The Chaco Paraná Basin rift basin system. An approach to the tectonic-stratigraphical evolution from the Late Cretaceous to Quaternary. South America

Roberto Torra

Departamento de Geociencias. Fac. de Ingeniería. Universidad Nacional del Nordeste
Avda. Las Heras 727, H3500COI. Resistencia. Chaco. Argentina.
e-mail: roberto_torra@arnet.com.ar

Resumo

O presente trabalho trata de um estudo de geologia regional, sedimentologia e tectônica feito nas seqüências marinhas costeiras rasas de idade neocretàcica a miocênica. Estas seqüências estão coligadas num sistema do tipo "*rift basin*" que evoluiu desde o neocretácico. A bacia em estudo encontra-se localizada no América do Sul, bordejando ao oeste do Escudo Brasileiro.

O sistema regional *rift basin* da Bacia Chaco Paraná formou-se como uma típica bacia extensional intracratónica, limitada no oeste pelo antepaís do orógeno andino, que ainda não tinha sofrido sua principal fase de orogênese e levantamento regional. As amplas áreas invadidas pelos mares e seus depósitos associados de seqüências costeiras superficiais cobriram uma ampla pediplanicie de relevo pouco pronunciado.

A primeira etapa transgressiva começou ao final do Senoniano tardío ou Maestrichtiano prematuro. Logo aconteceram oi avanços maiores até o Neo-Mioceno, com retrocessos e avanços sucessivos de menor importancia. Podem registrar-se pelo menos três etapas de associações de clímax extensionais (*crustal stretchs*) e de mar alto associadas com variações eustáticas ocorridas durante o Senoniano-Maestrichtiano-Paleoceno, o Eoceno e o Mioceno. O primeiro acontecimento transgressivo aconteceu durante o Neo-Cretàcico, mas seu registro sedimentológico conhecido é escasso. Porem, seríam necessarias um maior núme-

ro de perfurações para um reconhecimento mais exato dos depósitos desta transgreção marinha, bem exposta na região sud-andina (Serras Subandinas) do noroeste da Argentina e Bolivia.

A segunda e terceira transgressões marinhas aconteceram durante o Eoceno e o Meso-Neo-Mioceno. Os depósitos deixados por estes mares transgressivos rasos estão bem documentados tanto nos afloramentos quanto nos registros de perfurações por causa das suas associações características de fácies e restos fòsseis.

Os grandes estàgios de quiescência tectônica, pelo menos três, podem ser inferidos e associados simultâneamente com as grandes variações eustáticas do nivel do mar relacionadas às idades do Cretácico e Terciário que correspondem ao Senoniano-Maestrichtiano-Paleoceno, Neo-Eoceno eo Meso-Oligoceno ao Neo-Mioceno.

O estilo estrutural principal corresponde ao de falhas mestres extensionais normais de direção norte-sul (*tilted and faulted blocks*). Mesmo assim, encontram-se presentes em grande quantidade falhas de direção noroeste - sudeste (*strike-slip faults*). Para o margem da bacia do antepaís andino e a provincia de Serras Pampeanas, predominam as falhas inversas de alto ângulo (*upthrust faults*), algumas delas de tipo cisallante (*shear fault zones*).

Na superficie da região estudada aparece uma quantidade significativa de cúpulas, agulhas e "necks" vulcânicos e subvulcânicos. Esta atividade magmática é datada do Plioceno tardío, embora em sua maioria correspondam ao Pleistoceno e as Quaternário, dada as características morfológicas dos seus edificios vulcânicos, que não evidenciam nenhum sinal de erosão importante.

As seqüências estudadas não corresponderíam exatamente ao modelo de PROSSER (1993) descrito para sistemas de tipo *extensional rift basins*, talvez devido à grande extensão do área em análise neste trabalho, de caráter regional. Além disso, as seqüências sedimentars presentes têm uma certa semelhança com a sucessão de fácies "arenito-pelito-arenito" do modelo proposto por PROSSER (1993) (*sandstone-claystone-sandstone*), em especial as que correspondem ao Eoceno e Mioceno.

Análise paleogeográfica da região indica que as transgressões dos mares Paranense e Amazônico estiveram conetadas sincronicamente durante parte do Mioceno, especialmente durante Meso o Neo-Mioceno. Estes extensos mares também tiveram conesão, um pouco restrita, com o Oceano Pacífico, por meio dos sistemas de depressões intermontanas das serras do antepaís pré-Andico. Isto aconteceu antes do levantamento principal do Orógeno Andino ocorrido durante os últimos 7 M.a. (Plioceno-Neo-Pleistoceno).

Este trabalho apresenta pela primeira vez um modelo de interpretação regional tectônico-sedimentar sintético, com o fim de realizar posteriormente estudos de maior detalhe, da ampla Bacia Chaco Paraná. Alem disso, também deveriam estudar-se com maior rigor os potenciais recursos naturais ali presentes. A vinculação com a Bacia Amazônica revela significativamente a importância destas seqüências geológicas e de sua paleogeografia. A dificultade maior desta pesquisa se debe a escasez de bons afloramentos e abundante cobertura vegetal.

Palavras chave: estratigrafia; tectônica; *rift-system* bacia; paleogeografia; Neo-Cretácico-Quaternario; centro e norte do Argentina; regiones limítrofes - Sul America

Summary

This paper deals with a geologic “regional rift basin system pattern” and its stratigraphical relations with littoral shallow marine sedimentary succession paleogeography. These successions characterize the large extensional intracratonic Chaco Paraná Basin rift system. The basin is located in South America westwards of the Brazilian Shield. The analyzed rift basin system evolved from the Upper Cretaceous (Late Campanian-Senonian-Maastrichtian-early Paleocene) to Quaternary time. The siliciclastic littoral shallow marine successions were deposited from Early Campanian-Maastrichtian to Late Miocene during three main successive littoral shallow marine transgressions of continental extension.

These trangressions ocurred on the wide pediplanized terrains of South America. These lands exist toward the west of the more positive areas, between the Brazilian Shield and the foreland massifs that were settled in the more westernwards areas. Laterly, these regional foreland massifs coupled and raised to the Andean Orogen belt during the last 7 m.y.

The extense intracratonic pediplanized low topographic relief areas were the reservoirs of the siliciclastic littoral shallow marine succession deposits during

the three successive widespread vast continental littoral shallow marine transgressions.

The first transgressive phenomenon begun at the Latest Campanian-Senonian and/or early Maastrichtian. After this episode, the sedimentary depositional system continue during Cenozoic until Latest Miocene. These successions constitutes a major allostratigraphic unit. The limit with underlying units is the regional unconfortmity between the regional volcanic event (Jurassic-Cretacic and interleaved eolianite sandstones) at the base and the undifferentiated Quaternary sediments (called as the Pampeano and Post-Pampeano Formations *sensu lato*). Based on many facies analyses there had been checked out different levels in the eustatic sea level variations within the allostratigraphic unit.

Three major stages of extensional climax were recognized and related to stages of conspicuous eustatical sea level variations. They ocurred on Latest Senonian-Paleocene, Eocene and Miocene.

The first transgression occured during the Upper Cretaceous although the sedimentary deposits related to this event are scarce and only a few meters thickness. However, the Upper Cretaceous succession is very well recognized in the actual pre-andean zone at the north-west of Argentina and Bolivia (the Sierras Subandinas and the meridional faults system just joint to the actual orogen; i.e. Quebrada de Humahuaca outcrops).

The second and third extensive regional littoral shallow marine transgressions occured during Eocene and Middle to Latest Miocene. They are present either in well log registers as in most widespread outcrops on the entire Southamerican continent.

The regional analysis led to the deduction of long periods of tectonic quiescence, at least three of them. They may be inferred and synchronously related with eustatic highstand sea level variations that occured during Late Paleocene-Early Eocene, Latest Eocene-Early to Mid Oligocene and Middle-to-Late Oligocene-Early Miocene.

The structural style is related with major extensional N-S directed faultings (regional tilted and faulting blocks). On the other hand, a lot of strike-slip faults (mainly of regional characteristic) are present crossing the area. They have a clear influence on the accommodation and transfer zones of the rift basin system.

The strike is north-west to south-east on the border of the basin, to the west, in the contact with the Pampean Ridges and the narrow-meridionally-extense Sub-Andean folded trend (mainly Paleozoic units belonging to the so called Sierras Subandinas). Also, at the west edge of the studied area, there exist many large shear zones and upthrust faults. The strike-slip regional faults dislocated the Pampean and Sub-Andean blocks due to the interaction of crossing regional tilted and fault blocks. For this reason, an *en echelon* regional block model is characteristic. Incipient contaminated igneous activities were associated to this cortical weakness zones.

Domes, needles and necks of volcanic and sub-volcanic origin appears at the landscape of the region. A part of the igneous activity were dated on Latest Pliocene although mainly correspond to Pleistocene and Holocene. This deduction is obvious because their morphological constitution never was eroded. The volcanic aparatous are morphological unmodified from they extrusion to present days.

All the studied successions seems to resemble a long persisting erosive, transportation and depositation similar episodes. This phenomenon is linked to a large regional (continental) unconformity dated on Late Cretaceous. The entire analyzed sedimentary succession deposits and their siliciclastic facies associations correspond clearly to a “heterolithic facies” which are very common within persisting tide-dominated depositational systems. In fact, this was what happened during Cenozoical times (Torra, 1998b, 2001a). The heterolithic Miocene deposits constitutes one of the best continental expossed examples.

The paleogeographical evidences showed that the Paranense and the Amazonic Seas transgressions had been a littoral shallow marine connection during long time on Middle and Late Miocene. During the Late Cretaceous and Eocene periods marine connections were also active in the region. This fact is strongly supported by the tectonic and geomorphological framework of the proto-Southamerican continent, fossil remains as well as similar sedimentary deposits.

The Paranense and Amazonic epicontinental seas had been connected to the Pacific Ocean during the three marine episodes. The connection were formed by narrow inter-mountain valleys, presents in the pre-andean foreland massifs. These events occured previous to the main orogenesis elevation of the Andean Orogen belt, did occured during the last 7 m.y. (Pliocene-Latest Pleistocene).

This paper shows for the first time a syntethic tectonic-sedimentary regi-

onal model for the Chaco Paraná Basin rift system which should largelly improve upon later studies. The Chaco Paraná Basin carry many unexamined natural resources which need more regional and local studies for their evaluation. However, the area has the great problem of a significative vegetation coberture and a few good outcrops. The evolution of modern techniques of data acquisition will help to overcome on these difficulties.
Key Words: stratigraphy, tectonic, rift system basin, paleogeography, Late Cretaceous-Quaternary, Central-North Argentina and adjoining areas, South America

Introduction

This paper is focused on the last 75 m.y. to 65 m.y. of the Southamerican geological history Chaco Paraná Basin rift system evolution, including some Quaternary phenomena. The study approachs a new interpretation to its evolution and stratigraphy. The analysis extends from the Late Cretaceous until the Latest Miocene succession. The related sediment deposits are siliciclastic littoral shallow marine horizontal heterolithic facies successions. The whole successions constitutes a typical allostratigraphic unit. The studied area acted as an “active regional rift system basin” after Gondwana break up which caused that Southamerican Plate developed to displace west.

Littoral shallow marine environments were stablished over extense areas of the older pediplanized terrains, mainly meta-cristalline rocks or those that constituted the older allostratigraphic unit. The great thickness of underlaying “continental sedimentary successions” were integrated by aeolianite supermature sandstones, detritical fluvial clastic beds and tholeiithic basaltic lavas all were dated on Triassic-Early-to-Middle Cretaceous. These continental units (Early-to-Middle Cretaceous and older ones) largelly supplied most quartz grains to the analyzed basin successions.

The regional Chaco Paraná rift basin system showed a “persisting evolution on time and space since Late Cretaceous”. This phenomenon crearly differentiate from other systems of these classes which were aborted during the Late Cretaceous - Cenozoic periods. That is the case of the El Salado and El Colorado basins Argentina, as well as many other small rift system basins dated on previous

Maastrichtian age, as the well known General Lavalle basin (RUSSO *et al*. 1979; WEBSTER *et al*. 2004).

The studied area includes all central and northern regions of Argentina (with exception of the actual Andean orogen belt), the south-west of Uruguay, the south-west of Paraguay and the Chaco Paraguayo plain-region as well as the Bolivian wide plains (Figure 1). Extrapolations were made to another northwards territories of South America based on satellite imagery studies. Also, The analogue sedimentary bed successions are present in the Patagonia plateau and the Antarctica peninsula (MARTINIONI 1992).

There are several published papers focusing on pre-Upper Cretaceous underground paleogeography studies, paleontological analyses or specific geologic semi-detailed descriptive successions studies (CHEBLI *et al*. 1989; GENTILE & RIMOLDI 1979; HERBST 1971; PADULA 1972; PADULA & MINGRAM 1966).

TORRA (1999a, 2001a) appointed a new model for the Miocene regional littoral shallow marine Ituzaingó Formation. That model covered the whole studied region. Some of the ideas treated there have been now embedded in this paper (see also TORRA, 1998b).

This regional rift basin model is associated to crustal streching which caused regional subsidense as well as articulation friction phenomena among the South American Micro Plates motif (Torra, *in prep*.). The geologic phenomenon gave place to a regional set of major and secondary extensional faults. Thus, cortical terrains opened a large regional intracratonic rift basin system north-south axis which link to the east-west Amazonic rift basin system by a complex chafing framework of faults and secundary basins (TORRA, 2001a) and to the Orinoco rift basin system. This constituted a super-major system.

The regional rift basin was infilled by several conformable successions of siliciclastic heterolithic facies (the association sandstone-claystone-sandstone). They present a typical tabular strata geometry design which is clearly horizontal. The main sandy facies are supermature quartz arenites with bidirectional tidal internal structures as well others typical diagnostical structures (reactivation surfaces, herringbone cross-stratification, tidal bundles). The muddy facies are always massive conformable dark-greenish clay (mud) beds carrying typical fragmentary remains of several icnofacies (*Arenicolites, Skolithos, Zoophycos, Glossifungites,* *Cruziana*, *Tripanites*). They belong to high tide and wave energy environments (meso to macro "tidal flats" environments). The studied icnofacies developeded on the sand grains facies (shoreface) but much of their skeletons went to lie into lesser energetic facies deposits within the littoral shallow marine mud beds (offshore).

These facies had been largelly stained by epigenetic iron oxidation of very well rounded magnetite grains during later times. This phenomenon obscured and masked the recognition of the main facies and set of beds. The Holocene calcrete and caliche massive and/or laminar beds played an important role in secondary modifications as the mentioned iron stained did.

A major system of north-south in striking master extensional faultings, with kilometers to regional tilted blocks were recognized. The fault systems controlled the main subsidence architecture basin, the style of accommodation, the transfer zones and the sediment-balance supply to the basin which was also combined with eustatic variations during Cenozoical times.

The main infilling periods were related to sea level variations that occurred during Campanian-Senonian-Maastrichtian (Latest Cretaceous), Early to Middle Eocene and Middle to Late Miocene eustatic sea level oscillations according to HAQ *et al*. 1987 and HAQ & van EYSINGA 1998.

Volcanic and sub-volcanic alkaline igneous activity were checked in Argentina, Paraguay and Bolivia by means of satellite imagery studies. The main volcanic rocks occurs as domes, needles and necks. These forms have no signs of appreciable erosion. For these reason, we assume a Latest Pliocene-Pleistocene-Holocene age for these volcanic extrusions. The rocks composition, on the other hand, is just due to active extensional rift system present in several regions throughout the continents.

Regional Setting

The sedimentary Chaco Paraná Basin system extends from the Late Cretaceous to Holocene. This Latest Mesozoic - Cenozoic rift basin assemblage appears in the central, north areas of Argentina besides of many similar geomorphological-sedimentological frameworks placed at the Uruguay, Paraguay, Bolivia, Perú, Ecuador, Colombia, Venezuela, Guyanas and Brazil countries (TOR-

RA, 2001a).

At the Chaco Paraná rift basin lies outstanding strata heterolithical deposits that outcrops in the soutwest of Uruguay, southwest of Paraguay, the Chaco Paraguayo plains and the eastern Bolivian plains (i.e. Tarija). The outcropping siliciclastic heterolithic bed facies belong and are temporaly associated to the great "Southamerican Miocene Sea Transgression". Thus, the siliciclastic bed deposits were geographically distributed both on the Chaco Paraná Basin, the Orinoco Rift Basin and the Amazonic Large Complex Rift Basin system. This is registered through the presence of equal siliciclastic deposits (heterolithic facies with similar fossils) that outcrops in Argentina, Paraguay, Bolivia, Perú, Ecuador, Colombia, Venezuela, Guyanas and Brazil (HOVIKOSKY *et al*. 2004; RAMOS & ALONSO 1995; RÄSÄNEN *et al*. 1995; TORRA 1998b, 2001a).

The studied successions are those belonging to the Late Cretaceous (Latest Senonian-Maastrichtian) to Holocene. The analyzed deposits constitute a typical heterolithic facies that overlie the continental tholeiithic basaltic lavas of the Late Jurassic-Early Cretaceous age. The last unit is always linked to aeolianite quartz-arenite facies (GENTILE & RIMOLDI 1979; HERBST & SANTA CRUZ 1985; PADULA 1972).

The hugest amount of sediments that filled the basin came from clastic quartz grains successions, belonging to the Solari Formation (HERBST 1971; RUSSO *et al*. 1979), the Botucatú and Santa Maria Formations (Brazil) as the destroyed grains that were eroded through the time well innermost into the Brazilian Shield region.

There are a conspicuous absence of regional syntethic studies up to day, at least in the scale and point of view treated here. Nevertheles, several pioneers studies were carried out during the past century which contributed to the comprehension of some colateral aspects. We can cited to ACEÑOLAZA 1976; ACEÑOLAZA & SAYAGO 1980; ALBA 1953; AMEGHINO 1881; BONARELLI & LONGOBARDI 1929; BOLTOVSKOY 1979; BOSSI & PALMA 1982; CAMACHO 1967; CHEBLI *et al*. 1989; CORTELEZZI & LERMAN 1969; DEGRAF *et al*.1981; DEL RÍO 1991; FRENGUELLI 1945, 1950, 1955; GAVRILOFF & BOSSI 1992; GENTILE & RIMOLDI 1979; HERBST 1971; HERBST 1980; HERBST *et al*. 1976; HERBST & SANTA CRUZ 1985; IRIONDO 1973, 1980, 1999; IRIONDO & RODRÍGUEZ 1972;

PADULA 1972; PADULA & MINGRAM 1966; RUSSO *et al*. 1979; RAMOS & ALONSO 1995; SANTA CRUZ 1972; SAYAGO 1999; TORRA, 1998a,b, 1999a,b,c, 2000, 2001a, among others.

These studies gave few attention to the Cenozoic horizontal sequences that lies unconformable over the basaltic tholeiithic lavas. A possible reason that make clear this situation may be due to the probable low petroleum reservoir potential sediments that overlay the basic magmatic lavas. Petroleum geologists believed that beneath these Tertiary continental clastical beds, older sequences (continental and/or marine) present good possibilities for petroleum exploration.

The basement of the regional rift basin is constituted by the basaltic tholeiithic lavas, sometimes interstratified with supermature quartz arenites, supermature aeolianite sandstone beds and continental detritical clastic grains. They belong to the Serra Geral Group (HERBST & SANTA CRUZ 1985) and Santa Maria and Botucatú Groups (Brazilian Shield). Meta-sedimentites as well as high grade metamorphic facies and plutonic rocks are also present.

The main mother rocks were the supermature aeolianite sandstone beds and the Solari Formation (Serra Geral Group, Argentina), the Botucatú Group (Brazil) and the Santa Maria Formation (this last unit of local signification).

The Pampean Ridges Provinces located at Argentina, to the west of the main rift basin area, appear as a relative limit of the analyzed basin. Several studies demonstrate that the heterolithic facies appears widely dispersed in this geological province but, always, as an undergroud equivalent horizontal strata tabular lithosome. The beds appear to few depths, about of 1 to 10 meters. Their thickness ranges about of 1 to 200 meters according to CHEBLI *et al*. 1989; RUSSO *et al*. 1979; RAMOS & ALONSO 1995; TORRA, 1998a,b and Torra, 2001a.

The heterolithic facies originated during the littoral shallow marine transgressions were deposited all around the small positive isolated “island” areas at the Sierras Pampeanas Ridges Provinces (low-flatten ridges, small plateaus). The heterolithic facies also were deposited well westernward. Some isolated patches of these facies are exposed innermost to the inter-mountain valleys at the actual Andean orogen belt. At the northern areas of Argentine, in contact with the Sub-Andean folded trend (Sierras Subandinas), the framework is exactly the same. Here, once again, several heterolithic facies deposits were settled into the inter-mountain valleys in the foreland masiffs and pre-Andean orogen belt.

The east limit of the Chaco Paraná rift basin is formed by the Brazilian Shield. The Precambrian, Paleozoic and Mesozoic units served as source rocks for the Tertiary littoral shallow marine successions. Arenaceous sediments are well known for many cratonic formations in spite of the deposits of the giant very well sorted large ancient Botucatú desert sand, which was the main source unit for the three siliciclastic successions. It is completelly logical accept that the Botucatú deposits acted as a main reservoir supply for the Amazonic rift system deposits. A feedback proccesses of erosion, re-tranportation and sedimentation of sandy-muddy facies occured among these successions.

Several paleontological studies carried out at the Paraná "barrancos" and at deep gullies, revealed a characteristical fauna of foraminifer and mollusks. The *Ostrea sp.* is one of the more guide fossil of the Miocene succession. This mollusk was found in the sandy-muddy facies of many wells, as well as several foraminifers species, for example at the Santa Lucía and INCYTH 1 wells, Corrientes Province (HERBST & SANTA CRUZ 1985), the Entre Ríos Province (ACEÑOLAZA 1976; DEL RÍO 1991) and Buenos Aires Province siliciclastic marine heterolithic facies (BOLTOVSKOY 1979).

The subsurficial Buenos Aires heterolithic facies succession is locally named the "Puelches Formation". The heterolithic facies beds are exactly the same that the Miocene succession outcropping at others provinces and countries (Entre Ríos Province, Corrientes province, Uruguay, Paraguay, Bolivia, Perú, Brazil, Venezuela, etc.). For this reason, the subsurficial Buenos Aires lithosome constitutes the southward continuity of the Paraná and Ituzaingó Formations according to previous studies of TORRA, 1998b, 2001a, 2004. The above mentioned sediments and fossils are present into the Patagonia plateau as well as small outcrops at the Antarctica Peninsula (TORRA, 2001a) where the sequences were also deposited. At these regions the successions were less arenaceous but form many mudrock and claystone beds.

Methodology

It was done a field detailed recognition on the area, with special focus in tasks related to facies sedimentologic profiles, sketch and schematic drawings as well as micro, meso and macro geometrical and architectural analyses. These analyses also were maked through assemblage standard color photographs gabinet interpretations. Peelling technique on the siliciclastic slope gullies was done.

The detailed sedimentological profiles were performed on the entire analyzed region and architectural observations were carried out on well exposed outcrops, generally within fluvial river valleys. All the riverside "barrancos" and gullies of the Entre Ríos and Corrientes Provinces, the Esteros del Ñeembucú in Paraguay, the riversise "barrancos" and gullies of the Uruguay river at the south-west of Uruguay, the Sierras Subandinas of Bolivia (Tarija), the Sierras Subandinas, the Sierras Pampeanas, the Andean Orogen belt (Neuquén, Río Negro, Mendoza, San Juan, La Rioja, Catamarca, Salta, Tucumán, Jujuy Provinces), the Pampas plains (Buenos Aires, Santa Fé, Córdoba, San Luis, La Pampa, Santiago del Estero, Chaco, Formosa, Entre Ríos Provinces, Argentina) were studied in the field.

Detailed studies of hidrogeological core drill-holes log registers (about of 9,500 m of data) were analyzed. The wells are located mainly within the Chaco Paraná Basin (800,000 km^2) and the Mesopotámico Block (210,000 km^2). The analyzed hidrogeological wells were: "*Perforación Nº 1 Villa Angela (1941), Perforación Nº 2 Machagai (1937), Perforación Nº 1 Presidencia Roque Sáenz Peña (1945), Perforación Nº 1 Colonia Castelli (1942), Perforación Las Lomitas (1943), Perforación Pirané (1939), Perforación Mariano Boedo (1962), Perforación Nº 1, 2 y 3 Puesto V. Gómez (1941-1945), Perforación Nº 1 El Quebracho (1941), Perforación Nº 1 Posta San Martín (1944), Perforación Nº 1 Posta Cambio Zalazar (1942), Perforación Nº 1 Pozo del Tigre (1947), Perforación Resistencia Nº 1 (Ferrocarril Francés, 1906), Perforación Nº 1 Colonia Benítez (Ferrocarril Francés, 1906), Perforación Fontana (1942), Perforación Nº 1 Corrientes (INCYTH, 1977), Perforación San Cosme (MOSP, 1971), Perforación Santa Ana (MOSP, 1971), Perforación San Luis del Palmar (SADE SA, 1971), Perforación Paso de La Patria (SADE SA, 1971), Perforación General Paz (CARABAJAL SRL, 1974), Perforación Ituzaingó (MOSP, 1971), Perforación San Miguel (CARABAJAL SRL, 1974), Perforación Itá Ibaté (SADE SA,1971), Perforación Itatí (CARABAJAL SRL,1974), Perforación Concepción (CARABAJAL SRL, 1974), Perforación Mburucuyá (MOSP, 1968) y Perforación Santa Lucía (M. Frolich &*

Asoc. SRL, 1969)" (from TORRA 2001a).

Also, two exploratory petroleum wells were analyzed. They were named as the Nogoyá (Entre Ríos Province) and Mariano Boedo (Formosa Province) wells.

The geotechnical deep wells were also analyzed. These wells were drilled out during the construction of the large General Belgrano bridge. They were analyzed following to MAURO *et al*. 1998 methodologies.

One seismic line located at the center of the basin was analyzed (Chaco-Formosa Provinces). The line corresponds to the Argentinian CNE - 20 Block - Seismic Migrated Line CN20 - 95 -06 (Secretaría de Energía de Argentina, 1996). Others seismic lines cited in the specialized bibliography were compared to the CNE - 20 - Block (WEBSTER *et al*. 2004). The architectural, geometrical and structural relations of all the Late Cretaceous - Cenozoic successions detected by seismic lines were examined. They showed always the same pattern (horizontal tabular strata beds).

On the other hand, we employed scanning electron microscopy (SEM) looking for icnofacies rests. The mud, mudrock, tempestites silts and very fine sandy beds facies were analyzed with this technique looking for tiny remains.

Satellite imagery analyses were carried out to interpret the regional structural framework of the rift system basins. This last work comprises push broom optical sensor types as the SPOT 4 (HRV), 5 (HRG) and SAC-C (Medium Multispectral Resolution Sensor - MMRS and Medium Resolution Technology Camera - MRTC). Also, LANDSAT images were used as the TM 5 (*thematic mapper*), the older MSS 1, 2, 3, 4 (*multispectral scanner system*) and the new ones ETM 7 optical sensors (*enhanced thematic mapper*) in accord to TORRA, 2003a.

The technique of digital image proccessing was employed to examine extense plain areas and in this way be able to analyze the tectonical and geomorphological elements present in the actual basin reliefs (SABINS, 1997).

After digital image processing was concluded, we made one mosaikc (non-georreferenced) using SAC - C images (*paths* 223, 224, 225, 226, 227, 228, 229, 230, 231, 232) in a 4/5/3 enhanced compositions. The mosaick embraces almost the Argentinian zones as well as Uruguay, Brazil, Paraguay, Bolivia, Perú, Ecuador, Colombia, Venezuela and the Guyanas sectors. We used this temathic-planimetric preliminary chartography for structural interpretation as well as to outline Miocene deposits when possible.

Others more precise mosaicks in spatial resolution were done using Landsat TM 5 and ETM 7 images. They were used in selected areas of Argentina, Uruguay, Paraguay and Bolivia. Always, we used a 4/5/3 false coloured enhanced compositions.

Also, some papers cited in the geological literaure were compared, taking in consideration to CURIALE *et al*. 2002; DALRYMPLE 1992; HAQ *et al*. 1987; McCLAY *et al*. 2002; RAVNÅS & STEEL 1998; YOUNG *et al*. 2002; TRUDHILL & UNDERHILL 2002; UNDERHILL 1991; WALKER 1990.

Results

Sedimentology

After field data and core drill-holes analyses we found that the studied area was infilled by several conformable successions of sandy-muddy heterolithic facies, a succession of sandstone-claystone-sandstone strata beds.

The facies analysis in the field and inferrings obtained from chartopraphic map reveals that the characteristic of the deposits, specially the Miocene succession, has a similar composition both texture and internal structures. This reveals a similar sedimentological environment in which tide energy were responsible of them (bidirectional structures are diagnostics among others). The major sectors that showed Miocene outcrops at Argentina can see in Figure 2. The finest associated granulometrical facies carries fragmentary rests of icnofacies (previously not studied or identified) which belong to classical tide and wave high energy environments. The remains icnofacies studied went to lie into low energy facies of the littoral marine mud beds.

Figures 3 and 4 shows the basin with a regional cross-section of a northern sector of the Argentinian plains. The succession of the heterolitic facies are well developed in all wells, with an exception in the Las Piedritas and the Posadas drill-holes where older rock were drilled and outcrop due to a structural horst or elevated block (RUSSO *et al*. 1979). This is a main feature in the hemi-grabens assemblage of the marine rift basins according to RAVNÅS & STEEL (1998).

The sandy facies had been largelly stained by secundary iron oxidation by means of epigenetical ferricretization proccesses. The chalcretization proccesses gave place to laminar, massive and spherical (concretional) caliche irregular beds as well as pisolitic structures.

Three main littoral shallow marine siliciclastic successions were recognized:

Latest Campanian - Senonian - Maastrichtian – early Paleocene succession. This is the lowermost sequence of the Chaco Paraná Basin overlaying the Serra Geral-Solary Group. The succession no outcrops at the plains areas. The deposits are constituted for a heterolithical succession, in which arenaceous facies prevailed over mud beds. Some beds of limestone are present though they have few meters in thickness. This fact indicates that there were more warmer conditions in the waters which agrees with the paleo position of the Southamerican Plate about of 75-65 m.y. The geometry of the beds are horizontal to subhorizontal. The distribution of these deposits is scarce, scattered and a few meters thickness. The measured thickness in the analyzed wells ranges between 50 to 150 meters in the siliciclastic heterolithic facies succession.

The structural relation with underlaying rocks is unconformable. The succession overlain the Upper Jurassic-Late-to-Middle Cretacic tholeiithic basaltic lavas with an angle of about 0-3 grades. However, the continental pediplanization constitutes the main geomorphological element that mark the contact between sequences. Besides, the change of drastic lithologies. The lavas are, sometimes, interstratified with aeolianites quartz arenites supermature facies. The beds increase in thickness toward the west of the basin. The base of this succession is generally formed by tholeiithic lavas but many times the heterolithic succession is absent or is not well recognized due to burial modifications. This effect could be produced by differences in the proto-Latest Senonian-Maastrichtian low relief, climatic conditions or syntectonic depositational faulting systems.

Fault folded beds are present in the westernward folded ridges Sub-Andean Sierras Subandinas near to the Andean orogen (outside Chaco Paraná Basin). At this outcrops, thickness varies about of 250 meters. Littoral marine fossils are common into these beds. Collected diagnostical fossils rests are *Melania* *sp*. (Maastrichtian) and *Gasteroclupea branisai* (Campanian-Senonian) according to MINGRAMM *et al*. 1979. Some limestone and evaporites beds were cited by the above authors but in our analyzed wells they didn´t appear.

The Eocene succession. This succession is present at intermediate depths of the analyzed basin (Figure 4). The beds composition correspond to a typical heterolithic facies, a little more muddy that the older ones. None limestone beds were registered here. There is an increase in detritical tempestites facies composed by very fine sandy to coarse silty grains. Composition continues in the sort of supermature quartz arenite. The spatial distribution is homogeneous within the limits of the basin. This is based on available data registered on core drill-holes. The known thickness ranges about of 300 to 350 meters. The structural relations are quite conformable with the underlaying and overlaying heterolithic successions. Many sandstone beds present clear post-depositional modifications, specially stain coloured alteration beds to light yellowish, brownish or reddish. Some littoral shallow marine rest fossils were found as scattered *Pucalithus*, stromatolitic biostructures, bone, scale and vertebral discus fishes as well as many quelonia shells according to MINGRAMM *et al*. 1979.

The Middle to Latest Miocene succession. These beds are well known from the Alcides D'Orbigny epochs and they were registered in several papers (ALBA 1953; HERBST 1971; HERBST & SANTA CRUZ 1985; TORRA, 1998b, TORRA 2001a, 2004) based on direct outcrops recognitions. Its distribution is constant within the basin. The thickness ranges about of 250 to 300 meters. The structural succession relations is conformable and horizontal. Also, these beds constitute a very typical heterolithic facies. The architecture is amalgamated both macro and meso forms. These littoral shallow marine siliciclastic deposits showed similitude in texture, internal structure, composition and fossil rests.

The architecture and geometry of the siliciclastic littoral shallow marine deposits on the entire analyzed region are similar as can be interpreted in many seismic lines (Figure 6).

The succession was rigurously examined at the gullies and "barrancos". Characteristical rest fossils were found into the horizontal sandy-muddy beds. Mollusks and foraminifers are present elsewhere either outcrops or underground mud beds as the *Ostrea sp., Protelphidium tuberculatum D'Orbigny, Cyprideeis* *sp.* in accord to HERBST & SANTA CRUZ (1985).

The main reservoir or source rocks for the clastic grains of these deposits were derived from older continental siliciclastic bed successions, which are related to the mixed eolical/fluvial Solari (Serra Geral Group), Santa Maria and Botucatu Formations. Also, a feedback process (sedimentary reworking) with the Latest Campanian-Senonian-Maastrichtian - early Paleocene succession and the Eocene succession occured.

Figure 6 shows that the Eocene and Miocene successions, which are quite similar in composition, lies in conformable geometrical structure relation.

Tectonic

The structural style of the basin is related to major extensional faultings (regional tilted and fault blocks) with north-south striking in its main direction. Numerous strike-slip faults (mainly of regional origin) are present, crossing the entire area. They had a clear influence in the accommodation and transfer zones of the rift basin system. The strike is north-west to south-east on the border of the basin. To the west, in the contact with the Pampean Ridges Provinces and the narrow-meridionally-extense Sub-Andean folded trend (mainly Paleozoic units belong to the Sierras Subandinas Province) a complex mixed system of faults are present (Figure 7).

Also, at the west margin of the studied area, many large shear zones and upthrust faults are present. These faults dislocated the Pampean and Sub-Andean blocks due to the interaction with regional crossing strike-slip faults. An *en echelon* block model is characteristic at these zones. Incipient contaminated igneous activity were checked associated to these cortical weakness zones. The regional fault present at the Ypacaraí Lake (Paraguay) is one of the best examples of the regional strike-slip faulting as was stated long time ago by DEGRAFF *et al*. 1981.

By means of digital satellite imagery, employing mosaiking visual interpretation, we can determined a rift system tectonic framework for the whole analyzed subcontinental region. Major faults were possible to be compared by means of observations of geomorphological landscape. The use of this technique was very useful in the study of wide areas of low to very low relief to detect lineament and arenaceous deposits.

The east border of the basin an extend slide-subsidence crustal block with an arc contoured limit was recognizable in the false color images (Figure 7). This regional structural feature is clearly recognized on the SAC - C mosaick (MMRS sensor). The tectonic structure embraces large sectors of Brazil, Bolivia, Uruguay, Paraguay and Argentine Mesopotamic Block and the Chaco Pampean Plains. The large structure corresponds to one regional (subcontinental) tilted and block fault that slided and moved a large block downward recently. The age suggested corresponds to the Latest Pliocene-Pleistocene-Holocene.

Volcanism

The landscape of the studied region appears with domes, needles and necks of volcanic and sub-volcanic origin. Some products originated by this igneous activity were dated Latest Pliocene through the igneous facies mainly correspond to the Pleistocene and Holocene age. The composition of the igneous extrusion rocks were classified as an alkaline basaltical suite. This fact agrees with other magmatic events related to extensional rift basins elsewhere.

Another important feature, corresponds to the Quaternary vulcanism present in this region. It is present at Paraguay (south-west), Bolivia and Argentina in the form of volcanic domes of Latest Pleistocene-Holocene age. They can be originated in the fault crossing sites. At present days, is not well recognized this magmatic episode at southern Brazil places because several outcropping needles could correspond to exhumated reliefs. However, its presence is largely probable. It really seems very probable that the volcanic outcropping necks and needles near Santa Maria city were related to this activity. They could be directly related to the regional structural assemblage evolution studied here.

Paleogeography

The paleogeographical interpretation based on facies analysis, paleontological fossil remains and satellite imagery studies showed that the Paranense Sea and the Amazonic Sea transgressions were to a very wide littoral shallow marine transgression phenomena (eustatical and tectonicaly related) that sinchronously occurred. This happened during Middle to Late Miocene times and cover almost South America plains, sectors of depressed shields and foreland masiff areas. The Late Cretaceous-Paleocene and the Eocene sequences also cover those areas having its facies and fossils records great similitude with the geomorphotectonical style that predominate during last 75 m.y. in this region.

The succession of beds registered in the analyzed basins had a continuos and/or alternating connection which is based on its facies deposits similitude and fossils remains.

The propposed littoral shallow marine connections were spasmodic and short in time during Late Cretaceous and Eocene periods when several marine ingressions and regressions characterized the Paleogene paleogeography. Conversely, during Miocene times the littoral shallow marine connection was permanent throughtout the continent. A high stand system tract represented the major environment associations with their associated transgressive system tracts successions. The analyzed regional context supports this model based on unequivocal equal heterolithical facies and a similar faunal remains present elsewhere of South American Miocene heterolithical facies (HOVIKOSKY *et al*. 2004; Torra, 2001a, 2004).

The sea connections during Late Cretaceous and Eocene periods were highly feasible due to structural and geomorphological proto-Southamerican Plate assemblage. The model of Late Cretaceous and Eocene connection is mainly based on textural and compositional similitude of the siliciclastic littoral shallow marine bed succession deposits (the similar heterolithic facies) and the regional framework block and masiffs distributions, that configured a unique continental "tectosedimentary layout". The paleontological record reinforce such model. The presence of equal paleontological fossils refuse greatly the theory of possible "isolated sub-basins" which is only possible for a very local analysis. Of course, the basinal sediments of some local depocenter may carry slightly different facies (i.e. conglomerate) but the final "blanket stage" in the sense of PROSSER model (1993) largelly agreed with the propposed continental model. This is extremely obvious for the littoral shallow marine Miocene ingression. There, the correlations made through foraminifers, among others fossils (mollusks), demonstrate a permanent marine connection. Moreover, the extreme similitude of the heterolithical facies reinforce strongly this model (TORRA, 2001a, 2004).

According to this statement, the Miocene succession correlation is based on equal heterolithic facies and characteristic fossils. On the other hand, geomorphological studies made through satellite imagery reveals wide plains of topographic low energy relief and extense flat areas. The paleogeography had large shallow marine connection zones that developed during Middle to Late Miocene period (TORRA, 1998b, 2001a). The deposits present the same texture, composition and internal structures at the Argentina, Uruguay, Paraguay, Bolivia, Perú, Ecuador, Brazil and Venezuela outcrops as well as the fossil remains that belong to a similar sedimentological environment system.

The siliciclastic littoral shallow marine deposits of the successions present at Southamerican regions largelly support this thesis (HOVIKOSKY *et al*. 2004; RAMOS & ALONSO 1995; RÄSÄNEN *et al*. 1995; TORRA 1998b, 1999a, 2001a, 2004).

The Paranense and Amazonic Seas had been also connected to the Pacific Ocean during the three depositational succession facies defined herein. The model of these connections were related to many passing-channels that were formed in the narrow and very shallow inter-mountain valleys, formed in the pre-Andean foreland massifs. These connections occured before the main orogenesis elevation of the Andean orogen belt happened (Figure 8).

Discussion

The analyzed continental rift basin assemblage presents an extensive succession of littoral shallow marine siliciclastic heterolithic beds, which are mainly sandstone and mudstone facies. The average of the entire succession thickness is about of 600 meters at the wide epirogenetic region. Just in the margin of the westwards basin the thickness increase rapidly (RUSSO *et al*. 1979), specially the Neogene successions due to movile orogen belt cortical accomodations.

The beds of the older succession belong to the Latest Campanian-Senonian-Maastrichtian-early Paleocene age. This heterolithical facies succession with some sporadic episodes of interstratified limestone and evaporites (sabhka) facies correspond to the Yakoraite Formation. This unit appears at the Sierras Subandinas geological province, to the west of the basin. The texture, composition and fossil remains indicate a littoral shallow marine environment. We assume a

Latest Campanian-Senonian-Maastritchtian-to-early Paleocene age for this scarcely dispersed beds.

The Eocene succession is integrated by the underground siliciclastic Chaco and Mariano Boedo heterolithic facies Formations. These units are of underground existence within the Chaco Paraná Basin. There are not registered outcrops until now about the Chaco Pampean plains. However, the 250-300 meters of horizontal beds thickness were the results of a period of continuous erosion, re-transportation and predominantly tide (and marine storms)-dominated sedimentation in a wast area. Unconfomities were not observed between the underlaying Upper Cretaceous succession and the overlaying Chaco and Mariano Boedo heterolithical facies Formations. Because of the extreme textural and compositional similitude between these formations, we assume that they are of only one equivalent lithosome (the Eocene succession).

Several fossils were found in the cored drill-holes log registers (vertebrate disk, scale and bone fishes). They were classified as a marine fauna of littoral waters. A possible whale vertebrate disk rests also were found it. Several isolated fragment of wood and carbonized vegetation remains were checked too.

The interpretation may be due to some episodical delta and/or fluvial small environments near or joined to the coastlines. However, these very scarce fossils haven't insignificant influence about the analyzed regional littoral shallow marine successions regional context.

The Middle to Latest Miocene successions are integrated by the Paraná and Ituzaingó Formations. These units had extended continuity in depth into the analyzed basin. However, their outcrops, specially at the "barrancos" and deep gullies in the left margin of the Paraná and Paraguay rivers, served us to examine internal bidirectional structures and collected fossil remains (*Ostrea sp*. *Protelphidium tuberculatum D'Orbigny*, etc.) as well as high energy icnofacies (*Arenicolites*, etc.). As the Eocene successions, its thickness ranges near 250-300 meters indicating a possible similar balance in the source sediments which were incorporated to the succession.

They are considered equivalent lithosomes because of the extreme similitude in texture, composition and internal structures. The geometry and architecture of meso and macroforms are equal to the other successions.

The Buenos Aires Province underground heterolithical facies beds named "Puelches Formation", which carries foraminifers (*Protelphidium tuberculatum D'Orbigny*) is a lithosome equivalent to the littoral shallow marine Miocene succession. The Puelches lithosome was deposited in the same tidal flat environment during the Miocene transgression (TORRA 1998b, TORRA 2001a).

The heterolithic facies of the Puelches lithosome lies a little more deeper (1 to 10 m depending of the analyzed place). That is so due to recent tectonic Quaternary reactivation faults. To the west (at the La Pampa Province), the Puelches lithosome outcrops at the Puelches city and adjoining areas (TORRA, 1998a, 2001b, 2002) (Figure 3 to ubication).

The Ituzaingó, Paraná and Puelches Formations, a unique succession, have the same geochemical values elsewhere, both sandy or muddy lithofacies. Recent analyses made on these successions showed extreme similitude in several major and trace elements, for example: vanadium 247, barium 588, circonia 257, galium 26, cesium 12 and chromium 152 ppm. The silica values is always the same ranging 70 in percentage. The others major molecules are equals (see TORRA 2004).

The Ituzaingó and Paraná Formations and the underground heterolithical facies unit (the Puelches Formation) constitute an unique lithosome which was deposited on the vast Miocene tidal flat environment (TORRA, 1998b, 1999a, 2001a, 2004).

At the Paraná Formation we studied a significative small lithosome (or small lense bed) of what was previously described as a "conglomerate" bone rests. This was related to an erosive unconformity. It is interstratified into the sandy-muddy heterolithic facies. This fact gave origin to confusion and controversial discussions being interpreted as an unconformity (HERBST & SANTA CRUZ 1985).

The interpretation is that this small lense-lithosome indicates a short period of warmest water conditions followed by a rapid subsidence basin (few meters) which was suficient to cause the death of the entire association of faunal organisms (small and large *Ostrea sp*., many mollusks, etc.). The lithosome, laterly was fairly disturbed by movements that were originated just to water raising moment. During the Latest Pleistocene-Holocene the bed supported another final modification mainly induced by meteoric agents (pluvial). These facts obscured the geometrical relations.

We assume that this very small lithosome corresponds simply to a "singenetic faunal break coastline marine modification". It is representing a brief breacking into the heterolithical monotonous sandy-muddy facies succession development.

At the underground beds, in the core drill-holes of several wells, foraminifers species as well as small *Ostrea sp.* species were found. They were found into the core drill-holes registers from - 59 to - 270 meters resting into the paleofauna association of the siliciclastic heterolithic facies succession.

These sandy-muddy successions constituted several stadios of transgressive system tracts (TST) and highstand system tracts (HST), from the point of view of sequential stratigraphy. The entire recurrent major sequence was deposited close to the past 75-65 m.y. to recent 8-5 m.y.

So, we think that the form in which this pile of sediments deposited were predominantly by the action of tides, also including waves and marine hurricane phenomena (tempestites facies), during a period that began on the Late Cretaceous. This occured within an intracratonic subsidense regional rift basin system which constitutes a significative first order allostratigraphic unit. The 700-600 meters of supermature siliciclastic sediments pile (in average) were detached from the underlaying older unit by means of a regional first order unconformity and a drastical change in the environment and sedimentation conditions (ABBOTT 1998, 2000; TORRA 1998b).

Figure 6 shows a typical horizontal "blanket" that cover an extense area. This is in accord with previous ideas exposed early by PROSSER (1993) and UNDERHILL (1991) for marine rift basin systems. In this figure the hanging-wall and the foot-wall are not visible because they are parallel to the examined seismic line.

Figure 9 show a preliminar interpretation of depositational environment evolution related with eustatical variations according to Haq *et al*. (1998).

Periods of quiescence led to highstand system tracts as well as stages with few clastic sedimentation. These periods are well market between the Eocene successions-Miocene succession and between the Miocene successions-Quaternary (a mud-prone interval).

The vertical variation showed by the three successions assemblage be linked closely to the evolving tectonical and eustatical regime and sediment-balanced supply.

In the three succession, but specially at the Miocene ones, the arenaceous clastic grains represent the rift initiation and early synrift stage whereas the mud-prone beds are the climax of the rifting system (Pampeano and Post-Pampeano Formations which derives from the HST beds of the Miocene succession in accord to TORRA (2001a, 2004).

We emphasize that the signature of the three analyzed succesions belongs to rift phases system in accord to FAERSETH *et.al*. 1995, PROSSER, 1993, RATTERY & HAYWARD 1993 and UNDERHILL 1991 marine rift models.

Conclusions

During past 75 m.y. the proto-South American continent supported extensional lithospherical subsidense. This led to breack up large **rift basin systems** like the **Paraná**, **Amazonas** and **Orinoco** river areas and adjoining regions. They constitute a super giant rift continental structure.

These extense phenomenon served as a way to produce faunistical dispersion into South America, at the stage in which marine waters retired and so drainage network system reorganized in a giant cathment (Amazonas, Paraná and Orinoco actual fluvial systems). During marine ingressions the faunistical dispersion were also important (i.e. *Ostrea sp*.).

An important succession of supermature siliciclastic horizontal to slightly subhorizontal sediments were deposited between Brazilian Shield and the foreland westwards masiffs as well as between Brazilian Shield and the Guyanas Shield.

These successions were interpreted and categorized in three succession as follow:

The **Latest Campanian - Senonian - Maastrichtian – early Paleocene succession**

The **Eocene succession**

The **Middle to Latest Miocene succession**

The studied successions have an unequivocal and equal **heterolithical facies environment** and **marine fossil remains**.

The three successions contitute a first order **allostratigraphic units**.

These successions were **connected** among them during climax phase synrift subsidence. The last analyzed succession, **Miocene**, had an important and extensive connection stated by facies and fossils. This Sea covered the major area of South America (about of 60 to 70 in percentage or more).

The **connections with Pacific Ocean** also existed throughout the time of evolution of the studied successions in spite of characteristical fossils are yet not rigurously collected and studied due to orogenesis destroying processes deposits during Andean orogen elevation.

References cited

ABBOTT, S. T. Transgressive systems tracts and onlap shellbeds from mid-Pleistocene sequence, Wanganui Basin, New Zeland. Journal of Sedimentary Research. 68: 253-268. 1998.

ABBOTT, S. T. Detached mud origin of highstand systems tracts from mid-Pleistocene sequence, Wanganui Basin, New Zeland. Sedimentology. 47: 15-29. 2000.

ACEÑOLAZA, F. G. Consideraciones bioestratigráficas sobre el terciario marino de Paraná y alrededores. Acta Geológica Lilloana. XIII. 2: 91-107. 1976.

ACEÑOLAZA, F. G. & SAYAGO, J. M. Análisis preliminar sobre la estratigrafía morfodinámica y morfogénesis de la región de Villa Urquiza, provincia de Entre Ríos. Acta Geológica Lilloana. XV. 2: 139-154. 1980.

ALBA, E. Geología del Alto Paraná, en relación con los trabajos de derrocamiento entre Ituzaingó y Posadas. Revista Asociación Geológica Argentina. 8 (3): 129-161. 1953.

AMEGHINO, F. La Formación Pampeana o estudio de los terrenos de transporte de la Cuenca del Plata. Buenos Aires-Paris. 371 p. 1881.

BONARELLI, G. & LONGOBARDI, E. Memoria Explicativa del Mapa Geo-Agrológico y Minero de la Provincia de Corrientes. Imprenta del Estado. Provincia de Corrientes. Tomo II. pp. 285-346. 1929.

BOLTOVSKOY, E. Paleoocenografía del Atlántico sudoccidental desde el Mioceno, según estudios foraminiferológicos. Ameghiniana. 16 (3-4): 357-389. 1979.

BOSSI, G.E. & PALMA, M. Reconsideración de la estratigrafía del Valle de Santa

María, provincia de Catamarca, Argentina. V Congreso Latinoamericano de Geología. Actas I: 155-172. 1982.

CAMACHO, H. H. Las transgresiones del Cretácico superior y Terciario de la Argentina. Revista Asociación Geológica Argentina. 22 (4): 253-280. 1967.

CHEBLI, G.A., TÓFALO, O.R. & TURZZINI, G.E. Mesopotamia. In: Cuencas Sedimentarias Argentinas. (eds. by L. A. Spalletti & G. A. Chebli). Serie Correlación Geológica. Instituto Superior de Correlación Geológica. Universidad Nacional de Tucumán. Publicación 1430. 6: 79-100. 1989.

CORTELEZZI, C.R. & LERMAN, J.C. Estudio de las Formaciones Marinas de la Costa Atlántica de la Provincia de Buenos Aires. VIII Congreso Mundial del INQUA. Paris. pp. 135-164 (reimpresión del LEMIT, La Plata). 1969.

CURIALE, J.A., COVIGNON, G.H., SHAMSUDDIN, H.M., MORELO, J.A. & SHAMSUDDIN, K.M. Origin of Petroleum in Bangladesh. AAPG Bulletin. 86 (4): 625-652. 2002.

DALRYMPLE, R. W. (1992) Tidal depositional systems. In: Facies Models. Response to Sea Level Change. (eds. by R. G. Walker & N. P. James). pp. 195-218. Association Geological of Canada. Ontario. 1992.

DEGRAFF, J.M., FRANCO, R. & ORUÉ, D. Interpretación geofísica y geológica del valle de Ypacaraí (Paraguay). Revista Asociación Geológica Argentina. 36 (3): 240-256. 1981.

DEL RÍO, C. J. Revisión Sistemática de los Bivalvos de la Formación Paraná (Mioceno medio), Provincia de Entre Ríos, Argentina. Academia Nacional de Ciencias Exactas, Físicas y Naturales. Monografía 7. pp. 11-93. Buenos Aires. 1991.

D'ORBIGNY, A. Voyage dans L'Amerique Meridionale. Tomo III. Geologie et Paleontologie. (Traducción española de Editorial Futuro). Buenos Aires. 1846.

FAERSETH, R.B., SJØBLON, T.S, STEEL, R.J. LIJEDAHL, T. SAUAR, B.E. & TJELLAND, T. Tectonic controls on Bathonian-Volgian synrift successions on the Visund fault block, northern North Sea. In R.J. Steel, V.L. Felt, E.P. Johannessen and C. Mathieu, eds. Sequence Stratigraphy on northwest European margin: Norwegian Petroleum Society Special Publications 5. pp. 325-346. 1995.

FRENGUELLI, J. El Piso Platense. Revista del Museo de La Plata. Geología. II. pp. 287-311. La Plata. 1945.

FRENGUELLI, J. Rasgos generales de la morfología y la geología de la Provincia de Buenos Aires. LEMIT. Serie II. Nº 33. La Plata. 1950.
FRENGUELLI, J. Loess y Limos Pampeanos. Facultad de Ciencias Naturales y Museo de La Plata. Serie Técnica y Didáctica. Nº 7. La Plata. 1955.
GAVRILOFF, I. J. C. & BOSSI, G. E. Revisión general, análisis facial, correlación y edad de las formaciones San José y Río Salí (Mioceno medio), Provincias de Catamarca, Tucumán y Salta, República Argentina. Acta Geológico Lilloana. 27 (2): 5-43. 1992.
GENTILE, C. A. & RIMOLDI, H. V. Mesopotamia. In: Segundo Simposio de Geología Regional Argentina. (eds. Academia Nacional de Ciencias de Córdoba). Córdoba. Volumen I. pp. 185-223. 1979.
HAQ, B. U., HARDENBOL, J. & VAIL, P. R. Chronology of fluctuating sea levels since the Triassic. Science. 253: 1156-1167. 1987.
HAQ. B. U. & van EYSINGA, F. W. B. Geological Time Table. Fifth edition and enlarged edition. Elsevier. Amsterdam. 1998.
HERBST, R. Esquema estratigráfico de la Provincia de Corrientes, República Argentina. Revista Asociación Geológica Argentina. 24 (2): 221-243. 1971.
HERBST, R. Consideraciones estratigráficas y litológicas sobre la Formación Fray Bentos (Oligoceno inferior-medio) de Argentina y Uruguay. Revista Asociación Geológica Argentina. XXXV (3): 308-317. 1980.
HERBST, R., SANTA CRUZ, J. N. & ZABERT, L. L. Avances en el conocimiento de la estratigrafía de la Mesopotamia de Argentina, con especial referencia a la Provincia de Corrientes. Revista de la Asociación de Ciencias Naturales del Litoral. 7: 101-121. 1976.
HERBST, R. & SANTA CRUZ, J. N. Mapa Litoestratigráfico de la Provincia de Corrientes. D'Orbignyana. 2: 1-51. 1985.
HOVIKOSKY, J., RÄSÄNEN, M., GINGRAS, M., RODDAZ, M., BRUSSET, S., HERMOZA, W. & ROMERO PITMAN, L. Miocene semi diurnal tidal rhytmites in Madre de Dios, Perú. International Conference TIDALITES-2004. pp. 88 - 91. Copenhagen. 2004.
IRIONDO, M. H. Análisis ambiental de la Formación Paraná en su área tipo. Boletín de la Asociación Geológica de Córdoba. 2 (1-2): 19-23. 1973.
IRIONDO, M. H. El Cuaternario de Entre Ríos. Revista de la Asociación de Ciencias

Naturales del Litoral. 11: 125-141. 1980.
IRIONDO, M. Climatic changes in the South American plains: Records of a continent-scale oscilation. Quaternary International. 57-58: 93-112. 1999.
IRIONDO, M. H. & RODRÍGUEZ, E. D. Algunas características sedimentológicas de la Formación Ituzaingó entre La Paz y Brugo (Entre Ríos). Actas. V Congreso Geológico Argentino. I: 317-330. 1972.
MARTINIONI, D. R. La Formación Rabot (Cretácico superior, Isla James Ross, Antártida): un ciclo transgresivo-regresivo de plataforma con dominio de procesos de tormenta. In: Geología de la Isla James Ross. Instituto Antártico Argentino (eds.). pp. 101-124. Buenos Aires. 1992.
MAURO, M., PELLEGRINO, A, RAMONDINI, M. & URCIULI, G. A. Contribution to the geotechnical characterization of large areas for landing planning. pp. 195-201. In: Geotechnical Site Characterization. Robertson & Moyano (eds.). Balkema. Rotterdam, 1998.
McCLAY, K.R., DOOLEY, T., WHITEHOSE, P. & MILLS, M. 4-D evolution of rift systems: Insights from scaled physical models. AAPG Bulletin. 86 (6): 935-960. 2002.
MINGRAMM, A., RUSSO, A., POZZO, A. & CAZAU, L. Sierras Subandinas. Geología Regional Argentina. Academia Nacional de Ciencias de Córdoba. pp. 95-137. Córdoba. 1979.
PADULA, E. Subsuelo de la Mesopotamia y regiones adyacentes. Geología Regional Argentina. Academia Nacional de Ciencias de Córdoba. pp. 213-235. Córdoba. 1972.
PADULA, E. & MINGRAM, A. Estratigrafía, Distribución y Cuadro Geotectónico Sedimentario del “Triásico” en el subsuelo de la Llanura Chaco-Paranense. Actas. III Jornadas Geológicas Argentina. 1: 291-328. Comodoro Rivadavia. 1966.
PROSSER, S. Rift-related linked depositional systems and their seismic expression. In: G.D. Wouldiams & A. Dobbs, eds. Tectonics and seismic sequence stratigraphy. Geological Society Special Publication 71. pp. 35-66. 1993.
RAMOS, V. A. & ALONSO, R. N. El Mar Paranense en la Provincia de Jujuy. Revista del Instituto de Geología y Minería. 10: 73-80. 1995.
RÄSÄNEN, M. E., A. M. LINNA, J. C. R. SANTOS & NEGRY, F. Late Miocene Tidal deposits in the Amazonian foreland basin. Nature. 269: 368-390. 1995.
RAVNÅS, R. & STEEL, R. J. Architecture of Marine Rift-Basin Successions. AAPG

Bulletin. 82 (1): 110-146. 1998.
RATTERY, R.P. & HAYWARD, A.B. Sequence stratigraphy of a failed rift system: the Middle Jurassic to Early Cretaceous basin evolution of the central and northen North Sea. In J.R. Parker, ed. Petroleum Geology of northwest Europe: Proceedings of the 4th Conference: London. The Geological Society. pp. 215-249. 1993.
RUSSO, A., FERELLO, R. & CHEBLI, G. A. Llanura Chacopampeana. Geología Regional Argentina. Academia Nacional de Ciencias de Córdoba. pp. 139-183. Córdoba. 1979.
SABINS, F.F. Remote Sensing. Principles and Interpretation. 3rd edition. W. H. Freeman and Company. New York. 494 p. 1997.
SANTA CRUZ, J. N. Estudio sedimentológico de la Formación Puelches en la Provincia de Buenos Aires. Revista Asociación Geológica Argentina. 27 (1): 5-62. 1972.
SAYAGO, J. M. Aproximación regional al loess subtropical Argentino. Actas. I Congreso Argentino de Cuaternario y Geomorfología. Santa Rosa. La Pampa. pp. 159-175. 1999.
SECRETARÍA de ENERGÍA de ARGENTINA. Dirección Nacional de Recursos Hidrocarburíferos y Combustibles. Dirección de Exploración y Explotación. Desregulación de la Industria del Petróleo y Gas. 30 p. 1996.
TORRA, R. Estructuras sedimentarias marinas diagnósticas en las arenas de la Formación Ituzaingó (Mioceno medio), entre Itatí y Empedrado. Provincia de Corrientes. Mesopotamia Argentina. Revista del Instituto de Geología y Minería. 12 (1): 75-86. 1998a.
TORRA, R. A Brief Stratigraphy and Paleogeography of the Miocene Sea at the Mesopotamia Region, Northeastern Argentina, South America. Geocongress 98. Geological Society of South Africa. Proceedings. pp. 79-82. Pretoria. 1998b.
TORRA, R. Ituzaingó Formation: A Key for the Interpretation of the Upper Tertiary Stratigraphy, Mesopotamia-Chaco Paraná Basin, Argentina. Revista Ciência e Natura. 21: 139-168. 1999a.
TORRA, R. Rapid Backwearing and related processes at the slopes of the Paraná river valley, Mesopotamia region, Argentina. International Symposium on Engineering Geology, Hydrogeology and Natural Disasters with emphasis on Asia. Journal of Nepal Geological Society. Extended Abstract Volume 20. Special Issue. pp. 2-3. Kathmandu. 1999b.

TORRA, R. Geología del subsuelo del Gran Resistencia y Regiones aledañas. Comunicaciones Científicas y Tecnológicas 1999. Tomo VII Ciencias Tecnológicas. pp. 169-172. Corrientes. 1999c.
TORRA, R. Geochemistry of a Tidal Transgressive Heterolithic Succession: The Ituzaingó Formation (Middle Miocene), Argentina. Chinese Journal of Geochemistry. 19 (1): 52-59. 2000.
TORRA, R. Sedimentología de las arenas de la Formación Ituzaingó entre Itatí y Empedrado, Provincia de Corrientes con algunas observaciones adicionales en áreas adyacentes. *Unpublished Doctoral Thesis*. Instituto de Estratigrafía y Geología Sedimentaria Global (IESGLO). Facultad de Ciencias Naturales e Instituto Miguel Lillo. Universidad Nacional de Tucumán. 2 Volumes. 421 p. 2001a.
TORRA, R. Origin and evolution of the continental giant 'Chaco-Pampeano' shelf (Argentina): their evolution and morphology from the Miocene to present days. International Geological Correlation Program. Abstract Volume. Project No. 464. 1st Annual Conference (Asian Venue). pp. 49-50. Hong Kong. 2001b.
TORRA, R. The origin of the «Pampeano» Formation (Pleistocene-Holocene) at the Argentina plains and surrounding areas: an approach. International Geological Correlation Program. Abstract Volume. Project No. 464. 2nd Annual Conference (South American Venue). pp. 77-82. San Pablo. 2002.
TORRA, R. Satellite Images (Landsat TM 5) applied to geologic, landscape and management risk map of the Maipú Department, Chaco Province, northeastern region of Argentina. 2003 Annual Conference of the American Society of Photogrammetry and Remote Sensing (ASPRS). CD Rom Proceedings. Anchorage. 2003a.
TORRA, R. Geología del subsuelo del Área Metropolitana del Gran Resistencia (AMGR), Provincia del Chaco, Nordeste de Argentina. Ciência e Natura. 25: 83-100. 2003b.
TORRA, R. A Preliminary Geochemical study of Upper Cenozoic clastic sediments (Ituzaingó, Pampeano and Post-Pampeano Formations). Northeastern region of Argentina and neighbouring areas. Ciência e Natura. 26 (1): 59-83. 2004.
TORRA, R, *in prep*. The South American Micro Plates segmentation. A preliminar approaching.
TRUDGILL, B. & UNDERHILL, J. R. Introduction to the structure and stratigraphy

of rift systems. AAPG Bulletin. 86 (6): 931-934. 2002.
UNDERHILL, J.R. Controls on Late Jurassic seismic sequences. Inner Moray Firth, UK North Sea: a critical test of a key segment of Exxon's original global cycle chart. Basin Research. 3: 79-98. 1991.
WALKER, R. G. Facies Modeling and Sequence Stratigraphy. Journal of Sedimentary Petrology. 60: 777-786. 1990.
WEBSTER, R. E., CHEBLI, G. A. & FRITZ FISCHER, J. General Lavalle basin, Argentina: A frontier Lower Cretaceous rift basin. AAPG Bulletin. 88 (5): 627-6520. 2004.
YOUNG, M.J., GAWTHROPE, R.L. & SHARP, I. R. Architecture and evolution of syn-rift clastic depositional systems towards the tip of a major fault segment, Suez Rift, Egipt. Basin Research. 14 (1): 1-23. 2002.

Ackowledgements

I sincerely express my gratitude to the anonymous referees which made a strong effort to correct the manuscript as well as the Scientific Committee of Ciência e Natura. Also. I express my acknowledgement to expert Juan Carlos Gómez who greatly help me in satellite imagery proccessing tasks. Finally, the Authorities of the National University of Northeastern (Argentina) gave me the grant 0303/94 CS - 10.08.1994 which support some works concerning with this study. An anonymous spoken englishwoman help me with redaction of the first manuscript. Thank you to all.

Figura 1. Study area location map

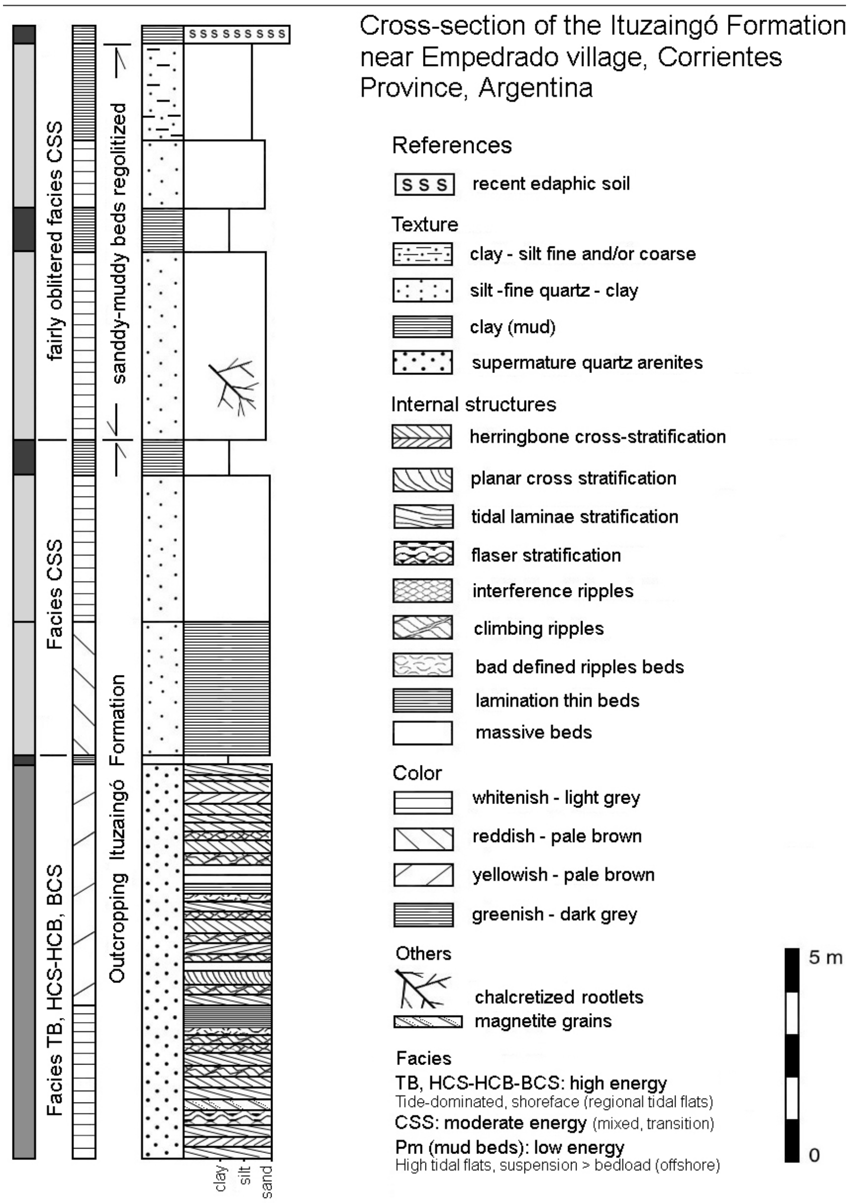

Figure 2. A typical cross-section of the Ituzaingó Formation near Empedrado village. Corrientes Province. Argentina. The profile shows a sandy-muddy succession which constitutes an heterolithic facies into the Middle to Late Miocene succession

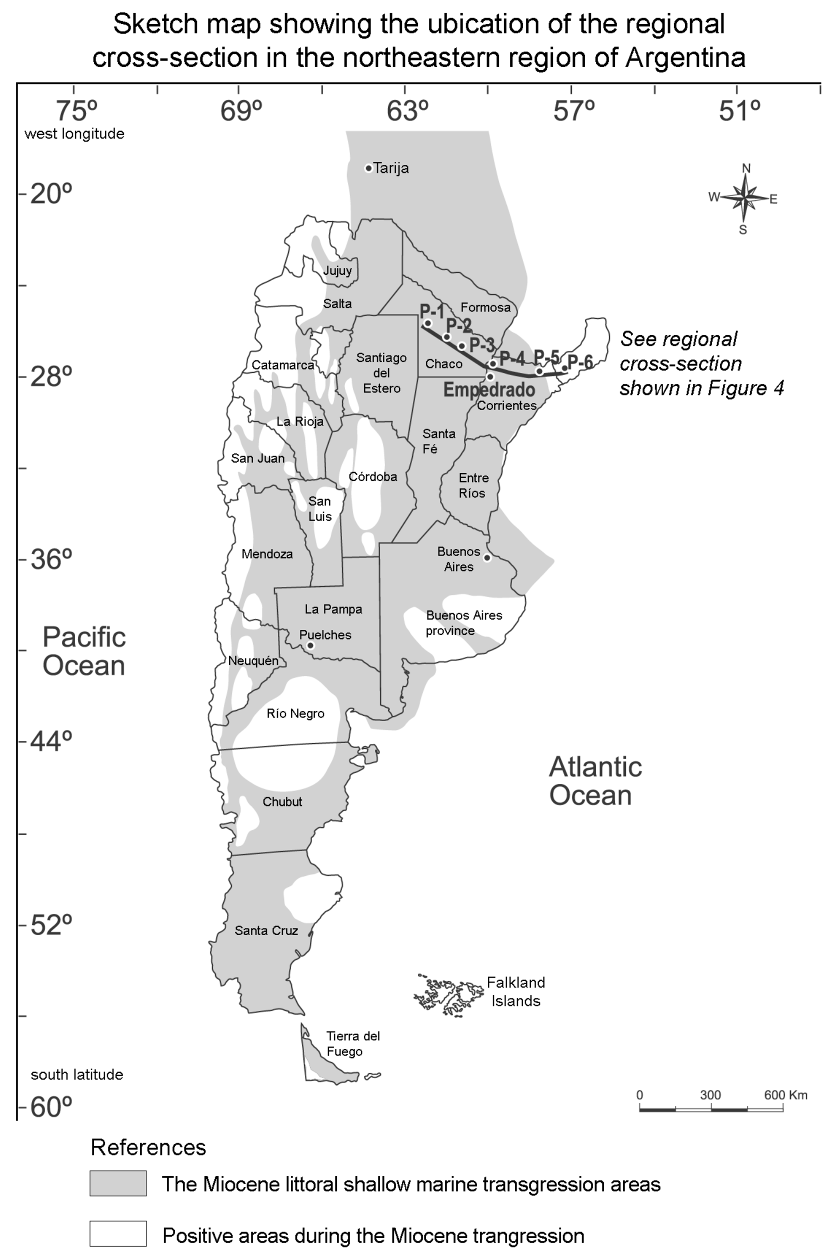

Figure 3. Sketch map that shows the ubication of the regional cross-section in the northeastern region of Argentina. Note the Puelches city location. The greyed zones correspond to the Miocene Sea transgression areas

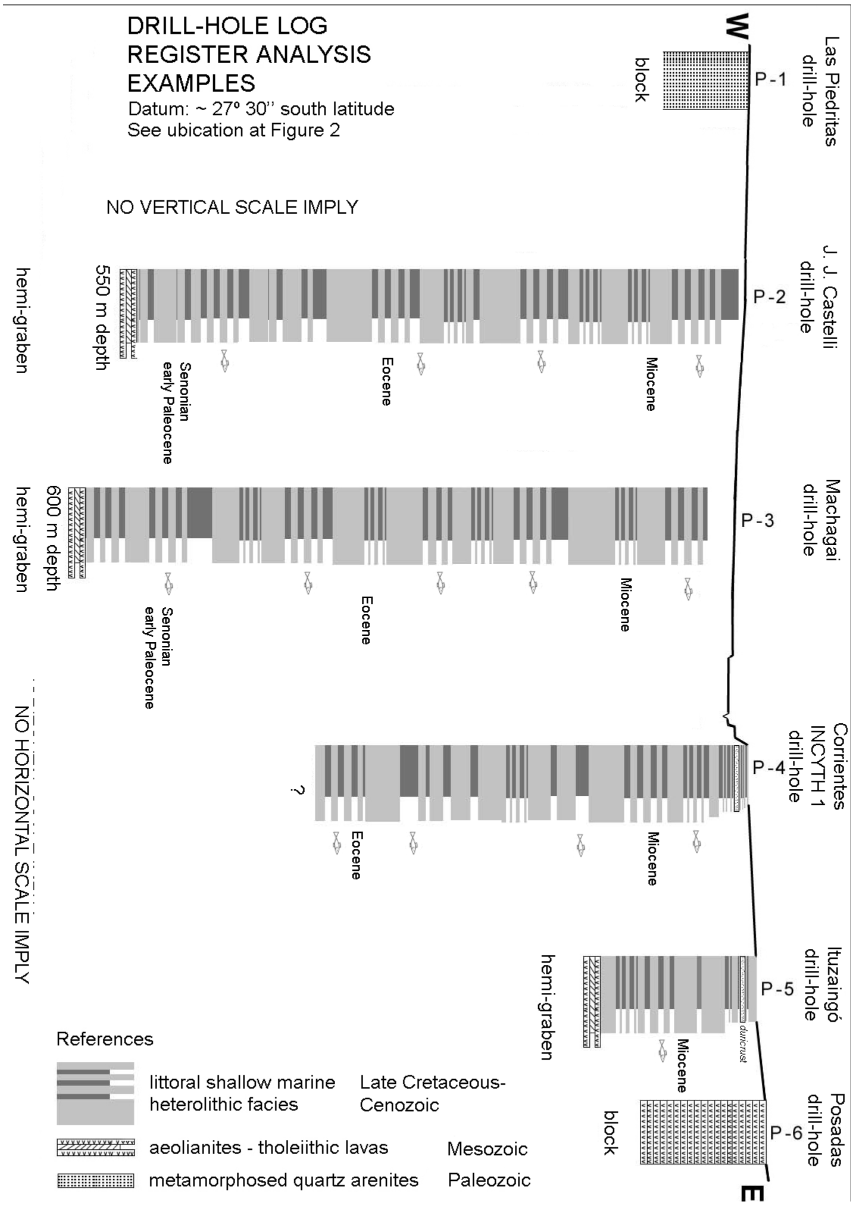

Figure 4. A sketch that shows correlation among core drill-holes registers at the regional intracratonic Chaco Paraná rift basin system

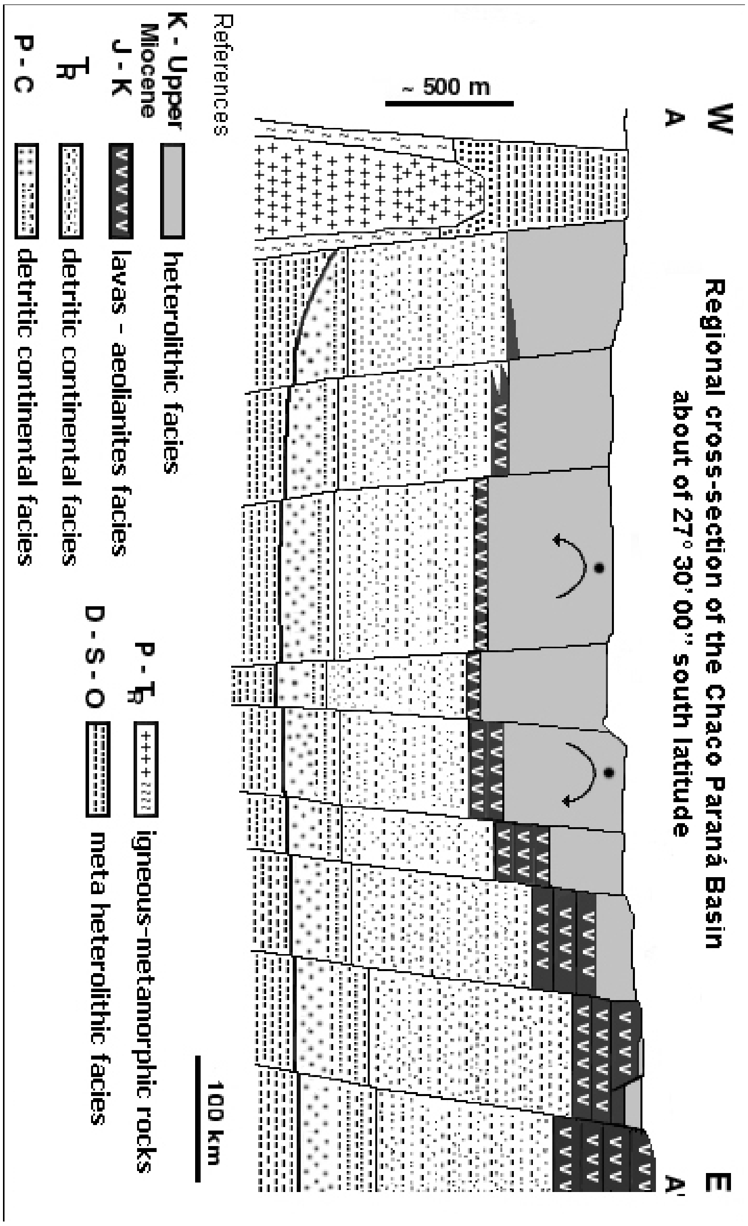

Figure 5. A regional cross-section of the Chaco Paraná rift basin system about of 27º 30' 00'' south latitude. Refer to Figure 3 for an approximate profile location

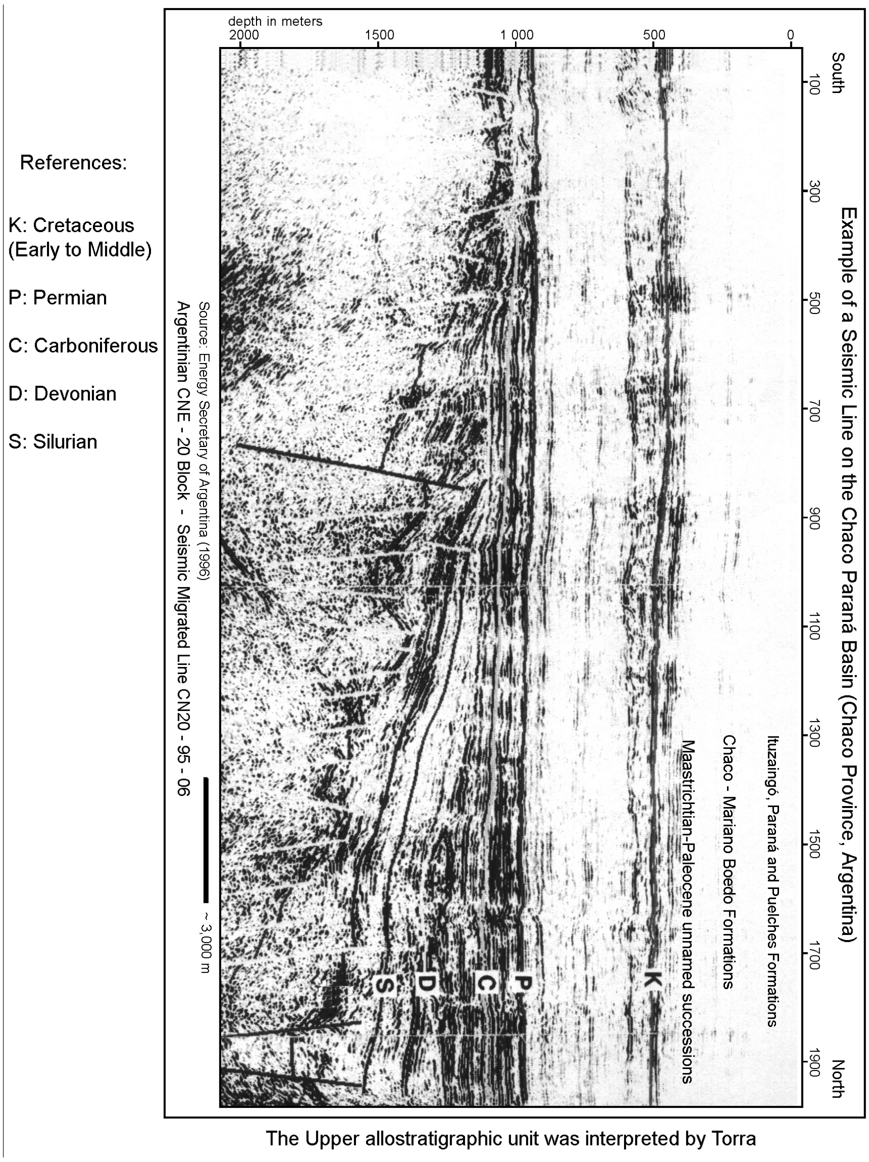

Figure 6. An example of the Seismic Line in the Chaco Paraná Basin (Chaco Province, Argentina). The geometry of the analyzed successions are horizontal as well as the tholeiithic Upper Jurassic-Early Cretaceous basaltic lavas.

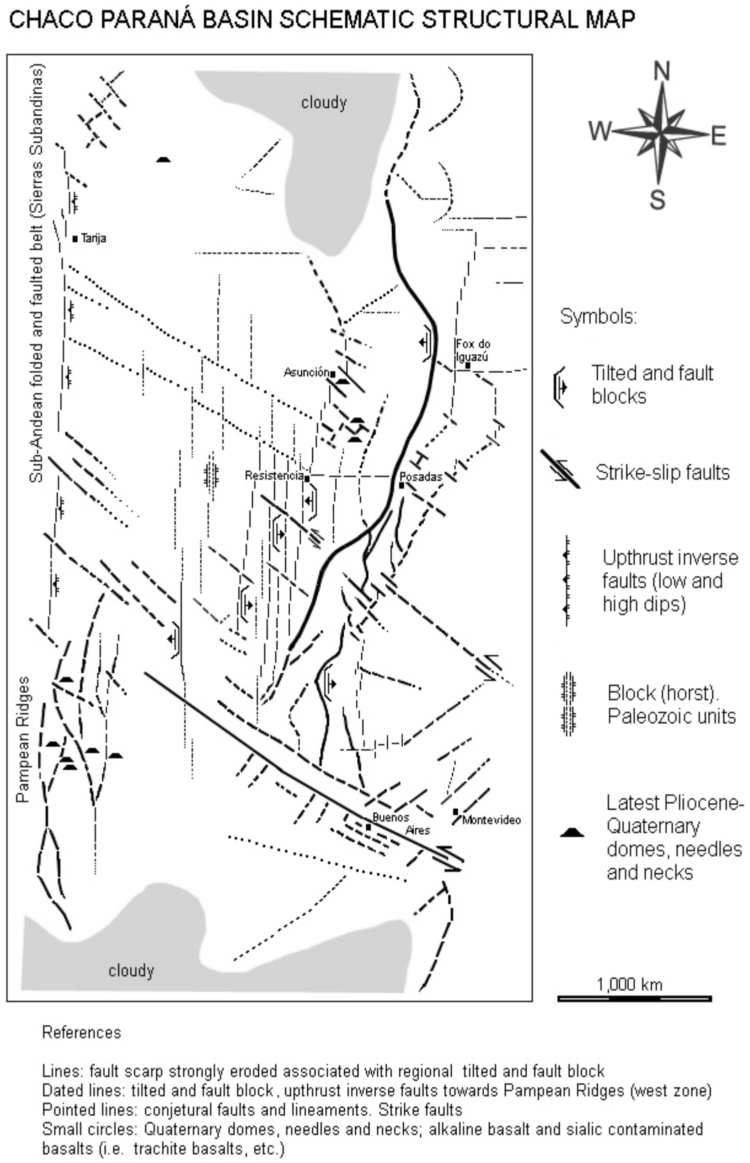

Figure 7. The regional intracratonic Chaco Paraná Basin rift system schematic approaching structural map. The map was made through field works and satellite imagery interpretations

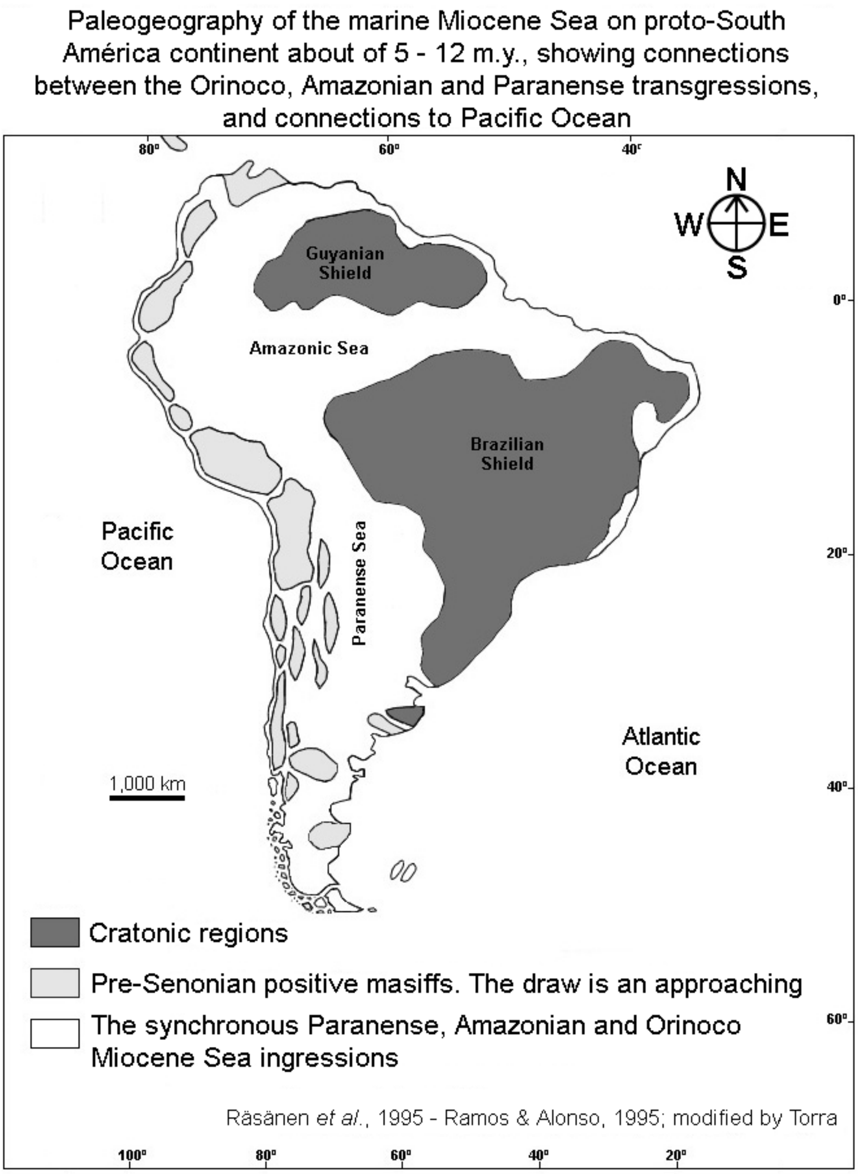

Figure 8. Paleogeographical map showing the Paranense, Amazonic and Orinoco system transgressions during the Middle to Late Miocene. This happened about of 5-14 m.y

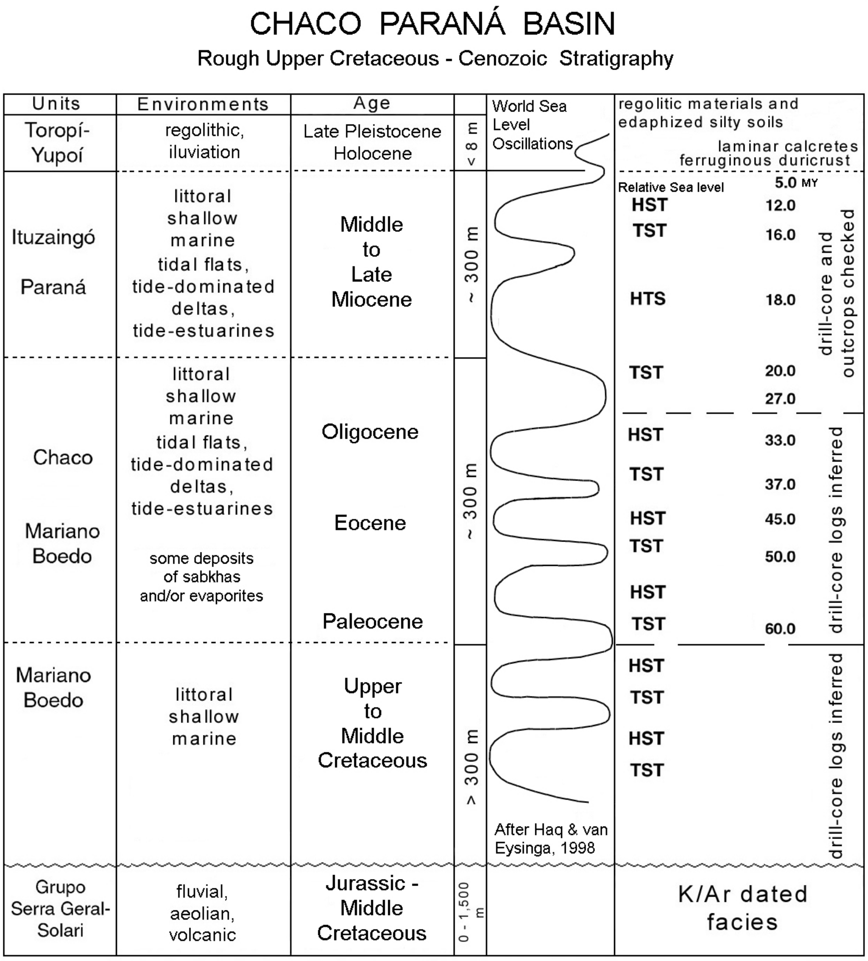

Figure 9. A sketch draw that shows rough Upper Cretaceous - Cenozoic Stratigraphy proposition related to the Chaco Paraná Basin regional rift system basin from the past 75 m.y.