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Paleoecology and environments of the Cretaceous sedimentary basins of Patagonia (southern Argentina)

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Abstract. The evolution of the continental and marine Cretaceous basins of Patagonia and adjacent areas (Chilean marine strip, basins developed around the Malvinas Islands, and the austral extremity of South America) is here considered, taking into account their origin, lithofacies, sequences, fossiliferous content, and paleoclimatic changes. An attempt to separate three stages of evolution, with transitional limits, has been made: 1) Early rift-syn-rift (Mid Jurassic-Barremian); 2) Thermal sink (sag stage), and increased continental sedimentation (Aptian-early Maastrichtian), and 3) The late Cretaceous transgression (late Maastrichtian-Paleocene). The first stage, during the late Triassic-Late Jurassic tectonism, produced extensional faults of regional extent with EW orientation, related to the opening of the southern Atlantic Ocean. Also a marginal basin (Magallanes or Austral basin) was sketched between the active magmatic arc and the stable platform with a NNW coast controlled by the Deseado Massif (Valanginian-Aptian). After the Initial Mirano events (Early Barremian) a westward regression occurs. In the San Jorge basin a progressive migration of the lacustrine depocenters to the East, and en the western and southern margins of the Magallanes basin the deposition of deeper slope and pelagic facies, related to ophiolithic magmatism occurred. Between the Initial and Middle Mirano movements (base of the Aptian) another magmatic cycle started on the western magmatic arc, throwing ashes into the San Jorge basin. Simultaneously, erosion of the faulted margins of this basin caused the progradation of fan deltas into the lacustrine sediments (Matasiete Fm.) and in NW Patagonia the sea invaded the Neuquén basin, with the deposition of deep marine anoxic shales, limestones, and submarine fans (Tithonian-Berriasian). This anoxic character is also common in the Malvinas, Magallanes and even the African basins. During the second stage, the Malvinas, North Malvinas and Magallanes basins include retrogradational and aggradational successions deposited in littoral to extensive distal platforms. In the Magallanes basin a progressive regression occurs by the rise of the Proto-Cordillera and the eustatic lowering of the sea level, while its deeper parts were filled by submarine fan deposits. The marine sedimentation continued up to the Coniacian, but coincident regressions occurs by the deforming intrusion of the Andean Batholith during the Main Mirano movements (Albian-Cenomanian). The late Turonian-Coniacian movements (85 My) define the end of this intrussive event. The Main Mirano movements separated the Neuquen basin from the Pacific Ocean and favoured the deposition of red fluvial clastics, evaporites and marine limestones of the Neuquen Group and of three fining-upwards fluvial cycles (Rio Limay, Rio Neuquen and Rio Colorado, as well (Cenomanian-early Campanian). In the San Jorge basin, the volcanic activity of the arc and subsidence processes (sag phase) allowed the deposition of thick volcaniclastic successions of the Chubut Group (Castillo, Bajo Barreal and Laguna Palacios Fms.), and the Cañadón Asfalto and Los Adobes depocenter were incorporated to the new enlarged basin. The third stage shows a widespread marine transgression related to subsidence accelerated by the Huantraquican tectonism (83 My) and due with the continued separation of the South American and African plates (Late Campanian - Late Maastrichtian-Paleocene). The sea entered into the Colorado, Valdes and Rawson basins, and partially covered the North Patagonian platform, with the deposition of lagoonal, open bays to deep marine sediments related to Allen, Jagüe, Los Alamitos, La Colonia, Huantraico, Paso del Sapo and Lefipan Fms. Later, during the Paleocene, a southward gradual regression occurs. The sea water was warm and oxygenated, allowing the development of pelagic foraminifers, diatoms and carbonate nannofossils, but the presence of a siliceous microfauna indicats an increasing influence of polar currents.

Key words. Argentina. Patagonia. Cretaceous. Sedimentary basins. Stratigraphy. Paleoevironments. Paleoecology.

Introduction

The history of the Cretaceous sedimentary basins of Patagonia is related to the initial break-up of Gondwana. Rifting began in the Triassic and continued to the Late Jurassic. Spreading and subsidence culminated in the earliest Cretaceous with the opening of the South Atlantic Ocean. The related basins, developed on the eastern side of Patagonia and on the marine platform, are represented by the Colorado and San Jorge Basins, and other smaller

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basins (Valdes, Rawson, San Julián and Argentine, Urien *et al.*, 1981; Yrigoyen, 1989a, Figueiredo *et al.*, 1996; Marinelli and Franzin, 1996; Marinelli *et al.*, 1996; Baldi and Nevistic, 1996; Ramos, 1996; Spalletti *et al.*, 1999a) (figure 1). Northeast of Patagonia, in the Buenos Aires Province, another basin was formed during de Cretaceous (Urien *et al.*, 1981; Juan *et al.*, 1996; Fryklund *et al.*, 1996). Along the permanent subduction zone of the Pacific Ocean floor under the South American Plate, Late Jurassic to Early Cretaceous ensialic marine back-arc troughs in central Chile and west-central and southern Argentina were initiated. At the same time, an active Andean volcanic arc on eroded Jurassic and granitic/metamorphic basement developed. The evolved marine and littoral successions are now exposed along the Principal Cordillera of Argentina and Chile and the Coastal Cordillera of Chile (Zambrano, 1987; Urien and Zambrano, 1996; Spalletti *et al.*, 1999a). The main marine basins, developed on the western and southwestern side of Argentina, are the Neuquén and the Austral or Magallanes Basins (Urien *et al.*, 1981; Arbe, 1989; Robbiano *et al.*, 1996; Spalletti *et al.*, 1999a). Other minor basins are located around the Malvinas Islands (Urien *et al.*, 1981; Yrigoyen, 1989b; Biddle *et al.*, 1996; Ross *et al.*, 1996; Galeazzi, 1996) (figure 1). They were subjected to successive marine cycles during the Cretaceous, but due to their tectonic instability, a great variety of other sedimentary environments such as littoral, lagoonal and fluvial, occurred during their evolution.

During the Late Jurassic-Late Cretaceous interval the continental region south of 43° LS, had a humid and temperate to warm paleoclimate. North of 43° LS the climate was warm and arid to semi-arid, with a well defined dry season. This paleoclimatic zonation persisted, with minor variations, until the Campanian. Due to the progressive expansion of the Maastrichtian sea over the adjacent flat continental areas of northern Patagonia, favourable conditions may have existed for a maritime climate with rains distributed over the whole year, resulting in a temperate to subtropical paleoclimate (Riccardi, 1988).

The early rift and syn-rift phases (Mid Jurassic-Barremian)

During the Late Triassic-Late Jurassic interval, tectonic movements produced extensional faults of regional extent with preferential EW, NW-SE or NNW-SSE orientation. These produced the San Jorge, Colorado, Malvinas, North Malvinas, East Malvinas, and other smaller basins (Valdes, Rawson, San Julián) (Urien *et al.*, 1981; Yrigoyen, 1989a; Marinelli and Franzin, 1996; Ramos, 1996; Spalletti *et al.*, 1999a). These movements represent the rift phase, and are related to the opening of the Southern Atlantic Ocean, with the formation of the Africa-South America passive margin, which was followed by the northward continental separation during the Early Cretaceous (130-120 My). This process produced also the separation of the Colorado and Rawson Basins from a deeper basin, the Argentine Basin (figure 1). The concomittant separation of Antarctica from South America and the related global eustatic sea level rise produced a large transgressive process that continued until the Hauterivian-Aptian interval. The marginal Magallanes Basin was formed in southern Patagonia and adjacent Chilean areas by expansion of the back-arc (Riccardi and Rolleri, 1980; De Giusto *et al.*, 1980; Nullo *et al.*, 1981; Arbe, 1989; Aguirre-Urreta, 1990; Urien and Zambrano, 1996). It includes mixed transgressive successions that onlap the eastern margin, with bioturbated and glauconite-bearing sandy littoral facies (lower Springhill Formation), as well as a distal platform containing black shales and bioturbated tuffs (Río Mayer Formation) (Riccardi and Rolleri, 1980; Arbe, 1989; Aguirre-Urreta, 1990). In the western and southern margins of the basin, along the insular volcanic arc, there was deposition of deeper slope (submarine fans and related debris flows and turbidites) and pelagic facies, including chert and basaltic flows (ophiolithic magmatism). This deep sedimentation was recognised in the Rocas Verdes and Yaghan Basins (Biddle *et al.*, 1986; Urien and Zambrano, 1996) (figure 1). The associated pyroclastic sediments were deposited during the intense arc volcanism related to the opening of the basin, while on the continent a hilly relief was covered by conifers and gymnosperms, and a thick vegetation of pterydophytes grew along river margins, in a humid and temperate paleoclimate.

Along the north-central Patagonian coast and the nearby platform, extensional faulting produced a series of hemigrabens with EW (Colorado, San Jorge, Valdes and Rawson Basins), or E-NE orientation (San Julián Basin). All these basins were initially filled by alluvial fans and related fluvial systems ending with the installation of shallow lake in the Late Jurassic. The rift phase ended with the opening of the Southern Atlantic Ocean during Barremian times (Urien *et al.*, 1981; Ramos, 1996). The San Jorge Basin appears as an elongated depression limited by a number of extended, but not integrated, grabens and semi-grabens. These structures were later interconnected by differential subsidence that produced the progressive enlargement of the depositional area and the inception of a lacustrine environment during the late-rift phase. A similar evolution occurred in the San Julián and North Malvinas Basins (Figueiredo *et al.*, 1996; Ross *et al.*, 1996). At the same time, north of

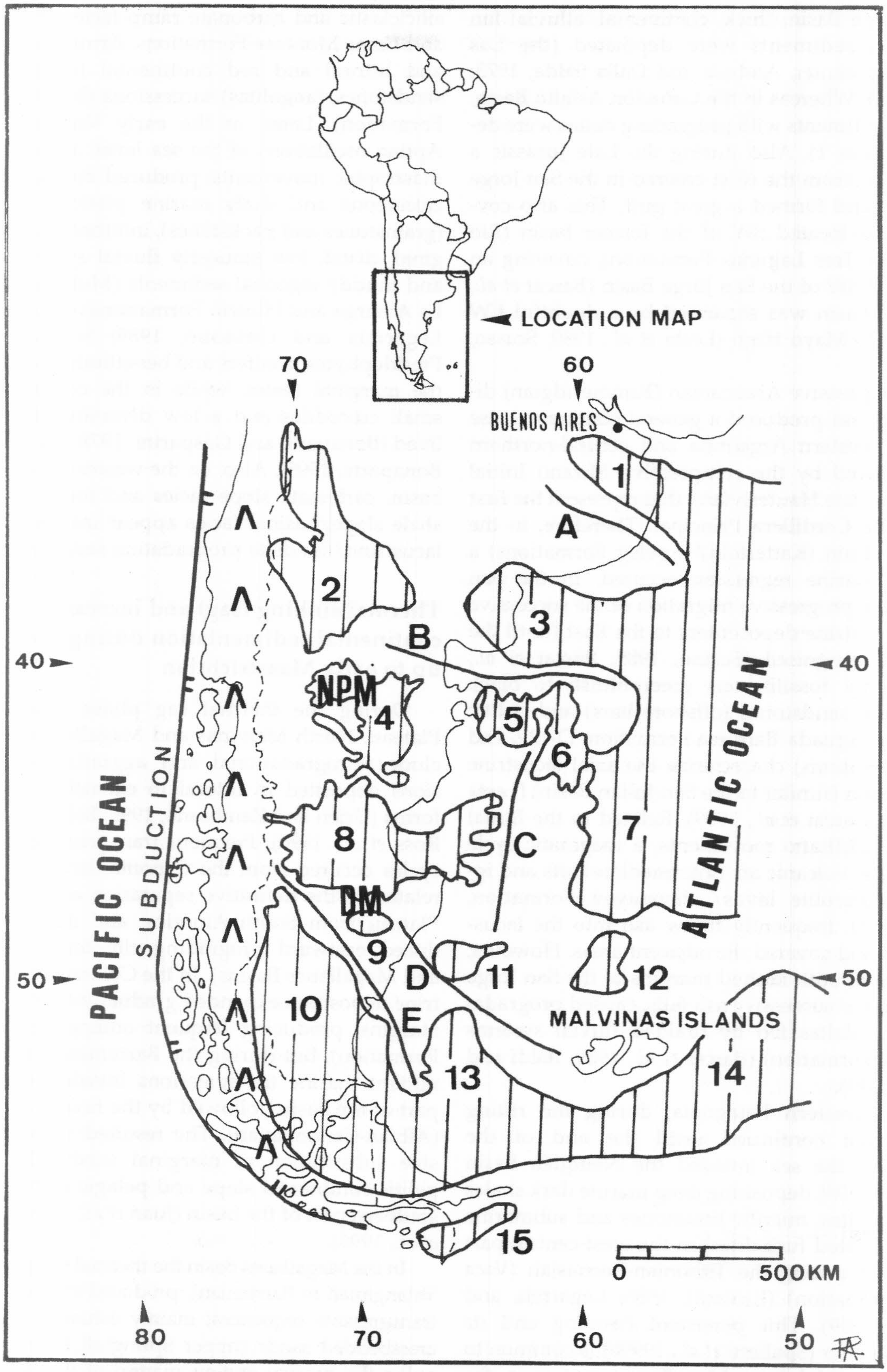

Figure 1. Cretaceous Patagonian and South Atlantic Basins. **A,** Tandil High; **B,** Río Negro High; **C,** Eastern Patagonia High; **D,** Deseado-Malvinas Arch; **E,** Río Chico-Dungeness Arch; **NPM,** North Patagonian Massif; **DM,** Deseado Massif; **1,** Salado Basin; **2,** Neuquén Basin; **3,** Colorado Basin; **4,** Cañadón Asfalto Basin; **5,** Valdes Basin; **6,** Rawson Basin; **7,** Argentina Basin; **8,** San Jorge Basin; **9,** El Tranquilo Basin; 10, Austral or Magallanes Basin; **11,** San Julián Basin; **12,** North Malvinas Basin; **13,** Malvinas Basin; **14,** East Malvinas Basin; **15,** Yaghan Basin; **A,** Magmatic Arc.

the San Jorge Basin, thick, continental, alluvial fan and fluvial sediments were deposited (the Los Adobes depocenter, Andreis and Dalla Salda, 1973; Nullo, 1983). Whereas in the Cañadón Asfalto Basin, lacustrine sediments with prograding deltas were deposited (figure 1). Also during the Late Jurassic a transgression from the west entered in the San Jorge depression and formed a great gulf. This also covered an area located SW of the former basin (Río Mayo Basin/Tres Lagunas Formation), covering an area located SW of the San Jorge Basin (Barcat *et al.*, 1989). This basin was separated by a doubtful EW high, the Río Mayo High (Lesta *et al.*, 1980; Scasso, 1989).

The compressive Araucanian (Kimmeridgian) diastrophic phase produced a general continental rise in central western Argentina and central-northern Chile, renewed by the compressive Mirano Initial movements (late Hauterivian), that represent the first uplift of the Cordillera Principal. Therefore, in the Río Mayo Basin (Katterfeld/ Apeleg Formations) a westward marine regression occured. In the San Jorge Basin a progressive migration of the successive shallow lacustrine depocenters to the East (until the Albian) is recognised (Scasso, 1989; Barcat *et al.*, 1989). Highly fossiliferous green-bluish to black shales, some sandstones (offshore bars) and oolitic limestones (Aguada Bandera Formation, D-129, and related formations) characterize the axial lacustrine sedimentation (similar to the San Julián Basin) (Lesta *et al.*, 1980; Barcat *et al.*, 1989). Related to the Initial and Middle Mirano movements, a magmatic cycle started in the volcanic arc (intermediate tuffs and ignimbrites, rhyolite lavas/ Payaniyeu Formation, Ramos, 1981), frequently threw ash into the lacustrine basin and covered the adjacent areas. However, the erosion of both faulted margins of the San Jorge Basin, allied to successive ash falls, caused progradation of fan deltas fed by braided fluvial systems (Matasiete Formation) (Barcat *et al.*, 1989; Baldi and Nevistic, 1996).

In northwestern Patagonia, during the rifting process (that continued until the end of the Neocomian), the sea invaded the Neuquén Basin from W and NW, depositing deep marine dark shales with ammonites, micritic limestones and submarine fans (and related turbidites) in the west-central part of the basin during the Tithonian-Berriasian (Vaca Muerta Formation) (Riccardi, 1988; Legarreta and Gulisano, 1989). This persistent flooding and its anoxic character (Spalletti *et al.*, 1999b) is common to other basins (Malvinas, Magallanes, and even the correlated African basins, Kress *et al.*, 1996). Due to these environmental conditions, the marine microfauna shows a general low diversity. Transgressive-regressive sequences were deposited, with marginal siliciclastic and carbonate ramp facies (Picún-Leufú and Loma Montosa Formations, Armella *et al.*, 1999), and littoral and red continental (conglomerates, sandstones, fangolitas) successions (Bajada Colorada Formation). Later, in the early Valanginian-early Aptian oscillations of the sea level, associated with diastrophic movements, produced the deposition of calcareous and shaly marine platform sediments (grainstones and packstones), interbedded with marginal, distal, low sinuosity fluvial systems, eolian, and muddy lagoonal sediments (Mulichinco, Agrio, La Amarga and Huitrín Formations) (Riccardi, 1988; Legarreta and Gulisano, 1989; Schwarz, 1999). Pteridophytes, conifers and benettitales flourished in the marginal realm, while in the continental area small crocodiles and a low diversity of dinosaurs lived (Bonaparte and Gasparini, 1978; Riccardi, 1988; Bonaparte, 1995). Also, on the western margin of the basin, carbonate slope facies and foetid limestone-shale slope/basinal facies appear interbedded with lacustrine/fan delta progradation sediments.

Thermal sinking (sag) and increased continental sedimentation during the Aptian up to early Maastrichtian

During the thermal sag phase, the Malvinas Plateau, North Malvinas and Magallanes Basins include retrogradational and aggradational successions deposited in littoral to extensive distal platforms (Urien and Zambrano, 1996; Biddle *et al.*, 1996; Ross *et al.*, 1996). Frequent transgressive-regressive cycles occured from the Cenomanian to Santonian, related to the definitive separation of the Malvinas Plateau from South America, and may have produced eastward prograding clinoforms (Malvinas and Magallanes Basins). In the Colorado Basin lacustrine deposition expanded gradually over both basin margins, producing frequent onlapping (Colorado Formation), but during the Barremian-Albian intermittent marine transgressions invaded the eastern part of the basin, followed by the final transgression (Albian-Cenomanian). The resulted in the progressive substitution of marginal sandy deposits by pelitic continental slope and pelagic deposits in the southern part of the basin (Juan *et al.*, 1996; Fryklund *et al.*, 1996).

In the Magallanes Basin the thermal sag phase (early Valanginian to Barremian), produced the deposition of transgressive sequences, mainly estuarine glauconitic crossbedded sands (upper Springhill Formation) that onlap the passive eastern margin of the basin (Arbe, 1989). Probably, at this time, the Magallanes and San Jorge Basins were connected along the Chilean part of the Cordillera. A rapid regression occurred in both margins of the basin during the Barremian (Arbe, 1989), due to the Initial Mirano movements (115 My). This was caused by the rise of the Proto-Cordillera and eustatic lowering of the sea level. Eastward or westward flowing fluvial systems, prograding deltas, and littoral sediments produced the continentalization of the marine basin (Río Belgrano and Piedra Clavada Formations). However, during the early Aptian, due to the Middle Mirano movements (110 My), the first foreland deep marine basin was created by a deep sea "entering" from the Paleo-Pacific Ocean (Arbe, 1989; Spalletti *et al.*, 1999a). This basin was filled with submarine fan turbidites and debris flows, while in the NW area limestones, tuffs and marginal fan-deltas grading to platform and continental sediments, were deposited (Río Tarde, Kachaike, and Cardiel Formations). Later, several transgressive-regressive events characterise the late Albian-early Maastrichtian sedimentation with repeated deposition of platform to slope deposits, and associated fluvial, deltaic and littoral facies (Mata Amarilla, Pari-Aike, El Alamo, and related formations). Despite the constant oscillations of the sea level, the marine sedimentation was not interrupted, but coincident regressions were recognised in relation to the deforming intrusion of the Andean Batholith during the Main Mirano diastrophic phase (Albian-Cenomanian, 95 My). Previously, the Andean volcanic arc developed entirely as a positive volcanic land separating southern South America from the Pacific Ocean (Spalletti *et al.*, 1999a). The intense volcanic activity was represented by andesitic, dacitic and basaltic lava flows, ignimbrites and tuffs (Coyhaique and La Cautiva Formations), followed by basaltic flows and related fluvial deposits containing trunks, stems and leaves (Cerro Tres Picos Prieto Formation) (Franchi and Page, 1980; Barcat *et al.*, 1989).

In the Neuquén Basin (Legarreta and Gulisano, 1989), the Aptian-Albian marine regressive phase allowed the establishment of an extended and restricted marginal alluvial plain characterised by fluvial-eolian deposits interbedded with evaporitic facies (anhydrite-halite). These deposits were followed by evaporites and stromatolites, and marine carbonates, of the Rayoso Group and Colimapu Formation (in Chile), characterising hypersaline conditions. The intersenonian movements (Mirano Main phase) inverted the regional dip, thus definitively separating the basin from the Pacific area. This positive character was maintained up to the Latest Cretaceous (Maastrichtian), and the red clastics of the Neuquén Group were deposited in the Cenomanian-early Campanian. This Group includes three fining-upwards cycles fluvial named Río Limay, Río Neuquén, Río Colorado Formations (Legarreta and Gulisano, 1989). These units may contain charophytes, ostracods, opalised trunks and large sauropod remains (Riccardi, 1988; Bonaparte, 1995). Most vertebrates (dinosaurs) are similar to those found farther south in the Chubut Group (Bonaparte and Gasparini, 1978; Bonaparte, 1995). In the western side of the basin (Chile), where the Coya Machali and Las Chilcas Formation were deposited, marine deposits (Turonian-Coniacian interval) are still included.

In western Patagonia, the Río Mayo Basin was definitively closed (Spalletti *et al.*, 1999a). However, in the San Jorge Basin, the intermittent volcanic activity of the volcanic arc during the Late Cretaceous and subsidence processes related to sag tectonism, caused the deposition of the thick volcanoclastic successions of the Chubut Group (Castillo, Bajo Barreal and Laguna Palacios Formations; Chebli *et al.*, 1976; Lesta *et al.*, 1980; Riccardi, 1988; Barcat *et al.*, 1989). Also, the Cañadón Asfalto and the Los Adobes depocenters were incorporated to the new enlarged basin (Upper Los Adobes and Cerro Barcino Formations; Musacchio, 1995, Manassero *et al.*, 1998). Similar tuffs and tuffaceous sediments were also recognized south of the San Jorge Basin in the El Tranquilo Basin (figure 1), and are represented by the late Barremian-early Albian Baqueró Group, that includes abundant gymnosperms (Benettitales, Conifers, Cycads), fewer ferns, and palynomorphs (Archangelsky, 1967; Baldoni, 1981; Caranza, 1988).

The rapid fill of the ancient lacustrine environment (Mina del Carmen, El Trebol and related formations) by several cycles of prograding fan deltas fed by fluvial systems and related turbiditic lobes, continued, but once again became a large and isolated continental depocenter. These successions are composed of primary massive tuffs and reworked volcaniclastics (Sciutto, 1981; Meconi, 1989). The coarse cross-bedded channel sediments may contain fragments of silicified tree trunks and dinosaur bones (sauropods), whereas shallow lakes with brackish water, marginal swamps and poorly developed paleosols are associated with the extended alluvial plains. Tuffaceous sediments are, to a large extent, replaced by zeolites (analcime, heulandite-clinoptilolite) caused by phreatic activity on extended plains or the presence of shallow alkaline ponds or lakes. This suggests a semi-arid climate with seasonal variations (Teruggi and Rossetto, 1963; Meconi, 1989). The development of paleosols is increased in the Laguna Palacios Formation, which includes axial roots, prismatic structures, plants smashed by ash fall, nests of insects, phytoliths (that suggest colonization by herbaceous vegetation) and the pollen of angiosperms (Sciutto, 1981; Sciutto and Martínez, 1996; González, 1999).

The Late Cretaceous transgression (Maastrichtian-Paleocene)

From the late Campanian up to the late Maastrichtian-Paleocene a persistent and widespread marine transgression related to subsidence (late sag stage, Spalletti *et al.*, 1999a), and accelerated by tectonism (Huantraiquican movements, 83 My), partially covered the North-Patagonian Platform. The Senonian continental successions, the Jurassic volcanic/volcaniclastic substrate (Marifil Formation), and also the early Maastrichtian brackish basins were replaced by marine deposits. This transgressive was contemporaneous with the continued separation of the South American and African Plates. The sea entered from the Atlantic Ocean along the Colorado Basin (and the Salado Basin as well), and probably connected the Atlantic with the Pacific Basins, creating new oceanic areas in which the appearance of new current systems had a great influence on the dispersion of the marine faunas (Riccardi, 1988). In the Colorado, Salado, Valdes and Rawson Basins shallow marine facies were deposited (Tavella and Wright, 1996; Fryklund *et al.*, 1996; Marinelli and Franzin, 1996). This extensive transgression is represented around the North Patagonian Massif and the NW part of Patagonia (Neuquén Basin) by lagoonal (sometimes restricted), open bays to deep marine sediments. This includes the Allen and Jagüe Formations (Malargüe Group; Legarreta and Gulisano, 1989) and the Los Alamitos, El Cain, La Colonia and related units, as well (Lesta *et al.*, 1980). In some units (Coli-Toro, Los Alamitos and Allen Formations), the sandy sediments contain trunks, mammal teeth, and reptile remains. Some bentonites may also occur (Allen Formation; Andreis *et al.*, 1974; Vallés, 1987; Impiccini, 1999). Some shallow marine units have been reported in the Cañadón Asfalto Basin, where pelites containing a rich Maastrichtian fauna (*Eubaculites*, oysters, calcareous nannofossils, ostracods) were deposited (Huantraico, Paso del Sapo and Lefipan Formations; Lesta *et al.*, 1980; Barcat *et al.*, 1989). The related marginal deposits are also characterised by sandy fluvial-deltaic successions and/or pelitic and pyroclastic sediments that contain palms, cycads, conifers, and angiosperms. Elsewhere, the shallow marine sediments contain plant fragments, turtle, snake, and crocodilian remains, fish teeth, freshwater mollusks, and microfossils, whereas the sandy channel river and littoral facies may contain hadrosaur and sauropod remains, mammal teeth, and sauropod eggs and eggshells (Allen and Los Alamitos Formations; Bonaparte, 1995; Magalhães-Ribeiro, 1997). Hadrosaurs colonised the extensive littoral ecosystems (central Patagonia) where ferns and some arborescent plants grew on poorly developed soils, while the titanosaurid sauropod communities lived on higher grounds nearby, where a number of nests have been found (Allen Formation; Bonaparte, 1995). The gradual southwards regression during the Paleocene, locally covered locally the Loncoche and Jagüel Formations with glauconitic (Salamanca Formation) or calcareous sandstones (Roca Formation).

During the early Maastrichtian-Paleocene, the Magallanes Basin shows a general regressive phase, the deepest area of the basin located in southern continental Argentina (Riccardi, 1988; Robbiano *et al.*, 1996). Glauconitic sandstones, shaly sediments and micritic mounds were deposited, and only on its northwestern margin a progradational molassic succession (deltaic?) was formed (Calafate and La Leona Subcycles of the Lago Argentino Depositional Cycle; Arbe, 1989). In the Malvinas Basin, the Late Cretaceous transgressive interval is represented by distal neritic to batial shaly sediments and related slope turbidites (Galeazzi, 1996; Biddle *et al.*, 1996). The sea water was warm and oxygenated, as shown by the presence of pelagic foraminifera, diatomites and calcareous nannofossils (Galeazzi, 1996), but the presence of a siliceous microfauna near the top of the sequence (??) indicates a progressive cooling of the sea waters, probably related to the increasing influence of polar currents.

References

Aguirre-Urreta, M.B. 1990. Paleogeography and biostratigraphy of the Austral Basin in Argentina and Chile: An appeal for sound systematics. *Episodes* 13: 247-255.

Andreis, R.R. and Dalla Salda, L.H. 1973. Paleocorrientes en el Cretácico Inferior de las manifestaciones uraníferas Pichiñan and Los Adobes (Sierra Pichiñanes, provincia de Chubut). *Revista de la Asociación Argentina de Mineralogía, Petrología y Sedimentología* 4: 33-48.

Andreis, R.R., Iñiguez Rodríguez, A.M., Lluch, J.J. and Sabio, D.A. 1974. Estudio sedimentológico de las formaciones del Cretácico Superior del area del Lago Pellegrini (provincia de Río Negro, República Argentina). *Revista de la Asociación Geológica Argentina* 29: 85-104.

Arbe, H.A. 1989. Estratigrafía, discontinuidades y evolución sedimentaria del Cretácico en la Cuenca Austral, provincia de Santa Cruz. In: G. Chebli and L. Spalletti (eds.), *Cuencas Sedimentarias Argentinas*; Universidad Nacional de Tucumán, Instituto Superior de Correlación Geológica, Serie Correlación Geológica 6: 419-442.

Archangelsky, S. 1967. Estudio de la Formación Baqueró, Cretácico Inferior de Santa Cruz, Argentina. *Revista del Museo de La Plata (Nueva Serie)*, 5, *Paleontología* 32: 63-171.

Armella, C., Cabaleri, N.G. and Leanza, H.A. 1999. Paleoambientes de la Formación Picún Leufú (límite Jurásico/Cretácico) en su localidad tipo, Cuenca Neuquina, Argentina. *5° Simpósio sobre o Cretáceo do Brasil y 1° Simpósio sobre el Cretácico de América del Sur (Serra* Negra, SP, Brasil), *Boletim*: 357-358.

Baldi, J.E. and Nevistic, V.A. 1996. Cuenca Costa Afuera del Golfo de San Jorge. In: V.A. Ramos and M.A.Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 10:171-192.

Baldoni, A. 1981. Tafofloras jurásicas y eocretácicas de América del Sur. In: W. Volkheimer and E.A. Musacchio (eds.), *Cuencas Sedimentarias del Jurásico y Cretácico de América del Sur* 2: 359-391.

Barcat, C., Cortiñas, J.C., Nevistic, V.A. and Zucchi, H.E. 1989. Cuenca Golfo San Jorge. In: G. Chebli and L. Spalletti (eds.), *Cuencas Sedimentarias Argentinas*; Universidad Nacional de Tucumán, Instituto Superior de Correlación Geológica, Serie Correlación Geológica 6: 319-345.

Biddle, K.T., Snavely III, P.D. and Uliana, M.A. 1996. Plateau de las Malvinas. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 13: 225-252.

Bonaparte, J.F. 1995. *Dinosaurios de América del Sur*. Museo Argentino de Ciencias Naturales "B. Rivadavia", Buenos Aires, 174 pp.

Bonaparte, J.F. and Gasparini, Z. de 1978. Los saurópodos de los Grupos Neuquén y Chubut y sus relaciones cronológicas. *7° Congreso Geológico Argentino* (Neuquén), *Actas* 2: 393-406.

Caranza, H.F. 1988. [*Estudio estratigráfico y paleoambiental de la Formación Baqueró (Cretácico Inferior), en el sector norte del Anfiteatro de Ticó, Depto. Magallanes, provincia de Santa Cruz.* Trabajo Final de Licenciatura, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Buenos Aires, Argentina, 74 pp. Unnpublished].

Chebli, G.A., Nakayama, C., Sciutto, J.C. and Serraiotto, A.A. 1976. Estratigrafía del Grupo Chubut en la región central de la provincia homónima. *6° Congreso Geológico Argentino* (Bahía Blanca 1975), *Actas* 1: 375-392.

De Giusto, J.M., Di Persia, C.A. and Pezzi, E. 1980. Nesocretón del Deseado. In: J.C.M. Turner (ed.), *Geología Regional Argentina* 2: 1389-1430, Academia Nacional de Ciencias, Córdoba.

Figueiredo, A.M.F., Miranda, A.P., Ferreira, R.F. and Zalan, P.V. 1996. Cuenca de San Julián. In: V.A. Ramos and M.A. Turic (eds.), Relatorio *13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 11: 193- 212.

Franchi, M.R. and Page, R.F.N. 1980. Los basaltos cretácicos y la evolución magmática del Chubut occidental. *Revista de la Asociación Geológica Argentina* 35: 208-229.

Fryklund, B., Marshall, A. and Stevens, J. 1996. Cuenca del Colorado. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 8: 135-158.

Galeazzi, J.S. 1996. Cuenca de Malvinas. In: V.A. Ramos and M.A. Turic (eds.), Relatorio *13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 15: 273-310.

González, M.G. 1999. Los paleosuelos de la Formación Laguna Palacios (Cretácico Superior) de Patagonia y la Formación Asencio (Cretácico Superior-Terciario inferior) de Uruguay. *5° Simpósio sobre o Cretáceo do Brasil y 1° Simpósio sobre el Cretácico de América del Sur* (Serra Negra, SP, Brasil), *Boletim*: 65-70.

Impiccini, A. 1999. Correlación entre capas de bentonita de edad Cretácico Superior y su vinculación con las áreas volcánicas de origen, en el norte de la Patagonia, Argentina. *5° Simpósio sobre o Cretáceo do Brasil y 1° Simpósio sobre el Cretácico de América del Sur* (Serra Negra, SP, Brasil), *Boletim*: 225-230.

Juan, R.C., Jager, J. de, Rusell, J. and Gebhard, I. 1996. Flanco norte de la Cuenca del Colorado. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 7: 117-134.

Kress, P.R., Franzin, H.J. and Marinelli, R.V. 1996. Cuenca de Malvinas Oriental. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 16: 311-321.

Legarreta, L. and Gulisano, C.A. 1989. Análisis estratigráfico secuencial de la Cuenca Neuquina (Triásico Superior-Terciario inferior). In: G. Chebli and L. Spalletti (eds.), *Cuencas Sedimentarias Argentinas*; Universidad Nacional de Tucumán, Instituto Superior de Correlación Geológica, Serie Correlación Geológica 6: 221-243.

Lesta, P., Ferello, R. and Chebli, G. 1980. Chubut extraandino. In: J.C.M. Turner (ed.), *Geología Regional Argentina* 2: 601-654, Academia Nacional de Ciencias, Córdoba.

Magalhães-Ribeiro, C.M. 1997. [*Descrição de caracteres morfológicos e estudo composicional de cascas de ovos de dinossauros da Formação Allen (Cretáceo Superior), do Bajo de Santa Rosa, provincia de Río Negro (Argentina).* Dissertação de Mestrado, Instituto de Geociências, Universidade Federal de Río de Janeiro, Brasil, 222 pp. Unnpublished].

Manassero, M., Zalba, P.E., Andreis, R.R. and Morosi, M. 1998. Ambientes volcanoclásticos de la Formación Cerro Barcino (Grupo Chubut, Cretácico Superior), entre Los Altares y Las Plumas, Chubut, Argentina. *7° Reunión Argentina de Sedimentología* (Salta), *Actas*: 268-279.

Marinelli, R.V. and Franzin, H.J. 1996. Cuencas de Rawson y Península Valdés. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 9: 159-170.

Marinelli, R.V., Rebay, G.A. and Franzin, H.J. 1996. Cuencas del Talud Continental. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 18: 343-358.

Meconi, G.R. 1989. [*Estratigrafía y paleoambientes del Grupo Chubut en el Codo del Río Senguerr (provincia de Chubut).* Trabajo Final de Licenciatura, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Buenos Aires, Argentina, 91 pp. Unnpublished].

Musacchio, E.A. 1995. Estratigrafía y micropaleontología del Jurásico y el Cretácico en la comarca del valle medio del río Chubut, Argentina. *6° Congreso Argentino de Paleontología y Bioestratigrafía* (Trelew, 1994), *Actas*: 179-187.

Nullo, F. 1983. Descripción geológica de la Hoja 45c, Pampa de Agnia, provincia del Chubut. *Servicio Geológico Nacional, Boletín* 158, 78 p. Buenos Aires.

Nullo, F., Proserpio, C. and Nullo, G.B. 1981. Estratigrafía del Cretácico Superior en el Cerro Indice y alrededores, provincia de Santa Cruz. *8° Congreso Geológico Argentino* (San Luis), *Actas* 3: 373-387.

Ramos, V.A. 1981. Descripción geológica de la Hoja 47a-b, Lago Fontana, provincia del Chubut. *Servicio Geológico Nacional, Boletín* 183, 80 p. Buenos Aires.

Ramos, V.A. 1996. Evolución tectónica de la Plataforma Continental. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 21: 385-404.

Riccardi, A.C. 1988. The Cretaceous System of Southern South America. *Geological Society of America, Memoir* 168, 161 p.

Riccardi, A.C. and Rolleri, E.O. 1980. Cordillera Patagónica Austral. In: J.C.M. Turner (ed.), *Geología Regional Argentina* 2: 1173-1306, Academia Nacional de Ciencias, Córdoba.

Robbiano, J.A., Arbe, H. and Gangui, A. 1996. Cuenca Austral Marina. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 17: 323-342.

Ross, J.G., Pinchin, J., Griffin, D.G., Dinkelman, M.G., Turic, M.A. and Nevistic, V.A. 1996. Cuenca de Malvinas. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 14: 253-272.

Scasso, R.A. 1989. La cuenca sedimentaria del Jurásico Superior y

Cretácico Inferior de la región sudoccidental del Chubut. In: G. Chebli and L. Spalletti (eds.), *Cuencas Sedimentarias Argentinas*; Universidad Nacional de Tucumán, Instituto Superior de Correlación Geológica, Serie Correlación Geológica 6: 395-418.

Sciutto, J.C. 1981. Geología del Codo del río Senguerr, Chubut, Argentina. *8° Congreso Geológico Argentino* (San Luis), *Actas* 3: 203-219.

Sciutto, J.C. and Martínez, R. 1996. El Grupo Chubut en el anticlinal Sierra Nevada, Chubut, Argentina. *13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Actas*: 65-75.

Schwarz, E. 1999. Modelo deposicional de una plataforma mixta silicoclástica-carbonática afectada por olas y mareas. Un ejemplo del Valanginiano del norte de la provincia de Neuquén, Cuenca Neuquina, Argentina. *5° Simpósio sobre o Cretáceo do Brasil y 1° Simpósio sobre el Cretácico de América del Sur* (Serra Negra, SP, Brasil), *Boletim*: 175-180.

Spalletti, L., Franzese, J.R., MacDonald, D. and Pérez, I.G. 1999a. Paleogeographic evolution of southern South America during the Cretaceous. *5° Simpósio sobre o Cretáceo do Brasil y 1° Simpósio sobre el Cretácico de América del Sur* (Serra Negra, SP, Brasil), *Boletim*: 87-95.

Spalletti, L., Veiga, G., Gasparini, Z., Schwarz, E., Fernández, M. and Matheos, S. 1999b. La rampa marina de la transición Jurásico-Cretácico en la Cuenca Neuquina (Argentina): facies anóxicas, procesos deposicionales y herpetofauna. *5° Simpósio sobre o Cretáceo do Brasil y 1° Simpósio sobre el Cretácico de América del Sur* (Serra Negra, SP, Brasil), *Boletim*: 345-348.

Tavella, G.F. and Wright, C.G. 1996. Cuenca del Salado. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Mendoza), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 6: 95-116.

Teruggi, M.E. and Rossetto, A. 1963. Petrología del Chubutiano del Codo del río Senguerr. *Boletín de Informaciones Petroleras (YPF)* 354: 18-35. Buenos Aires.

Urien, C.M. and Zambrano, J.J. 1996. Estructura de la Plataforma Continental. In: V.A. Ramos and M.A. Turic (eds.), *Relatorio 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (Buenos Aires), *Geología y Recursos Naturales de la Plataforma Continental Argentina* 3: 29-66.

Urien, C.M., Zambrano, J.J. and Martins, L.R. 1981. The basins of southeastern South America (Southern Brazil, Uruguay and Eastern Argentina), including south Atlantic paleogeographic evolution. In: W. Volkheimer and E.A. Musacchio (eds.), *Cuencas Sedimentarias del Jurásico y Cretácico de América del Sur* 1: 45-125.

Vallés, J.M. 1987. Posición estratigráfica y distribución de los horizontes de bentonita en Río Negro, Neuquén y La Pampa. *10° Congreso Geológico Argentino* (Tucumán), *Actas* 2: 33.

Yrigoyen, M.R. 1989a. Cuencas de Rawson y Peninsula Valdes. In: G. Chebli and L. Spalletti (eds.), *Cuencas Sedimentarias Argentinas*; Universidad Nacional de Tucumán, Instituto Superior de Correlación Geológica, Serie Correlación Geológica 6: 467-476.

Yrigoyen, M.R. 1989b. Cuenca de Malvinas. In: G. Chebli and L. Spalletti (eds.), *Cuencas Sedimentarias Argentinas;* Universidad Nacional de Tucumán, Instituto Superior de Correlación Geológica, Serie Correlación Geológica 6: 481-492.

Zambrano, J.J. 1987. Las cuencas sedimentarias de América del Sur durante el Jurásico y Cretácico. Su relación con la actividad tectónica y magmática. In: W. Volkheimer (ed.), *Bioestratigrafía de los sistemas regionales del Jurásico y Cretácico de América del Sur Buenos Aires*, 1: 1-48.

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