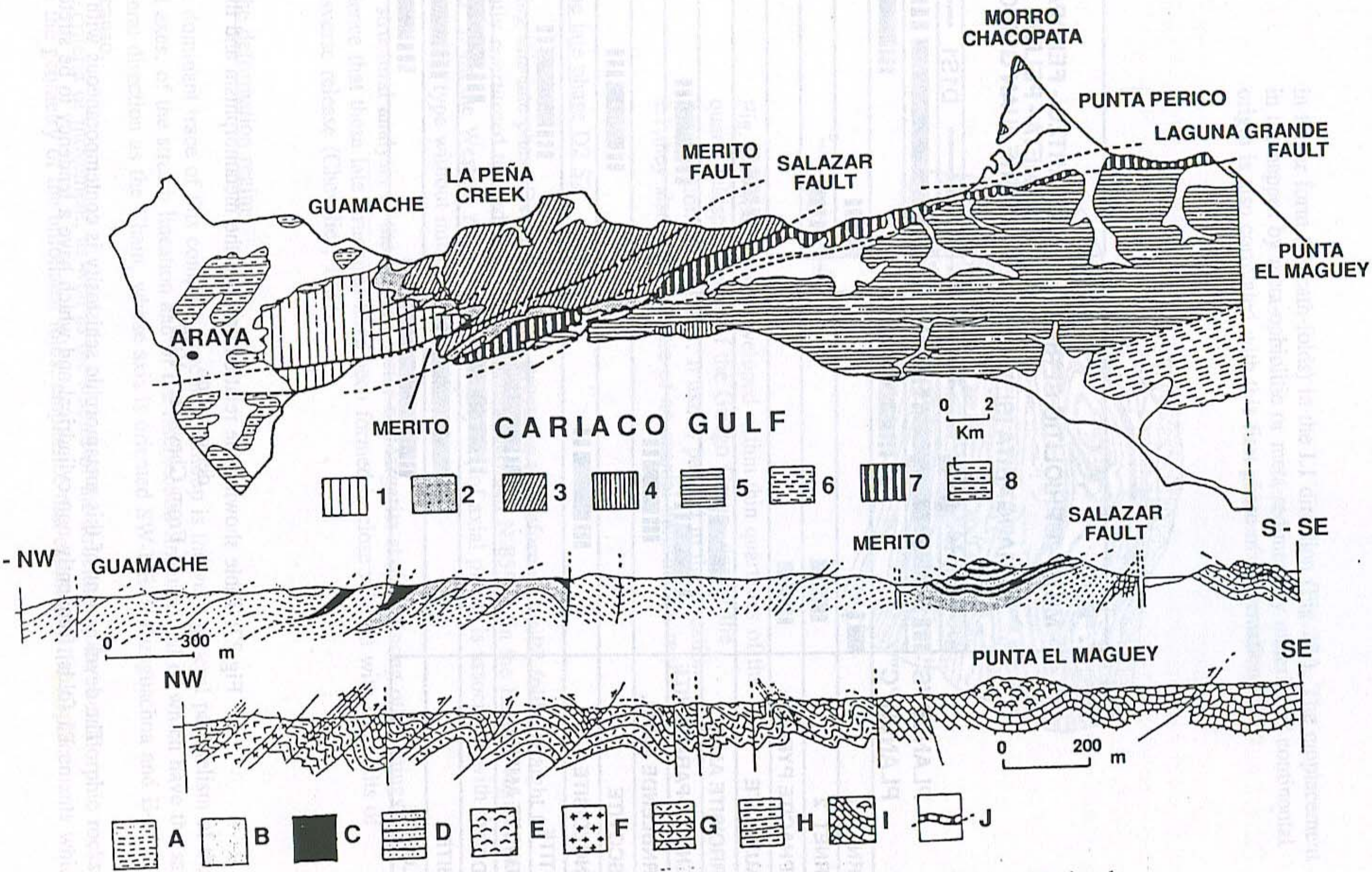


Fig.26 : Schematic geological map and cross-sections of Araya Peninsula. (After Chevalier, 1987).

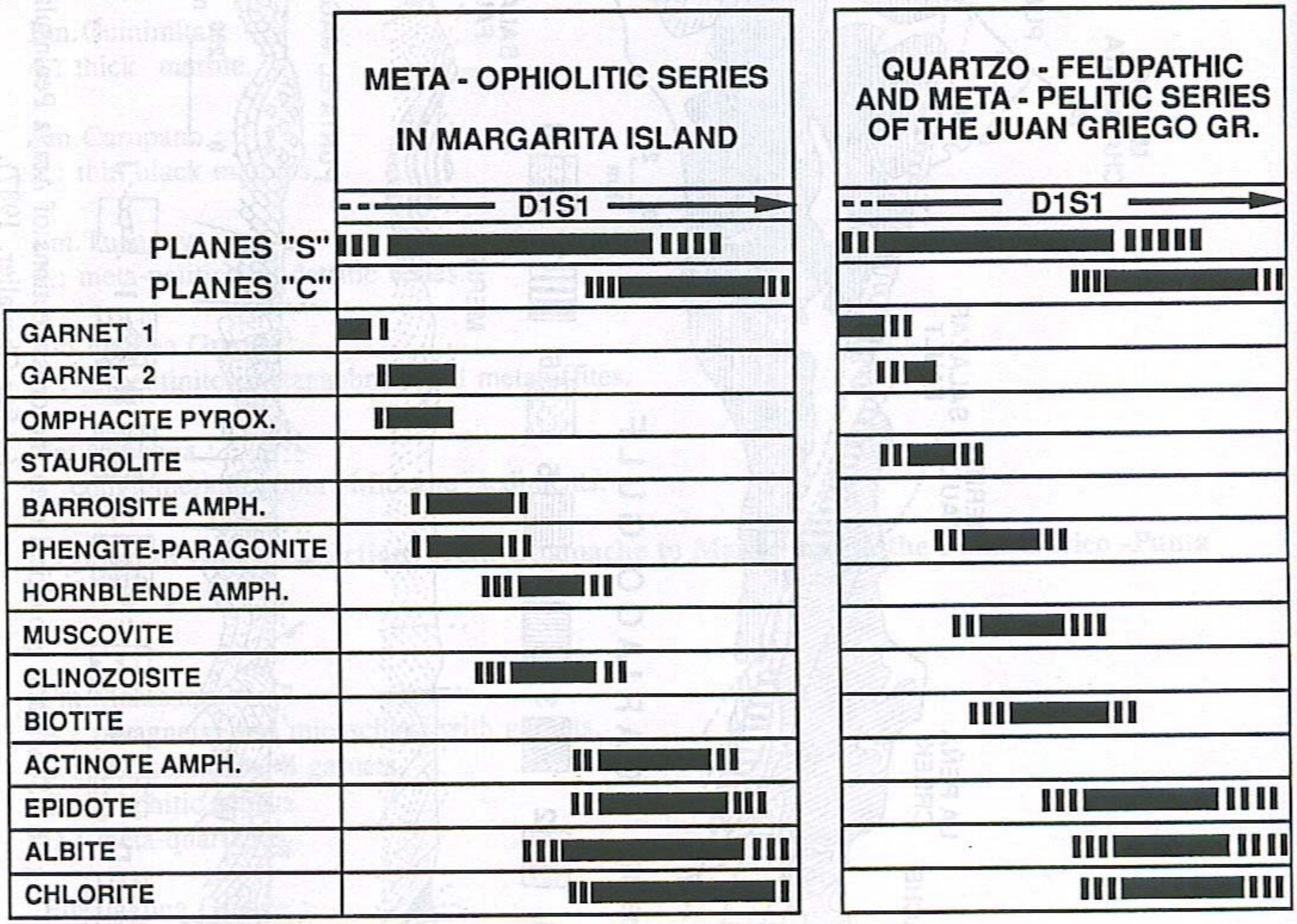


Fig.27: Table showing the relation between the metamorphism and the deformation.
(From Chevalier ,1987).

The development of this metamorphic schistosity is contemporaneous with the P1 folds, frequently non-cylindrical and which have a tendency to be stretched in finger form (Sheath-folds) in the L1 direction (Fig.28). The emplacement in the nappes by meta-ophiolitic or meta-sedimentary material of continental origin is also correlated with this first phase of deformation D1.

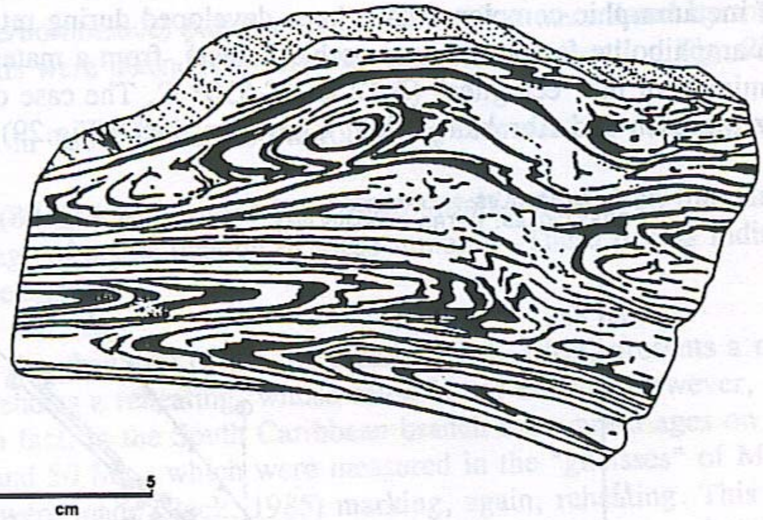


Fig. 28. Sheath-fold developed within thin quartzites of the quartz-feldspaticseries of the Griego Group, during the deformation phase D1S1. It axe is parallel to the lineation L1,they also characteristic of no-coaxial deformation regime.

2.<u>The late phase D2 S2</u>

During this late phase D2, the previous structures are deformed by P2 folds, straight to slightly overturned toward the SE and oriented between N 85° E (in the Eastern region) and N 45° E (in the Western region). A schistosity S2, of axial plane, is associated with these ofstrain-slip type without mineral neogenesis.

The structural analysis of the Eastern sector of Margarita shows, among other things, evidence that these late structures have been formed in close relation with the faults of transverse release (Chevalier, 1987).

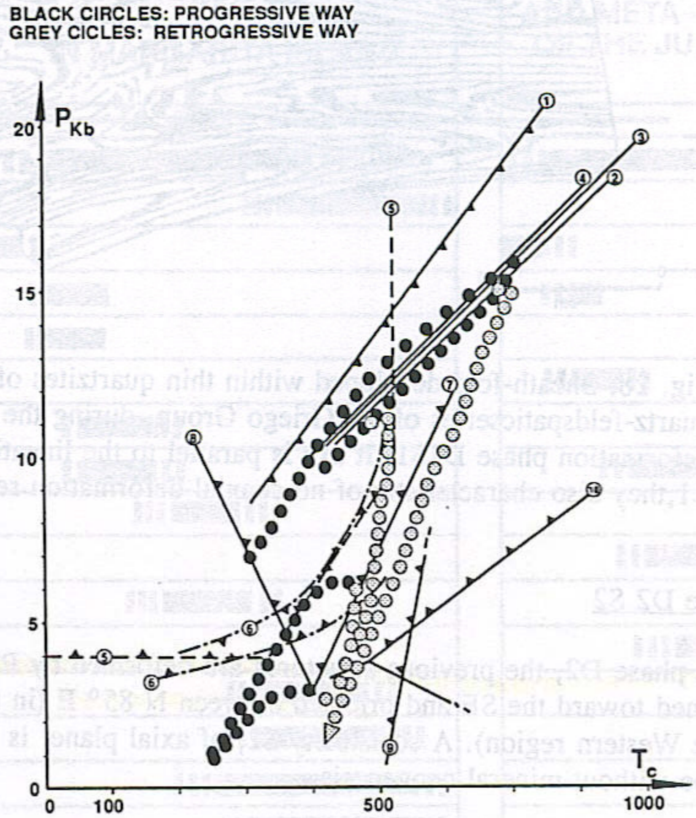
3.<u>The deformation regime</u>

The dominant trace of this complex structural buildup is the very general parallelism of the fold axes, of the stretch lineation and of the intersection lineation, all of which have the same general direction as the Chain, whose axis is oriented SW-NE in Paraguachoa and E-W in Macanao.
The criteria of movement, as well as the studies of the structure of the metamorphic rocks, and the geometry of the unfoliated folds, emphasize that essentially the displacements which

have occurred are longitudinal, parallel to the Chain.

4. <u>The P-T conditions of the deformation</u>

The majority of the observable metamorphic structures, under the different terms ortho and para-derived of metamorphic complexes have been developed during retrograde evolution (metamorphism amphibolite facies and green-schist facies), from a material which, has reached the dominion of the "eclogites" (P≈12 kb, T≈550° C. The case of the "eclogites" of Pedro González Maresch and Abraham, 1981; Chevalier, 1987)(Fig.29).



LEGEND:

1.- QUARTZ + JADEITE ALBITE (HIGH TEMPERATURE) (HOLLAND, 1979)
2.- = 39% JADEITE; 3 = 44.5%; 4 = 46.7% JADEITE (FROM CHEVALIER, 1987)
5.- GLAUCOPHANE STABILITY FIELD (MARESH, 1977)
6.- BARROISITE STABILITY FIELD (ERNEST, 1979)
7.- PARAGONITE STABILITY FIELD (EUGSTER et al, 1979)
8.- PARAGONITE STABILITY FIELD (CHATTERHEE et al, 1972)
9.- ANTIGORITE STABILITY FIELD (JOHANNES, 1975)
10.- CYANITE STABILITY FIELD (HOLDOWAY, 1971)

Fig. 29 : Diagram P / T showing the metamorphic evolution of the Margarita meta-ophiolitic complex.
(From Chevalier Y. 1987)

5. The age of the synmetamorphic structuring

a) Contribution of radiometric data

Amphiboles (barroisite/hornblende) paragonites and phengites were dated by the 40K-40Ar method. These minerals were taken from different samples (see location Fig. 23).

The results, presented in Table 1, lead to the following comments:

-The values obtained (80 ± 4 Ma) on the barroisites-hornblende and on the paragonites are interpreted to be the age of crystallization of these minerals. These results indicate the collision during the Senonian.

-The age obtained on the phengites of the orthogneis (60 ± 3 Ma) presents a more complex interpretation. This denotes a reheating, whose cause is not known. However, this anomalous age is not isolated. In fact, in the South Caribbean branch there are 5 ages on "muscovites" ranging between 67 and 50 Ma., which were measured in the "gneisses" of Margarita 9 dating of this nature were made (Beck, 1985) marking, again, reheating. This might indicate a more recent event, 50 Ma. which would affect the more metamorphosed rocks in our study area.

b) The relative chronology data

The results of the measurement of radiometric ages can be confronted with the arguments for relative chronology, which can be used to fix a minimum age of metamorphism.

The nappes, which are contemporaneous with the metamorphism, are cut by veins of tholeitic basalt, having no deformation by schistosity but are affected by a type of hydrothermal alteration. These veins appear to be congeneric with the volcanic flows of the Los Frailes Archipelago, conterminous with the Island of Margarita and dated by radiometric methods and by the fauna associated with the Cenomanian-Maestrichtian (Santamaria and Schubert, 1974). These veins do not cut the Lower or Middle Eocene series. All these arguments converge to assign an age intra-Senonian (80 ± 4 Ma) to the dynamothermic metamorphism.

TABLE 1 -RADIOMETRIC DATES

The measurements were done by Professor H. Bellon of the Laboratory of Geochemistry and Geochronology, University of Western Bretagne, Brest, France.
The isotopic ages (Column 2) were calculated according to the relation T= 4154,04 log 1 + 142.69 (40 Ar + 40K).
Desintegration constants Steiger and Jager (1977): 40 Ar in Cm^3, K in gr., in millions of years (M.a).
The uncertainties (Column 3) are estimated with + 5% of the calculated age. The percent of K^2O is over 0.1% ^{40} Ar/40 $_{Ar + 1}$, being over 15% (Column 5).

TABLA 1 DATOS RADIOCRONOMETRICOS

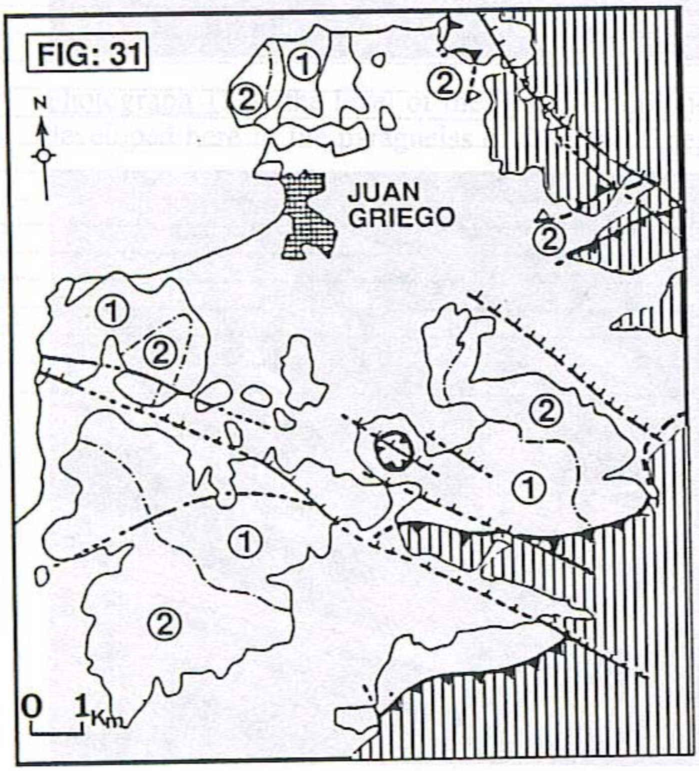
NUMBER OF SAMPLES	AGE (M.a)	± Inc (M.a)	40 * Ar (10^{-7} cc/g)	% $\frac{^{40}Ar^*}{^{40}Ar^T}$	K_2O (%)	WEIGHT (G)
MAR 36	84.6	± 4.2	11.2	27.5	0.4	0.2203
MAR 199	79.3	± 4.0	9.4	47.9	0.36	0.6013
MAR 35	62.5	± 3.1	55.4	72.6	2.7	0.2114
MAR 35	57.1	± 2.9	50.5	67.8	2.7	0.4016

DAY 3: THE METAMORPHIC SUBSTRATUM OF MARGARITA

The lower Unit: The Juan Griego Group (Stops 1 and 2)

Stop 1: Deformation in the paragneisses and mica-schists at the level of Punta Tacuantar half-window of Juan Griego(Fig. 31 and Fig.32).

The Juan Griego Group, composed of an old series od detritals and carbonates (see lithostratigraphic sequence) presents a tectono-metamorphic evolution marked by two periods of deformation: the first, synchronized with metamorphism D_1, is responsible for the development of the regional foliation S_1, of the folds at times sheath folds F_1, of the stretching lineations L1, and of the different structures in the nappes; the second, D_2, is characterized essentially by the folds F_2, straight or overturned toward the SE and for a cleavage of fold fracture S_2 without neogenesis minerals.



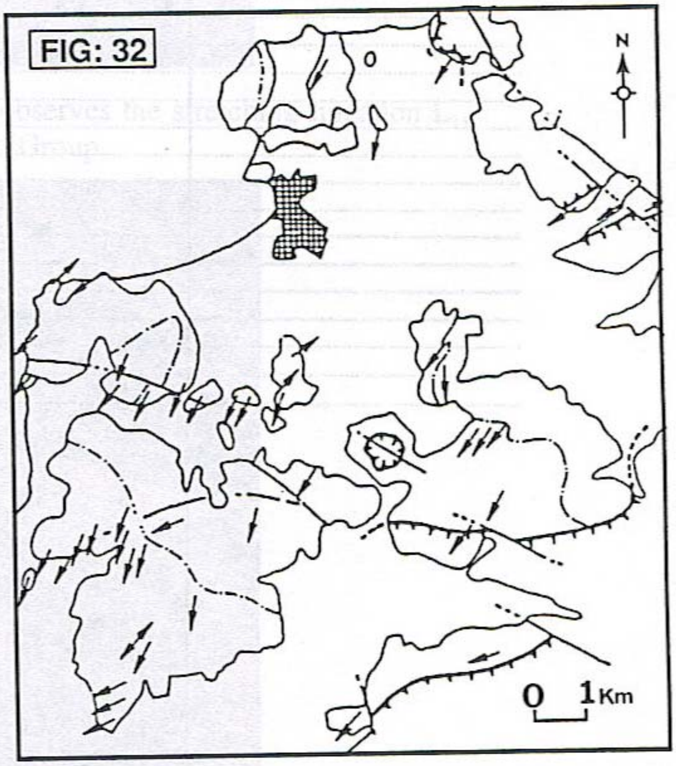
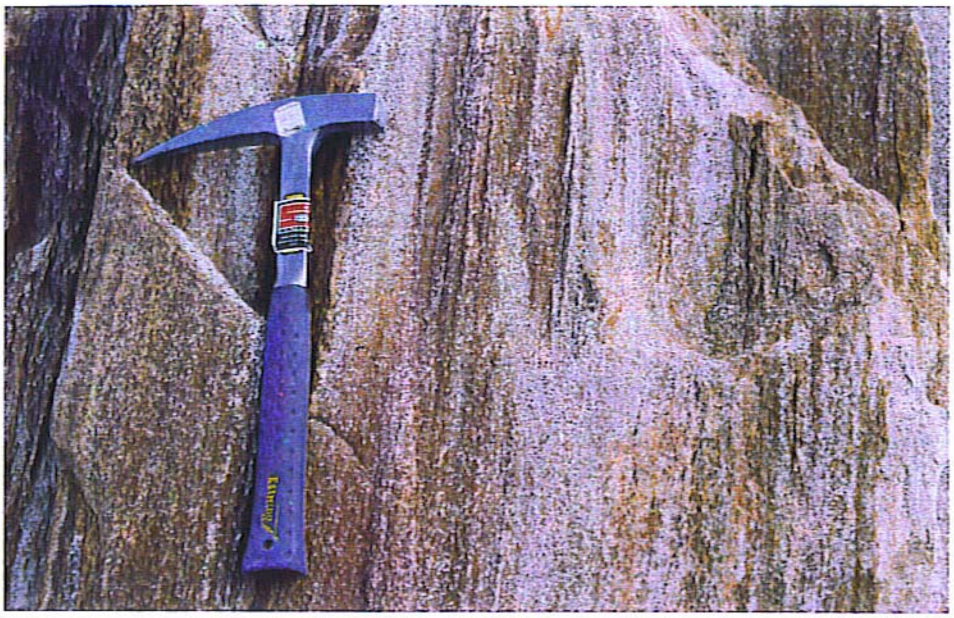


Fig. 31: Geological map of the Juan Griego windown.
1. Basal series (Juan Griego Gr.),2. Intermediate series (Juan Griego Gr.)

Fig. 32 : Direction map of L1 stretching lineation.

DAY 3: THE METAMORPHIC SUBSTRATUM OF MARGARITA



Photograph 1: At the level of the first outcrop one observes the stretching lineation L_1, developed here in the paragneiss of the Juan Griego Group.

Photograph 2: The second outcrop indicates the vergence of the tectonic transport associated with lineation L1. The sigmoidal form of the amphibolites (ancient tuffs) in the alternating levels of paragneiss and graphitic schists attests to the tangential movement toward the Northeast.

From the cartographic point of view these two outcrops belong to the half-window of Juan Griego.

DAY 3: THE METAMORPHIC SUBSTRATUM OF MARGARITA

Stop 2:

The metaconglomeratic level observed in Punta Maria Libre constitutes the top pf the quart-feldspathic sequence. Upon these lie the marbles of probable Jurassic age (see lithostratigraphic synthesis). Macroscopically this metacomglomerate contains clasts of 1 to 5 cm, very deformed. The petrographic analysis indicates that these fragments are essentially composed of metagraywackes with granoblastic texture.

These ancient clasts of sedimentary rock are surrounded by a cover of lepidoblastic grain texture in which biotites and muscovites of 600 u length have been found.

From the structural point of view the pebbles of this metaconglomerate are stretched parallel to the stretching lineation and of L_1 transport. The metaconglomeratic levels are affected in a late stage by F_2 folds and by cleavage of fracture folding S_2 (strain-slip cleavage) which possess an orientation similar to the metamorphic structures.

Photograph 3: The metaconglomerates of Punta Maria Libre. Mapwise the analysis of Juan Griego indicates a stretching lineation L_1, nearly constant NE-Sw. The presence of the bodies of amphibolites of sigmoidal form and the mapping of the different metamorphic facies in the half-window show the superposition of two structural directions, the first synchronous with the metamorphism presents a direction of transport and folding toward the NE; while the second possesses a compression direction NW-SE (Fig.31 and Fig.32). These observations drawn attention to the fact that in the chain the parallelism of the structures associated with the two phases of deformation D_1 and D_2.

DAY 3: THE METAMORPHIC SUBSTRATUM OF MARGARITA

Stop 3: The contact between the lower and upper units

The contact between the Juan Griego Group and the meta-ophiolites of Margarita is observable in Bahia de Plata, locality situated 5 Km north of Juan Griego. A mylonitic sole separates the serpentinites from the mica schists.
Incorporated in this tectonic mixture generated at great depths one observes lenses of black amphibolites with garnets and of orthogneiss.
The detailed micro-structural study of the underlying mica-schists with garnets show the development of secondary "C" planes of stretching over the "S" planes of foliation, in section parallel to the stretching lineament L_1. The geometrical disposition of the two planes, formed during the same tangential tectonics, indicates a shearing toward the SW. This observation, as well as the petrographic configuration of the overlying meta-ophiolitic units leads us to interpret a duplication of the basal meta-ophiolitic sheets toward the SW.(Fig.33)

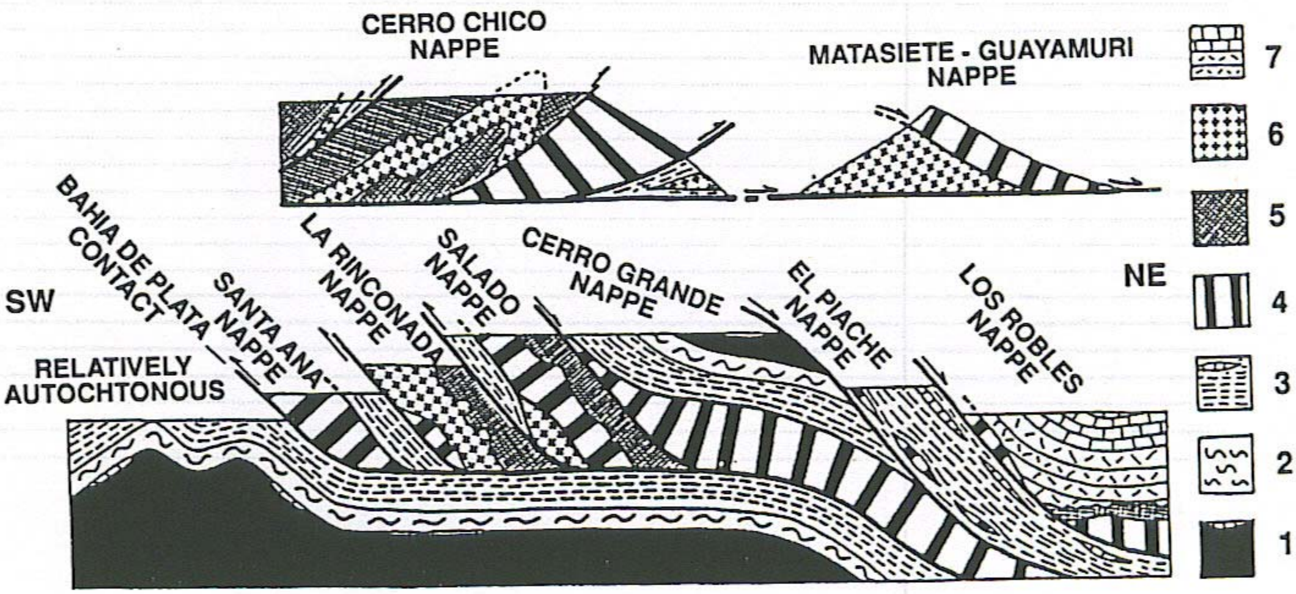


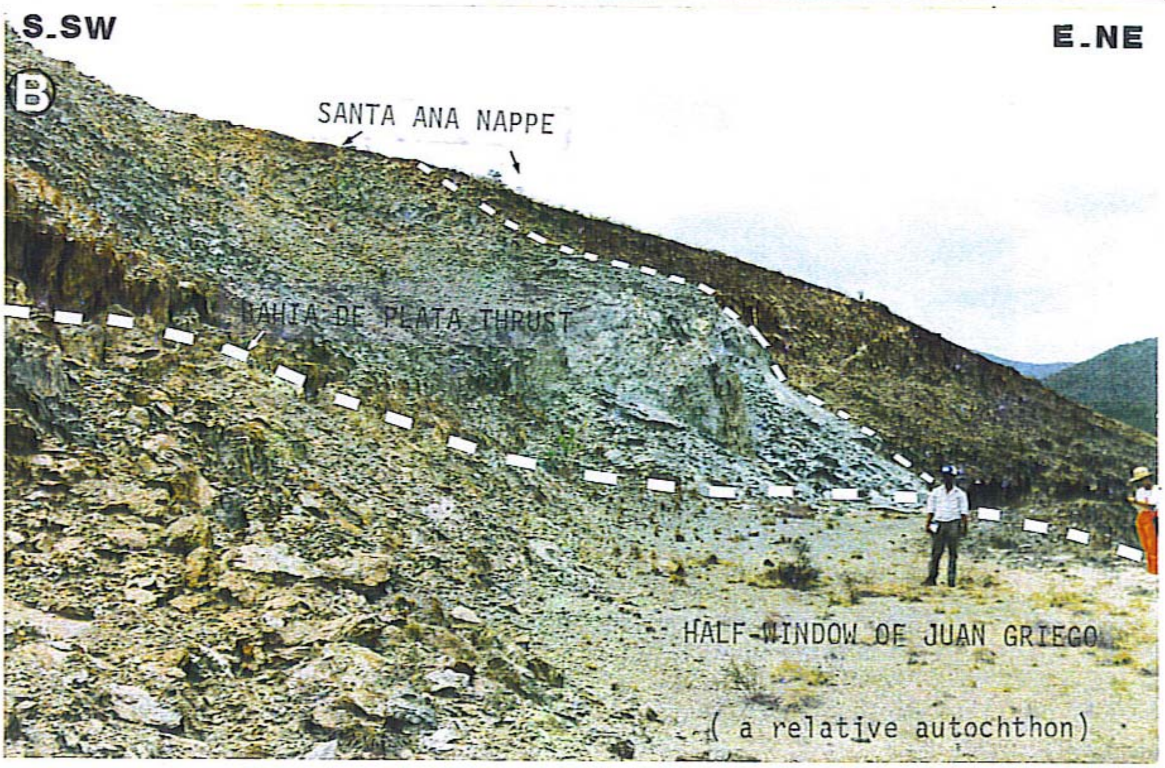
Fig.33: Structural organization of Paraguachoa Peninsula Nappes. (Eastern Margarita Island) (in Chevalier and Alvarez ,1990).

Legend:
The series of the Juan Griego Group:
1.basal series -2.mica schists -3.graphitic schists .
The Lithofacies of the Meta-ophiolitic complex:
4.ultramafic series (peridotites etc...)-5. mafic facies (amphibolites, flaser-gabbros etc...)-6.old granodioritic intrusions metamorphosed-7. metasedimentary cover of the meta-ophiolitic complex.

DAY 3: THE METAMORPHIC SUBSTRATUM OF MARGARITA

A panoramic view

A detail



Photograph 4: Contact between the platform series of the Juan Griego Group and the basal serpentinites of the allochthonous meta-ophiolites.

DAY 3: THE METAMORPHIC SUBSTRATUM OF MARGARITA

Stop 4: The meta-ophiolitic complex and the basalt veins of Upper Cretaceous

The northern coast of the Paraguachoa Peninsula (Eastern Margarita) has the most highly metamorphosed facies of the meta-ophiolites (Eclogites and Amphibolites with garnets). Associated with the Jurassic-Lower Cretaceous meta-ophiolitic complex, lenses of orthogneiss crop out in this sector of the island. Maresch (1973) indicates that these acid rocks, of geochemical composition near granodiorites, were in former times intrusives into the allochthonous ophiolitic body.

Cutting the structures inherited from the D_1 and D_2 phases and associated with the 80 Ma collision, veins of basalt attest to another geodynamic event. The basal flows, highly spilitized are correlatable with the remnants of the island are cropping out in the Los Frailes archipelago located 14 km to the Northeast of Margarita and dated by the K/AR method as Campanian-Maestrichtian (Santamaria and Schubert, 1974).

Photograph 5: A fault of probable late Eocene-middle Oligocene age displacing the veins of spilitised basalts cutting the foliation of the meta-ophiolitic complex.

Stop 5: The metagabbros of Playa El Agua

Not all the petrographic facies of the ophiolitic protolith suffered pressure-temperature conditions as high as the eclogite or amphibolite facies. Near Playa El Agua there crop out over 20 meters of flaser-gabbros. Toward the south these rocks pass into gabbro blastomylonites. Microscopic analysis of these gabbros permits one to observe in a section grano-lepidoblastic some mineral remnants of 800 to 850 in length of protolith; as amphiboles of developed over ancient ferro-magnesian minerals (probably pyroxenes).

Photograph 6: Metagabbro outcrop. White in color, massive, affected by shears coated by levels rich in chlorite.

Photograph 7: Gabbro blastomylonites indicating a high grade of shear deformation synchronized with the metamorphism and followed by a late recrystallization in the greenschist facies (Epidote, chlorite, albite, actinolite).

DAY 3: THE METAMORPHIC SUBSTRATUM OF MARGARITA

Stop 6: The La Mira section

The scales observable at the cut at La Mira can give a good example of all the structural complexity of a study of any internal zone of an alpine type Chain.

Over a distance of 50 meters there crop out successively from North to South, a series of micro-scales which exemplify a complex structural evolution (Fig.34).

Although the geometries observed in the section appear to indicate a displacement of the units toward the South, in reality all the material present possesses a stretching lineation L_1. Together with this thinning of the rocks during metamorphism, there occurred shears parallel to the direction of lineation L_1. An analysis of these criteria of movement, indicate transportation of the allochthonous units toward the E-NE.

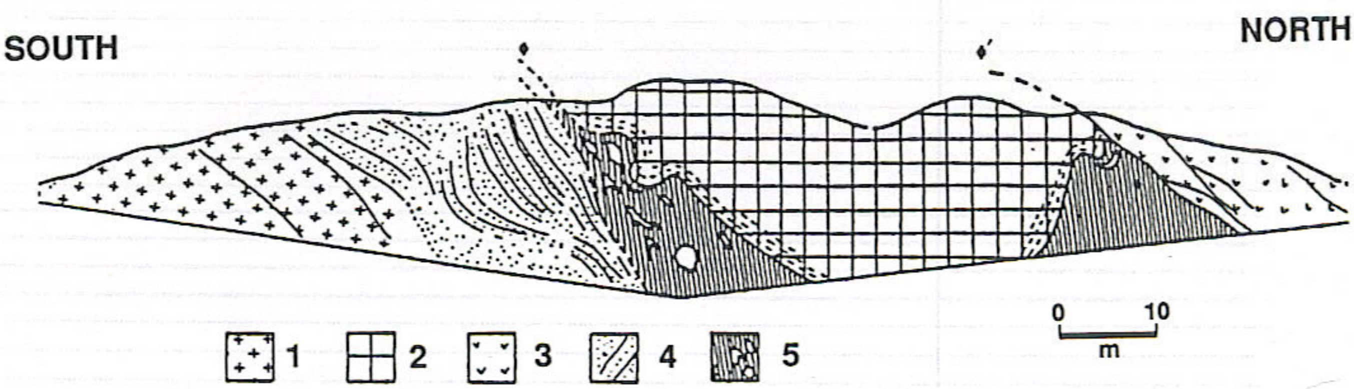
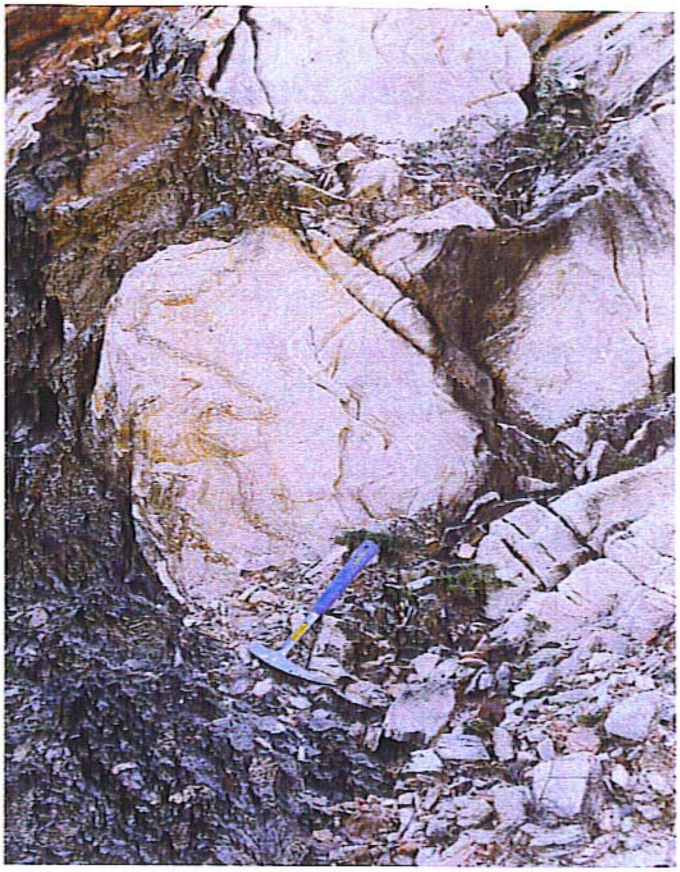


Fig.34:La Mira section.
(From Chevalier 1987)

Legend:
1.mafic complex (meta-gabbro and prasinites)-2.Guayacan orthogneiss-3.serpentinized peridotites-4.quartzites-5.melange.



Photograph 8: Detail of a contact between a scale of orthogneiss (Orthogneiss of Guayacan type) mylonitized and a tectonic mixture composed of stretched fragments of orthogneiss, lenses of actinolite, and of highly-sheared schists.

Photograph 9: Presence of microfolds of shearing in the base of the mylonitic sole of the orthogneiss scale.

THE TERTIARY SEDIMENTARY COVER OF MARGARITA ISLAND

I. Introduction

Sediments of Eocene and Mio-Pliocene age lie with angular unconformity on the metamorphic units on the island of Margarita.

The Paleogene series crop out in the southern part of the Paraguachoa Peninsula (Eastern Margarita). They were also recognized (by drilling) in the Carupano Basin (Campos, 1981; Pereira, 1985); and on the Island of Cubagua (Kugler, 1957, Bermudez 1975).

In the Island of Margarita these were grouped for a long time under the term Punta Carnero Group (Gonzalez de Juana et al, 1980). Muñoz (1973), after a detailed sedimentological study, was able to differentiate two different formations in these deposits:

<u>The Pampatar Formation</u> (1000 m) crops out in the extreme southeast of the Paraguachoa Peninsula. It is characterized by calcarenite sediments with several micro-conglomeratic levels.

<u>The Punta Carnero Formation</u> (2000 m), is divided into three members, from bottom to top:

- Las Bermudez Member (450 m), Kugler (1957) considered it a wild flysch.
- El Datil Member where the first calcarenite beds are found.
- Punta Mosquito Member, in which Muñoz (1973) recognized contourite type of sedimentary structures.

<u>The Neogene series</u> were grouped under the term Cubagua Formation (Graf, 1972; Macsotay, 1972: Hunter, 1977-1978). These beds lie in angular unconformity on the metamorphic basement or upon the near-vertical Eocene strata. They crop out in the southern border of the Island of Margarita, on the Island of Cubagua and on the extreme western end of the Araya Peninsula.

II. EOCENE

The absence of Paleocene in situ leads to a differentiation in the Pampatar and Punta Carnero Formations of a Lower Eocene, which has the characteristics of wildflysch and a Middle Eocene evidencing marine influence.

A. Lower Eocene or the Wild flysch at the base of the Eocene Basin.

The Member Las Bermúdez of the Punta Carnero Formation represents a basal wild flysch. Mapping wise these detrital facies constitute an East-West belt, limited to the North by tectonic contact with the schists and marbles of the Los Robles Group, and to the South by a transitional stratigraphic contact with the calcareous flysch-type series of the El Datil Member.

In the Pampatar Formation the wildflysch is composed detritus slides, of coarse-grains to pebbles, poorly sorted. This lithofacies is found in the base of this formation (Punta Moreno zone and South of the Gasparico Lagoon), but are equally observable through the entire column between the turbidites.

Different authors who worked with this wild flysch of Margarita tried to make a complete inventory of the blocks, pebbles and fragments of a differing origin and character.

These quantitative studies were complemented by numerous paleontological determinations.

As a consequence of this synthesis, taking into consideration the works of Hess and Maxwell (1949, Muñoz (1973), MacGillavry (1974) and Chevalier (1987) we can make the following observations:

1. The fragments found in largest quantity correspond to volcanic rocks, to cherts an limestones, which do not crop out in significant quantity in the Island of Margarita on the contrary, there are very few fragments of metamorphic rocks.

2. The fragments of volcanite and of keratophyr were affected by the low thermic metamorphism, responsible of the transformation of some minerals to chlorite, epidote, calcite and quartz.

3. Among the limestones collected the found that of Los Bagres principally in the base of the Las Bermudez member, much studied by Kugler (1957) Muñoz (1973) and Hunter (1977).

These reefal limestones of Los Bagres are of Paleocene-early Eocene age and include fragments of Volcanite, which indicate their precedence to the washing in of volcanics. In addition to these limestones with corals of the Los Bagres, black limestones with shells (gastropods, probably, Turitella and bivalves) have been observed, as have limestones of coffee color where a fauna of upper Paleocene lower Eocene (Eocunnulides wells), of Lower basal-Middle Eocene (Amphistegina Lopeztrigoi) and a Sulcoperculina of possible Campanian-Maestrichtian age (Determination J.M. Villa in Chevalier, Y., (1987).

As a source for these fragments of volcanic rocks, the outcrops on the Los Frailes Archipelago were studied by Chevalier (1987) for comparison. In this group of islands, located 14 km Northeast of Margarita, there crop out a series of volcanic rocks (Moticska, 1972) which belong to a cal-alkaline series of orogenic type (Basalts and Basic Andesites) associated with a subduction zone during Late Cretaceous. The presence in form of blocks and pebbles of volcanic rocks with petrography and geochemical composition equivalent to the rhyolites and andesites in the wildflysch of Margarita gives testimony to the Tertiary erosion of the island are formed on the metamorphic basement, which crops out in the Archipelago of Los Frailes.

B. Middle Eocene

Sediments dated as Middle Eocene are represented by the El Datil and Punta Mosquito Members of the Punta Carnero Formation. Several attempts to date the Pampatar Formation by micro-or nannofossils have resulted useless. From the sedimentological study carried out by Muñoz (1973) a great petrographic difference separates the two formations: The Pampatar Formation is composed principally of graywackes and calcarenites while the facies of the Punta Carnero Formation are mainly bioclastics interfingered with strata deposited in a deep-water marine environment, the turbidites show part of the Bouma sequence (A-B-C-D).

Without discarding the possibility of the existence of a current lengthwise of the basin, the measurements made by Muñoz (op.cit) indicate movement of materials from the North and South into the Eocene Basin . Some intraformational folds indicate great instability of the depositional environment.

Different paleontological determinations carried out on the topmost beds of the Punta Carnero Formation indicate that the Punta Mosquito

Member is not younger than the Truncorodaloides rohri. The Globigerinatheca semi-involuta zone has up to now been recognized in the Island of Margarita.

III. THE MIO-PLIOCENE OF MARGARITA ISLAND

The Mio-Pliocene series of the Paraguachoa Peninsula, grouped under the term Cubagua Formation, represent the older Formations La Guica (Bermudez, 1966) and La Tejita.

Above there, the Formation El Manglillo of Early Pleistocene age (Hunter, 1978) unconformably crops out,

With a thickness of 45 m., the Cubagua Formation lies with angular discordance on the Middle Eocene series and upon the metamorphic Mesozoic basement. A basal conglomerate three meters thick, composed mainly of pebbles made of quartz and schists, begins this series of transgressive marine beds. The column continues with sandstones and calcareous shales and ends with fossiliferous marls.

Hunter (1978) recognized Neogloboguadrina dutertie zone of the Upper Miocene of the Cubagua Formation. This age was, confirmed by the presence of Globorotalia acostaensis (Macsotay determination in Chevalier, 1987).

IV. STRUCTURING OF THE EOCENE BASIN

Located in the southern border of the Paraguachoa Peninsula, the Eocene (Pampatar and Punta Carnero Formation) is arranged on a mapping scale, into a secession at synclines and anticlines with an average orientation East-West. This deformation is closed by the angular unconformity of the Cubagua Formation horizontal, of Lake Miocene age, upon the near vertical beds of the Middle Eocene.

The hills around the town of Pampatar show turbiditic and congloromentic material affected by metric to hectometric folds oriented N 80° to 90° E showing scaling toward the South . These structures, without schistosity , upon isoclinal folds of gravitational origin. This assemblage was later affected by faults striking N 140° E with movement horizontal dextral or sinistral.

Equivalent structures, with a vergence toward the South, characterized by the absence of schistosity, were also observed in the Punta Mosquito sector.

The contact of the Eocene formations with the metamorphic basement can be studied west of the Margarita airport. Here, the Eocene beds are vertical and one sees the contact of the olistoliths, composed of the limestones of Los Bagres of the Las Bermudez Member, with the calcareous metapelites of the Los Robles Group, also vertical.

The present configuration of this contact leads one to believe that it results, in part, from a tectonic condition and is only of local value. However, the indications of shearing of small amplitude in the metamorphic basement are not sufficient to define this contact. The contract of structuring of both units allows one to take this separation into consideration. By way of hypothesis, we propose that the Eocene Basin was only tilled and that the basal unconformity plane was the place of a shear .

For the synsedimentary structures, we postulate a Middle Eocene age for their formation. As to the shears, the folds, affecting the Eocene beds, as well as for the tilting of the basin, we suppose a phase of compressive deformation of Late Eocene-Middle Oligocene age, by analogy with the deformation observed in the Carupano Basin (Pereira, 1985).

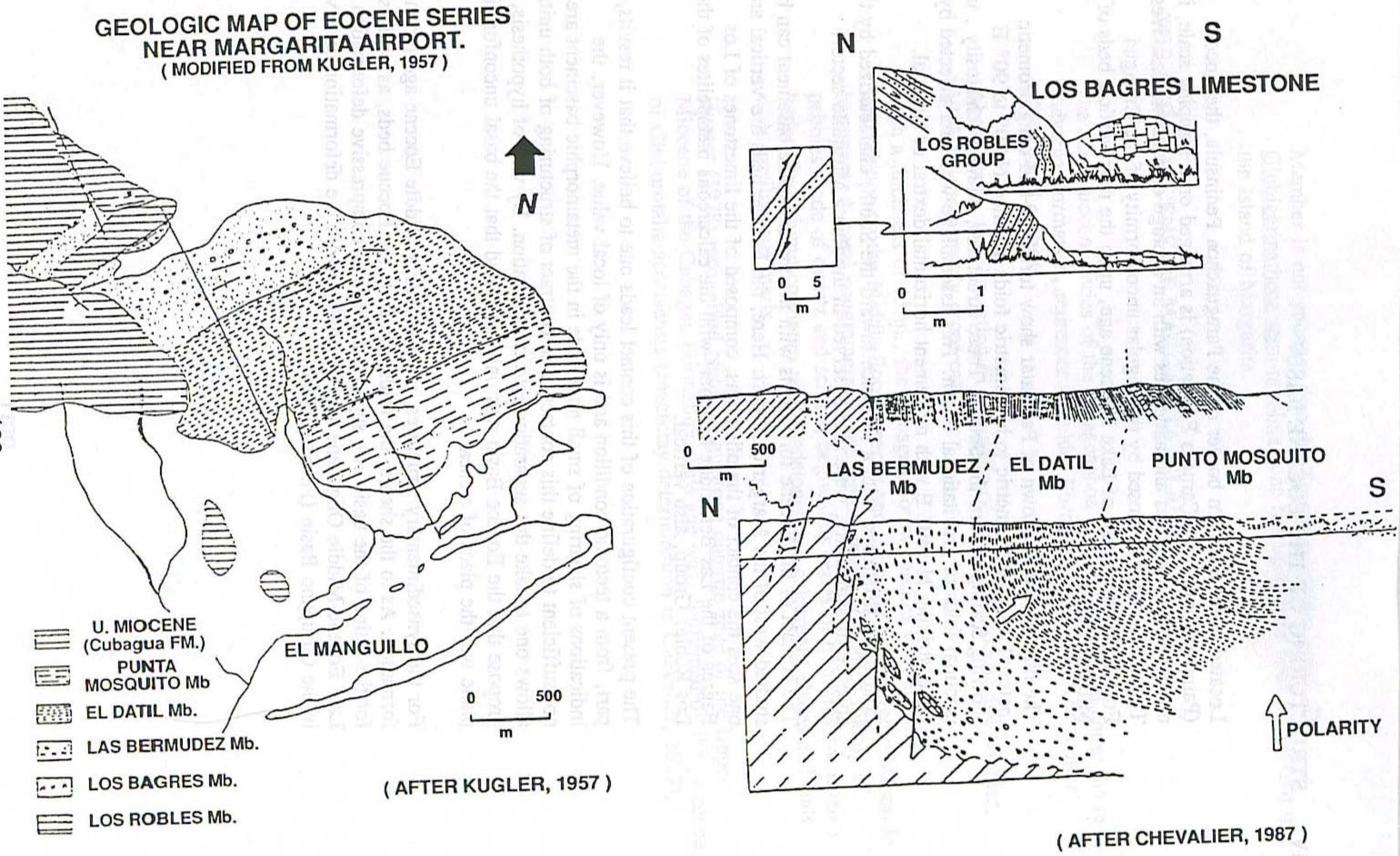


Fig.35 : The Eocene sediments of Punta Carnero Formation.

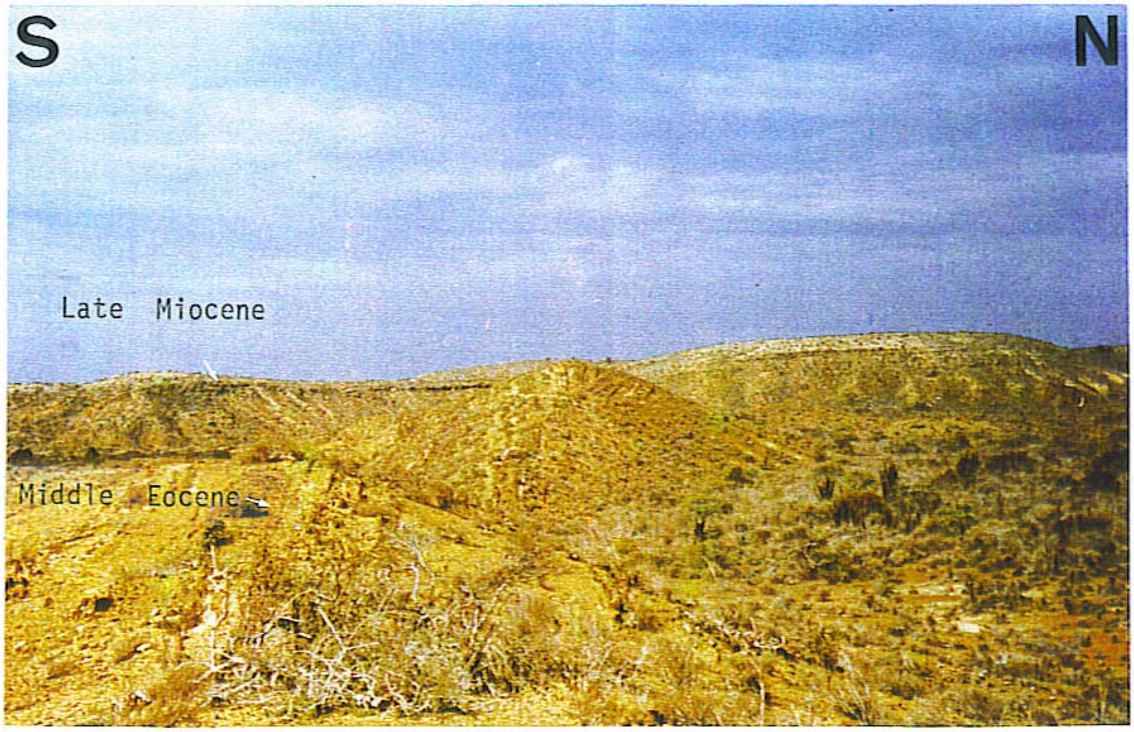
DAY 4: THE TERTIARY SEDIMENTARY COVER OF THE METAMORPHIC SUBSTRATUM OF MARGARITA

Stop 1: The Eocene basin near the airport

In this Western part of the Eocene basin of Margarita the sediments of Early to Middle Eocene age are grouped under the name of Punta Carnero Formation; which is divided into three members. The Las Bermúdez Member constitutes the base of the basin fill; it is composed of pebbles of volcanic rocks, of chert and of limestones. The El Datil Member is characterized by the appearance of the first calcarenite beds while the Punta Mosquito Member was laid down during the later part of Middle Eocene time.

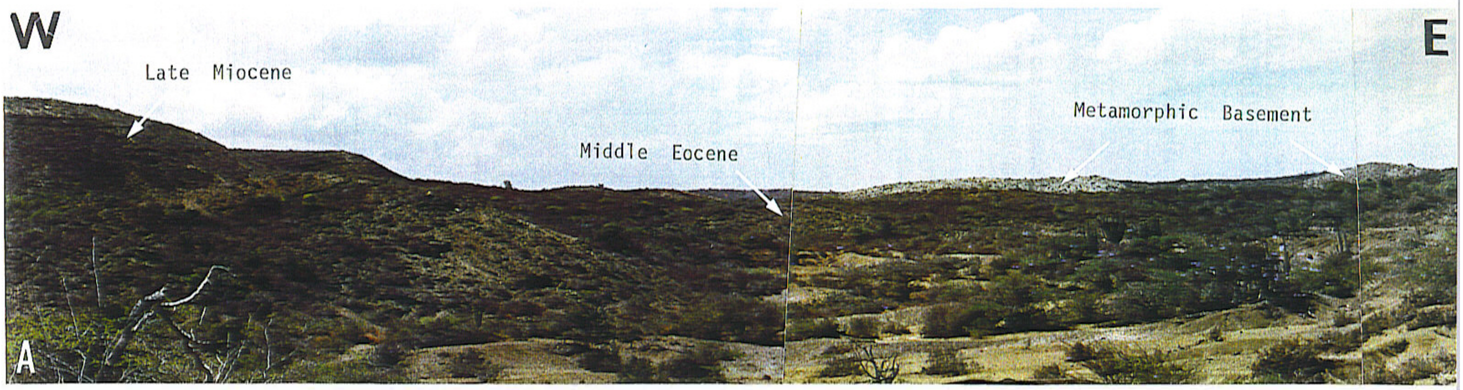
The contact between the Las Bermudez Member and the metamorphic substratum is interpreted as an old tectonized unconformity. Due to the difficulties of access in order to observe this contact we cannot invite the participants of this excursion to examine this sector in detail, the only one in all of Margarita. (Fig.35).

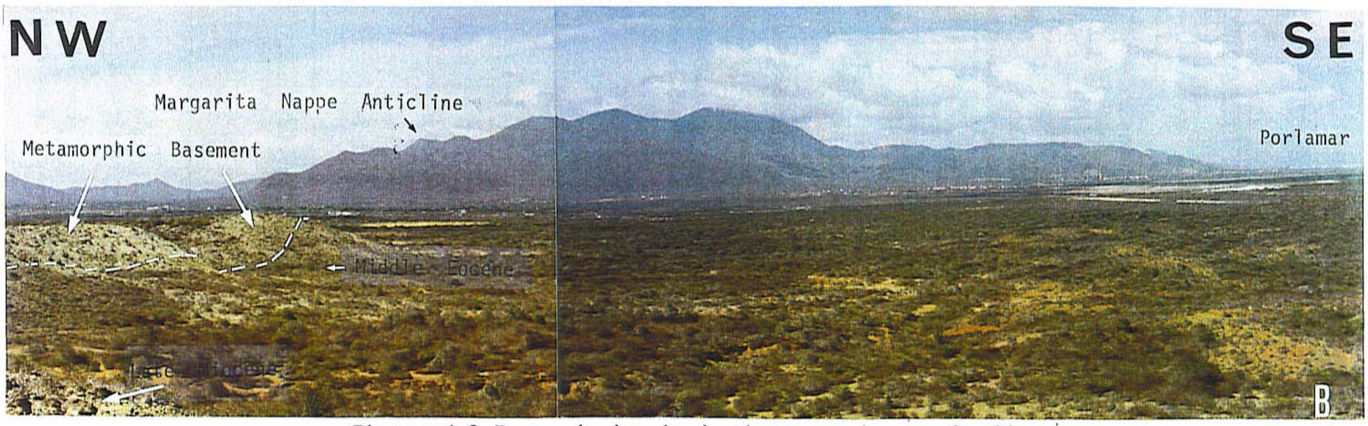
Upon these vertical Eocene strata there lie in angular unconformity the conglomerates and the beds of the Cubagua Formation dated as Late Miocene.



Photograph 1 and 2: Panoramic view showing the two angular unconformities:
1. between the vertical strata of the Middle Eocene and the horizontal conglomerates of the Cubagua Formation, of Late Miocene age.
2.(A and B), between the conglomerate beds of the Las Bermúdez Member and the Mesozoic metamorphic substratum (Photography F.Barrios ,1990).

DAY 4: THE TERTIARY SEDIMENTARY COVER OF THE METAMORPHIC SUBSTRATUM OF MARGARITA





Photograph 2: Panoramic view showing the two angular unconformities:
between the conglomerate beds of the Las Bermúdez Member and the Mesozoic metamorphic substratum (Photography A and B ; F.Barrios ,1990).

DAY 4: THE TERTIARY SEDIMENTARY COVER OF THE METAMORPHIC SUBSTRATUM OF MARGARITA

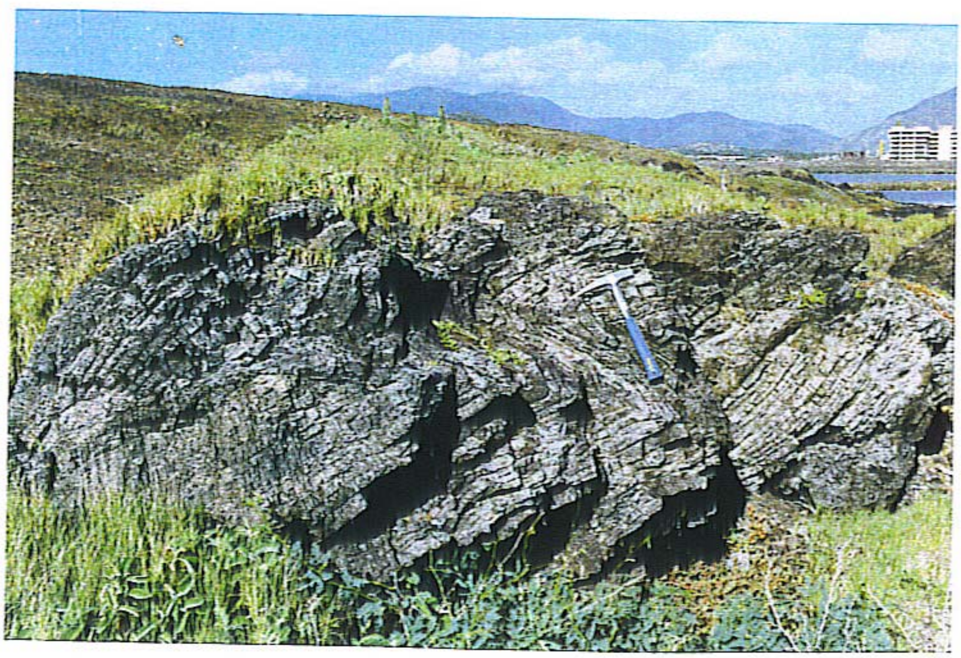
Stop 2: Laguna Gasparico. Basal wildflysch of the Pampatar Formation .

Located in the southeastern part of the Paraguachoa Peninsula (Eastern Margarita), the Pampatar Formation has not been able to be divided into members due to its homogeneity.

However one can differentiate a basal conglomeratic level from the turbidites which form the major part of this formation.

This stop is focused on presenting the conglomeratic levels of the base. In this sector one observes meter sized blocks of cherty beds folded and associated with very spilitisized basalts. Taylor (1960) considered these outcrops "in situ" and above all, indicated their resemblance to the lavas and cherts cropping out in the Los Frailes Archipelago, dated as Late Cretaceous (Santamaria-Schubert, 1979). These blocks, belonging to the first slides into the basin being formed were dated as Late Cretaceous by Dr. M. Furrer (in Chevalier, 1987).

Near these outcrops one sees the presence of heavy minerals forming a placer deposit, equal to other placer-type accumulations in the Island (Chevalier-Chauris, 1987).



Photograph 3: Synsedimentary folds emphasized by cherty levels and associated with spilitized basalt flows, corresponding to meter-sized blocks in the wildflysch of the Pampatar Formation.

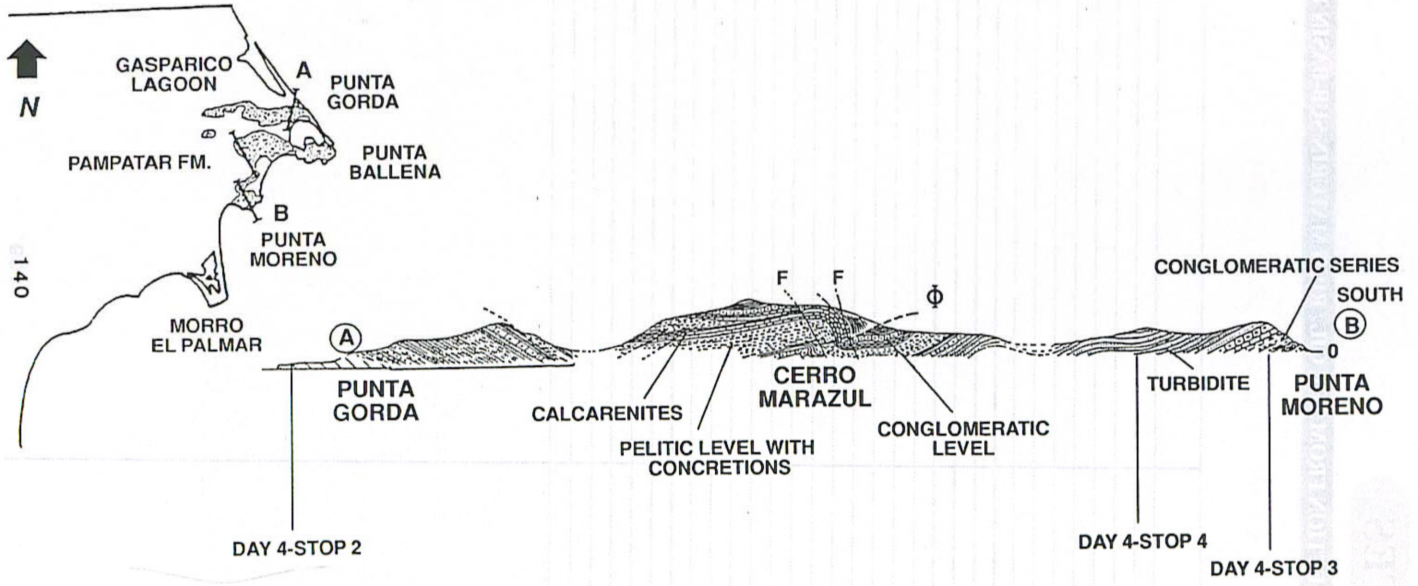


Fig.36 : A composite cross-section of the Pampatar Eocene series.
(from Chevalier ,1987).

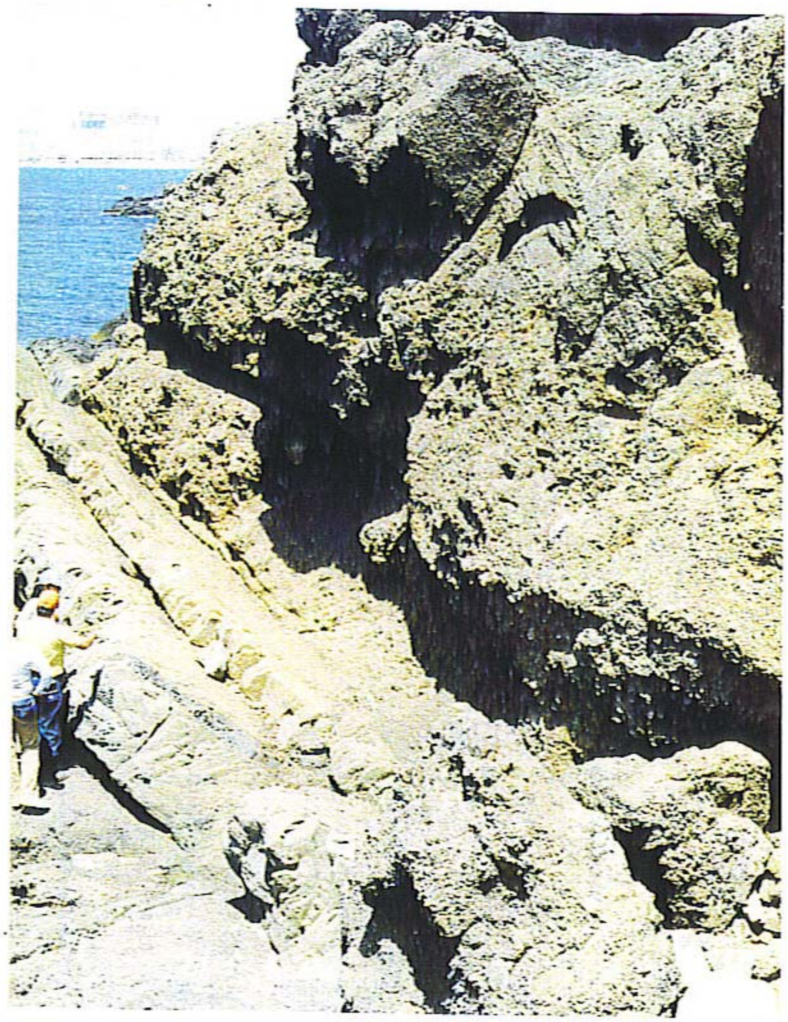
DAY 4: THE TERTIARY SEDIMENTARY COVER OF THE METAMORPHIC SUBSTRATUM OF MARGARITA

Stop 3: Punta Moreno. Contact between the basal conglomerates and the first turbidite strata of calcarenites.

Constituting the North flank of an anticline eroded by the sea (Fig.36). The beds of Punta Moreno are formed by two main facies.

1. A conglomeratic facies without visible stratification, with blocks of volcanic rocks (Andesite) and chert pebbles, of andesitic rocks, of limestones, etc (See Introduction).
2. A facies of calcarenites associated with concretions, forming beds up to 1 meter thick.

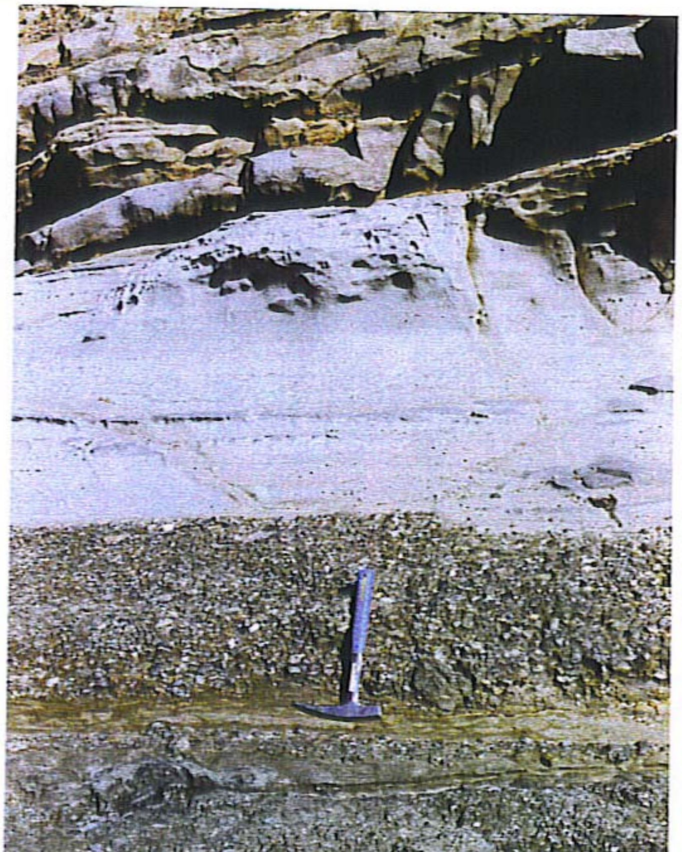
From the structural viewpoint, the structures affecting the Eocene series of the Pampatar Formation are not associated with the development of any cleavage plane. Of axial orientation the structures testify to a sub-meridional compression dated, by correlation with the data obtained from the Carupano Basin, as Upper Eocene to Lower Oligocene.



Photograph 4: Punta Moreno, general view showing the conglomeratic levels upon which the calcarenites were deposited. (Photography F.Barrios 1990).

DAY 4: THE TERTIARY SEDIMENTARY COVER OF THE METAMORPHIC SUBSTRATUM OF MARGARITA

Photograph 5: Micro-conglomeratic levels in the wild flysch of the Pampatar Formation, near Punta Moreno.



Photograph 6: First beds of calcarenites with concretions above the allodapic conglomeratic levels.

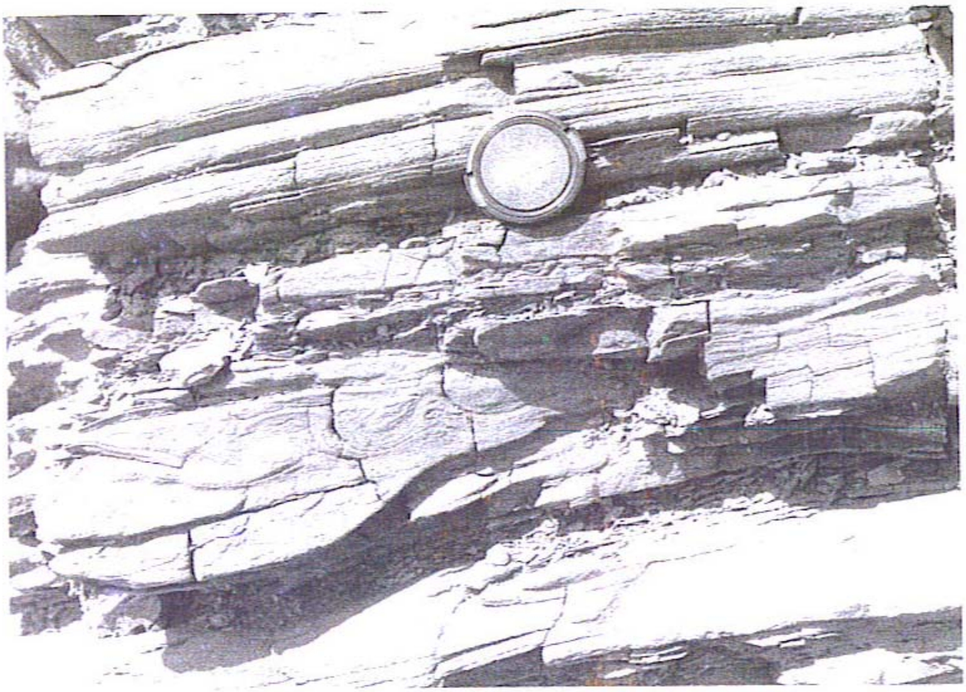
DAY 4: THE TERTIARY SEDIMENTARY COVER OF THE METAMORPHIC SUBSTRATUM OF MARGARITA

Stop 4: Punta Ballena. The turbidites of the Pampatar Formation

At Punta Ballena one sees a turbiditic series which permits one to propose a strong sinking of the basin during its evolution. The pelitic levels observable between each calcarenite bed are barren, which implies a Middle Eocene age for the Pampatar Formation based solely upon petrographic and litho-stratigraphic correlations.

Photograph 7: General view of the turbidites cropping out near Punta Ballena.

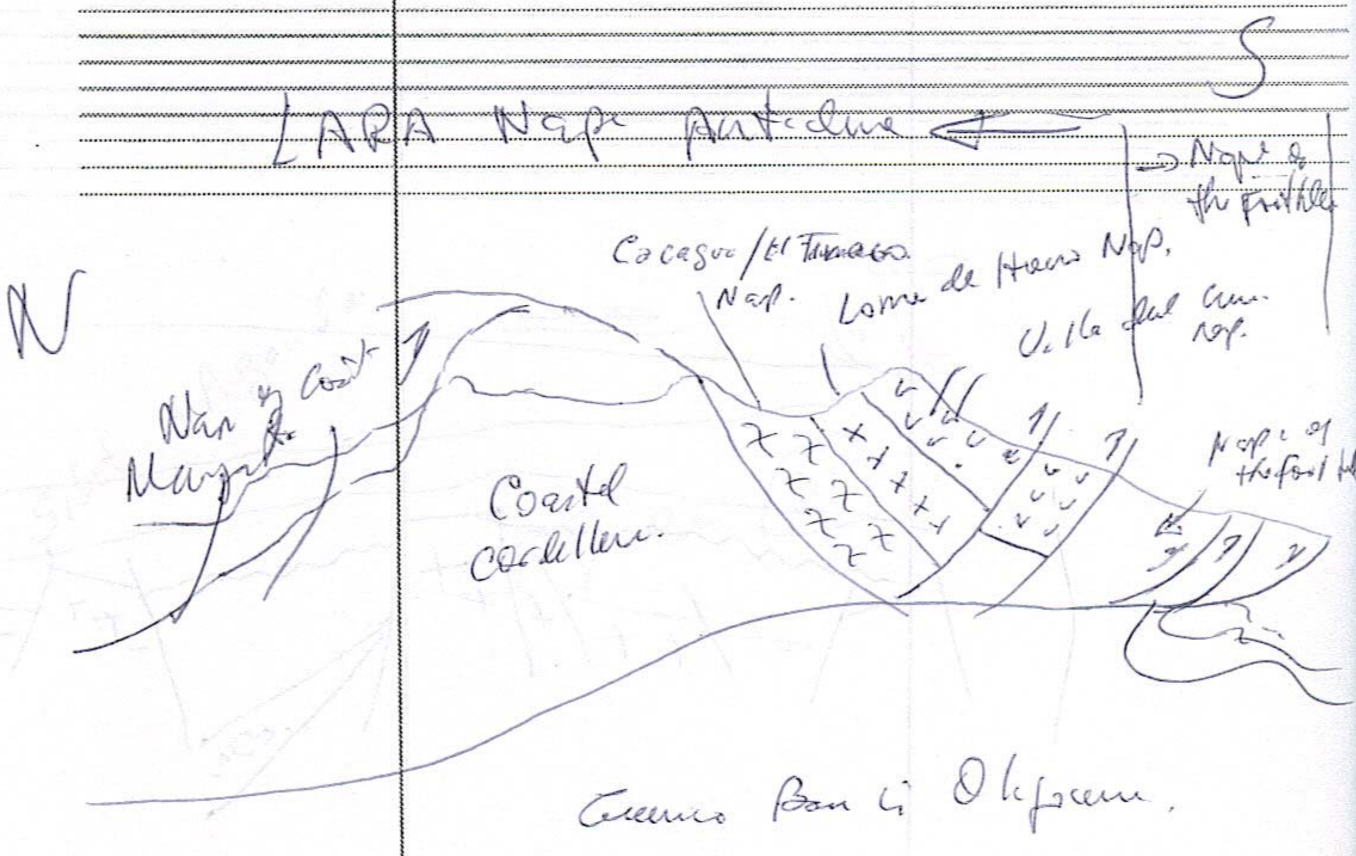
Photograph 8: Detail illustrating the basal microconglomerate levels and sandy levels with convolute bedding. Punta Ballena.



Photograph 9: Load figures in calcarenites Punta Ballena

NOTES

A CROSS SECTION FROM THE OIL / RICH MATURIN SUB-BASIN TO MARGARITA ISLAND



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.

Beck C., 1985
La Chaine Caraibe au meridien de Caracas : geologie , tectogenese , place dans l evolution geodynamique mesozoique , cenozoique des Caraibes meridionales.
These ,doctorat d Etat ,Paris VI .2 vol , 464 p.

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.

Bermúdez, J. 1975
Estudio de la sección del Eoceno en el pozo Cubagua. Estado Nueva Esparta. Venezuela.
Bull. Min. de Minas y Hidro. XII, 23, Pág. 493-503

Bermúdez J., Gamez, H. 1966
Estudio paleontológico de una sección del Eoceno Grupo Punta Carnero de la Isla de Margarita, Venezuela.
Mem. Soc. Cienc. Nat. (La Salle) XXVI, 75. Pág 205-259

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

Campos, V. 1981
Une transversale de la Chaine Caraibe et de la marge venezuelienne dans le secteur de Carupano (Venezuela Oriental): Structure geologique et évolution geodynamique
Thése Brest, Pág. 160

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. ; Chauris , L. 1987
Arenas pesadas de placer en Margarita.
Boll. Soc. Ven. de Geol., p 30-33.

Chevalier Y., Stephan J.F.,Darboux J.R., Gravelle M., Bellon H., Bellizzia A.,Blanchet R., 1988
Obduction et collision pretertiare dans les zones internes de la Chaine caraibe venezuelienne sur le transect Ile de Margarita -Peninsule d Araya.
C.R. Acad. ,Sci.,Paris, ,t.307 ,serie II,p.1925-1932.

Chevalier Y, Alvarez E. 1991
Consideraciones estructurales del transecto Cariaco-Maturin (Geología superficie-subsuelo)
Informe inedito Lagoven Nº 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, p.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

Di Croce J. 1987
Analisis sedimentologico de la Formacion San Juan en la Cuenca Oriental de Venezuela (Estado Anzoategui y Monagas)
Trabajo de Grado ,Magister Scientiarum en Ciencias geologicas,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

Graf, C. 1972
Sedimentos del Terciario superior y Cuaternario de la peninsula de Macanao-Venezuela
VI Conf. Geol. Caribe, Margarita, Pág. 28-32

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 de l unite ultrabasique du cerro Matasiete ,Ile de Margarita ,Venezuela.
C.R. Acad.,Sci. ,Paris, 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 .

Hedberg, H. D. 1937
Stratigraphy of the Rio Querecual section of northeastern 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

Hess, H.H., Maxwell J. 1949
Geological reconnaissance of the Island of Margarita.
Geol. Soc. Am. Bull. Vol. 60. Pág. 1867-1868

Hunter, V.F. 1977
Foraminiferal correlations of tertiary mollusc horizons of the Southern Caribbean area.
Abstract 8th Caribbean Geol Conf. Caracas. Pág. 75-76

Hunter, V.F. 1978
Notes on the tertiary stratigraphy of Margarita
Geol. Mijnbouw, 57 (2), Pág. 189-192

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

Kugler, H.G. 1957
Contribution of the island of Margarita and Cubagua, Venezuela
Geol. Soc. Am. Bull, 68, Pág. 555-556

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.

Mac Gillavry, H. J.M. 1974
Detritus in the Eocene of the Island of Margarita (Venezuela)
In: Contribution of the geology and paleobiology of the Caribbean and adjacent areas
Verhandl Naturf. Ges. Basel. Bd. 14,1 Pág. 191-201

Macsotay, O. 1965
Carta faunal de macrofosiles correspondientes a las formaciones cenozoicas de la peninsula de Araya. Estado Sucre
Geos 13. Univ. Central de Venezuela. Pág. 37-49

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.

Maresch W. 1973
Metamorfismo y estructura de Margarita Npororiental ,Venezuela
Boll,Geol., M.M.H. ,Vol XII,22,p.3-172.

Maresch W. 1975
The geology of northeastern Margarita Island ,Venezuela: a contribution to the study of Caribbean plate margins
Geol.,Rundschau 64,p. 846-883.

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

Moticska, P. 1972
Geologia del archipiélago de Los Frailes
VI Conf. Geol. Caribe. Margarita, Memorias Pág. 69-73

Muñoz, N. G. 1973
Geología sedimentaria del flysch eoceno de la Isla de Margarita-Venezuela
Geos, 20, Pág. 5-64

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
Nº 3000-11-5 Caracas Pág. 337

Pereira, J.G. 1985
Evolución tectonica de la Cuenca de Carúpano durante el Terciario
VI Cong. Geol. Venez. Pág. 2618-2647

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

Santamaria F., Schubert C., 1974
Geochemistry and geochronology of the Southern Caribbean -Northern Venezuela -Plate Boundary
Geol.,Soc., Am.,Bull., Vol 85 ,p.1085-1098.

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

Stephan, J.F. 1982
Evolution géodynamique du domaine Caraibe, Andes et chaine Caraibe sur la transversal de Barquisimento (Venezuela)
Thése d'etat, Univ. Paris IV. Pág. 512

Stephan J.F.,Beck C.,Bellizzia A.,Blanchet R.,1990.
La Chaine Caraibe du Pacifique a l Atlantique
Memoire du B.R.G.M. 115,26 eme Congr. Geol.,Intern.,
Colloque des chaines Alpines issues de la Tethys ,Paris ,p.38-59.

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.

Urbani F.P., 1969
Primera localidad fosilifera del Miembro Zenda de la Formacion Las Brisas cueva El Indio,La Guairita ,Estado Miranda
Bol.,Inf., Asoc., Venez., Geol., Min.y Petrol. ,Vol 12,p.447-449.

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

Vivas, V. 1981

Contribution al estudio de la Serranía del Interior Oriental
D.E.A. Lille Pág. 48

Vivas, V.1986

Contribucion al estudio de la Serrania del interior oriental (Venezuela); estratigrafía y tectónica de la región de Bergantin. Santa Inés.
Thése, Brest 3 volúmenes

Vivas, V.,Bellizia, A.,Macsotay, O.,1985

Deflexión de Barcelona: rasgo estructural primario en Venezuela nororiental.
VI Cong. Geol. Ven. Caracas, 1985. T. IV. Pág. 2712-2744

Vivas, V. ,Macsotay, O.,Furrer, M.,Alvarez, E.,1984

Inyectitas clásticas asociadas a desplomes en sedimentitas batiales del Cretácico Superior de Venezuela Nor-Oriental.
Bol. Soc. Venez. Geol., 34, Pág. 3-33-1988

Von Humbolt, A.1820

Voyage aux regions equinoxiales du nouveau continent
(T.4) N. Maze ed. Paris
(Traduction en 1956: eds. Min. Education, Caracas, t.3).