Zitteliana	4	3—72	München, 1. August 1978	ISSN 0373-9627

The Paleoecology and Paleogeography of the Uruguayan Coastal Area During the Neogene and Quaternary[1]

BY

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With 16 text figures and plates 1—6

ABSTRACT

Miocene, Pleistocene and Holocene foraminiferal and molluscan assemblages found in water wells and outcrops distributed along nearly 700 km of the coastal plain of Uruguay were analyzed. Marine Miocene faunas were found only in the Chuy No. 364 well. Faunal associations using well data were correlated by ecostratigraphic unit. Depositional environments of Neogene and Quaternary foraminiferids and molluscan bearing strata were reconstructed. The distributional pattern of the various faunas that today populate the Río de la Plata are analyzed in reference to the salinity gradient of the estuary. As a tool the Curve of Remane for foraminiferids and bivalves is used, as well as the distributional pattern of gastropods. Various criteria for the recognition of ancient estuaries are proposed. The early Holocene paleogeography in the Río de la Plata was reconstructed. A reconstruction of the Miocene and Quaternary geological evolution in the southernmost part of the Pelotas Basin (area of Chuy) since the Miocene is attempted. This is characterized by the alternation of marine (or marginal marine) and terrestrial depositional environments. The distribution of the paleozoogeographical littoral provinces of the eastern coast of South America during the Miocene and lower Holocene is elucidated.

KURZFASSUNG

Es werden Foraminiferen- und Mollusken-Vergesellschaftungen aus dem Miozän, Pleistozän und Holozän untersucht, die aus hydrogeologischen Bohrungen und Aufschlüssen entlang einer Strecke von ca. 700 km der Uruguayischen Küstenregion stammen. Die Assoziationen aus dem Miozän kommen aus einer einzigen Bohrung (Chuy Nr. 364). Die Fauna der Bohrungen wird ökostratigraphisch gegliedert; daraus werden die Ablagerungsräume im Neogen und Quartär rekonstruiert. Die gegenwärtige Zonierung verschiedener Faunen auf Grund von Salinitätsgradienten im La-Plata-Ästuar wird untersucht. Hierzu dient die Remane-Kurve für die Foraminiferen und die Muscheln, sowie die Verbreitung der Schnecken. Daraus ergeben sich Kriterien für die Erkennung ehemaiger Ästuare. Die Paläogeographie des Gebietes des La-Plata-Ästuars während des unteren Holozäns wurde rekonstruiert. Die geologische Entwicklung im südlichen Teil des Pelotas-Beckens (Chuy-Gebiet) während des Miozäns und Quartärs wird rekonstruiert. Es ist gekennzeichnet durch ein Ineinandergreifen mariner (oder marginal mariner) und kontinentaler Verhältnisse.

Abschließend wird ein Überblick über die litoralen paläozoogeographischen Provinzen an der Ostküste Südamerikas während des Miozäns und Holozäns gegeben.

RESUMEN

Se estudian asociaciones de foraminíferos y de moluscos del Mioceno, Pleistoceno y Holoceno halladas en perforaciones hidrogeológicas y en afloramientos situados a lo largo de casi 700 km de la planicie costera del Uruguay. Unicamente se hallaron asociaciones Miocénicas en la Perf. Chuy N° 364. La fauna de las perforaciones se correlaciona ecoestratigráficamente. Se reconstruyen los ambientes de deposición de las secuencias del Neógeno y Cuartario portadoras de foraminíferos y de moluscos. Asimismo se analiza el padrón de distribución de la fauna

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[1] Fossil-Vergesellschaftungen No. 76. — No. 75: Becker, G., Clausthaler Abh., 1979.

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que puebla actualmente el Río de la Plata en base al gradiente de salinidad, utilizándose la Curva de Remane de los foraminíferos y los bivalvos, y la distribución de los gastrópodos en el estuario. Se proponen varios criterios para la identificación de ambientes estuariales antiguos. Se reconstruye la paleogeografía de la región del Río de la Plata durante el Holoceno inferior. Por otra parte se describe la evolución geológica acaecida en el extremo sur de la Cuenca de Pelotas (área del Chuy) desde el Mioceno, caracterizada por la alternancia de depósitos marinos (o marginal marinos) y continentales. Finalmente se analiza la distribución de las provincias paleozoogeográficas litorales de la costa oriental de América del Sur durante el Mioceno y Holoceno inferior.

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I. PREFACE

This study was a research program for the development of micropaleontology and paleoecology in Uruguay with the support of Dr. R. Méndez-Alzola.

The Alexander von Humboldt Foundation supported the realization of this study by a research fellowship which was carried out in the Institut und Museum für Geologie und Paläontologie der Universität Tübingen. Dr. D. Herm acted as academic supervisor and coordinator and Dr. J. Wendt as referee. The publication of the results has been possible due to a financial support to the printing costs by the Alexander von Humboldt Foundation.

In this thesis J. da Silva helped with the preparation of bore-hole samples and evaluating lithological and stratigraphic data, A. Figueiras with the taxonomic determination of macro- and micromolluscs, V. Scarabino with the taxonomic determination of macromolluscs, H. Goso with the stratigraphic interpretation of Chuy N° 364, S. C. Bender Kotzian with the taxonomic determination of ostracods, and Dr. M. Scherer in the X-ray diffraction analysis. Valuable SEM work and photos were made with the expert help of Ms. R. Klett and Mr. W. Wetzel respectively.

Productive and beneficial suggestions, discussions and criticism were also made by Drs. A. Seilacher, F. Frölicher, F. Fürsich, Ch. Hemleben, W. v. Koenigswald, A. Liebau, W. Reif and D. Hilgemann.

For the taxonomic determination of the foraminiferids, comparisons were made with the collections of the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" (Buenos Aires) and Departamento de Paleontologia y Estratigrafia-Instituto de Geociências (Porto Alegre) with the assistence of Drs. E. Boltovskoy, A. Bertels and M. Madeira-Falcetta. The bore-hole samples were provided by the Instituto Geológico del Uruguay.

To all the above institutions and persons many thanks are due.

The largest helping of thanks are due to my wife Ana María who typed the manuscript and also my entire family and friends who kept me going and alive through these years of work.

II. INTRODUCTION: GEOLOGICAL SETTING

During the Cenozoic, sedimentation in Uruguay was predominately continental. Marine fossils were only found in exposures from the Camacho Formation (= Entrerriana) and Vizcaíno Formation (= Querandina); and in some subsurface (well) sequences attributed to the Chuy Formation.

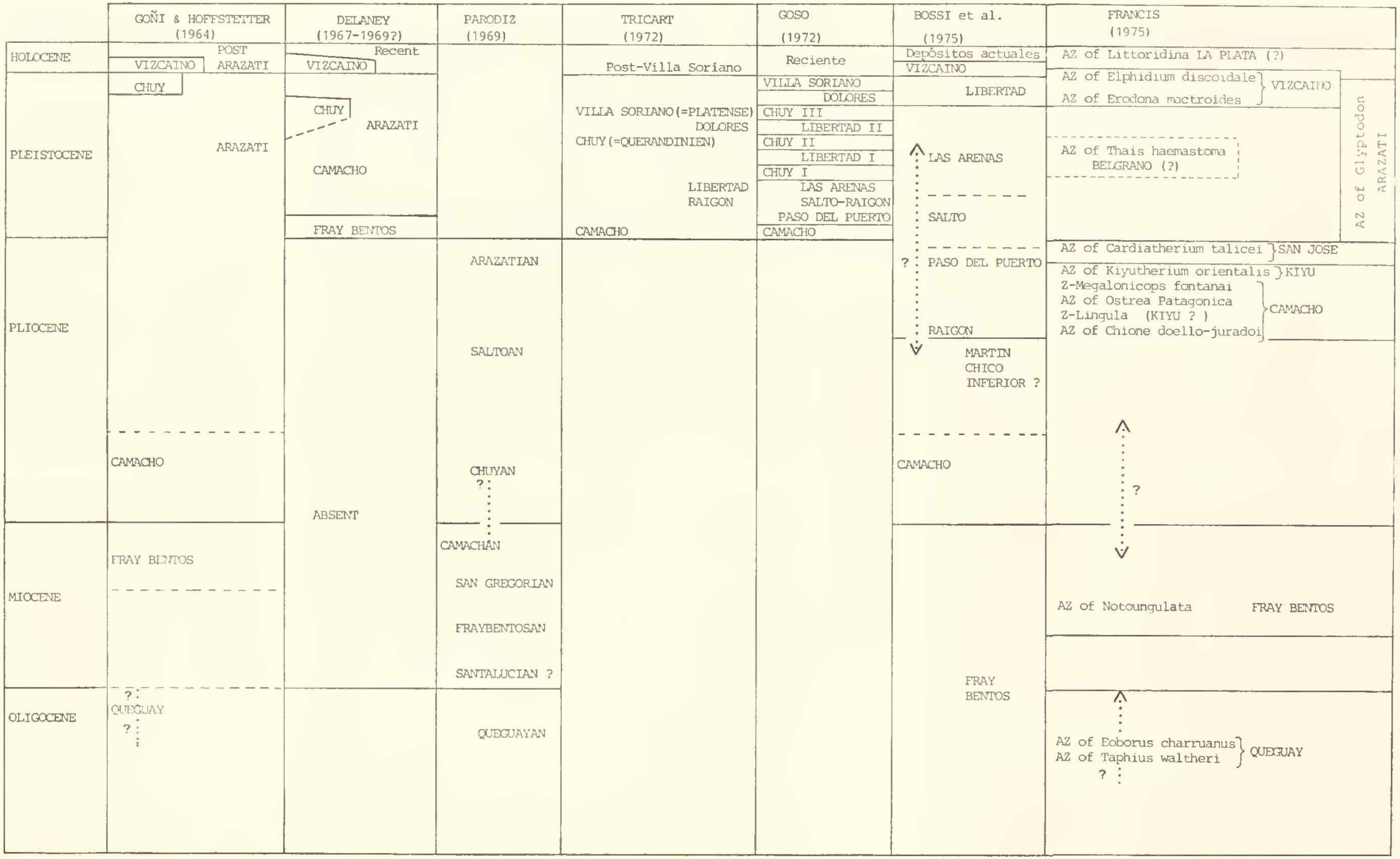
Features of regional geology in the area of study were summarized by Bossi (1966), Bossi et al. (1975) and Delaney (1967, 1969 ?).

In the course of the last twenty years several schemes were presented in an attempt to explain the geological evolution of Uruguay during the Tertiary and / or Quaternary (Bossi, 1966, 1969; Bossi et al. 1975; Caorsi & Goñi, 1958; Delaney, 1967, 1969?; Francis, 1975; Goñi & Hoffstetter, 1964; Goso, 1965, 1972; Harrington, 1956; Parodiz, 1969; Tricart, 1972). Some of these schemes are summarized in Table I. The analysis of these research publications shows a progressive increase in knowledge of the Uruguayan Cenozoic, although their conclusions were repeatedly contradictory. Furthermore extended regions were not even mapped in detail. No precise biostratigraphical studies have been made.

The greatest amount of disagreement is present in reference to relationships existing between stratigraphical units and their age (table I). The Camacho Formation is a good example of this situation. Two points of view have been given of its age: a) The Camacho Formation is ancient, belonging to the Miocene or lower Pliocene. This was the first opinion and was Darwin's, and traditionally was shared by Mendez-Alzola, Frenguelli, Serra, Lambert, Figueiras & Broggi, Parodiz, among others; b) The Camacho Formation is modern, being placed within upper Pliocene (Francis, 1975; Mones, 1975) or into the lower Quaternary (Bertels & Madeira-Falcetta, 1977; Closs, 1966a; Delaney, 1967, 1969?; Ecochard, 1970; Goso, 1972; Tricart, 1972). The age given to this marker horizon has direct implications in the reconstruction of this area, as will be shown.

III. GEOGRAPHICAL POSITION AND CHARACTERISTICS OF THE BORE-HOLES

The paleontological material analysed in this work was obtained from drillings made during a search for drinking water, and from an outcrop located in Parque Lecocq. The wells were made by the "Instituto Geológico del Uruguay". The samples are deposited in the "Sección Hidrología y Servicio de Perforaciones" of the above mentioned institution. Almost all of the wells were drilled by the cable-tool method. There were no continuous cores available, and the samples came from drill cuttings which were in chip and/or powder form. As Toomey & Winland (1973) have shown, the information for an identifi-



	GOÑI & HOFFSTETTER (1964)	DELANEY (1967-1969?)	PARODIZ (1969)	TRICART (1972)	GOSO (1972)	BOSSI et al. (1975)	FRANCIS (1975)
HOLOCENE	VIZCAINO POST ARAZATI	Recent VIZCAINO		Post-Villa Soriano	Reciente	Depósitos actuales VIZCAINO	AZ of Littoridina LA PLATA (?)
PLEISTOCENE	CHUY ARAZATI	CHUY ARAZATI CAMACHO FRAY BENTOS		VILLA SORIANO (=PLATENSE) DOLORES CHUY (=QUERANDINIEN) LIBERTAD RAIGON CAMACHO	VILLA SORIANO DOLORES CHUY III LIBERTAD II CHUY II LIBERTAD I CHUY I LAS ARENAS SALTO-RAIGON PASO DEL PUERTO CAMACHO	LIBERTAD LAS ARENAS SALTO	AZ of Elphidium discoidale AZ of Erodona mactroides } VIZCAINO AZ of Thais haemastoma BELGRANO (?) AZ of Glyptodon ARAZATI
PLIOCENE	CAMACHO	ABSENT	ARAZATIAN SALTOAN CHUYAN ?			? PASO DEL PUERTO RAIGON MARTIN CHICO INFERIOR ? CAMACHO	AZ of Cardiatherium talicei } SAN JOSE AZ of Kiyutherium orientalis } KIYU Z-Megalonicops fontanai AZ of Ostrea Patagonica Z-Lingula (KIYU ?) AZ of Chione doello-juradoi } CAMACHO ?
MIOCENE	FRAY BENTOS		CAMACHAN SAN GREGORIAN FRAYBENTOSAN SANTALUCIAN ?			FRAY BENTOS	AZ of Notoungulata FRAY BENTOS
OLIGOCENE	? QUEGUAY ?		QUEGUAYAN				AZ of Eoborus charruanus AZ of Taphius waltheri } QUEGUAY ?

TABLE I:

Comparison of stratigraphic interpretations cation of facies and microfaunas can be obtained from examination of drill cuttings. Nevertheless, this fact reduces part of the available information, because the sedimentary structures are not preserved, and a portion of the macrofossils were broken.

The location of the bore-holes are shown in Fig. 1. They are located on the Uruguayan coastal plain area. The geographic inner limit of the coastal plain usually forms the contact with the underlying crystalline rocks. This contact is usually marked by a low sloping topographic escarpment which occurs between the 20 and 40 meter contour lines on the topographic maps (Delaney, 1967, 1969?).

For each well the geographic coordinates are given according to the "Carta del Uruguay al Millonésimo", edited in 1971 by the "Servicio Geográfico y Militar".

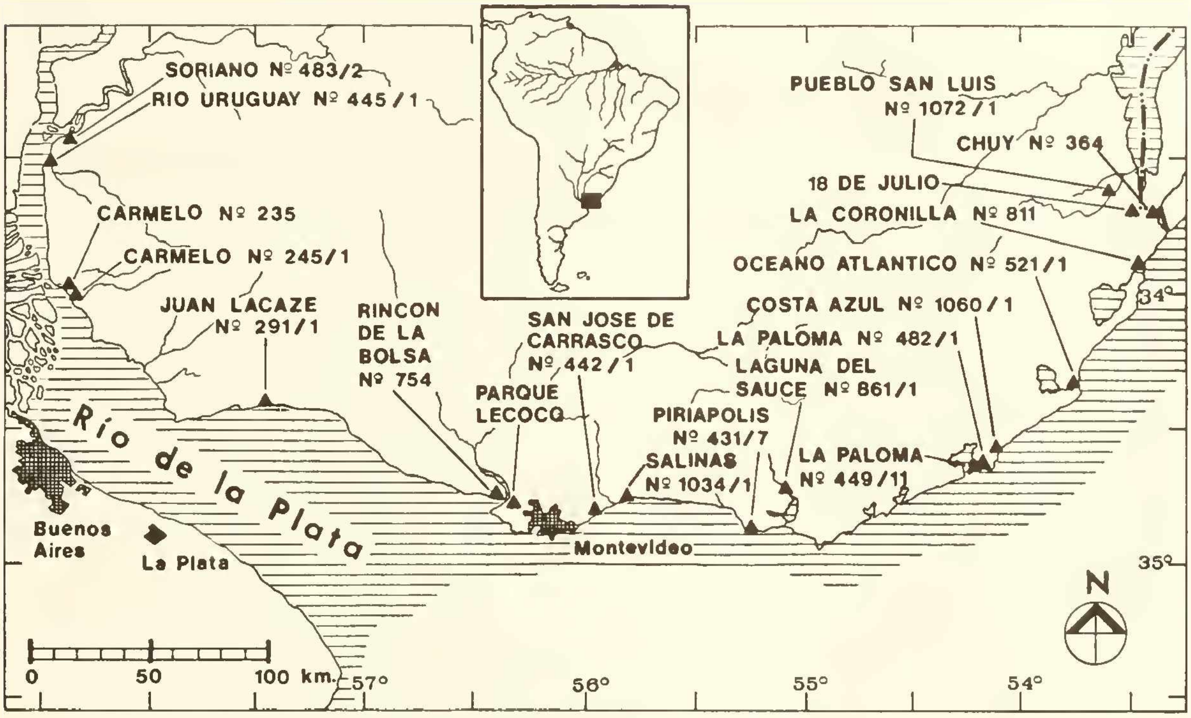


Fig. 1: Bore-hole locations dealt with in the text.

IV. METHODS AND MATERIAL

140—150 cm^3 of sediment from each sample of drill cutting was picked clean of all megafauna (molluscs and barnacle plates). 35—40 cm^3 of the above 140—150 cm^3 was then inspected for microfauna. This is equivalent to a core sample 4—5 mm high and 10 cm in diameter.

Samples were prepared in 15 % H_2O_2, washed, sieved (0,063 mm mesh net), and dried. In a smaller number of samples, so marked in Chapter VI-B, the tests were separated out by flotation in carbontetrachloride. The samples were then sieved as above. The rest of the sediment was inspected under the binocular microscope to check for any remaining microfossils in the residue. All tests were removed, taxonomically identified and counted. The photographs were made with a Cambridge Stereoscan electron microscope Type Mark 2 A.

The illustrated and photographed foraminiferids are deposited in the Bayerische Staatssammlung für Paläontologie und historische Geologie, Munich, N°. 1978 VIII. The bore-hole samples, the molluscs of the wells, and remaining microfossils are deposited in the Instituto Geológico del Uruguay and the Departamento de Paleontología, Facultad de Humanidades y Ciencias, Uruguay.

V. MARINE MIOCENE

Marine Miocene faunas were found only in one well: Chuy N° 364.

A. Location of Chuy N° 364

City of Chuy, Rocha County (Lat. 33°42′S, Long. 53°26′W) (fig. 1). Geomorphologically this region belongs to the coastal plain of southen Brazil and tectonically to the Pelotas Basin (Delaney, 1965, 1966).

B. Previous paleontological, geological and stratigraphical studies

This well has been the object of repeated studies, as it presently gives the most complete information about the evolution of the upper Tertiary and Quaternary of Uruguay (Antón & Armstrong, 1973; Bertels & Madeira-Falcetta, 1977; Bossi, 1966; Closs, 1966a, 1970; Closs & Madeira, 1968a; Ecochard, 1970; Figueiras & Broggi, 1971, 1972/73; Francis, 1975; Goso, 1972; Malumian, 1970, 1972; Medina, 1962).

The following publications provide taxonomic descriptons of the macro- and microfossils previously found in Chuy N° 364: 1) Medina (1962) studied the macrofauna of a single fossil level, at depth of 124 m, 2) Closs & Madeira (1968a) studied the microfauans of this well and described three forminiferid bearing beds, and 3) Figueiras & Broggi (1971, 1972/73) compiled a review of the molluscan fauna of the Camacho Formation. They include in this study the Chuy well. They also reviewed systematically the species previously described by Medina (1962), and proposed a modified taxonomy, henceforth used in this work.

C. Distribution of the micro- and macrofaunas

The distribution of the Miocene micro- and macrofaunas is shown in Table II. Remarks:

1) Mollusca: The species which were described by Medina (1962) are marked with "M" in Table II. The species described by Figueiras & Broggi (1971, 1972/73) are marked with "FB" in the same Table. The disintegration of the drill cuttings with H_2O_2 for micropaleontological porposes gave additional material not previously cited. In Table II these fossils are marked with "x".

Some remarks are made about the systematics of molluscs in Table II: a) *Semele* sp., was described as *Semele bravardiana* (in litt.) by Figueiras & Broggi (1972/73), b) *Ostrea* sp., was previously cited as *Ostrea patagonica* by Figueiras & Broggi (1972/73), and c) *Americuna* sp.: is a form that probably represents a new species. The genus *Americuna* was described on the basis of a single living species, *Americuna besnardi* (Cox, Newell, Boyd et al., 1969; Klappenbach, 1962).

2) Brachiopoda: Medina (1962) shows the presence of *Bouchardia transplatina* Ihering, 1907, at a depth of 124 m.

3) Bryozoa: The presence of the bryozoans *Cellaria* and *Discoporella* between 124—125 m was previously indicated by Closs (1966a) and Closs & Madeira (1968a).

TABLE II
Faunal distribution in Chuy Nº 364

Depth/m	122 124	124 125	125 128	128 130	130 133
FORAMINIFERA					
Ammonia beccarii var. *parkinsoniana*	•		•	•	
Amphistegina gibbosa	———	———	———	□□□	— —
Buccella peruviana, s. l.	—	•	••		
Cancris sagra		••			
Cassidulina curvata			•		
Cassidulina laevigata	———	— —	—	•	
Cassidulina subglobosa	•				
Cibicides aknerianus	▭	□□□	□□□	••	
Cibicides "*pseudoungerianus*"	□□□	□□□	— —		
Cibicides sp.?	•				
Discorbinella? *bertheloti* f. *boueana*	— —	••	—	•	
Elphidium depressulum	•	•			
Elphidium discoidale	••	••		••	
Elphidium gunteri	•				
Elphidium aff. *sagrum*	— —			•	
Elphidium cf. *tuberculatum*	———	—	— —	••	•
Elphidium sp. A	•				
Elphidium sp.			•		
Fursenkoina sp.		•			
Lagena laevis f. *perlucida*		•			
Lagena sp.	•				
Lenticulina rotulata	••				
Marginulina gr. *tenuis*	•				
Massilina secans	•				
Miliammina fusca	•				
Miliolinella subrotunda		••			
Nonionella atlantica	••	••	•	—	
Nonionella auricula			•		
Nonion grateloupii	•	••	•		
Nonion sp. A	•				
Nonion sp. B				•	
Oolina melo	•		•		
Poroeponides lateralis	••				
Pyrgo nasuta	•		•		
Quinqueloculina agglutinata	•				
Quinqueloculina patagonica	•		•		
Quinqueloculina seminulum	••	••	••		
Quinqueloculina vulgaris	••				
Quinqueloculina sp. A		•	•		
Quinqueloculina sp. B		•			
Quinqueloculina sp. C	•				
Quinqueloculina div. spp. indet.	••	••	•	•	
Rotorbinella rosea	••				
Textularia gramen		•			
Textularia sp. A	•				

References: Numbers of foraminiferids:

•	(1)	••	(2—5)
—	(6—10)	— —	(11—20)
———	(21—40)	□□□	(41—80)
▭	(81—160)		

TABLE II (continued)
Faunal distribution in Chuy N° 364

Depth/m	113	115	117	120	122	124	125	128	130
	115	117	120	122	124	125	128	130	133
BIVALVIA									
Adrana sp.					x		x	x	
Americuna sp.					x				
Amiantis purpurata		FB	FB		x	FB			
Anadara sp.		FB			x	M			
Cardita sp.						FB		x	
Chione doello-juradoi		FB	x			M			x
Chione meridionalis burmeisteri			FB		x	M	FB		FB
Chione sp.					x	x			x
Codakia sp.		x							
Corbula caribaea						x			
Corbula pulchella						M	FB		
Cyrtopleura lanceolata ornata								FB	
Diplodonta vilardeboana						M			
Diplodonta sp.								x	
Glycymeris sp.									FB
Laevicardium sp.?						x			
Lucina sp.					x		x		
Mactra bonariensis					x	M			
Mactra sp.		x							
Mactrellona sp.		x							
Nucula sp.		x		x	x				
Nuculana sp.				x				x	
Ostrea sp.				FB	x		FB		
Plicatula sp.					x				
Semele sp.						FB			
Solen sp.?					FB				
Tagelus plebeius entrerianus							FB		
Tellina sp.					x				
Tivela (Eutivela) isabelleana						FB		x	FB
Tivela sp.						x			x
debris	x	x		x	x	x	x	x	x
GASTROPODA									
Anachis sp.		FB							
Caecum (Micranellum) sp.					x				
Calliostoma sp.					x	FB			
Epitonium sp.					FB	FB			
Halistylus columna					x	FB			
Iselica anomala						FB			
"*Marginella*" sp.				FB					
Odostomia sp.		x							
Olivancillaria urceus						M			
Olivella (O.) puelcha				FB					
Olivella sp.							x		
Polinices entrerriana						M			
Tegula sp.						x			
Turbonilla (Pyrgiscus) sp.		FB			FB	x			
Turritella sp.						M			
debris			x	x	x	x	x		
POLYPLACOPHORA									
Chaetopleura sp.						FB			
SCAPHOPODA									
Dentalium sp.						FB			

TABLE II (continued)
Faunal distribution in Chuy N° 364

Depth/m	113	115	117	120	122	124	125	128	130
	115	117	120	122	124	125	128	130	133
BRACHIOPODA									
Bouchardia transplatina						M			
OSTRACODA[3])									
Bairdia								x	
Buntonia					x				
Caudites					x				
Callistocythere					x				
Cytherelloidea					x				
Cytheretta							x		
Cytheropteron					x				
Krithe					x				
Loxoconcha					x		x		
Mutilus					x				
Paradoxostoma					x				
Procytheropteron					x				
div. ssp. indet.					x	x			
BALANOMORPHA									
Balanus sp. (barnacle plates)	x	x		x	x	x	x	x	x
BRYOZOA									
Cellaria sp.					x	x	x	x	x
Discoporella sp.					x	x	x	x	x
ECHINOIDEA-REGULARIA									
spines					x	x	x	x	
plates						x			
CHONDRICHTHYES									
teeths					x		x		
OSTEICHTHYES									
debris							x		
OTOLITHS					x	x		x	

D. Microfaunal age

No planktonic foraminiferal associations are contained in the 122.10—133.00 m sequences in Chuy N° 364. Age dating was based on benthic species, which generally are not adequate for these purposes.

The microfauna of the 124—125 m sample is considered to be of Miocene age (Closs, 1966a, 1966b, 1970, 1971; Closs & Madeira, 1968a). The malacological associations of this well were included in the upper Miocene (Figueiras & Broggi, 1971, 1972/73). On the other hand Bertels & Madeira-Falcetta (1977) states that only Pleistocene foraminiferids are present in this well.

It must be pointed out, that the subdivision of the marine Miocene on the South American atlantic borderland is very controversial.

In Argentina the known assemblages are characteristic of shallow environments. Malumian & Masiuk (1973) distinguish between: 1) lower and middle Miocene assemblages; and 2) upper Miocene-Pliocene? assemblages. Bertels (1975) also distinguishes between two units: 1) the Superpatagonian, which is correlated with the Aquitanian; and 2) the Entrerrian, which is tentatively considered to belong to the Tortonian.

In southern Brazil the Miocene associations found in the Pelotas Basin contain numerous planktonic fo-

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[3]) Additional abundant ostracods were found in the 122.10—124.00 m level sample, and scarce specimens from the 124.00—125.40 m level. This material was also given to Prof. Kotzian for taxonomic identification.

raminiferal species, which are situated near the boundary of the *Globigerinatella insueta* and *Globorotalia foshi barisanensis*-Zones of the Trinidad sequences (CLOSS, 1966a, 1967, 1970). The *Globorotalia foshi barisanensis*-Zone is equivalent to the *Globorotalia foshi peripheroronda*-Zone (NOGUTI, 1975).

Species in the phylogenetic line *Globigerinoides bisphericus-Orbulina suturalis* are also found. They belong to the „*Orbulina*-Surface" (CLOSS, 1966a, 1966b, 1967). *Globigerinoides bisphericus* TOOD, 1954 is considered by NOGUTI (1975) to be a synonym of *Globigerinoides sicanus* DE STEFANI, 1951.

The ages attributed to these zones is very controversial. Some authors place them in the Aquitanian/Burdigalian boundary; others in the Tortonian (CLOSS, 1966a, 1966b, 1967, 1970, 1971; CLOSS & MADEIRA, 1968a). NOGUTI (1975) believes that the planktonic foraminiferids found in the Pelotas Basin indicate a lower Miocene age. TROELSEN & QUADROS (1971) analysed the calcareous nanoplankton found at a depth of 716 m in the well N° 2-MO-1-RS, located in the Pelotas Basin. They indicate a probable lower Miocene age. BERTELS & MADEIRA-FALCETTA (1977, p. 446) indicated that the transgression in the Pelotas Basin took place in late Miocene times, i. e., approximately at Zone N 14 of BLOW. This is supported by the presence of *Globorotalia acostaensis*, *Globigerina nepenthes* and other planktonic species. They also state that the series described by CLOSS (1966a, 1970), as well as other lower Miocene assemblages, were probably reworked from adjacent areas.

Elphidium cf. *tuberculatum* was found in Chuy N° 364 between 122.10—133.00 m. The first reference of the existence of this species in South America was given by MALUMIAN (1970), who makes several remarks about the chronological worth of *Elphidium tuberculatum*. This species indicates an upper Miocene-Pliocene? age.

The associations found in Chuy N° 364 between 122.10—133.00 m certainly belong to the Miocene for three reasons:

1) They are related with the faunas of the Pelotas Basin, and those of the Entrerrian Stage (= Entrerriense) of Argentina;

2) Paleoclimatologically the associations of foraminiferids, gastropods and bivalves indicate warm waters. The existence of these warm temperatures in the area point out a Miocene age (see Chapter VIII); and

3) Marine Pliocene sediments seem to be absent in the South American atlantic borderland (BARTELS, 1975; BERTELS & MADEIRA-FALCETTA, 1977).

There are no objective facts that permit the assigning of these assembleges of Chuy N° 364 to a certain stage or epoch within the Miocene.

E. Correlations

The microfauna found in the 124—125 m sample has been correlated with the Miocene sequences belonging to the "*Orbulina*-Surface" from different wells of the Pelotas Basin (CLOSS, 1966a, 1970; CLOSS & MADEIRA, 1968a). On the other hand, the Miocene sequences belonging to the wells drilled in the Pelotas Basin were separated into four subdivisions, named Mio 1, 2, 3 and 4 (CLOSS, 1970). The Miocene foraminiferal associations belonging to Chuy N° 364 are similar to those of Mio 1.

The time-stratigraphic correlation between the Las Flores N° 24 and Monte Veloz N° 1 wells (Buenos Aires County, Argentina) is clear. The faunal sequences found in Chuy N° 364 between 122.10—133.00 m belong to the "*Protelphidium*" *tuberculatum-zone*. This local informal zone ("hemerozona") was proposed by MALUMIAN (1970) and represents the "Paranense-Entrerriense Transgression".

F. Paleoecology

1. GENERAL CHARACTERISTICS OF THE FORAMINIFERAL ASSOCIATIONS

Only benthic species were found, whereas the planktonic foraminifera were completely absent.

For the most part the species found still exist today. This offers an excellent opportunity to establish paleoecological conclusions supported by present conditions. It allows the utilization and evaluation of ecological and biogeographical data that are available from the living fauna today.

In analyzing the Miocene associations, data pertaining to the present time foraminiferal fauna of Brazilian oceanic coasts will be used repeatedly (BOLTOVSKOY, 1959a, 1961, 1970a, 1976; BOLTOVSKOY & LENA, 1966; CARVALHO & CHERMONT, 1952; CLOSS & BARBERENA, 1960a, 1960b, 1962; CUSHMAN & PARKER, 1931; MADEIRA-FALCETTA, 1974; NARCHI, 1956; PEREIRA, 1969; RODRIGUES, 1968, 1971, 1972;

Roettger, 1970, 1973; Ribas, 1971; Tinoco; 1955, 1965/66, 1971, 1972). Almost all available information is contained in papers based on the study of empty tests.

Unfortunately only a few studies have differentiated between foraminiferids bearing protoplasm at collection time, and those which belong to the thanatocoenosis.

Murray (1968, 1973, 1976) proposed two criteria which are useful for characterizing foraminiferal associations:

a. Diversity. In order to determine they diversity the Fischer α index was used. Only samples with more than 100 specimens were evaluated. The following index values were obtained (fig. 2): α = 6 (128.00—125.40 m), α = 5 (125.40—124.00 m) and α = 8 (124.00—122.10 m).

b. Triangular plot of suborders. In plotting this diagram the occurence of the suborders Rotaliina-Miliolina-Textulariina is presented in percentile figures (fig. 2). This diagram although not a triangle, is similar in information presented (Murray, 1973, fig. 103).

2. ANALYSIS OF MICROFAUNAL MIXING

The distribution of the microfauna in shallow waters is affected to a large extent by displacement and mixing (Herm, 1969; Liebau, 1975). The forms found in a certain fossil assemblage do not exactly represent an ancient biotope. They do not automatically identify an ancient biocoenosis, neither in its qualitative or quantitative spectrum. The fossil fauna is a post mortum association resulting in the interaction of sedimentological factors such as transport; and fossil diagenesis. Through this mechanism a vertically mixed condensate is formed which incorporates epi- and endobenthic elements mixing those forms originating from the phytal with those of the pelagic environments. Studies made in one and the same region, in which living foraminiferids and empty tests were examined separately, demonstrate this phenomena clearly. Examples with special reference to foraminiferids are summarized by Boltovskoy (1965), Boltovskoy & Wright (1976), Grabert (1971), Pujos (1971) and Murray (1973, 1976). The transport originated by the current and the wave action can cause a selection or separation which is characteristic for the fossil microfauna. In contrast, submarine displacements or slumps can produce unmodified unmixed allochthonous faunal spectra.

The analysis of mixed microfaunal assemblages must be identified as to the autochthonous and allochthonous components which generally are contained in microfossil assemblages.

First it is necessary to establish the type of sediments in which the foraminiferids were found, and the type of preservation of its tests.

The sediment lithofacies were described by Antón & Armstrong (1973). Between 133.00—130.00 m loose quartz in size from coarse sand to granules was found. They contain pebbles of the "San Miguel" granophyre. The few foraminiferal tests that were found show evident abrasion signs and are size sorted. The sediments of the 130.00—128.00 m level of the core sample was made up of coarse quartz sands to granules sized particles. They also contain gravels of the "San Miguel" granophyre, which indicates the proximity of the sediment source.

Grain size decreases gradually, whereas the number of foraminiferal tests increases gradually. Between 128.00—125.40 m loose coarse quartz sand to granule deposites were found. Among 125.40—124.00 m fine quartz sand to granule deposits were found. Between 124.00 and 122.10 m level the sample shows fine quartzose sands. It is subangular and well sorted.

Preservation of the foraminiferal tests: The difference between autochthonous and allochthonous elements is primarily established with the help of *Amphistegina gibbosa* as this species is an excellent indicator for salinity, temperature and bathymetry (see pages 15—16).

The tests from the adult specimens of this species are found:

a) well preserved, frequently showing small fractures.

b) with polished exterior wall.

c) poorly preserved with large fractures.

This preservation observed from the tests of *Amphistegina gibbosa* can be explained by the following: 1) The tests come from a high energy biotope, where they are exposed to rolling in the substrate while still alive. 2) In high energy environments the tests are affected by postmortem transport. Only tests with thick and resistent walls are preserved, the rest is destroyed. 3) The effect of selective postmortem transport, that is governed by sedimentological laws, and consequently a size sorting.

At 122.10—125.40 m the tests of *Amphistegina gibbosa* constitute 12 % of the foraminiferal assemblages. The type a) and b) of preservation could be explained with the concept of the "rolled-abraded" foraminiferids (in German "Abroll" Foraminiferen) introduced by Liebau (1975, p. 375) who specially applied it to *Amphistegina*. The "rolled-abraded" foraminiferids are forms adapted to live in the sediment and are subject to rolling during life. These are adapted in life to a high energy biotope, where active sediment transport takes place. Generally the tests of the "rolled-abraded" foraminiferids are found in great numbers, and almost always evidence of rolling and abrasion is found. Therefore this preservation

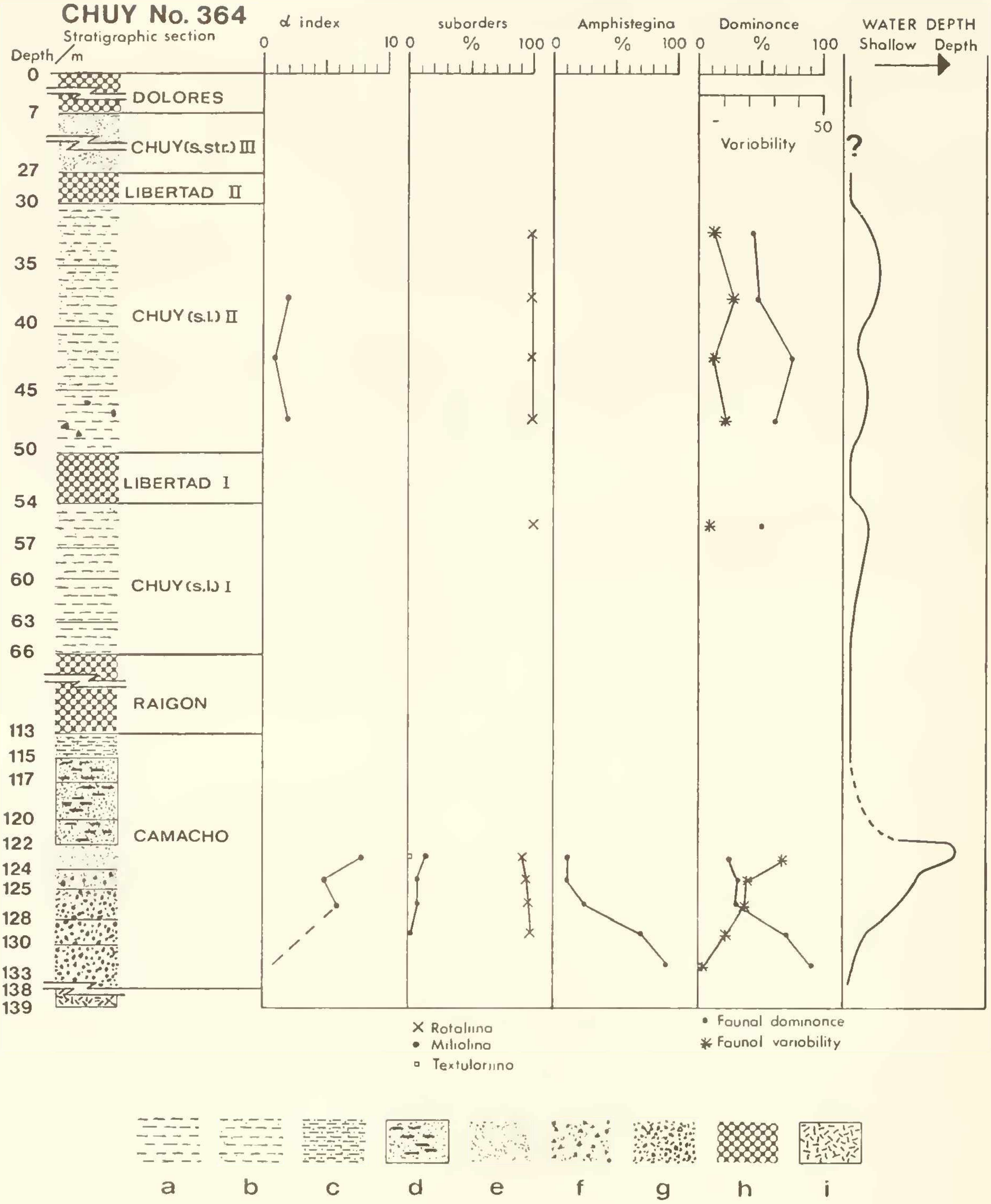

Fig. 2: Chuy N° 364 stratigraphic section. Different paramenters used in the text are plotted against the water depth. Key: a = mud, b = sandy silty mud, c = sandy mud, d = muddy sandstone, e = very fine to fine sands, f = poorly sorted sands of fine to granule quartz sand, g = coarse to granule sized quartz sand, h = terrestrial environments, i = bedrock. [Lithological section based on ANTON & ARMSTRONG's (1973) rock descriptions].

speakes for the fact that *Amphistegina gibbosa* is par-authochthonous. The term *par-authochtonous* is used according to Herm's (1969, p. 83) definition.

With the adult tests, juvenile specimens of *Amphistegina gibbosa* were also found. This fact confirms that this species is a par-autochthonous form. The presence of poorly preserved tests of *Amphistegina gibbosa* with large fractures and abrasions also points to the same cause as in 2) above.

The increase of the per cent fraction occurence of *Amphistegina gibbosa* between 125.40—133.00 m is directly proportional to the size of the sediments grains (fig. 2). That means that a selection takes place after death in connection with the fossil diagenesis, conserving the large and resistant tests, destroying the small and fragile ones. A size sorting effect also takes place.

Glauconitization of foraminiferids is frequent, and is confirmed by X-ray diffraction analysis. Glauconite fills the chambers and pores. Only rare specimens are filled with pyrite.

On the basis of these facts, the major part of the species are considered to be par-autochthonous. On the other hand, it is thought that *Miliammina fusca, Oolina melo, Lagena laevis* f. *perlucida* and *Lagena* sp. probably are allochthonous. This will be discussed later (see pages 17).

The relationship between numbers of species and per cent dominance gives additional criteria for the analysis of microfaunal mixing. It shows the relationship found, in each sample, between faunal variability and faunal dominance. In the Miocene associations found at 122.10—128.00 m stay within the normal variation range of the curve established by Walton (1964, fig. 26), which is typical for autochthonous assemblages.

3. POSSIBLE DEPOSITIONAL ENVIRONMENTS

In order to reduce the range of environmental possibilities the method proposed by Murray (1973) is applied, taking also into consideration the limitations indicated by Murray (1976). The summary diagram for the α index and the summary triangular plot are used (Murray, 1973, figs. 32, 101 and 102). The α index is very useful because it clearly restricts the environmental posibilities. The triangular plot, however, is not so obvious because the samples examined lie near the Rotaliina corner.

Synthesising both criteria, the environmental possibilities are reduced to: normal marine shelf seas, normal marine lagoons, and hypersaline lagoons.

In order to specify the environment the data given by the microfauna is used, in relation to the following factors:

a) Salinity. The α index values from 5 to 8 eliminate hypersaline environments.

The presence of the genus *Amphistegina* is most important. All finds known from the Present come from waters of normal marine salinity, or slight hypersality (Larsen, 1976; Murray, 1973). The species *Amphistegina lessonii* (and/or *Amphistegina radiata)* was also found on the atlantic South American coast in normal marine environments (Boltovskoy & Lena, 1966; Closs & Barberena, 1960b; Tinoco, 1965/66).

According to Murray (1973) the following genera contained in the analysed microfauna are characteristic for normal marine environments: *Amphistegina, Cassidulina, Cibicides, Buccella, Nonionella,* and *Textularia.* The fauna also includes the genera *Quinqueloculina* and *Miliolinella* (Miliolidae) which are characteristic for salinities above 32 per mil. The per cent incidence of these genera are:

Depth/m	122 124	124 125	125 128
Normal marine genera	75 %	88 %	84 %
Miliolidae	7 %	5 %	4 %
	82 %	93 %	88 %

The remaining genera can be found in normal marine conditions and also in hyper and hyposaline waters.

The presence of the bryozoan *Discoporella* gives an additional argument for the existence of a normal marine environment. Today this genus is virtually restricted to sands of the continental shelf (Driscoll, Gibson & Mitchell, 1971).

In summary, the faunas studied indicate normal marine salinities. Therefore *Miliammina fusca* is considered probably to be an allochthonous species, because it proliferated in hyper and hyposaline environments.

b) Temperature. *Amphistegina* is also important for determination of ancient temperatures during the Miocene, as was shown by Hornibrook (1968) and Tood (1976).

There are two points of view concerning the tolerance of *Amphistegina* to water temperature:

Murray (1973, p. 183—185) shows that *Amphistegina* is a stenothermal genus. All occurences in the oceans are encompassed by the 25°C surface-water isotherms for the southern and northern summers. The available information indicates that the critical temperature needed by *Amphistegina* for its reproduction seems to be close to 25°C. This genus can colonize areas where the water temperature is lower, but as it cannot reproduce, its colonization is temporary.

Larsen (1976, p. 18, 24) considers *Amphistegina* to be a tropical to warm subtropical genus. Its distribution can be limited by the 14° C winter isotherm of surface-water.

MURRAY and LARSEN used different criteria for their interpretation of the range of geographical distribution of *Amphistegina*. MURRAY considers the capacity of reproduction as the basic criterion. LARSEN cited laboratory experiments about the capacity of movement of different species of *Amphistegina* to suport his view.

At the present time, distribution of *Amphistegina* along the South American atlantic area confirms MURRAY's point of view. Today *Amphistegina* is only found north of 23° S latitude (BOLTOVSKOY, 1961, 1965, 1976; BOLTOVSKOY & LENA, 1966; BOLTOVSKOY & WRIGHT, 1976; CLOSS & BARBERENA, 1960b; RIBAS, 1971; RODRIGUES, 1968, 1971, 1972; TINOCO, 1965/66, 1971, 1972). It is a region of tropical warm waters, with mean annual temperatures higher than 24° C (BALECH, 1954). The surface-water temperatures range between 24° C in February and 21° C in August (BOLTOVSKOY, 1976, fig. 2).

Furthermore, adult and juvenile tests of *Amphistegina gibbosa* have been found in Chuy N° 364. This indicates the existence of high enough temperatures that the whole reproductive cycle of this species could be completed.

Cibicides aknerianus and *Cibicides "pseudoungerianus"* are the dominant species between 122.10 to 128.00 m. *Cibicides aknerianus* is a cosmopolitan species (BOLTOVSKOY, 1970a). The present geographical range covers warm and cold water bodies. This species is frequent along the coasts of the State of Pernambuco (BOLTOVSKOY & LENA, 1966) and in the Malvin or Falkland Islands area (BOLTOVSKOY, 1965, 1970a; BOLTOVSKOY & WRIGHT, 1976). *Cibicides "pseudoungerianus"* is considered to be actually a common form on the South Brazilian and Uruguayan shelf seas, between 21—35° S latitudes. It is also frequent in the littoral zone of Pernambuco (BOLTOVSKOY & LENA, 1966).

If we exclude the extinct forms, and the living ones such as *Miliammina fusca* and *Cassidulina subglobosa*, the remaining species belong to the present warm water faunas of the South American atlantic shelf areas. Most of them also live south of this parallel.

Rare specimens of *Buccella peruviana*, s. l. were found in the Miocene assemblages. The highest per cent occurence is 1,5 % in the 125.40—128.00 m level. This species is a characteristic living form in cold water bodies. Today its northermost occurence lies at 21°46'S latitude (BOLTOVSKOY, 1961, p. 257, 338). This species was also found in the Cabo Frio area (TINOCO, 1955). *Cassidulina subglobosa* is considered to be an indicator of the Malvinian current (PEREIRA, 1969).

It must be concluded that the analized microfaunas indicate warm water temperatures equivalent to those existing today in the Cabo Frio area. It must also be pointed out that during the Miocene the world mean annual temperatures were undoubtedly higher than today (BRASIER, 1975b; SCHWARZBACH, 1974).

c) Bathymetry. *Amphistegina* is also useful for bathymetric zonation. Different opinions are given in reference to its depth range. According to MURRAY (1973) *Amphistegina* possesses excellent reliability as a bathymetric indicator. All reported finds of this genus came from shallow waters (5—20 m, inner shelf). BOLTOVSKOY & LENA (1966) and BOLTOVSKOY & WRIGHT (1976) agreed with this point of view. In contrast other evidence is given that indicates that *Amphistegina* lived at somewhat greater depth (BANDY, 1956, 1964; BRASIER, 1975a; POAG & SIDNER, 1976; TINOCO, 1972). Additional data from the literature is summarized by LARSEN (1976, p. 18).

These apparent contradictions have been recently explained. TODD (1976) concluded that different species of *Amphistegina* have their major concentrations in different environments and different depths. Furthermore, there is a relationship between the shape of the tests of *Amphistegina* and the environment where it lives. Probably fragile and complanate tests imply deeper water more distant from shore, than the thick, heavy walled tests that would be more suitable to withstand the turbulence. LARSEN (1976, fig. 3) found that different species of *Amphistegina* live within distinct depth intervals. Shallow water species are thick shelled (small diameter/thickness ratio) while the deeper species are thin shelled. Generalizing, there is a variation from almost globular shallow species to almost plate-like depth species. This means that there is a general tendency towards increasing shape index with increasing depth (LARSEN, 1976, table 1). It is suggested that this is the consequence of a relationship between the surface area to the amount of incoming light, because this genus is dependant on symbionts.

The adult tests of *Amphistegina* found in Chuy N° 364 are thick or globular shaped and heavy walled. That means that they belong to the shallow water species, i. e. a shallow environment.

Other genera which are useful for bathymetric zonation are *Elphidium* and *Quinqueloculina*. Several *Elphidium* species are characteristic for shallow environments, particularly *Elphidium discoidale*. *Quinqueloculina* is regularly found on the inner shelf (BANDY, 1964; BOLTOVSKOY, 1965; BOLTOVSKOY & WRIGHT, 1976; MURRAY, 1973; WALTON, 1964). The remaining genera and/or species have a low reliability as far as depth zonation goes.

Moreover the foraminiferal fauna is different from that of the outer shelf. In the Miocene assemblages planktonic foraminiferids are absent. The benthic genera which are typically found in greater depths, such as *Nodosaria, Uvigerina, Fissurina, Gyroidina, Lenticulina, Lagena,* are nearly completely absent. In their diversity the investigated associations are also different from those of the outer continental shelf.

Summarizing, the assemblages indicate nearshore shelf environments.

d) Substrate. The facies found between 122.10—133.00 m are made up of sandy deposits that were accumulated during a progressive overlap.

Lists were made that established relationships between the substrate type and the distributional pattern of certain genera and/or species of benthic foraminiferids (BOLTOVSKOY, 1965; BOLTOVSKOY & WRIGHT, 1976; MURRAY, 1973). Sometimes the data offered are contradictory. This is also valid for *Amphistegina* (LARSEN, 1976, p. 17, 18; MURRAY, p. 185, 248). This difference originates in the fact that many genera and/or species do not possess a strict dependence on a certain facies type. Deposits formed by unconsolided sands are characterized by a lack of or low vegetation growth. This fact could partially explain the absence of *Peneroplis, Marginopora, Amphisorus,* and other common genera that actually develop in the warm water zone of the South American atlantic coast. These genera grow on sea flora, especially seagrasses (BRASIER, 1975b; MURRAY, 1973). This fact could also explain the low abundance of other Miliolids. It must be noted that sea grasses are today, significantly, absent from the major part of the South American coasts, except the tropical Atlantic region and a few finds from Chile and Argentina. This fact is related to the evolution of the seagrass communities in this region (BRASIER, 1975b; HARTOG, 1970).

According to MURRAY (1973) the genera *Oolina* and *Lagena* live on muddy sediments. Therefore *Oolina melo, Lagena laevis* f. *perlucida* and *Lagena* sp. could be considered as allochthonous forms.

4. PALEOECOLOGICAL RESULTS SUPPORTED BY FORAMINIFERAL ASSOCIATIONS

The foraminiferids indicate a normal marine shallow environment with warm waters. The substrate probably had no sea flora cover.

No studies have been made of living foraminiferids from normal marine lagoons in the South American tropical region that could be used to establish relationships. Using available information, a normal marine lagoon as a possible depositional environment is rejected. The present living foraminiferal assemblages found in this type of lagoon differ clearly from the associations found in the Chuy drilling (see MURRAY, 1973, table 12).

The characteristics of the foraminiferal assemblages of Chuy N° 364 are similar to the idealized depth zonation on a continental shelf gived by MURRAY (1973, p. 168). This shows a nearshore shelf environment, particularly within the turbulence zone. The foraminiferal assemblage possess a low diversity ($\alpha = 5—8$) and the triangular plot show an evident predominance of Rotaliina (fig. 2). The values are typical for this idealized depth zone. The value number of the faunal variability and the faunal dominance also indicates the same environment, according to WALTON's (1964) method.

This environment is related to a nearshore sedimentation zone. The assemblages are par-autochthonous and distinctive for high energy moving waters. A rolling of the microfossils during life is evident. The empty tests can also be worn down by rolling after death. Subsequently glauconitization took place. This type of fossilization can be explained at least in the following ways:

a) A fraction of the test were transported to an adjacent area, where somewhat lower energy conditions exist. The test accumulated in a basin or a pan situated on the shelf sea. This acted as a trap, where a great number of tests, larger fossil debris, and organic matter was accumulated. This process was described by WHATLEY & WALL (1969). In this situation slight reduction conditions appear, which produce the glauconitization.

b) Weak influence of hyposaline waters or fluviatile sediments led to slight anaerobic conditions. In this situation glauconitization took place as described by SEIGLE (1970) in the Yabucoa Bay. Large fluviatile influences prevent glauconitization. SELLEY (1976, p. 78) points out that glauconite occurs in ancient sediments of marine origin.

In high energy waters a reworking of the foraminiferids took place. These reworked tests are mostly glauconitized and subsequently rolled. This foraminiferal preservation is typical for this kind of depositional environment.

The following events occured during a transgression. Information found at the 133.00—130.00 m level of the sample indicate the beginning of the transgression. The greatest water depth was reached at the 124.00—122.10 m level of core sample. Here the foraminiferal assemblage has its major diversity and abundance. The sandy deposits contain the finest grain sizes, and are well sorted.

The foraminiferal assemblages also indicate the existence of a transgressive sequence. This is shown by an increase in the faunal variability, and a decrease in the faunal dominance (fig. 2). Both concepts are used according to WALTON's (1964) criteria.

The fossil assemblages found between 122.10—113.00 m contain only molluscan fragments and barnacle plates. No microfossils are present. This sequence may have been deposited during a regression.

VI. QUATERNARY

A. General considerations and previous works on foraminiferal microfaunas

During the Quaternary only local transgressions took place in the South American atlantic borderland. This fact explains the low number of papers referring to Quaternary foraminiferids in this zone.

In Uruguay studies were made only by Closs (1966a) and Closs & Madeira (1968a). Brief references are also given by Bertels & Madeira-Falcetta (1977) and Closs (1970).

The present knowledge of the Quaternary foraminiferal associations found in Brazil is summarized by Bertels & Madeira-Falcetta (1977). Quaternary sequences of bore-holes drilled in the Pelotas Basin contain foraminiferal associations characterized by low diversities. Only 15 benthic and a single planktonic species were found (Closs, 1970).

In Argentina the exposures show littoral deposits, lying subparallel to the shore, from Buenos Aires to the southernpart of the country. The foraminiferal assemblages also have low diversities (Bertels, 1975; Bertels & Madeira-Falcetta, 1977; Boltovskoy, 1959b; de Carli & Farinati, 1975; Malumian, 1970).

B. Distribution of the microfossils and macrofossils

The distribution of the associations found in each bore-hole and outcrop is given in Tables III—XVII. The geographic location of the wells and exposures, and the identified stratigraphic units, are also presented. Complete lithological profiles of the bore-holes are not given for the following reasons: 1) previous publication, 2) no autorization was obtained for the publication of the remaining geological sections.

PUEBLO SAN LUIS (WELL) N° 1072/I

Well location: Pueblo San Luis, Rocha County (Lat. 33°36' S, Long. 53°43' W). Length of drill column: 42 m.

Paleontology: Distribution of fossils is shown in Table III.

TABLE III
Faunal distribution in San Luis N° 1072/I

Depth/m	21 25	25 28	28 29	29 30	30 32	32 35	35 36
FORAMINIFERA							
Ammonia beccarii var. *parkinsoniana*	•		•	——			
Elphidium discoidale			•	—			
Elphidium gr. *excavatum*				•			
Elphidium galvestonense				•			
Elphidium gunteri				••			
Elphidium div. spp. indet.	••	••	••	——			
BIVALVIA							
Pitar (P.) rostrata							x
debris	x	x	x	x	x	x	x
GASTROPODA							
Littoridina sp.				x			
debris				x			
OSTRACODA	x		x	x			x
BALANOMORPHA							
barnacle plates					x		
PLANTAE							
debris					x		

References: Numbers of foraminiferids: • (1) •• (2—5) — (6—10) —— (11—20)

Lithostratigraphic units: These are established using the criteria indicated in Chapter VII. The following units were identified: Raigón Formation (42—36 m), Chuy (sensu lato) I (36—21 m), Libertad I (21—17 m), Chuy (sensu lato) II (17—6 m), and Libertad II (6—0 m).

CHUY (WELL) N° 364

Well location and previous studies: See Chapter V—A and V—B.

Distribution of Quaternary micro- and macrofauna: is indicated in Table IV.

TABLE IV
Faunal distribution in Chuy N° 364

Depth/m	2 7	30 35	35 40	40 45	45 50	54 57	57 60	60 63	63 66
FORAMINIFERA									
Ammonia beccarii var. *parkinsoniana*		———	▬	▭	▭	— —			
Bolivina striatula			—		••				
Bolivina sp.			—	••					
Buccella peruviana, s. l.		••	•		—				
Bulimina cf. *affinis*					•				
Buliminella elegantissima		—	▭	—	••				
Cibicides "pseudoungarianus"					•				
Discorbis sp.?					•				
Elphidium discoidale		••	———	—	— —	••			
Elphidium gr. *excavatum*		••	———	••	— —	••			
Elphidium gunteri			••		— —				
Elphidium sp. B			•						
Elphidium div. spp. indet.		— —	— —	— —	———	—			
Fissurina laevigata			•						
Fissurina sp.			•						
Quinqueloculina sp.			•						
(+)									
BIVALVIA									
Erodona mactroides						x	x	x	x
debris					x	x	x	x	x
OSTRACODA									
Argilloecia			x						
Bensonia			x						
Callistocythere			x		x				
Cyprideis			x	x	x	x			
Cytherella					x				
Cytheropteron				x	x				
Harmanites?				x					
BALANOMORPHA									
Balanus sp. (barnacle plates)		x	x	x		x			
ECHINOIDEA-IRREGULARIA									
spines			x						
PLANTAE									
pollen	x	x							

(+) Closs & Madeira (1968a) also recorded the presence of *Elphidium galvestonense* between 54.20—57.60 m.

References: Numbers of foraminiferids:
• (1)
•• (2—5)
— (6—10)
— — (11—20)
——— (21—40)
▭ (81—160)
▬ (> 160)

Stratigraphy: See Chapter VII.

COSTA AZUL (WELL) N° 1060/1

Well location and previous studies: This bore-hole was drilled in Balneario Costa Azul, in the property of O.S.E., Rocha County (Lat. 34°37' S, Long. 54°09' W) and attained the depth of 66 m. The lithofacies of this well were described by Da Silva (1975).

Paleontology: The distribution of the micro- and macrofauna is shown in Table V.

TABLE V
Faunal distribution in Costa Azul N° 1060/1

Depth/m	19 21	21 25	25 28	28 32
FORAMINIFERA				
Ammonia beccarii var. *parkinsoniana*	□□□	••	•	•
Buccella peruviana, s. l.	▬	———	•	••
Buliminella elegantissima	—			
Cibicides aknerianus	•			
Discorbis peruvianus	•	•		
Discorbis gr. *vilardeboanus*	••			
Discorbis williamsoni f. *praegeri*	— —			•
Discorbis gr. sp. "A"	•			
Discorbis div. spp. indet.	•	••		••
Elphidium discoidale	———	••	•	
Elphidium gr. *excavatum*	—			
Elphidium gunteri	••			
Elphidium div. spp. indet.	••	•		•
Guttulina problema	•			
Oolina melo	•			
Poroeponides lateralis	•	•		
Pyrgo nasuta	•			
Pyrgo ringens patagonica	•			
Quinqueloculina seminulum	•			
Quinqueloculina sp.	•			
Rosalina sp. ?	•			
Textularia sp.	•			
BIVALVIA				
Amiantis purpurata	x	x	x	
Brachidontes (B.) rodriguezi	x	x		
Corbula caribaea	x			
Corbula lyoni		x		
Corbula sp.	x		x	
Crassinella cf. *maldonadoensis*	x			
Mactra patagonica	x	x		
Mactra sp.	x	x	x	
Mytilus sp.	x			
Ostrea sp.	x			
Plicatula cf. *gibbosa*			x	

TABLE V (continued)
Faunal distribution in Costa Azul N° 1060/1

Depth/m	19 21	21 25	25 28	28 32
GASTROPODA				
Caecum sp.	x			
Crepidula aculeata	x			
Epitonium aff. *unifasciatum*		x		
Halistylus cf. *columna*	x		x	
Ocenebra cala		x		
Olivella (O.) cf. *tehuelcha*	x			
OSTRACODA	x	x		x
BALANOMORPHA				
Balanus sp. (barnacle plates	x	x	x	
MALACOSTRACA				
cheliped	x			
BRYOZOA	x			
ECHINOIDEA-CLYPEASTEROIDEA				
Mellita sp.		x		
ECHINOIDEA-IRREGULARIA				
spines	x	x		

References: Numbers of foraminiferids:

•	(1)	••	(2—5)
—	(6—10)	— —	(11—20)
———	(21—40)	□□□	(41—80)
■	(> 160)		

LA PALOMA (WELL) N° 482/1

Well location and previous studies: La Paloma City, Rocha County (Lat. 34°39′ S, Long. 54°09′ W), in the Parque Andrecito. Length of drill column: 73.30 m. The lithofacies were described by DA SILVA (1975) and SCARABINO (1974).

Paleontology: The first paleontological approach of the well was given by SCARABINO (1974), who mainly studied the macro-molluscs, which are marked with "S" in Table VI. The disintegration of the drill cuttings with H_2O_2 for micropaleontological porposes gave scarce foraminiferids. Small and juvenile molluscs were also found, which are marked with "x" in Table VI. The fossils are mostly abraded and transported.

TABLE VI
Faunal distribution in La Paloma N° 482/1

Depth/m	3.9 5.8	5.8 7.8	7.8 9.0	9.0 10.0	10.0 10.9	10.9 12.9	12.9 13.9	13.9 18.0
FORAMINIFERA								
Ammonia beccarii var. *parkinsoniana*	•							
Buccella peruviana, s. l.	••							
Discorbis williamsoni f. *praegeri*	•							
Poroeponides lateralis					••			
Quinqueloculina sp.	•							
BIVALVIA								
Abra uruguayensis			x					
Amiantis purpurata			S					
Brachidontes (B.) rodriguezi	x		x		x			
Cardita (C.) plata			x		x			
Chlamys tehuelcha			S		S			
Crassinella cf. *guadalupensis*					x			
Crassinella maldonadoensis			x					
Glycymeris longior		S	S				x	x
Mactra isabelleana	x		S	S	S		x	
Mactra cf. *marplatensis*		x						
Mytilus platensis			S		x			x
Ostrea equestris			S		S	S		x
Ostrea puelchana			S		S			
Ostrea sp.				x	x	x	x	
Sphenia hatcheri			x					
Strigilla (R.) cf. *rombergii*	x							
GASTROPODA								
Anachis isabellei			x				x	
Anachis moleculina							x	
Caecum (Caecum) sp.			x					
Calliostoma sp.?			x					
Crepidula aculeata			S		x			
Crepidula protea			x		S			
Halistylus columna	x		S		S		x	
Odostomia (C.) aff. *jadisi*			x					
Odostomia sp.?			x					
Olivella (O.) tehuelcha			x					
Tegula (A.) cf. *patagonica*			x					x
Turbonilla (Bartschella) sp.			x					
Turbonilla (Strioturbonilla) sp.			x					
Turbonilla sp.					x			
Urosalpinx rushi			x		x			
Vitrinellidae?			x					
OSTRACODA	x				x			
BALANOMORPHA								
Balanus sp. (barnacle plates)	x			x	x		x	x
BRYOZOA	S		S					
SERPULIDAE			x					
PLANTAE								
debris					x			

References: Numbers of foraminiferids: • (1) •• (2—5)

PUERTO LA PALOMA (WELL) N° 449/11

Well location and previous studies: La Paloma, Rocha County (Lat. 34°39′ S, Long. 54°09′ W). The bore-hole was drilled in the Puerto Nuevo area. Length of drill column: 8.50 m. DA SILVA (1975) and SCARABINO (1974) described the lithofacies.

Paleontology: The macro-molluscs were described by SCARABINO (1974), and mare marked with "S" in Table VII. Micropaleontological study allowed identification of foraminiferids and micro-molluscs. The latter are marked in Table VII with "x". The microfossils of the 7.50—8.00 m drill cutting level were found in 140 cm³ of sediment. The tests were separated out by flotation in CCl_4. In this way more information about diversity and faunal spectrum is obtained. The microfauna of the remaining drill cutting was prepared in H_2O_2 using 35—40 cm³ of sediment.

TABLE VII

Faunal distribution in Puerto La Paloma N° 449/11

Depth/m	0.0 0.5	0.5 2.5	2.5 3.5	3.5 4.5	4.5 5.0	5.0 6.5	6.5 7.5	7.5 8.0	8.0 8.5
FORAMINIFERA									
Ammonia beccarii var. *parkinsoniana*			••		••		•	—	
Baggina sp.?								•	
Buccella peruviana, s. l.	———	••	— —	—	— —	———	— —	■	••
Cibicides aknerianus								••	
Dentalina communis								•	
Discorbis peruvianus		•	••					•	
Discorbis williamsoni f. *praegeri*					•			— —	
Discorbis sp.								•	
Elphidium discoidale	••		••	•	••	•	••	———	•
Elphidium gr. *excavatum*								••	
Elphidium galvestonense								•	
Elphidium gunteri	•				•	•		••	
Elphidium div. spp. indet.	••	•	••	••			•		
Flintinella sp.								•	
Guttulina plancii						•			
Miliolinella subrotunda	••		•	•		•	•	———	
Miliolinella sp.			••					••	
Oolina melo								•	
Poroeponides lateralis	— —		••	—	— —	— —	— —	▭	••
Pyrgo nasuta								•	
Pyrgo ringens patagonica		•			•		••	••	•
Pyrgo sp.							••		
Quinqueloculina angulata f. *typica*								•	
Quinqueloculina atlantica							•	••	
Quinqueloculina aff. *frigida*					•				
Quinqueloculina intricata								•	
Quinqueloculina seminulum	••	•	•	••	••	•	••	— —	•
Quinqueloculina sp. D								•	
Quinqueloculina sp. E								—	
Quinqueloculina div. spp. indet.	••			••	—	•	••	— —	•
Textularia gramen							•		
Textularia sp. B								•	

References: Numbers of foraminiferids:

• (1)
•• (2—5)
— (6—10)
— — (11—20)
——— (21—40)
▭ (81—160)
■ (> 160)

TABLE VII
Faunal distribution in Puerto La Paloma N° 449/11
(continued)

Depth/m	0.0 0.5	0.5 2.5	2.5 3.5	3.5 4.5	4.5 5.0	5.0 6.5	6.5 7.5	7.5 8.0	8.0 8.5
BIVALVIA									
Brachidontes (B.) rodriguezi	S	S	S	S	x	S	x	S	x
Cardita (C.) plata			x			x		S	
Crassinella guadalupensis						x			
Crassinella maldonadoensis	x			x	S	x	x	x	
Diplodonta vilardeboana				S					
Glycymeris longior		S	x	S	S	S	S	S	x
Mactra isabelleana	S	S	S		S		S	S	
Mactra marplatensis			x			x			
Mactra sp.	x		x				x		x
Mytilus platensis				S				S	
Ostrea equestris?	S								
Ostrea puelchana		S		S			S	S	
Ostrea sp.	x								
Petricola sp.				x					
Pleuromeris sanmartini				x					
Sphenia hatcheri				x					
GASTROPODA									
Acmaea subrugosa		S		S			S	S	
Buccinanops sp.			x						
Caecum (Brochina) sp.						x		x	
Caecum sp.	x			x					
Crepidula aculeata		S	x	S	S	S		S	
Crepidula protea					S				
Diodora patagonica						S	S		
Epitonium sp.					S				
Halistylus columna	S		x	x	x	S	S	x	
Littoridina australis	S								
Ocenebra cala	x		x	S			x		
Olivella (O.) puelcha		S			S		S		
Olivella (O.) tehuelcha				S					
Tegula (A.) patagonica							S	S	
Triphora sp.			x			S			
Turbonilla sp.	x								
Urosalpinx rushi		S			S	x	S		
POLYPLACOPHORA									
Chaetopleura isabellei							S		
Chaetopleura sp.			x						
OSTRACODA	x	x	x	x	x	x	x	x	x
BALANOMORPHA									
Balanus sp. (barnacle plates)	x	x	x	x	x	x	x	x	
BRYOZOA	x		x	x	x	x	x	x	x
ECHINOIDEA-IRREGULARIA									
spines	x				x				
ALGAE	x	x	x	x	x	x	x	x	x

LA CORONILLA (WELL) N° 811

(Lat. 33°54′ S, Long. 53°31′ W). Unfossiliferous.

OCÉANO ATLÁNTICO (WELL) N° 521/1

(Lat. 34°20′ S, Long. 53°48′ W). Unfossiliferous.

18 DE JULIO (WELL) N° 801/1

(Lat. 33°41′ S, Long. 53°33′ W). Unfossiliferous.

LAGUNA DEL SAUCE (WELL) N° 861/1

Located in the property of I.G.G.A.M. Uruguay; 8 km north of the km. 119.5 of the national road N° 5, in Maldonado County. Unfossiliferous.

PIRIÁPOLIS (WELL) N° 431/7

Well location and previous studies: Piriápolis City, Maldonado County (Lat. 34°53′ S, Long. 55°16′ W), in the Jardín de los Angeles district. Length of drill column: 23 m. Maytía de Scarabino (1974) described the lithofacies and molluscs of this bore-hole (Table VIII). *Littoridina australis* was shown to be the dominant species between 5.50—7.00 m.

Paleontology: No foraminiferids were found.

TABLE VIII
Faunal distribution in Piriápolis N° 431/7

Depth/m	5.5 7.0	7.0 9.0
BIVALVIA		
Anomalocardia brasiliana	x	x
Ostrea puelchana	x	
GASTROPODA		
Littoridina australis	x	x
OSTRACODA	x	

SALINAS (WELL) N° 1034/1

Well location and previous studies: Salinas, Canelones County (Lat. 34°46′ S, Long. 55°49′ W), in the place of the O.S.E. reservoir tank. Length of drill column: 72.70 m. The lithofacies of this bore-hole were studied by Da Silva (1975).

Paleontology: The distribution of the fossils found is shown in Table IX.

TABLE IX
Faunal distribution in Salinas N° 1034/1

Depth/m	28 31	31 32	32 34	34 37	37 39
FORAMINIFERA					
Ammonia beccarii var. *parkinsoniana*		• •	—	• •	•
Bolivina striatula		•	— —		•
Bolivina div. spp. indet.	•	• •	—		
Buccella peruviana, s. l.			—	• •	
Buliminella elegantissima	• •	• •	□ □ □	—	• •
Cibicides aknerianus			• •		
Discorbis sp.			•		
Elphidium discoidale	• •	• •	□ □ □	• •	• •
Elphidium gunteri			•		
Elphidium div. spp. indet.	• •	• •	— —	—	• •
Fissurina laevigata			• •		
Lagena laevis f. *perlucida*			•		
Lenticulina limbosa			•		
Nonionella atlantica			• •		
Nonion tisburyensis			• •		
Pyrgo nasuta			• •		
Pyrgo sp.			•	•	
Reophax artica			•		
BIVALVIA					
debris	x	x	x	x	x
OSTRACODA	x		x	x	x
BALANOMORPHA					
Balanus sp. (barnacle plates)			x		
ECHINOIDEA-IRREGULARIA					
spines			x		

References: Numbers of foraminiferids:
• (1) • • (2—5)
— (6—10) — — (11—20)
□ □ □ (41—80)

SAN JOSÉ DE CARRASCO (WELL) N° 442/1

Well location and previous studies: San José de Carrasco, Canelones County (Lat. 34°51′ S, Long. 55°58′ W). Length of drill column: 73 m. MAYTÍA DE SCARABINO (1974) described the lithofacies and the molluscs belonging to the macrofauna. These are marked on Table X with "MS". The micropaleontological study allow the identification of foraminiferids; juvenile and micromolluscs. They are marked in Table X with "x".

TABLE X
Faunal distribution in San José de Carrasco N° 442/1

Depth/m	11 13	13 17	17 18	18 19	19 21	21 23
FORAMINIFERA						
Ammonia beccarii var. *parkinsoniana*	•	• •	— —			
Bolivina striatula			•			
Bolivina sp.		•	• •			
Buccella peruviana, s. l.	• •	———	□□□			
Buliminella elegantissima		•	• •			
Discorbis williamsoni f. *praegeri*			•			
Discorbis sp.			•			
Elphidium discoidale	• •	—	— —			
Elphidium cf. *discoidale*			•			
Elphidium galvestonense			• •			
Elphidium div. spp. indet	•	• •	—			
Miliolinella sp.			•			
Poroeponides lateralis	•	•	• •			
Quinqueloculina div. spp. indet.	• •	—	———			
Triloculina sp.			• •			
BIVALVIA						
Chlamys cf. *tehuelcha*			MS			
Chlamys sp.			x			
Mactra isabelleana	MS	MS		MS	MS	
Mactra marplatensis		x			x	
Mactra sp.		x	x			
Ostrea equestris	MS	MS	MS			
Ostrea puelchana		MS	MS			
Ostrea sp.			x			
Pitar (P.) cf. *rostrata*			MS			
debris	MS	MS	MS	MS	MS	
GASTROPODA						
Anachis sp.?			x			
Buccinanops gradatum		MS				
Crepidula aculeata	MS					
debris	x		x	x	x	
OSTRACODA			x			
BALANOMORPHA						
Balanus sp. (barnacle plates)	x	x	x	x		x
BRYOZOA	x	x	x			
PLANTAE						
debris				x		

References: Numbers of foraminiferids:

• (1)	• • (2—5)
— — (6—10)	—— (11—20)
——— (21—40)	□□□ (41—80)

ARENERAS CALCAGNO

Location and previous studies: This exposure is situated in Avenida Calcagno, 600 m, SE of the Camino Carrasco, near Arroyo Carrasco, Canelones County (Lat. 34°52′ S, Long. 56°03′ W). The molluscs of this outcrop were described by FIGUEIRAS (1962, 1967, 1973) and DE MATA (1947), and were assigned to the Vizcaíno Formation. The foraminiferids of this outcrop were studied by SICARDI (1969), as shown in Table XI.

TABLE XI
Faunal distribution in Areneras Calcagno

Dominant species: *Elphidium discoidale*, *Buccella peruviana*, s. l.

Frequent species: *Ammonia beccarii* var. *parkinsoniana*, *Discorbis williamsoni* f. *praegeri*,
In decreasing frequency were also reported: *Buliminella elegantissima*, *Bolivina striatula*, *Poroeponides lateralis*, *Quinqueloculina seminulum*, *Oolina costata*, *Pyrgo nasuta*, *Pyrgo ringens*, *Lagena laevis* and *Nonionella* sp. Fragmentary tests of Miliolidae and Nonionidae were also reported.

PARQUE LECOCQ

Location and previous studies: This outcrop is situated in the Zoológico Municipal, in Parque Lecocq, Montevideo County (Lat. 34°47′ S, Long. 56°10′ W). DA SILVA (1975) described the lithofacies and stratigraphy of this locality. Exposures of similar characteristics were described in the same area by CARDELLINO & FERRANDO (1965, 1969). The microfaunas found in 80 cm³ of sediment from each sample are shown in Table XII. The tests were separated in CCl_4.

TABLE XII
Faunal destribution in Parque Lecocq

Depth/m below surface scooped out by shovel	0.3	0.5	0.6	0.7	0.9	1.0	1.1	1.2
FORAMINIFERA								
Ammonia beccarii var. *parkinsoniana*	•	•	— —	———	• •	□□□	———	———
Bolivina compacta						• •		• •
Bolivina cf. *lomitensis*			•			—		• •
Bolivina cf. *variabilis*						• •		
Bolivina sp.			• •					• •
Discorbis peruvianus			•					
Discorbis gr. *vilardeboanus*			•					
Discorbis sp.						•		•
Elphidium discoidale		• •	• •	• •		—	— —	— —
Elphidium galvestonense			—	— —	• •	□□□	• •	— —
Elphidium gunteri		•				—	• •	•
Elphidium div. spp. indet.				• •		• •	• •	• •
OSTRACODA		x		x	x	x		x
BALANOMORPHA								
Balanus sp. (barnacle plates)			x					

References: Numbers of foraminiferids:
• (1)   • • (2—5)
— (6—10)   — — (11—20)
——— (21—40)   □□□ (41—80)

The faunal spectrum of the molluscs is as follows:

BIVALVIA: *Anomalocardia brasiliana*, *Brachidontes (H.) darwinianus mulleri*, *Corbula caribaea*, *Corbula patagonica*, *Erodona mactroides*, *Mactra isabelleana*, *Mytilus platensis*, *Ostrea* cf. *equestris*, *Ostrea puelchana*, *Ostrea* sp., *Tagelus plebeius*.

GASTROPODA: *Acmaea subrugosa*, *Acteocina* sp., *Anachis isabellei*, *Anachis paessleri*, *Austroborus lutescens*, *Buccinanops globulosum*, *Crepidula aculeata*, *Crepidula protea*, *Littoridina australis*, *Littoridina charruana*, *Odostomia* sp., *Parodizia uruguayensis*, *Rissoa* sp.?, *Scolodonta* sp., *Siphonaria (P.) lessoni*, *Triphora medinae*.

Lithostratigraphic unit: Vizcaíno Formation.

RINCÓN DE LA BOLSA (WELL) N° 754

Well location and previous studies: This well was drilled in the Delta del Tigre disctrict, 193 m to the south of the water reservoir tank, San José County. Length of the drill column: 810 m. The lithofacies and stratigraphy were described by BOSSI (1966), CARDELLINO & FERRANDO (1969) and GOSO (1965). The following lithostratigraphic units were identified: Vizcaíno Formation (0—4 m); Raigón Formation (4—6 m); Fray Bentos Formation (6—95 m); Miguez Formation (95—801 m); Precambrian (801—810 m).

Paleontology: The disintegration of samples of drill cuttings using H_2O_2 only allowed the identification of fossil assemblages in the strata belonging to the Vizcaíno Formation (Table XIII).

TABLE XIII
Faunal distribution in Rincón de la Bolsa N° 754

Depth/m	1.5 2.8	2.8 4.0
FORAMINIFERA		
Ammonia beccarii var. *parkinsoniana*	▬	—
Elphidium discoidale	□□□	• •
Elphidium cf. *discoidale*	•	
Elphidium gr. *excavatum*	———	
Elphidium galvestonense	—	
Elphidium gunteri	— —	•
Elphidium div. spp. indet	— —	• •
BIVALVIA		
Corbula caribaea	x	
Ostrea sp.	x	
debris	x	x
GASTROPODA		
Littoridina sp.?	x	
debris	x	
OSTRACODA	x	x
BALANOMORPHA		
Balanus sp. (barnacle plates)	x	

References: Numbers of foraminiferids:

•	(1)	• •	(2—5)
—	(6—10)	— —	(11—20)
———	(21—40)	□□□	(41—80)
▬	(> 160)		

JUAN LACAZE (WELL) N° 291/1

Well location and previous studies: Juan Lacaze City, Colonia County (Lat. 34°26′ S, Long. 57°26′W). Length of drill column: 118 m. The lithofacies and stratigraphy were described by Da Silva (1975) and Serra (1943). Only shark teeth were identified between 20.70 and 21.70 m.

CARMELO (WELL) N° 245/1

Well location and previous studies: Carmelo City, Colonia County, in the property of the Usina de Filtración y Bombeo, O.S.E. (Lat. 33°59′ S, 58°17′ W). Length of drill column: 45.30 m. The lithofacies and stratigraphy of the bore-hole were described by Da Silva (1975) and Serra (1943). The strata of the Vizcaíno Formation are found between 0 and 19 m, and those of the Fray Bentos Formation between 19 and 37 m.

Paleontology: Only molluscs were found, whose distribution is shown in Table XIV. The presence of *Erodona mactroides* in the 9 to 17 m drill cutting is given according to Serra (1943).

TABLE XIV
Faunal distribution in Carmelo N° 245/1

Depth/m	0.0	7.5	9.0
	7.5	9.0	17.0
BIVALVIA			
Brachidontes (H.) cf. *darwinianus mulleri*	x		
Chione sp.		x	
Erodona mactroides	x	x	x
Mactra isabelleana	x		
Ostrea sp.		x	
Pitar (P.) rostrata	x		
Tagelus cf. *plebeius*	x		
GASTROPODA			
Littoridina australis	x	x	
Littoridina charruana	x	x	
BALANOMORPHA			
Balanus sp. (barnacle plates)	x	x	

CARMELO (WELL) N° 235

Well location and previous studies: Carmelo City, 300 m north of Carmelo N° 245/1, Colonia County. The lithofacies and stratigraphy were described by Serra (1943).

Paleontology: Fossils were found in strata of the Vizcaíno Formation, as indicated in Table XV.

TABLE XV
Faunal distribution in Carmelo N° 235

Depth/m	1	3	7	11	15	18	23	31
	3	7	11	15	18	23	26	37
BIVALVIA								
Erodona mactroides		x	x	x	x	x	x	x
Mytilus sp.?		x						
Ostrea sp.		x						
Tagelus cf. *plebeius*			x	x	x			
GASTROPODA								
Littoridina australis		x	x	x	x			
Littoridina sp.?	x							
MOLLUSCA								
debris	x		x		x			x
PLANTAE								
debris								x

RIO URUGUAY (WELL) N° 445/1

Well location and previous studies: In the nearness of the Río Uruguay and Río San Salvador confluence, Soriano County. Length of drill column: 31.20 m. The lithofacies were studied by DA SILVA (1975).

Paleontology: The assemblages found are shown in Table XVI.

TABLE XVI
Faunal distribution in Río Uruguay N° 445/1

Depth/m	10.0 20.0	20.0 25.0	25.0 31.2
BIVALVIA			
Brachidontes (H.) cf. *darwinianus mulleri*	x		
Erodona mactroides	x	x	x
GASTROPODA			
Littoridina australis	x	x	
OSTRACODA			x

SORIANO (WELL) N° 483/2

Well location and previous studies: Soriano City, Soriano County (Lat. 33°24′ S, Long. 58°19′ W). Length of drill column: 78 m. The lithofacies of this bore-hole were studied by DA SILVA (1975).

Paleontology: See Table XVII.

TABLE XVII
Faunal distribution in Soriano N° 483/2

Depth/m	14.0 17.0	26.0 26.7	43.0 48.0	48.0 51.0	51.0 51.5
BIVALVIA					
Erodona mactroides		x	x	x	x
debris	x	x	x		

C. Ages of the fossil assemblages

1) FORAMINIFERIDS:

Large differences were found between the microfaunas of the Miocene and the Quaternary in regard to:

a) the faunal spectrum. Whereas the Miocene assemblages indicate warm climate, the Quaternary ones are typical of cold temperate waters, being similar with the biocoenosis of this area.

b) their diversities. The Miocene assemblages are more diversified than the Quaternary ones. During the Quaternary sedimentation took place in estuarine and marginal marine environments, whereas in the Miocene generally deeper water is indicated.

c) the preservation and coloration of the tests (CLOSS, 1970 p. 35).

2) MOLLUSCS:

The faunal spectrum of the Quaternary associations are analogous with the living ones.

In reference to age the fossil assemblages do not allow for a more precise fine-stratigraphy within the Quaternary strata.

3) THE AGE OF QUATERNARY FORMATIONS WITH MARINE FOSSILS:

Chuy Formation: According to DELANEY (1963, 1965, 1966, 1967, 1969?) the Chuy Formation was deposited as a beach or bar deposit during the last Pleistocene interglacial. BERTELS & MADEIRA-FALCETTA (1977), GOÑI & HOFFSTETTER (1964), GOSO (1972) and TRICART (1972) also considers the Chuy Formation as belonging to the Pleistocene. Antón (1975) also placed this formation in the Pleistocene, particularly in the Belgranense Stage. Closs (1970) indicated a Pleistocene age, but considered a Holocene age as possible. Holocene age is proposed by Closs & Forti (1971). Jost, Pinto & Loss (1972) considered the top of the formation to probably be of lower Holocene age, whereas Jost (1972) included this unit in the upper Pleistocene, lower and middle Holocene.

There is a general agreement between previous workers that the Chuy Formation was deposited during a time of high sea level. The regional geologic history during the upper Pleistocene and Holocene (Chapter VI-E) shows: a) the existence of Holocene high sea levels, b) the presence of previous transgressive events. The age and extension of these Pleistocene high sea level events is very controversial. On the other hand new data shows that in many parts of the world a widespread occurence of active sand dunes can be observed between 18,000—16,000 y. BP in coincidence with the peak of last glacial intensity. New research is necessary to solve contradictions data by C 14 datings. Taking into consideration the available information, an upper Pleistocene age seems to be probable for the Chuy Formation.

Vizcaíno Formation (= Querandina): This unit belongs to the Holocene, as is indicated by geological and paleontological approaches (Bordas, 1957; Bossi et al. 1975; Calcaterra, 1971; Cardellino & Ferrando, 1969; de Mata, 1947; Figueiras, 1961, 1962, 1967; Forti, 1968, 1969; Goñi & Hoffstetter, 1964), and by radiometric datings (Auer, 1974; Delaney, 1967, 1969?; Urien & Ewing, 1974; Vogel & Lerman, 1969).

The above is dealt more extensively by Sprechmann (1978a).

D. Stratigraphy

In order to establish lithostratigraphic correlations, the identification of stratigraphic units is indispensable. Several handicaps are apparent in identifying these units:

1) The cable-tool method used to drill the cores.

2) The lack of informations in establishing the exact altitude of some bore-holes.

3) The imprecision with which some of the Tertiary and Quaternary superficial stratigraphic units were defined and described by their lithology.

4) In addition rapid facies changes are observed.

5) The lack of geological maps with appropiate scales and cross sections for the greater part of the well region.

Classically, it is considered that the greater part of the molluscan and foraminiferal faunas, found in the Uruguayan Quaternary, were deposited in the Holocene during a single transgressive event, the so called "Querandina Transgression", which was assigned to the Vizcaíno Formation. In this way a tacit time-stratigraphic correlaction was established between different exposures bearing fossils from the Querandinense. Only few exceptions were marked: a) The molluscan assemblages found in the ex-cementerio de Nueva Palmira. The prevailing point of view is that these molluscan assemblages belong to the Vizcaíno Formation. Some authors, however, have attributed them to the Belgranense Transgression; b) the associations from the Arroyo La Palma outcrop, tentatively attributed to the Belgranense by Figueiras (1974); and c) the foraminiferids found in the Quaternary strata of Chuy N° 364 (Chapter VII). Closs (1970) proposed a time-stratigraphic correlation of these strata of Chuy N° 364 with bore-holes PJst-1-RS (Ponta do Juncal), Cast-1-RS (Curral Alto), and Cist-1-RS (Cassino) from the Pelotas Basin.

For the solution of some of these questions of Quaternary stratigraphy it would be very useful tool to review the geological history of this region (Chapter VI-E). Secondly it is indispensable to recognize and use certain marker horizons as marker beds, to clarify the chaotic situation existing in this area. With this aim new ecostratigraphic correlations are proposed in Chapter VI-G.

E. Upper Pleistocene and Holocene history of the Río de la Plata region

An understanding of geological evolution and development of the Río de la Plata area in the modern Quaternary is necessary for biostratigraphical and paleogeographical studies. Only data based on C 14 age dating are used.

35,000 years ago, during middle Wisconsin time (Porter, 1971), the shore line was situated not less than 120 m below the present level. The most probable level has been estimated to be approximately 150 m below present (Boltovskoy, 1973; Closs, 1970; Delaney, 1966, 1967; Fray & Ewing, 1963; Richards, 1966; Richards & Broecker, 1963; Richards & Craig, 1963).

15,300 y. BP the shore line was situated between 55 and 73 m lower than present (Auer, 1970, 1974; Boltovskoy, 1973; Fray & Ewing, 1963; Richards & Craig, 1963; Urien, 1967).

12,000 to 11,000 y. BP sea level was 110 to 140 m below present. (Auer, 1970, 1974; Boltovskoy, 1973; Fray & Ewing, 1963; Richards, 1966; Richards & Craig, 1963; Urien, 1967; Urien & Ottmann, 1971).

Between 11,000 and 7,000 y. BP a transgressive phase commenced, raising the sea level from minus 110 to 140 m to somewhat higher than the present.

The shore of 8,620 ± 100 years ago can be found 18 m below ground surface. This was confirmed by radiocarbon dating made on peats underlying sediments of the Querandina Formation from Boring 2, in Delta of Río Paraná near Campana, Buenos Aires County, Argentina (Auer, 1970, 1974; Vogel & Lerman, 1969).

According to Urien & Ottmann (1971), the delineation of the following episodes in the Río de la Plata area are possible:

1) During the culmination of the early Holocene transgression, the waters flooded into the estuary, penetrating to the site of the city Rosario (Argentina), reaching a level 7 to 8 m higher than the present sea shore.

2) Between 7,000 and 3,000 y. BP the advance of the sea seems to have stabilized itself, showing only small oscillations. About 6,000 years ago the sea retreated to approximately 30 m below present, and a barrier complex formed, obstructing the estuary. These waters then formed an enormous lagoon.

3) Afterwards the sea advanced once again back into the Río de la Plata estuary, but the climatic conditions were more humid, therefore showed increasing runoff. The marine phase was restricted to the outer part of the estuary.

4) About 3,000 y. BP until present the sea level tends progressively to regress, exposing the coastal plains of today which border on the estuary.

Only few radiocarbon dates have been made for this part of the South American atlantic coastal region. According to Auer (1974) and Vogel & Lerman (1969) some of them probably were carried out on allochthonous shells. There is no guarantee that in every case the dates were corrected in relation to contaminations, as were those of Erlenkeuser (in: Einsele, Herm & Schwarz, 1974).

Urien & Ewing (1974) stated that only the following evidence seems to hold: 1) The Holocene transgression began at 11,000 ± 500 y. BP, raising the sea level from minus 139 m to its present level; and 2) between 9,000 and 2,000 y. BP sea level oscillated, and then stabilized.

Nevertheless the Holocene sea level fluctuations described by Urien & Ottmann (1971) show clearly the existence of the following events:

1) The first transgressive phase was reached and the highest vertical rise attained i. e. penetration of marine facies into the inner estuary.

2) A regression follows, and a barrier complex was formed.

3) A second less extensive transgressive stage took place.

In the inner estuary only fluvial facies existed.

4) The sea level reached its actual stand.

These succesive transgressive and regressive events, and their amplitude are similar to the oscillation of sea level curves reported by Auer (1974, Appendix), Einsele, Herm & Schwarz (1974, fig. 5), and Einsele et al. (1977). These curves are similar to other Holocene sea level oscillations recorded from different world regions. This is also true for the South American atlantic coasts, as reported in papers which based their conclusions on radiocarbon dates (Bigarella, 1964; Delibrias & Laborel, 1971).

The most adequate explanation for sea level changes, which occur during the late Quaternary in the Río de la Plata region, is eustasy. This explanation does not reject the incidence of hydro-isostasy or local epeirogenic movements.

At present it is not possible to correlate these Holocene transgressive events in the Río de la Plata, with those reported in other regions. Reliable conclusions about this topic can be made only with radiocarbon datings and field work on the Quaternary terraces, together with an analysis of the cores from this area. Nonetheless it is very significant that the presence of two chronostratigraphic sequences, designated as Vizcaíno 1 and Vizcaíno 2 were recognized by Goso (1965) and Bossi (1966).

F. Paleoecology

A paleoecological approach based on actualistic method of Schäfer (1962) has to be supported by recent researches, particularly those made in the same geographical area. The studied area is related to the Río de la Plata estuary and its zone of influence, and also with the Uruguayan and South Brazilian Atlantic coasts.

1. THE RIO DE LA PLATA ESTUARY

a) Physical characteristics

In the Río de la Plata estuary, the tides are of low amplitude. On the Uruguayan shore they may reach 60 cm, being somewhat greater on the Argentine coast, with a 1 m mean average (Ottmann & Urien, 1967, 1972). The current systems in the estuary are reported by Urien (1967, 1972).

Records of the annual and daily water temperature changes are given by Boltovskoy & Lena (1974a). The highest summer mean water temperature was 27.5° C. The lowest mean water temperature for the winter was 7° C. The daily change of the water temperatures fluctuated between 0.3° C and 7° C.

The value of salinities in the estuary show a net longitudinal change, this was verified by measurements made on surface and bottom waters. In the inner estuary fresh water conditions are always present, however in the outer zone marine salinities are encountered. In the middle of the estuary great fluctuation of the salinities are found. This longitudinal zonation in salinity value is typical for positive or normal estuaries. A vertical stratification also occurs, i. e. higher the salinities are found in bottom waters than in surface waters (Ottmann & Urien, 1965a, 1965b; Urien, 1967, 1972).

A considerable amount of suspended sediments is carried by the estuarine waters, with average values of 150—300 mg/l. Frequently they exceed 600 mg/l (Ottmann & Urien, 1965a, 1966; Urien, 1966, 1967).

The sediment distribution and bathymetry in the estuary and in the adjacent shelf, were much analysed in the past few years. Diverse physiographic charts were also made (Biscaye, 1972; Ottmann & Urien, 1965b, 1966; Urien, 1966, 1967, 1972; Urien & Ewing, 1974; Urien & Ottmann, 1971). Urien (1972) described the sediment distribution and the depositional environments. The actual sedimentary pattern is mostly controlled by the estuarine environments, and correlated in a broad way with zones of water salinities.

b. Previous work on living foraminiferids and thecamoebians.

A study of the thecamoebians in this estuary was made by Boltovskoy (1957b) and Boltovskoy & Lena (1974a). The foraminiferids of the Río de la Plata and its zone of influence were described by Boltovskoy (1957a, 1958, 1970a), and Boltovskoy & Lena (1971, 1974b). Additional references were also given by Boltovskoy (1954, 1959a, 1961, 1976) and Boltovskoy & Wright (1976). The fauna from the Arroyo Chuy was described by Closs & Madeira (1962) and Madeira-Falcetta (1974), and of the mouth of the Río Santa Lucía by Scarabino (1967).

c) Characteristics of the foraminiferal biocoenosis.

The salinity is the controlling factor in the distributional pattern of the living foraminiferids in the Río de la Plata. The distribution of the foraminiferids is correlated as well with the depositional environments found in the estuary.

Boltovskoy & Lena (1974b) defined three biofacies for the living foraminiferal fauna of the Río de la Plata estuary (fig. 3):

1. Biofacies of *Nonion tisburyensis*. This biofacies overlaps with: a) the inner-fluvial environment, which corresponds to the upper river delta front platform, and is characterized by the presence of limnic conditions, and b) the outer-fluvial environment, also called the intermediate river (Urien, 1972). In this area fresh water conditions are mostly found. At times of stormy winds, water bodies from the east can be pushed into this area, raising the salinities. Measurements indicate fluctuation in salinities ranging between 0.5 and 25 ‰. The most characteristic species of this biofacies is *Nonion tisburyensis*. Thecamoebians were also reported living (Boltovskoy & Lena, 1971, 1974a, 1974b).

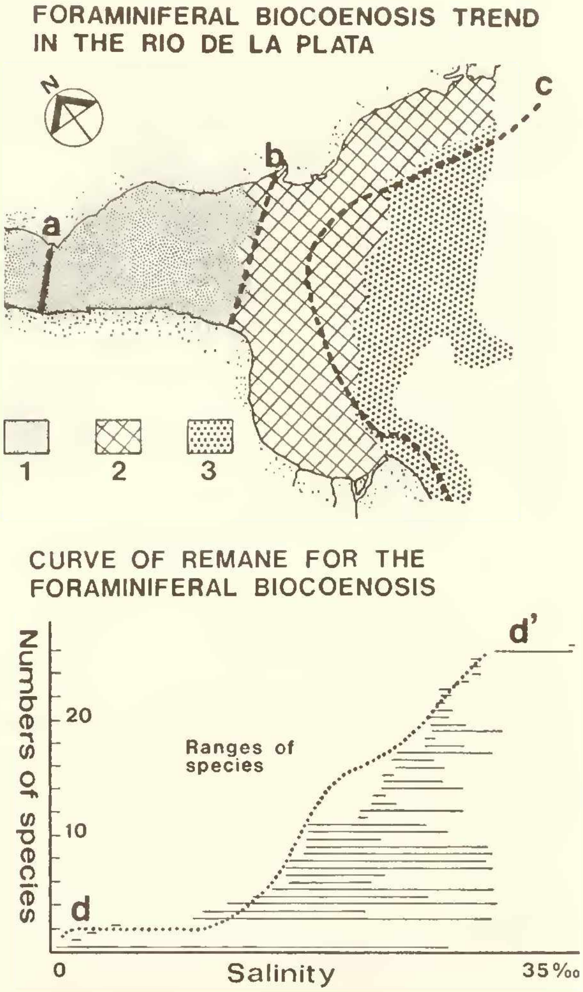

Fig. 3: Foraminiferal biocoenosis trend in the Río de la Plata (after Boltovskoy & Lena, 1974b). Key: 1 = Biofacies of *Nonion tisburyensis*, 2 = Biofacies of "*Rotalia beccarii parkinsoniana*", 3 = Biofacies of *Buliminella elegantissima*. These biofacies overlap with the following environments defined by Urien (1972): inner-fluvial environment from line a to the west; intermediate-fluvial environment between lines **b** and **b**; fluvio-marine environment between lines **b** and **c**; and marine zone from line c to the east. Curve of Remane for the foraminiferal biocoenosis of the Río de la Plata (d — d'). Parallel lines indicate the distributional range of living species (after Boltovskoy & Lena, 1974b).

2. Biofacies of "*Rotalia beccarii parkinsoniana*". This corresponds to the fluvio-marine environment, or "Río exterior" (Urien, 1967, 1972). The dominant species are *Ammonia beccarii* var. *parkinsoniana*, which is distributed within the whole biofacies; and *Elphidium discoidale*, which prevails in the northern and southern coasts. *Miliammina fusca* is present in smaller amounts.

3. Biofacies of *Buliminella elegantissima*. This biofacies has boundaries which are similar with those of the Río de la Plata marine zone. *Buliminella elegantissima* is the most frequent and typical species, followed by *Bolivina striatula*.

Boltovskoy & Wright (1976, fig. 113) showed the distributional patterns of the species which are characteristic for these biofacies in the Río de la Plata estuary. *Epistominella exigua* is the dominant species in the shelf sea adjacent to the Biofacies of *Buliminella elegantissima*.

Boltovskoy & Lena (1974b) indicated that the salinity has an additional effect on the distribution of the living foraminiferids. The per cent fraction occurence of the agglutinated species in the estuary increases with the decrease of salinity. A zonation of similar characteristics was observed in different marginal marine environments and estuaries (Bandy, 1964; Boltovskoy & Boltovskoy, 1968; Closs, 1963; Closs & Medeiros, 1965; Ellison & Nichols, 1970; Murray, 1968, 1973; Walton, 1964).

d. Remane's curve for the foraminiferal biocoenosis of the Río de la Plata.

Remane (1934, 1940, 1963, 1971) formulated another criterion to reveal the relationship existing between the water salinity and the number of species. The most important characteristics of the curve are present in Chapter VI-F-4.

Remane's curve for foraminiferal biocoenosis of the Río de la Plata estuary (fig. 3, d—d') was plotted using the distributional ranges of living species illustrated by Boltovskoy & Lena (1974b, map. 17).

In Fig. 3 Remane's curve here presented was correlated with the pattern of salinity zonation of this estuary proposed by Urien (1972), and with the foraminiferal biofacies reported by Boltovskoy & Lena (1974b).

Remane's curve for living foraminiferids in the Río de la Plata shows clearly, that the number of species decreases with reduction in water salinities. This is similar with Remane's curve of the living foraminiferal faunas in the Balthic Sea (Lutze, 1965, fig. 28).

2. PALEOECOLOGICAL INTERPRETATION BASED ON FORAMINIFERIDS.

The Uruguayan Quaternary foraminiferal assemblages provide information of the following environmental factors:

a. Bathymetry: The foraminiferids encounted in the drill samples and outcrops are characteristic of shallow environments (estuaries, bays, lagoons, beaches, etc.). The water depth does not exceed 20 m (Bandy, 1964; Boltovskoy, 1965, 1970a, 1976; Boltovskoy & Wright, 1976; Murray, 1968, 1973; Walton, 1964). The absence of *Epistominella exigua* seems to confirm this point of view. At the Present this is the dominant species in the open shelf areas beyond the Río de la Plata estuary (Boltovskoy, 1957a; Boltovskoy & Wright, 1976, fig. 113).

b. Temperatures: The foraminiferal associations are typical of cold-temperate water masses. The species which indicate the influence of warm water masses are *Ammonia beccarii* var. *parkinsoniana*, *Elphidium discoidale*, *Bolivina striatula* and *Poroeponides lateralis*. The cold water influence is shown chiefly by *Buccella peruviana*, s. l. (Boltovskoy, 1954, 1965, 1970a, 1976; Boltovskoy & Wright, 1976). This faunal spectrum is representative of the Argentina Biogeographic Province, also called the "kingdom" of *Buccella peruviana*, s. l., defined for living foraminiferal faunas. Most precisely they belong to the northern sub-area of this biogeographical unit, which is denoted as the North-patagonian subprovince (Boltovskoy, 1970a, 1976; Boltovskoy & Wright, 1976). Other species which are frequent in the drill cuttings, and that are characteristic of living assemblages of the North-patagonian subprovince are *Buliminella elegantissima* and *Miliolinella subrotunda*.

c. Substrates: No correlations were postulated in the Río de la Plata region between the distributional pattern of living foraminiferids and the type of substrates. Material from the wells is inappropriate for this kind of study because the number of drill cuttings where tests were found is not large enough to establish a relationship of any kind. Besides, changes in biotope are frequently found in estuarine inhabitants. Their main biotope in brackish water thus differs from that in the sea. This is particularly true for their substrate dependence (Remane, 1971).

d. Salinities: In nearly all the estuaries the salinity is the most important factor in determining the extent of the foraminiferal biocoenosis. Only in those environments, such as in the Baltic Sea (Lutze, 1965), in which a thermohaline stratification occurs salinity *and* temperature are the main factors that control the foraminiferal distribution.

In an attempt to establish the Quaternary depositional environments, paleoecologic analysis is primarly based on the identification of the tolerance of each foraminiferal assemblage in relation with salinity. Different criteria were described for recognizing brackish foraminiferal assemblages (HILTERMANN, 1963a, 1963b; LUTZE, 1965; MURRAY, 1968, 1973; WALTON, 1964).

The foraminiferal biocoenosis of the Río de la Plata and Río Quequén Grande were used to determine the range of the salinity tolerance for each species found in the Quaternary well boring sequences (BOLTOVSKOY, 1958, 1976; BOLTOVSKOY & BOLTOVSKOY, 1968; BOLTOVSKOY & LENA, 1971, 1974b; WRIGHT, 1968). In addition data from different biocoenosis and biotopes of the South American atlantic area was also evaluated to establish the salinity tolerance of various species (CLOSS, 1963, 1964; CLOSS & MADEIRA, 1962, 1967, 1968b; CLOSS & MEDEIROS, 1965, 1967; LENA & L'HOSTE, 1975). Likewise, the available information about the distribution of foraminiferids from different estuaries was used (BOLTOVSKOY, 1965; BOLTOVSKOY & WRIGHT, 1976; ELLISON & NICHOLS, 1970; KANE, 1967; LUTZE, 1965; MADEIRA-FALCETTA, 1974; MURRAY, 1968, 1973; PUJOS, 1973).

Only those species found and recorded in the Uruguayan Pleistocene and Holocene were classified with reference to their salinity tolerance within three Quaternary biofacies:

1. Quaternary Biofacies of *Buliminella elegantissima:* In this ecozone salinities are close to marine. Those species which are capable of tolerating small fluctuations in salinities, as well as some euryhaline species, were included in this biofacies: *Buliminella elegantissima, Buccella peruviana,* s. l., *Poroeponides lateralis, Bolivina compacta, Bolivina striatula, Bolivina* cf. *lomitensis, Cibicides aknerianus, Dentalina communis, Discorbis peruvianus, Discorbis williamsoni* f. *praegeri, Fissurina laevigata, Guttulina problema, Lagena laevis* f. *perlucida, Lenticulina limbosa, Miliolinella subrotunda, Nonionella atlantica, Oolina melo, Pyrgo nasuta, Pyrgo ringens patagonica, Quinqueloculina angulata* f. *typica, Quinqueloculina atlantica, Quinqueloculina* aff. *frigida, Quinqueloculina intricata, Quinqueloculina seminulum, Reophax artica* and *Textularia gramen.*

2. Quaternary Biofacies of *Ammonia beccarii* var. *parkinsoniana:* This overlaps the fluviomarine environment, and includes high and intermediate euryhaline species: *Ammonia beccarii* var. *parkinsoniana, Elphidium discoidale, Elphidium* gr. *excavatum, Elphidium galvestonense, Bolivina compacta, Discorbis peruvianus, Lagena laevis* f. *perlucida, Nonion tisburyensis, Oolina melo* and *Reophax artica.*

3. Quaternary Biofacies of *Nonion tisburyensis:* This biofacies contains species which are able to dwell permanently or temporarly in fresh waters: *Nonion tisburyensis* and *Reophax artica.*

This classification is based on studies made of the biocoenosis and indicates the lowest salinity needed by the species to survive, but does not indicate the lowest allowable salinity needed for reproduction.

The most abundant species found in the drill cuttings which characterize the Quaternary biofacies, are cosmopolitan. They are typical for these environments even if in different geographical areas.

The depositional environments are determinated chiefly on the basis of the percentile occurence of the dominant species for each biofacies, but not exclusively indicative of a single association.

A second method is a so used to evaluate the salinity tolerance shown by the Quaternary associations. It is based on the evaluation of the capacity of the genera to withstand changes in salinities. The information given by MURRAY (1973) is used (table XVIII).

In the wells and exposures shown in Table XVIII foraminiferal assemblages were found that allow one to make paleoecological interpretations. In each locality the sample with the greatest diversity was used.

3. PALEOECOLOGICAL CONCLUSIONS OF DEPOSITIONAL ENVIRONMENTS BASED ON BENTHIC FORAMINIFERIDS.

The analized foraminiferal assemblages indicate shallow and cold temperate waters. Their salinity tolerance was the greatest difference found between assemblages.

In almost all the estuaries salinities, and other physical characteristics (bathymetry, substrate, etc.) gradually change in direction of its longitudinal axis. The water salinities decrease in a gradational way and a zonation is produced, which is particularly evident in the channels. This type of zonation is herewith called "estuarine front".

A second latitudinal zonation is also present in the estuarine environment, which is reflected as well in its physical and biological characteristics. Shorewards the limnic influence increases, as a consequence of rivers, rivulets, marshes, lagoons and other marginal environments. This latitudinal or lateral zonation is herewith designated the "lateral-marginal zone of influence".

Along the longitudinal estuarine axis, the boundaries between facies and biofacies are gradual. In contrast, along latitude these lateral changes are sudden, and therefore the environmental and faunal limits are sharp (ELLISON & NICHOLS, 1970). The presence of this double zonation makes paleoecological reconstruction difficult.

TABLE XVIII
Salinity tolerance of foraminiferal associations

Locality	α	Rotaliina	Miliolina	Genera	Salinity
Chuy N° 364 (40—35 m level, drill cutting)	2	100 %		*Ammonia* 48 % *Bolivina* 4 % *Buliminella* 27 % *Elphidium* 20 %	hyposaline
Costa Azul N° 1060/1 (21—19 m level, drill cutting)	4.5	99 %	1 %	*Buccella* 60 % *Discorbis* 6 % *Ammonia* 14 % *Elphidium* 12 %	slightly hyposaline
Puerto La Paloma N° 449/11 (8.00—7.50 m level, drill cutting)	6	82 %	16 %	*Buccella* 46 % *Discorbis* 3 % *Elphidium* 7 % *Poroeponides* 23 % *Miliolinella* 5 % *Quinqueloculina* 10 %	normal marine
Salinas N° 1034/1 (34—32 m level, drill cutting)	4	99 %	1 %	*Ammonia* 4 % *Bolivina* 8 % *Buccella* 4 % *Buliminella* 32 % *Elphidium* 44 %	moderately hyposaline
Areneras Calcagno[4])					slightly hyposaline
San José de Carrasco N° 442/1 (18—17 m level, drill cutting)	3	81 %	19 %	*Ammonia* 11 % *Buccella* 37 % *Elphidium* 21 % *Quinqueloculina* 10 % other Miliolidae 9 %	slightly hyposaline
Parque Lecocq (1 m below surface, scooped out)	2	100 %		*Ammonia* 51 % *Bolivina* 6 % *Elphidium* 40 %	hyposaline
Rincón de la Bolsa N° 754 (2.80—1.50 m level, drill cutting)	1	100 %		*Ammonia* 59 % *Elphidium* 41 %	hyposaline

The Quaternary foraminiferal assemblages are included in the following biofacies:

a. Quaternary Biofacies of *Buliminella elegantissima:* Well La Paloma N° 449/11. Perhaps Costa Azul N° 1060/1.

b. Transitional area between the Quaternary Biofacies of *Buliminella elegantissima* and *Ammonia beccarii* var. *parkinsoniana:* Salinas N° 1034/1, San José de Carrasco N° 442/1, and Areneras Carrasco.

c. Quaternary Biofacies of *Ammonia beccarii* var. *parkinsoniana:* Parque Lecocq, Rincón de la Bolsa N° 754 and Chuy N° 364.

In each well or exposure only those samples carrying the highest species diversity were considered. *Nonion tisburyensis* was nearly completely absent in foraminiferal assemblages originating from drill cuttings. This species characterizes a biofacies of living foraminiferids in the Río de la Plata. Today this biofacies overlaps with the inner and intermediate-fluvial environments. Furthermore, this biofacies presents the highest standing crop for the estuarine biocoenosis (Boltovskoy & Lena, 1974b). *Miliammina fusca* was not found, although it is frequent today in this biofacies.

The same authors have analysed the longitudinal

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[4]) The information given by Sicardi (1969) about foraminiferids from this exposure is not sufficient to establish the α index as well as the percentile occurence of the genera. However, the available data of the species composition shows that the salinity was slightly hyposaline.

distribution in each environment of the calcareous and arenaceous foraminiferids in the Río de la Plata. The per cent occurence of the arenaceous species increases with a decrease in salinity. In the Quaternary foraminiferal assemblages only scarce specimenes of Textulariina were found. This absence is interpreted to mean that the depositional environments were not related with the inner and intermediate-fluvial estuarine zone, at least in the drill samples that have supplied foraminiferids. Nevertheless it must be pointed out, that the "arenaceous pattern" does not always offer total reliability, and can lead to errors in paleoecological interpretations (LUTZE, 1965, p. 133).

The Quaternary foraminiferal assemblages indicate an estuarine or lagoonal environment. Hyposaline, normal marine and hypersaline marshes are rejected on the basis of the absence of Textulariina in the studied assemblages; and in the species composition, because no "typical" marsch species were found (MURRAY, 1973, p. 26—27, table 5).

MURRAY (1968, 1973, 1976) also pointed out the difficulties that exist in distinguishing between estuaries and lagunes and other marginal marine environments, using foraminiferal associations. It is thought that almost all the foraminiferal associations were deposited in an estuarine environment, because they indicate a longitudinal distributional pattern. They reveal a decrease of water salinities toward the head of the estuary. The foraminiferal assemblages from, La Paloma N° 449/11, Salinas N° 1034/1, San José de Carrasco N° 442/1, Areneras Calcagno and Lecocq correspond to the "estuarine front". In contrast, the foraminiferal assemblages from Chuy N° 364 could indicate an environment belonging to the "lateral-marginal zone of influence". Probably to a lesser extent this is also valid for Costa Azul N° 1060/1 and Rincón de la Bolsa N° 754.

In Fig. 4 the paleoecological results are shown by the foraminiferids and are schematically illustrated. The percentile occurence of each species is plotted in a cumulative histogram. For every well only the sample carrying the greatest foraminiferal diversity is considered. Those species illustrated with dotted signature indicate the marine influence and belong to

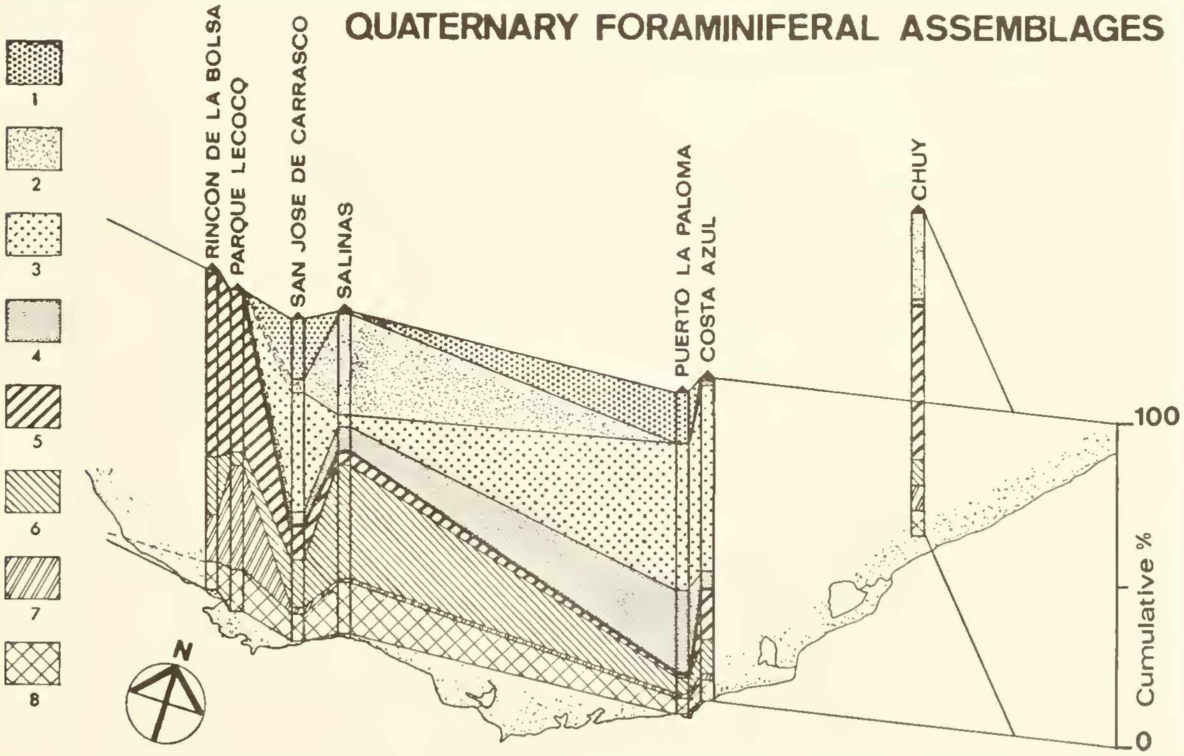

Fig. 4: Longitudinal distribution pattern of the Quaternary foraminiferal assemblages. The percentile occurence of species is shown in a cumulative histogram. Species illustrated with dotted signature indicate the marine influence. Slanting lines represent areas chiefly fluvio-marine. Key: 1 = Miliolidae, 2 = *Buliminella elegantissima*, 3 = *Buccella peruviana*, s. l., 4 = other species characteristic for the Quaternary Biofacies of *Buliminella elegantissima*, 5 = *Ammonia beccarii* var. *parkinsoniana*, 6 = *Elphidium discoidale*, 7 = other species indicating the Quaternary Biofacies of *Ammonia beccarii* var. *parkisoniana*, 8 = Non indicative species.

the Quaternary Biofacies of *Buliminella elegantissima.* Slanting lines represent areas chiefly fluvio-marine, and are typical for the Quaternary Biofacies of *Ammonia beccarii* var. *parkinsoniana.* The cumulative histogram clearly shows the longitudinal zonation which is characteristic for this estuarine environment. Towards the head of the estuary, the Quaternary Biofacies of *Ammonia beccarii* var. *parkinsoniana* gradually replaces the *Buliminella elegantissima* one.

The depositional environment of Puerto La Paloma N° 449/11 (8.00—7.50 m level, drill sample) probably was an open sandy beach. This is supported by the lithofacies, and the fact that the foraminiferal assiciation is similar to living ones in this biotope (Closs & Barberena, 1962; Madeira-Falcetta, 1974; Murray, 1973).

In San José de Carrasco N° 442/1 (18—17 m level, drill cutting) many abraded tests were found due to the characteristics of the lithofacies which is an angular quartzose sand. The environment was probably a sand beach exposed to waves and located on the estuarine shore. This environment is a difficult biotope for many animal groups, because it is mobile and unstable. The only permanent residents from the benthic macrofauna belong to the infauna (Hedgpeth, 1957; Herm, 1969; Perkins 1974; Seilacher, 1953). Destruction of foraminiferids and molluscs due to abrasion is usual in this environment (Einsele et al., 1977; Murray, 1973).

The distribution of the foraminiferids in Chuy N° 364 does not agree with the trend that is normal in estuarine longitudinal zonation. This fact can be explained in two ways: a) deposition took place in a marginal marine environment, revealing estuarine latitudinal or lateral zonation; b) the foraminiferids were deposited during a different transgressive event, being older or younger.

The wells which are located in Colonia and Soriano Counties, do not contain foraminiferids. These boreholes are located in the innermost estuarine region. The sequences of these bore-holes, that were considered as belonging to the Vizcaíno Formation, probably were deposited in a hyposaline environment. Foraminiferids usually are not adequate for paleoecological reconstruction of these biotopes, because only few species are able to survive there. This is also valid for living foraminiferids of the Río de la Plata, and is clearly illustrated by Remane's curve of this estuary (fig. 3, d-d'). Post mortal diagenetical effects as i.e post depositional dissolutions, also could have affected the microfaunas.

It is necessary to evaluate other fossil assemblages to reconstruct the depositional environments of the sequences which are attributed to the Vizcaíno Formation, namely the wells located in Colonia and Soriano Counties. Mollusca are used for this purposes.

4. PALEOECOLOGICAL INTERPRETATION OF MOLLUSCAN ASSEMBLAGES.

a. Methods.

The Quaternary malacological associations found in the wells can be evaluated for paleoecological and paleogeographical information. On one hand it allows one to compare and check the paleoecological conclusions that were given, by foraminiferal assemblages. On the other hand they offer a valuable additional information, particularly for those environments that are not suitable to foraminiferal life or preservation.

The bivalves and gastropods in the wells are mainly used to delineate the boundaries between the Quater-

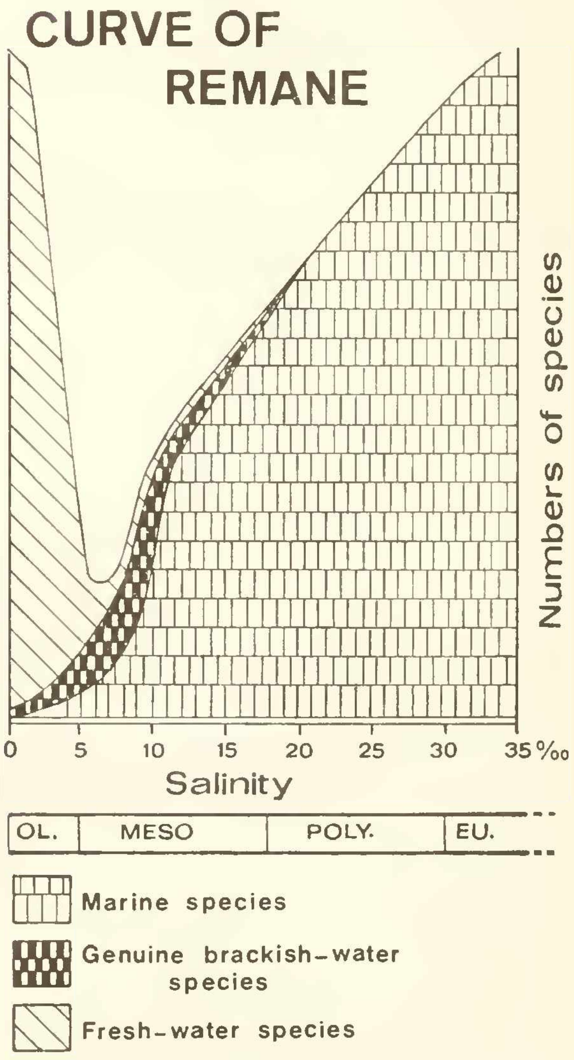

Fig. 5: Graph of numbers of marine, fresh-water, and genuine brackish-water species in different salinities [after Remane (1934, 1940, 1963, 1971)].

nary biofacies and/or environments. They also offer information that allows one to verify and define the range of the biofacies during the Querandina Transgression.

For this purpose it was particularly useful to use criteria that allow a discrimination between marine and limnic organisms:

1. Marine and limnic environments have been colonized by different species.

2. The curve that establishes a relationship between the species number and the water salinities was made by REMANE (1934, 1940, 1963, 1971) (fig. 5). Towards the head of the estuary (inwards the estuary) — with decreasing salinities — the number of species decreases. With salinity of 18 ‰ approximately half of the marine species survive. Limnic organisms are already very scarce at a salinity of 3 ‰. The species minimum is near the boundary of fresh water environments, with salinities in the range of 5—8 ‰ (REMANE, 1934), 5—7 ‰ (REMANE, 1963, 1971), 4—6 ‰ (HILTERMANN, 1963b) or by 5 ‰ (McLUSKY, 1971; PERKINS, 1974). The asymmetry on REMANE's curve originates by the fact that fresh water species react with much greater mortality with the increase of water salinities than the marine faunas do with increase of fresh water. Therefore marine environments are separated from the limnic ones by a zone characterized by a low species diversity, with salinities ranging between 5—8 ‰.

3. Brackish waters are characterized by the presence of some species which reach their highest abundance in this environment, and which have been designated "genuine brackish-water species" or "true estuarine species" (HILTERMANN, 1963b; REMANE, 1934, 1940, 1963, 1971). Generally these species belong to genera which are present in marine environments, with a few belonging to limnic environments.

4. An additional useful way is to evaluate the vicariad species, i. e. closely related species whose distribution is allopatric.

b. Curve of REMANE for living bivalves from the Río de la Plata estuary.

To use the actualistic principle the first step is to reconstruct REMANE's curve for the living malacological assemblages of the intertidal and sublittoral zones of the Uruguayan part of the estuary. With this aim a review of the available literature about the living molluscan faunas at the Uruguayan coasts was made.

Some limitations of the reconstruction of the curve that relates the species number to salinities are given:

1. Generally the available information is imprecise in reference to the species range of dispersion.

2. Usually no discrimination is made between the information based on living species, and those obtained on the thanatocoenosis.

3. The presence of some species previously refered to this area must be considered as fortuitous, or are questionable.

4. The nonexistence in the literature of precise data about the salinities that existed at the moment in which the molluscs were capturated.

Notwithstanding these limitations, it was possible to plot the curve of REMANE for the living bivalves of intertidal and sublittoral zones of the Uruguayan coast, within a very acceptable approximation (fig. 6). For this purpose the number of bivalve species reported from the following areas were counted:

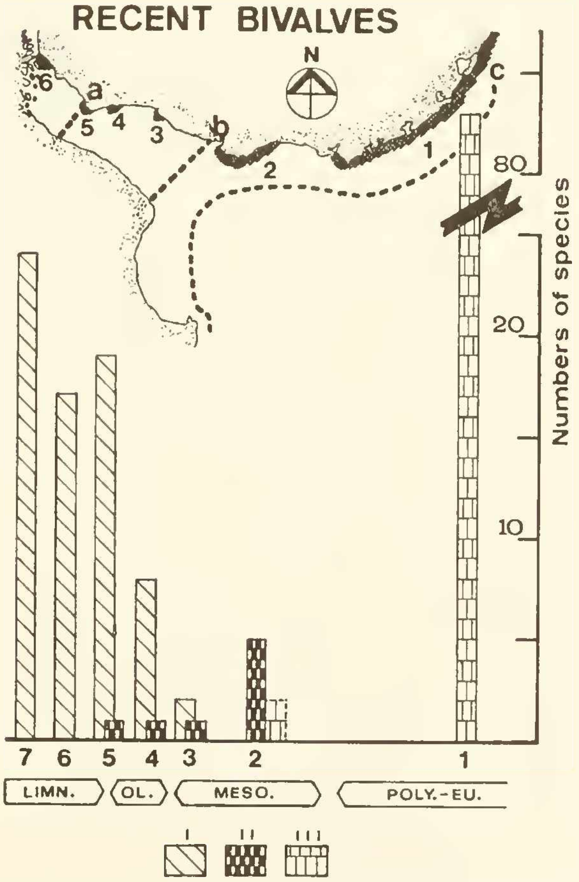

Fig. 6: Curve of REMANE for living bivalves from the Río de la Plata estuary. Key: I = fresh-water species, II = genuine brackish-water species, III = marine species. Geographical setting of areas 1—6, as well as references of column 7 of histogram are shown in pages 40. Lines a, b and c are the boundaries between estuarine environments, as shown in Fig. 3.

Uruguayan oceanic region (fig. 6, area 1): This covers the coasts of Rocha County in all its extension, and those of County Maldonado, from Portezuelo to the east. The characteristics of the living communities of the sandy beaches in this area were reported by Scarabino, Maytía & Faedo (1973).

The rocky substrates of this region are characterized by the presence of the *Mytilus platensis-Brachidontes rodriguezi-Perna perna* Community (Scarabino, Maytía & Cachés, 1975).

To establish the number of bivalvian species of this area, the information provided by the "Catálogo de los moluscos marinos del Uruguay" was used (Figueiras & Sicardi, 1968b, 1969, 1970a, 1970b), as well as additional data by Barattini & Ureta (1960) and Figueiras (1975). A total of 109 species of pelecypods belonging to the biocoenosis and thanatocoenosis were reported. They are tentatively classified as:

1. marine species, of the intertidial and upper sublittoral zones: 83(?)
2. middle and lower sublittoral marine species: 17 (?)
3. genuine brackish-water species: 5
4. not classified and doubtfull species: 4

This data is approximate, because the available information about the distribution and ecology of many species is insufficient. *Petricola pholadiformis* can be used to illustrate the point. According to Frey, Voorhies & Howard (1975) this species is one of the best indicators for estuarine environments. Nevertheless, in the Río de la Plata area, its distributional range is reported as being only along oceanic coasts.

Area of Montevideo (fig. 6, area 2): The bivalve species living in this zone are described by Scarabino, Maytía & Cachés (1975). In the "sandy beach" physiographic unit, characterized by sandy substrates with high organic matter the following bivalve species were found: *Erodona mactroides*, *Mactra isabelleana* and *Tagelus plebeius*. These species live in the intertidal and upper sublittoral zones. In rocky substrates the *Brachidontes darwinianus* Community is dominant, being frequently associated with *Mytella charruana*. Both species are also dwellers of the littoral sensu stricto and upper sublittoral zones. Teisseire (1927, 1928) has reported already the presence of these five species for the coasts of the Montevideo County. Figueiras & Sicardi (1968b, 1969, 1970a, 1970b) also recorded along coasts of Counties Montevideo and Canelones the presence of the same five species, which were described as euryhaline forms. They also reported the presence of *Macoma uruguayensis* and *Mactra petiti* in the same area. Therefore the Area of Montevideo also includes the coasts of Canelones County, mainly in its western region.

It must be pointed out, that the *Brachidontes darwinianus-Mytella charruana* Community, which lives in the area of Montevideo, is substituted in the oceanic region by another community, integrated by the vicariad species *Mytilus platensis-Brachidontes rodriguezi-Perna perna* (Scarabino, Maytía & Cachés, 1975). This latter species invaded the Atlantic Uruguayan coasts only recently (Figueiras & Sicardi, 1968b, p. 265).

Coasts of the Colonia County: To obtain the distributional range of the bivalve species of this estuarine zone, the information detailed by Olazarri (1966) was used. This autor described the bivalves of Colonia County. For each analyzed species a list of the localities in which it was found is presented. In using Remane's curve only those localities were considered which were located on, or near the Río de la Plata, and also those situated on the Río Uruguay, between Punta Gorda and Arroyo Sauce. The localities in the inner part of the County were excluded, because they could not provide any information about salinity zonation. The localities in question were grouped into four zones, along the coasts of Colonia County:

Mouth of Arroyo Cufré area (fig. 6, area 3)

Artilleros area (fig. 6, area 4): localities of Arroyo Artilleros, Balneario Santa Ana y Puerto Platero.

Area of Colonia City (fig. 6, area 5): localities of Playa Ferrando, Bahía de Colonia, Playa La Arenisca, Barrancas San Pedro e Isla San Gabriel.

Area of Carmelo and Nueva Palmira (fig. 6, area 6): localities of Punta Piedras, Playa Seré, Balneario Zagarzazú, Punta Gorda, Nueva Palmira and Brisas del Uruguay.

According to Olazarri (1966) the total number of limnic bivalve species found in Colonia County is 24 (fig. 6, column 7). Figueiras (1965a, 1965c) presented a review of freshwater pelecypods of the Uruguayan territory. He described 29 species. No precise distributional data is offered for many species. The total number of species is close to that given by Olazarri (1966), especially if it is considered that Olazarri restricted his observations to Colonia County. The total number of species previously referred to do not include various subspecies which were reported by both authors, because in some cases their allopatric distribution are not evident.

The resultant histogram and curve (fig. 6) reveals a very similar distribution as in Remane's curve (fig. 5). They also are similar to that Remane's curve which was exclusively plotted for molluscan faunas (Hiltermann, 1963b; Remane, 1934, 1940, 1963, 1971).

For ecological reconstruction, the salinities of each area previously referred to must be estimated. For this purposes the zonation of the salinities in the Río de la Plata reported by Urien (1972) is used. This allows one to establish the relationship existing between the inner-fluvial, intermediate-fluvial, fluviomarine and marine environments of the estuary, i. e. areas 1 to 6, of the histogram of Fig. 6. The boundaries between these environments are graphically illustrated in the same figure. They also overlap with the biofacies limits, which were defined using living foraminiferids.

The histogram and curve of Fig. 6 indicate the following conclusion:

In the oceanic region the species diversity is very high (area 1). According to Remane's curve it must have a relationship with euhaline and polyhaline salinities.

In the inner-fluvial environment, where limnic conditions are always present, the fauna of fresh water bivalves is also diversified (areas 5 and 6).

In the intermediate-fluvial environment the increasing salinities causes a quick decrease of the number of limnic bivalve species. In the Artilleros area eight fresh water species were reported (area 4), and in the mouth of Arroyo Cufré only two (area 3). These limnic bivalves coexist with *Erodona mactroides*. Remane (1963) and Hiltermann (1963b) reported that the dominant fauna in oligohaline waters is a limnic one, but with an evident decrease in species diversity. The lowest diversity is reached in the miomesohaline (= ß mesohaline). According to Remane (1971) fresh-water bivalves are rather intolerant of brackish water. Only a few reach the 5 ‰ boundary, none transgress the 8 ‰ salinity limit. Based on these data it can be concluded that the bivalves of the Astilleros area indicates an approximate oligohaline environment; and those of the Arroyo Cufré shows a miomesohaline one.

In the fluvio-marine environment only seven bivalve species were reported of marine origin. This faunal spectrum indicates mesohaline salinities.

An examination of the range of distribution of the genuine brackish-water species shows clearly that their optimum lies in the mesohaline. The salinity ranges from about 3 ‰ to 18 ‰ and is the habitat of over 90 % of the genuine brackish-water organisms (Remane, 1971).

The genuine brackish-water species are here defined according to Remane's (1934) wider definition: "Genuine brackish-water species are those which abound in brackish water and occur only occasionally in the sea or fresh water". Often great practical difficulties exist in establishing if a species belongs to this category, or if it is a euryhaline form. A classical example is the case of *Mytilus.*

Erodona mactroides, Brachidontes darwinianus, Mytella charruana and *Tagelus plebeius* are considered to be genuine brackish-water species. Scarabino, Maytía & Cachés (1975) included these species within the "estuarine association".

Probably *Mactra isabelleana* must also be considered a genuine brackish-water species. This species is dominant in several exposures of the Querandinense which are characterized by very low saline depositional environments. Calcaterra (1971) reported that *Mactra isabelleana* constitutes about the 60 % of the fossil assemblage in Cantera Ferrando. This species is also dominant in Punta Francesa constituting 40 % of the molluscan fauna, and in the ex cementerio de Nueva Palmira, where its occurence goes to 90 %. Bordas (1957) also considered *Mactra isabelleana* as being an "estuarine species". Klappenbach & Scarabino (1969, p. 54) reported that this species prefers waters of low salinity. It must be pointed out that Teisseire (1927, 1928) was the first who recognized the paleoecological value of these five genuine brackish-water species.

Macoma uruguayensis and *Mactra petiti* are considered as euryhaline marine species. Their range of distribution goes from Montevideo toward the east, but they do not constitute dominant forms in this environment.

Among these five genuine brackish-water species there is one, *Erodona mactroides*, that has been repeatedly mentioned as being useful for ecological and paleoecological interpretations (Carcelles, 1941; Closs, 1963; Costa, 1971; Figueiras, 1965a; Olazarri, 1966; Teisseire, 1927, 1928).

Closs (1963) offers precise information about the distributional pattern of *Erodona mactroides*, and its direct correlation with water salinities. In Laguna de los Patos this species is scarce in areas with relatively high salinities (polyhaline), and is completely absent in fresh water zones. It is frequent in salinities ranging between 15—8 ‰, and can be very abundant in waters whose salinities fluctuate between 9—3 ‰.

In reference to the westernmost penetration of *Erodona mactroides* in the Río de la Plata, the most accurate information is given by Teisseire (1927) and Olazarri (1966). The former author indicated that this species was found near Colonia City. Olazarri (1966) described the presence of some big specimens in the harbour of Colonia City, together with nayades, emphasizing that *Erodona mactroides* never was found living at the NW of this geographical area, on the Uruguayan coast.

These biological data are in total agreement with the physical parameters of water salinities, which were described by Urien (1972). The limnic sensu stricto environment begins somewhat to the NW of Colonia City, on the Uruguayan coast. There *Erodona mactroides* disappears in living assemblages. That means that the maximum headward estuarine penetration of *Erodona mactroides* indicates the nearness of the boundary between the inner-fluvial and intermediate-fluvial environments.

The remaining genuine brackish-water species were not found living on the Colonia County coasts (Olazarri, 1966), not even in San José County. Towards the head of the estuary the maximum penetration was observed along the coasts of the area of Montevideo (fig. 6, area 2), as was described by Figueiras & Sicardi (1968b, 1969, 1970a, 1970b) and Teisseire (1927, 1928).

Life habits of the dominant genuine brackish-water species.

The life habits of *Tagelus plebeius* were extensively described by Stanley (1970) as being a suspension-feeder of the deep infauna.

No detailed biological studies have been made of *Erodona mactroides* and *Mactra isabelleana* life habits. However they have been tentatively established using criteria formulated by Cox, Nuttall & Trueman (1969), Kauffman (1969) and Stanley (1970).

Erodona mactroides is considered to be a suspension-feeder of the upper infauna, based on the functional morphology of its test, i. e., absence of a pallial sinus and its taxonomic position within the Myacea.

Mactra isabelleana is a suspension-feeder of the intermediate infauna.

Apparently no genuine brackish-water bivalve detritus feeders exist in the Río de la Plata. In almost all estuaries the detritus-feeders are present as characteristic forms. Suspension-feeding bivalves are, however, generally rare in estuaries (Barnes, 1974).

c. Distribution of the living gastropods in the Río de la Plata estuary, and its zone of influence.

The distributional pattern of the gastropod species is as follows (fig. 7):

In the oceanic Uruguayan region the presence of about 183 species of gastropods from the biocoenosis and/or thanatocoenosis were reported (Figueiras & Sicardi, 1970c, 1971, 1972, 1973, 1974; Sicardi, 1975). The taxonomic status and/or the ecology of many of these species are little or not at all known. These species were tentatively, and in an approximate form, grouped as:

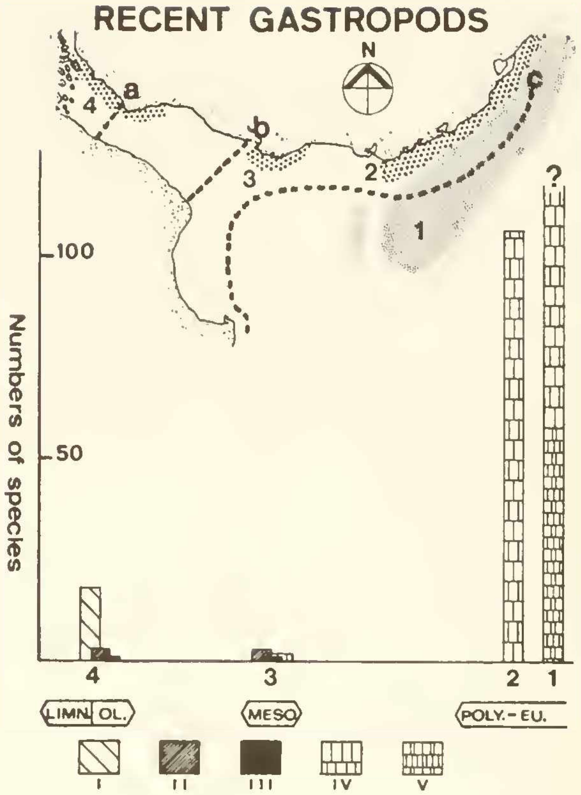

Fig. 7: Distribution of living gastropods in the Río de la Plata estuary, and its zone of influence. Key: I = freshwater gastropods, II = genuine brackish-water and/or euryhaline limnic species, III = genuine brackish-water species, IV = marine intertidal and upper sublittoral species, V = middle and lower sublittoral marine species, and pelagic forms. Location of areas 1—4 and their features are given in pages 42, 43. Lines a, b and c are the boundaries between estuarine environments, as shown in Fig. 3.

1. marine species which are typically from the middle and lower sublittoral zones; and pelagic forms: 58(?) (fig. 7, area 1). They live together with many species of the next area.
2. marine intertidal and upper sublittoral species: 102 (?) (fig. 7, area 2)
3. genuine brackish-water and euryhaline species: 2.
4. unclassified and doubtful species: 21.

According to Figueiras (1964) and Figueiras & Sicardi (1971, 1972, 1974) the following species were recorded from the littoral sensu lato of Montevideo County (fig. 7, area 3): *Littoridina australis*, *Littoridina charruana*, *Littoridina isabelleana*, *Parodizia uruguayensis*, *Buccinanops deformis*, *Cylichna (Cylichnella) bidentata*, *Caecum capitanum* and *Meioceras tumidissimum.* The presence of the last two species in this region must still be confirmed (Klappenbach, 1964). *Buccinanops deformis* is a marine stenohaline species (Figueiras & Sicardi, 1968a, p. 237). *Cylichna (Cylichnella) bidentata* is not abundant.

Littoridina australis is the unique dominant gastropod in this region, and is considered as an "estuarine species" by Bordas (1957), Oliver et al. (1972) and Scarabino, Maytía & Cachés (1975). According to the latter authors, this genuine brackish-water species is found on sandy substrates with high a content of organic matter, in the intertidal and upper sublittoral zones; and also in the "marshland" i. e. in muddy sediments.

No precise data were published about the tolerance of *Littoridina australis* in relation to decreasing water salinities. Parodiz (1962) indicates that its habitat is always "brackish". Barattini & Ureta (1960) considered that it is a typical species in "brackish" and "limnic" environments. This point of view is also supported by Figueiras (1964), who writes that the normal biotope of *Littoridina australis* lies in "brackish waters". Camacho (1966) considered this species as an euryhaline form. Castellanos (1965) has described *Littoridina australis* in Punta Lara (Buenos Aires County), as being very abundant and coexisting with numerous limnic species. Punta Lara is located in the region were the boundary between the inner-fluvial and intermediate-fluvial environments is found.

Littoridina charruana, Littoridina isabelleana, and *Parodizia uruguayensis* were also reported from the coasts of the Montevideo County (Barattini & Ureta, 1960; Figueiras, 1964; Pereira de Medina, 1959). The available information about these species is mainly based on the thanatocoenosis. The lack of ecological data of the biocoenosis makes it difficult to decide if they are genuine brackish-water species or euryhaline limnic ones.

Besides, it must be remembered that a more marked tolerance of changes in salinity is found in the limnic gastropods than in bivalves (Remane, 1971).

Along the coasts of Colonia County (fig. 7, area 4) the existence of 17 to 19 stenohaline freshwater gastropod species were reported (Figueiras, 1964, 1965c). This number must be considered as an approximation due limitations previously cited. Moreover, *Littoridina australis, Littoridina charruana, Littoridina isabelleana* and *Parodizia uruguayensis* are also present.

The distributional pattern of gastropod species from the intertidal and upper sublittoral zones of the Uruguayan estuarine and oceanic regions, shows an evident similarity with those of the bivalve fauna:

1. in the oceanic region a high species diversity is present, indicating an euhaline and polyphaline environment.
2. the fluvio-marine environment is characterized by a low species diversity. The genuine brackish-water species *Littoridina australis* is here dominant. Besides, in this environment were found limnic euryhaline and marine species.
3. in the inner-fluvial environment high species diversity is present.
4. no precise data are available for the intermediate-fluvial environment, which could be fitted graphically into Remane's curve. It can be inferred that the species diversity decreases, if the highs of columns 3 and 4 on the histogram in Fig. 7 are interpolated.

Some facts about the distribution of the living molluscs in the Río de la Plata region must be given. The salinity is the main environmental factor which determines the distribution of the bivalves and gastropods. This result is the same as that given for the molluscan faunas in different estuaries (Davies, 1972; Dörjes & Howard, 1975; Hedgpeth, 1957; Hiltermann, 1963b; McLusky, 1971; Remane, 1934, 1940, 1963, 1971). Therefore they are valid correlations, between the molluscan assemblages and environments, based fundamentaly on the salinity tolerance of the bivalve and gastropod species. Nevertheless, it must be remembered that the distributional pattern of the molluscan faunas is also subjected to other environmental factors, as temperatures, type of sediment, currents and tides, bathymetry, water turbidity, food availability, oxygen concentration, ionic concentration, flocculation of silt particles, etc. (Davies, 1972; Dörjes & Howard, 1975; Emery & Stevenson, 1957; Green, 1968; Hedgpeth, 1957; McLusky, 1971; Parker, 1955, 1959, 1975). In an estuarine environment a faunal dislocation, like te one illustrated by Emery & Stevenson (1957, fig. 2) can also occur, as well as sediment and faunal mixings.

The fine sediments deposited in the estuarine environment display another particularly important feature. Their interstitial water is more constant in its salinity than the overlying water body. Although the interstitial salinity reflects the salinity of the overlying water, changes in the interstitial salinity take place at a much slower rate. Many species utilize this ameliorating effect of the substrate to survive in this unstable environment (Barnes, 1974; McLusky, 1971). This ameliorating effect also favours the paleoecological reconstruction because it has a stabilizing result on the biocoenosis, and therefore on the thanatocoenosis.

In short, the present day distributional pattern of the molluscs in the Río de la Plata estuary show very evident trends, which will be used for the paleoecological and paleogeographical interpretation.

d. Reconstruction of Quaternary depositional environments

The molluscan faunas deposited in Uruguay during the Querandina Transgression have been referred to in many publications. The most important are those of Bordas (1957), Broggi (1967, 1970, 1973), Calcaterra (1971), de Mata (1947), Figueiras (1961, 1962, 1967, 1973), Francis (1975), Frenguelli (1930), Goñi & Hoffstetter (1964), Ihering (1907, 1923, 1930), Kraglievich (1928, 1932), Parodiz (1962) and Teisseire (1927, 1928). Recently Closs & Forti (1971) and Forti (1969) described molluscan faunas of the same age from southern Brazil. The largest part of this research concerns itself with taxonomy and stratigraphy, whereas the paleoecological and paleogeographical interpretation were somewhat downgraded. The work of Teisseire (1928) was the exception in which the paleoecological data is still of great use today.

QUATERNARY MOLLUSCS

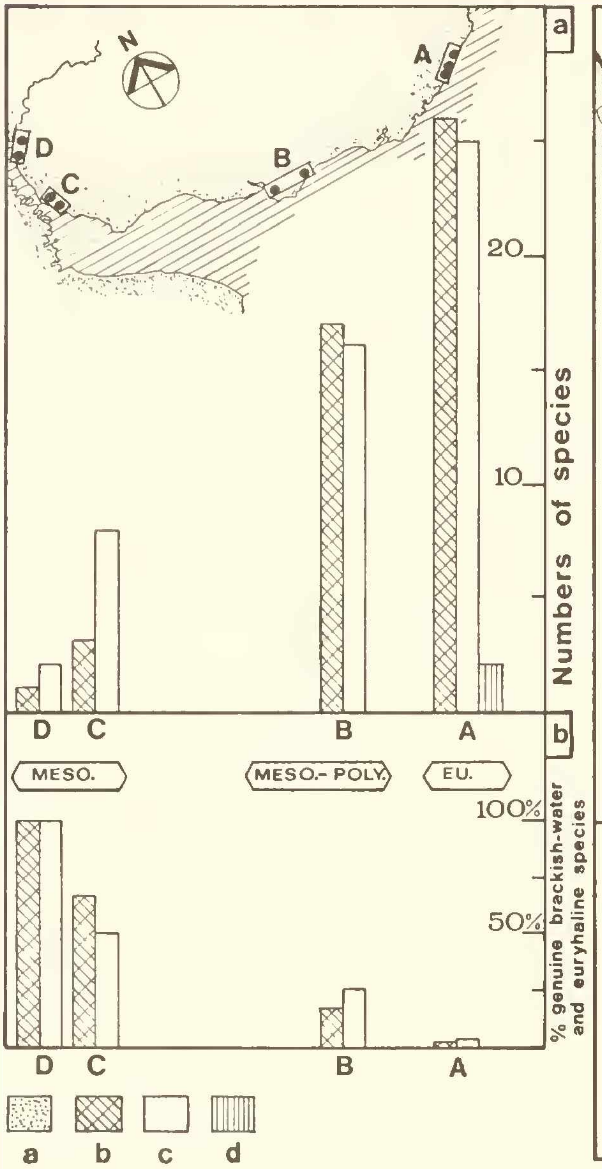

Fig. 8a: Distribution of Quaternary molluscs found in bore-holes and Lecocq. The bore-holes are grouped in areas A to D, as is explained in pages 45. Fig. 8b: Shows the percentile occurence of genuine brackish-water and euryhaline species in each area. Key: b = gastropods, c = bivalves, d = polyplacophorids.

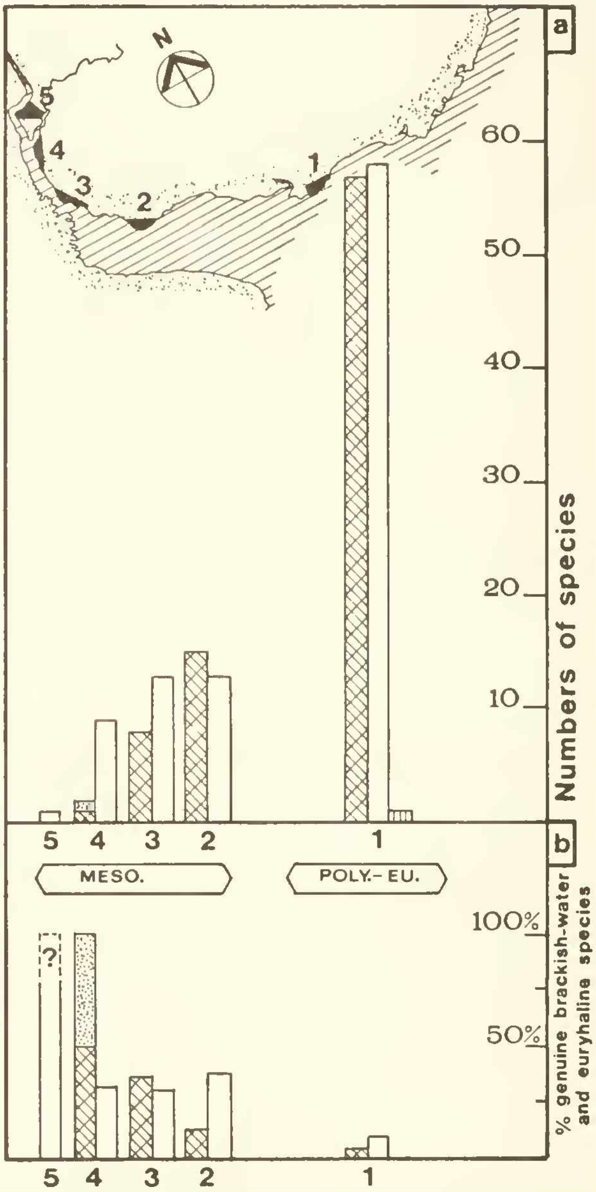

Fig. 9a: Distribution of molluscs recorded at exporsures of Vizcaíno Formation. These outcrops are located in areas 1 to 5. Their geographic location are given in page 45. Fig. 9b: Percentile occurence of genuine brackish-water and euryhaline species. Key: a = Chilina sp.?, b = gastropods, c = bivalves, d = polyplacophorids.

To establish the tolerance of certain species of water salinity, the work of Frey, Voorhies & Howard (1975), Parker (1955, 1956, 1959, 1975) and Stanley (1970) were also taken into consideration.

The study of Quaternary malacological assemblages begins with faunas recorded from wells and in Parque Lecocq. The histogram of Fig. 8a is designed to study the distribution of Quaternary molluscs, and their relationship to Remane's curve. Only those assemblages which allow one to identify the "estuarine front" of the transgression were used. The malacological faunas which were deposited in the "lateral-marginal zone of influence" were excluded. The bivalve and gastropod associations are grouped as follows:

Area A: species found in Costa Azul N° 1060/1, La Paloma N° 482/1 and La Paloma N° 449/11.

Area B: San José de Carrasco N° 442/1 and Parque Lecocq.

Area C: Carmelo N° 235 and Carmelo N° 245/1.

Area D: Bore-holes Río Uruguay N° 445/1 and Soriano N° 483/2.

The distribution of the bivalve and gastropod species is similar to those illustrated in the right half of Remane's curve.

The species spectrum of area A is similar to that reported for living assemblages of the oceanic region of Uruguay. *Brachidontes rodriguezi* and *Mytilus platensis* are also present. Both species make up a living community, which was defined for the living malacological faunas of the oceanic region of Uruguay. The area A assemblage indicate the prevalence of marine conditions.

In area B the species diversity decreases. In San José de Carrasco N° 442/1 the faunal spectrum indicates a polyhaline environment. In Lecocq it suggests a greater fall of water salinity, which was partially determinated by Río Santa Lucía runoff.

The diversity and faunal spectrum in area C corresponds predominately to a miomesohaline (= β mesohaline) environment, with a certain influence of pliomesohaline (= α mesohaline) waters. According to Remane (1963) and Hiltermann (1963b) the pliomesohaline is characterized by the dominance of a marine fauna, represented by few species. They coexist with genuine brackish-water species, and with some very tolerant limnic euryhaline ones. The miomesohaline is the most optimum environment for the genuine brackish-water species development, scarce euryhaline and limnic forms also being present. The associations in area D indicate miomesohaline salinities.

The *Brachidontes darwinianus* Community is present from Lecocq towards the inner part of estuary. This species is also recorded at Carmelo N° 245/1 and at Río Uruguay N° 445/1. Today this community lives in the fluvio-marine environment.

The percentile occurence of genuine brackhish-water and euryhaline species in areas A - D is illustrated in Fig. 8b. It is minimal at area A. At San José de Carrasco N° 442/1 it reaches 11 % for bivalves. From Lecocq towards the estuarine head or to the NW, it is evident that there is an increase in the percentile occurence of these species, which are excellent indicators for reduction in water salinity.

The given data are almost exclusively based on the malacological assemblages found in the wells. This fact may imply some limitations:

1. the number of specimens recorded from each drill cutting is low, and could introduce a bias in reference to species diversity,

2. the localities in which the wells are situated, are not always the most appropriate in analyzing faunas of the Querandina Transgression. The study of the molluscan assemblages recorded from wells also can bring adventages, because the drill samples generally contain those species which are dominant in their associations.

To verify the authenticity and validity of any given conclusions, a review of the available literature about molluscan faunas recorded from the Vizcaíno Formation exposures will be made. The re-examination of these faunas is offered, in an attept to adjust the information in reference to species diversity, and obtain additional data that are not available through the wells.

A faunal study made with this method presents several handicaps. The most relevant one is the multiplicity of criteria and methods used in faunal descriptions by different researchers. All the consulted work was not written with an aim towards paleoecological results. It is not possible in many situations to decide if the assemblages are autochthonous or allochthonous. Besides, faunas collected in different facies are related.

A histogram is given that indicates species diversity, in the following areas (fig. 9a):

Montevideo and Areneras de Carrasco (area 1).
Colonia City (area 2).
Carmelo and Nueva Palmira (area 3).
Soriano (area 4).
Fray Bentos and Mercedes (area 5).

The geographic extension of these areas, the implicated exposures, and the bivalve and gastropod species that they contain, are contained in Sprechmann (1978b).

The resulting histogram (fig. 9a) possess a similar configuration with the one prepared for the malacological faunas recorded from the wells (fig. 8a).

The following conclusions are established on the molluscan assemblages recorded from the Vizcaíno Formation exposures:

The area 1 (Montevideo and Areneras Carrasco) is characterized by:

1. a high species diversity (fig. 9a),
2. the per cent occurence of the genuine brackish-water species is small (fig. 9b); and
3. these associations possess predominantely a marine species spectrum, indicating an euhaline-polyhaline environment.

Area 2 shows:

1. an evident decrease of the diversity (fig. 9a);
2. the per cent occurence of the euryhaline and genuine brackish-water species increases greatly;
3. these associations possess predominantely a marine species coexist. This association is attributed to a pliomesohaline environment.

The assemblage of area 3 is also included within the mesohaline environment, but having lower salinity than area 2.

In area 4 a definite difference between the bivalve and gastropod diversity is present. The former are represented by eight species, whereas the latter only possess two. The diversity, faunal spectrum and per cent occurence of the genuine brackish and euryhaline bivalve species, indicate pliomesohaline salinities (fig. 9a—b). In contrast the gastropods reveal a miomesohaline environment. They are only represented by *Littoridina australis,* a genuine brackish-water species, and *Chilina* sp.?, probably a fresh water snail.

For area 5 only *Erodona mactroides* was reported, but the faunal content of the exposures in this region are little known as yet. They are considered as belonging to the miomesohaline environment.

The Archaeogastropoda (excluding the Neritacea) are the most intolerant gastropods as far as brackish environments is concerned (Remane, 1963). In area 1, which is considered a euhaline-polyhaline environment, five Archaeogastropod species were reported, whereas in the remaining areas, only one was found.

These results, carried out on the molluscan faunas from different exposures could be affected by some built in errors. The weakest aspect is the overevaluation of the incidence and value of uncommon and rare species. In the case of the histogram in Fig. 9a this risk is grater, because the majority of the authors that have described the molluscan faunas of the Vizcaíno Formation put a special emphasis on the description of rare species. They gave special importance to reporting even greater numbers of molluscan species in each different exposure. This could even be enlarged by taxonomic and nomenclatural disagreements.

To counteract this as much as possible, the percentile occurence of genuine brackish-water species must be evaluated. These data are not obtainable from assemblages in drill cuttings. Data as to percentile occurence of the recorded species in each fossiliferous locality are not found in the literature. The unique exception is a paper of Calcaterra (1971). This worker studied several exposures of the Vizcaíno Formation which are located in Colonia and Soriano Counties. For each outcrop the percentile occurence of found specimens belonging to each species is presented. Only those species that constitute more than 1 % of the assemblages in each outcrop were considered. Fig. 10 was plotted by using Calcaterra's data. There the per cent occurence of genuine brackish-water species in the following exposures is offered: Cantera Ferrando (area i), Bahía de Colonia (area ii), Arroyo San Pedro (area iii), Punta Francesa (area iv), ex-cementerio de Nueva Palmira (area v), Colonia Concordia (in Rincón del Catalán) (area vi), and Pueblo Soriano (area vii). From an analysis of fig. 10, the fact stands out that the genuine brackish-water species constitute more than 90 % of the assemblages located between Bahía de Colonia and Pueblo Soriano. They make up the trophic nucleus of their assemblages. Somewhat to the east, in Cantera Ferrando, they constitute 65 % of the assemblages. This evidence shows the value of genuine brackish-water species, and this fact must be taken into consideration for paleoecological and paleozoogeographical reconstructions.

Fig. 11 is designed with this aim in mind, based also on data of Calcaterra (1971). For each locality the percentile occurence is illustrated by the following:

1. marine species,
2. the recorded genuine brackish-water species: *Tagelus plebeius, Mactra isabelleana* and *Erodona mactroides,*
3. limnic species.

The assemblages plotted in Fig. 11 can be grouped as follows:

Brackish assemblage, with a moderate marine influence: locality i.

Brackish "polyspecific" assemblages. They have three dominant genuine brackish-water species: localities ii and iv.

Brackish "monospecific" assemblages. A single genuine brackish-water species is dominant: localities iii, v, vi and vii.

One of the greatest difficulties for paleoecological reconstruction of an estuarine region, is to discriminate between the "estuarine front" and the "lateral-marginal zone of influence".

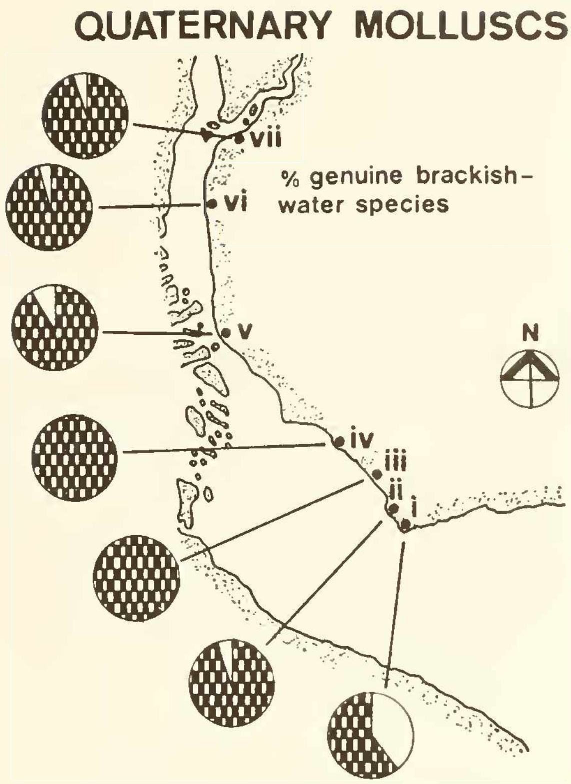

Fig. 10: Percentile occurence of genuine brackish-water species from several exposures from the Vizcaíno Formation in Colonia and Soriano Counties (after Calcaterra, 1971). Exposure location is indicated on page 46.

On Fig. 11 criteria for the identification of the associations deposited in the "estuarine front" are given. It allows to select the representative assemblages for reconstruction of saline zonation during the Querandina Transgression.

The assemblages ii and iv are comparable with the living ones on the shores of Montevideo County. Hence, they belong to the fluvio-marine environment, and indicate mesohaline salinity. According to Scarabino, Maytía & Cachés (1975) their faunal spectrum is typical for sandy muddy sediments. The absence of *Brachidontes darwinianus mulleri* and/or of *Mytella charruana* is a consequence of the absence of hard grounds in this area.

The brackish "monospecific" assemblages are considered as indicative of intermediate-fluvial environments (oligohaline-mesohaline). Only two brackish "monospecific"assemblages identify the "estuarine front": the associations found in the exposures of the ex-cementerio de Nueva Palmira (fig. 11, area v), and in Pueblo Soriano (fig. 11, area vii). On the contrary, the fauna recorded from localities iii and vi were deposited in the "lateral-marginal zone of influence".

Detailed evidences allows one to establish, with reasonable certainty the geographical setting of the Transitional-area between fluvio-marine and intermediate-fluvial environments during the Querandina Transgression. It was located approximately between Punta Francesa and Nuava Palmira. The term "Transitional-area" is used to underscore the fact that the changes between the environments are gradual. The faunal association of a "Transitional-area" is constituted by a combination of those species from adjacent environments.

The analysis of depositional environments provided by malacological assemblages of bore-holes Carmelo N° 245/1 and Carmelo N° 235 (fig. 13) permits one to define even more closely the location of the Transitional-area between fluvio-marine and inter-

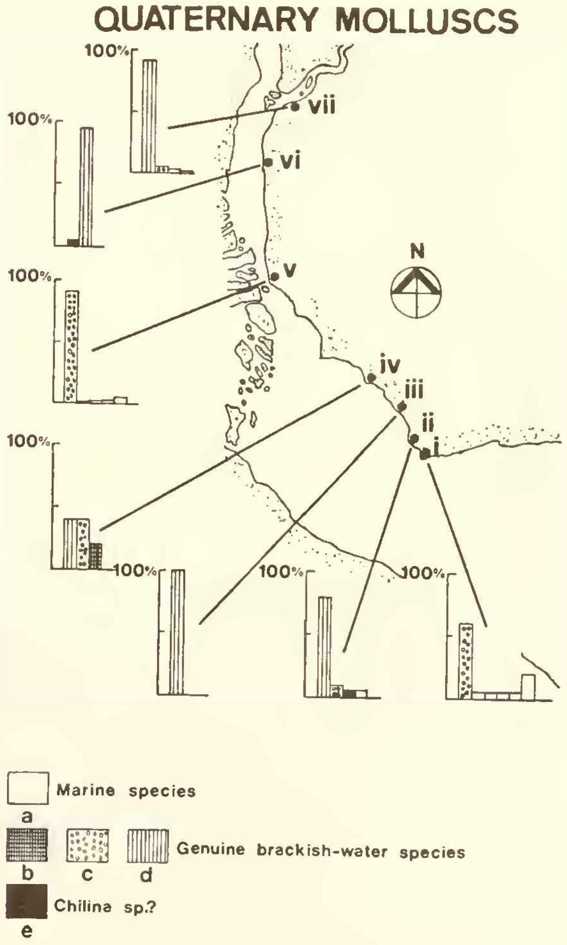

Fig. 11: Faunal composition in the various exposures from the Vizcaíno Formation in Colonia and Soriano Counties (after Calcaterra, 1971). Key: a = marine species, b = *Tagelus plebeius*, c = *Mactra isabelleana*, d = *Erodona mactroides*, e = *Chilina* sp.?. Location of exposures i — vii is shown on page 46.

mediate-fluvial environments. It allows one to deduce that it was situated between Carmelo and Nueva Palmira (fig. 12).

During the Querandina Transgression, the Transitional-area between intermediate-fluvial and inner-fluvial environments was located somewhat to the north of Fray Bentos, and a little east from Mercedes (fig. 12).

Identification of euryhaline bivalve and gastropod species

Several molluscan species found in the Río de la Plata estuary were defined as genuine brackish-water species and marine euryhaline ones by the malacologists that studied the living faunas of the region (Chapter VI. F. 4. b—c). The analysis of the range of distribution from the species found in the Querandina Transgression allows one to infer that the following species must be considered as marine euryhaline forms: *Anomalocardia brasiliana, Ostrea equestris, Pitar rostratum, Acmaea subrugosa, Thais (S.) haemastoma* and *Siphonaria (P.) lessoni.*

e) Paleoecological reconstruction on molluscs from additional localities of the Querandina Transgression.

The depositional environments of the strata of various outcrops which were assigned to the Querandina Transgression, are established on the basis of their molluscan assemblages. For this purpose a method of analysis is used, which defines following parameters:

1. the faunal spectrum,
2. the number of present stenohaline-marine, euryhaline-marine, genuine brackish-water, euryhaline-limnic and stenohaline-limnic species, and their per cent occurence.
3. determination of the number of dominant species in each assemblage.

These data are compared with ones used for living assemblages, and also for those plotted on Figs. 8, 9, 10 and 11.

This method is applied on the molluscan assemblages described by the named authors in localities from:

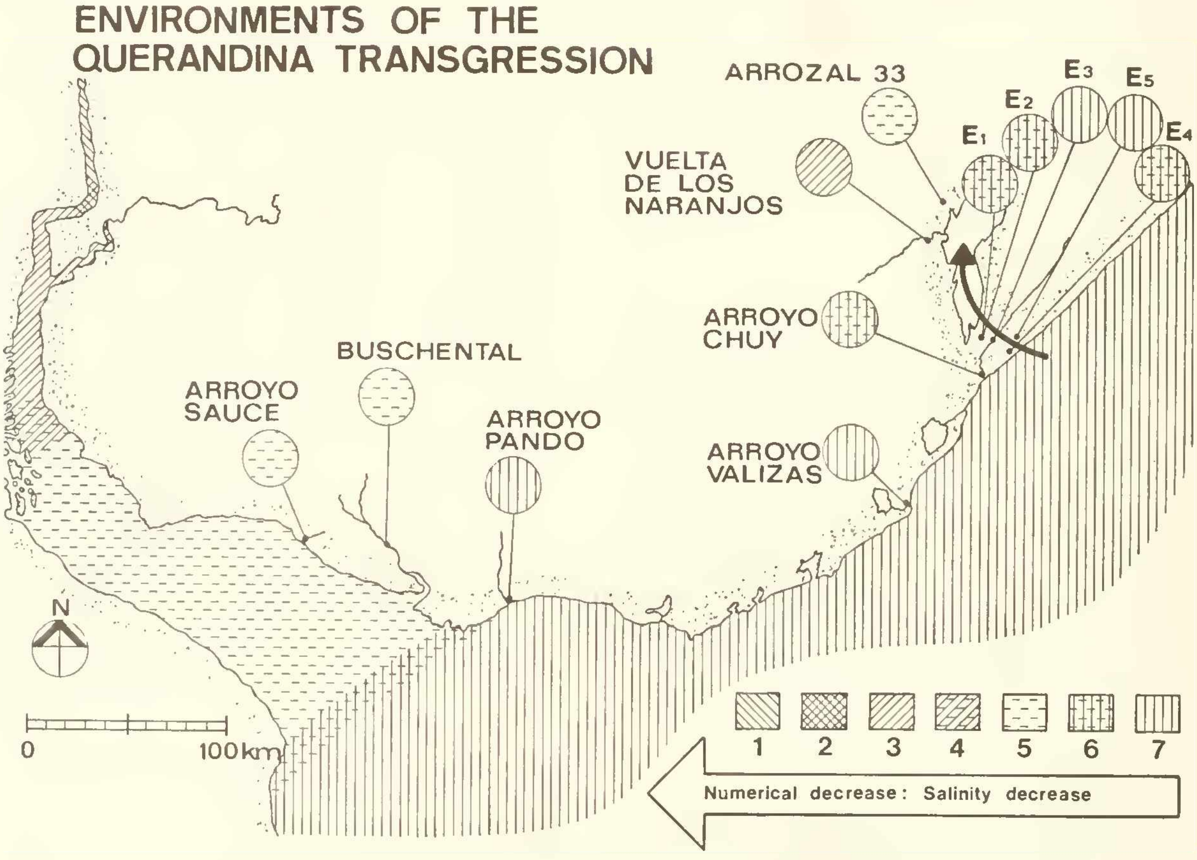

Fig. 12: Paleoecological reconstruction of estuarine environments as well as on additional localities of the Querandina Transgression. The following environments were identified: 1 = inner-fluvial environment, 2 = Transitional-area between intermediate-fluvial and inner-fluvial environments, 3 = intermediate-fluvial environment, 4 = Transitional-area between fluvio-marine and intermediate-fluvial environments, 5 = fluvio-marine environment, 6 = Transitional area between marine and fluvio-marine environments, 7 = marine environment. See pages 49 for information about indicated localities.

Rio Grande do Sul (southernmost Brazil): malacological associations from exposures E_1, E_2, E_3, E_4 and E_5, located in the Santa Vitória do Palmar County (Closs & Forti, 1971).

Uruguay: Arrozal 33 (Serra, 1944), Vuelta de los Naranjos, section II (Serra, 1944), Arroyo Chuy (Figueiras, 1967), Arroyo Valizas (Broggi, 1970), Arroyo Pando (Broggi, 1967), Buschental (Kraglievich, 1932), Arroyo Sauce-Boca de los Ceibos (Teisseire, 1928).

Using the proposed criteria corresponding environments were established, as is illustrated in Fig. 12. These environments are related with the shown estuarine zonation during the Querandina Transgression. It must be remembered that the reconstruction was approximate in determined environments. The degree of correctness in this approach depends on the realiability and accuracy with which faunal records were made in each fossiliferous locality.

The depositional environments show the following relationships with the estuarine ecozones (fig 12):

1. The assemblages from the exposures E_3, E_5, Arroyo Valizas, Arroyo Pando and Sauce-Boca de los Ceibos belong to the marine and "estuarine front" depending on their geographic setting.

2. The molluscs of localities Arroyo Chuy, E_1, E_2, E_4, Arrozal 33 and Vuelta de los Naranjos were deposited in the "lateral-marginal zone of influence".

3. During the Querandina Transgression the Laguna Merín was inhabited (settled), in the Arrozal 33 region, by a molluscan fauna which is characteristic for the fluvio-marine environment. In contrast, today in the inner part of the Laguna Merín the salinities do not exceed values of 0.2 ‰, reaching exceptionally up to 1 ‰ (Closs & Medeiros, 1967; Madeira-Falcetta, 1974).

4. Throughout the course of the lower Holocene Transgression, the Laguna Merín was directly open to the ocean in its southernmost part. The molluscan assemblages from Santa Vitória do Palmar County and Laguna Merín display a zonation beginning with marine environments that range to fluvio-marine, and

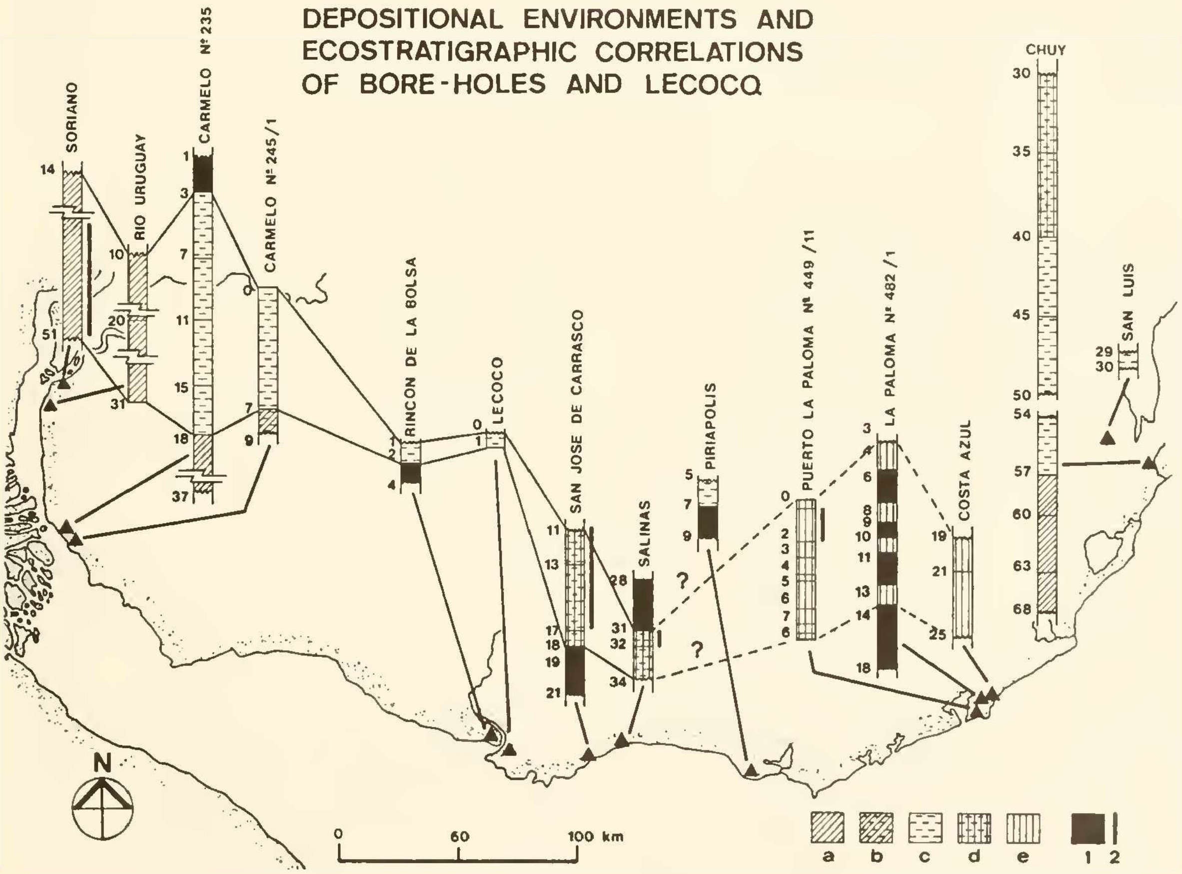

Fig. 13: Depositional environments of bore-holes and Lecocq, and ecostratigraphic correlations. Key: a = intermediate-fluvial environment, b = Transitional-area between fluvio-marine and intermediate-fluvial environments, c = fluvio-marine environment, d = Transitional-area between marine and fluvio-marine environments, e = marine environment. — 1 = environment not identified, material lacking, 2 = environment tentatively established.

somewhat to the north into those of the intermediate-fluvial environment (fig. 12). It is not the purpose of this paper to make a detailed reconstruction of the facies and paleogeography of the Laguna Merín during the Querandina Transgression, or to determine its relation with the coastal plain evolution. Jost, Soliani Jr. & Godolphin (1975) studied the paleogeographical evolution of this region during the Quaternary. They described the existence during the Flandrian Transgression of an inlet between the sea and Laguna Merín, located in the proximity of the locality of Taim, which was designated as "Vertedouro do Taim". However, they did not mention the presence of any Holocene connexion between Laguna Merín and the ocean, which was situated to the south of "Vertedouro do Taim".

5. DEPOSITIONAL ENVIRONMENTS DETERMINED BY WELL DRILLING AND IN PARQUE LECOCQ

The ancient environment of each Quaternary fossiliferous drill cutting from bore-holes, and from Lecocq, is represented on the basis of the evaluation of foraminiferal and molluscan associations (fig. 13). The conclusions which were established on those drill cuttings carrying scarce fossiliferous material must be considered as approximate.

G. Biostratigraphy

The paleoecological and paleogeographical reconstructions previously presented have several different biostratigraphic consequences:

1. ECOSTRATIGRAPHIC CORRELATIONS

It is not possible to make time-biostratigraphic correlations using index fossils. This is the usual situation working with Quaternary benthic assemblages. Besides, there are no climatic fluctuations of great enough extent to be used for time-stratigraphic correlations.

The only way to establish biostratigraphic correlation is by using ecostratigraphic units or ecozones. These ecozones are correlated by their place in the cycle of greatest salinity. A similar technique was used by Israelski (1949) and Krumbein & Sloss (1963, fig. 10—18), who made their correlations using the method of position in the bathymetric cycle.

The ecostratigraphic correlations that are proposed are illustrated on Fig. 13. The presented time-stratigraphic horizon contain fossil associations carrying different faunal spectra. For these correlations only those assemblages are taken into consideration which were deposited in the "estuarine front". Only the assemblages that indicate environments with the greatest salinity for each estuarine region are used. This stratigraphic position then may be considered to be time equivalent at each well.

The fossil associations of San Luis N° 1072/1, Chuy N° 364 and Piriápolis N° 431/7 show environments that are not in agreement with the cycle of the greatest salinity for their geographical setting. They could have been deposited in:

a) the "lateral-marginal zone of influence" being in this case isochronous.

b) the course of an earlier or latter transgressive event. For Chuy N° 364 it is shown that the fossil assemblages were more ancient, being deposited during the Pleistocene (Chapter VII).

The reliability of the provided correlations increases towards the head of the estuary. From Salinas to the NW net differences between the contemporaneous depositional environments are present, as a consequence of displacements of depositional environments during the Querandina Transgression. On the contrary, the depositional environments found in Costa Azul N° 1060/1, La Paloma N° 482/1, and La Paloma N° 449/11 correspond to a marine environment, being coincident with the ones existing today in these localities. Hence, a correlation supported on the environmental displacement is not possible, due to the absence of differentiated depositional environments. The indicated correlation between these wells must be considered as tentative.

The ecostratigraphic correlations illustrated in Fig. 13 must be confirmed and verified by C 14 dating.

The above is dealt more extensively by Sprechmann (1978a).

2. DATA SHOWING THAT THE ASSEMBLAGE ZONES DESCRIBED FOR THE URUGUAYAN QUATERNARY ARE INVALID

The age of malacological associations found in the region of Nueva Palmira and southern Fray Bentos have given origin to some controversy. The prevailing opinion has assigned them to the Querandinense, but some workers included them within the Belgranense (Castellanos, 1948; Francis, 1975; Frenguelli, 1930; Goñi & Hoffstetter, 1964; Kraglievich, 1928, 1932). A paleontological argument was used supported on the presence or absence of certain species, which were considered typical for each stage. *Mactra isabelleana* and *Thais haemastoma* were mentioned as characteristic fossils for the identification of the Belgranense. The faunal assemblages deposited during the Querandinense may be recognized by the dominance of *Erodona mactroides*. Nevertheless, Forti (1969) correctly considered that *Mactra isabelleana* is a typical form in the Querandinense.

The time-stratigraphic interpretation supported on the presence or absence of these species are incorrect. They are isochronous. Their presence or absence in a certain time equivalent assemblage is due to environmental factors, one being the salinity. Moreover, the benthic molluscs have a patchy distributional pattern (Parker, 1975).

Francis (1975) defined the following biostratigraphic units:

a. *Thais haemastoma* Assemblage Zone (middle Pleistocene?), which is tentatively correlated with the Belgranense;

b. *Erodona mactroides* Assemblage Zone (Vizcaíno Formation: upper Pleistocene-Holocene);

c. *Elphidium discoidale* Assemblage Zone (Chuy Formation and Vizcaíno Formation: upper Pleistocene-Holocene); and

d. *Littoridina australis* Assemblage Zone (La Plata Formation?: Holocene).

The results proposed by Francis are the consequence of a mistake. As is indicated in the present work, the species that identify the assemblage zones are essentially time-parallel. Therefore they can not be used as time-stratigraphic indicators, because their presence or absence in an association is determined by facial and ecological changes.

H. Results of the Holocene paleogeography in the Río de la Plata region

The available data of the history of the Río de la Plata supported on C 14 datings (Chapter VI-E), and the proposed ecostratigraphic correlations (Chapter VI-G-1), allow one to conclude that the major part of the foraminiferal and molluscan assemblages were deposited during the first transgresive phase of the Holocene Transgression.

According to Urien & Ottmann (1971) during the early Holocene the waters transgressed penetrating deep into the estuary. Sea level reached as far as + 8 m above present stand.

The paleoecological reconstruction corroborated the existence of displacement of the estuarine depositional environments simultaneously with the first transgresive phase of the Holocene Transgression. The geographic range covered by each depositional environments was evidently different from the prevailing today (fig. 14).

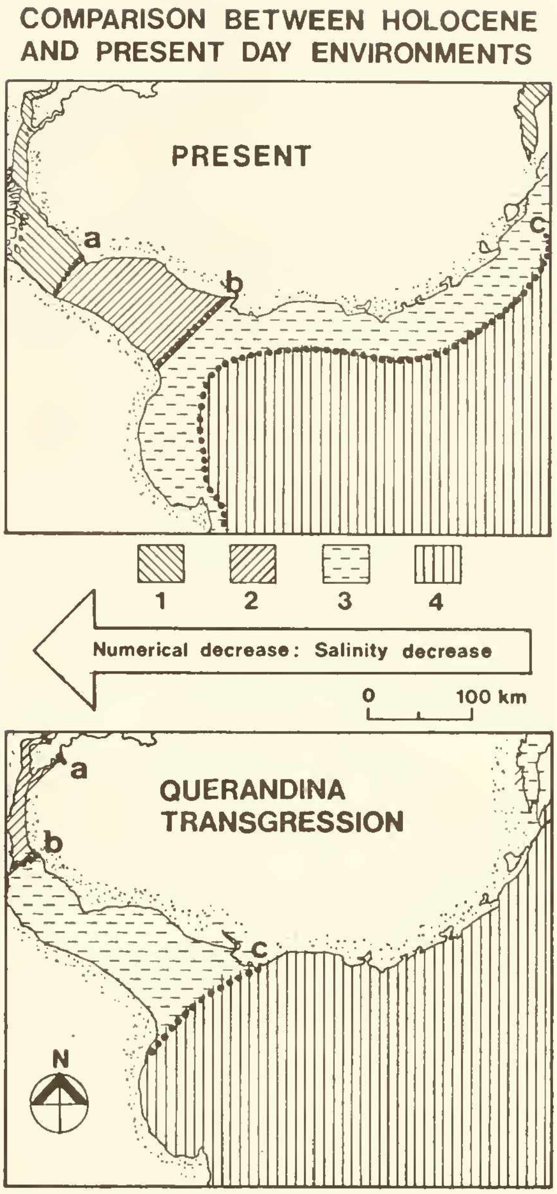

Fig. 14: Comparison between depositional environments from the first transgressive phase of the Holocene Transgression, and those of the present day, showing environmental displacements. Key: 1 = inner-fluvial environment, 2 = intermediate-fluvial environment, 3 = fluvio-marine environment, 4 = marine environment. a, b and c location of transitional-areas (also see figs. 3 and 12).

The assemblages of foraminiferids are most suited to reveal the location (situation) of the Transitional-area between marine and fluvio-marine environments during the earlier phase of the Holocene Transgression. It formed an arch along the Uruguayan coast, extending from Salinas as fas as San José de Carrasco, Areneras de Carrasco, and the eastern coastal region of Montevideo County. In contrast, the foraminiferids are not useful in the reconstruction of the location of the remaining transitional-areas. By evaluating molluscan assemblages, reconstruction of the geographical setting of fluvio-marine and intermediate-fluvial environments was possible. The Transitional-area between fluvio-marine and intermediate-fluvial environments was located between Carmelo and Nueva Palmira. The transitional-area between intermediate-fluvial and inner-fluvial environments was localized in the Río Uruguay somewhat to the north of Fray Bentos; and a little east from Mercedes on the Río Negro (fig. 12).

The depositional environments and transitional-areas were reconstructed using foraminiferal and molluscan assemblages found on the Uruguayan coast of the Río de la Plata. Their projection towards the central and southern estuarine region is tentatively outlined.

The great extent of the movement of the depositional environments shown in Fig. 14 shows that they could not had occured as a consequence of a saline stratification.

Paleogeographical reconstruction has confirmed the validity and authenticity of the argument that the foraminiferal and molluscan associations were deposited during the earlier Holocene transgressive events. Urien & Ottmann (1971) wrote that the transgressive events during the upper Holocene had less vertical amplitude and smaller superficial extent. Furthermore, the marine influence remains restricted to the outer part of the estuary.

These results are also in agreement with those of Urien (1972), who by using sedimentological methods showed the existence of:

1. an onlap of marine sandy facies during the Querandina Transgression, which was followed by,
2. an offlap of fluvial sitly muddy facies.

The sea also invaded the Laguna Merín area simultaneously to the Querandina Transgression. It was connected with the ocean by it southernmost part. Jost, Soliani Jr. & Godolphin (1975) previously described the existence of a second connecting body designated the "Vertedouro do Taim". The molluscan assemblages of the Querandina Transgression reveal in the Laguna Merín region the existence of zonation, beginning in the south with marine environments, that gradually change north into fluvio-marine and intermediate-fluvial environments.

VII. CONCLUSIONS ABOUT THE NEOGEN-QUATERNARY EVOLUTION IN THE CHUY AREA

Chuy well N° 364 is located in the western region of the Pelotas Basin. This well presents the most complete known sedimentary sequences for the study of the Uruguayan Neogene and Quaternary. This fact explains the repeated studies made about this bore-hole, and justifies the inclusion of a special review of this well. Several stratigraphic interpretations were made for the well (see Chapter V-B). Only the interpretation proposed by Goso (1972) shows good parallelism with the distribution of fossil assemblages. For this reason it is used as a basic reference for the stratigraphic interpretation.

The drill cuttings situated between 133.00—113.00 m (fig. 2) had been assigned to the Camacho Formation (Ecochard, 1970; Figueiras & Broggi, 1971, 1972/73; Goso, 1972; Medina, 1962). The depositional environments corresponding to these drill samples are analysed in Chapter V-F-4. The assemblages show a Miocene age.

Between 113.00—66.00 m continental sedimentation took place that lithostratigraphically corresponds to the Raigón Formation (Goso, 1972). Probably it was deposited during the Pliocene.

The Quaternary sequences of Chuy N° 364 which contain foraminiferids and molluscs are analyzed in Chapter VI. Its distribution shows that between 66.00—57.60 m only the bivalve *Erodona mactroides* occured. This species is also present between 57.60—54.20 m associated with foraminiferids, ostracods and barnacle plates. The whole assemblages found between 66.00—54.20 m shows a shallow, cold temperate, and hyposaline (oligohaline, mesohaline) depositional environment.

Between 50.00—30.00 m assemblages made up of foraminiferids, ostracods, barnacle plates and bivalve fragments are present. Their faunal spectrum indicate shallow, cold temperate, and hyposaline (polyhaline-mesohaline) waters.

Goso (1972) points out that these transgressive episodes correspond lithostratigraphically to the Chuy Formation. He also refers to the same formation the drill samples which lie between 27.40—7.10 m. These three sequences which are part of the entire lithostratigraphic Chuy Formation, were named Chuy I, Chuy II and Chuy III.

The Chuy Formation was defined by Delaney (1963, 1965). Only the sediments lying between 27.40—7.10 m are the same of those found in the type locality of the Chuy Formation. The lithofacies of the Chuy Formation were described by DELANEY (1963, 1965, 1966, 1967, 1969?) and JOST (1972). The sequence situated between 27.40—7.10 m, whose lithofacies is equivalent with that of the Chuy Formation, is here named Chuy (sensu stricto) III (fig. 2). Probably it belongs to the upper Pleistocene (see Chapter VI-C-3).

The drill cuttings found between 66.00—54.20 m, and 50.00—30.00 m, lithologically are not similar to the facies of the Chuy Formation sensu stricto. For their identification the names Chuy (sensu lato) I, and Chuy (sensu lato) II are used (fig. 2). Its position in the section indicates that they were deposited probably during the Pleistocene.

According to GOSO (1972), the continental strata that were deposited after each one of the chronostratigraphic events Chuy (sensu lato) I, Chuy (sensu lato) II, and Chuy (sensu stricto) III, belong lithostratigraphically to the Libertad Formation. Each of these continental events are chronostratigraphically named Libertad I, Libertad II, and Libertad III. Libertad III ist considered to be a synonym for Dolores Formation (fig. 2).

GOSO (1972) correlated the Chuy I, Chuy II and Chuy III events with the first, second and third Quaternary interglaciations, respectively. Libertad I, Libertad II and Dolores were considered as being time equivalent with the second, third and fourth glaciation, whereas Raigón is considered to have been deposited during the first glaciation. ECOCHARD (1970) also established time-stratigraphic correlations between the sedimentary sequences of Chuy N° 364, and the Quaternary glaciations and interglaciations. TRICART (1972) also provided time-stratigraphic correlations between the Quaternary glaciations and interglaciations and the Uruguayan formations. But the correlations proposed by these authors do not in themselves agree.

In this work none of these criteria has been adopted. There is no objective evidence for dating, even less to verify time-stratigraphic correlations with certain glaciations or interglaciations.

VIII. DISTRIBUTION OF THE PALEOZOOGEOGRAPHICAL LITTORAL PROVINCES

The paleozoogeographical evolution of the region in study, since the Miocene up to the Holocene, is very controversial.

One of the most polemic aspects was postulated by IHERING (1927). He theorized that the Gulf of Mexico-Caribbean area was connected with the South Atlantic by an arm of the Tethys crossing through the continent and providing tropical waters. This hypothesis has been examined from different points of view. In reference to foraminiferids it has been discussed by BOLTOVSKOY (1958, 1973, 1976), BOLTOVSKOY & LENA (1971, 1974b), CLOSS (1963) and MALUMIAN (1970).

In this chapter an attempt is made to make a paleozoogeographical contribution with a different point of view. The relationships between the distribution of the marine currents and the paleozoogeographical littoral provinces that they determine are analyzed from the Miocene to Holocene. This paleozoogeographical zonation must be considered the first approach to this subject for this region. It must be completed and adjusted on the basis of new fossiliferous findings and the use of other phyla.

The evaluated data have been provided by:

a. the fossil assemblages found in Uruguayan boreholes; and

b. the interpretation of available information contained in previous literature.

This analysis presents difficulties as a consequence of the low number of known fossil localities. In addition, great disagreement exist in reference to the time-stratigraphic relations of the Miocene assemblages recorded from the South American atlantic region. This fact has been documented by BERTELS (1975), BERTELS & MADEIRA-FALCETTA (1977), BOLTOVSKOY (1973), CLOSS (1967, 1970), MALUMIAN (1970), MALUMIAN & MASIUK (1973), NOGUTI (1975) and STAINFORTH (1975). This problem is even more acute in the Quaternary.

The distributional pattern of the littoral foraminiferids from the atlantic coasts of South America since the Miocene, can be explained by the existence of two marine currents; one flowing from north to south carrying warm masses, and another that flowing in the opposite direction, transporting cold water bodies. It is assumed and hypothesized that these currents are the Brazilian and the Malvin respectively. Therefore, the information offered by the foraminiferal associations of the wells, can be related to the present-day distribution of the littoral zoogeographical provinces in this region. The term littoral is used in the broad sense. It includes the intertidal zone and the upper part of the sublittoral zone (upper sublittoral zone).

The present distribution of the West Indian Province (= Caribbean or Antillean Province) in South America, and its division into subprovinces is described by Boltovskoy (1964, 1965, 1976), Boltovskoy & Wright (1976), and Tinoco (1971), (fig. 15c). The features of the Argentine Province (= "kingdom" of *Buccella peruviana*, s. l. or South American Atlantic Province) were given by Boltovskoy (1970a, 1976) and Boltovskoy & Wright (1976), (fig. 15c).

A. Miocene

Studies on the paleogeography of the Entrerriana Transgression are provided by Harrington (1962) and Camacho (1967).

The Miocene foraminiferal assemblages found in Chuy N° 364 (133.00—122.10 m) are characterized by the presence of *Amphistegina gibbosa.* At the present time, *Amphistegina radiata* (and/or *Amphistegina lessonii*) is the most characteristic foraminiferid from the littoral and upper sublittoral warm waters of nordeast Brazil. Its present range of distribution is situated between the 23° S and 4° N parallels. This species disappears north of Cabo Orange, and south of Cabo Frio, and defines the North-brazilian Subprovince (Tinoco, 1971). In this subprovince tropical waters of the Brazilian current are found and the cold Malvin stream has no influence. It is a region of tropical warm waters, with mean annual temperatures higher than 24° C (Balech, 1954). The surface-water temperatures range between 24° C in february and 21° C in august (Boltovskoy, 1976, fig. 2).

The presence of *Amphistegina gibbosa* in the Chuy area during the Miocene, indicates that the North-brazilian Subprovince possessed a geographical distribution which extended further south, reaching al least 34° S latitude (fig. 15 a).

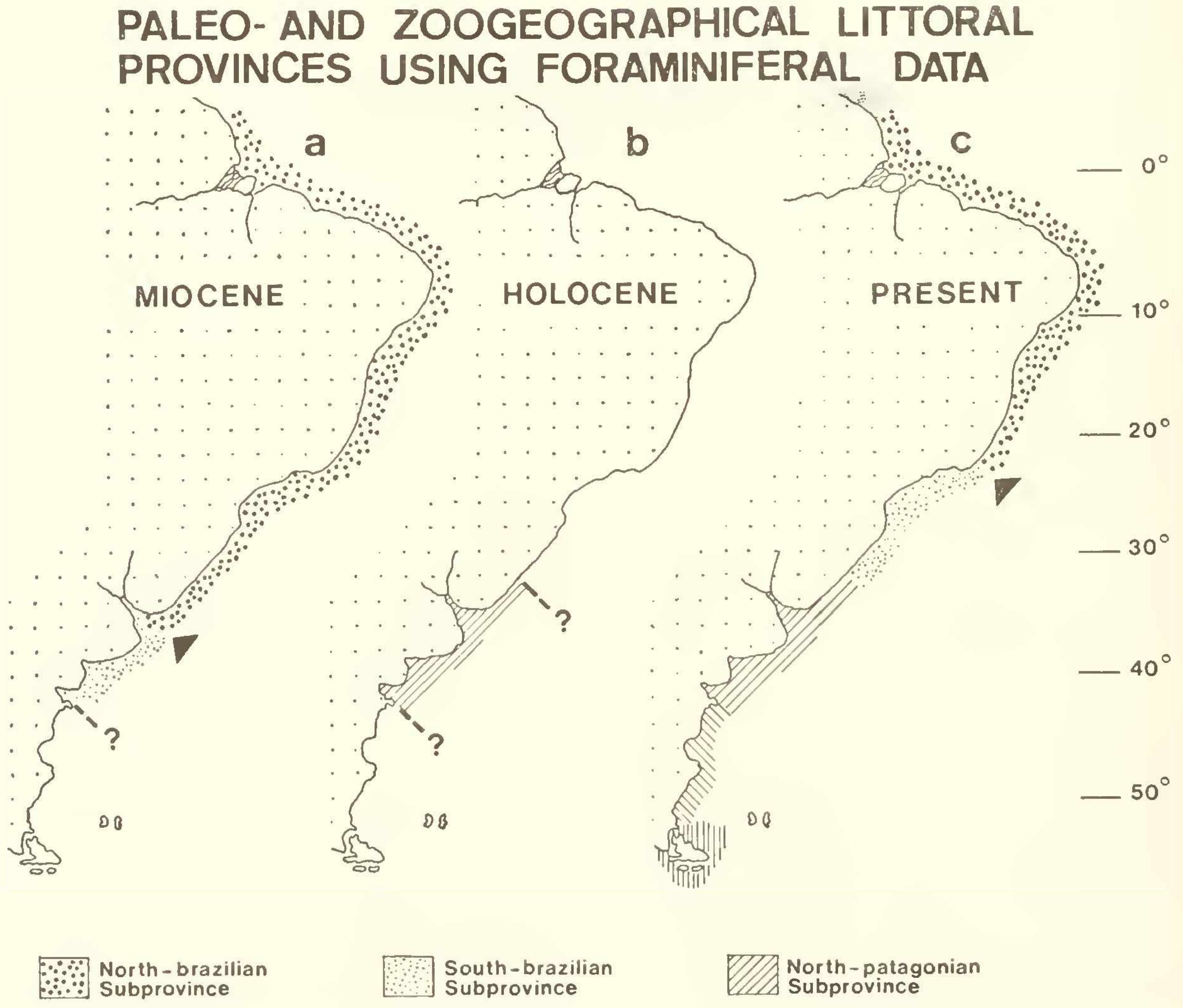

Fig. 15: Distribution of paleozoogeographical littoral provinces from Miocene to Holocene, based on foraminiferids.

Todd (1976, p. 388) also said that during the Eocene and Miocene *Amphistegina* significantly reach a greater geographic area than in modern seas. This may be related in part to the warmer climates during those times, and in part to the possibility of different positions of the continents to the equator and to the influence of oceanic currents.

These data are coincident with a pantropical expansion of certain shallow-water foraminiferids, specially seagrass-dwelling forms, that took place during the lower and middle Miocene. This is correlated with a climatic amelioration of 5—8° C that occured in higher latitudes of the southern hemisphere during early and middle Miocene times (Brasier, 1975b, p. 693—695).

The existence of warm water bodies in the Brazilian Miocene has also been shown for the Pelotas Basin (Closs, 1966a, 1967, 1970), the Marajó Basin (Petri, 1954) and the Pirabas Basin (Petri, 1957). In these fossiliferous localities *Amphistegina* is also present. Therefore all these regions must be included in one paleozoogeographic unit, which is designated as North-brazilian Miocene Subprovince (fig. 15a). The concept "paleozoogeographic province" is used to signify a climatic unit. This is a consequence of the fact that temperature is the most important factor limiting the geographic range of the species distribution (Boltovskoy, 1965; Boltovskoy & Wright, 1976; Valentine, 1963).

In Argentina, the microfaunas from the Entrerriense and/or Paranense (upper Miocene-lower Pliocene?) of the Salado Basin, indicate somewhat higher temperatures than exist today in this region (Malumian, 1970; Malumian & Masiuk, 1973). *Amphistegina* is absent. Bertels (1975) considered that the ostracods from the Argentinian Entrerrian Stage (= Entrerriense) indicated warm temperate waters. Based on these evidences, it is thought that warm temperate waters from the Entrerriense of Argentina correspond with those of the South-brazilian Subprovince. Today this subprovince is characterized by the presence of warm temperate water bodies, the influence of the Brazilian current prevailing on the Malvin. For this unit the name South-brazilian Miocene Subprovince is proposed. These results complement those of Groot et al. (1967, p. 215). They indicated that the subtropical zone of convergence was situated, at least during the lower and middle Tertiary, somewhat further south than today.

These results obtained for the marine faunas agree with the paleoclimatological reconstructions made for continental areas. Meléndez (1971) showed that in the Miocene tropical floras prevail at this latitude. Volkheimer (1971) indicated that in the Pampas region during the Miocene a very warm climate existed, and in Patagonia temperate temperatures.

The existence of warm water bodies in the Uruguay nearshore shelf during the Miocene must have had consequences for the distribution of the gastropods and bivalves. For the analysis of Miocene malacological assemblages from Uruguay, a comparison is made with their present range of distribution.

The influence of the marine currents on the distribution of the present day molluscs from Uruguay was studied by Sicardi (1967), who described the distributional range of 81 gastropod species, and 73 bivalves species. These are classified into:

1. species reaching this region by influence of the Malvin Current;
2. species belonging to the Brazilian current;
3. autochthonous ones.

There is a direct relationship between both mentioned currents and the zoogeographical provinces defined on the basis of the molluscan assemblages (Balech, 1954; Carcelles, 1944; Castellanos, 1967; Forti, 1969; Sicardi, 1967). The Magellanic Province is related to the influence of the cold Malvin current; the Caribbean or Antillean is characterized by the presence of the warm Brazilian current; and the autochthonous species correspond with the Argentinian or Patagonian Province. The boundary between the Caribbean and Argentinian Provinces lies approximately in the 28° S latitude. The boundary between the latter and the Magellanic Province is situated at the 43° S latitude (fig. 16a).

Carcelles (1944) found that bathymetric zonation is also present in the distributional pattern of molluscs. The species from the Caribbean or Antillean Province possess for the most part a more superficial distribution. In middle depths the autochthonous species are most frequently represented, whereas in deeper water the number of species belonging to the Magellanic Province increases. Evidently this bathymetric zonation is determined by the distribution of the marine currents. The water that is carried by the Brazilian current lies in a more superficial position than those transported by the Malvin current. Similar results were obtained and supported by the study of foraminiferids. On the coastal areas the Brazilian and autochthonous species are dominant, whereas outside of the 80 m isobath the typical species of the Malvin current prevail (Boltovskoy, 1965, 1973, 1976; Boltovskoy & Wright, 1976). This is interesting because they allow errors to be avoided in paleogeographical interpretation. In each association from the different zoogeographical provinces the percentile occurence of the individual species is determined not only by the latitude, but also by the bathymetry.

The zoogeographical littoral provinces, defined on the basis of foraminiferids and molluscs, disagree somewhat in their conventional boundaries. But the criteria used for their definition are the same, since they are based on the interaction between the Malvin and Brazilian currents. Hence the comparisons that follow are legitimate.

Based on the data of SICARDI (1967, 1975) the per cent occurence of the species given for the present day Uruguayan gastropod and bivalve faunas is determined. The gastropod fauna is composed of 37 % of the species related to the Brazilian-Antillean influence, and therefore brought by the Brazilian current; 17 % are related to the Malvin current; 46 % are autochthonous (fig. 16b). The bivalve fauna consists of 44 % of the species attributed to the Brazilian current, 20 % of a Magellanic origin, having been carried by the Malvin current, and the remaining 35 % are autochthonous (fig. 16c).

For the paleozoogeographical interpretation the Miocene molluscs found in Chuy N° 364 are evaluated in relation to their present distributional range. Only the surviving Miocene species are taken into consideration; the extinct ones have been rejected, because their paleozoogeographical distributional pattern is controversial. The analyzed species are classified in reference to their present zoogeographical distribution (table XIX).

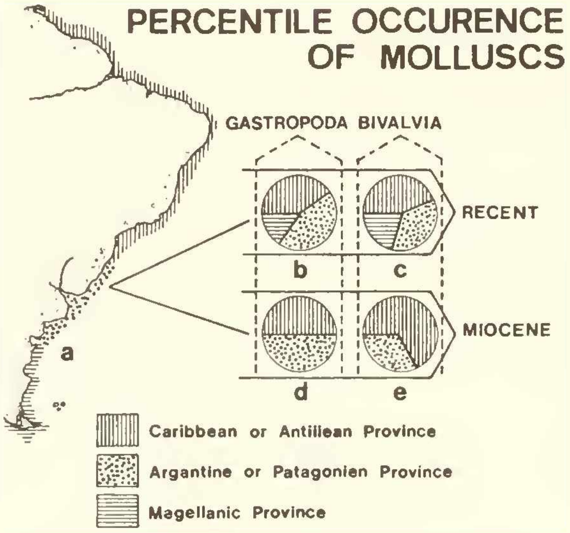

Fig. 16: Percentile occurence of Uruguayan Miocene and Recent molluscs belonging to the Caribbean, Argentinian and Magellanic Provinces.

TABLE XIX
Paleozoogeography of molluscs from Chuy No 364

Caribbean or Antillean Province	Argentinian or Patagonian Province
GASTROPODA	
Halistylus columna	*Olivella puelcha*
Iselica anomala (+)	
Olivancillaria urceus	
BIVALVIA	
Amiantis purpurata	*Mactra bonariensis*
Corbula caribaea	*Tivela (Eutivela) isabelleana*
Diplodonta vilardeboana	
(Cyrtopleura lanceolata ornata)	
(Tagelus plebeius entrerianus)	

Cyrtopleura lanceolata ornata and *Tagelus plebeius entrerianus* constitute extinct subspecies of species that today live in the Caribbean Province. In Table XIX they are placed between parenthesis to indicate that their paleozoogeographical distribution is tentatively established.

The number of Miocene molluscan species of Chuy N° 364 which can be evaluated is relatively low. This could introduce a bias in the paleozoogeographical interpretation. Therefore Table XX was plotted — using the same criteria — with the Miocene molluscs found at Chuy N° 364 as well as additional species of the Camacho Formation found in exposures of the Colonia and San José Counties (Figueiras & Broggi, 1971, 1972/73). The percentile occurence of the Miocene molluscs from the entire Camacho Formation belonging to the different provinces in shown in Fig. 16d-e.

TABLE XX
Paleozoogeography of molluscs from the Camacho Formation

Caribbean or Antillean Province	Argentinian or Patagonian Province
GASTROPODA	
Halistylus columna	*Olivella puelcha*
Iselica anomala (+)	*Buccinanops gradatum*
Olivancillaria urceus	*Buccinanops uruguayensis*
Epitonium aff. *unifasciatum* (+)	*Buccinanops duartei*
Dorsanum moniliferum	*Adelomelon brasiliana*
BIVALVIA	
Amiantis purpurata	*Mactra bonariensis*
Corbula caribaea	*Tivela (Eutivela) isabelleana*
Diplodonta vilardeboana	*Nucula puelcha*
Adrana electa	*Lithophaga patagonica* (+)
Plicatula gibbosa	*Tellina (Angulus)* gibber
Crassostrea rizophorae (+)	
Dinocardium robustum (+)	
Labiosa (Raeta) plicatella (+)	
(Cyrtopleura lanceolata ornata)	
(Tagelus plebeius entrerianus)	

The species are assigned to their provinces primarly using the data of Sicardi (1967). The zoogeographical classification of species identified in Tables XIX and XX with a plus (+) is supported by the data of their present distribution as stated by Figueiras & Broggi (1971, 1972/73).

From the analysis in Tables XIX and XX and from Fig. 16d-e a total and significant absence of Miocene species belonging to the Magellanic Province is seen. The gastropod and bivalve associations are exclusively made up of species from the Caribbean and Argentinian Provinces. They indicate a predominance of warm water bodies transported by the Brazilian current, in latitudes located between the 34°—35° south parallels.

The comparison between the percentile occurence of the Miocene and Recent gastropod and bivalve species shows that:

1. The percentile occurence of species belonging to the Argentinian or Patagonian Province remains very similar.

2. The incidence of Magellanic species in present day Uruguayan faunas was a consequence of substitution for the Miocene Caribbean or Antillean forms.

These paleozoogeographical results agree and confirm those given by the foraminiferids. Furthermore they offer an explanation for a reiterated observation. Several mollusc species from the Entrerriense sea still exist in the Caribbean region. The explanation for this is that both regions were integrated during the Miocene in the same paleozoogeographical province, characterized by tropical waters.

B. Pliocene

In Uruguay marine Pliocene fossil faunas have not been found. According to Bertels (1975) and Bertels & Madeira-Falcetta (1977) no marine Pliocene sediments were found on the atlantic borderland of South America.

Camacho (1967) reported that Pliocene molluscs from Patagonia indicate the prevalence of species from temperate waters. They show a greater influence of the Brazilian current in comparison to the situation existing today in this region. The substitution of species of the Brazilian current by others of polar origin began in the Pliocene, and have increased primarily since the Pleistocene. In contrast Boltovskoy (1973) considers that the Pliocene climate was colder than today. The characteristics and distribution of the Pliocene floras are very similar to the present (Meléndez, 1971).

C. Quaternary

Two different points of view exist with regard to the Quaternary paleotemperatures which existed in the temperate South American atlantic region.

Bordas (1957) and Parodiz (1962) reject categorically the existence of changes in the molluscan faunas which could be related to climatic cycles during the Quaternary.

In contrast, Richards & Craig (1963) and Richards (1966) consider that the climate was colder than the present one during Pleistocene glaciations, particularly during the last glacial (Wisconsin). Their conclusions are based on molluscs from the Argentinian shelf. Similar results are given by Groot et al. (1967), supported by palynological studies, and by diatoms; as well as by evaluation of foraminiferids (Boltovskoy, 1973).

The foraminiferal assemblages from the lower Holocene of Uruguay, typically indicate cold temperate waters, similar to the biocoenosis of this area (Chapter VI-F-2). They belong to the Argentinian Province, or "kingdom" of *Buccella peruviana*, s. l., and particularly to the North-patagonian Subprovince. This zoogeographical unit is delineated by 32°—41° S latitudes, and is characterized by the abundance of *Elphidium discoidale* (Boltovskoy, 1970a, 1976; Boltovskoy & Wright, 1976). In this subprovince the Malvin current is dominant, but subtropical influences still exist, determined by the Brazilian current. Other studies made on Quaternary microfaunas of foraminiferids and ostracods from this region agree with these results, showing that the temperature was similar to the present day (Bertels, 1975; Boltovskoy, 1959b; Closs, 1966a, 1970).

In contrast, the analyzed malacological assemblages from the lower Holocene indicate mean annual temperatures somewhat higher than those that exist today. This conclusion arises from the analysis of the percentile occurence of those species whose distribution is considered to be determined: 1. by the Brazilian current; 2. by the Malvin Current; and 3. are autochthonous forms.

The comparison between the present day assemblages of molluscs (gastropods, bivalves and polyplacophorids) and those of the wells and Lecocq shows, that those from the Querandinense have a lower occurence of species considered to belong to the Malvin current, therefore from the Magellanic Province (table XXI.). Similar results were reported by Forti (1968, 1969) studying malacological associations from the coastal plain from southern Brazil, which are considered to probably be from the lower Holocene. The data given by Forti are expressed in percentages in Table XXI. Figueiras (1962) reported that all molluscan species of the Querandinense from Uruguay are still found in the present assemblages. They are classified in species correspoinding to the Caribbean, Magellanic and Argentinian Provinces. Their percentile occurence is shown on Table XXI. Further, this author indicates that the distributional range of some species has changed. Several species, which lived or were abundant during the Querandinense in the Uruguayan region, are very rare today, or else are found living somewhat farther north.

To what extent the percentages given in Table XXI can be considered significant, depends on the following features:

1. First of all on the accuracy of knowledge of the distributional pattern of living molluscan species. Richards & Craig (1963) and Richards (1966) point out that for many species the available information is inadequate.
2. The malacological assemblages from the lower Holocene were deposited in shallow water environments. As has been indicated, the species from the Brazilian current today have a more superficial distributional range than the autochthonous and Malvin ones. It is very difficult to establish to what degree the given percentages are determined by the paleotemperatures, or whether they are only the consequence of a bathymetric selection.
3. The malacological assemblages found in the wells allow only the study of faunal diversity, and are not appropriate in analyzing the species dominance.
4. The risks formulated by Herm (1969, p. 87) are inherent if a comparison is to be made between faunas from different biotopes.

The results provided by molluscs and foraminiferids found in the wells and Lecocq, are in disagreement concerning the paleotemperatures which existed during the Querandina Transgression. A possible explanation for this discrepancy is that the bivalves, and the majority of marine gastropods, have a free-swimming trochophore and veliger larvae. On the contrary, the benthic foraminiferids do not possess true pelagic stages during their ontogenethic development. This enables a greater potential speed in the migration rate of bivalves and the majority of marine gastropods.

This difference is most evident during short-term environmental changes, as those occuring during the Holocene.

Taking all evidence into consideration the interpretation that follows has to be considered tentative. Probably during the Querandina Transgression, the warm Brazilian current, in the Río de la Plata region, had a greater influence than today, with mean annual water temperatures somewhat higher than at present. Hence, the existence of warm climatic cycles during the Holocene was repeatedly postulated (SCHWARZBACH, 1974). This slight increase in the water paleotemperatures did not appreciably modify the distribution of the littoral paleogeographical provinces. The faunas from Querandina Transgression, as well as the present ones, belong to the North-patagonian Subprovince (fig. 15b).

TABLE XXI
Percentile occurence of molluscs belonging to zoogeographic provinces

	Caribbean or Antillean Province	Argentinian or Patagonian Province	Magellanic Province
PRESENT DAY FAUNAS			
Puerto Quequén (CARCELLES, 1944)	29 %	44 %	25 %
Uruguay (SICARDI, 1967)	39 %	41 %	19 %
QUERANDINA TRANSGRESSION			
Uruguay (present study)	34 %	55 %	10 %
Uruguay (FIGUEIRAS, 1962)	38 %	57 %	4 %
Southermost Brazil (FORTI, 1969)	55 %	37 %	6 %

The shown percentages in Table XXI include the faunas of gastropods, bivalves and polyplacophorids. No corrections were made for the number of species attributed to each province by the authors listed. The only exception is the zoogeographical classification of the genus *Anachis*. The *Anachis* species referred to by FIGUEIRAS (1962), SICARDI (1967) and in the present study, are grouped according to SICARDI's (1975) criterion.

IX. FAUNAL REFERENCE LIST

A. Foraminiferids

The Foraminiferids found in the wells and Lecocq are listed alphabetically below citing the original description. Additional references are often given for each of the species. Where changes in classification have been made, the reasons for these are discussed briefly.

Ammonia beccarii (LINNAEUS) var. *parkinsoniana* D'ORBIGNY: *Nautilus beccarii* LINNAEUS, 1758, Systema naturae. Ed. 10. Holmiae, impensis L. Salvii, tomus 1, p. 710, pl. 1, fig. 1a—c, pl. 19, figs. h—h, i—i.

Ammonia beccarii (LINNÉ), SCHNITKER, 1974, Journ. Foram. Res. v. 4, no. 4 : 217—223, pl. 1. The variety *parkinsoniana* is morphologically used according to the criterion of BOLTOVSKOY (1957a, p. 58).

Amphistegina gibbosa D'ORBIGNY: *Amphistegina gibbosa* D'ORBIGNY, 1839. In: Ramón de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, p. 120; pl. 8, figs. 1—3 (in Ibid., vol. 8). — *Amphistegina gibbosa* D.'ORBIGNY, HOFKER, Sr., 1969. Studies fauna Curaçao other Caribbean islands, vol. 31, no. 115, p. 81, figs. 235—237.
See also: LARSEN, 1976, p. 151.

Baggina sp.?

Bolivina compacta SIDEBOTTOM: *Bolivina robusta* BRADY var. *compacta* SIDEBOTTOM, 1905, Manchester Lit. Philos, Soc., Mem., Proc., vol. 49, no. 5, p. 15, pl. 3, fig. 7a, b.

Bolivina cf *lomitensis* GALLOWAY & WISSLER: *Bolivina lomitensis* GALLOWAY & WISSLER, 1927, Journ. Paleont. vol. 1, no. 1, p. 71, pl. 11, fig. 7a, b. — *Bolivina* cf. *lomitensis* GALLOWAY & WISSLER, BOLTOVSKOY, 1954, Rev. Inst. Nac. Invest. Cienc. Nat. y Mus. Argentino Cienc. Nat. "B. Rivadavia", Cienc. Geol., tomo 3, no. 4, p. 281, pl. 26, figs. 3a, b, 4.

Bolivina striatula CUSHMAN: *Bolivina striatula* CUSHMAN, 1922, Carnegie Inst., Publ. no. 311 (Dept. Marine Biol., Papers, vol. 17) Washington, D. C., p. 27, pl. 3, fig. 10. — *Bolivina Striatula* CUSHMAN, BOLTOVSKOY, 1954, p. 190, pl. 13, fig. 12a, b, 13a, b, 14a, b, 15a, b, 16a, b.

Bolivina cf. *variabilis* (WILLIAMSON): *Textularia variabilis* WILLIAMSON, 1858, On the Recent foraminifera of Great Britain. Ray Soc., London, p. 76, pl. 6, figs. 162—163. — *Bolivina variabilis* (WILLIAMSON), BOLTOVSKOY, 1954, p. 187, pl. 12, fig. 13a—c.

Buccella peruviana (D'ORBIGNY), sensu lato: *Rosalina peruviana* D'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale; Foraminifères, tome 5, pt. 5, p. 41, pl. 1, figs. 12—14. — BOLTOVSKOY, 1970a, p. 342.

Bulimina cf. *affinis* D'ORBIGNY: *Bulimina affinis* D'ORBIGNY, 1839, Foraminifères. In: Ramón de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, p. 105; pl. 2, figs. 25—26 (in: Ibid., vol 8). — *Bolivina affinis* D'ORBIGNY (?), BOLTOVSKOY, 1954, p. 179, pl. 10, fig. 18.

Buliminella elegantissima (D'ORBIGNY): *Bulimina elegantissima* D'ORBIGNY 1839, Voyage dans l'Amérique Méridionale; Foraminifères tome 5, pt. 5, p. 51, pl. 7, figs. 13—14. — *Buliminella elegantissima* (D'ORBIGNY), BOLTOVSKOY, 1954, p. 173, pl. 8, figs. 9—10.

Cancris sagra (D'ORBIGNY): *Rotalina (Rotalina) sagra* D'ORBIGNY, 1839, Foraminifères. In: Ramón de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, p. 77; pl. 5, figs. 13—15 (in Ibid., vol. 8). — *Cancris sagra* (D'ORBIGNY), BOLTOVSKOY, 1957a, p. 59, pl. 11, figs. 1a, b, 2a—c.

Cassidulina curvata PHLEGER & PARKER: *Cassidulina curvata* PHLEGER & PARKER, 1951, Geol. Soc. Amer., Mem. no. 46, pt. 2, p. 26, pl. 14, fig. 5a, b.

Cassidulina laevigata D'ORBIGNY: *Cassidulina laevigata* D'ORBIGNY, 1826, Ann. Sci. Nat., Paris, sér. 1, tome 7, p. 282, pl. 15, figs. 4—5, 5 bis.

Cassidulina subglobosa BRADY: *Cassidulina subglobosa* BRADY, 1881, Quart. Jour. Micr. Sci., London, n. s., vol. 21, p. 60; pl. 54, fig. 17a—c (in BRADY 1884, Rept. Voy. Challenger, Zool., vol. 9).

Cibicides aknerianus (D'ORBIGNY): *Rotalina akneriana* D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 156, pl. 8, figs. 13—15. — *Cibicides aknerianus* (D'ORBIGNY), BOLTOVSKOY, 1954, p. 213, pl. 15, fig. 6a, b, pl. 18, fig. 8.

Cibicides "pseudoungerianus" (CUSHMAN): *Truncatulina pseudoungeriana* CUSHMAN, 1922, U. S. Geol. Suv., Prof. Pap., no. 129—E, p. 97, pl. 20, fig. 9. — *Cibicides "pseudoungarianus"* (CUSHMAN), BOLTOVSKOY & LENA, 1966, p. 291, pl. 2, fig. 4.

Dentalina communis D'ORBIGNY: *Nodosaria (Dentaline) communis* D'ORBIGNY, 1826, Ann. Sci. Nat., Paris, sér. 1, tome 7, p. 254. — *Dentalina communis* D'ORBIGNY, BOLTOVSKOY, 1959a, p. 63, pl. 9, fig. 1.

Discorbinella? bertheloti, forma *boueana* (D'ORBIGNY): *Truncatulina boueana* D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 169, pl. 9, figs. 24—26. — *Cibicides bertheloti* (D'ORBIGNY), forma *boueana* (D'ORBIGNY), BOLTOVSKOY, 1959a, p. 106, pl. 17, figs. 5a, b, 6.

Discorbis peruvianus (D'ORBIGNY): *Rosalina peruviana* D'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale; Foraminifères, tome 5, pt. 5, p. 41, pl. 1, figs. 12—14. — *Discorbis peruvianus* (D'ORBIGNY), BOLTOVSKOY & LENA, 1966, p. 297, pl. 3, figs. 4—7.

Discorbis gr. *vilardeboanus* (D'ORBIGNY): *Rosalina vilardeboana* D'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale; Foraminifères. Strasbourg, Levrault, tome 5, pt. 5, p. 44, pl. 6, figs. 13—15. — *Discorbis vilardeboanus* (D'ORBIGNY), BOLTOVSKOY, 1954, p. 201, pl. 14, fig. 9a—c.

Discorbis williamsoni (CHAPMAN & PARR), forma *praegeri* HERON-ALLEN & EARLAND: *Rotalina nitida* WILLIAMSON, 1858, On the Recent foraminifera of Great Britain, Ray Soc., London, p. 54, pl. 4, figs. 106—108. — *Discorbina praegeri* HERON-ALLEN & EARLAND, 1913, Proc. Roy. Irish. Acad. vol. 31, no. 64, p. 122, pl. 10, figs. 8—10. — *Discorbis nitidus* (WILLIAMSON), BOLTOVSKOY, 1957a, p. 55, pl. 9, figs. 1a—c, 2a—c, 3a—c, 4a—c, 5a-c, 6a-c. — *Discorbis williamsoni* (CHAPMAN & PARR), forma *praegeri* HERON-ALLEN & EARLAND, BOLTOVSKOY, 1959a, p. 89. According to LOEBLICH & TAPPAN (1964, p. C578) this species belongs to the genus *Gavelinopsis* HOFKER being its type-species.

Discorbis gr. sp. "A" BOLTOVSKOY: *Discorbis* sp. "A", BOLTOVSKOY, 1954, p. 203, pl. 15, fig. 4a, b.

Elphidium depressulum CUSHMAN: *Elphidium advenum* (CUSHMAN) var. *depressulum*, CUSHMAN, 1933, U. S. Nat. Mus. Bull. 161, p. 51, pl. 12, fig. 4. — *Elphidium depressulum* CUSHMAN, BOLTOVSKOY, 1954, Rev. Inst. Nac. Inv. Cienc. Nat. y Mus. Argentino Cienc. Nat. "B. Rivadavia", Cienc. Geol., tomo 3, no. 4, p. 276, pl. 25, figs. 3a, b, 4a, b. — *Elphidium advenum depressulum* CUSHMAN, BOLTOVSKOY, 1959a, p. 96, pl. 15, fig. 4. — *Elphidium depressulum* CUSHMAN, BOLTOVSKOY, 1976, p. 223.

Elphidium discoidale (d'ORBIGNY): *Polystomella discoidalis* d'ORBIGNY, 1839. In: Ramón de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, p. 56; pl. 6, figs. 23—24 (in Ibid., vol. 8). — *Elphidium discoidale* (d'ORBIGNY), BOLTOVSKOY, 1957a, p. 43, pl. 8, figs. 1a, b, 2a, b, 3a, b, 4a, b, 5a, b.

Elphidium gr. *excavatum* (TERQUEM): *Polystomella excavata* TERQUEM, 1875, Soc. Dunkerquoise, Mém., Dunkerque, 1876, vol. 19 (1874—1875), p. 429, pl. 2, fig. 2a, b. — *Elphidium excavatum* (TERQUEM), CLOSS, 1963, p. 56, pl. 4, fig. 4, 7.

Elphidium galvestonense KORNFELD: *Elphidium gunteri* COLE var. *galvestonensis* KORNFELD, 1931, Stanford Univ. Dept. Geol., Contr., vol. 1, no. 3, p. 87, pl. 15, figs. 1a, b, 2a, b, 3a, b. — *Elphidium galvestonense* KORNFELD, CLOSS, 1963, p. 57, pl. 4, fig. 6, pl. 6, fig. 28a, b.

Elphidium gunteri COLE [sensu CLOSS, 1963]: *Elphidium gunteri* COLE, 1931, Florida State Geol. Surv., Bull., no. 6, p. 34, pl. 4, figs. 9—10. — *Elphidium gunteri* COLE, CLOSS, 1963, p. 55, pl. 4, figs. 1—3, 5, 8, pl. 6, fig. 29a, b. non: *Elphidium günteri* COLE, ROSSET-MOULINIER, 1976, Revue Micropaléont., vol 19, no. 2, p. 92, pl. 1, figs. 10—11, pl. 2, figs. 1—4. In ROSSET-MOULINIER a different species from the Bretagne coast is described under the same species designation. As ROSSET-MOULINIER does not give references about the holotype, the concept of CLOSS is adopted. — *Elphidium guntheri* COLE, HANSEN & LYKKE-ANDERSEN, 1976, p. 12, pl. 8, figs. 10—12, pl. 9, figs. 1—3.

Elphidium aff. *sagrum* (d'ORBIGNY): *Polystomella sagra* d'ORBIGNY, 1839, In: Ramón de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, p. 55; pl. 6, figs. 19—20 (in Ibid., vol. 8).

Elphidium cf. *tuberculatum* (d'ORBIGNY): *Nonionina tuberculata* d'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche) p. 108, pl. 5, figs. 13—14. — *Protelphidium tuberculatum* (d'ORBIGNY), MALUMIAN, 1972, p. 116, pl. 4, fig. 4a, b. — *Elphidium tuberculatum* (d'ORBIGNY), HANSEN & LYKKE-ANDERSEN, 1976, p. 14, pl. 12, figs. 1—4.

Elphidium sp. A

Elphidium sp. B

Fissurina laevigata REUSS: *Fissurina laevigata* REUSS, 1850, K. Akad. Wiss. Wien, Math.-Nat. Cl. Bd. 1, p. 366, pl. 46, fig. 1a, b. — BOLTOVSKOY, 1954, p. 157, pl. 11, fig. 5a, b.

Flintinella sp.

Fursenkoina sp.

Guttulina plancii d'ORBIGNY: *Guttulina (Guttulina) plancii* d'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale; Foraminifères, tome 5, pt. 5, p. 60, pl. 1, fig. 5. — *Guttulina plancii*, d'ORBIGNY, BOLTOVSKOY, 1954, Rev. Inst. Nac. Invest. Cienc. Nat. y Mus. Argentino Cienc. Nat. "B. Rivadavia", Cienc. Geol., tomo 3, no. 4, p. 270, pl. 23, fig. 5a—c.

Guttulina problema d'ORBIGNY: *Guttulina problema* d'ORBIGNY, 1826, Ann. Sci. Nat., Paris, sér. 1, tome 7, p. 266, no. 14. — *Guttulina problema* d'ORBIGNY, CLOSS & BARBERENA, 1962, p. 31, pl. 2, fig. 8, pl. 6, fig. 8.

Lagena laevis (MONTAGU), forma *perlucida* (MONTAGU): *Vermiculum perlucidum* MONTAGU, 1803, Testacea Britannica, or natural history of British shells, marine, land and fresh-water, including the most minute. Romsey, England, p. 525, pl. 14, fig. 3. — *Lagena laevis* (MONTAGU), *forma perlucida* (MONTAGU), BOLTOVSKOY, 1959a, p. 67, pl. 9, fig. 8.

Lagena sp.

Lenticulina limbosa (REUSS): *Robulina limbosa* REUSS, 1863, Sitzber. kaiserl. Akad. Wissensch., math.-naturw. Cl., Wien, vol. 46, pt. 1, p. 55, pl. 6, fig. 69. — *Robulus limbosus* (REUSS) s. l., BOLTOVSKOY, 1959a, p. 61, pl. 7, figs. 6, 7.

Lenticulina rotulata (LAMARCK): *Lenticulites (rotulata)* LAMARCK, 1804, Mus. National Hist. Nat., Ann., Paris (An 13), tome 5, p. 188; pl. 62 (14), fig. 11 (in Ibid., vol. 8, 1806). — *Lenticulina rotulata* LAMARCK, MALUMIAN, 1972, p. 111, pl. 3, fig. 8.

Massilina secans (d'ORBIGNY): *Quinqueloculina secans* d'ORBIGNY, 1826, Ann. Sci. Nat., Paris, sér. 1, tome 7, p. 303. — *Massilina secans* (d'ORBIGNY), BOLTOVSKOY, 1957a, p. 26, pl. 6, fig. 1a, b, 2a, b, 3a, b, 4a, b, 5a, b.

Marginulina gr. *tenuis* BORNEMANN: *Marginulina tenuis* BORNEMANN, 1855, Z. Deutsch. geol. Ges., Berlin, vol. 7, p. 326, pl. 13, fig. 14a, b.

Miliammina fusca (BRADY): *Quinqueloculina fusca* BRADY, 1870, Ann. Mag. Nat. Hist., London, ser. 4, vol. 6, p. 286, pl. 11, figs. 2a—c, 3a, b. — *Miliammina fusca* (BRADY), 1963, CLOSS, p. 27, pl. 1, figs. 8—10, pl. 6, figs. 1a—c, 6—16.

Miliolinella subrotunda (MONTAGU): *Vermiculum subrotundum* MONTAGU, 1803, Testacea Britannica, or natural history of British shells, marine, land and fresh-water, including the most minute. Romsey, England, J. S. Hollis, p. 521. — *Miliolinella subrotunda* (MONTAGU), PONDER, 1974, Micropaleontology, vol. 20, no. 2, p. 201, pl. 1, figs. 1a, b, 2a, b, pl. 2, fig. 6a—c, 7, 8a, b, 9a—i, 10, 11.

Nonion grateloupii (d'ORBIGNY): *Nonionina grateloupii* d'ORBIGNY, 1839, Foraminifères. In: Ramón de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, p. 46; pl. 6, figs. 6—7 (in Ibid., vol. 8). — *Nonion grateloupi* (d'ORBIGNY), BOLTOVSKOY & LENA, 1966, p. 315, pl. 5, fig. 7. — *Florilus grateloupi* (d'ORBIGNY), ANDERSEN, 1975, Tulane Stud. Geol. Paleont., vol. 11, no. 4, p. 298, pl. 10, fig. 10. The genus *Nonion* is used according to HANSEN & LYKKE-ANDERSEN (1976) point of view.

Nonion tisburyensis BUTCHER [sensu BOLTOVSKOY, 1958]: *Nonion tisburyensis* BUTCHER, 1948, Cushman Lab. Foram. Res., Contr., vol. 24, p. 21, p. 22, tfs. 1—3. — *Nonion tisburyensis* BUTCHER, BOLTOVSKOY, 1958, p. 18, pl. 6, figs. 1a, b, 2—4, 5a, b, 6. The genus *Nonion* is used according to HANSEN & LYKKE-ANDERSEN (1976) criterion.

Nonion sp. A.

Nonion sp. B.

Nonionella atlantica CUSHMAN: *Nonionella atlantica* CUSHMAN, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, p. 90, pl. 20, figs. 4a—c, 5. — *Nonionella atlantica* CUSHMAN, BOLTOVSKOY, 1959a, p. 76, pl. 10, fig. 14a—c. — *Nonionella atlantica* CUSHMAN, HANSEN & LYKKE-ANDERSEN, 1976, p. 23, pl. 21, figs. 9—12.

Nonionella auricula HERON-ALLEN & EARLAND: *Nonionella auricula* HERON-ALLEN & EARLAND, 1830, Roy. Micr. Soc., Jour., London, ser. 3, vol. 50, p. 192, pl. 5, figs. 68—70. — *Nonionella auricula* HERON-ALLEN & EARLAND, BOLTOVSKOY, 1954, p. 167, pl. 7, fig. 9a—c.

Oolina melo d'ORBIGNY: *Oolina melo* d'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale, Foraminifères, Strasbourg, Levrault, tome 5, pt. 5, p. 20, pl. 5, fig. 9.

Poroeponides lateralis (TERQUEM): *Rosalina lateralis* TERQUEM, 1878, Soc. Géol. France, Mém., sér. 3, tome 1, no. 3, p. 25, pl. 2, fig. 11a—c. — *Poroeponides lateralis* (TERQUEM), BOLTOVSKOY, 1957a, p. 59, pl. 10, fig. 5a—c.

Pyrgo nasuta CUSHMAN: *Pyrgo nasutus* CUSHMAN, 1935, Smithsonian Inst. Misc. Coll. vol. 91, no. 21 (publ. 3327), p. 7, pl. 3, figs. 1a, b, 2—4. — *Pyrgo nasuta* CUSHMAN, BOLTOVSKOY, 1957a, p. 30, pl. 4, fig. 9a—c.

Pyrgo ringens patagonica (d'ORBIGNY): pars? *Miliolites (ringens) subglobosa* LAMARCK, 1804, Mus. National Hist. Nat., Ann., Paris, (An 13), tome 5, p. 351; pl. 17 (15), fig. 1 (in Ibid., vol. 9, 1807). — *Biloculina patagonica* d'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale; Foraminifères, tome 5, pt. 5, p. 65, pl. 3, figs. 15—17. — *Pyrgo patagonica* (d'ORBIGNY), BOLTOVSKOY, 1954, p. 133, pl. 3, fig. 3a—c, pl. 19, fig. 7a, b. — [pars] *Pyrgo ringens patagonica* d'ORBIGNY, BOLTOVSKOY & LENA, 1966, p. 326.

Quinqueloculina cf. *agglutinata* CUSHMAN: *Quinqueloculina agglutinata* CUSHMAN, 1917, U. S. Nat. Mus., Bull., no. 71, p. 43, pl. 9, fig. 2a—c. — *Quinqueloculina* cf. *agglutinata* CUSHMAN, BOLTOVSKOY, 1957a, p. 24, pl. 4, figs. 1, 2, 3a—c, 4.

Quinqueloculina angulata (WILLIAMSON), forma *typica: Miliolina bicornis* (WALKER) var. *angulata* WILLIAMSON, 1858, On the Recent foraminifera of Great Britain. Ray Soc., London, p. 88, pl. 7, fig. 196. — *Quinqueloculina angulata* (WILLIAMSON), BOLTOVSKOY, 1954, p. 123, pl. 2, fig. 1a—c. — *Quinqueloculina angulata* (WILLIAMSON), forma *typica*, BOLTOVSKOY & LENA, 1966, p. 327.

Quinqueloculina atlantica BOLTOVSKOY: *Quinqueloculina atlantica* BOLTOVSKOY, 1957, Rev. Inst. Nac. Invest. Cienc., Nat. y Mus. Argentino Cienc. Nat. "B. Rivadavia", Cienc. Geol., tomo 6, no. 1, p. 25, pl. 5, fig. 2a—c, 3, 4a—c, 5, 6a—c.

Quinqueloculina aff. *frigida* PARKER: *Quinqueloculina frigida* PARKER, 1952, Mus. Comp. Zool., Bull., Cambridge, vol. 106 (1951—1952), no. 9, p. 406, pl. 3, fig. 20a, b. — *Quinqueloculina* aff. *frigida* PARKER, BOLTOVSKOY, 1957a, p. 24, pl. 4, fig. 7a—c.

Quinqueloculina intricata TERQUEM: *Quinqueloculina intricata* TERQUEM, 1878, Soc. Géol. France, Mém., sér. 3, tome 1, no. 3, p. 73, pl. 8, figs. 16a, b, 17a, b, 18a—c, 19a—c, 20a—c, 21a, b. — *Quinqueloculina intricata* TERQUEM, WRIGHT, 1968, p. 250, pl. 2, figs. 1—4.

Quinqueloculina patagonica d'ORBIGNY: *Quinqueloculina patagonica* d'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale; Foraminifères, Strasbourg, Levrault, tome 5, pt. 5, p. 74, pl. 4, figs. 14—16. *Quinqueloculina pata-*

gonica d'ORBIGNY, BOLTOVSKOY, 1954, p. 122, pl. 1, figs. 4a—c, 5a, b.

Quinqueloculina seminulum (LINNAEUS): *Serpula seminulum* LINNAEUS, 1758, Systema naturae. Ed. 10. Holmiae, impensis L. Salvii, tomus 1, p. 786, pl. 2, fig. 1a—c. — *Quinqueloculina seminulum* (LINNAEUS), BOLTOVSKOY, 1954, p. 120, pl. 1, figs. 1a—c, 2, 3a—c.

Quinqueloculina vulgaris d'ORBIGNY: *Quinqueloculina vulgaris* d'ORBIGNY, 1826, Tableau méthodique de la classe des Céphalopodes. Ann. Sci. Nat., Paris, sér. 1, tome 7, p. 302. — *Quinqueloculina vulgaris* d'ORBIGNY, CUSHMAN, 1929, U. S. Nat. Mus. Bull. 104, pt. 6, p. 25, pl. 2, fig. 3a—c.

Quinqueloculina sp. A

Quinqueloculina sp. B

Quinqueloculina sp. C

Quinqueloculina sp. D

Quinqueloculina sp. E

Reophax artica BRADY: *Reophax artica* BRADY, 1881, K. Akad. Wiss. Wien, math.-naturw. Cl., Bd. 43, Abth. 2, p. 99, pl. 2, fig. 2a, b.

Rosalina sp.?

Rotorbinella rosea (d'ORBIGNY): *Rotalia (Rotalie) rosea* d'ORBIGNY, 1826, Ann. Sci. Nat., Paris, sér. 1, tome 7, p. 272. Type fig.: Modeles, no. 35, 2me livraison. [PARKER, JONES & BRADY, 1865, Ann. Mag. Nat. Hist., London, vol. 16, ser. 3, pl. 3, fig. 79], d'ORBIGNY, 1939, Foraminifères. In: Ramón de la Sagra, Hist. Phys. Pol. Nat. Ile Cuba, p. 72, pl. 3, figs. 9—11. *Rotorbinella rosea* (d'ORBIGNY), HOFKER, Sr., 1969, Studies Fauna Curaçao other Caribbean islands, vol. 31, no. 115, p. 85, figs. 247—250.

Textularia gramen d'ORBIGNY: *Textularia gramen* d'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 248, pl. 15, figs. 4—6. — *Textularia gramen* d'ORBIGNY, BOLTOVSKOY, 1957a, p. 19, pl. 2, figs. 1a, b, 2a, b, 3a, b, 4a, b, 5a, b, 6a, b, 7a, b, 8a, b, 9a, b.

Textularia sp. A

Textularia sp. B

Triloculina sp.

B. Molluscs

An alphabetical list of species of bivalves, gastropods and polyplacophorids found in the bore-holes and Lecocq is given. In recent years several reviews of the systematics of Neogene, Quaternary and living molluscs in this area were published. FIGUEIRAS & BROGGI have a paper in preparation of taxonomic descriptions of species found in the Vizcaíno Formation, and include data from the wells and Lecocq outrop. For this reason only the original and present names of the recorded species are given, as well as a reference to help in researching original bibliographic sources.

1. BIVALVIA

Abra uruguayensis: Semele (Abra) uruguayensis PILSBRY, 1897; FIGUEIRAS & SICARDI, 1969, p. 372, pl. 4, fig. 65.

Amiantis purpurata: Cytherea purpurata LAMARCK, 1818; FIGUEIRAS & BROGGI, 1972/73, p. 226.

Anomalocardia brasiliana: Venus brasiliana GMELIN, 1791; FIGUEIRAS & SICARDI, 1969, p. 363, pl. 4, fig. 49.

Brachidontes (Hormomya) darwinianus mulleri: Mytilus mulleri DUNKER, 1875; FIGUEIRAS & SICARDI, 1968b, p. 265, pl. 2, fig. 19.

Brachidontes (Brachidontes) rodriguezi: Mytilus rodriguezi d'ORBIGNY, 1846; FIGUEIRAS & SICARDI, 1968b, p. 266, pl. 2, fig. 20.

Cardita (Carditamera) plata: Cardita plata IHERING, 1907; FORTI, 1969, p. 78, pl. 3, fig. 3a, b.

Chione doello-juradoi: Chione doello-juradoi MEDINA, 1962, pl. 1, fig. 1—2.

Chione meridionalis burmeisteri: Venus burmeisteri BORCHERT, 1901; FIGUEIRAS & BROGGI, 1972/73, p. 228.

Chlamys tehuelcha: Pecten tehuelchus d'ORBIGNY, 1846, FIGUEIRAS & SICARDI, 1968b, p. 269, pl. 2, fig. 26.

Corbula caribaea: Corbula caribaea d'ORBIGNY, 1845; FIGUEIRAS & SICARDI, 1970a, p. 409, pl. 5, fig. 75.

Corbula lyoni: Corbula lyoni PILSBRY, 1897; FIGUEIRAS & SICARDI, 1970a, p. 410, pl. 5, fig. 77.

Corbula patagonica: Corbula patagonica d'ORBIGNY, 1846; FIGUEIRAS & SICARDI, 1970a, p. 410, pl. 5, fig. 76.

Corbula pulchella: Corbula pulchella PHILIPPI, 1893; FIGUEIRAS & BROGGI, 1972/73, p. 232.

Crassinella guadalupensis: Crassatella guadalupensis d'ORBIGNY, 1842. In: Ramón de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, p. 288, pl. 27, fig. 21—23.

Crassinella maldonadoensis: Crassatella (Eriphyla) maldonadoensis PILSBRY, 1897; FORTI, 1969, p. 77, pl. 3, fig. 2a, b.

Cyrtopleura lanceolata ornata: Pholas ornata BORCHERT, 1901, FIGUEIRAS & BROGGI, 1972/73, p. 234.

Diplodonta vilardeboana: Lucina vilardeboana d'ORBIGNY, 1846; CASTELLANOS, 1967, p. 243, pl. 18, fig. 7—9.

Erodona mactroides: Erodona mactroides DAUDIN, 1801; COSTA, 1971, p. 4, fig. 1—27.

Glycymeris longior: Pectunculus longior SOWERBY, 1832; FORTI, 1969, p. 70, pl. 2, fig. 2a, b.

Mactra bonariensis: Mactra bonariensis PHILIPPI, 1893; FIGUEIRAS & BROGGI, 1972/73, p. 220.

Mactra isabelleana: Mactra isabelleana d'ORBIGNY, 1846; CASTELLANOS, 1967, p. 237, pl. 21, fig. 9, 10.

Mactra marplatensis: Mactra marplatensis DOELLO-JURADO, 1949; CASTELLANOS, 1967, p. 234, pl. 21, fig. 11—13.

Mactra patagonica: Mactra patagonica d'ORBIGNY, 1846; CASTELLANOS, 1967, p. 235, pl. 21, fig. 1—3.

Mytilus platensis: Mytilus platensis D'ORBIGNY, 1846; CASTELLANOS, 1967, p. 210, pl. 17, fig. 3, 4.

Ostrea equestris: Ostrea equestris SAY, 1834; FIGUEIRAS & SICARDI, 1968b, p. 272, pl. 2, fig. 33.

Ostrea puelchana: Ostrea puelchana d'ORBIGNY, 1842; FIGUEIRAS & SICARDI, 1968b, p. 271, pl. 2, fig. 32.

Pitar (Pitar) rostrata: Cytherea rostrata KOCH, 1844; CAMACHO, 1966, p. 81, pl. 18, fig. 1a—c.

Pleuromeris sanmartini: Pleuromeris sanmartini, KLAPPENBACH, 1970, p. 36, fig. 1—5.

Plicatula cf. *gibbosa: Plicatula gibbosa* LAMARCK, 1801; FIGUEIRAS & BROGGI, 1972/73, p. 209.

Sphenia hatcheri: Sphenia hatcheri PILSBRY, 1899; FIGUEIRAS & SICARDI, 1970b, p. 22, pl. 7, fig. 103.

Strigilla (Rombergia) cf. *rombergii: Strigilla rombergii* MÖRCH, 1853; COX, NEWELL & BOYD et al., 1969, p. N 622; *Strigilla rombergi* MÖRCH, FIGUEIRAS & SICARDI, 1969, p. 375, pl. 4, fig. 71.

Tagelus plebeius: Solen plebeius SOLANDER, 1786; FIGUEIRAS & SICARDI, 1969, p. 369, pl. 4, fig. 60.

Tagelus plebeius entrerianus: Tagelus gibbus entrerianus IHERING, 1907; FIGUEIRAS & BROGGI, 1972/73, p. 224.

Tivela (Eutivela) isabelleana: Venus isabelleana d'ORBIGNY, 1846; FIGUEIRAS & BROGGI, 1972/73, p. 225.

2. GASTROPODA

Acmaea subrugosa: Acmaea subrugosa d'ORBIGNY, 1841; FIGUEIRAS & SICARDI, 1970c, p. 28, pl. 8, fig. 110.

Anachis isabellei: Nassa isabellei, d'ORBIGNY, 1841; SICARDI, 1975, p. 106.

Anachis moleculina: Columbella moleculina DUCLOS, 1840; SICARDI, 1975, p. 104.

Anachis paessleri: Columbella (Seminella) paessleri STREBEL, 1905; SICARDI, 1975, p. 107.

Austroborus lutescens: Bulinus lutescens KING & BRODERIP, 1832; FIGUEIRAS & BROGGI, 1969, p. 349.

Buccinanops globulosum: Buccinum globulosum KIENER, 1834; CASTELLANOS, 1967, p. 90, pl. 7, fig. 5.

Buccinanops gradatum: Buccinum gradatum DESHAYES, 1844; CASTELLANOS, 1967, p. 92, pl. 7, fig. 6.

Crepidula aculeata: Patella aculeata GMELIN, 1791; FIGUEIRAS & SICARDI, 1971, p. 116, pl. 10, fig. 145.

Crepidula protea: Crepidula protea d'ORBIGNY, 1835; FIGUEIRAS & SICARDI, 1971, p. 116, pl. 10, fig. 146.

Diodora patagonica: Fissurella patagonica d'ORBIGNY, 1841; CASTELLANOS, 1967, p. 20, pl. 1, fig. 8.

Epitonium aff. *unifasciatum: Scalaria unifasciata* SOWERBY, 1844; FIGUEIRAS & SICARDI, 1971, p. 109, pl. 9, fig. 132.

Halistylus columna: Halistylus columna DALL, 1889; CASTELLANOS, 1967, p. 38, pl. 4, fig. 1.

Iselica anomala: Narica (?) anomala ADAMS, 1850; FIGUEIRAS & BROGGI, 1971, p. 140.

Littoridina australis: Paludina australis d'ORBIGNY, 1835; CASTELLANOS, 1967, p. 47, pl. 4, fig. 3.

Littoridina charruana: Paludestrina charruana d'ORBIGNY, 1835; FIGUEIRAS, 1964, p. 175.

Ocenebra cala: Ocinebra cala PILSBRY, 1897; FIGUEIRAS & SICARDI, 1972, p. 173, pl. 12, fig. 167.

Odostomia (Chrysallida) aff. *jadisi: Odostomia (Chrysallida) jadisi* OLSSON & MC GINTY, 1958; FIGUEIRAS & SICARDI, 1974, p. 334, pl. 19, fig. 242.

Olivancillaria urceus: Porphyria urceus RODING, 1798; FIGUEIRAS & BROGGI, 1971, p. 149.

Olivella (Olivina) puelcha: Oliva puelcha, d'ORBIGNY, 1840; FIGUEIRAS & SICARDI, 1973, p. 265, pl. 15, fig. 194.

Olivella (Olivina) tehuelcha: Oliva tehuelcha d'ORBIGNY 1840; FIGUEIRAS & SICARDI, 1973, p. 265, pl. 15, fig. 195.

Parodizia uruguayensis: Parodizia uruguayensis NIEVES DE MEDINA, 1959, p. 53, 1 fig.

Polinices entrerriana: Natica entrerriana BORCHERT, 1901; FIGUEIRA & BROGGI, 1971, p. 142.

Siphonaria (Pachysiphonaria) lessoni: Patella lessoni BLAINVILLE, 1824; CAMACHO, 1966, p. 146, pl. 17, fig. 12a, b.

Tegula (Agathistoma) patagonica: Trochus patagonicus, d'ORBIGNY, 1840; FORTI, 1969, p. 100, pl. 7, fig. 3a, b.

Triphora medinae: Triphora medinae PARODIZ, 1955; FIGUEIRAS & SICARDI, 1971, p. 107, pl. 9, fig. 128.

Urosalpinx rushi: Urosalphinx rushi PILSBRY, 1897; CASTELLANOS, p. 77, pl. 5, fig. 8.

3. POLYPLACOPHORA

Chaetopleura isabellei: Chiton isabellei d'ORBIGNY, 1841; CASTELLANOS, 1967, p. 161, pl. 1, fig. 11.

X. SUMMARY AND CONCLUSIONS

The ecology and paleoecology of the Uruguayan coastal area was studied by Miocene, Pleistocene, Holocene and present-day micro- and macrofaunal assemblages. They are:

Miocene assemblages. Marine Miocene faunas were only found in well Chuy N° 364 between 133.00—113.00 m. The associations are make up of benthonic foraminiferids, molluscs, brachiopods, ostracods, bryozoans, barnacle plates and additional microfossil remains, all which are listed on Table II. They are considered to be of Miocene age, using mainly paleoclimatological data. This fact is supported mainly by the distribution of *Amphistegina gibbosa,* as well as by foraminiferal and molluscan associations. Time-stratigraphic correlations with bore-holes from the Pelotas Basin and Salado Basin were establisched and/

or confirmed. The depositional environments of these strata were reconstructed using foraminiferids, and indicate a normal marine nearshore environment, with high energy warm waters. The substrate probably had no sea flora cover. They were deposited during a pregressive overlap. An analysis of microfaunal mixing was made to find allochthonous foraminiferids. The preservation of the foraminiferal tests is related to the environmental parameters of the depositional environments where they were found.

New data are given of the ecological distribution of the present-day faunas of the Río de la Plata estuary and its zone of influence. They include:

Foraminiferids: The curve of REMANE for the estuarine biocoenosis was plotted.

Bivalves: The curve of REMANE was reconstructed evaluating data from living and dead assemblages.

Gastropods: Their distributional pattern was reconstructed.

The genuine brackish-water and euryhaline molluscan species were identified, and the life habits of the dominant genuine brackish-water species were established.

Quaternary assemblages. The foraminiferal and molluscan assemblages found mainly in the bore-holes were widely distributed along nearly 700 km of coast line of the Río de la Plata and Río Uruguay, and these are analyzed. The depositional environments of strata bearing foraminiferids and molluscs were reconstructed. Faunal associations indicate shallow and cold temparate-waters. The depositional environments show great differences in salinity. The study of the foraminiferids allowed one to be able to distinguish between the Quaternary Biofacies of *Buliminella elegantissima* and the Quaternay Biofacies of *Ammonia beccarii* var. *parkinsoniana*. This was made on the basis of the percentile occurence of the dominant species, as well as evaluating the capacity of the genera to withstand changes in salinities. The foraminiferal associations show an estuarine environment because they indicate a longitudinal distributional pattern. Towards the head of the estuary the Quaternary Biofacies of *Ammonia beccarii* var. *parkinsoniana* replaces the *Buliminella elegantissima* one. The environments of the innermost estuarine region were reconstructed using bivalves and gastropods, using the Curve of REMANE, the identification of genuine brackish-water species, the faunal composition and the existence of vicariad species. Various criteria are given for the identification of ancient estuarine environments, and how they differ from other marginal marine environments. Paleontological criteria are also given in order to be able to distinguish between the estuarine zonation existing along a longitudinal axis, and its latitude.

The early Holocene paleogeography in the Río de la Plata and its zone of influence was reconstructed. It shows the existence of a displacement of the estuarine depositional environments simultaneous to the Querandina Transgression. On the Uruguayan coastal area, the marine environments penetrated inwards towards the head of the estuary, being found as far west as Arroyo Pando. The Transitional-area between marine and fluvio-marine environments formed an arch along the Uruguayan coast, extending from Salinas to San José de Carrasco, Areneras de Carrasco, and the eastern coastal region of Montevideo County. The Transitional-area between fluvio-marine and intermediate-fluvial environments was located between Carmelo and Nueva Palmira. The Transitional-area between intermediate-fluvial and inner-fluvial environments was localized in the Río Uruguay somewhat to the north of Fray Bentos; and a little east from Mercedes on the Río Negro. Throughout the course of the lower Holocene Transgression, the Laguna Merín was directly open to the ocean at its southernmost part. The molluscan associations display a zonation from marine environments, to fluvio-marine to intermediate-fluvial environments.

Biostratigraphic correlations were made using a new method, i. e. ecostratigraphic units. These are correlated by their place within the cycle of greatest salinity. Several assemblage zones previously described for the Uruguayan Quaternary are invalidated.

The Neogene and Quaternary geological evolution of the southernmost part of the Pelotas Basin was analyzed. It is characterized by the alternation of marine (or marginal marine) and terrestrial (continental) depositions. The following stratigraphic units were recognized: Camacho, Raigón, Chuy (sensu lato) I, Libertad I, Chuy (sensu lato) II, Libertad II, Chuy (sensu stricto) III and Dolores.

The distribution and boundaries of the paleozoogeographical littoral provinces of the atlantic region of South America since the Miocene were reconstructed using foraminiferids and molluscs. Two Miocene littoral units were identified, which are designated as: 1) North-brazilian Miocene Subprovince. This is characterized by the existence of tropical water bodies, extending at least from 34°—35° south latitude to the north; 2) South-brazilian Miocene Subprovince, characterized by warm temperate water bodies, which extended south of the 34°—35° south latitude. Therefore there is proof that tropical waters reached 1800 km further south along the eastern South American coast line during the Miocene than they do at the present time. This is supported by the faunal composition of the Miocene foraminiferids of Chuy N° 364, specially by the presence of *Amphistegina gibbosa*. It is also confirmed by the study of bivalves and gastropods from the entire Camacho Formation.

The gastropod and bivalve associations are exclusively made up of species of the Caribbean and Argentinian Provinces, the Magellanic forms being completely absent.

The foraminiferal faunas of the Querandina Transgression indicate cold temperate climes, similar to those prevailing today. In contrast, the malacological assemblages indicate mean annual temperatures somewhat higher than those existing today in this region. This is shown by the lower percentile occurence of cold species carried by the Malvin current in the malacological associations from the Querandina Transgression. This difference is explained by the greater potential speed in the migration rate of bivalve larvae and the majority of marine gastropod larvae. It is concluded that the faunas from the Querandina Transgression, as well as the present ones belong to the North-patagonian Subprovince. Probably the mean annual water temperature was somewhat higher than today.

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Zeitschrift/Journal: Zitteliana - Abhandlungen der Bayerischen Staatssammlung für Paläontologie und Histor. Geologie

Jahr/Year: 1978

Band/Volume: 4

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Artikel/Article: The Paleoecology and Paleogeography of the Uruguayan Coastal Area During the Neogene and Quaternary 3-72