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Marine Upper Jurassic-Lower Cretaceous stratigraphy and biostratigraphy of the Aconcagua-Neuquén Basin, Argentina and Chile

Estratigrafía y bioestratigrafía del Jurásico Superior-Cretácico Inferior marino de la Cuenca Neuquina-Aconcagüina, Argentina y Chile

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ABSTRACT

This review provides updated information on the stratigraphy and ammonoid biostratigraphy of the marine Upper Jurassic-Lower Cretaceous of the Aconcagua-Neuquén Basin of Argentina and Chile. The ammonoid faunal affinities and the level of confidence in correlation with the Mediterranean standard zones are also discussed here.

Keywords: Upper Jurassic, Lower Cretaceous, Aconcagua-Neuquén Basin, stratigraphy, biostratigraphy, Argentina, Chile.

RESUMEN

Esta revisión presenta información actualizada sobre la estratigrafía y la bioestratigrafía de amonoideos del Jurásico Superior-Cretácico Inferior marino de la Cuenca Aconcagüina-Neuquina de Argentina y Chile. También se discuten las afinidades de las faunas de amonoideos y el nivel de fiabilidad en su correlación con las zonas estándar del Mediterráneo.

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Palabras clave: Jurásico Superior, Cretácico Inferior, Cuenca Aconcagüina-Neuquina, estratigrafía, bioestratigrafía, Argentina, Chile.

INTRODUCTION

The Aconcagua-Neuquén Basin of Argentina and Chile is worldwide famous for its nearly continuous marine sedimentary record from the early Jurassic to the early Cretaceous, lately extending down to include late Triassic marine rocks, and the quality of the fossil record, and probably represents the most complete Mesozoic basin of the Southern Hemisphere. The outcrops form a narrow belt along the Andes in the north, covering part of the Chilean and Argentine Cordillera, and extending eastward in the south to form the Neuquén Embayment (Fig. 1). The invertebrate macrofaunas of the Jurassic-Cretaceous marine successions are mollusc-dominated. The Jurassic biostratigraphy is well defined, based on ammonites, and to a lesser extent on bivalves, brachiopods and microfossils (Riccardi *et al*., 1990 a-c, 2000), but the Lower Cretaceous biostratigraphy was much less refined until recently (Leanza, 1981; Riccardi, 1984). However, new research on the ammonites has established a detailed biostratigraphy for most of the marine Lower Cretaceous (Aguirre-Urreta and Rawson, 1997; Aguirre-Urreta *et al*., 1999).

Classic monographs with illustrations of late Jurassic-early Cretaceous ammonites include Beherendsen (1891-92), Gerth (1925), Krantz (1928), Weaver (1931) and Leanza (1945). In recent years revisions and new findings of these ammonite faunas are from Riccardi *et al.* (1971), Leanza (1980), Leanza and Wiedmann (1980, 1989, 1992), Aguirre-Urreta (1995, 1998), and Aguirre-Urreta and Rawson (1993, 1995, 1996, 1998, 1999a-c) among others.

The objectives of this paper are threefold: 1) to summarize the stratigraphy of the late Jurassic-early Cretaceous successions and, 2) to integrate the current ammonite biostratigraphy in order to 3) correlate the local successions with the Mediterranean standard.

REGIONAL GEOLOGICAL SETTING

The Mesozoic Andean Basin of central Argentina and Chile extends from 31° to 39°S latitude and encompasses two major depocenters, the Aconcagua in the north and the Neuquén Embayment in the south (Fig. 1).

The Aconcagua area has a complex history with diverse marine and continental facies mainly controlled by the variable tectonic setting through late Jurassic to early Cretaceous times (Mpodozis and Ramos, 1990). The carbonate Neocomian deposits are interfingered with volcanic and pyroclastic rocks, either to the west or to the east, outlining a series of intraarc basins as defined by Nasi and Thiele (1982) and Charrier (1984), as well as retroarc and forearc basins (Malumián *et al*., 1983). The geological setting of the region has been

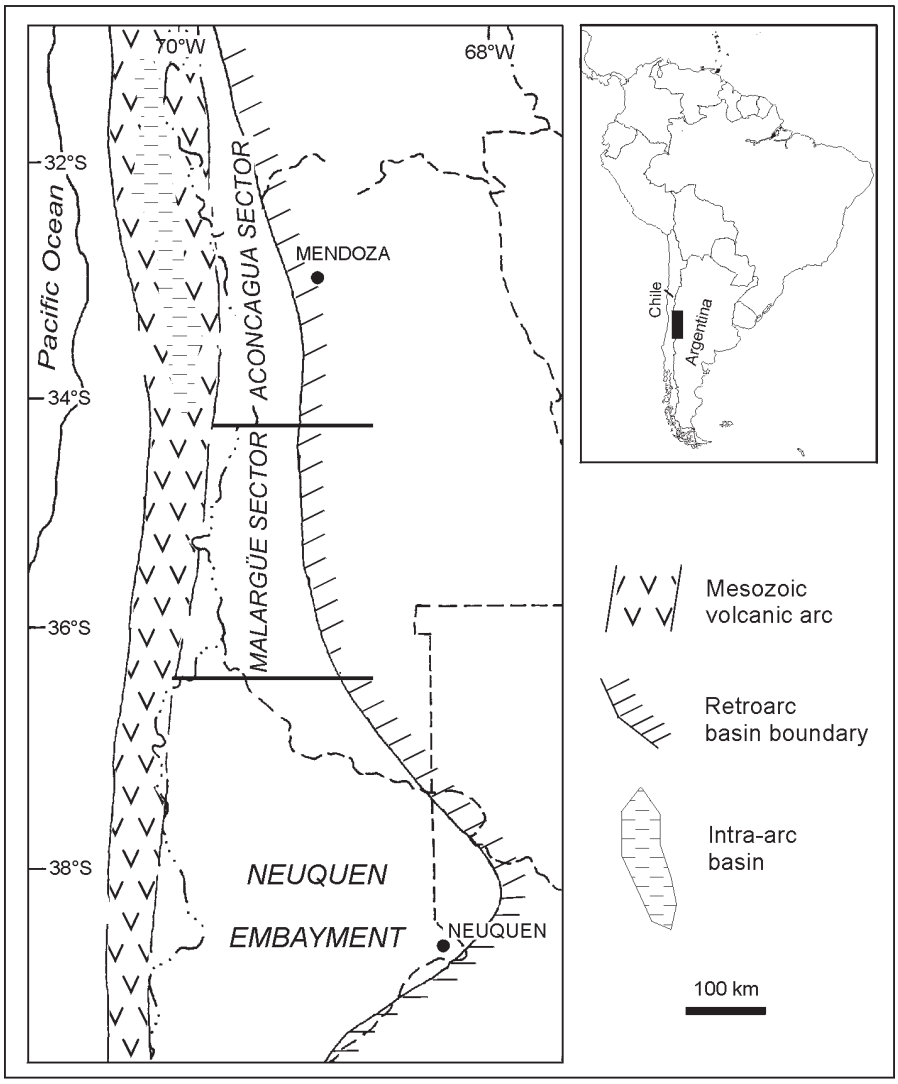

FIG. 1. Location map of the Aconcagua-Neuquén Basin in central Argentina and Chile.
FIG. 1. Ubicación de la Cuenca Neuquina-Aconcagüina en Argentina y Chile.

known since the beginning of the last century (Schiller, 1912; Stelzner, 1923; Groeber, 1951; Polanski, 1972; Ramos 1985 a and b, among others). For the stratigraphic framework see Ramos (1985a), Aguirre-Urreta (1993), Legarreta *et al*. (1993), and Cegarra *et al.* (1993). The analyzed area is located near the international Argentine-Chilean boundary, between 31°-34° south latitude,

and is exposed in the present High Andes. The Argentine side corresponds to the San Juan and Mendoza provinces; the Chile area is part of the V Metropolitan Region.

South of 35°S latitude, the Neuquén Basin expands eastwards to the foreland forming a large embayment. It is a retroarc basin flooded by marine influxes from the Pacific, where several thousand metres of sediment accumulated during Jurassic and early Cretaceous time. The first stratigraphic work was done by Bodenbender (1892), followed by Windhausen (1918), and mostly the fundamental studies of Groeber (1946, 1953). Modern views have been expressed by Gulisano *et al.* (1984), Legarreta and Gulisano (1989), and Legarreta and Uliana (1991, 1999).

The area of southern Mendoza, the Malargüe sector, albeit with its own characteristics, is more related to the Neuquén Embayment than to the Aconcagua region. Regional studies comprises those of Legarreta *et al.* (1981, 1993) and Legarreta and Kozlowski (1981, 1984).

STRATIGRAPHY

In order to provide a clearer picture of the stratigraphy, this chapter will be divided in three sectors:

1. Aconcagua - Central Chile

The marine Neocomian deposits are exposed in two narrow belts, one in the Coastal Cordillera in the west, and the other in the Main Cordillera to the east. They are represented in two different tectonic settings. The forearc deposits correspond to the Lo Prado Formation (more than 4,000 meters of sandstones, limestones, and shales interbedded with andesites) exposed in the Coastal Cordillera (Nasi and Thiele, 1982). Within the magmatic arc the Neocomian crustal extension never led to the development of oceanic crust, but produced narrow and thick pods of marine (San Felipe limestones) and non-marine (Las Chilcas Formation) sediments interfingered with or locally replaced by volcanic (Veta Negra Formation) and volcaniclastic (Juncal and Pelambres Formations) deposits (Legarreta and Uliana, 1991; Ramos and Aguirre Urreta, 1992).

The retroarc sequence is represented by the Mendoza Group in Argentina and the San José, Lo Valdés, and Baños del Flaco Formations in Chile. These last three units, predominantly calcareous, are partially equivalent to each other (Fig. 2).

The San José Formation, exposed in the northern part of the region, comprises more than 700 m of carbonates, and has ammonites in three distinct stratigraphic levels comprising the Valanginian and early Hauterivian.

Towards the south, the Lo Valdés Formation is a richly fossiliferous, thick sequence of more than 1,300 meters of bindstones, mudstones, packstones, wackestones, and submarine lavas. González (1963), who proposed the Lo Valdés Formation for a section cropping out in the Volcán river valley, remarked that the

FIG. 2. Correlation chart of the lithostratigraphic units corresponding to the retroarc deposits of the Aconcagua-Neuquén basin.
FIG. 2. Cuadro de correlación de las unidades litoestratigráficas correspondientes a los depósitos de retroarco de la cuenca Neuquina-Aconcagüina.

formation comprises two transgressive, mainly carbonate sections, separated by an episode of clastics and evaporites representing a regressive phase. The Lo Valdés Formation spans from the Tithonian to the Hauterivian based on its ammonite succession. Unfortunately, González did not correlate this new formation with the classic Baños del Flaco Formation, previously proposed by Klohn (1960). More recently Biró-Bagóczky (1984) and Hallam *et al.* (1986) studied again these Neocomian deposits and concluded that while the Lo Valdés Formation represents a 1,300 meters thick sequence comprising the Tithonian to the Hauterivian, the Baños del Flaco Formation should be restricted only to the Tithonian, criterion which is not followed here (Fig. 2) (see also Riccardi, 1988 and Aguirre-Urreta and Charrier, 1991).

The Mendoza Group in the Aconcagua area of Argentina (Fig. 2) is represented by the shales and bituminous marls of the Vaca Muerta Formation and the limestones of the Quintuco Formation during Tithonian-Berriasian times. The contemporaneous detrital deposits have been assigned to the Lindero de Piedra Formation (Legarreta *et al*., 1981). The early Valanginian beds show some lithological variations but are mostly greenish to reddish clastics of the Mulichinco Formation. The late early Valanginian-Hauterivian Agrio Formation is represented by packstones, wackestones and calcareous sandstones (Aguirre-Urreta and Lo Forte, 1996).

In general terms, those sequences are less fossiliferous than their equivalents in the Chilean side (Ramos and Aguirre-Urreta, 1992), most probably related to a shallower environment, which is in fact dominated by bivalves and gastropods. The Mendoza Group in the Aconcagua area presents its uppermost fossiliferous levels in the early Hauterivian, while towards the west and south, the marine transgression comprises up to the late Hauterivian-early Barremian.

2. Malargüe sector

In the Malargüe sector, the Mendoza Group is represented by the black shales and mudstones of the Vaca Muerta Formation (Tithonian), the mudstones, packstones, and wackestones of the Chachao Formation (Berriasian-early Valanginian) (Legarreta and Kozlowski, 1981), and by dark shales, micritic limestones, and oolitic limestones of the Agrio Formation (late early Valanginian- early Barremian) (Fig. 2) (Legarreta *et al*., 1981; 1993). The Mulichinco Formation of continental to littoral sandstones and shales in the northern and southern part of the basin is the time equivalent sequence of the Chachao Formation of the Malargüe sector.

3. Neuquén Embayment

The Andean cycle in the Neuquén Basin, as defined by Groeber (1946) comprises both marine and continental deposits, that are assembled in the Mendoza Group. The marine Tithonian-Early Valanginian is represented by rich, organic dark shales with calcareous nodules (Vaca Muerta Formation), and thinly laminated limestones (Quintuco Formation). The paleogeography was complex, especially during the Valanginian, when a regression took place, and there was a coexistence of continental and volcaniclastic beds, marine shales and thick carbonate deposits of the Mulichinco Formation (Legarreta and Gulisano, 1989). A transgressive phase occurred in the late early Valanginian with the deposition of the shales and limestones of the Agrio Formation (Fig. 2). In the eastern part of the basin, contemporaneous continental clastics are referred to the Centenario Formation while towards the south there is a lateral passage into another sequence of continental red beds, the La Amarga Formation. The Agrio Formation grades upwards to the evaporites and limestones of the Huitrín Formation, indicating the regression of the Pacific sea during Barremian times.

Weaver (1931) divided the Agrio Formation into lower and upper divisions separated by a thin but laterally persistent sandstone, the Avilé Member. The three divisions are generally regarded as members. Both the lower and upper Agrio members are marine. The intervening Avilé Sandstone Member consists of some 25-30 m of grayish brown coarse sandstones, often cross-bedded. It is non-marine and marks a significant sea-level fall across the basin. The sandstone provides an excellent marker horizon, generally forming a distinct topographic feature.

Marine mollusk fossils are abundant through the sequence, except in the Avilé member and in part of the Valanginian, where the faunas are only found in the deeper parts of the Neuquén Embayment.

PALEOGEOGRAPHY

A major episode of inundation occurred in the Aconcagua-Neuquén Basin in the early Tithonian, after a period dominated by clastic continental deposition. Following a very brief stage when shallow conditions prevailed, wide basinal

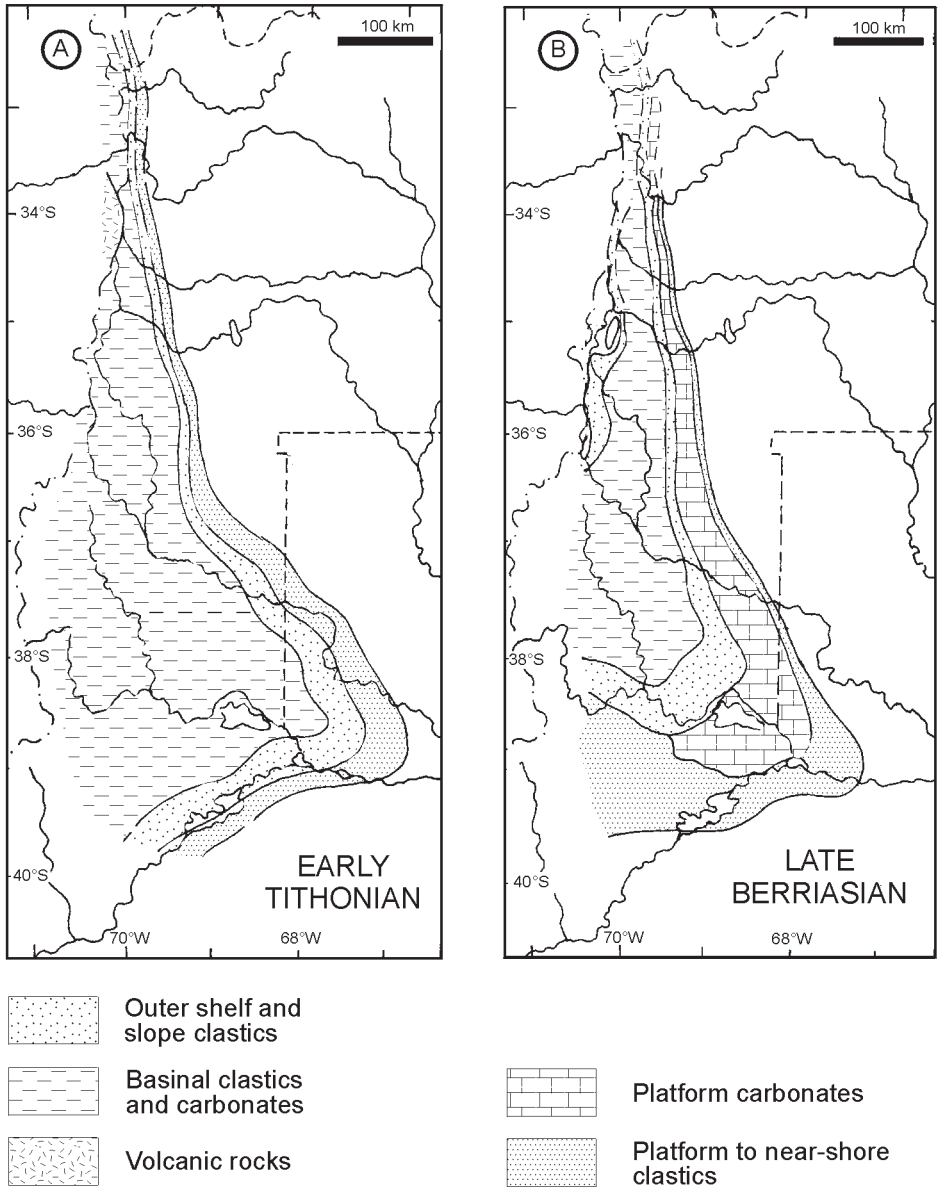

FIG. 3. Paleogeographic sketch of the Aconcagua-Neuquén Basin. a) early Tithonian. b) late Berriasian (modified from Legarreta and Uliana, 1991, 1999).
FIG. 3. Esquema paleogeográfico de la Cuenca Neuquina-Aconcagüina. a) Tithonico temprano. b) Berriasiense tardío (modificado de Legarreta y Uliana, 1991, 1999).

areas were developed (Fig. 3a), with euxinic conditions. Later in the Tithonian, a shallow-water carbonate shelf extended in the eastern border of the basin, a condition that prevailed until the Berriasian. However, during this period, as a higher amount of clastics reached the shelf, the carbonate deposition was reduced, specially in the southern part of the Neuquén Embayment. This tendency toward shallower conditions can also be seen with the arrival of detrital material from the west (Fig. 3b).

The severe areal restriction of the early Valanginian deposits to the center of the basin (Fig. 4a) reflects a very low sea level, that can be correlated with a global sea level drop (Haq *et al*., 1987). Most of the southern portion of the Neuquén Embayment was exposed above sea level, and the western part of the basin received an increased clastic influx. By the end of the early Valanginian an important paleogeographic change took place, with a renewal flooding and drowing of important portions of the basin, a situation that continued during the rest of the Valanginian and the early Hauterivian (Fig. 4b). A short episode of shallowing occurred at the end of the early Hauterivian, with the deposition of a widespread eolian-fluvial sandstone, the Avilé Sandstone Member of the Agrio Formation in the Neuquén Embayment (Fig. 5a). In the Malargüe sector, contemporaneous deposits are represented by evaporites and mudflats. Most of the basin was rapidly flooded again and widespread shelf accumulation in a clastic-carbonate ramp prevailed during late Hauterivian times (Fig. 5b). Early in the Barremian the facies assemblage represents again shallow-water conditions, suggesting a general lowering in the base level and a retraction of the depositional area.

BIOSTRATIGRAPHY

The lower Tithonian marine transgression is highly synchronous in all the basin. Shelf-basinal facies, outer to middle shelf deposits, and nearshore clastics exhibit the same ammonite association belonging to the *Virgatosphinctes mendozanus* Zone. Therefore, the age of the flooding in the Aconcagua area, the Malargüe sector, and the Neuquén Embayment corresponds to the middle early Tithonian (Fig. 6) (Leanza, 1981; Riccardi, 1984; Lo Forte *et al*., 1996).

The absence of upper Tithonian and Berriasian ammonite faunas is a common situation in the Argentine part of the Aconcagua sector. Therefore, the Jurassic-Cretaceous boundary can not be established with accuracy there. In the Chilean side, the Lo Valdés Formation is highly fossiliferous in its Tithonian-Berriasian interval and most of the ammonites zones were identified there (Aguirre-Urreta and Álvarez, 1997). However, it should be noted here, that in the Andean basins a significant paleogeographic and paleobiologic change took place not at the Jurassic-Cretaceous boundary as established worldwide, but at the base of the Tithonian, when a major flooding episode occurred (Groeber, 1946, 1951).

The most complete succession of Tithonian-Berriasian ammonite faunas is in the Malargüe sector where, besides the six typical Tithonian zones and the two classic division of the Berriasian, an extra fauna can be identified. This corre-

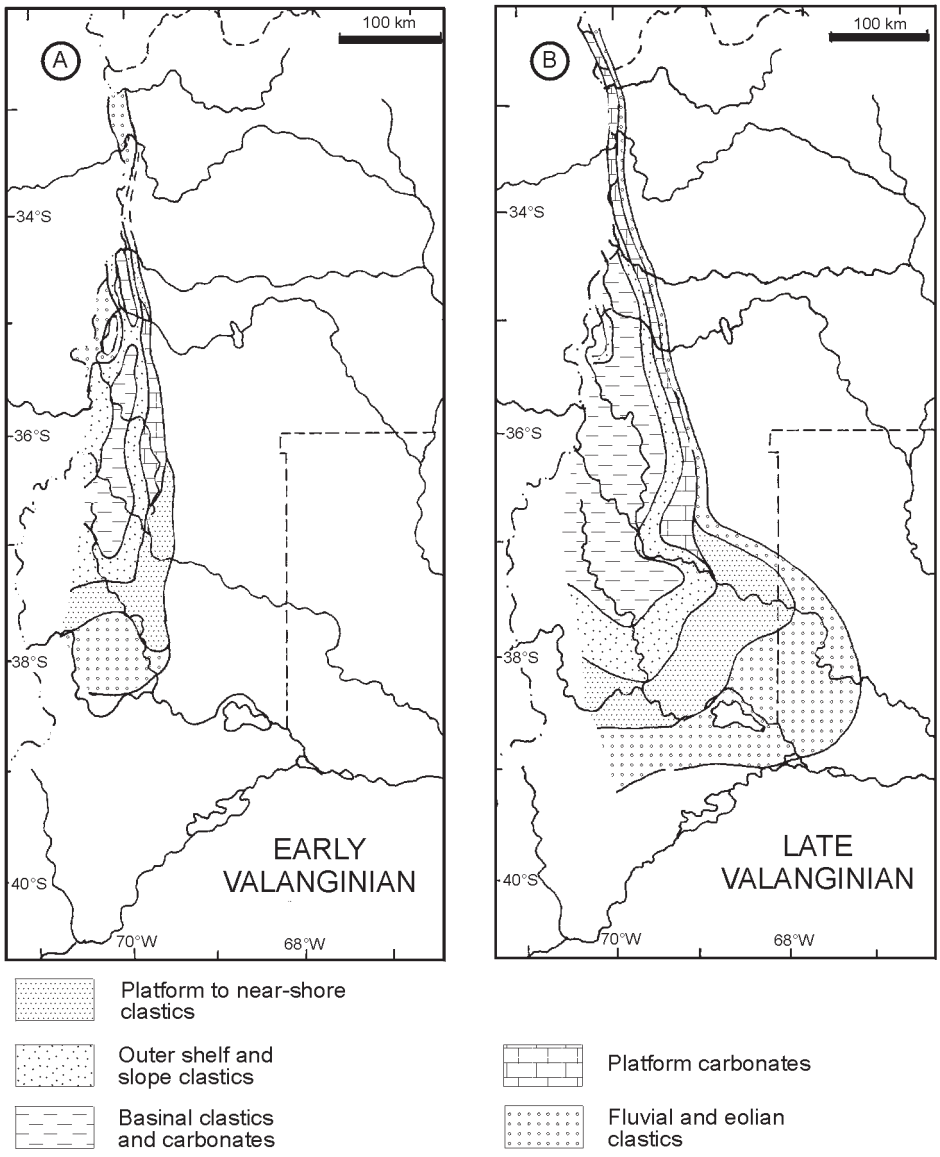

FIG. 4. Paleogeographic sketch of the Aconcagua-Neuquén Basin. a) early Valanginian. b) late Valanginian (modified from Legarreta and Uliana, 1991, 1999).
FIG. 4. Esquema paleogeográfico de la Cuenca Neuquina-Aconcagüina. a) Valanginiense temprano. b) Valanginiense tardío (modificado de Legarreta y Uliana, 1991, 1999).

sponds to the enigmatic genus *Andiceras* that is represented by a single species recorded between the *Substeuroceras koeneni* and the *Argentiniceras noduliferum* zones (Aguirre-Urreta and Alvarez, 1999). This species, with its type locality in the Paraguay creek of southern Mendoza (not in the Paraguay country as stated by Arkell (1957) and Wright (1996) in both editions of the Treatise of Invertebrate Paleontology) has yet to be identified in the Neuquén Embayment according to the author's records.

Recently, Riccardi *et al.* (2000) have presented a new Andean ammonite zonation and its correlation with the standard zones. According to them, the Zone of *Substeueroceras koeneni*, traditionally placed in the late Tithonian embraces now the topmost of the Tithonian, and the early Berriasian. The *Argentiniceras noduliferum* Zone which marked the base of the Berriasian (and that of the Cretaceous) was moved to the Middle Berriasian. The reasons of these displacements remain unexplained so we still favour the traditional dating but placing the *Andiceras trigonostomum* Zone embracing the Jurassic-Cretaceous boundary (Fig. 6).

The earliest Valanginian ammonites are very poorly known and in need of a complete revision, and they have been enclosed in the *Neocomites wichmanni* Zone (Fig. 7). It should be noted here that the only description and illustration of the ammonite index species of this zone is a single half whorl specimen studied by Leanza (1945).

The following ammonite assemblage is represented by the *Lissonia riveroi* Zone that has been recorded in southern Mendoza and northern-central Neuquén. This zone has been proposed recently as the index species, together with *Acantholissonia gerthi*, conform a distinctive association, that is situated stratigraphically below that of *O. atherstoni* (Aguirre-Urreta and Rawson, 1999b) (Fig. 7). An interesting ammonite has been found in the boundary between the *Neocomites wichmanni* and the *Lissonia riveroi* zones. It corresponds to *Valanginites argentinicus* that is restricted stratigraphically to a very thin horizon and geographically to only two localities of central Neuquén. In one locality, Cerrito La Ventana in central Neuquén, a single specimen of *Olcostephanus* aff. *O. drumensis* has been recovered from the same horizon.

The next zone corresponds to the *Olcostephanus atherstoni* Zone and represents the second widespread ammonite occurrence in the basin after that of the early Tithonian. In the Neuquén Embayment, the detailed biostratigraphy has permitted to distinguish three subzones: a lower one of *Olcostephanus (O.) atherstoni*; a second one of *Karakaschiceras attenuatum;* and the third one of *Olcostephanus (Viluceras) permolestus*. The first subzone has been identified from northern Mendoza, near the Aconcagua mountain to southern Neuquén, while the other two have also been identified in the northern segments but with very scattered occurrences (Fig. 7).

Late Valanginian ammonites again are widespread in the basin, represented by the *Pseudofavrella angulatiformis* Zone, also divided in three subzones. The index species, representing the first subzone, is common throughout the basin, recorded from Aconcagua in the north to southern Neuquén. The second subzone,

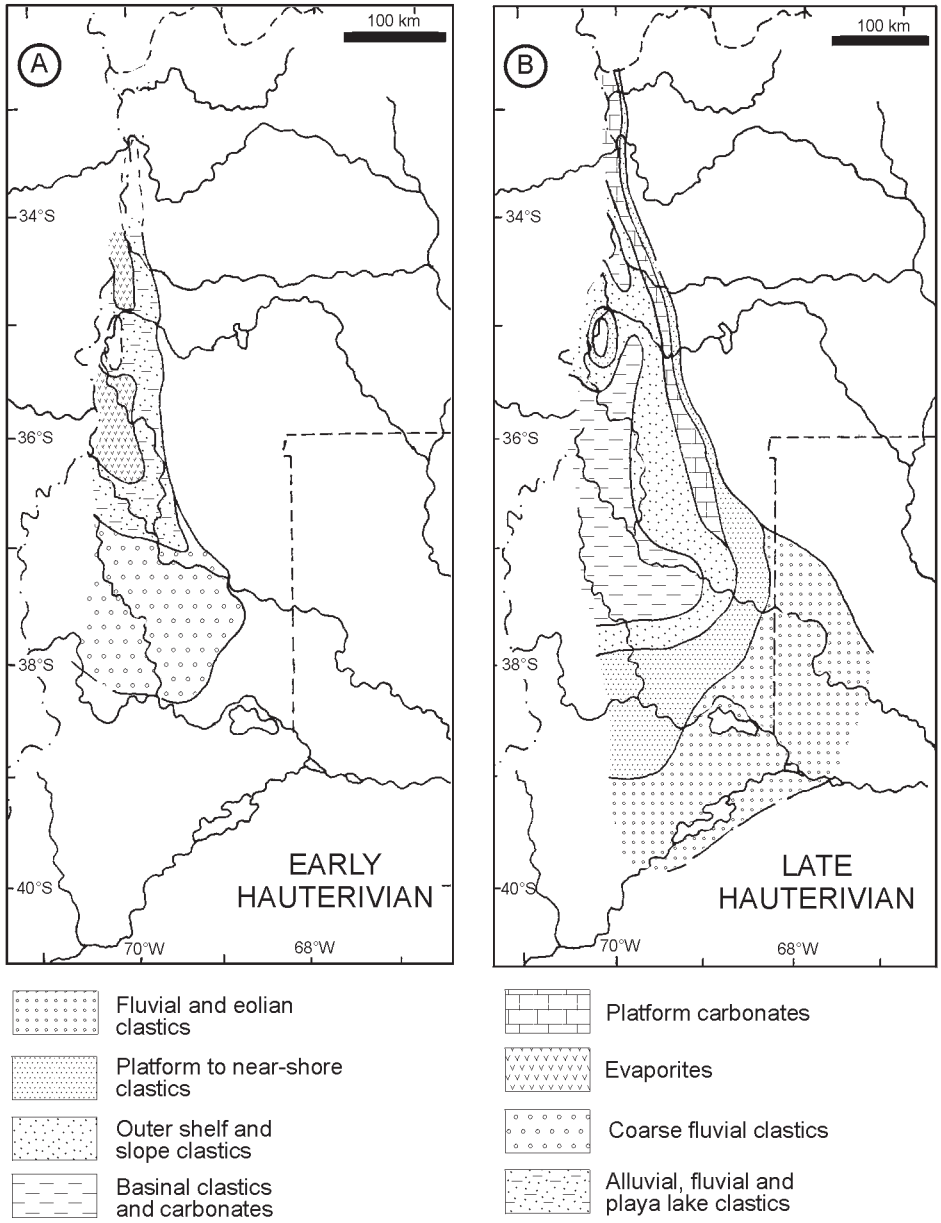

FIG. 5. Paleogeographic sketch of the Aconcagua-Neuquén Basin. a) early Hauterivian. b) late Hauterivian (modified from Legarreta and Uliana, 1991, 1999).
FIG. 5. Esquema paleogeográfico de la Cuenca Neuquina-Aconcagüina. a) Hauteriviense temprano. b) Hauteriviense tardío (modificado de Legarreta y Uliana, 1991, 1999).

characterized by the index fossil *Chacantuceras ornatum* has the peculiarity that was not only known from southern Mendoza and Neuquén, but also recorded in the Austral basin of southern Patagonia (Aguirre-Urreta and Rawson, 1999a). A recent revision of the ammonites collected by Schiller at the beginning of last century in the Aconcagua area has shown a single well preserved specimen of *Chacantuceras ornatum* from the Horcones river, that drains the Aconcagua glaciers (Fig. 7). The third and last subzone, that of *"Neocomites"* spp. is presently under study, but up to now it has only been recorded in Neuquén.

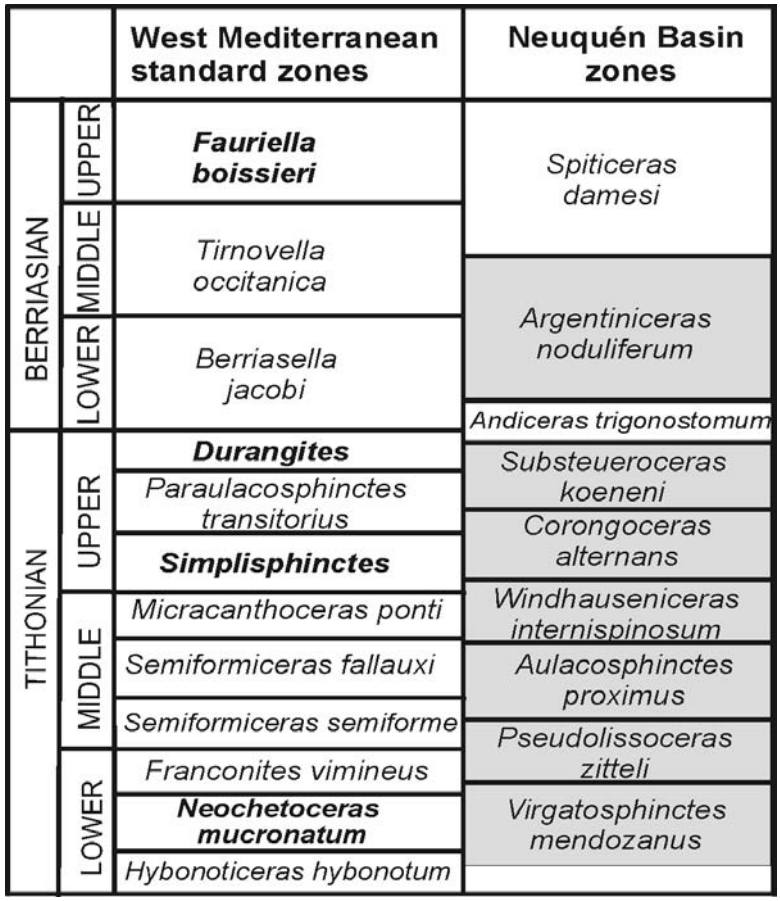

FIG. 6. Biostratigraphic ammonoid zonation of the Neuquén Basin during the Tithonian-Berriasian and the correlation with the Mediterranean standard zones. The zones recognized in the Aconcagua region are shaded in grey.
FIG. 6. Zonación bioestratigráfica de la Cuenca Neuquina durante el Tithonico-Berriasiense y su correlación con las zonas estándar del Mediterráneo. Las zonas reconocidas en la región del Aconcagua están representadas en gris.

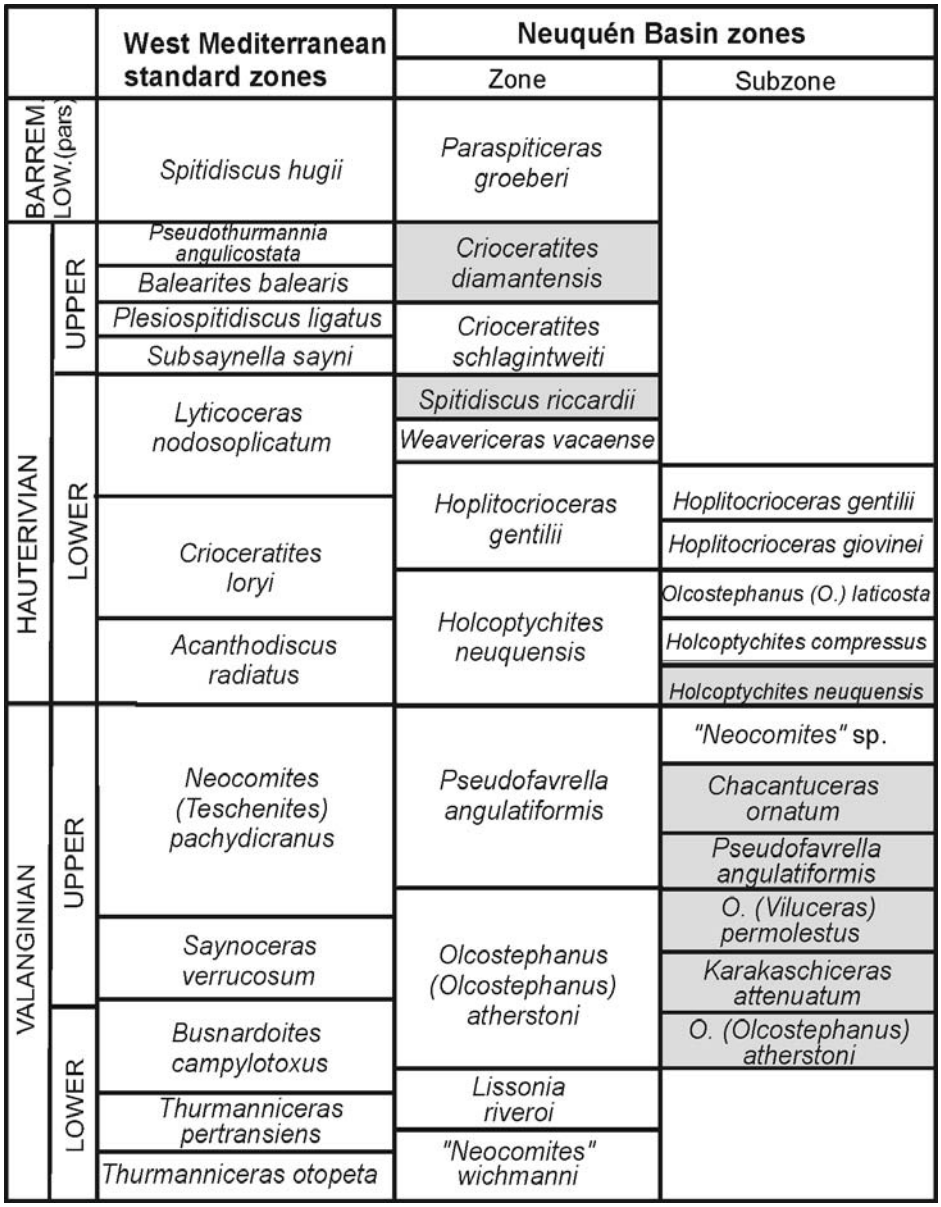

FIG. 7. Biostratigraphic ammonoid zonation of the Neuquén Basin during the Valanginian-Barremian and the correlation with the Mediterranean standard zones. The zones recognized in the Aconcagua region are shaded in grey.

FIG. 7. Zonación bioestratigráfica de la Cuenca Neuquina durante el Valanginiense-Barremiense y su correlación con las zonas estándar del Mediterráneo. Las zonas reconocidas en la región del Aconcagua están representadas en gris.

The first Hauterivian zone corresponds to the *Holcoptychites neuquensis* Zone, that has been subdivided in three subzones in the Neuquén Embayment (Fig. 7). This threefold division can also be recognized south of Diamante river in southern Mendoza, but the record north of that area is restricted to a single reference of *Holcoptychites neuquensis* in Puente del Inca, a classic locality of the Aconcagua region. Special importance for interregional correlation is the upper subzone of *Olcostephanus laticosta* (see below). The next *Hoplitocrioceras gentilii* and *Weavericeras vacaense* zones of the early Hauterivian are mostly present in the Neuquén Embayment reaching as south as El Marucho hill and Picún Leufú in southern Neuquén. The last zone of the early Hauterivian corresponds to the *Spitidiscus riccardii* Zone. This species has been recognized as north as Piuquenes pass in central Mendoza, but is widespread in the Neuquén Embayment. The local species shows close similarities with European forms, thus providing a very good correlation level.

The late Hauterivian faunas are restricted to different species of *Crioceratites* that have been divided in two biozones, a lower one of *Crioceratites schlagintweiti* and an upper one of *Crioceratites andinus* (Fig. 7). The first one is represented by species very similar to those "mid Hauterivian" species of Europe, but is geographically restricted while the second one is more widespread in the basin, but the species have no closer counterpart in the Mediterranean.

The last ammonite biozone recorded in the basin corresponds to the *Paraspiticeras groeberi* Zone of the early Barremian (Fig. 7).This monospecific zone is known from southern Mendoza to south-central Neuquén in the uppermost levels of the Agrio Formation.

CORRELATIONS

The ammonite successions developed in the Aconcagua-Neuquén Basin during the Tithonian-Barremian interval consist of a mixture of globally distributed forms and more geographically restricted genera. The latter group includes forms found also in the Himalayas, the Madagascan region, and other South American Andean basins.

The Tithonian-Berriasian ammonite faunas present affinities with the Himalayan province, as well as with northern South America and the Mediterranean areas (Riccardi, 1991).

Early Valanginian faunas in Central Chile, the Malargüe sector, and the Neuquén Embayment have been assigned to Mediterranean taxa, as *Neocomites* and *Thurmanniceras*, but these placements have been doubted (see Company, 1987) and the systematics should be revised. Taxa as *Lissonia* and *Acantholissonia* are also present in other Andean basins of Chile, Perú, and Colombia, and also probably in the Himalayas.

The late Valanginian-Hauterivian ammonites from Aconcagua-Central Chile are less diverse than those from the Neuquén Embayment, but share the same genera. In the Neuquén Embayment, the early Hauterivian is represented by a series

of Andean genera as *Pseudofavrella*, *Holcoptychites*, *Hoplitocrioceras* and *Weavericeras* together with Mediterranean components (*Olcostephanus, Spitidiscus*). In Aconcagua - Central Chile the higher marine horizons correspond to the lower Hauterivian, becoming younger to the south.

In the late Hauterivian the faunas are dominated by *Crioceratites* of Mediterranean affinities. The Barremian faunas in the Neuquén Embayment (Leanza and Wiedmann, 1992; Aguirre-Urreta and Rawson, 1993) point to Mediterranean connections.

The paleogeographical distribution of the ammonite species within the Aconcagua-Neuquén Basin seems to be related to sea level changes. Periods of sea level rises allow a dispersion of the faunas in a basin with a complex north-south paleogeography. This is specially true in the early Tithonian and the late early Valanginian with the coexistence of clastic, volcaniclastic, and carbonate facies. Both *Virgatosphinctes mendozanus* and *Olcostephanus (Olcostephanus) atherstoni* spread all along the basin and have been recorded in all kind of different facies.

After the dispersion of *Olcostephanus atherstoni* by the late early Valanginian global sea level rise, there is an increase in the geographic isolation of the Andean faunas, with the onset of more local populations during a period of stable conditions in the basin. Afterwards, only very brief periods of renewal communication with the Mediterranean area are observed. One of these periods corresponds to the *Olcostephanus laticosta* Subzone (*Holcoptychites neuquensis* Zone) and the *Hoplitocrioceras giovinei* Subzone (*Hoplitocrioceras gentilii* Zone) in the early Hauterivian, with the presence in the Neuquén Embayment of *Olcostephanus (Jeannoticeras*) sp. nov. and *Olcostephanus variegatus*. The occurrence of the short-ranged subgenus *O. (Jeannoticeras*) as a minority element of the fauna of the upper half of the *Olcostephanus laticosta* Subzone indicates a possible correlation with the *jeannoti* Horizon of France, which lies in the *Crioceratites loryi* Zone. *O. variegatus* from the upper part of the *Hoplitocrioceras giovinei* Subzone, suggests a correlation with the *variegatus* Horizon of France, which lies immediately above the *jeannoti* Horizon.

The early crioceratitids that appear in the basin, *Crioceratites schlagintweiti* and *C. apricus* closely resembles the European *C. nolani* and *C. duvali* (regularly open coiled forms, with a variable number of fine intermediate ribs, intercalated with stronger ribs with or without tubercles) typical of the European "mid Hauterivian". Both *Crioceratites diamantensis* and *C. andinus* characteristic of the *C. diamantesis* Zone are more involute and compressed than the underlying crioceratitids, from which they are probably derived. The tendency to recoil demonstrated by this faunas parallels that seen in the change from *Crioceratites* to *Pseudothurmannia* in western Tethys during the late Hauterivian.

As a final conclusion it can be stated that although the Andean faunas of southern South America are quite well known, the centers of origin and the migration patterns are still unclear, and more oceanographic, paleogeographic, and paleoclimatic information is required before more refined models can be postulated and biostratigraphic correlations can be improved.

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