

FERNANDEZ-LOPEZ S., CHONG G., QUINZIO L.A. & WILKE H.G. 1994. The Upper Bajocian and Bathonian in the Cordillera de Domeyko, North-Chilean Precordillera : sedimentological and biostratigraphical results. [Le Bajocien supérieur et le Bathonien de la Cordillère de Domeyko, Précordillère Nord-Chilienne : résultats sédimentologiques et biostratigraphiques].

ABSTRACT

The Jurassic ammonites of the Cordillera de Domeyko have been studied in several monographies. The classic memoirs of Steinmann (1881), Tornquist (1898), Burckhardt (1903) and Stehn (1923) are particularly relevant. However, the biostratigraphic problems concerning stage boundaries arisen only in recent dates. New sedimentological and biostratigraphical data have been obtained in relation to the Bajocian/Bathonian of this region. Several sections have been studied in two separate areas : Caracoles and Sierra de Varas. More than one thousand ammonites were collected *in situ* from these localities. Facies analysis shows that sedimentation during Late Bajocian and Bathonian occurs in a marine environment on a carbonate platform with abundant siliciclastic supply. Facies distribution was controlled by structural segmentation of the platform and processes of differential subsidence. The stratigraphical-sedimentological results together with taphonomical-palaeoecological observations are a diagnostic tool for sequence analysis. The successive ammonite assemblages which were found have allowed the establishment of four biostratigraphic units, spanning the interval from Upper Bajocian to Upper Bathonian. The sedimentological and biostratigraphical results indicate the existence of a regional discontinuity at the base of the Bathonian.

KEY-WORDS : MIDDLE JURASSIC, BAJOCIAN, BATHONIAN, AMMONITINA, BIOSTRATIGRAPHY, BIOCHRONOLOGY, ANDES, SOUTH-AMERICA, CHILE.

RÉSUMÉ

Les ammonites du Jurassique de la Cordillère de Domeyko ont été traitées dans plusieurs monographies, parmi lesquelles les mémoires classiques de Steinmann (1881), Tornquist (1898), Burckhardt (1903) et Stehn (1923) sont particulièrement importants. Cependant, les problèmes biostratigraphiques de limites d'étages n'ont été évoqués que récemment. Des données biostratigraphiques et sédimentologiques sont présentées pour la limite Bajocien-Bathonien, à travers l'analyse de plusieurs coupes situées dans deux aires différentes de la Cordillère de Domeyko : Caracoles et Sierra de Varas. Dans l'ensemble, une importante quantité d'ammonites a été récoltée *in situ*. L'analyse des faciès montre que la sédimentation durant le Bajocien supérieur et le Bathonien s'est développée dans un environnement marin de plate-forme carbonatée avec d'abondants apports siliciclastiques. La distribution des faciès est contrôlée par le découpage structural de cette plate-forme et par la subsidence. Les données stratigraphiques et sédimentologiques constituent, avec les observations taphonomiques et paléocéologiques, un argument utile permettant d'individualiser les différentes séquences sédimentaires. Les associations d'ammonites identifiées permettent d'établir quatre unités biostratigraphiques couvrant l'intervalle Bajocien supérieur - Bathonien supérieur. Les résultats sédimentologiques et biostratigraphiques indiquent l'existence d'une discontinuité régionale à la base du Bathonien.

MOTS-CLÉS : JURASSIQUE MOYEN, BAJOCIEN, BATHONIEN, AMMONITINA, BIOSTRATIGRAPHIE, BIOCHRONOLOGIE, ANDES, AMÉRIQUE DU SUD, CHILI.

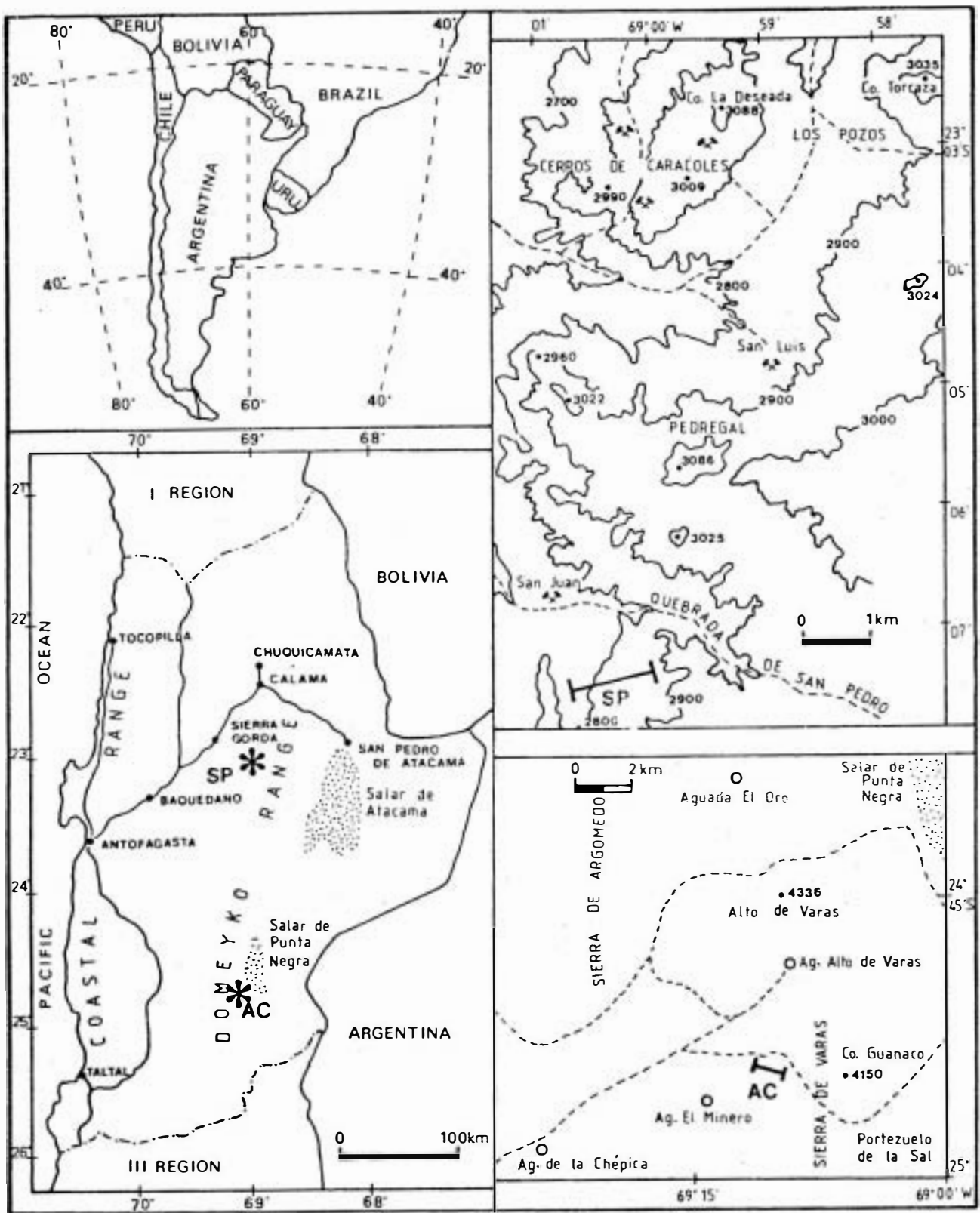


Figure 1 - Location maps of sections at Quebrada de San Pedro (Caracoles) and Aguada Colorada (Sierra de Varas). *Cartes de situation des coupes de Quebrada de San Pedro (Caracoles) et d'Aguada Colorada (Sierra de Varas).*

INTRODUCTION

Some ammonites from the Middle Jurassic of the Cordillera de Domeyko have been studied in several monographies at the end of the last century and in the first decades of this century. The studies by Steinmann (1881), Tornquist (1898), Burckhardt (1903) and Stehn (1923) are particularly interesting. Most of the ammonites described or mentioned in these studies belong to the Callovian, being less abundant the biostratigraphic data concerning the Upper Bajocian and Bathonian of this region. Stratigraphical and paleontological data have been recently provided by various authors such as : Harrington (1961) ; Westermann (1967, 1981) ; Hillebrandt (1970, 1972, 1973, 1977) ; Chong (1973, 1977) ; Covacevich & Piracés (1976) ; Montaña (1976) ; Baeza (1979) ; Westermann & Riccardi (1979, 1980, 1985) ; Jensen & Quinzio (1979, 1981) ; Bogdanic (1983) ; Gröschke & Hillebrandt (1985) ; Bogdanic & Chong (1985) ; Hillebrandt, Gröschke, Prinz & Wilke (1986) ; Gröschke, Hillebrandt, Prinz, Quinzio & Wilke (1988) ; Riccardi, Westermann & Elmi (1988, 1989, 1990a) ; Riccardi & Westermann (1991a,b).

The Upper Bajocian has been recognized in many localities of the North-Chilean Precordillera due to the presence of *Megasphaeroceras* and *Lep-tosphinctes*, whereas the finding of *Epistrenoceras paracontrarium* (BURCKHARDT) in some outcrops has made it possible to distinguish a horizon of *Epistrenoceras* attributable to the Upper Bathonian (Hillebrandt 1970). However, the scarce ammonites found so far in the rocks from the Bajocian-Bathonian interval in the Chilean Precordillera have not allowed to make a biostratigraphic subdivision of the Upper Bajocian or the Bathonian. Despite the scarce detailed biostratigraphic data, some authors have defended that in the Cordillera de Domeyko there are probably sediments from Upper Bajocian and Lower Bathonian (Westermann 1981 ; Bogdanic & Chong 1985 ; Gröschke & Hillebrandt 1985), whereas other authors have stated the possibility of these sediments being condensed or missing (Riccardi, Westermann & Elmi 1988, 1989, 1990a).

The main objective of this paper is to provide new biostratigraphical and sedimentological data concerning the Bajocian-Bathonian boundary in the Cordillera de Domeyko. Over the March-April 1991 period we have studied several outcrops in the Caracoles area and in Sierra de Varas (Fig. 1). In these outcrops there is a relevant succession of carbonate sediments from the first beds with *Megasphaeroceras* up to the horizon with

Epistrenoceras. Two sections have been studied in detail, bed by bed, and the results obtained are shown in this paper. These sections are Quebrada de San Pedro (Caracoles area) and Aguada Colorada (Sierra de Varas), where more than a thousand ammonites have been found, *in situ*.

STRATIGRAPHIC SECTIONS

QUEBRADA DE SAN PEDRO (69°00' Long. W, 23°07' Lat. S).

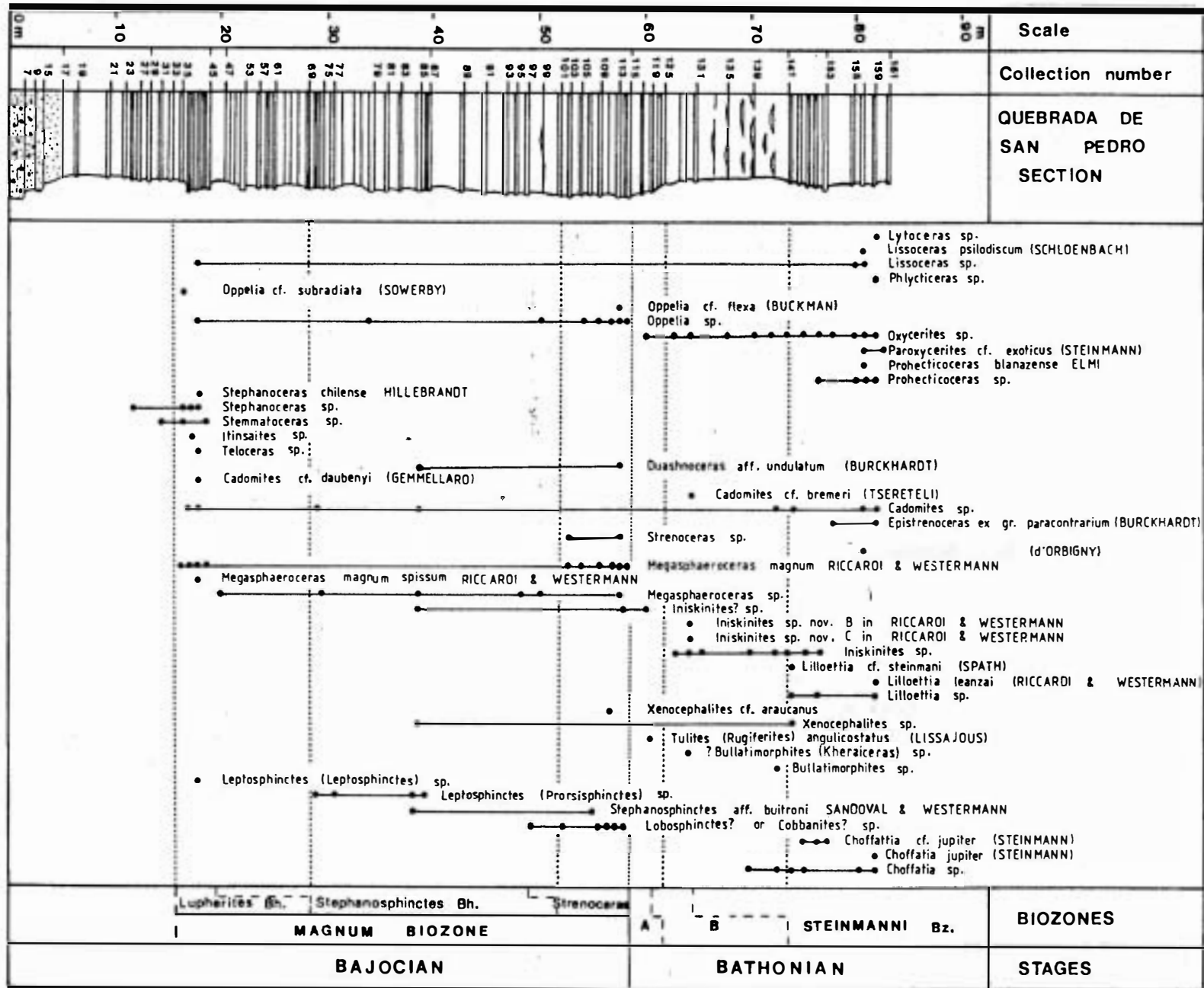
In the Caracoles area, above the volcanoclastic and metamorphic rocks from the Triassic, and unconformably with them, there is a relevant succession of fossiliferous marine sediments from the Middle Jurassic. The best exposures of Bajocian and Bathonian rocks are to be found at the Quebrada de San Pedro. In this locality, the following stratigraphical intervals can be distinguished (Fig. 2) :

4,5 to 5 m (SP1 - SP17). Conglomerates and microconglomerates, dark-brownish in the lower part of the interval and whitish on the upper part, becoming sandy upwards, passing into fine-grained sandstone. The clasts are rounded, some of them being over 20 cm long in the lower part of the interval, but not so long in the upper part. The macrofossils are frequent and, in general resedimented : solitary and colonial corals, bivalves and gastropods.

8 to 12 m (SP17 - SP29). Calcareous sandstone and sandy limestones, grey or yellowish, with thin beds of silty limestones whose lateral extension is not usually longer than 10 metres. There are frequent macrofossils, in general resedimented : bivalves, gastropods and ammonites. It has only been possible to identify one fragmented *Stephanoceras* sp. macroconch, around 25 cm in diameter.

3 to 8,2 m (SP29 - SP45). Silty limestones, bioclastic limestones and marls, greyish-yellowish. The limestone beds are of variable thickness, from 15 to 40 cm, and their lateral extension is usually several tens of metres. Some layers containing abundant resedimented and silicified macrofossils, often forming lumachelles, being concentrated in the lower part and finer-grained towards the top, and exhibiting sole marks, can be identified as tempestites. The most abundant fossils belong to costuled brachiopods, bivalves, ammonites, belemnites and gastropods. In the following taxonomic lists, (M) = macroconch, (m) = microconch, S = specimen(s).

Figure 2 - Columnar section at Quebrada de San Pedro (Carnegie), with ammonites occurrences and stratigraphic units. *Column stratigraphique de Quebrada de San Pedro (Carnegie) avec la position des ammonites et les unités stratigraphiques.*



In the lowest beds of the interval :
Stemmatoceras sp. (M), 1 S.

In the upper part (SP33 - SP45) :

Lissoceras sp. (M?), 1 S.

Oppelia cf. *subradiata* (SOWERBY, 1823) (M), 1 S.

Oppelia sp. (M), 2 S.

Stephanoceras chilense HILLEBRANDT, 1977 (M), 1 S.
Stephanoceras spp. (M), 7 S.

Stemmatoceras spp. (M), 2 S.

Itinsaites sp. (m), 2 S.

Teloceras sp. (M), 1 S.

Cadomites cf. *daubenyi* (GEMMELLARO, 1877) (M), 1 S.

Cadomites sp. (M?), 2 S.

Megasphaeroceras magnum RICCARDI & WESTERMANN 1991 (M) + (m), abundant.

Megasphaeroceras magnum spissum RICCARDI & WESTERMANN 1991 (M), 1 S.

Leptosphinctes (Leptosphinctes) sp. (M?), 1 S.

Within this association, it is noteworthy the relative abundance of *Megasphaeroceras*, probably monospecific, which are represented by macroconchs and microconchs, as well as by juvenile and adult forms. The specimens of other genera belong to adult forms.

2 to 4 m (SP45 - SP47). Greenish or yellowish lutites, which fray out laterally towards the NW, and contain very few resedimented macrofossils : bivalves and ammonites. *Megasphaeroceras* sp., fragments of shells preserved as flattened impressions.

18 to 20 m (SP47 - SP87). Silty limestones, brownish-reddish in color, and yellowish lutites. The thickness of their beds is variable, from 20 to 30 cm, and their lateral extension is usually over several tens of metres. Macrofossils are only frequent in some local levels and are resedimented, but the remains of millimeter-sized gastropods and bivalves are abundant. Ammonites occur as flattened impressions. Within these materials we have found :

Oppelia sp. (M), 1 S.

Duashnoceras aff. *undulatum* (BURCKHARDT 1927) (m), 1 S.

Cadomites sp. (M) + (m), 3 S.

Megasphaeroceras sp. (M) + (m), frequent.

Iniskinites? sp. (M), 1 S.

Xenocephalites sp. (m), 2 S.

Leptosphinctes (Prorsisphinctes) sp. (M), 4 S.

Stephanosphinctes aff. *buitroni* SANDOVAL & WESTERMANN, 1986 (M?), 2 S.

19 m (SP87 - SP115). Bioclastic limestones and lutites, brownish-yellowish in color. Their beds

are of variable thickness, from 30 to 40 cm, becoming thicker towards the top of the unit, their lateral extension is over one hundred metres and they are organized in coarsening-upward sequences. Macrofossils are very abundant and in general resedimented : bivalves, brachiopods, ammonites, gastropods and belemnites. At about 8 m below the SP115 level, we have found two large smooth, serpulid-encrusted, ammonites (D60 cm), belonging to *Cobbanites?* sp. The last 5 m (SP101 - SP115) span the most fossiliferous part of the section and some fossils are preserved as internal, pyritic moulds :

Oppelia cf. *flexa* (BUCKMAN, 1924) (M) + (m), 3 S.

Oppelia sp. (M) + (m), frequent.

Duashnoceras aff. *undulatum* (BURCKHARDT, 1927) (m), 1 S. Plate 1, figure 11.

Strenoceras sp. (m), 6 S. Plate 1, figure 7.

Megasphaeroceras magnum RICCARDI & WESTERMANN, 1991 (M) + (m), abundant. Plate 1, figures 9 - 10.

Iniskinites? sp. (M), 2 S.

Xenocephalites cf. *araucanus* (BURCKHARDT, 1903) (m), 1 S.

Stephanosphinctes aff. *buitroni* SANDOVAL & WESTERMANN, 1986 (m), 1 S. Plate 1, figure 8.

Lobosphinctes? sp. or *Cobbanites?* (M), 5 S. Plate 1, figures 12ab.

Within this association, noteworthy is the relative abundance of *Megasphaeroceras*, probably monospecific, represented by macroconchs, microconchs, juvenile and adult forms. Among the *Oppelia* the remains of adult macroconchs predominate, and the juveniles or microconchs are very scarce. Other genera are exclusively represented by adult forms.

15 m (SP115 - SP141). Marls, gypsiferous lutites and shales, greenish-grey in color. In the lower part of the interval there are several bioclastic limestones interbedded, locally ferruginous, of centimetric thickness, becoming thinner towards the top of the unit. In the upper part of the interval there are thin, lenticular, silty limestones. Macrofossils are more frequent in the upper part of the interval and they are usually resedimented. Remains of ammonites and bivalves are predominant, but in the upper part, disk-shaped colonial corals, up to 25 cm in diameter, are found locally. In the lowest beds of the interval :

Oxycerites sp. (M), 7 S.

Iniskinites? sp. (M), 4 S.

Tulites (Rugiferites) angulicostatus (LISSAJOUS, 1923) (M), 1 S. Plate 1, figures 6ab.

In the middle part (SP125-SP131) :
Oxycerites sp. (M) + (m), abundant.

Cadomites cf. bremeri TSERETELI, 1968 (M), 1 S.
Iniskinites sp. nov. B in RICCARDI & WESTERMANN, 1991 (M), 3 S.
Iniskinites sp. nov. C in RICCARDI & WESTERMANN, 1991 (M), 2 S. Plate 1, figure 5.
Iniskinites sp. (M), frequent.
?Bullatimorphites (Kheraiceras) sp. (M), 1 S.

In the upper part :

Oxyerites sp. (M), frequent.
Cadomites sp. (M), 1 S.
Iniskinites sp. (M), abundant.
Bullatimorphites sp. (M), 1 S.
Choffatia sp. (M), 5 S.

In these marls and lutites it is noteworthy the relative abundance of adult forms belonging to *Oxyerites* and *Iniskinites*. The representatives of each of these genera belong to several new species. However, the presence of juveniles of any of these genera is practically nil. Only in the upper part of the interval we have found some juvenile forms belonging to *Oxyerites*.

4 m (SP141 - SP153). Bioclastic limestones and sandy lutites, brown-yellowish in color. The thickness of this beds ranges from 20 to 40 cm, and their lateral extension is usually several tens of metres. Macrofossils are abundant and most of them resedimented : bivalves, ammonites and brachiopods. Among the ammonites we have identified:

Oxyerites sp. (M), 6 S.
Prohecticoceras sp. (M), 1 S.
Cadomites sp. (M), 1 S.
Iniskinites sp. (M), frequent.
Lilloettia cf. steinmanni (SPATH, 1928), 1 S.
Lilloettia sp. (M), 3 S.
Xenocephalites sp. (m), 1 S.
Choffatia cf. jupiter (STEINMANN, 1881) (M) + (m), abundant.

This association is characterized by the relative abundance of representatives of *Choffatia*, among which there are macroconchs and microconchs. However, the remains of juvenile forms from this taxonomic group are very scarce.

6 m (SP153 - SP161). Lutites and marls, greyish in color, with thin intercalated beds of limestones with millimeter-sized intraclasts. The thickness of the layers range from 10 to 20 cm, but their lateral extension is often around one hundred metres. Macrofossils are frequent and resedimented : bivalves, ammonites, brachiopods and belemnites.

Lytoceras sp. (M?), 1 S.
Lissoceras psilodiscum (SCHLOENBACH, 1865) (M?), 1 S.
Lissoceras sp., 3 S.
Phlycticeras sp. (M), 8 S. Plate 1, figure 3.
Oxyerites (Paroxyerites) cf. exoticus (STEINMANN, 1881) (M), 3 S.
Oxyerites sp. (M) + (m?), frequent.
Prohecticoceras blanazense ELMI, 1967 (M), 1 S.
Prohecticoceras sp. (M), 6 S.
Cadomites sp. (M), 2 S.
Epistrenoceras ex gr. *paracontrarium* (BURCKHARDT, 1927), frequent. Plate 1, figure 2.
Hemigarantia cf. julii (d'ORBIGNY, 1846), 1 S. Plate 1, figures 1ab.
Lilloettia leanzai RICCARDI & WESTERMANN, 1991 (M), 1 S.
Lilloettia sp. (M), 2 S.
Choffatia jupiter (STEINMANN, 1981) (M) + (m), 4 S.
Choffatia sp. (M) + (m), frequent.

Among the different taxonomic groups of this association, only *Epistrenoceras* is represented by juvenile and adult forms. Most of the *Choffatia* specimens belong to adult forms, macroconchs or microconchs. The rest of the taxonomic groups are more scarce and represented by adult macroconchs.

AGUADA COLORADA (69° 13' Long. W, 24° 54' Lat. S).

The oldest sediments on this outcrop are very fossiliferous and contain ammonites characteristic of the Upper Bajocian. The sediments from the Lower Bajocian are covered by quaternary sediments, but they are well represented on other outcrops located near by. A relevant succession of carbonate sediments, containing frequent *Epistrenoceras* in their last metres, corresponds to the Bathonian.

At this locality, sediments from the Upper Bajocian and Bathonian show similar lithofacies. The most common sediments are silty shales, which are associated with silty limestones and sandy limestones. These rocks are organized in thickening and coarsening-upward sequences, with several tens of metres in thickness and kilometer-sized lateral extension, which are made up of sediments from three successive facies (Fig. 3) :
- in the lower part there are marly limestones and lime marls, becoming more shaly towards the top, greyish-whitish in color, with calcareous nodules ranging from 20 to 50 cm in diameter. Macrofossils are abundant, particularly resedimented shells of ammonites, and accumulated or

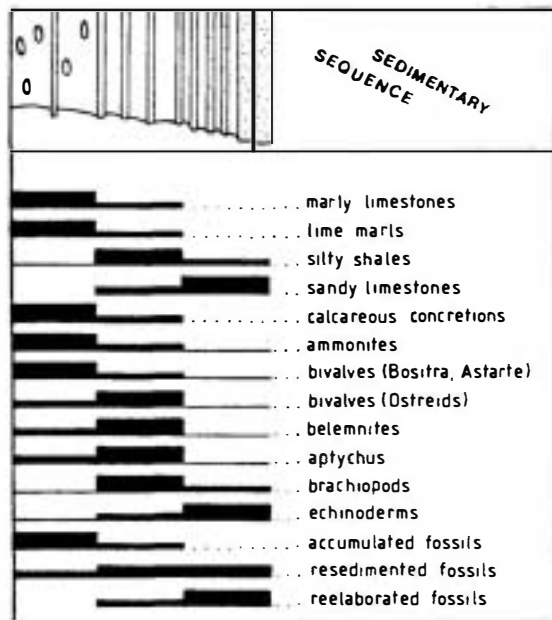


Figure 3 - Variations of lithological and paleontological features in carbonate sequences developed at Aguada Colorada. *Variations des caractéristiques lithologiques et paleontologiques dans les séquences carbonatées développées à Aguada Colorada.*

resedimented small bivalves (including *Bositra* and *Astarte*). Many shells of ammonites were ostreids-encrusted during the biostratinomic phase. The fossils found inside the nodules have their lower part well preserved, whilst most ammonites have their upper part deformed due to compaction during the early diagenesis,

- the middle part of the sequences are silty shales and lutites, greyish, with intercalated calcareous siltites and silty limestones. Calcareous nodules are scarce and smaller than in the previous term of the sequence. Macrofossils are frequent, resedimented in general, and they are usually crushed by diagenetic compaction. Remains of ostreids, ammonites (fragments of shells and aptychi), belemnites and smooth brachiopods are predominant,

- in the upper part of these sequences there are silty limestones and sandy limestones, arranged in thick layers, from 20 to 50 cm, reddish-brown in color, which are more resistant to erosion than the previous materials, and whose lateral extension is usually over one hundred metres. The lower surface of these layers is sometimes irregular, whereas the top is more homogeneous. Some layers present low angle lamination in the lower part, which becomes parallel in the middle part. Macrofossils in this term of the sequence are highly sporadic. Mainly resedimented or reelaborated fragments (*sensu* Fernández-López 1991): ostreids, costuled brachiopods, and echinoderms.

From the biostratigraphic point of view, several successive intervals can be distinguished (Fig. 4): 30 m (AC1 - AC2). One sequence where marly facies and fossiliferous nodules are predominant. Capping this sequence there are 4 or 6 metres of magmatic rocks, of porphyritic fabric and intrusive origin. Within the marly sediments we have identified:

Liroxyites cf. kellumi IMLAY, 1961 (M), 1 S.

Oppelia cf. subradiata (SOWERBY, 1823) (M), 1 S.

Stephanoceras chilense HILLEBRANDT, 1977 (M), 1 S.

Stephanoceras spp. (M), 7 S.

Stemmatoceras spp. (M), 3 S.

Teloceras sp. (M), 5 S.

Cadomites sp. (M) + (m), 3 S.

Lupherites sp. (M), 4 S.

Orthogarantiana? sp. (M), 4 S.

Spiroceras orbigny (BAUGIER & SAUZÉ, 1843), abundant.

Megasphaeroceras magnum RICCARDI & WESTERMANN, 1991 (M) + (m), abundant.

Megasphaeroceras magnum spissum RICCARDI & WESTERMANN, 1991 (M), 5 S. Plate 1, figures 14ab.

Leptosphinctes (Leptosphinctes) sp. (M), 3 S.

This interval spans the most fossiliferous part of the section. Most of the specimens from this association correspond to adult shells, which were often colonized by ostreids on its external surface. The most abundant taxonomic group is *Megasphaeroceras*, probably monospecific, which is represented by macroconchs and microconchs.

125 m (AC2 - AC8). Six successive sequences, mainly made up of silty shales and calcareous lutites, are distinguished. Calcareous nodules and macrofossils are more scarce than in the previous sequences. 4 m below AC5 level we have found:

Megasphaeroceras magnum RICCARDI & WESTERMANN, 1991 (M), 1 S.

Megasphaeroceras sp. (M), 2 S.

Iniskinites? sp. (M), 1 S.

Xenocephalites sp. (m), 1 S.

Leptosphinctes (Prorsisphinctes) sp. (M), 3 S. Plate 1, figure 13.

5 m below AC8 level:

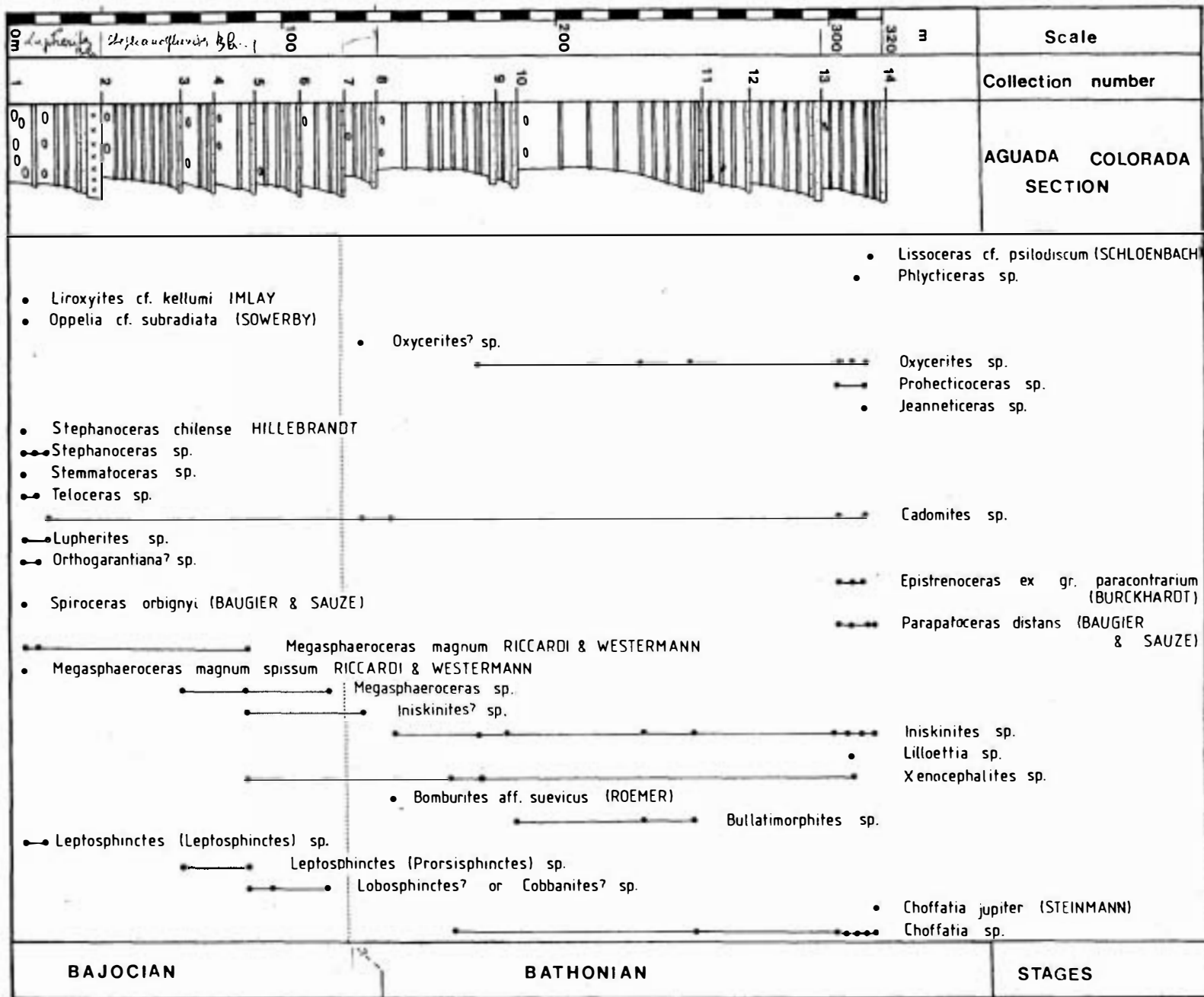
Oxyerites? sp. (M), 1 S.

Cadomites sp. (M), 1 S.

Iniskinites? sp. (M), 2 S.

171 m (AC8 - AC13). Five successive sequences, most of them thicker than the previous ones and made up mainly of silty shales, calcareous siltites and sandy limestones, can be distinguished. Calcareous nodules are scarce. Macrofossils are fre-

Figure 4 - Columnar section at Aguada Colorada (Sierra de Varas), with ammonites occurrences and chronostratigraphical units. Columnar stratigraphique d'Aguada Colorada (Sierra de Varas) avec la position des ammonites et les unités chronostratigraphiques.



quent, but they are usually remains of fragmented shells, often silicified, and crushed by compaction during the early diagenesis. At the bottom of this stratigraphic interval :

Cadomites sp. (m), 1 S.

Iniskinites? sp. (M), 1 S.

Bomburites aff. *suevicus* (ROEMER, 1911) (m), 1 S.
Plate 1, figure 4.

20 m below AC9 level :

Oxyerites sp. (M), 1 S.

Iniskinites sp. (M), frequent.

Xenocephalites sp. (m), 2 S.

Choffatia sp. (M?), 3 S.

10 m below AC11 level :

Oxyerites sp. (M), 6 S.

Iniskinites sp. (M), frequent.

Bullatimorphites sp. (M), 1 S.

Choffatia sp. (M), frequent.

30 m (AC13 - AC14). One sequence made up of calcareous lutites, silty shales and sandy limestones. Macrofossils are abundant but most of them are resedimented. Locally, the presence of pyritic fossils and nuclei of centimeter-sized ammonite shells is frequent. We have identified :

Lissoceras cf. *psilodiscum* (SCHLOENBACH, 1865) (M) + (m?), frequent.

Phlycticeras sp. (M), 1 S.

Oxyerites sp. (M), frequent.

Prohecticoceras sp. (M), 4 S.

Jeanneticeras sp. (m), 1 S.

Cadomites sp., 1 S.

Epistrenoceras ex gr. *paracontrarium* (BURCKHARDT, 1927), frequent.

Parapatoceras distans (BAUGIER & SAUZÉ, 1843), abundant.

Iniskinites sp. (M), frequent.

Lilloettia sp., 1 S.

Xenocephalites sp. (m), 2 S.

Choffatia jupiter (STEINMANN, 1981) (M), 1 S.

Choffatia sp. (M) + (m), frequent.

Among *Parapatoceras*, remains of juvenile forms are more frequent than those of adults. Juvenile forms of *Epistrenoceras* are scarce. The remaining taxonomic groups are represented by adult forms.

BIOSTRATIGRAPHICAL AND BIOCHRONOLOGICAL INTERPRETATIONS

The successions of ammonite assemblages found on the outcrops of the Quebrada de San Pedro and the Aguada Colorada allow the definition of four successive biostratigraphic units, with the rank of biozone, for the Upper Bajocian and Ba-

thonian sediments. Biostratigraphic distribution of the ammonites genera and subgenera, and their relative abundance, are shown in figure 5.

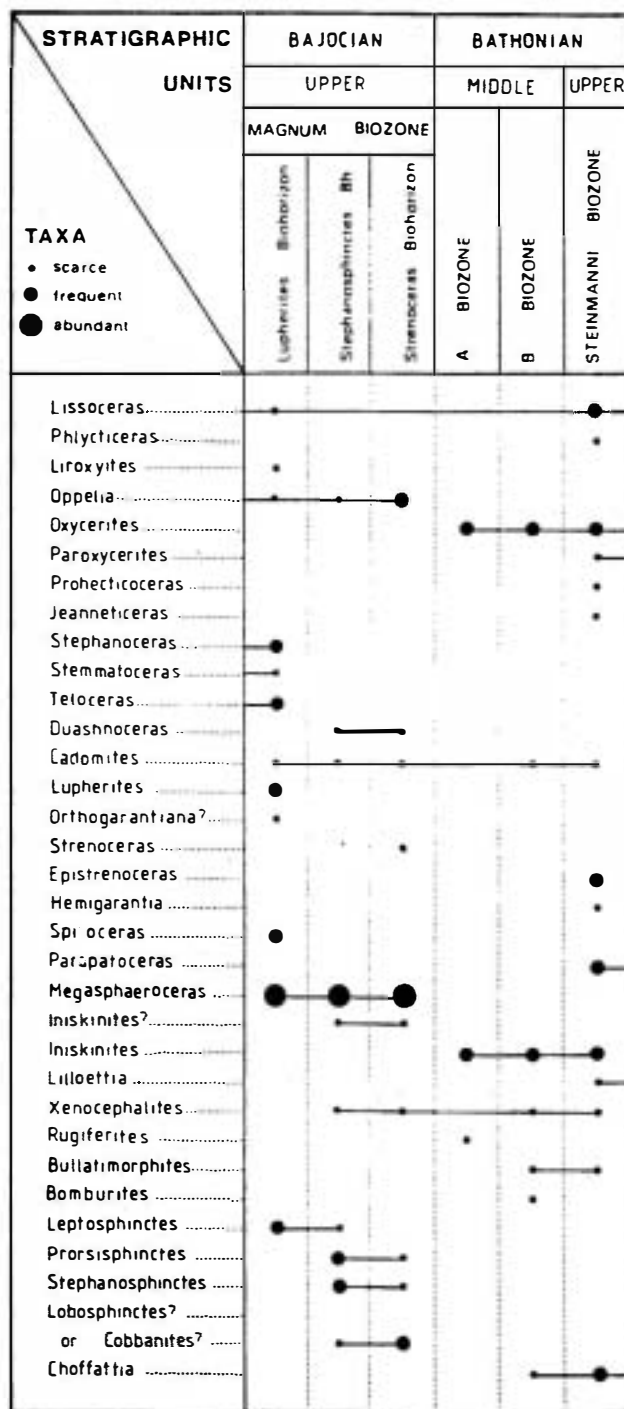


Figure 5 - Biostratigraphic distribution of the ammonites genera and subgenera, and their relative abundance, within Upper Bajocian and Bathonian of the Quebrada de San Pedro and Aguada Colorada. Répartition biostratigraphique des genres et des sous-genres d'ammonites et de leur abondance relative dans le Bajocien supérieur et le Bathonien de Quebrada de San Pedro et d'Aguada Colorada.

For the Upper Bajocian only one biozone has been recognized (Magnum Biozone). The Bathonian ammonites belong to three successive biozones. The first two (Biozone A and Biozone B) must be attributable to the Middle Bathonian, whereas the third (Steinmanni Biozone) corresponds to the Upper Bathonian.

MAGNUM BIOZONE (UPPER BAJOCIAN).

It is characterized by the presence of *Megasphaeroceras magnum* RICCARDI & WESTERMANN. In the Quebrada de San Pedro, this biozone is about 50 m thick and is at least represented by the sediments between SP33 and SP115 levels. In Aguada Colorada, this biozone is up to 150 m thick (AC1 - AC7). Hall & Westermann (1980) have formally established an "Assemblage Zone of *Megasphaeroceras rotundum*", characterized in South Alaska and Oregon (USA) by the index species with *Leptosphinctes*, *Spiroceras* and the last stephanoceratids. This assemblage zone has also been utilized in the Andes, but its denotation has been more generic because the *Megasphaeroceras rotundum* IMLAY species does not seem to be represented (Westermann & Riccardi 1979 ; Riccardi *et al.* 1990a,b). The Magnum Biozone, proposed for the Chilean basin in this paper, at least partly corresponds to the Magnum

Zone and the Rotundum Zone recognized in other Andean and North American basins (cf. Riccardi *et al.* 1991a). Correlation of this biozone with the Niortense Biozone established in Europe (cf. Dietl 1981) and with the Standard Subfurcatum Zone (cf. Pavia 1985) are indicated by the presence of late stephanoceratids, as well as *Leptosphinctes*, *Spiroceras* and *Strenoceras*. In the Cordillera de Domeyko it is possible to distinguish three successive subunits in the rocks from the Magnum Biozone, which we call respectively : Luperites Biohorizon, Stephanosphinctes Biohorizon and Strenoceras Biohorizon.

The Luperites Biohorizon is characterized at its base by the appearance of *Megasphaeroceras magnum* (incl. *M. magnum spissum*), and by the presence of the last *Stephanoceras* and *Teloceras*, which are usually associated with *Spiroceras orbigny*, *Leptosphinctes*, and *Luperites*. Representatives of *Orthogarantiana?* sp., *Oppelia* cf. *subradiata* and *Liroxyites* cf. *kellumi*, are not frequent. This biohorizon is well represented in the Quebrada de San Pedro (SP33 - SP45) and in the Aguada Colorada (AC1 - AC2). It is partially equivalent to the "*Luperites dehmi* Assemblage Subzone" defined by Westermann & Riccardi (1979).

PLATE 1

Fig. 1ab - *Hemigarantia* cf. *julii* (d'ORBIGNY). SP159/5. D = 27,0 ; H = 9,8(0,36) ; E = c.10,6(0,39) ; U = 10,6(0,39) ; Ni/2 = 16 ; Ne/2 = 24.

Fig. 2 - *Epistrenoceras* ex gr. *paracontrarium* (BUCKHARDT, 1927). SP159/3. D = 34,6 ; H = 12,0(0,34) ; E = 16,6(0,48) ; U = 12,3(0,35) ; Ni/2 = 16.

Fig. 3 - *Phlycticeras* sp. (M). SP159/4. D = 37,5 ; H = 17,2(0,45) ; E = 13,0(0,34) ; U = 9,6(0,25) ; Ne/2 = 25.

Fig. 4 - *Bomburites* aff. *suevicus* (ROEMER, 1911) (m). AC8+1/1. D = 24,0 ; H = 10,9(0,45) ; E = 23,2(0,96) ; U = 2,9(0,12).

Fig. 5 - *Iniskinites* sp. nov. C in RICCARDI & WESTERMANN, 1991 (M). SP130/2.

Fig. 6ab - *Tulites* (*Rugiferites*) *angulicostatus* (LISSAJOUS, 1923) (M). SP119/4.

Fig. 7 - *Strenoceras* sp. (m). SP105/4. D = 14,0 ; H = 4,2(0,30) ; U = 6,1(0,43).

Fig. 8 - *Stephanosphinctes* aff. *buitroni* SANDOVAL & WESTERMANN (m). SP107/1. D = 23,9 ; H = 8,1(0,33) ; U = 10,7(0,44) ; Ne/2 = 30.

Fig. 9 - *Megasphaeroceras magnum* RICCARDI & WESTERMANN, 1991 (m). SP111/1. D = 30,5 ; H = 15,1(0,49) ; E = 16,5(0,54) ; U = 3,9(0,12) ; Ne/2 = 28.

Fig. 10 - *Megasphaeroceras magnum* RICCARDI & WESTERMANN, 1991 (M). SP105/1. D = 71,0 ; H = 40,8(0,57) ; E = 35,9(0,50) ; U = 3,4(0,05).

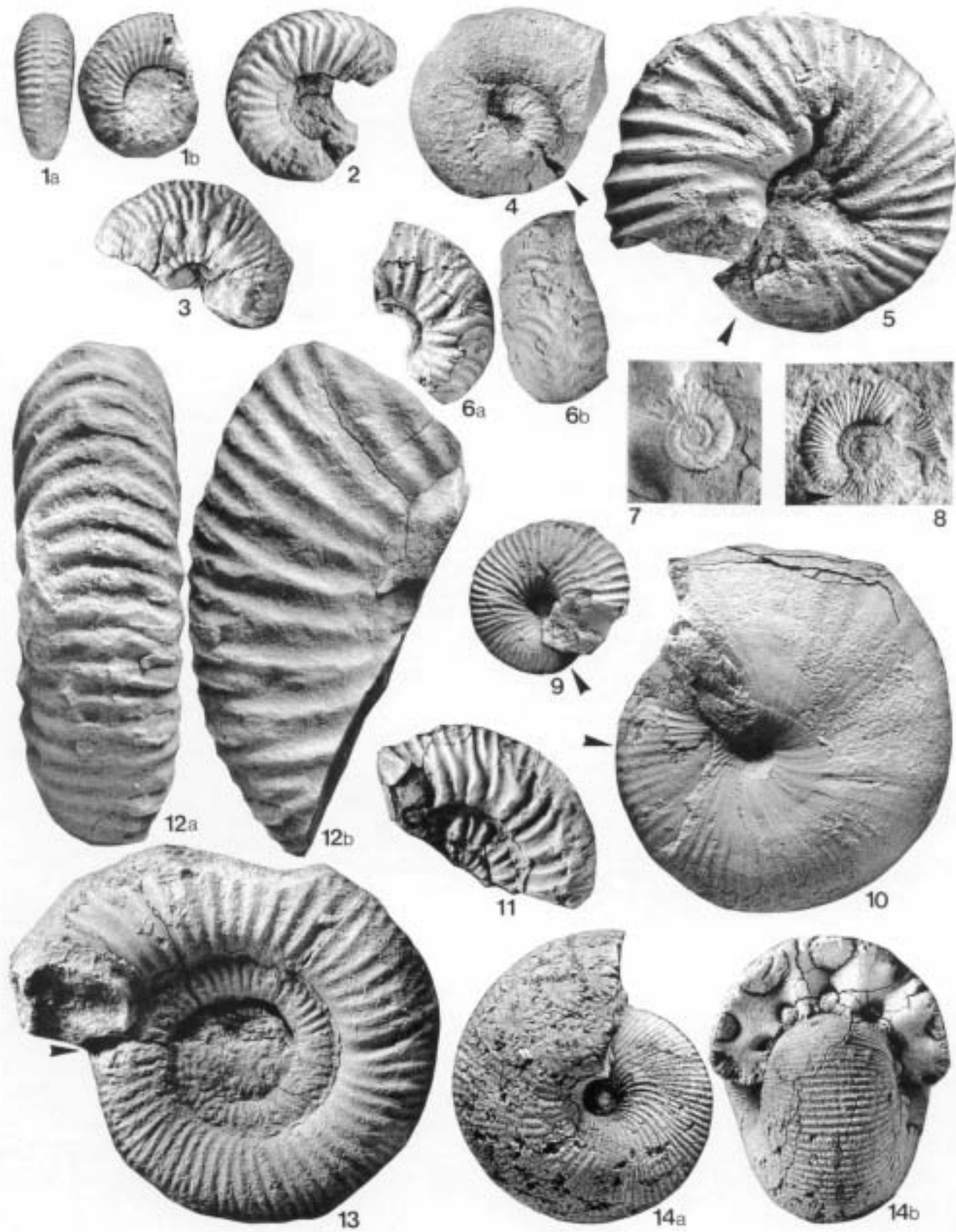
Fig. 11 - *Duashnoceras* aff. *undulatum* (BUCKHARDT, 1927) (m). SP113/8.

Fig. 12ab - *Lobosphinctes?* sp. or *Cobbanites?* sp. (M). SP109/1.

Fig. 13 - *Leptosphinctes* (*Prorsisphinctes*) sp. (M?). AC5-1/1. D = 82,0 ; H = 26,0(0,31) ; E = c.22,8(0,27) ; U = 37,7(0,46) ; Ni/2 = 24.

Fig. 14ab - *Megasphaeroceras magnum spissum* RICCARDI & WESTERMANN, 1991 (M). AC1/1. D = 55,5 ; H = 28,4(0,51) ; E = 45,4(0,81) ; U = 8,7(0,15) ; Ne/2 = 48.

Measurements in mm : D = diameter ; H = whorl height ; W = whorl width ; U = diameter of umbilicus ; Ni/2 = number of primary ribs per half-whorl ; Ne/2 = number of secondary ribs per half-whorl. All figures natural size. The arrow indicates the end of the phragmocone. Mesures données en mm : D = diametre ; H = hauteur du tour ; W = épaisseur du tour ; U = diametre de l'ombilic ; Ni/2 = nombre de côtes internes par demi-tour ; Ne/2 = nombre de côtes externes par demi-tour. Toutes les figures sont en grandeur naturelle. La flèche indique la fin du phragmocône.



In the Stephanosphinctes Biohorizon, *Megasphaeroceras magnum* is found with the first representatives of *Iniskinites?* (M) and *Xenocephalites* (m) group. The *Prorsisphinctes* can outnumber the *Leptosphinctes*. Several new species of *Prorsisphinctes*, *Stephanosphinctes* and other smooth perisphinctids of large size (*Cobbanites?* sp.) are present. The stephanoceratids *Cadomites* and *Duashnoceras* are scarce. This biohorizon is well developed in the Quebrada de San Pedro (SP69 - SP99) and can be recognized in the Aguada Colorado (AC3 - AC5). To date, *Stephanosphinctes* have only been identified in Mexico, together with *Duashnoceras* spp. and *Subcollina lucretia* (d'Orbigny) from the "*Duashnoceras floresi* Zone" (Westermann 1983 ; Sandoval & Westermann 1986).

The *Strenoceras* Biohorizon is characterized by an assemblage which includes *Megasphaeroceras* and *Strenoceras*. The perisphinctids identified as *Lobosphinctes?* or *Cobbanites?* (Plate 1, figs 12ab) are relatively frequent, but their taxonomy remains dubious. The *Oppelia* are also frequent. In this biohorizon there are very few *Duashnoceras* and *Stephanosphinctes*. *Stephanoceras*, *Stemmatoceras* and *Teloceras* are virtually absent. The best rock exposures assigned to this biostratigraphical unit are to be found on Caracoles. The characteristic assemblage has been identified in the Quebrada de San Pedro (SP101 - SP115) on the last five metres of Bajocian sediments. The AC7 - AC8 interval in the Aguada Colorado can correspond to this biohorizon, but the fossils found are still very scarce. The *Strenoceras* of this biohorizon strongly suggest a rough parallelism with the Subfurcatum Zone of Europe.

The Southamerican perisphinctids belonging, according to some authors, to the *Lobosphinctes* are the main biochronological criterium used to defend the possibility that in the Chilean Precordillera the Standard Garantiana and Parkinsoni Zones, established in Europe, are represented. However, in the Caracoles area these perisphinctids (*Lobosphinctes?* or *Cobbanites?*) are associated with *Strenoceras*. It is possible that the Chilean representatives of *Strenoceras* are not as old as the European ones ; however, at present there are not biochronological criteria to confirm that the Garantiana or Parkinsoni Zones are represented in the Chilean Basin.

BIOZONES A AND B (MIDDLE BATHONIAN).

The Bathonian sediments are characterized in the Cordillera de Domeyko by the presence of *Iniskinites* with *Oxycerites* and *Choffatia*. The ex-

treme rarity of non-crushed ammonites from the Middle Bathonian sediments represents a serious difficulty for the establishment of a detailed biostratigraphic scheme. Taking into account the biostratigraphic data from different sedimentary basins obtained by other authors (cf. Westermann & Callomon 1988 ; Sandoval 1983 ; Mangold 1981 ; Galacz 1980), the specimen of *Tulites (Rugiferites) angulicostatus* (LISSAJOUS), found on SP119 level in the Quebrada de San Pedro is the only Bathonian ammonites which probably corresponds to the lower part of the Middle Bathonian. Based on these data it is possible to justify a first "A" Bathonian biozone.

Taking into account the presence of *Cadomites* cf. *bremeri* TSERETELI, the assemblage identified between SP125 and SP131 levels, with a thickness from three to five metres, and containing abundant *Oxycerites* and *Iniskinites*, belongs to younger sediments and corresponds to the upper part of the Middle Bathonian. The ammonite assemblage found in this sediments allow to distinguish a second "B" Bathonian biozone.

In the Aguada Colorado, the Bathonian encompasses a further considerable thickness of silty shales with frequent but crushed ammonites. The presence of *Bomburites* aff. *suevicus* (ROEMER) in the lowest beds of the sequence (AC8 - AC9) is a biostratigraphical reason for suspecting that the Lower Bathonian is missing at this locality.

In the two areas under study we have not found ammonites characteristics of the Lower Bathonian. The two assemblages mentioned above correspond partially to the "*Cadomites-Tulitidae* Mixed Assemblage", which Riccardi *et al.* (1988) have distinguished in the Chacay Melehue area (Argentina). This assemblage was identified bearing in mind the presence of *Cadomites* from the *C. orbigny* (GROSS.) and *C. bremeri* TSERETELI groups, together with scarce *Tulites?* (*Rugiferites?*) cf. *davaiacensis* (LISS.). All these ammonites are characteristics of the Middle Bathonian. However, in Chacay Melehue area most or all *Cadomites* are reworked and recorded in sediments from the Upper Bathonian (Riccardi *et al.* 1990a).

STEINMANNI BIOZONE (UPPER BATHONIAN).

The boundary stratotype of the Steinmanni Zone has been established in Chacay Melehue by Riccardi *et al.* (1989a), and has been recognized in the North of Chile and in Mexico (cf. Riccardi *et al.* 1990b, Sandoval *et al.* 1990). To the Stein-

manni Biozone correspond the Quebrada de San Pedro sediments found between SP141 and SP161 levels, which are up to 10 m thick. Sediments in the Aguada Colorada are thicker than 30 m (AC13 - AC14) and ammonites are more abundant. Apart from the other forms comparable to the index species, it is noteworthy the relative abundance of *Choffatia* gr. *jupiter* (STEINMANN) and *Iniskinites* spp. in the lower part of this biozone. Above these levels relatively frequent is the presence of representatives of *Epistrenoceras* ex gr. *paracontrarium* (BURCKHARDT, 1927) and *Parapatoceras distans* (BAUGIER & SAUZÉ), as well as the first *Oxycerites* (*Paroxycerites*) gr. *exoticus* (STEINMANN). *Lissoceras* are frequent locally in some levels. *Prohcticoceras* and *Phlycticeras* are usually scarce. There are rare specimens which show a close similarity with members of the *Hemigarantia julii* (d'ORBIGNY) group, along with *Prohcticoceras blanazense* ELM1, in SP159 level. These ammonite assemblages of the Steinmanni Biozone are comparable to those found in the middle and upper parts of the European Retrocostatum Zone (cf. Westermann *et al.* 1984, 1988 ; Riccardi & Westermann 1991a).

Among the Upper Bajocian and Bathonian ammonites of the Cordillera de Domeyko, Eurycephalitinae predominates in most of the stratigraphical levels. *Megasphaeroceras* and *Iniskinites* are widespread fossils, among which juveniles can outnumber the adult forms. These ammonites were endemic (*sensu* Callomon 1985) in the Chilean basin. At isolated levels, *Lissoceras*, *Epistrenoceras*, *Spiroceras*, and *Parapatoceras* are also locally quite abundant and consist of microconchs and macroconchs, including juveniles and adult forms. These data suggest that ammonites may have colonized the basin at least during two episodes, concerning the lower part of the Magnum Biozone (Lupherites Bh.) and the Steinmanni Biozone.

On the contrary, *Oppelia*, *Oxycerites*, *Paroxycerites*, *Stephanoceras*, *Teloceras*, *Cadomites*, *Lupherites*, *Strenoceras*, *Leptosphinctes*, *Prorsisphinctes*, *Stephanosphinctes*, *Cobbanites?* and *Choffatia*, although locally may be frequent, are almost exclusively adult forms. The *Phlycticeras*, *Liroxyites*, *Prohcticoceras*, *Jeanneticeras*, *Duashnoceras*, *Orthogarantiana?*, *Hemigarantia*, *Rugiferites*, *Bullatimorphites* and *Bomburites* are a minority, exclusively adult forms, restricted to sporadic levels. All these genera and subgenera probably were ademic (cf. Fernández-López 1991) in the Chilean basin, and they could have been the result of post-mortal dispersion of empty shells from distant regions.

CHRONOSTRATIGRAPHIC UNITS			Biostratigraphic Units
STAGES	ZONES		
BATHONIAN	UPPER	DISCUS	Steinmanni Biozone
		RETROCASTATUM	
	MIDDLE	BREMERI	B Biozone
		SUContractus	A Biozone
		PROGRACILIS	
J.	ZIGZAG		
BAJOCIAN	UPPER	PARKINSONI	HIATUS
		GARANTIANA	
		SUBFURCATUM	

Strenoceras Biohorizon
Stephanosphinctes Bh.
Lupherites Biohorizon

Figure 6 - Correlation chart of the Upper Bajocian and Bathonian biostratigraphic units recognized in the Caracoles area, scaled on the Submediterranean standard zonation. *Tableau de corrélation des unités biostratigraphiques du Bajocien supérieur et du Bathonien de Caracoles, comparées avec la zonation Standard de la province subméditerranéenne.*

The biostratigraphic units recognized in the Caracoles area, and their suggested correlation with the European Standard Zones, are shown in figure 6. The presence of a stratigraphic discontinuity between the Upper Bajocian and the Bathonian in the Caracoles area is corroborated by the obtained sedimentological and biostratigraphical data. The interval SP101-SP115 is a coarsening-upward sequence, which is bounded above by an overall fining-upward sequence (SP115-SP125). This boundary is a paraconformity between two carbonate sequences developed in a marine environment on a carbonate platform with abundant siliciclastic supply. The sequential sedimentation feature is more noticeable in Sierra de Varas, although sediments from these meridional areas present a higher concentration of siliciclastic components, attain larger thickness, and must have been the result of higher sedimentation rates. In Aguada Colorada, the interval AC7 - AC8 represents a coarsening-upward sequence, but it is poorly fossiliferous. Lithology and thickness of these sections are very variable and a lithostratigraphical correlation is not possible. Each one of the two locality has a distinctive sedimentation pattern. In the Quebrada de San Pedro section the quick and irregular variations in thickness and lithology suggest a more near-shore deposition than in the Aguada Colorada section. In the Caracoles area at least, there is a stratigraphic break comprising the Garantiana, Parkinsoni and Zigzag Biochrones.

This large hiatus filled well with the earlier belief that the Cordilleran regions of both North and South America had experienced a major regression at that time (cf. Hall 1988, 1984). Nevertheless, biostratigraphical and sedimentological differences between the different areas in the Cordillera de Domeyko, for the Bajocian and Bathonian, are not only due to eustatic changes and processes of subsidence, but also to the platform structural segmentation. Data recently obtained (Fernández-López, Chong & Wilke, in preparation) show that this marine platform was structurally differentiated in blocks and affected by active fractures during the Early Bajocian. For these reasons, other areas in the Cordillera de Domeyko, where more complete sections than those of Caracoles or Aguada Colorada, might exist.

CONCLUSIONS

The obtained biostratigraphical and sedimentological data indicate the existence of a regional discontinuity at the base of the Bathonian. In all the outcrops studied so far, the Upper Bajocian is only represented by the Magnum Biozone, even where the sediments from this substage are more than 150 m of thick. It is possible to distinguish three successive biohorizons : Luperites Bh., Stephanosphinctes Bh. and Strenoceras Bh. At least in the Caracoles area there is a stratigraphic break comprising the Garantiana, Parkinsoni and Zigzag Biochrones. In the Quebrada de San Pedro there are ammonites characteristic of the Middle Bathonian. The Upper Bathonian is widely represented in the Cordillera de Domeyko by Steinmanni Biozone sediments.

Acknowledgements - This research was funded by the projects "Estudio de facies marinas bajocienses en la Cordillera de Domeyko, Chile" (DGICYT, BE90-277, Ministerio de Educación y Ciencia de España) and "Programa de Investigación en Geología Regional" (Departamento de Ciencias Geológicas, Universidad Católica del Norte, Chile).

REFERENCES

- BAEZA L. 1979 - Distribución de facies sedimentarias marinas en el Jurásico de Cerritos Bayos y zonas adyacentes, norte de Chile. *II Congr. Geol. Chileno*, Arica, **3** : H45-H61.
- BOGDANIC T. 1983 - Antecedentes Generales y Bioestratigrafía del Sistema Jurásico en la Zona Preandina entre los 24° 30' y los 25° 30' de lat. sur y los 69° 00' y 69° 30' de long. oeste, II Región de Antofagasta-Chile. *Tesis Univ. del Norte, Dpto. Geociencias*, Antofagasta : 1-240 (unpublished).
- BOGDANIC T. & CHONG G. 1985 - Bioestratigrafía del Jurásico de la Zona Preandina chilena entre los 24° 30' - 25° 30' de Lat. Sur. *IV Congr. Geol. Chileno*, Antofagasta, **1** : 38-57.
- BURCKHARDT C. 1903 - Beiträge zur Kenntnis der Jura- und Kreideformation der Cordillere. *Palaeontographica*, **50** : 1-144.
- CALLOMON J.H. 1985 - The evolution of the Jurassic ammonite family Cardiocerataidae. *Special Papers in Paleontology*, **33** : 49-90.
- CHONG G. 1973 - El Sistema Jurásico en la Cordillera de Domeyko (Chile) entre 24° 30' y 25° 30' de Lat. Sur. *II Congr. Latinoam. Geol.*, Caracas : 765-785.
- CHONG G. 1977 - Contribution to the knowledge of the Domeyko Range in the Andes of Northern Chile. *Geol. Rundsch.*, **66** : 374-404.
- COVACEVICH V. & PIRACÉS R. 1976 - Hallazgo de Ammonites del Bajociano superior en la Cordillera de la Costa de Chile Central entre la Cuesta El Melón y Limache. *Primer. Congr. Geol. Chileno*, Concepción, **1** : 67-85.
- DIETL G. 1981 - Zur systematischen Stellung von *Ammonites subfurcatus* ZIETEN und deren Bedeutung für die *subfurcatum*-Zone (Bajocium, Mittl. Jura). *Stuttgarter Beitr. Naturk.*, (B), **81** : 1-11.
- FERNANDEZ-LOPEZ S. 1991 - Taphonomic concepts for a theoretical Biochronology. *Revista Española de Paleontología*, **6** : 37-49.
- FERNANDEZ-LOPEZ S., CHONG G. & WILKE H.-G. (en preparación) - Sedimentación y volcanismo durante el Jurásico medio en la Precordillera chilena entre 21°45' y 22°00'S.
- GALACZ A. 1980 - Bajocian and Bathonian ammonites of Gyenespuszta, Bakony Mts., Hungary. *Geol. Hung.*, ser. paleont., **39** : 1-227.
- GRÖSCHKE M. & HILLEBRANDT A.v. 1985 - Trias und Jura in der mittleren Cordillera Domeyko von Chile (22° 30' - 24° 30'). *N. Jb. Geol. Paläont. Abh.*, **170** : 129-166.
- GRÖSCHKE M., HILLEBRANDT A. v., PRINZ P., QUINZIO L.A. & WILKE H.-G. 1988 - Marine Mesozoic Paleogeography in Northern Chile between 21° - 26° S. *Lecture Notes Earth Sci.*, **17** : 105-117.
- HALL R.L. 1984 - Lithostratigraphy and biostratigraphy of the Fernie Formation (Jurassic) in the southern Canadian Rocky Mountains. *Canadian Society of Petroleum Geologists Memoir*, **9** : 233-247.
- HALL R.L. 1988 - Late Bajocian and Bathonian (Middle Jurassic) ammonites from the Fernie Formation, Canadian Rocky Mountains. *J. Paleont.*, **62** : 575-586.
- HALL R.L. & WESTERMANN G.E.G. 1980 - Lower Bajocian (Jurassic) Cephalopod Faunas from Western Canada and Proposed Assemblage Zones for the Lower Bajocian of North America. *Palaeontographica Americana*, **9** (52) : 1-93.
- HARRINGTON H.L. 1961 - Geology of parts of Antofagasta and Atacama Provinces, Northern Chile. *Am. Assoc. Petrol. Geol. Bull.*, **45** : 169-197.
- HILLEBRANDT A. v. 1970 - Zur Biostratigraphie und Ammoniten-Fauna des südamerikanischen Jura (insbes. Chile). *N. Jb. Geol. Paläont. Abh.*, **136** : 166-211.
- HILLEBRANDT A. v. 1972 - Sobre la bioestratigrafía y la fauna de ammonites del Jurásico de América del Sur (especialmente de Chile). *Publ. Dpto. Geología Univ. Chile*, **39** : 1-50.

- HILLEBRANDT A. v. 1973 - Neue Ergebnisse über den Jura in Chile und Argentinien. *Münster. Forsch. Geol. Palaeontol.*, **31/32** : 167-199.
- HILLEBRANDT A. v. 1977 - Ammoniten aus dem Bajocien (Jura) von Chile (Südamerika). Neue Arten der Gattungen *Stephanoceras* und *Domeykoceras* n. gen. (Stephanoceratidae). *Mitt. Bayer. Staatslg. Paläont. Hist. Geol.*, **17** : 35-69.
- HILLEBRANDT A. v., GRÖSCHKE M., PRINZ P. & WILKE H.-G. 1986 - Marines Mesozoikum in Nordchile zwischen 21° und 26°S. *Berliner geowiss. Abh.*, **66** : 169-190.
- JENSEN A. & QUINZIO L.A. 1979 - Geología del Area de Pampa Elvira y contribución al conocimiento del Jurásico marino entre los 23° 00' y 23° 30' Latitud Sur y los 68° 45' y 69° 03' Longitud Oeste. II Región de Antofagasta, Chile. *Memoria Univ. del Norte, Dpto. Geociencias, Antofagasta* : 1-141 (unpublished).
- JENSEN A. & QUINZIO L.A. 1981 - Hallazgo de Batoniano y descripción de facies sedimentarias marinas del Dogger en Quebrada San Pedro, Caracoles, II Región - Antofagasta (Chile). *Estudios geol.*, **37** : 209-214.
- MANGOLD Ch. 1981 - Le Bathonien de l'Est du Subbétique (Espagne du Sud). *Cuad. Geol.*, **10** (1979) : 271-281.
- MONTAÑO J. 1976 - Estudio Geológico de la Zona de Caracoles y áreas vecinas, con énfasis en el Sistema Jurásico. Provincia de Antofagasta, II Región, Chile. *Tesis Univ. Chile, Dpto. Geología, Santiago* (unpublished).
- PAVIA G. 1985 - Report of the Bajocian working group. *Intern. Symp. Jurassic Strat.*, Erlangen 1984 : 55-65.
- RICCARDI A.C., WESTERMANN G.E.G. & ELMIS S. 1988 - Las Zonas de Ammonites del Bathoniano-Calloviano inferior de los Andes Argentino-Chilenos. *V Congr. Geol. Chileno, Santiago*, **2** : C415-C426.
- RICCARDI A.C., WESTERMANN G.E.G. & ELMIS S. 1989 - The Bathonian-Callovian Ammonite Zones of the Argentine-Chilean Andes. *2nd Intern. Symp. Jurassic Strat.*, Lisboa 1987 : 347-358.
- RICCARDI A.C., WESTERMANN G.E.G. & ELMIS S. 1990a - The Middle Jurassic Bathonian-Callovian Ammonite Zones of the Argentine-Chilean Andes. *Geobios*, **22** : 553-597.
- RICCARDI A.C., WESTERMANN G.E.G. & DAMBORENEA S.E. 1990b - Middle Jurassic of South America and Antarctic Peninsula. *Newsl. Stratigr.*, **21** : 105-128.
- RICCARDI A.C. & WESTERMANN G.E.G. 1991a - Middle Jurassic ammonite fauna and biochronology of the Argentine-Chilean Andes. Part III : Bathonian-Callovian Eurycephalitinae, Stephanocerataceae. *Palaeontographica*, **216** : 1-110.
- RICCARDI A.C. & WESTERMANN G.E.G. 1991b - Middle Jurassic ammonite fauna and biochronology of the Argentine-Chilean Andes. Part IV : Bathonian-Callovian Reineckeidae. *Palaeontographica*, **216** : 111-145.
- SANDOVAL J. 1983 - Bioestratigrafía y Paleontología (*Stephanocerataceae* y *Perisphinctaceae*) del Bajocense y Bathonense en las Cordilleras Béticas. *Tesis Doct. Univ. Granada* (1982) : 1-613,
- SANDOVAL J. & WESTERMANN G.E.G. 1986 - The Bajocian ammonite fauna of Oaxaca. *J. Paleont.*, **60** : 1220-1271.
- SANDOVAL J., WESTERMANN G.E.G. & MARSHALL M.C. 1990 - Ammonite fauna, stratigraphy and ecology of the Bathonian-Callovian (Jurassic) Tecocoyunca Group, South Mexico. *Palaeontographica*, **210** : 93-149.
- STEHN E. 1923 - Beiträge zur Kenntnis des Bathonian und Callovian in Südamerika. *N. Jb. Min. Geol. Pal.*, **49** : 52-158.
- STEDTMANN G. 1881 - Zur Kenntnis der Jura- und Kreideformation von Caracoles (Bolivia). *N. Jb. Min. Geol. Pal.*, **49** : 239-301.
- TORNQUIST A. 1898 - Der Dogger am Espinazito-Pass, nebst einer Zusammenstellung der jetzigen Kenntnisse von der argentinischen Juraformation. *Paläont. Abh. Jena*, **8** : 1-135.
- WESTERMANN G.E.G. 1967 - Sucesión de ammonites del Jurásico medio en Antofagasta, Atacama, Mendoza y Neuquen. *Rev. Asoc. Geol. Argent.*, **22** : 65-73.
- WESTERMANN G.E.G. 1981 - Ammonite Biochronology and Biogeography of the Circum Pacific Middle Jurassic. In HOUSE M.R. & SENIOR J.R. (eds.) : "The Ammonoidea". *Syst. Ass. Spec. Vol.*, London, **18** : 459-498.
- WESTERMANN G.E.G. 1983 - The Upper Bajocian and Lower Bathonian (Jurassic) ammonite faunas of Oaxaca, Mexico and West-Tethyan affinities. *Paleontol. Mexicana*, **46** (1981) : 1-63.
- WESTERMANN G.E.G. & RICCARDI A.C. 1979 - Middle Jurassic ammonoid fauna and biochronology of the Argentine-Chilean Andes. Part II : Bajocian Stephanocerataceae. *Palaeontographica*, **164** : 85-188.
- WESTERMANN G.E.G. & RICCARDI A.C. 1980 - The Upper Bajocian Ammonite *Strenoceras* in Chile : first circum-Pacific record of the Subfurcatum Zone. *Newsl. Stratigr.*, **9** : 19-29.
- WESTERMANN G.E.G., CORONA R. & CARRASCO R. 1984 - The Andean Mid-Jurassic *Neuquenicer* ammonite assemblage of Cualac, Mexico. *Geol. Assoc. Canada Spec. Paper*, **27** : 99-112.
- WESTERMANN G.E.G. & RICCARDI A.C. 1985 - Middle Jurassic Ammonite Evolution in the Andean Province and Emigration to Tethys. *Lecture Notes Earth Sci.*, **1** : 6-34.
- WESTERMANN G.E.G. & CALLOMON J.M. 1988 - The Macrocephalitinae and associated Bathonian and Early Callovian (Jurassic) ammonoids of the Sula Islands and New Guinea. *Palaeontographica*, **203** : 1-90.

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