Foraminiferal Assemblages and Palaeoenvironmental Inferences of the Lowermost Colón Formation (Late Campanian): Catatumbo Basin, Colombia*

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Abstract

The La Luna Formation is the main source rock in the Cretaceous successions of Catatumbo basin (northern Colombia) and the Maracaibo area. However, few paleontological studies have focused on the contact with contiguous units such as the Colon Formation. To clarify the possible paleoenvironments of this unit, the foraminiferal content of several wells in the basin were examined for the lowermost Colon Formation and its contact with La Luna Formation.

For the lowermost Colon Formation, the foraminiferal assemblages are highly diverse, mainly composed by epifaunal benthic and non-keeled planktonic foraminiferal suggesting well to moderately oxygenated conditions on an inner shelf. Taxa such as *Globotruncana* spp., *Rugoglobigerina* spp., *Siphogenerinoides* spp., *Anomalina* spp., *Pullenia cretacea*, *Praebulimina petroleana* and *Haplophragmoides excavata* are characteristic of this section of Colon Formation. In contrast, the upper part of La Luna Formation contains less diversified foraminiferal assemblages with a high proportion of infaunal foraminiferal and biserial plancktonics, suggesting an oxygen-depleted open marine environment, probably related to higher surface productivity. Taxa such as *Bolivinoides* spp. (*Bolivina explicata*), *Anomalina redmondi*, *Praebulimina* spp., and *Heterohelix* spp. are found in this unit.

This contrast in foraminiferal assemblages and suggested paleoenvironments agrees with previous studies that propose a regional discordance between the Colon and La Luna Formations in the Catatumbo basin. Furthermore, this contrast in the foraminiferal assemblages has been observed in coeval successions in the Middle Magdalena Basin and the Perijá Range.

Selected References

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Martinez, J.I., 1989, Foraminiferal biostratigraphy and paleoenvironments of the Maastrichtian Colon mudstones of Northern South America: Micropaleontology, v. 35/2, p. 97-113.

Parra, M., L. Moscardelli, and M.A. Lorente, 2003, Late Cretaceous Anoxia and Lateral Microfacies Changes in the Tres Esquinas Member, La Luna Formation, Western Venezuela: Palaios, v. 18/4-5, p. 321-333.

FORAMINIFERAL ASSEMBLAGES AND PALEOENVIRONMENTAL INFERENCES OF THE LOWERMOST COLÓN FORMATION (LATE CAMPANIAN): CATATUMBO BASIN, COLOMBIA

TRABAJAMOS PARA PRODUCIR BARRILES LIMPIOS

German David Patarroyo; Gustavo Torres; Claudia Cárdenas; Daniel Rincon

Grupo de Bioestratigrafía ECOPETROL-ICP
CGA-LTDA

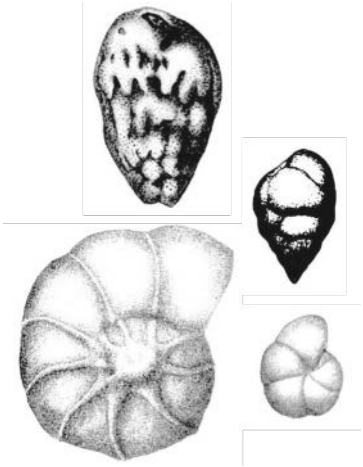
ecopetrol

STRUCTURE

The microfossils of the lowermost Colón Formation

- What we knew
- What we have found
- What must know

WHAT WE KNEW ABOUT THE MICROFOSSILS OF THE LOWERMOST COLÓN FORMATION…



PREVIOUS WORKS

CONTRIBUTIONS FROM THE CUSHMAN LABORATORY FOR FORAMINIFERAL RESEARCH

232. UPPER CRETACEOUS FORAMINIFERA FROM SANTANDER DEL NORTE, COLOMBIA, S. A.

By JOSEPH A. CUSHMAN and HOLLIS D. HEDBERG

The medial Cretaceous Cogollo and La Luna limestone formations of northwestern Venezuela and northeastern Colombia are overlain by a predominantly shale section of late Cretaceous age. The lower portion of this section consists of about 1,500 feet of gray highly foraminiferal shale (Colon shale). The upper portion consists of about 1,200 feet of greenish-gray silty or sandy sparingly foraminiferal shale (Mito Juan formation). A facies development of thin marine limestones and ironstones in the upper part of the Mito Juan formation is known as the Rio de Oro formation and has yielded species of *Sphenodiscus* and *Coahuilites* indicative of Maestrichtian age. The Mito Juan formation is overlain by a series of alternating shales, sandstones, and coal beds of latest Cretaceous or early Tertiary age included in the "Orocue" or "Third Coal" formation. (A synopsis of formations in this region is given by Hedberg, H. D. and Sass, L. C., Boletin de Geologia y Mineria [Caracas], Vol. 1, Nos. 2, 3, 4, pp. 73-115, 1937.)

The Upper Cretaceous shales are particularly well exposed in the Barco Concession of the Department of Santander del Norte, Colombia, north of the city of Cucuta and between the Rio Sardinata and the Colombia-Venezuela boundary (see sketch map). Collections from numerous sections in this area have shown that these sediments may be zoned readily on the basis of foraminifera as follows (bottom to top):

Pullenia cretaceá zone

Lower 1,000 feet of Colon shale. Distinctive forms:

Pullenia cretacea Cushman

MINISTERIO DE MINAS E HIDROCARBUROS
DIRECCION DE GEOLOGIA
Vol. II, Nº 5, Págs. 231-310; 18 Figs., 11 Láms. ABRIL, MAYO, JUNIO 1952

ESTUDIO DE LA MICROFAUNA DE LA SECCION-TIPO DEL MIEMBRO SOCUY DE LA FORMACION COLON DISTRITO MARA, ESTADO ZULIA (*)

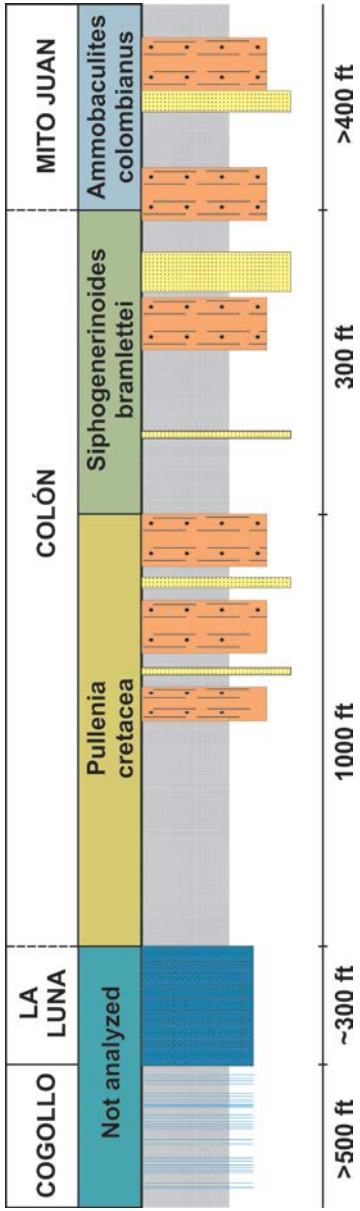
POR

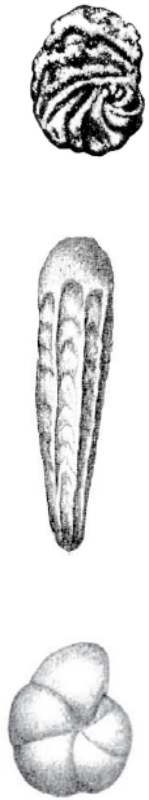
J. M. SELLIER DE CIVRIEUX

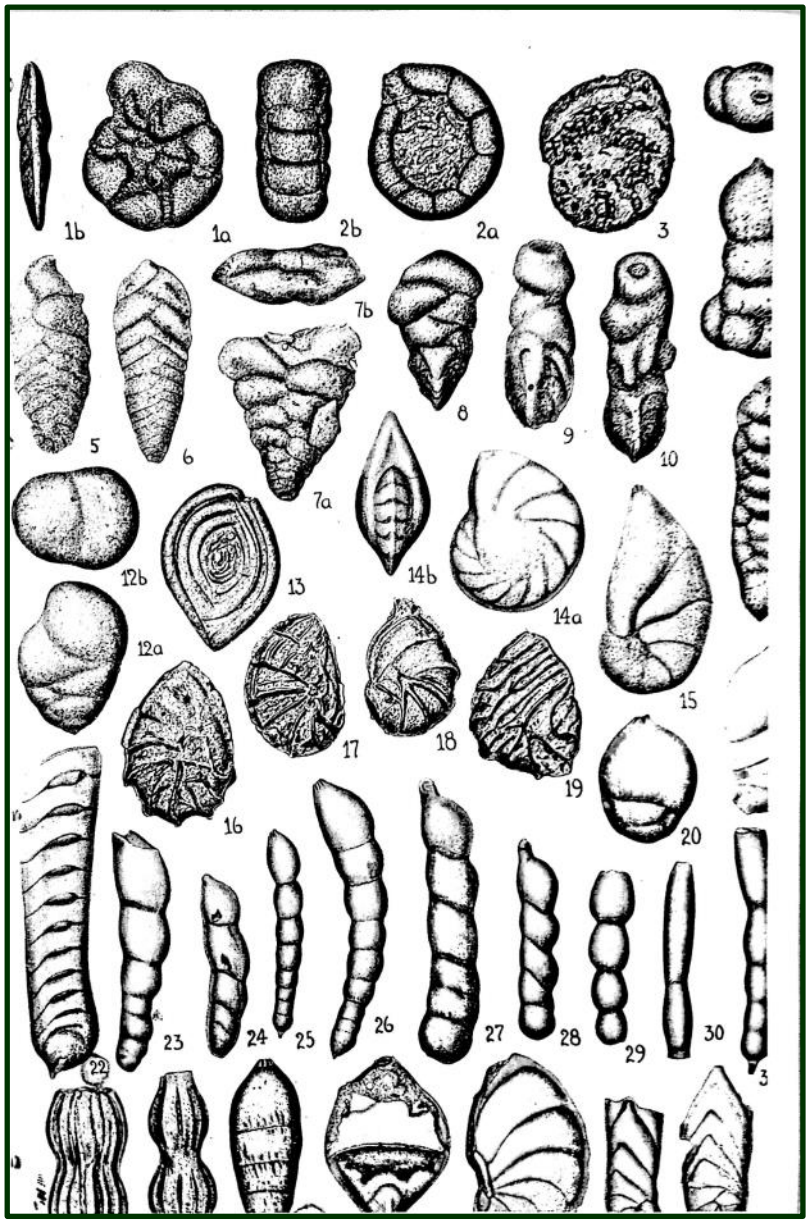
INDICE

ILUSTRACIONES

(*) Publicado con la autorización de la Creole Petroleum Corporation.

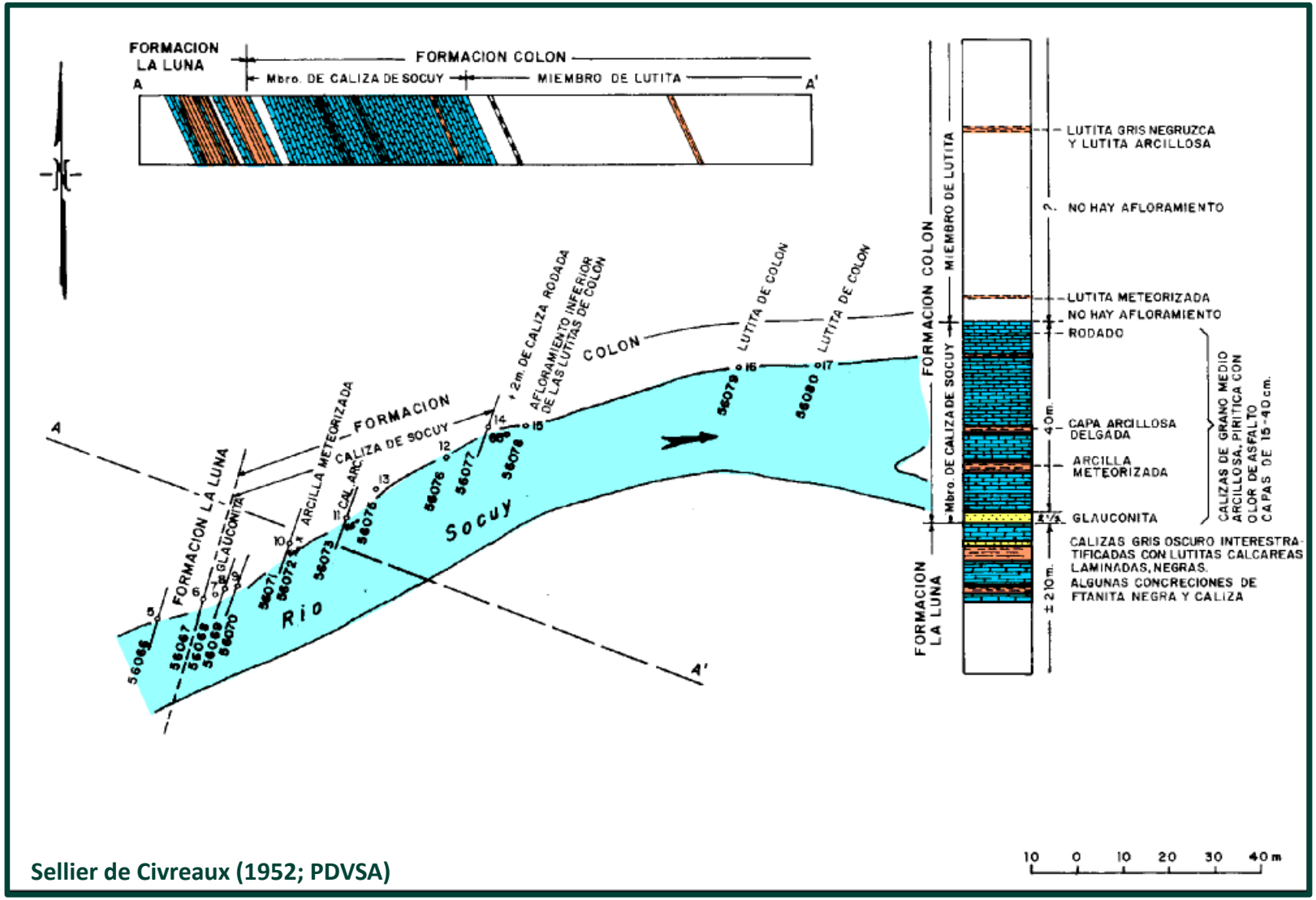






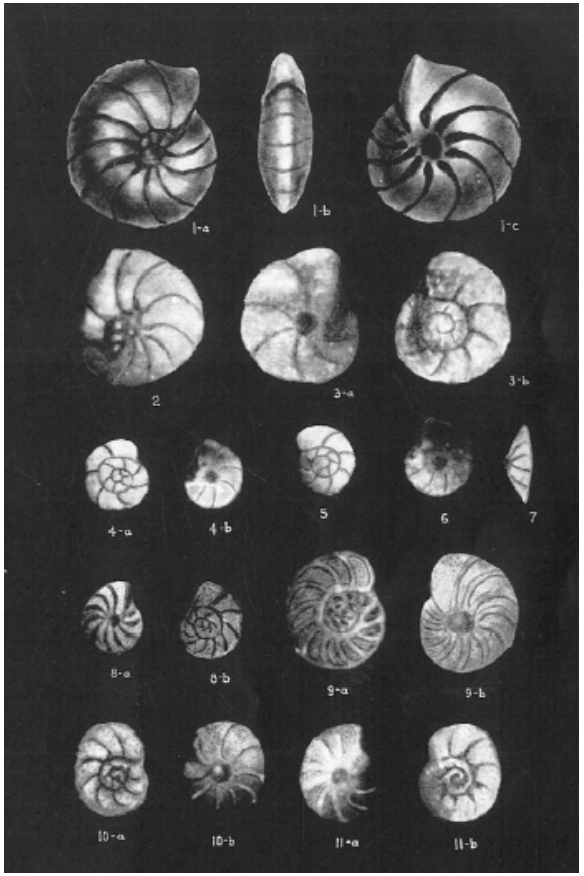
Cushman & Hedberg (1941)

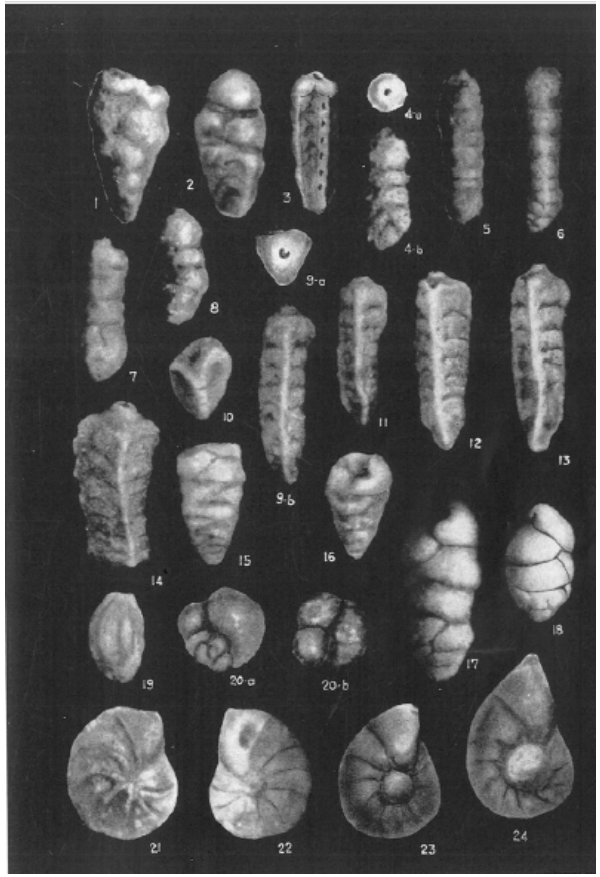
TYPE SECTION OF THE SOCUY MEMBER (COLÓN FORMATION)

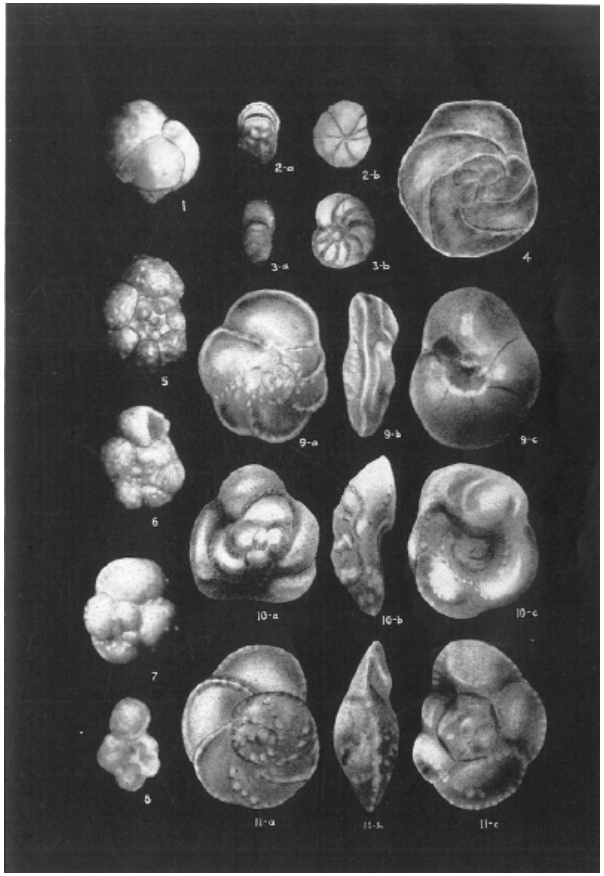


Sellier de Civreaux (1952; PDVSA)

FORAMINIFERA OF THE SOCUY MEMBER (COLÓN FORMATION)







Sellier de Civreaux (1952)

PREVIOUS WORKS

Foraminiferal biostratigraphy and paleoenvironments of the Maastrichtian Colon mudstones of northern South America

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ABSTRACT: The *Globotruncana aegyptiaca*, *Gansserina gansseri* and *Abathomphalus mayaroensis* planktonic foraminiferal zones were found in the Colon mudstones of the Colon Formation (Molino River section, northern Colombia, S.A.). A Maastrichtian age is assigned to this unit, rather than the Campanian(?)-Maastrichtian age previously proposed. The *Siphogenerinoides cretacea* benthonic foraminiferal zone reaches the *Gansserina gansseri* zone and hence is Maastrichtian rather than Santonian-Campanian, at least for the Ranchería province. The upper boundary of this zone could be either diachronous or "isochronous". The relative sea level curve for the Colon Formation shows two "deep" water intervals (Socuy Member and middle Colon mudstones), separated by an "intermediate" depth interval (lower Colon mudstones). The upper part of the sequence shows a marked regression. Such a pattern is comparable with that of the Arabian Peninsula and NW Europe-W Paris basin with differences due to local tectonics and sedimentation rate. Anomalous samples of the middle part of the Colon mudstones and similar samples described previously at the DSDP site 146 are characterized by a sudden drop of heterohelicids compared to "unkeeled" and "keeled" planktonic foraminifera, and by a sudden increase of agglutinated foraminifera and buliminids compared to other benthonic groups. Such samples are possibly the result of a subtle decrease in paleoxygenation within a dysaerobic zone.

INTRODUCTION

The intensive study of planktonic foraminifera during the last four decades has proved them to be more useful than benthonics for interregional and intercontinental correlation over the Cretaceous period. A number of datum points have been proposed and a series of zonations for different latitudes have been erected (e.g. Bolli 1966; Pessagno 1967; Sigal 1977; Van Hinte 1976; Wonders 1980; Caron 1985; *cited in* Caron 1985). However, some debate still remains as to whether the appearance or the extinction of a particular species is a more reliable datum.

In the same way, the assumption of "isochronicity" given by calibration against localized radiometric datings has been questioned (e.g. Scott 1985). It seems that the "less diachronous datums" are those obtained from the comparison of detailed biostratigraphic data within the same bioprovince rather than with an original reference section from a different bioprovince (cf. Scott 1985).

Upper Cretaceous Zonations in Northern South America

The Upper Cretaceous foraminiferal faunas of northern South America are part of the southern termination of the Gulf Coast bioprovince (Gandolfi 1955; Petters 1955; Douglas 1972; text-fig. 4). At the same time they are near the borders of the Peruvian-Pacific bioprovince (Bertels 1979). In this region Tethyan correlations and reference to well known Gulf Coast and Trinidad sections are quite admissible. However, little has been done in this respect (Gandolfi 1955) and the zonations are widely based on benthonic foraminifera (Cushman and Hedberg 1941; Petters 1955). Unfortunately, these zonations have given unsatisfactory results possibly due to their facies dependence and hence are of limited use as chronological markers (De Porta 1966). Although the work of Gandolfi (1955) was pioneering at that time, it was based on crude comparisons with zonations of the Gulf Coast of North America, on planktonic zones, and on Petters's zonation.

Cretaceous Foraminifera and Paleobathymetry

Several techniques are used to construct the paleobathymetry of Cretaceous sequences. Such attempts can be classified in two types: those that attempt to infer absolute depths (e.g. Olsson and Nyong 1984), and those that infer relative depths (e.g. Seiglie and Baker 1984).

Absolute depths have been questioned on the basis of inconsistencies with other paleobathymetry methods. Such is the case with the mid-Cretaceous Greenhorn limestone of the western interior of North America, where foraminiferal faunas and paleoslope estimates suggest 500–1000 meters, while stratigraphical, paleoecological and tectonic considerations suggest 30–90 meters (Eicher 1969; Hattin 1975; *cited in* Jenkyns 1986). There are indications that benthonic foraminifera migrate in depth through time in response to changes in the properties of water masses (e.g. Douglas 1979; Zobel 1984). Furthermore, there are cases of misuse of Recent physiographic terms (i.e. slope and rise) as metaphors of absolute depth without any proof of their existence. For these reasons, only relative depth estimations will be attempted here.

Paleobathymetry of the Upper Cretaceous of northern South America

Some general studies on the Upper Cretaceous sequence of northern South America suggest that the presumed Santonian interval was a time of maximum transgression and standstill, followed by a single regressive cycle during the Campanian-Maastrichtian (i.e. Ghosh 1984). Conversely, it has also been suggested that the Campanian-Maastrichtian Colon Formation was the product of sedimentation at absolute depths of less than 70 meters for the Socuy Member and between 1500 and 2000 meters for the lower part of the upper

Late Cretaceous Anoxia and Lateral Microfacies Changes in the Tres Esquinas Member, La Luna Formation, Western Venezuela

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PALAIOS, 2003, V. 18, p. 321–333

The Tres Esquinas Member of the La Luna Formation is a glauconite-rich phosphorite unit associated with changes that took place in depositional environments in the Maracaibo Basin at the end of the Late Cretaceous. The unit marks the end of La Luna Formation sedimentary cycle. This paper presents results of petrographic studies of samples from two sections, one outcrop (Río Guaruries), and one well core (Perijá), and from seismic profiles across the Perijá and Colón areas in the Maracaibo Basin.

The Tres Esquinas Member is three meters thick in both locations. In the Río Guaruries outcrop, it contains an abundant foraminiferal fauna in addition to common allochemical material. Perijá core samples contain voluminous carbonate matrix, scarce allochemical materials, rare foraminifera, and poor definition of mineral facies, which may reflect higher-energy conditions on the sea floor.

The deposition of the Tres Esquinas Member resulted from altered sea-floor topography during an episode of intense tectonic activity in the eastern part of the Maracaibo Basin. The modified shelf configuration ended anoxic conditions on the sea floor and led to increased erosion characteristic of the Tres Esquinas Member.

INTRODUCTION

The Tres Esquinas Member of the La Luna Formation is a glauconite-rich phosphorite unit that represents a profoundly different depositional environment in the Maracaibo Basin from the underlying units of La Luna Formation (Gosh, 1984; de Romero, 1991; de Romero and Alvarez, 1995; Erlich et al., 1997). This investigation concerns the petrography and paleontology of the unit in two localities (Fig. 1) and their significance in terms of depositional environment.

Tomalin (1938) first described this unit as a distinctive horizon at the top of La Luna Formation in Mérida State. Stainforth (1962) formally described the unit as green layers of sandy, calcareous, fossiliferous glauconite. Equivalent horizons have been identified in other Andean states and in the Perijá foothills (Renz, 1959; Ford and Houbolt, 1963; Carmona, 1971; Van Hinte, 1976; Gosh, 1984) (Fig. 2). This phosphatic unit has been mined commercially and is a key marker for petroleum exploration in the Maracaibo Basin. Although numerous studies have been carried out in relation to the origin and paleoenvironment of the Tres Esquinas Member, the unit is not yet entirely understood.

GEOLOGICAL SETTING

Stratigraphic Framework

The Tres Esquinas Member is the uppermost member of La Luna Formation (Galea, 1989) (Fig. 2), the main petro-

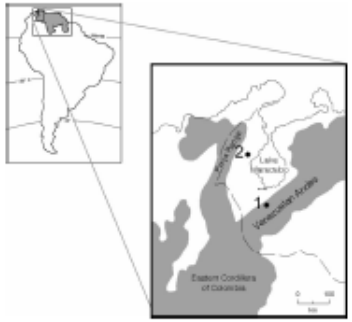

FIGURE 1—Location of the study area showing outcrop section (1), well (2), and seismic profiles (dotted lines).

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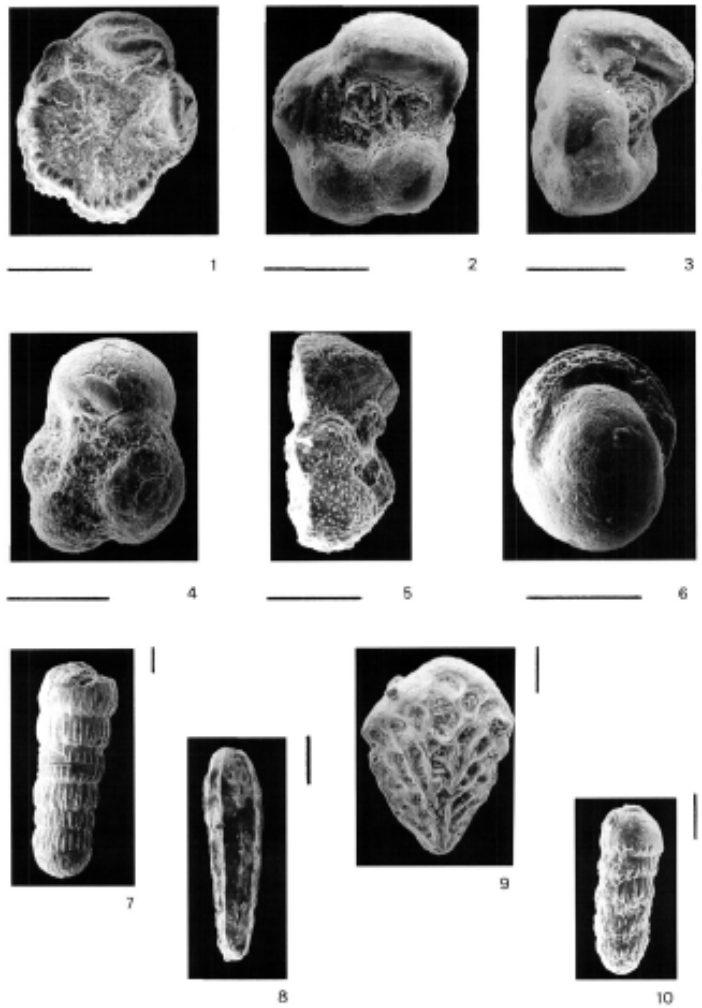
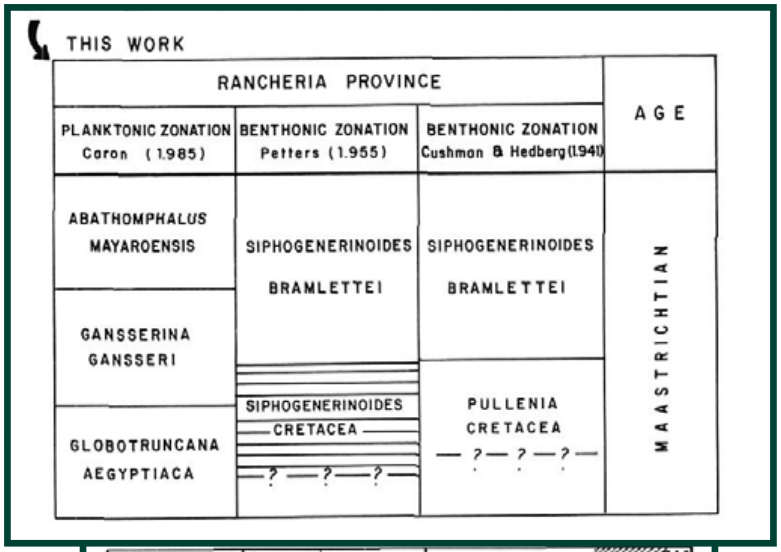
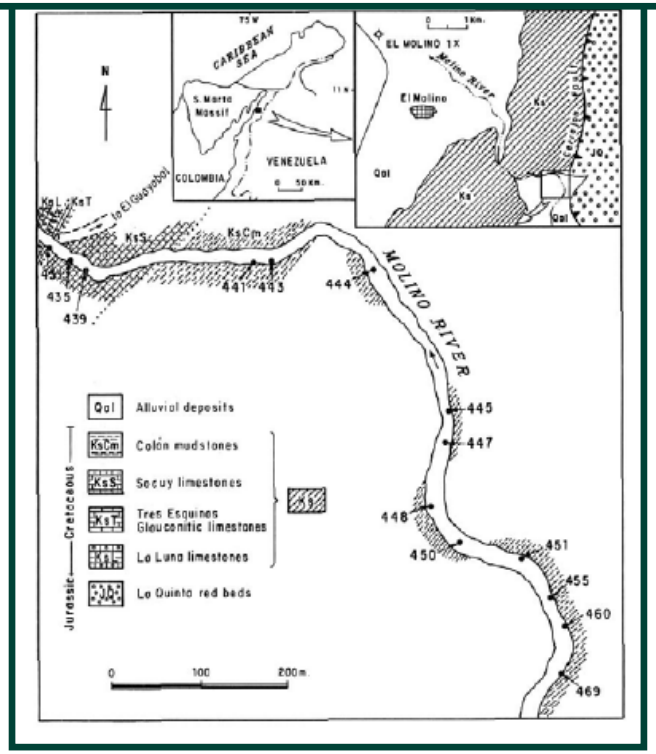
FORAMINIFERA OF THE MOLINO FORMATION (~COLÓN FORMATION)

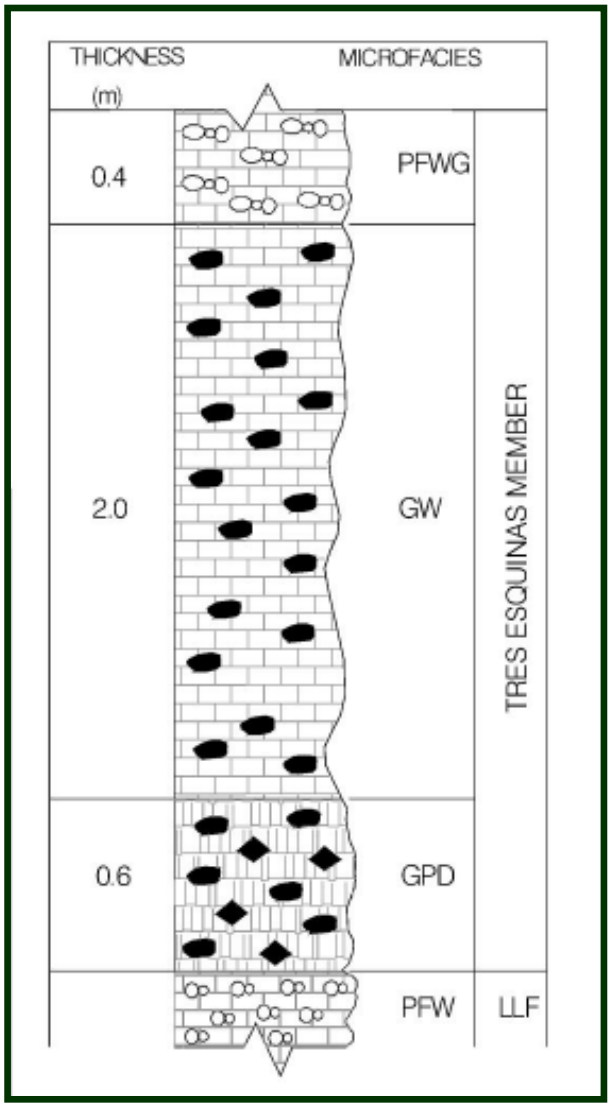


Martínez (1989)

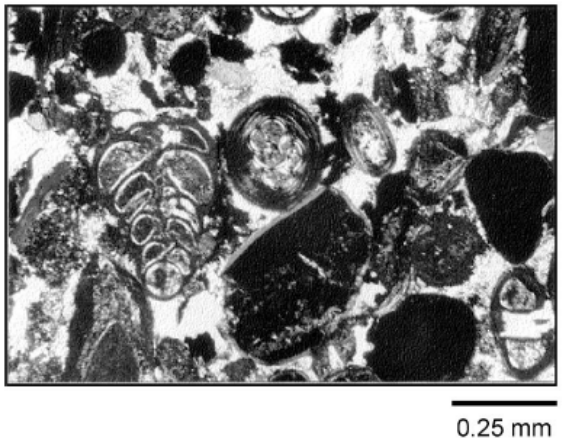


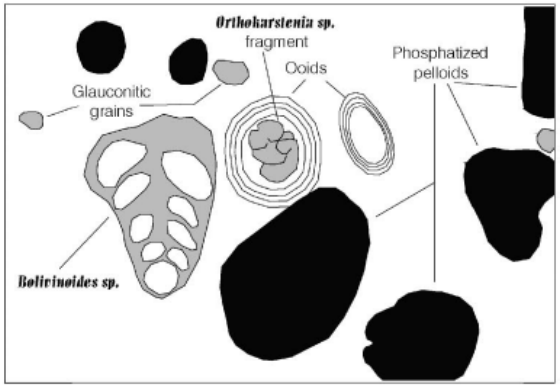


FORAMINIFERA OF THE TRES ESQUINAS MEMBER (PERIJÁ RANGE)



Parra *et al*. (2003)



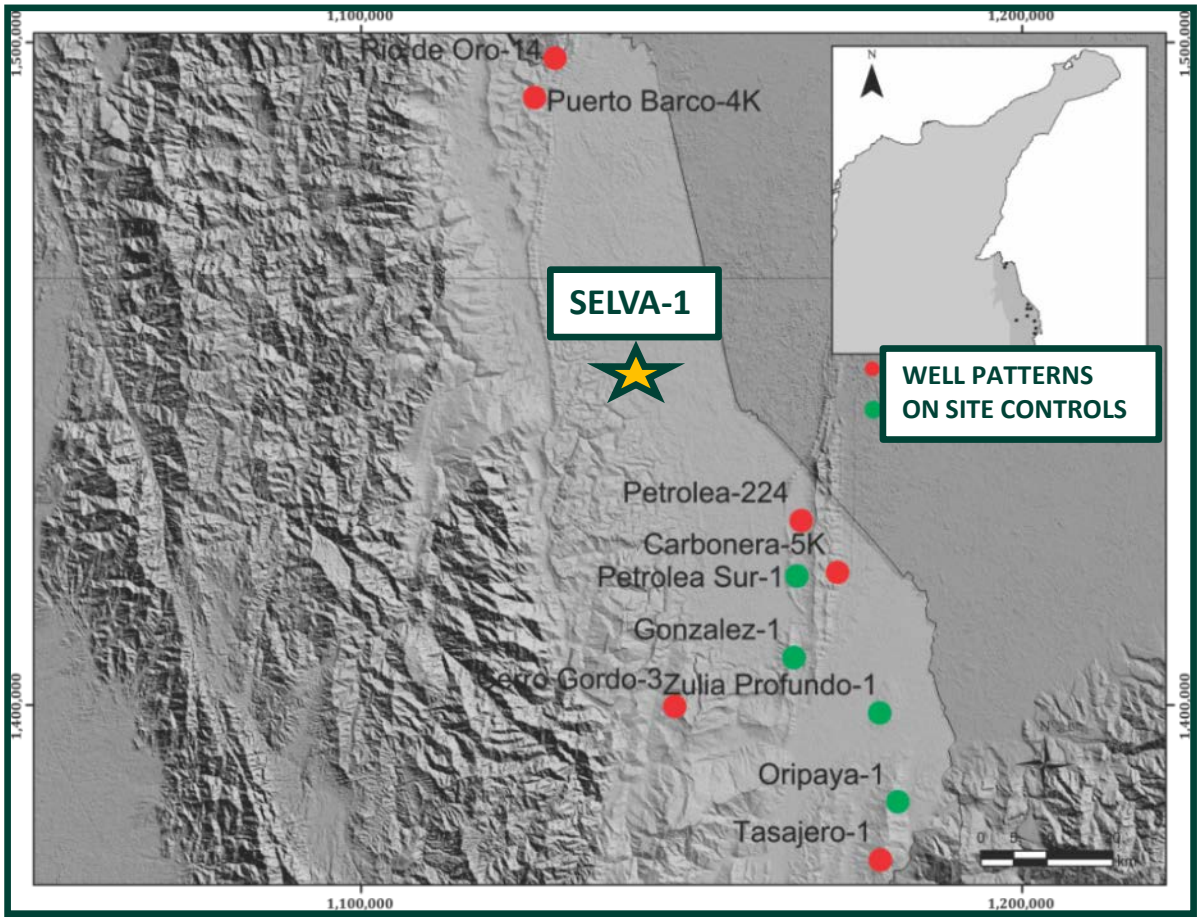


Bolivina explicata
© PDVSA INTEVEP

Bolivina explicata
Holotype

WHAT WE HAVE FOUND ABOUT THE MICROFOSSILS OF THE LOWERMOST COLON FORMATION…

ANALYZED WELLS OF THE CATATUMBO BASIN



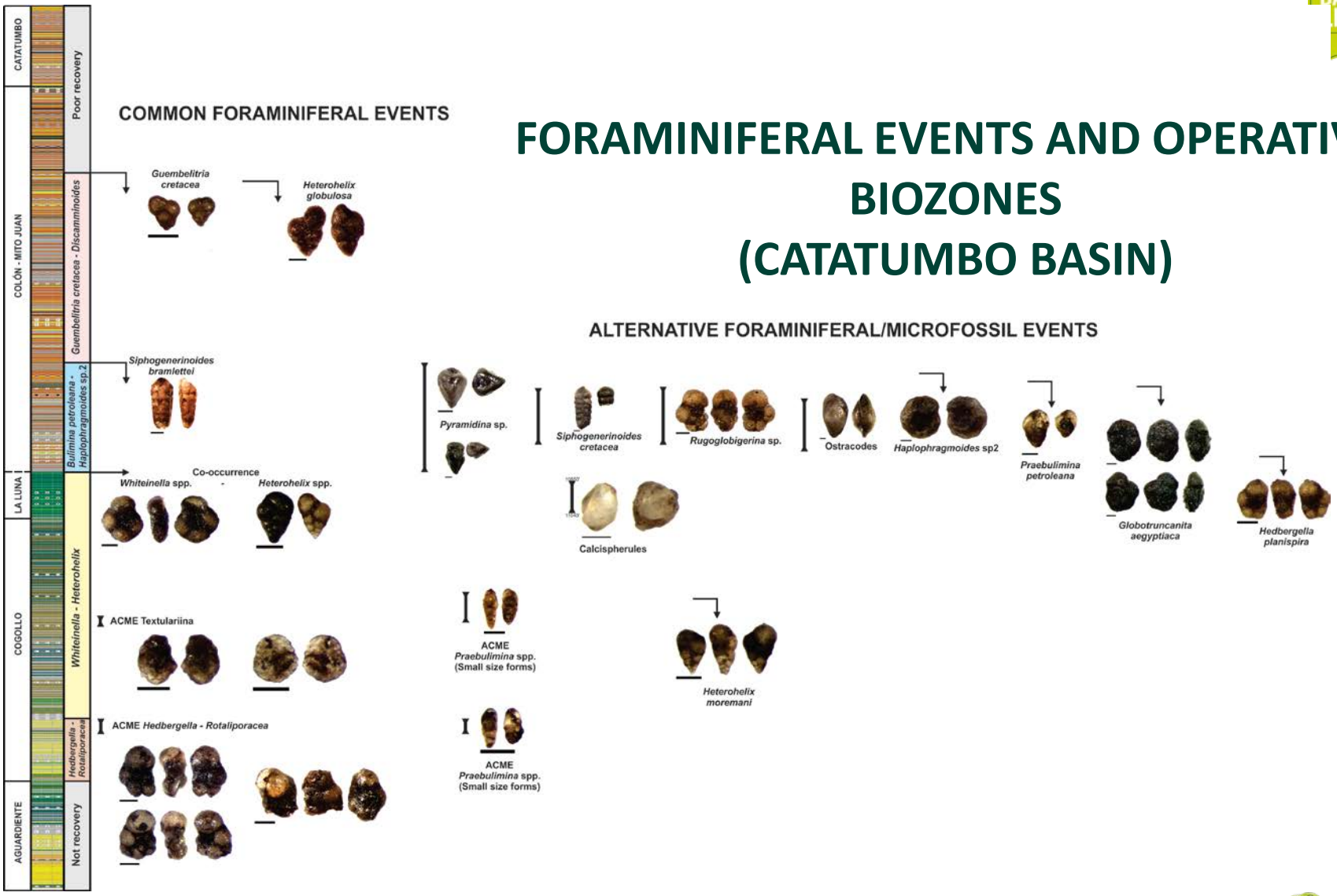
ECOPETROL-ICP

7 analyzed wells with Colón material (cuttings!)

WELL SELVA-1

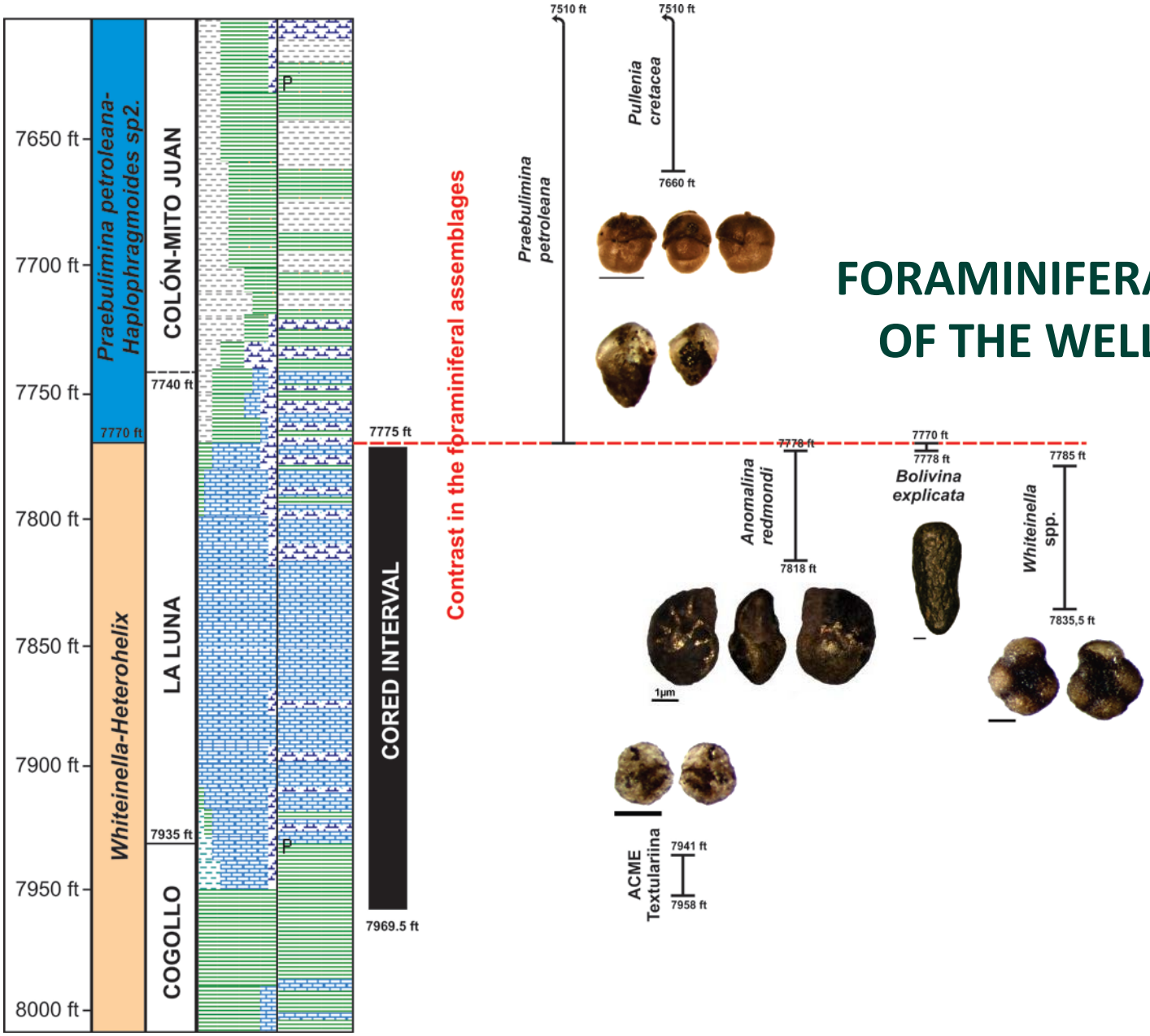
- La Luna Formation was cored
- Colón samples (cuttings)

FORAMINIFERAL EVENTS AND OPERATIVE BIOZONES (CATATUMBO BASIN)

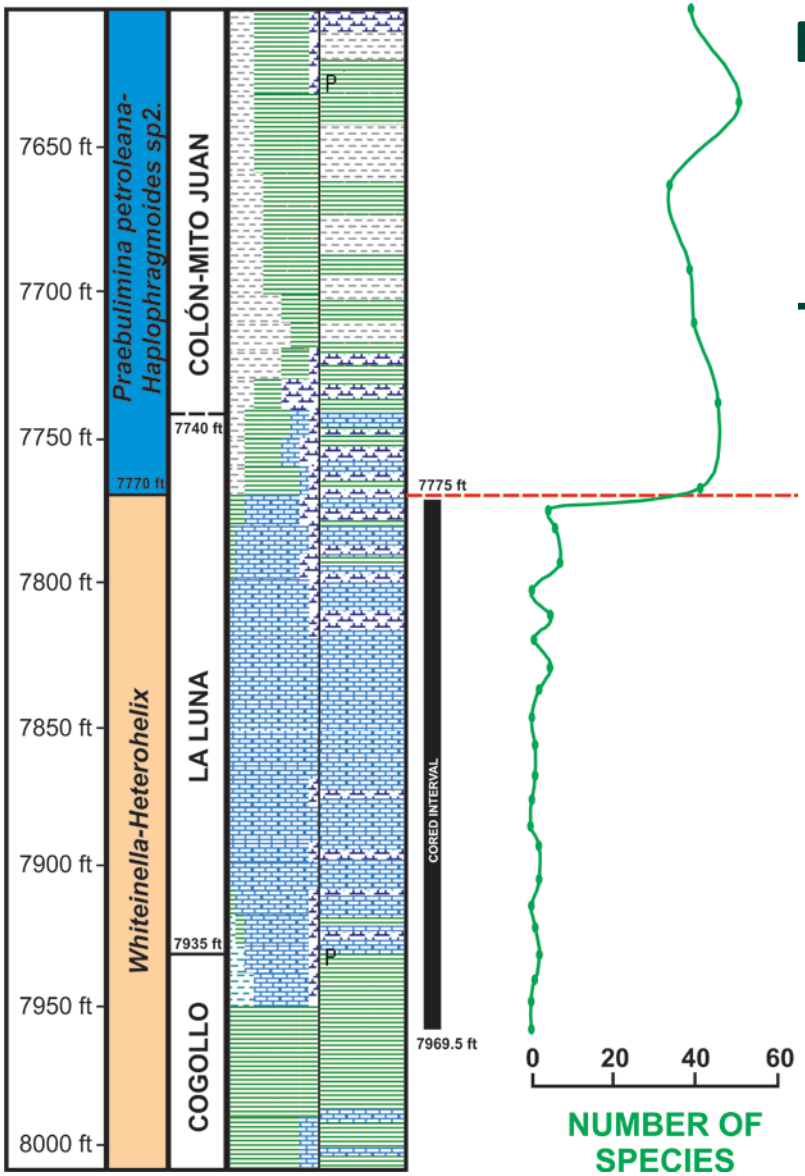


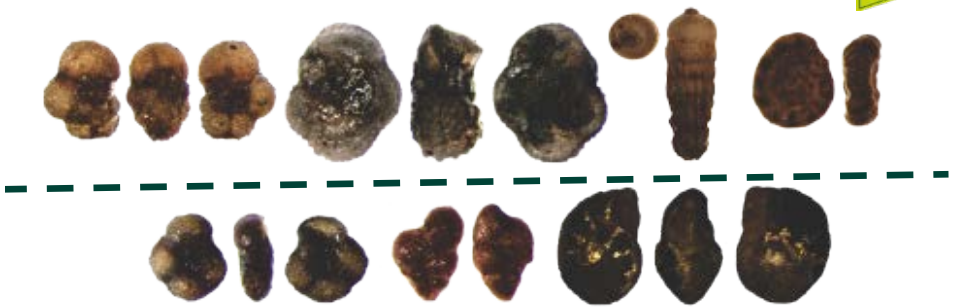
ECOPETROL-ICP

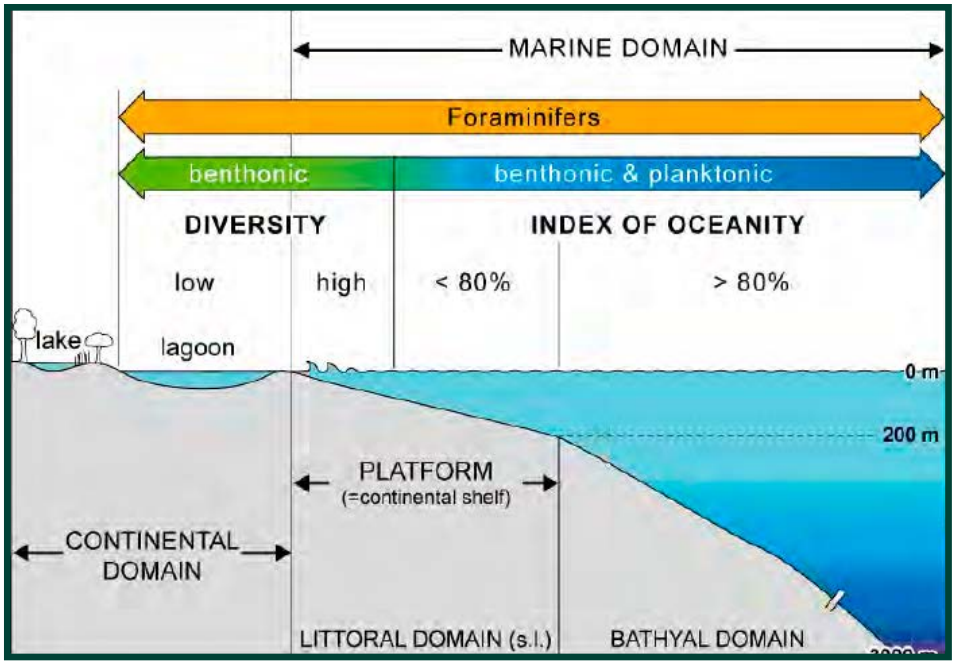
FORAMINIFERAL RECORD OF THE WELL SELVA-1



PALEOECOLOGICAL INFERENCES

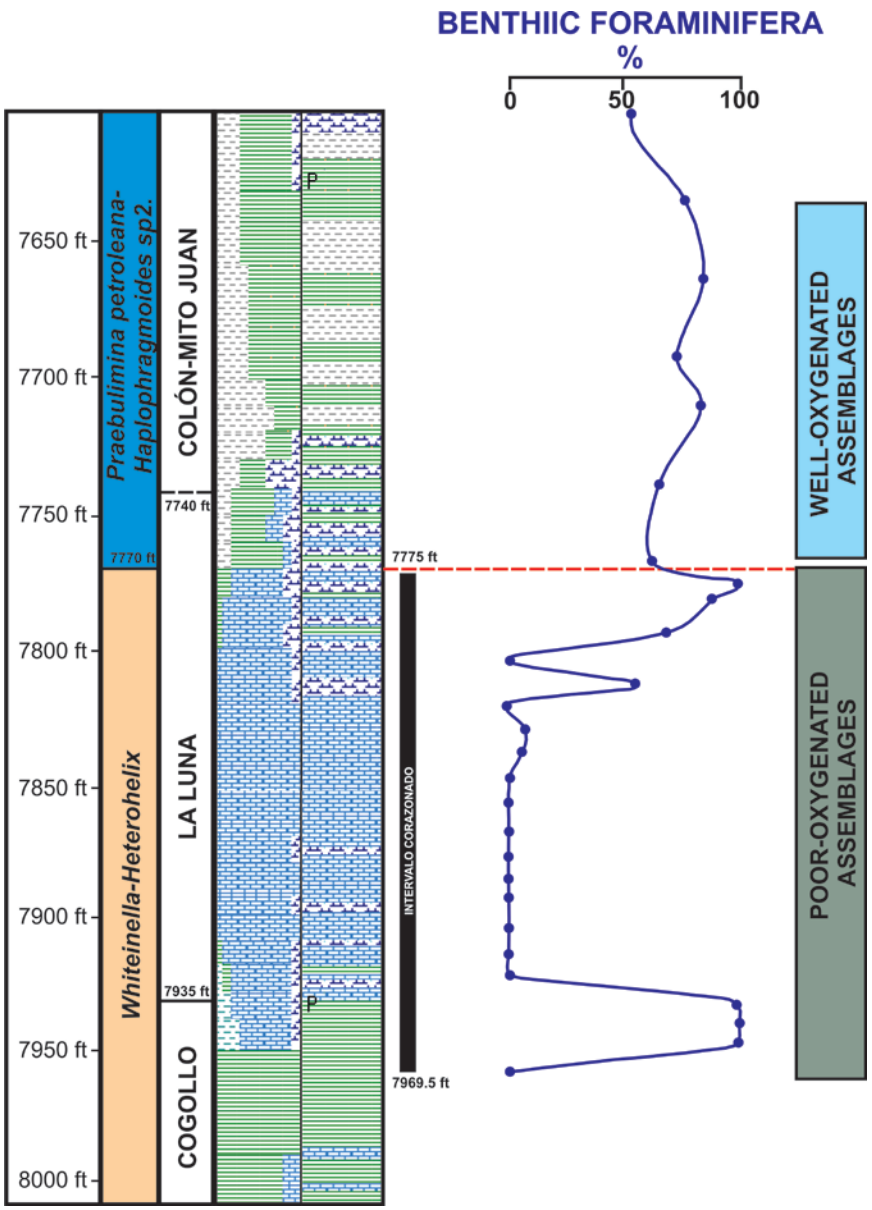


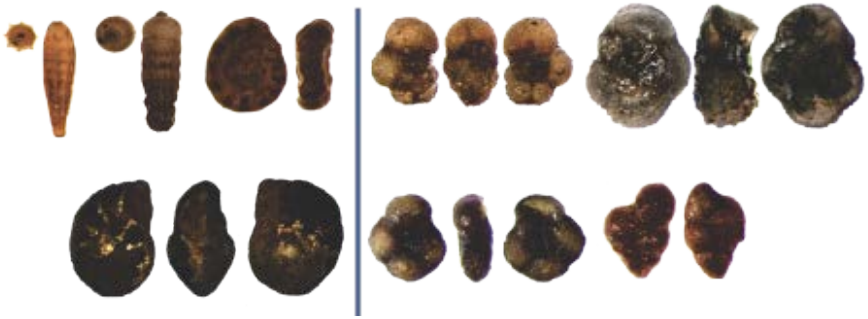


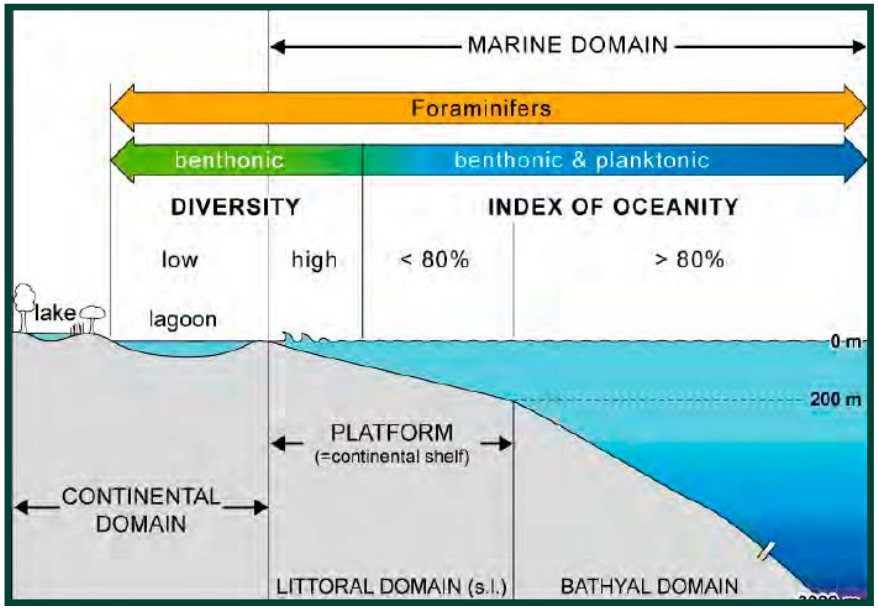


Bellier *et al*. (2008)

PALEOECOLOGICAL INFERENCES





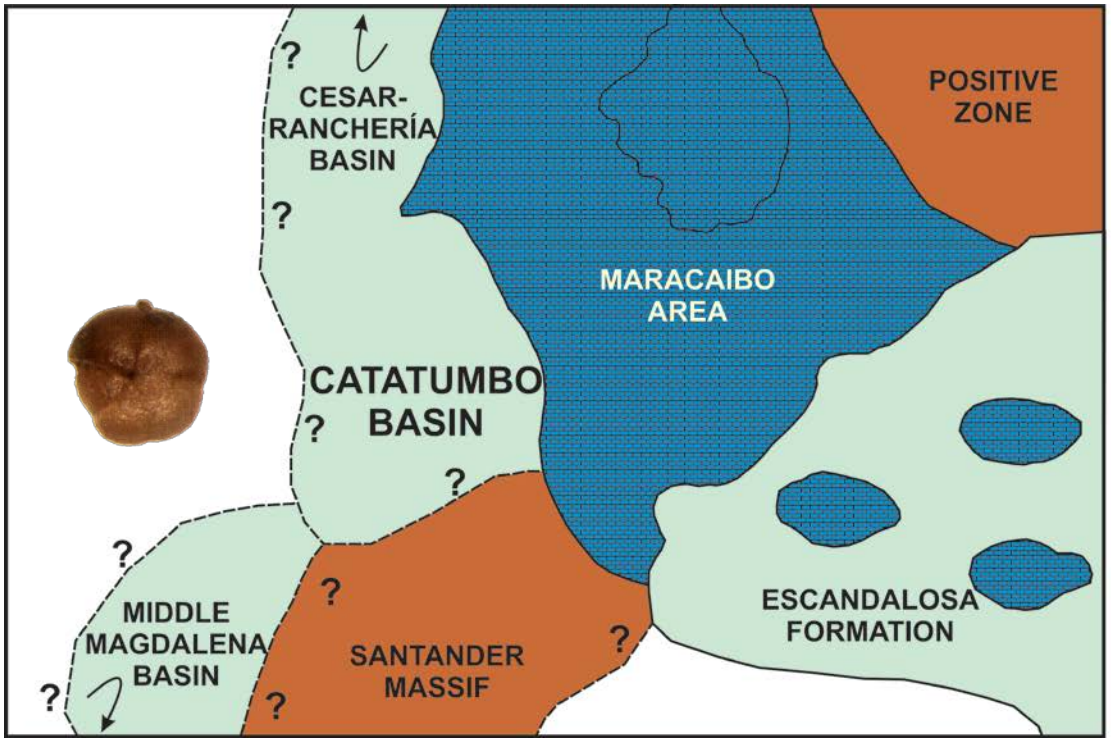


Bellier *et al*. (2008)

TRABAJAMOS PARA PRODUCIR BARRILES LIMPIOS

WHAT WE MUST KNOW ABOUT THE MICROFOSSILS OF THE LOWERMOST COLON FORMATION…

PALEOGEOGRAPHICAL EXTENSION OF THE COLÓN FORAMINIFERA



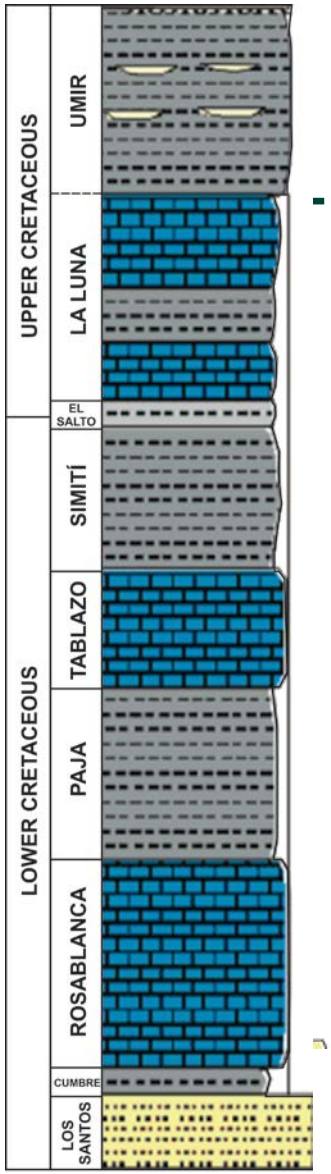
Adapted from Parra *et al*. (2003)

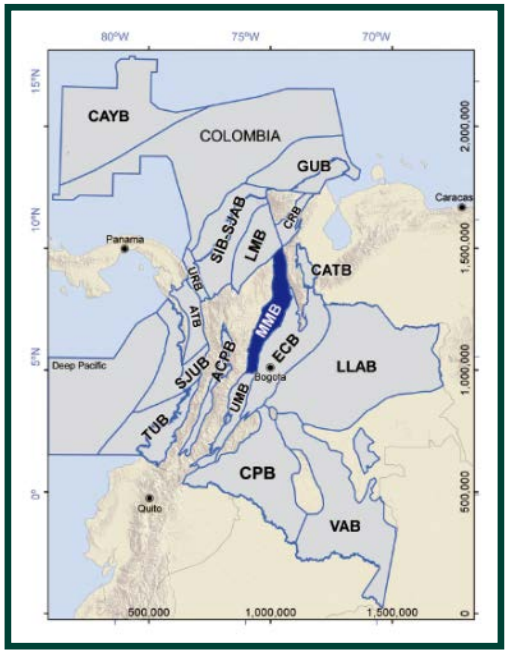
LATE CAMPANIAN ESTIMATED PALEOGEOGRAPHY

MAIN FACIES

- ANOXIC SHELF ENVIRONMENTS
- SHALLOW MARINE ENVIRONMENTS

FORAMINIFERAL ASSEMBLAGES OF THE MMB

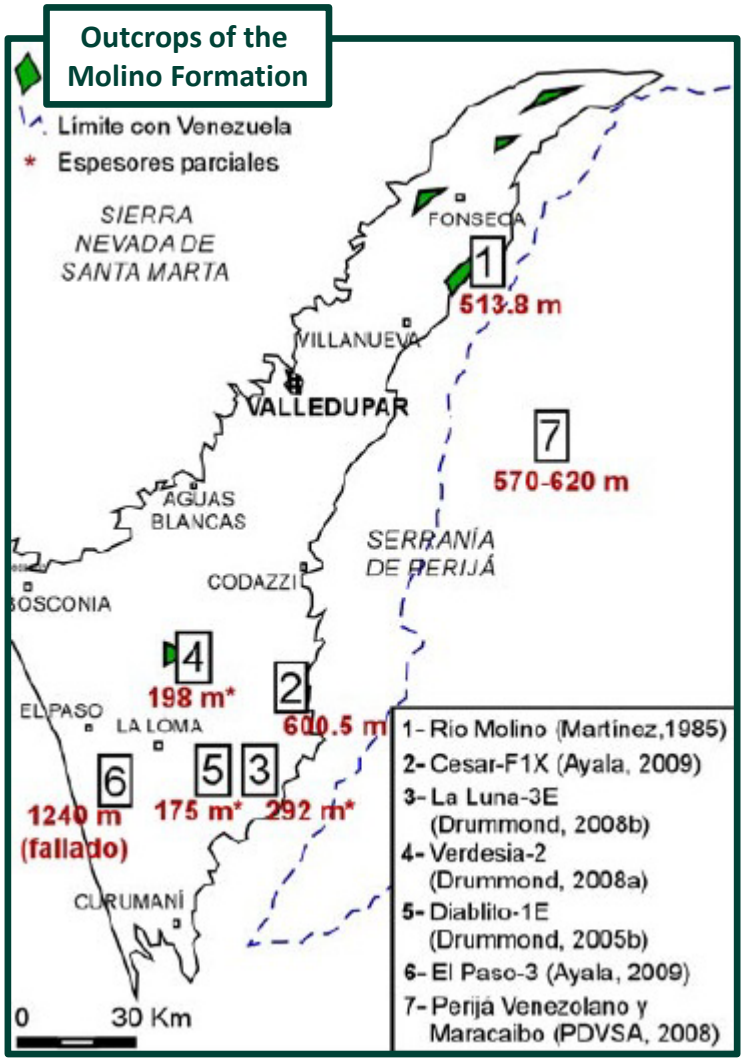




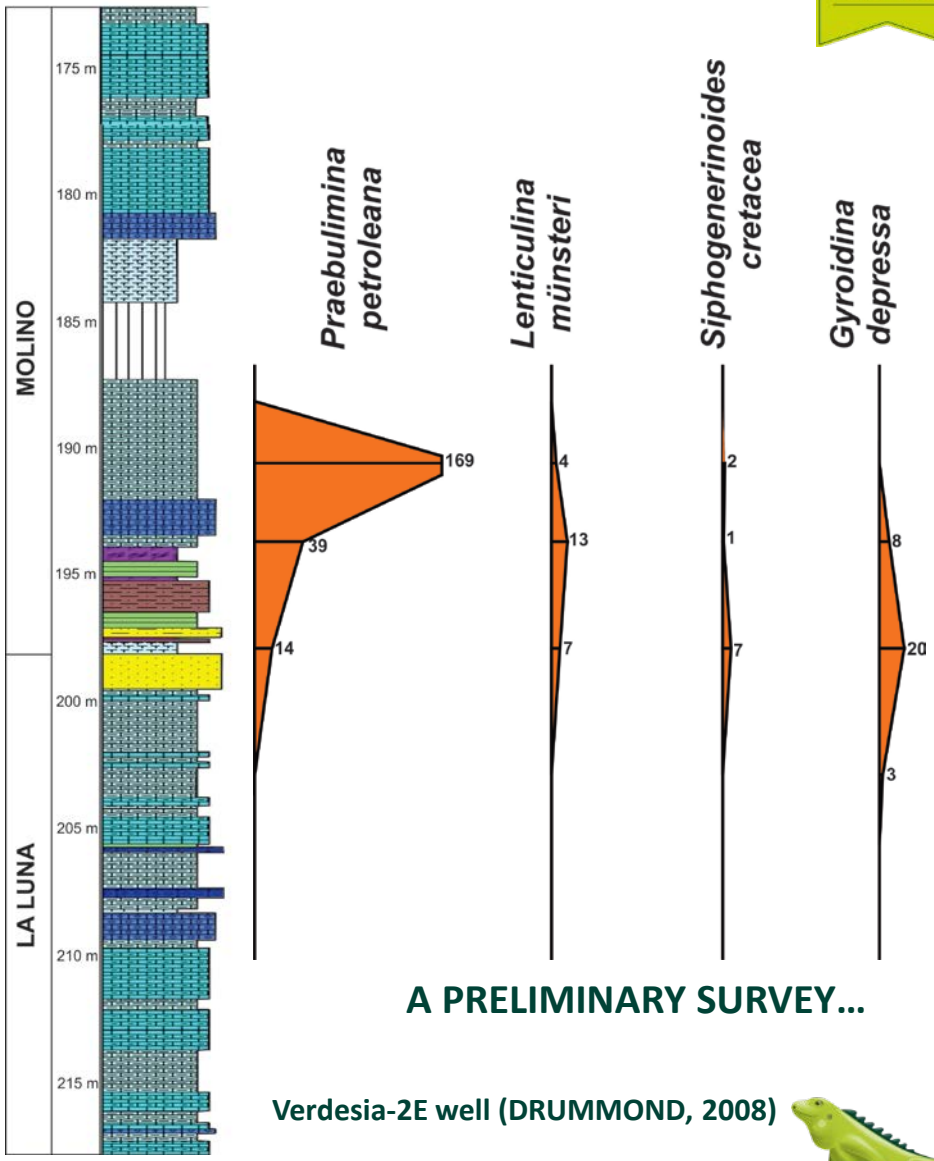
ECOPETROL-ICP

ANH (2011)

FORAMINIFERAL ASSEMBLAGES OF THE PERIJÁ RANGE



Ayala-Calo *et al*. (2009)



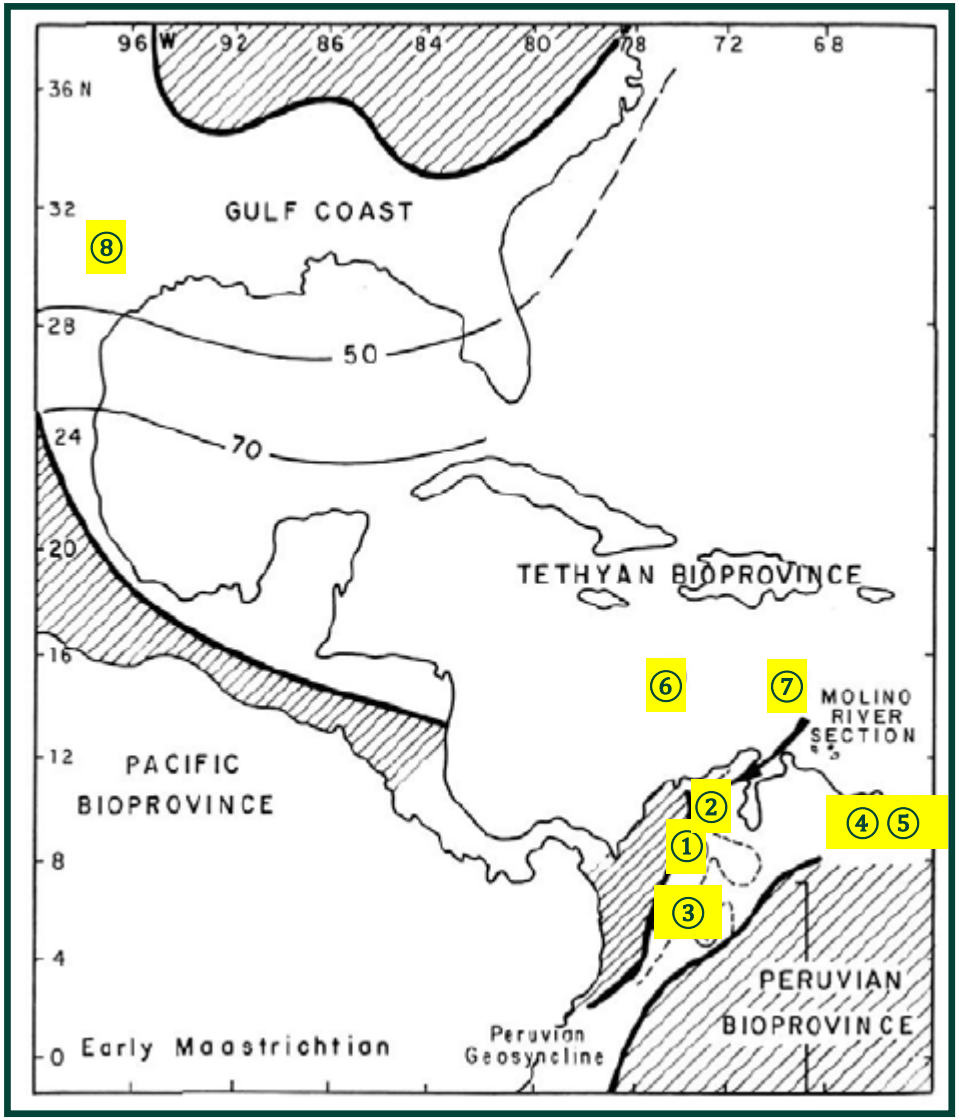
A PRELIMINARY SURVEY…

Verdesia-2E well (DRUMMOND, 2008)

FORAMINIFERAL ASSEMBLAGES OF THE PERIJÁ RANGE

La Luna-3E well (ECOPETROL-ICP)

FORAMINIFERAL BIOPROVINCES IN THE LATEST CRETACEOUS

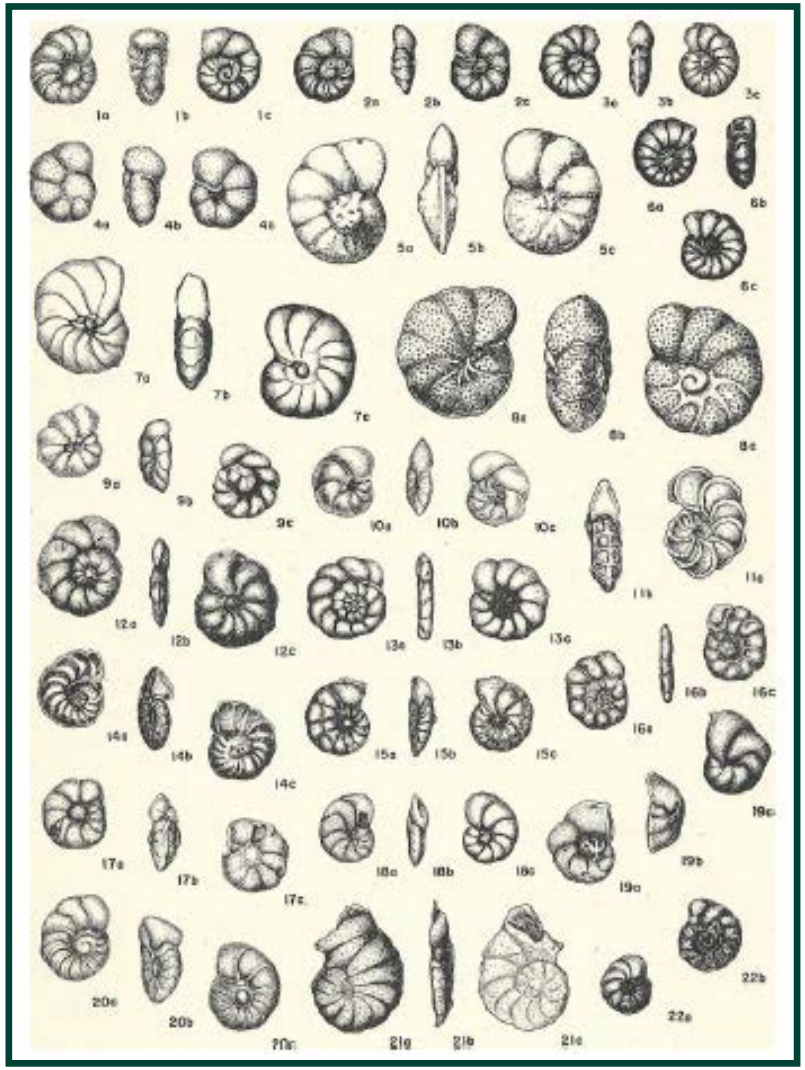


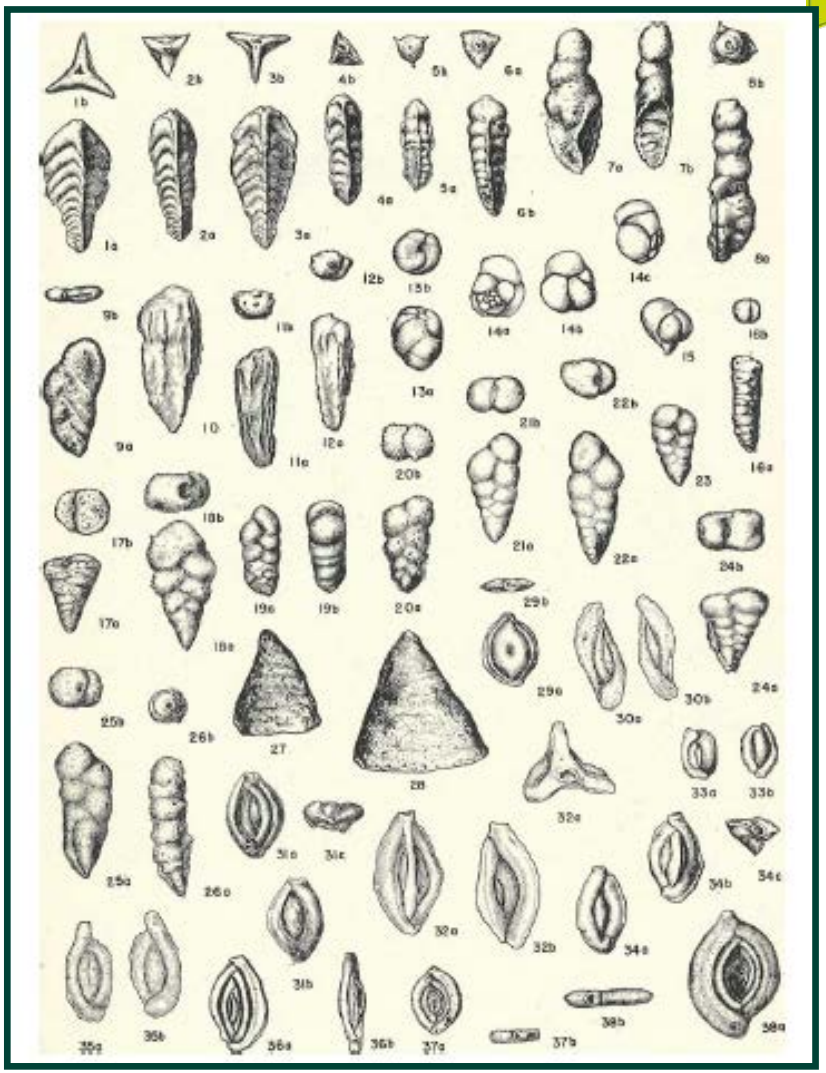
Reference sections

① Catatumbo Basin
② Perijá Range
③ Middle Magdalena Basin
④ Eastern Venezuela (San Antonio Fm)
⑤ Trinidad
(Naparima Hill; Guayaguayare Fms)
⑥ DSDP Site 152
⑦ DSDP Site 146
⑧ Western Interior Sea (Corsicana Fm)

Martínez (1989)

COMMON FORAMINIFERA FROM THE NAVARRO GROUP (GULF COAST REGION)





Frizzell (1954)

FINAL REMARKS

- **The microfossils of the lowermost Colón Formation are highly diverse, illustrating "optimal" paleoenvironmental conditions.**
- **A clear faunal turnover is observed above the La Luna-Colón contact, possibly recording a major tectonic event.**
- **The paleoenviromental inferences and the paleogeographical models for the Late Campanian in northern South America could be improved using those remarkable foraminiferal assemblages…**