Review of the Cambrian Stratigraphy of the Argentine Precordillera

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The Cambrian rocks of the Argentine Precordillera are analyzed and updated providing a new stratigraphic interpretation. The lithostratigraphic assemblages provide evidence that the Precordilleran Cambrian Basin was a rimmed platform. The lithostratigraphy record enables to distinguish three large areas corresponding to an inner platform, an outer platform to slope environment and a mixed zone where both platforms and the rim interfinger. The biostratigraphic proposal based on trilobites include restricted shelf biozones to the East, characterized by sparse, endemic and low diversity polymeroid faunas. Moreover, to the West outer shelf biozones are characterized by widespread, high diversity, mixed endemic and cosmopolitan polymeroid and agnostoid faunas. The lithostratigraphic and biostratigraphic data prove the existence of an important hiatus near the Lower-Middle Cambrian boundary, which is correlated to the Hawke Bay regressive event recorded along the eastern margin of Laurentia. The *Olenellus* Zone assemblage trilobites underlies the *Glossopleura* or the *Ehmaniella* Zone. The early Middle Cambrian zones (from *Plagiura*-*Poliella* to *Albertella*) are lacking in the whole Precordillera.


INTRODUCTION

The presence of Cambrian rocks in the Argentine Precordillera has been known since the last century and they have been the object of numerous studies from the stratigraphic, paleontologic, sedimentologic as well as geodynamic viewpoints. The last decade has seen publication of several interpretative reference proposals in terms of the origin of the Precordillera terrane, linking it to a Laurentian origin, with the subsequent drift and collision against Gondwana. Also during recent years, there have been many contributions yielding new data for the regional stratigraphic interpretation.

This paper is a summarized update of what is known about the Cambrian stratigraphy in the Precordillera, and mainly analyzes the lithostratigraphic units and trilobites biozones assembled in a rimmed platform palaeogeographic model.

GEOLOGICAL SETTING

The Precordillera is a morphostructural province in the central western pre-Andes of Argentina, placed between the Western Sierras Pampeanas to the east and the Cordillera Frontal to the west, with extended longitudinal valleys between them both. The Cambrian rocks of the Precordillera are distributed over 400 km from N to S and, having a maximum E-W extension of 66 km; They extend from the southern part of the province of La Rioja, across the center of the province of San Juan and to the northern part of the province of Mendoza (Fig. 1). Within this belt, it is possible to differentiate inner platform facies in its eastern part (Precordillera Oriental and Central) close to the Sierras Pampeanas, while the outer platform rocks are located in its western part (Precordillera Occidental) close to the Cordillera Frontal (Bordonaro, 1992). The southern end is named Precordillera Mendocina, where mixed out-
FIGURE 1: Distribution of Cambrian outcrops in the Argentine Precordillera, differentiated into inner platform, outer platform and mixed outer and inner platform. The Precambrian basement is also indicated.
crops of inner and outer platform and rim facies exist (Banchig and Bordonaro, 1997). Figure 1 shows the location of 25 outcrops with critical sections or paleontological localities essential to the assemblage of the regional framework of the Precordillera Cambrian stratigraphy. Figure 2 shows an updated synthesis of the Cambrian stratigraphy, using the chronostatigraphy of North America as proposed by Palmer (1998).

Similarities between the Cambrian carbonate lithofacies and faunas of both the Appalachian and the Precordillera suggest that the Precordillera was an allochthonous terrane accreted to Gondwana during the Ordovician (Astini et al., 1996).

CAMBRIAN LITHOSTRATIGRAPHIC UNITS
Autochthonous Units

These units are distributed within the Precordillera Oriental and Central as inner platform facies, except in the Precordillera Mendocina, where the facies belong to the inner-platform and rim and outer platform types (Fig. 1). This complete stratigraphic succession, predominantly carbonates, ranges from the upper Lower Cambrian to the Lower Ordovician, (Fig. 2). Below follows a brief synthesis of the characteristics of each unit.

Cerro Totora Formation

This unit crops out at the Totora Hill (1 in Fig. 1), west of Guandacol, in the La Rioja Precordillera (Astini and Vaccari, 1996). The unit is composed of shales, red sandstones, siltstones, laminated gypsum, calcareous dolomites, claystones and cyclically laminated sandstones. Toward the top, the formation contains olenellids (*Arcuolenellus megafrontalis* VACCARI) belonging to the *Olenellus* Zone of the late Lower Cambrian (Vaccari, 1988).

La Laja Formation

This formation is distributed along the western flank of the Villicum, Chica de Zonda and Pedernal Ranges (Borrello, 1962, emended Bordonaro, 1980; 10, 16 and 18 in Fig. 1). It consists of limestones, argillaceous limestones and marlstones or siltstones arranged in four members, reaching a thickness of almost 700 m. These members were named by Baldis and Bordonaro (1981) as El Estero, Soldano, Riva- davia and Juan Pobre (Fig. 2). Originally the depositional record of this unit was considered to be continuous from the late Early Cambrian to the Lower Ordovician. (Fig. 2). Below follows a brief synthesis of the characteristics of each unit.

Los Hornos Formation

This unit has been informally defined at the locality of Totora Hill, west of Guandacol, La Rioja (Astini and Vaccari, 1996; 1 in Fig. 1). The formation is formed by massive dolomites corresponding to deposits of a shallow hypersaline platform. It could be of Middle Cambrian age, owing to the fact it overlies paraconformably the Cerro Totora Formation, even though lithologically it could be correlated to the Zonda Formation which is of Upper Cambrian age.

Zonda Formation

This formation is distributed along the entire Precordillera Oriental and also at the La Silla Hill in Yáchal (Bordonaro, 1980; 7, 10, 11, 14, 15, 16, 17 and 18 in Fig. 1). It is composed of a succession of 300 m of dolomitic limestones and dolomites with shallow-water sedimentary structures, especially microbial lamination and stromatolites. Arroqui Langer and Bordonaro (1996) recognized hypersaline shallowing-upward cycles in this unit. At present, no fossils have been found that would allow dating, but because of its stratigraphic position it is assigned to the early Late Cambrian.

La Flecha Formation

This unit crops out mostly in the Precordillera Oriental and Central of San Juan and La Rioja (Baldis et al., 1981; 2, 3, 5, 7 to 11 and 14 to 18 in Fig. 1). With an average thickness of 500 m, it is characterized by a shallowing-upward, cyclic alternation of cherty limestones and dolomites, with abundant stromatolitic and thrombolitic patch reefs with diverse forms (Keller et al., 1989; Armel la, 1994). The age of this formation varies within the Late Cambrian, with trilobites indicating Steptoean and Sunwaptan age (Keller et al., 1994).

La Silla Formation

This unit is largely found in the Precordillera Oriental and Central of San Juan and La Rioja, from Guandacol to the Pedernal Hill (Keller et al., 1994; 2 and 18 in Fig. 1). It is composed of 400 m of dark-gray limestones with intercalations of laminated dolomite, peloidal grainstones, intraclastic grainstones and lime mudstones, with abundant bioturbation. The base of the formation contains trilobites from the *Saukia* Zone of the Upper Cambrian and the remainder of the unit contains conodonts from the Lower Ibexian (Keller et al., 1994).

Alojamiento Formation

This unit crops out at the Alojamiento and Santa Clara Ranges between San Juan and Mendoza (Harrington, 1971; emended by Banchig and Bordonaro, 1997; 20 and 21 in Fig. 1). It is composed of limestones and dolomites,
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with intercalations of sandstone, shales and calcareous breccias, indicating outer platform environments near the base, with inner platform and rim settings in the rest of the unit. The Middle Cambrian age of the base is shown by a trilobite fauna belonging to the *Ptychagnostus gibbus* and *Oryctocephalus* zones.

**Cerro Pelado Formation**

This unit stretches along the ridge of the Pelado Hill west of the city of Mendoza (Heredia, 1996; 24 in Fig. 1). Toward the base, it contains conglomerates and sandstones, bioturbated wackestones and packstones. In the middle part there are thrombolitic boundstones with chert, and the upper part contains bioturbated wackestones-packestones. The top is of late Steptoean-early Fraconian age with trilobites from the *Elvinia* Zone, while the age of the base is unknown.

**El Relincho Formation**

This formation crops out at the Pelado Hill (Heredia, 1996; 24 in Fig. 1) and is characterized by dark, laminated lime mudstones alternating with dark shales. The age of the basal beds is latest Cambrian, as shown by *Proconodontus tenuiserratus* Zone (Heredia, 1996) and by trilobites of the *Saukia* Zone (Shergold et al., 1995). The age of the shales at the top is unknown.

**Unnamed Formation**

This is a newly recognized unit by Bordonaro et al. (1999), cropping out at Totoral to the northwest of Mendoza city (23 in Fig. 1). It contains massive limestones of shallow platform origin in the lower part, black lime mudstones and calcareous shales of an outer platform and upper slope environment in the middle part, and black

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**FIGURE 2** Cambrian stratigraphic record of the Argentine Precordillera grouping the stratigraphic successions into an inner platform, slope - outer platform and mixed zones. The names of the olistoliths correspond to the localities where they are found. Laurentian chronology is after Palmer (1998).
shales at the top. At the base of the unit species of *Bathyuriscus* and *Bathyuriscidella* trilobites, representing the Middle Cambrian *Oryctocephalus* Zone, are found.

**Allochthonous Units (Olistoliths)**

A number of allochthonous blocks (olistoliths) are located along the Precordillera Occidental of San Juan and in the Precordillera Mendocina at numerous localities (Fig. 2). They are composed mainly of limestones and are enclosed in Middle and Upper Ordovician olistostromes of the Los Sombreros and Empozada formations (Bordonaro et al., 1999; see also Beresi in this volume). Many of these olistoliths are small, ranging from a few centimeters to a few meters in size. Others, have sizes ranging from several tens of meters to several hundreds of meters.

**Ancaucha Olistolith**

This is an olistolith located at the Ancaucha gulch, north of the Jáchal River (Astini and Thomas, 1999a; 4 in Fig. 1). It is composed of sandstones and shales, with beds of bioclastic grainstones containing olenellid and Salterella faunas of late Early Cambrian age.

**San Martín Olistolith**

This body is a resedimented megablock in the Empozada Formation cropping out in the San Isidro area, near Mendoza city (Bordonaro et al., 1993; 25 in Fig. 1). It is composed of alternating limestones, marlstones and black shales deposited as periplatform carbonate muds and contains agnostoids from the late Middle Cambrian age.

**San Isidro Olistoliths**

These are several medium-sized olistolithic blocks, enclosed in the Empozada Formation, and cropping out in the San Isidro area, Mendoza (Bordonaro et al., 1993; 25 in Fig. 1). They are composed of marlstones and oncolitic limestones. Some of these blocks contain trilobites from the *Glossopleura* Zone, and others ones from the *Oryctocephalus* Zone.

**La Cruz Olistoliths**

This is a set of small and medium-sized carbonate olistoliths within the Empozada Formation, outcropping at San Isidro (Bordonaro, 1992; 25 in Fig. 1). They contain trilobites from the Upper Cambrian, belonging to the *Saukia*, *Elvinia*, *Glyptagnostus reticulatus* and *Crepicephalus* zones.

**Los Sombreros Olistoliths**

This is a set of large olistoliths within the Los Sombreros Formation and located at the Los Sombreros stream, Tontal Range (Bordonaro and Banchig, 1996; 19 in Fig. 1). They are composed of dark limestones and contain trilobites from the Middle Cambrian (*Tonkinella stephensis* KOBAYASHI, *Bathyuriscus* aff. *rotundatus* Rasetti); and the Upper Cambrian (*Glyptagnostus reticulatus, Angelin*). These olistoliths also contain ibexian conodonts of the *Cordylodus proavus* Zone (Lehnert, 1994).

**Ojos de Agua Olistoliths**

This is a group of small and medium-sized blocks within the Los Sombreros Formation. These olistoliths crop out at the Ojos de Agua section, of the eastern flank of the Tontal Range (Bordonaro and Banchig, 1996; 13 in Fig. 1). These blocks belong to the outer platform facies and contain trilobites such as *Tonkinella stephensis* KOBAYASHI, *Bathyuriscus* aff. *rotundatus* Rasetti and *Glossopleura* aff. *leona* LOCHMAN, from the Middle Cambrian and *Pseudagnostus idalis* OPIK, from the Upper Cambrian also occurs.

**Los Ratones Olistoliths**

These olistoliths form a set of small blocks within the Los Sombreros Formation and are exposed at the northern end of the Tontal Range, in the Los Ratones gulch (Bordonaro and Banchig, 1996; 12 in Fig. 1). They are composed of shales and calcareous shales from the platform margin, containing middle Cambrian trilobites such as *Kootenia* sp. and *Glossopleura* sp.

**Los Túneles Olistoliths**

These olistoliths are located within the Los Sombreros Formation and are exposed at the Los Túneles Range along the Jáchal River (Bordonaro and Banchig, 1996; 6 in Fig. 1). They are two large carbonate olistoliths from the outer platform facies (Benedetto and Vacari, 1992). The first one contains a fauna of *Olenellus* sp. and *Sombrerella argentina* VACCARI and BORDONARO, from the low Lower Cambrian, and the second one *Chilometopus tunelensis* VACCARI and BORDONARO, and *Ptychagnostus praecurrens* WESTERGARD, from the Middle Cambrian (Vaccari and Bordonaro, 1993).

**Solitario Olistolith**

This olistolith crops out in Solitario Hill, North of Mendoza city (Bordonaro and Banchig, 1996; 22 in Fig. 1). It is considered that this unit has the characteristics of an olistolithic body owing to its dimensions and synsedimentary deformation, although it is impossible to observe its relationship with the host rock; its position could also be caused by tectonic emplacement. It consists of black limestones, intercalated with dark calcare-
ous shales from the deeper periplatform setting. It contains agnostoid trilobites from the late Middle Cambrian *Lejopyge laevigata* Zone.

**CAMBRIAN BIOSTRATIGRAPHIC UNITS**

The biostratigraphic units recognized throughout the entire Precordillera are defined on the basis of either polynoid or agnostoid trilobites. In the stratigraphic chart (Fig. 2), the units are grouped in inner platform biozones, defined by Laurentian endemic polynoids, and outer platform biozones, defined by both endemic and cosmopolitan agnostoids and polynoids.

**Inner Platform Biozones**

**Olenellus Zone (Lower Cambrian)**

Borrello (1963, 1964) documented the presence of the Lower Cambrian with *Fremontella inopinata* BORRELLO, found at the southwestern extreme of the Villicum Range and northeast of the Chica of Zonda Range. Later Borrello (1971) assigned it to the upper *Olenellus* Zone, limited to the basal part of the La Laja Formation. The original elements mentioned by Borrello in this biozone are: *Payerides? dubius* HUPE, *Laudonia* sp., *Olenellus aff. brachycephalus* (EMMONS), *Fremontella inopinata* BORRELLO, *Eoptychoparia acuminita* HUPE, *Villicumia borrelloi* HUPE, *Zacanthoides* *sp.*, *Paedeumias* *sp.* and *Kootenia* sp. Bordonaro (1986) recognized the *Bonnia-Olenellus* Zone in the El Estero Member through findings of *Olenella zondaensis* BORDONARO, Bonnia villicumica BORDONARO, *Antagmus argenti-nus*, *Bordonaro* and *Bristolia* sp. Astini and Vaccari (1996) recognized *Arcuolenella megalfrontalis* VACCARI, characteristic of the upper part of the *Olenellus* Zone in the Cerro Totora Formation, La Rioja. Bordonaro and Banchig (1996) demonstrated that the *Olenellus* Zone can be recognized in the entire late Lower Cambrian of the San Juan and La Rioja Precordillera after the concept of Palmer and Repina (1993).

**Ehmaniella Zone (Middle Cambrian)**

This biozone was established in the Precordillera by Bordonaro and Banchig (1996), in agreement with the concepts of Sundberg (1994), to replace the *Bathyuriscus – Elrathina* Zone adopted by Borrello (1971). This biozone is present in most of the Soldano Member of the La Laja Formation, and is identified by a variety of taxa belonging to Ehmaniellidae (Bordonaro, 1999).

**Bolaspidella Zone (Middle Cambrian)**

At the Zonda gulch, this biozone was recognized in the upper part of the La Laja Formation with elements of *Modocia* sp. and *Asaphiscus* sp. (Baldis and Bordonaro, 1981).

**Cedarla Zone (Upper Cambrian)**

Borrello (1965) reported this biozone from El Totoral, Mendoza Precordillera. It was defined by the presence of remains of *Cedarina* sp., *Blountia* sp., *Olenoides* sp. and *Maryvillia?* sp. Borrello (1971) also mentioned it (questionably) in San Isidro, Mendoza, on the basis of the presence of *Blountia?* sp. and *Tricrepicephalus anurusconi RUSCONI.*

**Crepicephalus Zone (Upper Cambrian)**

Keller et al. (1994) recognized this biozone in the La Flecha Formation, close to Guadacol, La Rioja, due to the presence of *Madarocephalus laetus* RASSETTI, *Komaspidella laevis* RASSETTI and *Crepicephalus cf. C. scillitis Resser.*

**Aphelaspis Zone (Upper Cambrian)**

These zone was identified by Keller et al. (1994) at the base of the La Flecha Formation, in La Angostura, near Guadacol, La Rioja through the presence of *Dytrema-cephalus strictus* RASSETTI.

**Saukia Zone (Upper Cambrian)**

Keller et al. (1994) identified this biozone in the La Flecha Formation, at the La Flecha gulch, San Juan, based on the presence of *Stenopilus convergens* (RAYMOND), and in Guadacol, La Rioja, due to *Plethopeltis cf. P. armatus BILLINGS.* It was also recognized at the base of the La Silla Formation in its type section, with the occurrence of *Plethopeltis obtusus* (RASSETTI).

**Outer Platform Biozones**

**Olenellus Zone (Lower Cambrian)**

Identified by Vaccari and Bordonaro (1993) in the Los Túneles olistolith with *Olenella sp.*, *Prozacanthoides sp.* , and *Sombrerella argentina* VACCARI and BORDONARO.

**Glossopleura Zone (Middle Cambrian)**

Identified by Poulsen (1958) at San Isidro, Mendoza, based on the presence of *Glossopleura sp.*, *Chilometopus parabolicus* RUSCONI, *Asperocare argentinum* POULSEN, *Alokistocare elongatum* POULSEN, *Alokistocare australis* POULSEN, *Kistocare mendozanum* (RUSCONI), among others. Bordonaro and Banchig (1990) described *Glossopleura aff. leona LOCHMAN* in the Ojos de Agua olistoliths in...
the Tontal Range, San Juan. Glossopleura sp. was also observed in the Los Ratones olistoliths (Bordonaro and Banchig, 1996).

**Oryctocephalus Zone (Middle Cambrian)**

This biozone was first recognized in the Precordillera of Mendoza and San Juan in facies from the outer platform (Bordonaro, 1992). Later, Bordonaro and Banchig (1995) identified it in the olistoliths from San Isidro and Los Sombreros through the presence of Oryctocephalus burgessensis Resser, Bathyriscus elegans (Walcott), Parkaspis endecamera Rasetti, Elrathia kingii, (Meek), Tonkinella stephensis Kobayashi and Athabasquia anax (Walcott). It is also reported from the Alojamiamento Formation by Banchig and Bordonaro (1997) with Tonkinella sp., Bathyriscus sp., and Peronopsis sp.

**Bolaspidella Zone (Middle Cambrian)**

This biozone is reported at the Solitario Hill near Mendoza, as defined by the presence of Williamsina sp., Talbotinella communis Poulsen, Bolaspidella lucieae Poulsen, Canotaspis aliena Poulsen and Goyoica brevicaudata Poulsen, among others (Poulsen, 1960).

**Ptychagnostus gibbus Zone (Middle Cambrian)**

This biozone is reported at the Alojamiamento Formation because of the presence of Ptychagnostus intermedius Robison, Banchig and Bordonaro (1997).

**Ptychagnostus atavus Zone (Middle Cambrian)**

Tortello and Bordonaro (1997) recognized this biozone in olistoliths at San Isidro by the presence of Hypagnostus parvifrons (Linnarsson) and Ptychagnostus cuyanus (Rusconi).

**Ptychagnostus punctuosus Zone (Middle Cambrian)**

This biozone occurs in the San Isidro olistoliths with Homagnostus pehuencensis Rusconi, Ptychagnostus cuyanus (Rusconi), and Tomagnostella excelsa (Angelin), (Tortello and Bordonaro, 1997).

**Lejopyge laevigata Zone (Middle Cambrian)**

Bordonaro and Liñán (1994) detected this biozone in the limestones of the Solitario Hill, Mendoza, and in olistoliths at Los Sombreros. The accompanying agnostoids are Agnostus exsulatus Poulsen, Clavagnostus caitonensis (Rusconi), Oedorhachis australis Poulsen, Kormagnostus seclusus (Walcott), Peronopsis tenais (Illing), Tomagnostella excelsa (Angelin), and Ptychagnostus aculeatus (Angelin). Tortello and Bordonaro (1997) also recognized Lejopyge laevigata (Dalman) at the Solitario Hill.

**Crepicephalus Zone (Upper Cambrian)**

Borrello (1965) mentioned this biozone at San Isidro, Mendoza, based on the presence of Tricrepicephalus sp., Modocia sp., and Coosia sp. In addition, Bordonaro and Banchig (1996) recognized it in one of the La Cruz olistoliths in San Isidro, as indicated by the presence of Tricrepicephalus texanus (Shumard) and Cedaria selwyni Pratt.

**Glyptagnostus reticulatus Zone (Upper Cambrian)**

This biozone is reported in the Los Sombreros olistoliths of the Tontal Range, San Juan, by Glyptagnostus reticulatus (Angelini.), (Shergold et al., 1995). This species was also reported in some of the La Cruz olistoliths, in the San Isidro area, near Mendoza (Bordonaro and Banchig, 1996).

**Elvinia Zone (Upper Cambrian)**

The occurrence of Elvinia oblicuoensis Rusconi, and Irvingella jorusconi Rusconi, indicates the presence of this biozone in San Isidro, Mendoza, (Borrello, 1971). Bordonaro and Banchig (1996) confirmed this biozone in the La Cruz olistoliths of San Isidro, based on the presence of Elvinia roemeri (Shumard) and Irvingella major Ulrich and Resser. Bordonaro et al. (1999) also mentioned the Elvinia Zone in the El Relincho Formation at the Cerro Pelado, Mendoza, with elements of Elvinia sp. and Irvingella sp.

**Saukia Zone (Upper Cambrian)**

This biozone was recognized in the limestones of the La Cruz olistoliths in San Isidro, Mendoza by Borrello (1971), who noted the occurrence of Lotagnostus sp., Bienvillia sp., Parabolinella peladoensis Borrello, Hungaia puelchana Rusconi, and Rasetta sp., among others. The Saukia zone in San Isidro is represented by olistoliths of La Cruz bearing Lotagnostus (L.) peladoensis Borrello, Lotagnostus triseptus (Salter), and Bienvillia corax (Billings), (Shergold et al., 1995). Bordonaro et al. (1999) also identified this zone in the El Relincho Formation of Mendoza, based on the presence of Hungaia sp. and Saukia sp.

**THE HAWKE BAY HIATUS**

A faunistic and stratigraphic hiatus, recorded in the entire Precordillera occurs at the boundary between the Lower and the Middle Cambrian.
In the restricted platform (Fig. 2) the hiatus is found between the top of the El Estero Member and the base of the Soldano Member (Bordonaro, 1999), where Keller (1999) recognized a type I sequence boundary. This bounding surface separates mixed siliciclastic-carbonate platform sediments from entirely calcareous deposits. Trilobites of the Olenellus Zone are present in the El Estero Member, with species of Olenellus, Antagmus, Bonnia, Fremontella, Bristolia and pagetiids, frequently associated with Hyolithes and Salterella. These species are diagnostic of the middle part of the Olenellus Zone in Laurentia (Palmer and Repina, 1993). At the base of the Soldano Member, there are 2 m of glauconitic grainstones marking a change from the preceeding mixed siliciclastic-carbonate sedimentation towards some 20 m of marlstones with thin cyclic intercalations of mudstones, fossiliferous wackestones and grainstones. The first trilobites recorded in this new sequence are ehmanniellids, which are typical representatives of the Ehmanniella Zone (sensu Sundberg, 1994) that characterizes the lower part of Marjumiid Biomere of the late Middle Cambrian. In this basal 2 m of glauconitic grainstones level it has not been possible to find early Middle Cambrian trilobites typical of the Corynexochid Biomere, which contains the Plagiura-Poliella, Albertella and Glossopleura zones.

On the other hand, Cañas (1988) described a hardground with an erosional unconformity at the base of the Los Hornos Formation carbonates, resting on the siliciclastic and carbonate deposits of the Cerro Totora Formation. Astini and Thomas (1999b), showed an erosional unconformity between the red clastic rocks and evaporites of the Cerro Totora Formation and the overlying dolomitic carbonate-shelf succession of the Los Hornos Formation. At the base of the Los Hornos Formation, there are also 2 m of glauconitic sandstones (Astini and Thomas, 1999b) overlaying a green shale with Olenellus of the Cerro Totora Formation.

These glauconitic levels probably represent the regressive Hawke Bay event, manifested as a condensed interval with formation of glauconite. It is correlated with the Hawke Bay Formation from western Newfoundland and equivalent units from the Appalachian, which contain fossils from the Olenellus Zone at the base, and fossils from the later Middle Cambrian at the top (Palmer and James, 1984).

Even though work is still being done on this subject, it is estimated that in the inner platform the Hawke Bay Event lasted from the upper part of the Olenellus Zone of the late Lower Cambrian through the early Middle Cambrian Plagiura-Poliella, Albertella and Glossopleura Zones.

On the outer platform, and in spite of the fact that there is no continuous sedimentary record, no trilobites representative of the Plagiura-Poliella and Albertella zones have been found. However, there are elements of the Glossopleura Zone such as Glossopleura aff. leona in the Ojos de Agua olistolith and Glossopleura sp. in the Los Ratones and San Isidro olistoliths. Also an Olenellus sp. and Sombreroella argentina (Vacciari and Bordonaro, 1993) association is recorded at the Los Túneles olistolith, which indicates the middle part of the Olenellus Zone. Astini and Vacciari (1996) recognized Arcuolenella megafemoralis as representative of the base of the upper Olenellus Zone in the Cerro Totora Formation. Astini and Thomas (1999a) mentioned the finding of olenellids and Salterella in the Anchauca Olistolith.

The faunistic and stratigraphic evidence found until now indicates that the Hawke Bay Event had a greater duration on the inner platform than on the outer platform (Fig. 2). This fact suggests the formation of an onlap-type structure caused by the Middle Cambrian transgression succeeding the Hawke Bay regression. This transgression affected first (during the Glossopleura Zone) the outer platform in the western Precordillera, and later, during the Ehmanniella Zone, flooded the inner platform toward the eastern Precordillera.

The Hawke Bay Hiatus appears to be a nearly worldwide regressive event. It is widely represented in the Appalachians, where it marks the boundaries of Sauk I and Sauk II sequences (Palmer, 1981), and has also been recognized in Baltoscandia and the Iberian Peninsula (Ahlberg, 1998; Lifán and Gámez-Vintañed, 1993).

CAMBRIAN – ORDOVICIAN BOUNDARY

In the basal 15 m of the La Silla Formation, in its type locality at La Silla Hill (Fig. 1), Keller et al. (1994) found Plethopeltis obtusus, which range from the Saukia serotina Subzone of the later Upper Cambrian up to the Mississqua depressa Subzone of the early Lower Ixbean in North America (Ludvigsen, 1982). At 70 m above the base there appear conodonts from the Cordylocus hintzei Subzone, belonging to the Cordylocus intermedius Zone (Miller, 1988), of the Canadian Stage (or Tremadocian) are present at a distance of 70 m over the base of the formation. Based on the position of the trilobites in the succession, it can be inferred that the Cambrian-Ordovician boundary is lacated in the lower 15 m of the La Silla Formation.

In the Precordillera Occidental of San Juan, at the Los Sombreros stream (Fig. 1), the Los Sombreros Formation consists of shaly olistostromic deposits of Middle and Upper Ordovician age. The youngest olistolith found was a block of limestone and calcareous shale containing Cordylocus proaurus (Lehnert, 1994). Possibly, the Cambrian-Ordovician boundary is located within this olistolith, within outer platform facies, as Cordylocus proaurus...
has a range between the late Upper Cambrian and the early Ibexian.

In the Alojamiento Range (Fig. 1), above the Cambrian carbonates of the Alojamiento Formation there is an apparently conformable sandy-pelitic siliciclastic succession (Cortaderas Formation, Fig. 2) which yields abundant traces of *Tommaculum problematicum* and *Didymaulichnus* isp. (Durand et al., 1997) of Ordovician age. The Cambrian-Ordovician boundary may be present in this unit, but diagnostic fossils are absent.

At Cerro Pelado (Fig. 1), the upper levels of El Relincho Formation, which contain trilobites from the *Saukia* Zone, are overlaid by black shales that yielded undetermined graptolites (Fig. 2). This sequence potentially records the Cambrian-Ordovician boundary in deeper basinal facies.

**CONCLUDING REMARKS**

The complete and updated lithostratigraphic as well as biostratigraphic data, which are shown in this summarized overview, provide evidences to confirm that the Precordillera basin was a rimmed platform.

The lithostratigraphic and biostratigraphic data allow the detection of an important hiatus in the Precordillera near the Lower-Middle Cambrian boundary, which is proposed to be correlated with the Hawke Bay regressive event in the Appalachian area of North America. This hiatus shows a greater longer duration on the inner platform than on the outer platform. This fact is interpreted as a consequence of the onlap of successive units, which was produced by the Middle Cambrian transgression succeeding the Hawke Bay regression.

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**REFERENCES**


Armella, C., 1994. Thrombolitic-stromatolitic cycles of the Cam-


Bordonaro, O., 1999. Hiatus faunístico (evento Hawke Bay ?) entre el Cámbrico Inferior y el Cámbrico Medio en la Formación La Laja, Precordillera de San Juan. XIV Congreso Geológico Argentino, Salta, Argentina. Actas, 1, 45.


Utah and Nevada. Contributions in Science, 446, 1-137.

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