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The marine Neogene of Eastern Venezuela
A preliminary report

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ABSTRACT

Key words: Neogene; Quaternary; Biostratigraphy; NE Venezuela.

The studied marine Neogene-Quaternary of NE Venezuela outcrop in the localities of the Araya peninsula and in the Cubagua and Margarita islands discordant upon a basement of metamorphic rocks and pre-miocenic sediments. These neogene-quaternary sections belong principally to the Cubagua Formation, which is composed of a lower clayish interval (Cerro Verde Member) and an upper one of calcareous nature (Cerro Negro Member), and to La Tejita and Tortuga formations.

The age of this sedimentary interval, based upon analysis of planktonic foraminifera, ranges from the lower part of Late Miocene to Holocene. According to the calcareous nannoflora, in the Cubagua Formation a floral assemblage was identified which goes from the Zone NN10 until the limit of NN16-NN17 zones.

The fauna of benthic foraminifera allowed one to establish that the paleoenvironmental evolution of the Cubagua Formation varied from bathial to neritic depths during the Early Pliocene.

After a period of elevation an erosion during the greater part of the Pleistocene, water invading the eroded surface depositing upon it the calcareous sequence of the Tortuga Formation.

INTRODUCTION

The studied sediments of the marine Neogene and Quaternary of NE Venezuela outcrop in the Araya peninsula and on Cubagua and Margarita islands (Fig.1).

The sections studied belong principally to the Cubagua Formation in those three areas. Only in Margarita island do the Neogene sediments also belong, in its lower part, to La Tejita Formation.

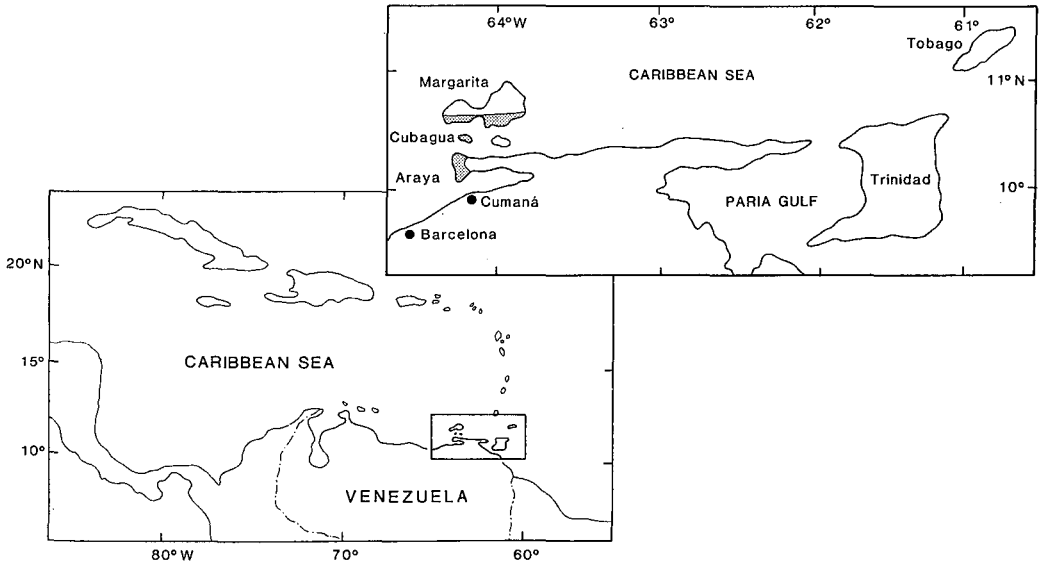

Fig. 1 — Localization (shaded area) of the marine Neogene and Quaternary deposits in Eastern Venezuela.

REGIONAL TECTONIC FRAMEWORK

The sedimentary covering of the marine Neogene and Quaternary of NE Venezuela rests upon a basament composed of metamorphic rocks of an age which varied between Triassic(?)-Jurassic-Early-Middle Cretaceous (Schubert, 1971) and pre-miocenic sedimentary rocks. Erlich and Barret (1990) interpret this area in terms of a sole metamorphic complex which was "lifted up" and transported to the east - to its present position - during the Middle-Late Eocene. This area constitutes one of the structural elements of northern Venezuela and it is limited to the south and west by two other such elements: the fault zone of El Pilar and the Cariaco basin respectively (Fig. 2).

LITHOSTRATIGRAPHY

Araya Peninsula

The sediments of the marine Neogene-Quaternary outcrop in the most western part of the peninsula (Fig.3) and this is, of the three localities studied, the one which presents the most complete and continuous sections. For the stratigraphic study the following hills were selected: Barrigón, El Macho, Guaranache, La Cantera, Pariche, Arapuy, La Cruz and Cangrejero, and the capes Punta Guachi, Punta Arenas and Punta La Caja. In the case of Cubagua Formation, the lower contact was not observed in any of the localities above mentioned.

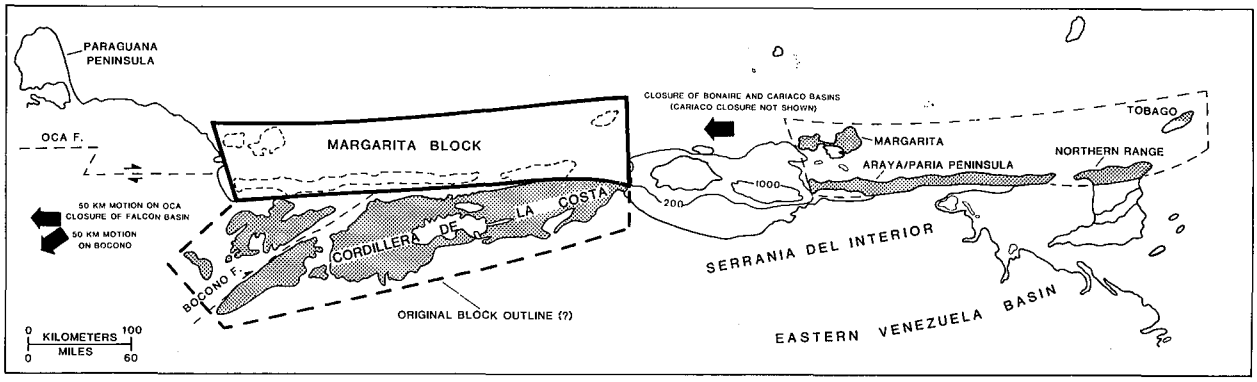

Fig. 2 — The Margarita Block restored to its Middle to late Eocene position (from Erlich & Barrett, 1990).

To the south-east of the town of Araya, on Barrigón hill, outcrops the most continuous and complete sections of the Neogene in the north-eastern region of Venezuela. It consist of an inferior interval of grey clays; 160 m thick, not calcareous and with abundant secondary gypsum; whose grain size increases towards the upper part of the interval with the development of clayish siltstones and sands, at times cemented with gypsum and of a thickness of 33 m. This lower clayish sequence has been assigned to the Cerro Verde Member. Overlying on the previous member is a calcareous development of 19 m composed of yellow coloured siltstones with an abundant content of molluscs, stratified limestones, with an abundant content of siliciclastic material and bioclastic fragments, beds of red algae and conglomerates of calcareous matrix at the top of the sequence. This upper calcareous interval has been assigned to the Cerro Negro Member and the lower sandy-silty interval is considered to be the transitional phase from one member to another. This transitional phenomenon is not so easily recognized in the remaining localities.

Laterally towards the East, at the Barrigón hill site, the Cubagua Formation thins out and presents an increase in both the content and grain size of siliciclastic material in the limestones.

The El Macho section presents a vertical development equal to that of Barrigón hill with reference to the inferior member, yet when we refer to the upper member this not the case. This member is principally composed of calcareous silty sandstone, of an ochre colour, with abundant bioturbation structures of the *Gyrolithes* sp. type and thin sandy limestones. Lateral equivalents of this sandy-silty interval are found outcropping in the northern part of the peninsula, at Punta Guachi and Amarillo hill sections.

To the south of Barrigón, in the hills of La Cantera, Cangrejero, La Cruz and Punta La Caja cape, only the upper part of the Cubagua Formation outcrops, and it is represented by bioturbated, calcareous sandy siltstones. There, the top is a hardened layer with an abundance of pectinid fauna, and it is followed by a layer of red algae and, finally, by a conglomerate of calcareous matrix.

The sections outcropping in the Pariche and Arapuy hills, to the NW of the town of Manicuare, present the same characteristics concerning the lower interval. With respect to the upper one, the presence of sandstones at the base and the intercalations of grey claystones and limestones towards the top is remarkable. It is also important to note the presence of two monospecific layers: one of *Anadara* sp. and other of *Crassostrea virginica* Gmelin, this last one being 1 m thick.

A sections of calcareous sediments denominated "terrazas" by diverse authors (Vignali, 1965; Bermúdez, 1966 and Macsotay and Moore, 1974) is found discordant upon sediments of the Cubagua Formation and metamorphic rocks. This calcareous sediments. which ranges from sandy

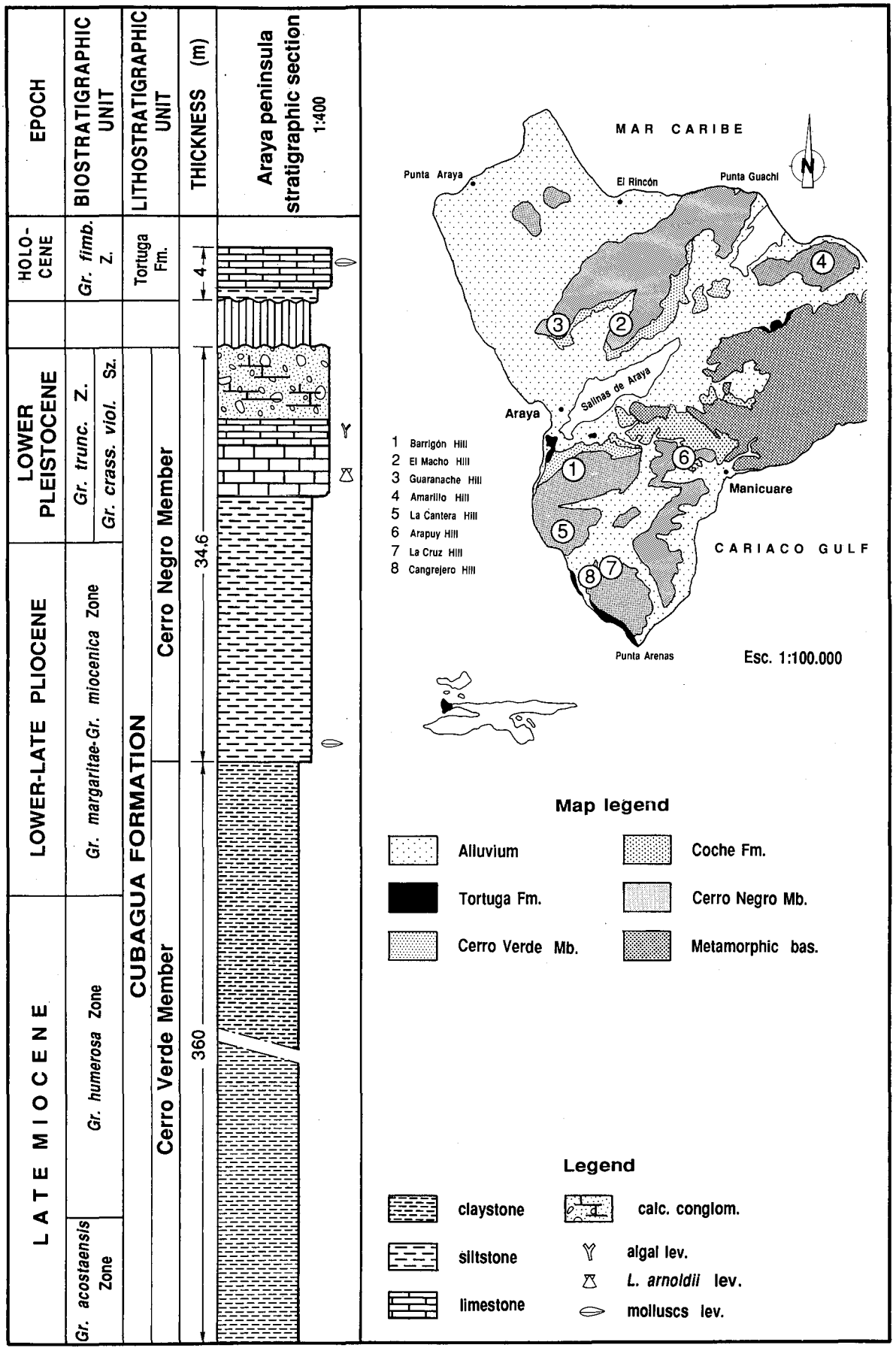

Fig. 3 — Generalized stratigraphic section and geological map of the Neogene-Quaternary outcropsfrom Araya peninsula.

siltstones to limestones, outcrop to the south of the Salina Madre and Punta La Caja and Punta Arenas capes, and contain abundant mollusc and barnacles. These sediments are assigned to the Tortuga Formation.

Cubagua island

Cubagua island is superficially covered by neogene and quaternary sediments belonging, respectively, to the Cubagua Formation (Cerro Negro Member) and to the Tortuga Formation, the second one to a lesser degree. In their biostratigraphic study of the Cubagua wells 1 and 2, Bermúdez and Bolli (1969) identified the two members of the Cubagua Formation and although they did not present a lithological description of these, they compared them with the exposed beds to the south of the island of Margarita and with those outcropping on the extreme western part of Araya peninsula. On the mentioned island the sections studied outcrop at Cañón de las Calderas and the south of Charagato inlet (Fig.4).

Such sections, which have similar vertical development, begin with a calcareous sandy siltstones layer of a yellowish ochre colour with abundant molluscs fauna, followed by an intercalation of grey, non calcareous, gypsiferous claystones, with abundant equinoderms spines, and thin limestones with mollusc and coral remains, which becomes thicker towards the East, reaching a thickness of 8 m. These sections have an identical development that the sections in Arapuy and Pariche hills in Araya peninsula.

All along the perimeter of the island, a sequence of calcareous siltstones and limestones outcrop in a discontinuos way. Towards the top of this outcropping there is abundance of barnacles, corals and the gastropod *Strombus gigas* (Linné). These calcareous sediments, discordant upon the Cubagua Formation, have been assigned to the Tortuga Formation.

Margarita island

In this area, the Cubagua Formation has not been adequately described. Bermúdez (1966) used the name "La Tejita beds" to refer to an inferior interval of the aforementioned formation. These sediments do not bear any relation to those described for the lower member of the Cubagua Formation. This unit outcrops in the environs of the airport (Fig.5) and, in its lower part, consists of an alternance of grey sandy siltstones with an abundance of bioturbation structures of the *Thallasinoides* sp. type, ochre coloured calcareous sandstones with abundant gastropod fauna (*Turritella* sp.) and layers of *Crassostrea virginica* Gmelin. Toward the top of this sections an intercalation of non calcareous grey claystones, gypsiferous and limestones develops. This sequence comes into contact, in a discordant and abrupt way, with rocks of the Eocene and of the Cerro Verde Member, in its inferior and superior parts respectively.

On Margarita island, the Cubagua Formation outcrops in a dispersed way and its lower part may be identified in the airport vecinities and El Manglillo area (Fig.5) and it consists of a thin sequence of dark grey coloured claystones with abundant foraminiferal fauna. Its lower contact is discordant upon rocks of La Tejita Formation and of the Eocene. The upper contact was not observed.

The upper part (Cerro Negro Member) outcrops in the followig localities: Las Hernández and Punta Carnero and Punta Arenas capes. This member is composed of clastic sediments which vary from yellowish ochre coloured siltstones, sandstones and conglomerates, to limestones. All of them contain molluscan fauna, and in the former locality a well preserved foraminiferal assemblage has been recolted. It must be noted that in the locality of Punta Arenas, the vertical development of the section is very similar to the upper part of the sections to the south of Barrigón hill in the Araya area: a layer rich in *L. arnoldi* (Aguerrevere) followed by another of red algae.

At the Juan Griego locality and all along the southern coast of the island and Macanao peninsula, a section of calcareous sediments outcrops, which vary from conglomerates at the base, to sandstones in the middle part and to limestones at the top. These sediments present cross stratification and are found discordant both upon metamorphic rocks and neogene materials. They have been assigned to the Tortuga Formation.

BIOSTRATIGRAPHY

The zonal schemes for the Tertiary of low latitudes were originally developed in the area of Trinidad and Venezuela (Cushman & Stainforth,1945; Cushman & Renz, 1947; Stainforth, 1948, Bolli, 1957 and Bolli & Bermúdez, 1965). Based on data from the DSDP, in the Caribbean area, Bolli and Premoli-Silva (1973) proposed a more detailed zonation which has been mantained, with few modifications, up to the present by Bolli and Saunders (1985) and it is the zonal scheme used in the present study.

The Neogene-Quaternary sequences studied show a rich assemblage of planktonic foraminifera due to which five biostratigraphic zones (Fig. 6) and three subzones has been recognised in the Cubagua Formation:

**Gr. acostaensis* Zone Bolli & Bermúdez (1965)
**Gr. humerosa* Zone Bolli & Bermúdez (1965)
**Gr. margaritae* Zone Bolli & Bermúdez (1965)
* *Gr. margaritae margaritae* subzone Bolli & Bermúdez (1965)
* *Gr. margaritae evoluta* subzone Cita (1970)
**Gr. miocenica* Bolli (1970)
**Gr. trunc. truncatulinoides* Zone Bolli & Bermúdez (1965)
* *Gr. crassaformis viola* subzone Bolli & Premoli-Silva (1973).

For the Tortuga Formation the *Gr. truncatulinoides truncatulinoides* Zone was defined, where the presence of *Gr.ungulata* restricts the unit to the Holocene (Bolli & Saunders, *op. cit.*).

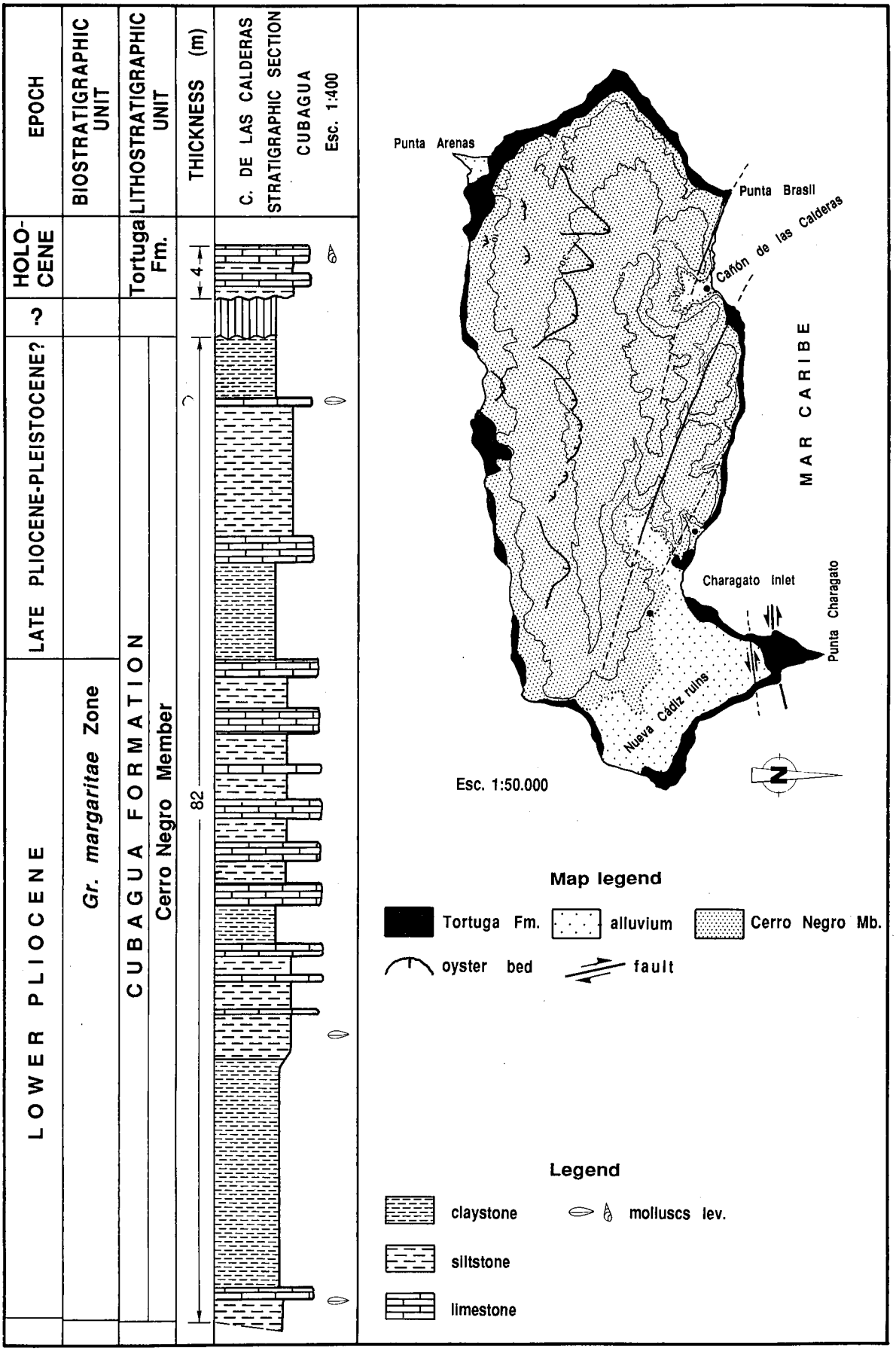

Fig. 4 — Stratigraphic section of Cañon de las Calderas and geological map of Neogene-Quaternary outcrops of Cubagua island.

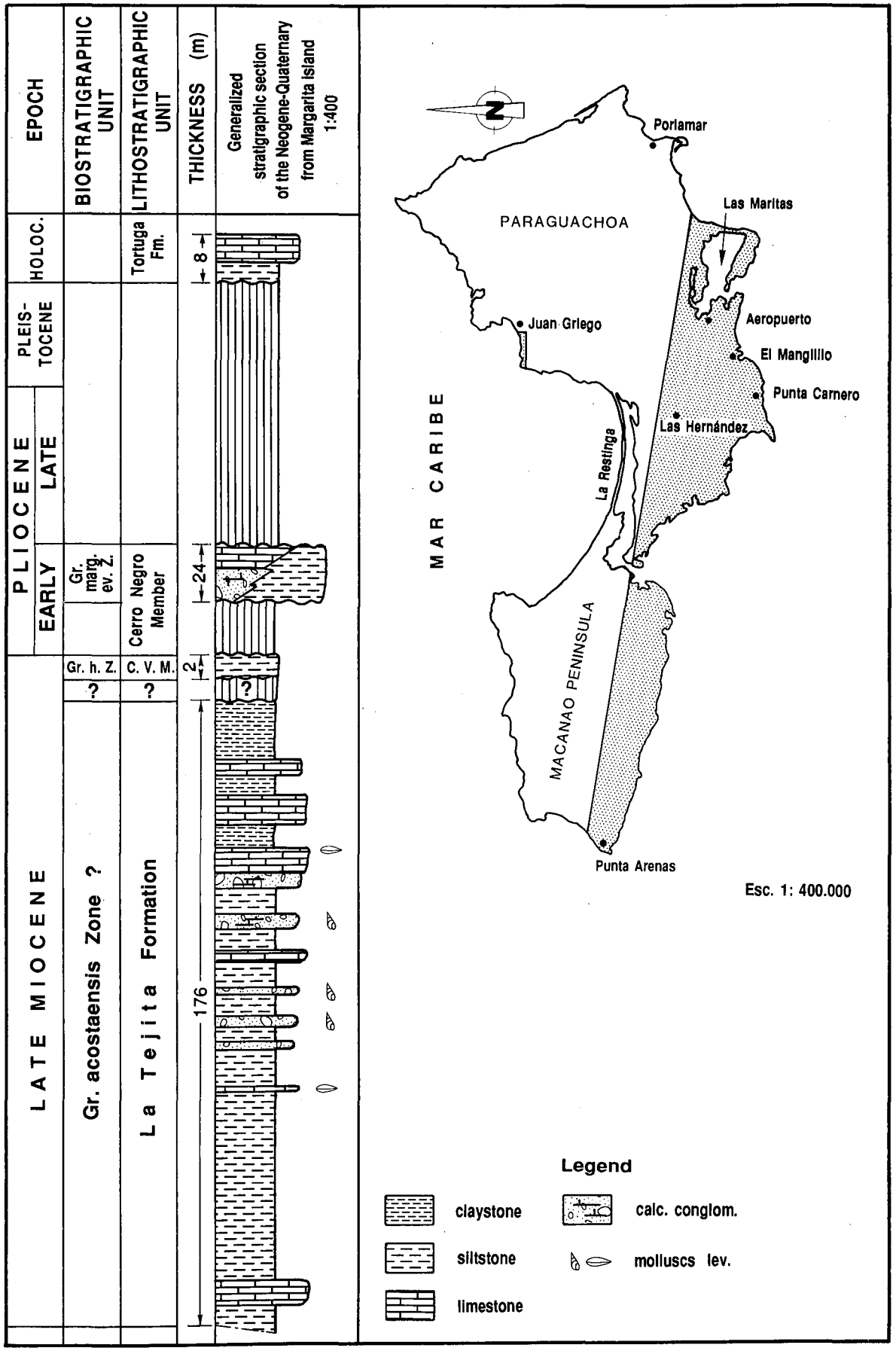

Fig. 5 — Generalized stratigraphic section and outcroping area (shaded) of Neogene-Quaternary sediments of Margarita island.

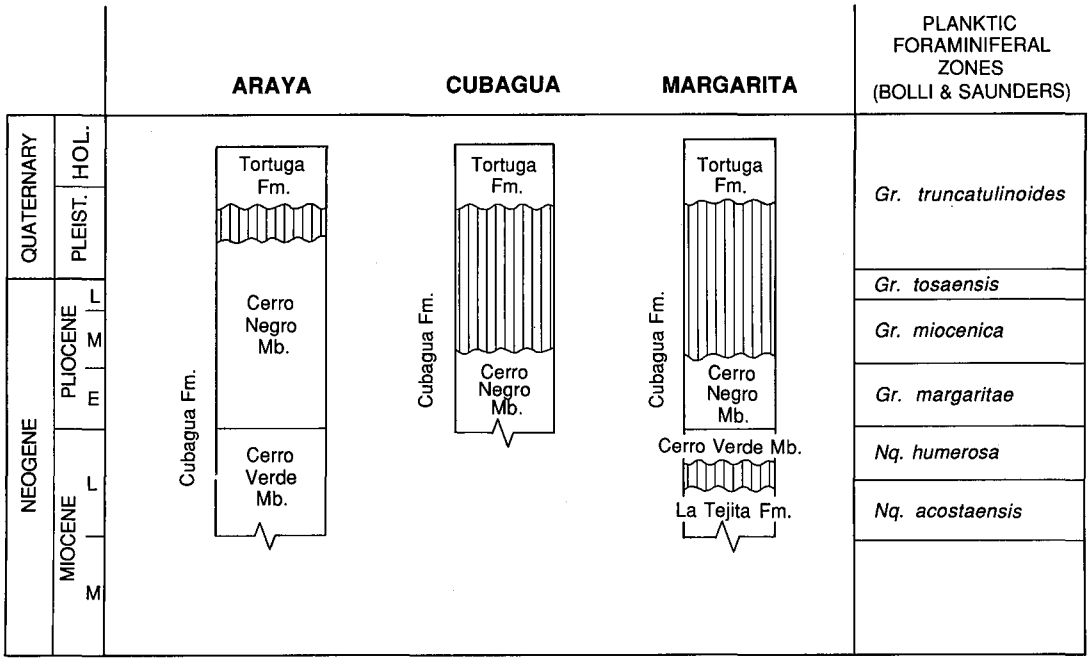

Fig. 6 — Neogene marine units in Eastern Venezuela.

Through this biostratigraphic analysis, the age of the Cubagua Formation ranges from the lower part of the Late Miocene to the lower part of the Early Pleistocene. The age of the Tortuga Formation in considered to be Late Pleistocene-Holocene.

The age of La Tejita Formation is Late Miocene, based in molluscan fauna (*Turritella gatunensis* Conrad) (Hernández & Ibarra, 1989).

The analysis of the calcareous nannoplancton from Araya and Margarita shows an abundant and diversified assemblage which goes from the *Discoaster calcaris* Zone (NN10) to the limit between the *Discoster surculus* and *Discoaster pentaradiatus* zones (NN16-NN17).

PALEOENVIRONMENTAL EVOLUTION

The present relationship between the distribution of benthic foraminifera and the ecological parameters such as salinity, temperature and type of substratum are not the clearest. This had led the majority of investigators to use the water depth parameter as the method for expressing the distribution of the different forms of benthic foraminifera.

In the specific case of the Neogene-Quaternary of NE Venezuela, 106 species has been recognised, on the whole belonging to Cubagua Formation. From an analysis of the samples three faunal grouping may be distinguished. The first of these, characteristic of Cerro Verde Member, is typical of medium-superior bathial depths (Morkhoven, *et*

Bathyal species (Morkhoven, *et al.* 1986; Murray, 1991)	Neritic species (Murray, 1991)	Eurybathic species (Morkhoven *et al.* 1986; Murray, 1991)
Bulimina aculeata	*Hanzawaia concentrica*	*Lenticulina americana*
Planulina ariminensis	*Cibicides floridanus*	*Lenticulina calcar*
Sigmoilopsis schlumbergeri	*Fursenkoina pontoni*	*Pseudononion atlanticum*
Bulimina mexicana	*Ammonia becarii*	*Brizalina sub. mexicana*
Sphaeroidina bulloides	*Quinqueloculina* sp.	*Bulimina marginata*
Cibicides compresus	*Amphistegina lessonii*	*Bolivina acerosa*
Siphonina pozonensis	*Buliminella elegantissima*	*Lenticulina iota*
Cyclammina sp.	*Textulariella barretti*	*Uvigerina per. parvula*
Martinotiella communis	*Textularia* cf. *panamensis*	*Uvigerina peregrina*
Bolivina imporcata	*Elphidium poeyanum*	

Table I - Selection of benthic foraminifera markers of depth on Cubagua and Tortuga Formations .

al., 1986); the second, characteristic of Cerro Negro Member, represents a clear nerithic association (Murray, 1991); and the third one, common to both members, is made up of a numerous grouping of eurybathic species.

A selection of the aforementioned benthic foraminifera may be observed in Table I.

If to these bathimetric parameters, obtained from the benthic foraminiferal fauna, we add the biostratigraphical positions of the associated planktonic species, the sedimentological data and that obtained from the macrofauna of molluscs, we obtain a clear panorama of the paleoenvironmental evolution of the sequences studied:

During the Late Miocene (*Gr. acostaensis - Gr. humerosa* zones) the sedimentation of the Cerro Verde Member took place in bathial depths. Towards the end of this epoch and the begining of the Pliocene it experienced a shallowing of the environments, which provoked the dissapearance of the fauna susceptible to changes in depth, another less susceptible continues and new taxa appear. During the Pliocene and Early Pleistocene, there is a development of, apart from foraminifera, an abundant biota of molluscs, ostracodes, cirripedes, bryozoans and equinoderms, associated with the growth of red algae reefs on a platformal domain (Araya and Margarita) and of a restricted bay (northern and south-east part of Araya and Cubagua island). These conditions become quite stable during the Early Pleistocene, in which monospecific ensembles of ostreids and pectinids are frequent. From this epoch on, the conditions become more shallow leading to the complete emergence and subaerial exposure to the erosion of a great part of the neogene-quaternary secuences during the rest of the Pleistocene. At the end of this epoch and at the beginning of the Holocene, water invades the eroded zones and produces, apart from a reworking of the basement, an extensive colonization by endolithic organisms (mainly molluscs and sponges) of the upper part of the Cerro Negro Member. As consequence, the layers of *L. arnoldi* (Aguerrevere), present abundant traces of bioerosion (*Gastrochaenolites, Entobia, Caulosptrepsis*, etc.), which permits the deduction of an important event after the lithification.

CONCLUSIONS

The marine Neogene-Quaternary of NE Venezuela is represented principally by the Cubagua , La Tejita (on Margarita island) and Tortuga formations.

On the basis of an analysis of planktonic foraminifera, five biostratigraphic zones, in the Cubagua Formation, were determined. The zones being *Gr. acostaensis*; *Gr. humerosa*; *Gr. margaritae*, subzones of *Gr. margaritae margaritae* and *Gr. margaritae evoluta*; *Gr. miocenica* and *Gr. truncatulinoides truncatulinoides*, *Gr. crassaformis viola* subzone, which assigns to the aforementioned formation an age ranging from the lower part of the Late Miocene to the lower part of the Early Pleistocene.

Gr. ungulata was identified in samples of Tortuga Formation which restricts this unit to the Holocene.

The age of La Tejita Formation is Late Miocene, based in molluscan fauna (*Turritella gatunensis* Conrad).

In the case of the sediments of the Cubagua Formation, the calcareous nannoflora identified allowed the dating of these to an age ranging from the *Discoaster calcaris* Zone (NN10) to the limit of *Discoaster surculus* and *Discoaster pentaradiatus* zones (NN16-NN17).

On the basis of the analysis of the benthic foraminifera it was determined that the paleobathimetric evolution of the sedimentary environments of the Cubagua Formations goes from the middle-upper bathial depth (Cerro Verde Member), to nerithic depth (Cerro Negro Member), establishing thus three associations for the area of study: bathial, nerithic and euribathic.

Together with these data the information obtained from the sedimentology, the malacological content and the ichnology allows us to drawn an almost complete panorama of the paleoenvironmental evolution of the sequences.

During the Late Miocene (*Gr. acostaensis - Gr. humerosa* zones) the sedimentation of the Cerro Verde Member took place in bathial depths. Towards the end of this epoch and the begining of the Pliocene it experienced a shallowing of the environments, which provoked variations in the faunal content.

During the Pliocene and Early Pleistocene there was a development of shallow fauna on a shelf an a restricted bay domains. These conditions become quite stable during the Early Pleistocene.

At the end of this epoch and at the beginning of the Holocene, water invades the eroded zones and produces, apart from a reworking of the basement, an extensive colonization by endolithic organisms (mainly molluscs and sponges) of the upper part of the Cerro Negro Member.

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