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# Middle Eocene foreland sediments covered by late Oligocene foredeep turbidites on Margarita Island, northeastern Venezuela

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ABSTRACT. **On eastern Margarita lsland local outcrops are found of thick marine, Paleogene sediments deposited on Late Cretaceous-Early Paleocene pelagic sequence of phlyllite-chert-limestone alternations. The eastern outcrops are a typical flysch sequence (Pampatar Formation), more than 1,000 m thick, with a basal sequence of reworked andesitic rocks, radiolarian limestones of Campanian age and cherts of Maastrichtian age. These are lithologically identical to the Matatere Formation of the Lara Nappe of western Venezuela. Early Eocene fossils were collected in the upper part of the sequence.**

**The western outcrops were deposited in a subsiding trough: Las Bermudez diamictites, whose massive mudstones exhibit submarine canyon-fill lenses containg conglomerates and diamictites up to 800 m thick. At the base, lenses of limestone/sandstone (Los Bagres) alterations carry molluscs of early Middle Eocene age. The Los Bagres is interpreted as slide deposits of shelf sediments; the Las Bermudez, as slope deposits, identical to the Guaiquera Formation from the Villa de Cura Nappe's sedimentary cover. Conformably above, El Datil shales are distal turbidites deposited during the late Middle Eocene in a foreland.**

**Thrust on or slid over the former, the Punta Mosquito Formation's kilppe, is a succession of limestones, calcisiltites and lutites (calcareous turbidites) of the same age as the Datil Shale. Unconformably above, massive siltstones and shales of the Caracolito Formaton contain greywake sandstones, slumps and trace fossils belonging to the *Nereites* ichnofacies indicating a deep basinal location. Preliminary palaeontological examination suggests a late Oligocene age.**

## 1. INTRODUCTION

Ever since the introduction of plate tectonic concepts to Venezuela, the igneous-metamorphic core of Margarita Island was considered allochthonous (Stephan, 1977, 1985; Beck, 1985). The original palaeoposition of Margarita Island's igneous-metamorphic core has been placed in the Pacific Ocean, in a position NW of the South American Plate (Dewey and Pindell, 1985; Guth and Avé Lallemant, 1989; Pindell *et al*., 1991, 1998).

A Caribbean origin has been proposed for all southern Caribbean allochthonous units by Meschede and Frisch (1998). They argued that a Pacific origin for the Caribbean Plate would require an estimated offset of 3,000 to 4,000 km along its southern boundary, and this was contradicted by the palaeoposition of Central American ophiolites, which clearly formed in an equatorial position.

Guth and Avé Lallemant (1989) proposed a model of west to east displacement from the north of Guajira Peninsula's palaeoposition, 55 Ma ago, to its present position north of Araya Peninsula (Figs 1-2). According to the Pindell *et al*. (1998) palinspastic reconstructions, Margarita only reaches a palaeoposition offshore, to the northeast from La Guajira, during Early Eocene times (c. 46 Ma). Somewhere north of Paraguaná during early Late Eocene (35 Ma) it would be placed in the eastern Falcón basin by the Late Oligocene (25 Ma) and to Caracas' latitude by late Early Miocene times (16-17 Ma).

In view of the geological model that proposes the suturing of the Araya-Margarita and Tobago terranes in the Early Cretaceous (Speed and Smith-Horowitz, 1998), we decided to test the Cenozoic evolution using geological field evidence. We tried to concentrate on Paleogene sediments, whose equivalents should be scattered along the allochthonous mountain ranges of Venezuela.

Paleogene aged sedimentary outcrops are restricted to the southern and eastern margins of the Paraguachoa Peninsula of Margarita Island. Additionally, Eocene and Oligocene marine sediments were drilled in the Carupano Basin (Castro and Mederos, 1985), and Eocene sediments on Cubagua Island (Bermudez, 1975).

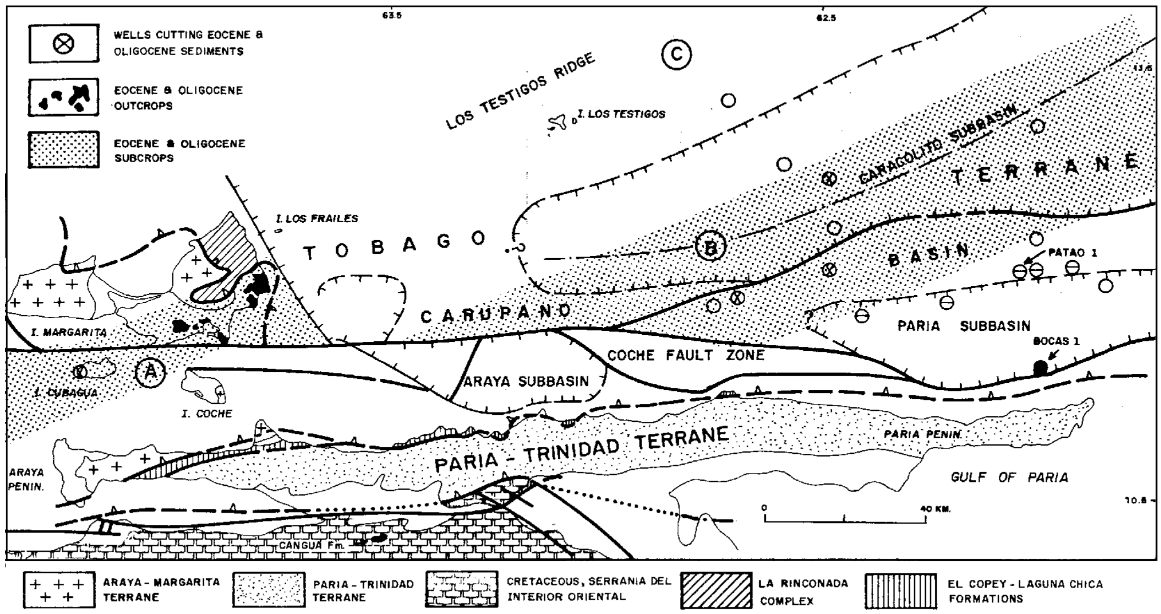


**Figure 1. Outcrops and subcrops of Eocene and Oligocene marine sedimen ts in NE Venezuela.**

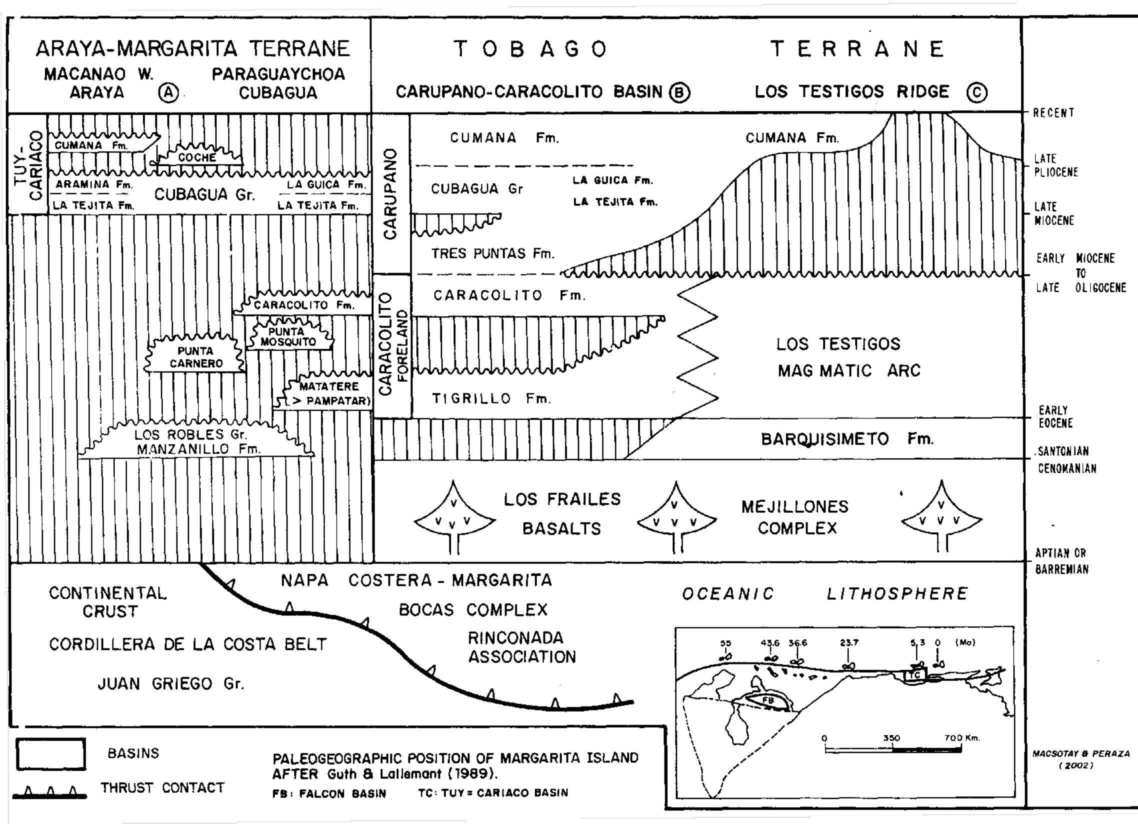


**Figure 2. Synthetic stratigraphy of Araya-Margarita and Tobago terranes.**

This suggests the original continuity of an extensional basin, barely deformed during Neogene times (Fig. 1).

In Venezuela's mainland (El Pato realm of the Serrania del Interior), a sequence of clay/shales (Cangua Formation) topped by radiolarian limestones of Middle Eocene age, has been discovered recently (Vivas and Macsotay, 1995). These shales are purely pelagic sediments with no turbidites or any volcanoclastic content

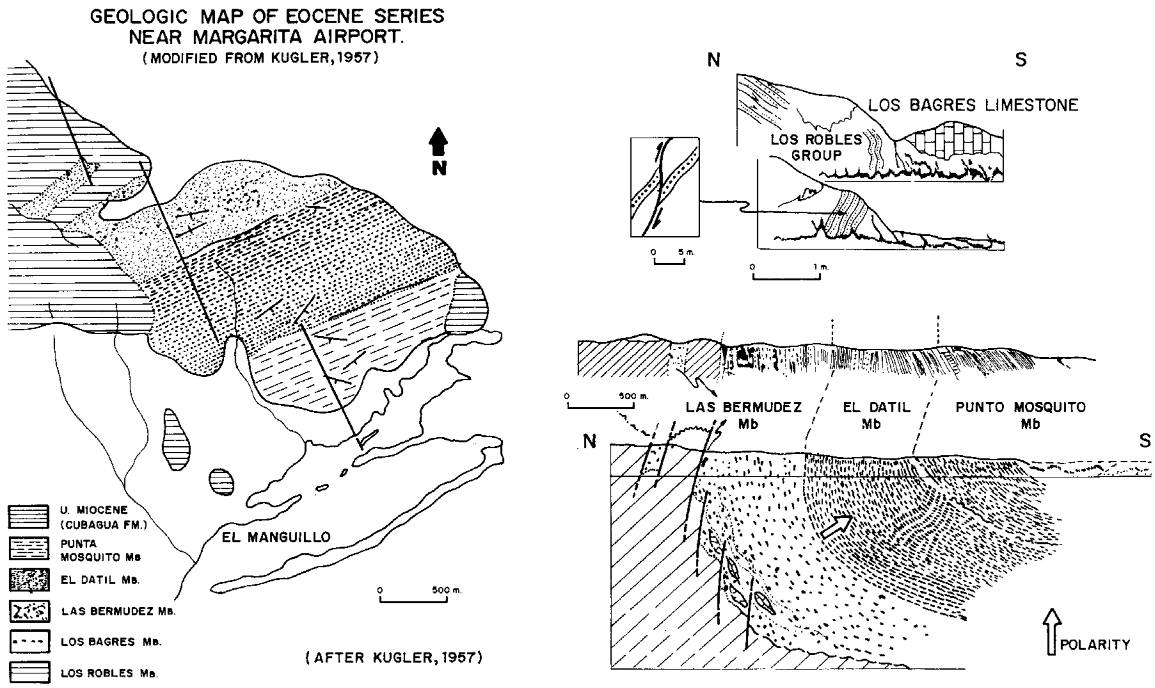


**Figure 3. Chevalier's (1987) interpretation of the Cretaceous-Eocene field relations. Notice the setting of Los Barges Limestone.**

that were deposited on the epicontinental apron of the South American Plate. In these sediments *Chondrites*, *Zoophycos* and *Tomaculum* are the dominant ichnogenera; the age was determined through nannoplankton and foraminifers.

## 2. Margarita Island - Paraguachoa Peninsula

In the published literature we have observed a lack of awareness about the locations of these outcrops, despite their precise locations on Venezuela's geological map (Bellizzia *et al.*, 1976). Also the stratigraphic nomenclature has changed, with additional important biostratigraphic contributions. From west to east, the outcrops can be grouped into: the Airport section; La Isleta; and the Pampatar section.

### 2.1. Margarita airport section.

Formally called the Punta Carnero Group, this unit included all the presumed Eocene-aged outcrops on Margarita Island (Charlton de Rivero *in* Lexico Estratigrafico de Venezuela, 1956). Later, the easternmost outcrops were separated under the term Pampatar Formation (Muñoz, 1973), and Punta Carnero was elevated to formational rank, and contained three members: Las Bermudez, El Datil and Punta Mosquito (Fig. 3).

Field work by the authors revealed a tectonic contact between the vertical Las Bermudez-El Datil members and the south-dipping Punta Mosquito Formation (Fig. 4) and its cover, the Caracolito Formation, known formerly only from the subsurface. So, the section is composed of the following units, from northwest to southeast:

***1. Las Bermudez Member.*** A mud-dominated wild-flysch, 700 m thick, deposited upon Los Robles Group (Chevalier, 1987). This unit starts with Los Bagres limestone, an alternation of shales, fossiliferous limestones and calcareous shales, only 20 m thick. In place molluscs and corals [*Atopocoenia kugleri* Wells, *Venericardia (Rotundicardia) flabellum* Harris and *Mesalia* cf. *scotti* Rutsch] suggest an early Middle Eocene or latest Early Eocene age. Above, the monotonous sequence of mudstones and siltstones exhibits lenticular beds of pebble to boulder conglomerate. The clasts are of quartz, schist, igneous rock (mostly andesites) and chert, in a sandy matrix (Mac Gillavry, 1973). The chert, tuff and radiolarites were attributed to the Mejillones complex by Speed and Smith-Horowitz (1998), but their similarity is with the Barquisimeto Formation of the Lara Nappe.

The Barquisimeto Formation is the uppermost unit of the Lara Group, a km-scale megasequence, constituting the basal part of the Lara Nappe (Stephan, 1985; Macsotay *et al.*,

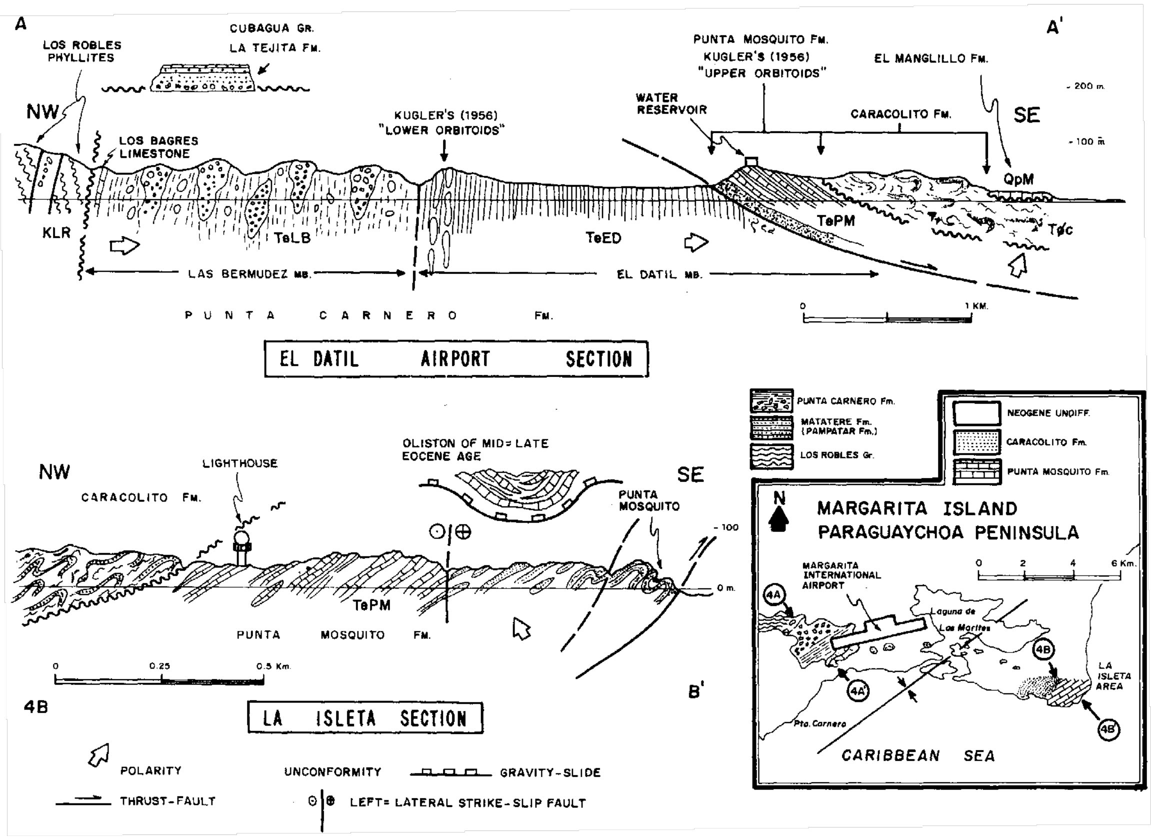


**Figure 4. Geological transects exposing field relationships of Late Cretaceous-Eocene-Oligocene marine sedimentary sequences. Arrow indicates polarity.**

1987). The imbricated thrusting of the nappe during Early and Middle Eocene times, produced extensive turbidites, called the Matatere-II and –III formations by Stephan (1985). Their mineralogical and lithological composition matches exactly those reported for the Las Bermudez member and 'Pampatar' Formation.

In the Tobago terrane, the km-thick Barquisimeto Formation has an age spanning Cenomanian to Early Paleocene and rests on the Mejillones complex, of the Araya-Margarita and Tobago terranes rather than the Carorita and Bobare formationsin the Lara Nappe (a fact not recognized by Speed and Smith-Horowitz, 1998).

***2. El Datil Member.*** A silty shale, finely laminated, with km thickness, overlies the Las Bermudez Member with a gradational contact (Fig. 4A). A thin carbonate horizon with orbitoidal foraminifers seems to be a submarine slump reworked by contour currents. The overlying shale/silt alternations are considered a distal flysch. An abundant foraminieral assemblage suggests the *Truncorotaloides rohri* zone of latest Middle Eocene age, with reworked microfaunas of the *Morozowella lehneri* and *Orbulinoides beckmanni* zones (Bermudez and Gamez, 1966; Bermudez *in* Muñoz, 1973). This suggests the reworking of still unconsolidated pelitic sediment.

The whole section of the Punta Carnero Formation became tilted to vertical in the Margarita Airport section. Largely undeformed El Datil shale was drilled in Cubagua-1 Well beneath Late Miocene marine shales (Bermudez, 1975). It confirms the extension of the basinal Eocene sediments towards the south-west (Fig. 1).

***3. Punta Mosquito Formation.*** Originally treated as the uppermost member of the Punta Carnero Formation (Hunter, 1978, fig. 1), recent field evidence suggests a tectono-sedimentary contact between this unit and the El Datil shales (Fig. 4A). The Punta Mosquito Formation begins with a 20 m thick pocket of litharenites with slump structures, followed by alternation of metre-thick beds of orbitoidal limestone, laminated marl and calcareous shale. It is considered a calcareous flysch of orbitoidal biocalcarenites, biocalcilutites and shales. The biocalcilutites are bottom-current deposited (Muñoz, 1986). Shale horizons rich in rodoliths and *in situ* echinoids suggest a deep shelfal or upper slope palaeoenvironment.

The exposed section of 140 m forms a true klippe-structure, thrust (or gravity-slid) upon the Punta Carnero Formation (which was already vertical) in the Latest Eocene or Early Oligocene, and related to the un-roofing of Margarita Island (Stöckhert *et al*., 1995).

***4. Caracolito Formation*** (Castro and Mederos, 1985). The original description of the Punta Mosquito Formation, included an 'upper part' (Gonzalez de Juana *et al*., 1980) of non-carbonate horizons consisting of massive, dark brown silty shales, with laminated, micaceous dark green fine-grained sandstones (up to a few cm thick). Some lenses of coarse-grained graded sandstones with occasional flute casts at the base contain a bathyal ichnofauna of the *Nereites* ichnofacies (predicted by Pereira, 1985). We collected some well-preserved ichnofossils on the base of the sandstones [*Paleodictyon maximum* (Eichwald), *Paleodictyon hexagonum* Marck, *Helminthoida* isp., *Granularia* isp. and *Megagrapton irregularis* Ksiaczkiewic, among others].

The fine-grained sandstones frequently are calcareous and rare beds (a few cm thick) of biodetritic limestone were found. The whole section is imbricated with structures showing a southward vergence (Fig. 4A). These bathyal pelagites are lithologically indistinguishable from the typical Caracolito Formation of the Caracolito foreland basin (Castro and Mederos, 1985). These bathyal turbidites overlie the Punta Mosquito Formation (observable on aerial photographs). The estimated thickness in the scattered outcrops is about 120 m (Figs 2, 4A).

**2.2. La Isleta section**

Also called the Punta Mosquito section, this exposes good outcrops of the Punta Mosquito Formation (the type locality), the Caracolito Formation (as now redefined) which was original including in the Punta Mosquito Formation.

***1. Punta Mosquito Formation*** (Charlton de Rivero *in* Lexico Estratigrafico de Venezuela, 1956, emend). The lower part that is exposed contains thick sandstones and litharenites (with plant remains and rudaceous, cherty and orbitoidal limestone clasts) that show synsedimentary folding. Above this, is a calcareous flysch composed of alternations of biocalcarenites, biocalcirudites and shales of metre to decimetre thickness. The shales are interbedded with metre to decimetre thick calcilutites and biocalcisiltites composed of reworked globigerinid oozes, probably deposited by bottom currents. The top is a rhythmic alternation of fine-grained calcarenite and deep-water pelagites containing abundant nannoplankton. The commonest sedimentary structures are load casts and parallel laminations.

In the middle part of the formation, frequent horizons of rhodoliths are found in the calcilutites below the calcirudite beds. These rhodoliths are up to several cm in size, and suggest a water depth of 150-350 m. In this horizon, crinoid stems are also locally found. The echinoid cf. *Linthia caraibensis* Jeannet, originally recorded from the Late Eocene of Trinidad, suggests a deep shelf setting. Frequent ichnofossils of the *Cruziana* ichnofacies were illustrated by Macsotay (1967, figs. 47, 48, 52). The thickness is similar to that in the Airport section.

***2. Caracolito Formation.*** The outcrops on La Isleta are similar to those of the Airport section; the only difference being the development of a subgreywacke/shale alternation with a little slumping in the upper part near the axis of the syncline (Fig. 4). The abundant ichnofauna belongs to the *Nereites* ichnofacies, and is very different from that of the underlying Punta Mosquito Formation.

The mineralogy of the greenish litharenites and subgreywackes, is dominated by quartz and glauconite, but metamorphic components (epidote, chlorite, garnets, muscovite, sericite and iron oxides) are common in some beds (P. Moticska, private report). This association is very similar to the one of the subsurface Caracolito Formation (Castro and Mederos, 1985), but different from the assemblage from the Las Bermudez Member of Punta Carnero Formation (MacGillavry, 1974).

The heavy mineral suites suggest an Oligocene palaeoposition just north of the Cordillera de la Costa Nappe that had already emerged (Stephan, 1985). We consider Margarita mostly still in a submarine position (Guth and Avé Lallemant, 1989), and part of the Cordillera de las Costa (Pindell *et al*., 1998). It was submerged like the Caracolito Basin (Fig. 2).

**2.3. Pampatar secton.**

Called the 'Agua de Vaca-Punta Gorda-Salina de Pampatar' by Muñoz (1973, 1986), this was simplified to Pampatar section by Chevalier (1987). These outcrops are more extensive than the previous ones (Fig. 1) measuring about 1,000 m thick.

***1. Matatere Formation*** (=Pampatar Formation of Muñoz, 1973). Originally proposed as part of the Punta Carnero Group, these outcrops were named

Pampatar Formation by Muñoz (1973) who noticed important differences with the former. Among these, were the absence of orbitoid limestones and the development of a classical flysch sequence with rhythmic alternations of subgreywackes and shales; true olistostromes towards the base were also distinctive features.

More than 1 km thick, the sequence includes basal conglomerates with abundant volcanic, volcanoclastic, chert and quartz pebbles and cobbles. Radiolaria chert olistoliths up to 10 cm size are frequent. These black, thin-bedded cherts are chevron-folded, and contain a microfauna of Maastrichtian and occasionally Campanian age, very similar to the Barquisimeto and Rio Chavez formations.

The middle member starts with brown massive mudstones with calcareous olistoliths with foraminifers of Campanian age. They grade upward into sandy turbidites, with frequent slumps. The upper member is an alternation of decimetric beds of greywackes and shales, with olistoliths at the base. These are exactly like the outcrops of the Matatere Formation (of Bellizzia and Rodriguez, 1968) in Lara State, western Venezuela.

In the absence of diagnostic foraminifers, Muñoz (1973, 1986) proposed the unit to be laterally equivalent to the Punta Carnero horizons, although he noted that palaeocurrents were oriented southeast-northwest, in contrast to the western outcrops. Three localities of the upper member, furnished slumped gastropod-dominated lenses. Their age is Early Eocene, pre-dating the western sections. This unit is not distinguishable from the Matatere Formation, proving the palaeoposition of Margarita, to the north of the Falcon area. This unit is the best proof of the relationship with the Lara Nappe.

### 3. Discussion

Speed and Smith-Horowitiz (1998, fig. 3) in their synthesis of the Tobago Terrane, suggested that above the Mejillones Complex and Los Frailes Basalts, an unknown unit was deposited during Late Cretaceous-Paleocene time. They called this unit the Mejillones Complex, but in fact the hemipelagic unit deposited there was the Barquisimeto Formation that is widely represented in the Lara Nappe of western and central Venezuela. This unit, with an age of Cenomanian to Early Paleocene is a typical hemipelagic sequence, starting with olistostromes, followed by radiolaria-limestones, radiolaria cherts and shales (Stephan, 1977; Macsotay *et al*., 1987).

Originally studied in the Lara Nappe where it was deposited upon the pelagic Carorita and turbiditic Bobare formations of Early Cretaceous age (Stephan, 1985), it became imbricated in Paleogene times. The Late Cretaceous-Paleocene sequence drilled in several JOIDES wells in the Venezuelan Basin contains the same lithological types as the Barquisimeto Formation, above basaltic lavas. The association of Mejillones complex-Barquisimeto Formation in the Tobago terrane suggests a typical Caribbean Plate affinity.

In the Lara Nappe the Cretaceous part of the sequence was exposed to erosion, and its limestones and cherts can be found reworked within all the sedimentary sequences of the Matatere Formation (Stephan, 1985). Due to this Paleogene erosion, complete sections of the Barquisimeto Formation can only be found locally. This is true for the Tobago terrane, where sediments were reworked into extensive Paleogene grabens (Fig. 2).

In the Late Paleocene oblique collision of the Palaeo-Caribbean Plate against the South American Plate began in western Venezuela (Stephan, 1985). This oblique collision continued until Late Eocene time, when suturing was completed (Stephan *et al*., 1994). During these compressive phases, extensional grabens developed behind the collision front.

The Caracolito foreland basain was filled during the Early Eocene with sediment from the southeast derived from the thrust front of emergent Cretaceous and Paleocene hemipelagics that now forms the Lara Nappe, and the Falcón Basin subsurface. Sedimentation was from southeast.

During the Middle Eocene the Araya-Margarita-Tobago area was unroofed and provided sediment from the north-west. This is demonstrated by the increasing importance of volcaniclastic sediments.

By the Early Oligocene, a general subsidence, which started during Late Eocene times, produced silt-dominated bathyal turbidites suggesting the apron and slope of the emerged Cordillera de la Costa in Venezuela. Sediment came from the south, and the emerging Los Testigos arch to the north.

With this sedimentary record, we tend to support the model of Guth and Avé Lalleraant (1991) for the Paleogene evolution of the Araya-Margarita and Tobago Terranes. The Paleocene-Eocene evolution proposed by Stöckhert *et al*., (1995) is also confirmed. But all previous studies, including Pindell *et al*. (1998), fail to document the subsidence of the Caracolito foreland basin, including Margarita Island.

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