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Article

The Tithonian stratigraphy and ammonite fauna of the transect Portada Covunco-Cerrito Caracoles (Neuquén Basin, Argentina)

Horacio Parent, Alberto C. Garrido, Günter Schweigert, and Armin Scherzinger

With 30 figures and 1 table

In memorian Sara Ballent, John H. Callomon and Gerhard Schairer

Abstract: The stratigraphy and the ammonite fauna of the Vaca Muerta and Picún Leufú formations outcropping along the transect Portada Covunco-Cerrito Caracoles (south-central Neuquén Basin) were studied by means of two representative sections. The detailed study of the lithological succession of the two sections has allowed to complete the formal subdivision of the Vaca Muerta Formation by the introduction of two new members: the Portada Covunco Member (nov.) at the base, and the Pichi Moncol Member (nov.) at the top; the middle part of the formation is currently known as the Los Catutos Member. The ammonite fauna is mainly composed by species already recorded in other localities of the basin. There are six new species, but they remain to be formally described based on better and more abundant material: *Choicensisphinctes* cf./aff. *platyconus*, *Catutosphinctes* aff. *rafaeli*, *Catutosphinctes* n. spp. A & B, *Steueria* aff. *alternans*, and *Sutneria* n. sp. A. The lowermost Tithonian (lower Picunleufuense Zone) is well represented in the section P. Covunco by the guide assemblage (*Lithacoceras picunleufuense*, *Choicensisphinctes platyconus* and *Catutosphinctes guenenakenensis*) at the base of the P. Covunco Mb. The Zitteli Zone (which seems to overlap the Mendozanus Zone) and the Proximus Zone occur in the middle and upper parts of the P. Covunco Mb, as recongnized by their characteristic ammonite assemblages. The upper part of the Middle Tithonian, the Internispinosum Zone, corresponds to the Los Catutos Mb and, apparently, the upper part of the Vaca Muerta Fm (Pichi Moncol Mb), although it is fossiliferous only in its lower part. The lower Upper Tithonian Alternans Zone is well documented by ammonites, whereas the upper Upper Tithonian yielded only scarce fossils which could even represent the lower Berriasian Noduliferum Zone.

Key words: Argentina, Eastern Neuquén Basin, Tithonian, Vaca Muerta Fm, Picún Leufú Fm, ammonites.

1. Introduction

The fossiliferous locality named Portada Covunco (PC hereafter; see Figs. 1-2) is one of the oldest known of the Neuquén Basin (NB). In this area outcrops a rock succession spanning the Andean Lower, Middle and Upper Jurassic and also a part of the Lower Cretaceous. The Middle Jurassic includes the Los Molles, Lajas, Challacó, Tábanos and lower part of the Lotena formations; the Upper Jurassic is formed by the upper part of the Lotena, La Manga, Tordillo, Vaca Muerta and the lower part of the Picún Leufú formations, whereas the Lower Cretaceous consists of the upper part of the P. Leufú and the complete Mulichinco for-

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mations. There exists a moderately large number of papers dealing at least in part with the geology and Upper Jurassic stratigraphy of the area shown in Fig. 2. A representative list of papers which contain additional references includes Groeber (1952, with references to older literature), Leanza (1973, Vaca Muerta Fm), Leanza & Hugo (1997, Vaca Muerta and Picún Leufú formations), Leanza & Zeiss (1990, Vaca Muerta Fm), Parent (2006, Lotena, La Manga and Tordillo formations). The Tithonian ammonite fauna of Portada Covunco has never been described before. Only the ammonites of the upper Middle Tithonian of the nearby locality Los Catutos have been partially described by Leanza & Zeiss (1990, 1992) and Zeiss & Leanza (2010). Recently, Armella et al. (2008) have studied the sedimentology of the Picún Leufú Fm in the outcrop of the Cerrito Caracoles (Fig. 1) and mentioned the occurrence of *Pseudosubplanites grandis*, *Substeueroceras* sp. and *Corongoceras* sp. from the base of the formation. The ammonite succession and stratigraphy of Portada Covunco was preliminary described by Parent & Cocca (2007).

The purpose of the present paper is to describe the stratigraphy and ammonite fauna of the Vaca Muerta and Picún Leufú formations at Portada Covunco and the neighboring Cerrito Caracoles (named Cerro del Bum in old maps and literature, but entrenched in the modern literature as Cerrito Caracoles).

The results presented in this paper originate from a study which is part of a research program of the Andean Tithonian ammonite fauna and stratigraphy of the Neuquén-Mendoza or Neuquén Basin based on the description of the faunas of key localities and revision of old collections. Studies already published cover the following localities (Fig. 1): Picún Leufú (Parent, Garrido et al. 2011), Barda Negra (Parent et al. 2007), Cañadón de los Alazanes (Parent 2001), Casa Pincheria (Parent 2003a), and Arroyo Cieneguita (Parent et al. 2011). These studies have provided much new information on the systematics and biostratigraphy of the fauna, showing that it is much more homogeneous than previously assumed (*e.g.* Leanza 1980, 1981). Indeed, the ammonite fauna of the NB seems to be composed of the Andean lineages of the ataxioceratid genera *Choicensisphinctes* and *Catutosphinctes* (Lower to Upper Tithonian); an extension of the Tethyan genus *Lithacoceras* (Lower to Middle Tithonian) which seems to have given origin to *Zapalia* (Middle to ?Upper Tithonian); *Platydiscus* (Middle to Upper Tithonian), *Krantziceras* (Upper Tithonian to Berriasian), and *Mazatepites* (Middle to ?Upper Titho-

Fig. 1. Map of West-Central Argentina and Central Chile showing the location of the fossiliferous localities (black squares) cited in text and approximate limits of the Neuquén-Mendoza Basin (gray area). The broken line indicates the Huincul Arch. Locality names: PLB: Paso Los Bayos, ACP: Arroyo, Cruz Piedra, RD: Río Diamante, AM: Arroyo de la Manga, CB: Cajón del Burro-Río Choicas, AP: Arroyo Paraguay, AA: Arroyo Alberjillo, BDF: Baños del Flaco, AC: Arroyo Cieneguita, RV: Rodeo Viejo, AD: Arroyo del Durazno, AL: Arroyo Loncoche, PM: Paso Montañés, CP: Casa Pincheira, MC: Molinos Colgados, BB: Bardas Blancas, AY: Arroyo del Yeso, MR: Mallín Redondo, VV: Vega de la Veranada, PT: Pampa Tril, CM: Chacay Melehué, CDA: Cajón de Almanza, SVM: Sierra de la Vaca Muerta, MQ: Mallín Quemado, CA: Cañadón de los Alazanes, PC: Portada Covunco, LC: Los Catutos-Cerrito Caracoles, CG: Cerro Granito - La Amarga, CL: Cerro Lotena, PL: Puente Picún Leufú, CH: Charahuilla.

nian). The Berriasellinae are represented by the genera *Parodontoceras* (Upper Tithonian to Lower Berriasian), *Substeueroceras* (Upper Tithonian to Lower Berriasian) and *Blanfordiceras* (Upper Tithonian). The Himalayitidae are also well represented by *Windhauseniceras* (a late Middle Tithonian derivative of *Catutosphinctes*), *Steueria* and *Corongoceras* (Upper Tithonian). The Aspidoceratidae are represented by *Aspidoceras* and *Physodoceras* (Lower to Upper Tithonian), *Toulisphinctes* and *Pseudhimalayites* (Middle Tithonian). The haploceratoid *Pseudolissoceras* is abundant (*P. zitteli*, lower Middle Tithonian). The oppeliids are scarce in the Neuquén Basin; this family includes the genera *Cieneguiticeras* (Lower to Middle Tithonian) and *Pasottia* (Middle Tithonian). Additionally, some poorly represented or doubtful genera have been recorded: *Malagasites, Chigaroceras, Micracanthoceras, Himalayites, Parastreblites, Uhligites*, and *Semiformiceras.*

The biostratigraphic approach adopted in this paper is based on bed-by-bed samplings through the studied sections. We distinguish: (a) a biozone as a body of rock characterized by their fossil content, (b) a chronostratigraphic zone as a sheet of rock (one or more strata) bounded by two time-planes, and (c) a standard chronostratigraphic zone as a chronostratigraphic zone defined only by a faunal horizon at its base, then conforming a succession of standard zones without gaps or overlaps. These definitions are widely discussed by Callomon (1995, 2001). Abbreviations are used for Biozone (Bz.), Chronostratigraphic Zone (Zone or Z.) and faunal or ammonite horizon (Hz.).

The regional subdivision of the Tithonian adopted is the tripartite, with a middle part differentiated. All the localities mentioned in the text are indicated in Fig. 1, where in addition the abbreviations used throughout the text are indicated. For short the following references are abbreviated: Parent, Garrido et al. 2011 (PGSS 2011); Parent et al. 2011 (PSG 2011), Parent, Myczinski et al. 2010 (PMSS 2010); Parent, Schweigert et al. 2008 (PSSE 2008).

2. Stratigraphy

2.1. Geological setting

The Neuquén Basin has been recognized as an ensialic depression emplaced in southwestern South America, between 34-41°S 66-71°W. It is characterized by a thick sedimentary sequence of Triassic-Paleogene age, reaching 6000-7000 m in thickness (Legarreta & Gulisano 1989; Gulisano & Gutiérrez-Pleimling 1995; Vergani et al. 1995). For the study of the tectonic evolution of the basin, one of the most distinctive structural features is the denominated Huincul High (Dorsal de Huincul, see Fig. 1; Orchuela et al. 1981; Ploszkiewicz et al. 1984). This structure behaved intermittently as a positive topographic feature, dividing asymmetrically the basin and influencing strongly on the distribution of the depositional systems on both sides (de Ferrariis 1947; Marchese 1971; Vergani et al. 1995). The indispensable time-control of short-term processes of these depositional systems can be solely obtained from the comparison of the successions of ammonite biohorizons of outcrops located south and north of the Huincul Arch. An advanced, although preliminary scheme of the succession of biohorizons has been presented in PSS (2011: fig. 40).

From the Kimmeridgian up to the Valanginian, a transgressive-regressive sedimentary cycle produced a succession of marine sediments up to 1100 m thick, which are included into the Mendoza Group (Digregorio 1972; Leanza et al. 1977; Digregorio & Uliana 1980; Legarreta & Gulisano 1989) and informally grouped as the Lower Mendoza Group (Vergani et al. 1995; Leanza 2009; Arregui et al. 2011; Leanza et al. 2011). All throughout the basin this succession is limited by the Araucanican (~ Oxfordian/Kimmeridgian boundary) and Huncalican (Intravalanginian) unconformities, and is composed by the Tordillo, Vaca Muerta, Carrín Curá, Quintuco, Picún Leufú, Bajada Colorada, Chachao and Loma Montosa formations (Leanza 1973; Leanza et al. 1977; Leanza & Hugo 1977; Gulisano et al. 1984; Mitchum & Uliana 1985; Legarreta et al. 1993; Spalletti et al. 2000). Several studies have demonstrated for this cycle a predominance of deep marine facies in the northern area of the basin, as well as a progressive displacement of the shallow marine facies from south to north as the regressive phase developed (Leanza et al. 1977; Leanza & Hugo 1977; Mitchum & Uliana 1985; Spalletti et al. 2000; among others).

The study area (Portada Covunco: 39°47’39.6”S, 70°11’46.4”W) comprises the southern end of the Sierra de la Vaca Muerta (Fig. 1), which shows extensive outcrops of marine and continental Jurassic deposits (Lambert 1956; Leanza & Hugo 2001; Zavala & González 2001; Zeiss & Leanza 2010). In this area the Lower Mendoza Group comprises the Tordillo, Vaca Muerta and Picún Leufú formations (Leanza & Hugo 2001), the latter two being the object of the present study.

2.2. Vaca Muerta Formation (Weaver 1931)

The name Vaca Muerta Formation was introduced by Weaver (1931) for rocks previously known under the informal denominations of "depósitos del Kimeridge-Portlandiano" (Windhausen 1914, 1916), "Titónico" (Windhausen 1914), "Titoniano" (Windhausen 1916), "capas portlandienses" (Keidel 1925), or "sedimentos del Tithoniano-Berriasiano" (Groeber 1929).

This lithostratigraphic unit consists of a thick succession (maximum 1250 m) of marine deposits of Tithonian-Early Valanginian age, composed by pelites and calcipelites (95%) and by sandstones and siltstones (5%) (Leanza 1993). The most characteristic lithology is represented by bituminous black shales frequently containing calcareous concretions rich in ammonites and vertebrates (Leanza 1993). In the first regional studies of these deposits, Groeber (1929) and Weaver (1931) recognized strong lithological variations from south to north along the basin, proving the existence of deeper marine facies towards the northern sector of the basin. Later, detailed stratigraphic and palaeontological studies were performed by different authors, which provided detailed data on the palaeogeography, palaeoenvironments, age, and facies distribution of the deposits of this unit (e.g., Leanza 1973, 1975, 1980, 1981; Leanza & Hugo 1977; Leanza et al. 1977, 2003, 2011; Gulisano et al. 1984; Leanza & Zeiss 1990; Parent et al. 2006, PGSS 2011; PSS 2011; Spalletti et al. 1999, 2000; Zeiss & Leanza 2010).

In general the Vaca Muerta Fm overlies the non-marine deposits of the Tordillo and Quebrada del Sapo formations with sharp contact. However, in the immediate vicinity of the Huincul High this unit can overlay in angular discordance on different pre-Tithonian units (Keidel 1925; Suero 1942, 1951; Leanza & Hugo 1997; Leanza 2009). The top of this formation is indicated in the depocentre area of the basin by the Huncalican Unconformity, followed by the marine deposits of the Mulichinco and Agrio formations of Late Valanginian-Early Barremian age (Leanza 2009; Leanza et al. 2011). Towards the southern area of the basin and close to the Huincul High, the Vaca Muerta Fm passes transitionally towards the limestones and siltstones of the Picún Leufú Fm, both Tithonian and partially Berriasian in age (Leanza 1973; Leanza & Hugo 1997; see below).

During the deposition of the Vaca Muerta Formation, the Neuquén Basin acted as a back-arc basin, being partially isolated from the Proto-Pacific Ocean by a magmatic arc in the West and adopting a gulf-like configuration (Howell et al. 2005). In a recent paper Spalletti et al. (2008) proposed for the northwestern area of the basin, a depositional model linked to a western, tectonically active margin, which resulted in the deposition of a thick succession of turbidites and gravity-flows through a well developed talus slope. Within de Vaca Muerta Fm these turbidite deposits have been designated Huncal Member by Leanza et al. (2003). However, for the cratonic, passive margin area of the basin (where our study area is located) the sedimentary model proposed for the Vaca Muerta Fm deposits is characterized by a tidally dominated, mixed carbonate-siliciclastic ramp, delineating a gently dipping sea-floor profile (Spalletti et al. 2000, 2008).

We propose to differentiate formally the lower and upper members of the Vaca Muerta Fm (cf. Leanza & Zeiss 1990), which can be recognized along the outcrops located on the ancient cratonic margin of the basin. The type locality of each of these new members is situated within our study area, which also includes the type locality of the middle member of the formation, the Los Catutos Mb (Leanza & Zeiss 1990). The close proximity between the three type localities facilitates the identification and characterization of each member within the sequence.

Portada Covunco Member (nov.): We propose this name for the lower section of the Vaca Muerta Fm. This member is characterized by a thick succession of sandy shales, rich in organic matter, with thin intercalations of calcareous sandstones, calcareous sandy siltstones, calcareous siltstones, wacky sandstones, and calcareous lutites (Fig. 3: levels PC-1 to PC-69). The type locality is situated in the surroundings of the bridge of the Road 40 over the Arroyo Covunco (Fig. 2), on the right banks of this creek (38°47'43.0"S, 70°11'40.8"W), what is properly the locality herein named Portada Covunco. According to Leanza & Zeiss (1990) the thickness of this unit is 164 m, whereas our own measurements indicate a thickness of 172 m.

The sandy shales are fissile, slightly calcareous, with variable proportions of organic content, but always in remarkable concentrations (>2%). The predominant colours of this lithology in the outcrop are greenish gray, greenish yellow, light yellow, and ochre. However, in non-weathered surface the colour varies from light to dark gray. Generally these rocks show a very thin, varve-like lamination. Fish remains (vertebrae and scales) and invertebrate shells are abundant. Frequently, these beds are characterized by the development of diagenetic, calcareous concretions (calcar-

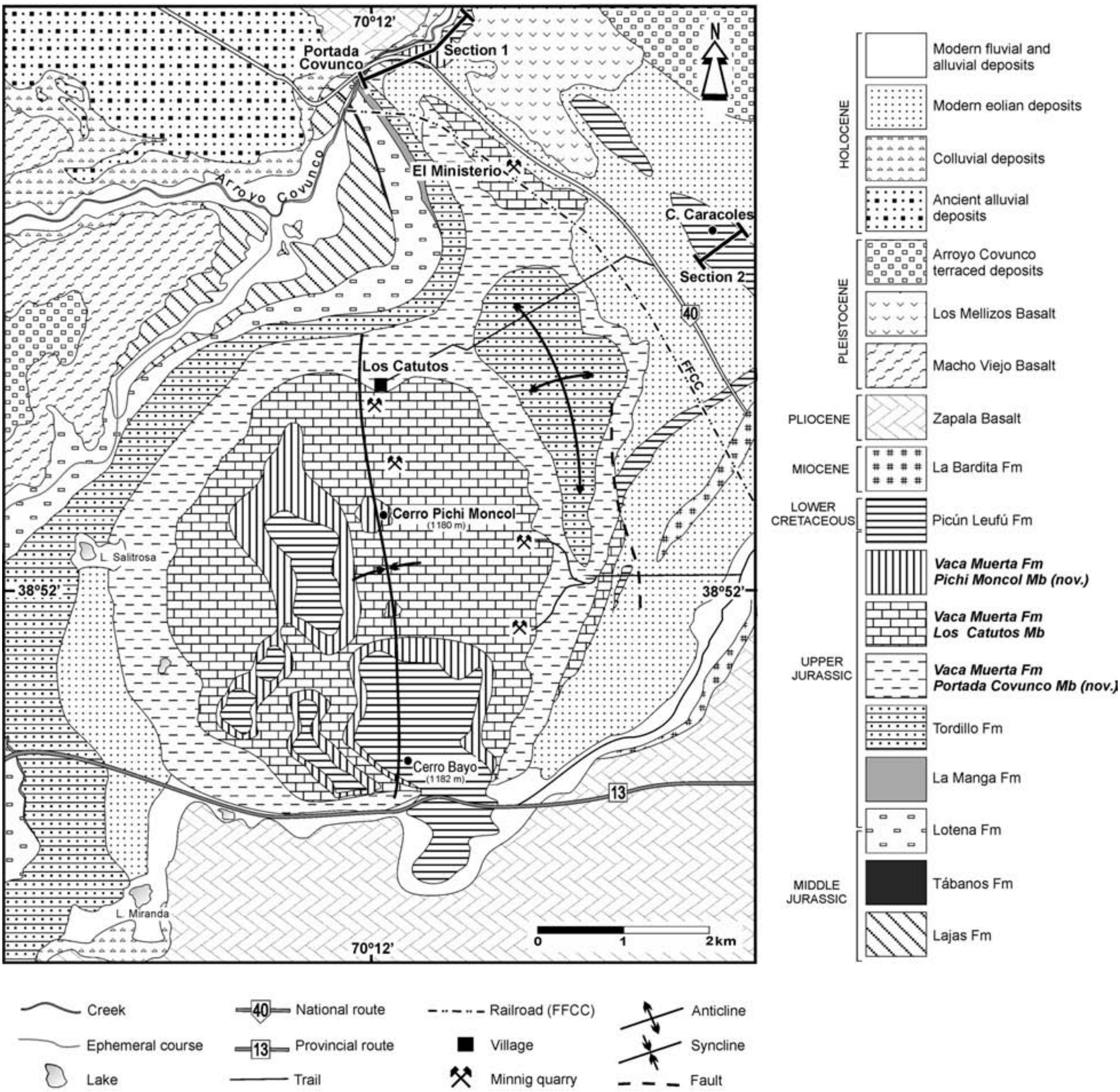

Fig. 2. Geological map of the study area (modified from Leanza & Zeiss 1990) showing the Portada Covunco and Cerrito Caracoles sections. The Portada Covunco Mb (nov.) and Pichi Moncol Mb (nov.) of the Vaca Muerta Fm are introduced in this paper.

eous lutite type) rich in ammonites and oysters. Occasionally, small fragments of silicified wood are also present in these levels. This facies comprises approximately 76% of the total thickness of the member.

The other lithologies occur mainly in the lower 46 m of the unit. In this case, the differentiation between calcareous sandstones, calcareous sandy siltstones and calcareous siltstones, depends on the percentage relations between the different grain-size of the epiclastic fraction. These deposits have a flagstone-type aspect, whitish to creamy in colour, containing abundant molds and poorly preserved remains of ammonites and small gastropods. The wacky sandstones occur in much lower proportion. These rocks are composed of laminated, medium- to fine-grained, quartz-lithic sandstones, rich in argillaceous matrix. The colour range varies between greenish yellow to dull green. No fossils were found in these levels.

The Portada Covunco Mb can be recognized along the outcrops of Cerro Lotena, Cerro Granito, and Sierra de la Vaca Muerta (see Fig. 1). In the shallower marginal areas of the basin, such as the Puente Picún Leufú area, this member is also characterized by the dominance of sandy shales, more or less rich in organic matter content (see PGSS 2011: fig. 3: levels PL-2 to PL-38). In the north of the basin, towards the deepest areas, the Vaca Muerta Fm becomes more homogenous. However, the Portada Covunco Mb can always be recognized on the basis of its high content of organic matter, a feature that allows to differentiate it from the higher levels of the formation. In this case, the dominant lithology of the Portada Covunco Member consists of black shales or bituminous shales, being one of the main hydrocarbon source lithologies of the Neuquén Basin. Also, in all cases, deposits of this member are those that have provided the largest abundance and variety of Tithonian marine reptiles within the Vaca Muerta Fm. In terms of the palaeoenvironments these facies types have been attributed by Spalletti et al. (2000) to basinal deposits sedimented from suspension under anoxic to dysoxic conditions. However, PGSS (2011) suggested for the southern area of the basin a shallower depositional environment, where the dysoxic to anoxic conditions may have resulted from a restriction of the basin and the poor circulation of the water mass.

Los Catutos Member (Leanza & Zeiss 1990): This unit has been defined at Los Catutos mining quarry, close to the homonymous village (Fig. 2). The origin of the name “Los Catutos” is uncertain, but possibly the term is derived from the deformation of the word “Locastuto”, the name of a water spring (Aguada Locastuto) located in this place, according to the ancient topographic chart of the region (Instituto Geográfico Militar 1930).

The Los Catutos Mb (levels PC-70 to PC-89 in Fig. 3) is composed by a rhythmic succession of lithographic limestones, marls and shales (Leanza & Zeiss 1990). The limestones (considered marly limestone in this paper) are thin-bedded and consist of fine-grained bioclastic micrites (pelbiomicrites and biopelmicrites), yellowish to whitish in colour, and dark gray in non-weathered surface (Leanza & Zeiss 1990; Scasso et al. 2002). These rocks present a maximum value of total organic content (TOC) of 2%, and the siliciclastic terrigenous content ranges from 18% to 30% (Scasso et al. 2002). These levels are rich in fossils, mainly abundant fishes, ichthyosaurs, turtles, and scarce plesiosaurs and pterosaurs (Cione et al. 1987; Leanza & Zeiss 1990). The invertebrates are represented by abundant ammonites and scarce bivalves, gastropods and crustaceans (Leanza & Zeiss 1990, 1992; Zeiss & Leanza 2010). The microfossils recorded here are coccolithophorids, radiolarians, foraminiferan tests, and sponge spicules (Leanza & Zeiss 1990; Scasso et al. 2002).

The marls are similarly composed as the limestones described above but have a higher content of epiclastic material. In this case the beds exhibit a larger fissility, due to a weak cementation of the rocks. Towards the upper part of this unit, whitish calcareous sandy shales are interbedded with the marly limestone levels.

The total thickness of this succession is difficult to estimate due to the high deformation of the sequence. Leanza & Zeiss (1990) indicated a thickness of 70 m for the Los Catutos Mb in the type locality. Our measurements through the transect of section 1 (Fig. 2), indicate for the same unit a thickness of 116 m (Fig. 3), thus confirming previous measurements in the same section (Parent & Cocca 2007). This unit exhibits a wide distribution along adjacent areas to the Huincul High, forming an about 90 km long outcrop belt between the Cerro Lotena and Sierra de la Vaca Muerta (Fig. 1). In this sense, Leanza & Hugo (2001) indicated a gradual reduction of thickness of these deposits from Los Catutos locality towards the Sierra de la Vaca Muerta, then disappearing towards the north of the Cerro Mallín Quemado (Fig. 1).

Leanza & Zeiss (1990) and Scasso et al. (2002) have suggested that the deposition of the Los Catutos Mb took place on a shallow, gently dipping outer ramp system, under dysaerobic, low-energy, open marine conditions.

Fig. 3. Log-section of the Vaca Muerta Fm in the section of Portada Covunco (section 1 in Fig. 2), shown in six parts. TF: Tordillo Fm; other references in Fig. 4. The arrowhead at top of bed PC-119 indicates the point where the National Road 40 covers the outcrop (see Fig. 2).

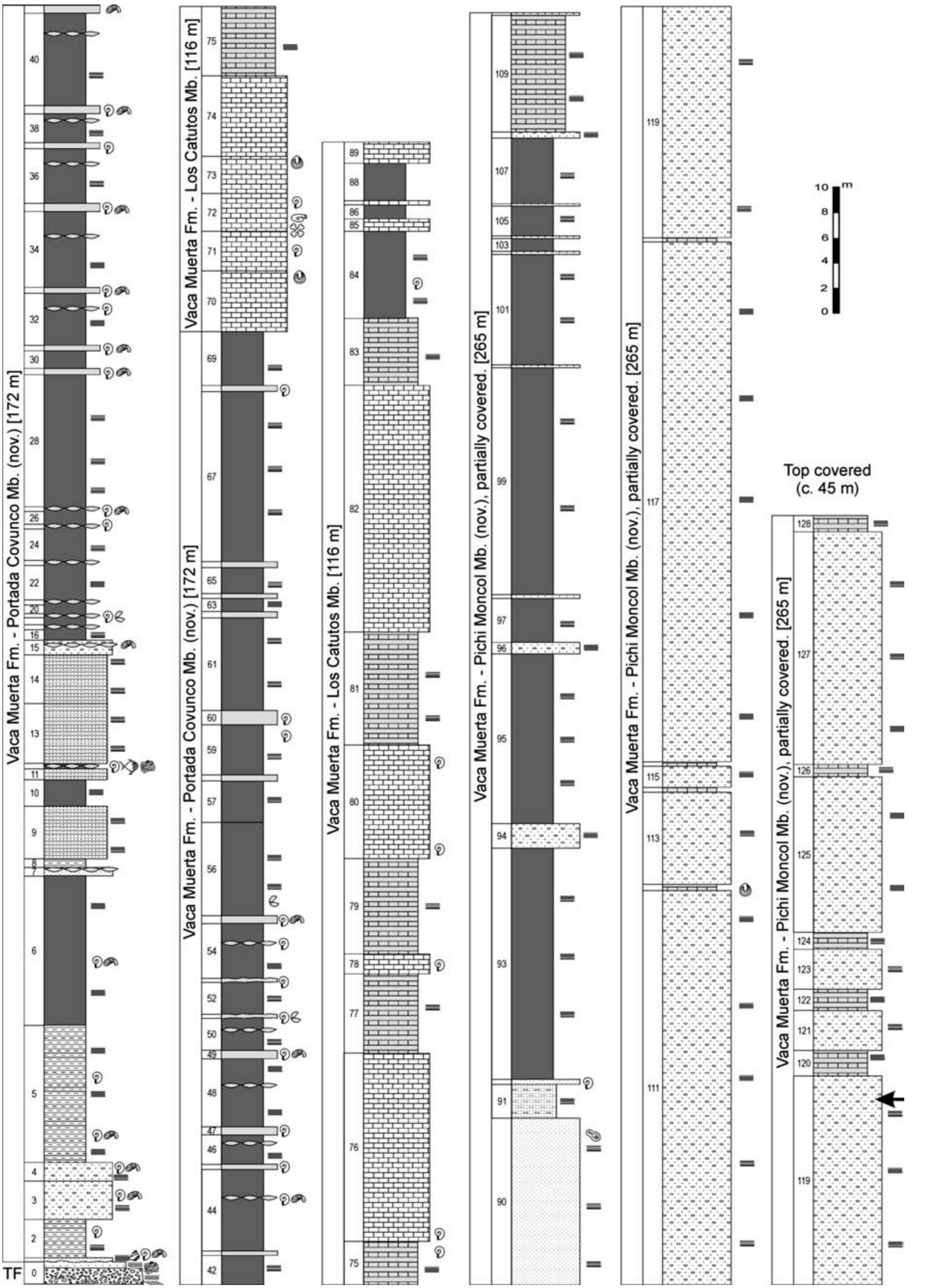
Vaca Muerta Fm. - Portada Covunco Mb. (nov.) [172 m]
TF
Vaca Muerta Fm. - Los Catutos Mb. [116 m]
Vaca Muerta Fm. - Portada Covunco Mb. (nov.) [172 m]
Vaca Muerta Fm. - Los Catutos Mb. [116 m]
Vaca Muerta Fm. - Pichi Moncol Mb. (nov.), partially covered. [265 m]
Vaca Muerta Fm. - Pichi Moncol Mb. (nov.), partially covered. [265 m]
Top covered
(c. 45 m)
Vaca Muerta Fm. - Pichi Moncol Mb. (nov.), partially covered. [265 m]
10 m
8
6
4
2
0

Fig. 3.

Pichi Moncol Member (nov.): Following the above line of analysis, we propose the name Pichi Moncol Member for the upper section of the Vaca Muerta Fm (Fig. 3: levels PC-90 to PC-128, partial). The type locality is designated in the environs of the bridge of the National route 40 over the stream Arroyo Covunco (Fig. 2), on the right banks of this creek. The name is derived from the eponymous hill, located at 38°51'21.4"S, 70°12'10.7"W, 2.25 km south of the Los Catutos Village, where this member is exposed. In the Portada Covunco area this unit is incomplete or partially covered. According to Leanza & Zeiss (1990) this member has a thickness of 94 m, however, our measurements along the exposed outcrops of the section 1 (Portada Covunco, Fig. 2) indicate a thickness of 265 m. If we consider that the top of the unit in this latter section is covered along approximately 45 m, we assume that the deposits of the Pichi Moncol Mb may exceed 300 m in thickness.

This unit is characterized by a thick, monotonous succession of thinly laminated calcareous sandstones and sandy shales, with thin intercalations of marls and scarce levels of fine-grained sandstones and silty sandstones (Fig. 3). Within the Pichi Moncol Mb, sandy shales dominate the lower 93 m, while the remaining upper 172 m are mainly composed of the laminated, fine-grained, calcareous sandstones. The predominant colour is dark yellow and ochre, and, to a lesser degree, dull light green. Unlike the lower members, these deposits have a much lower content of organic matter, becoming practically absent in some cases. Furthermore, these levels are very poor in fossils; only few levels provided scarce and poorly preserved ammonites and oysters.

The Pichi Moncol Mb can be clearly recognized in different areas of the basin. In the Cerro Lotena, Cerro Granito and Sierra de la Vaca Muerta area (Fig. 1), the deposits of the Pichi Moncol Mb always overlay the limestone beds of the Los Catutos Mb. In the Puente Picún Leufú area, this unit can be recognized according to the lithostratigraphic section described by PGSS (2011: fig. 3: levels PL-39 to PL-59). Towards the north of the basin, the Pichi Moncol Mb overlies directly on the Portada Covunco Mb which is distinguished by the lower content of organic matter, lighter colour of their rocks and minor presence of fossils.

In terms of the palaeoenvironments the Pichi Moncol Mb deposits have been attributed by Spalletti et al. (2000) to an outer ramp facies. Usually the authors accord to indicate the development of a gradual shallowing and increasing oxygenation of the waters towards the top of the Vaca Muerta Fm (Gulisano et al. 1984; Spalletti et al. 2000; PGSS 2011).

2.3. Picún Leufú Formation (Leanza 1973)

The Picún Leufú Fm has been defined as a succession of micritic and coquinoid limestones with intercalations of mudstones and sandstones (Leanza 1973; Leanza et al. 2011). Its age as indicated by the ammonite fauna is Late Tithonian to Early Berriasian. This unit extends from the outcrops of Puente Picún Leufú (type locality, see Fig. 1) up to the Sierra de la Vaca Muerta (Fig. 1: SVM), reaching a maximun thickness of 350 m (Leanza 1993). Some authors have attributed the deposits of the Picún Leufú Fm lying on the southern part of the basin as representatives of the Quintuco Fm (e.g., Weaver 1931; Herrero-Ducloux & Leanza 1943; Groeber 1952; Zavala & Freije 2002), however, as pointed out by Leanza et al. (2011) this latter unit of epiclastic domain has a more northern distribution on the basin and, on the other hand, is stratigraphically younger (Late Berriasian to Early Valanginian). In this sense it is possible that the subsurface limestone deposits identified by petroleum geologists as Quintuco Fm, actually belongs to the Picún Leufú Fm.

In the Portada Covunco area the outcrops of the Picún Leufú Fm are incomplete (covered, see Fig. 4). Indeed, in the Portada Covunco section this unit has 241 m exposed, while in the Cerrito Caracoles section it shows 102 m exposed. There exists a lithological transition between the Vaca Muerta and Picún Leufú formations; however, the base of the latter is indicated by the dominant presence of fossiliferous calcareous sandy siltstones of yellowish brown to yellowish green colour. In this sense, the Picún Leufú Fm is composed in the section of P. Covunco by 94.5% of calcareous sandy siltstones with minor intercalations of calcareous sandstones, and only 5.5% corresponds to bioclastic limestones. In the section of C. Caracoles, the sandy and bioclastic limestones reach 27% of the exposed succession (Fig. 4). In general, the deposits of the Picún Leufú Fm are very rich in fossils, mainly a wide variety of bivalves associated with ammonites, brachiopods, gastropods, echinoderms, hermatypic corals, and serpulids (cf. Weaver 1931; Leanza & Hugo 2001).

The outcrops of Cerrito Caracoles have been recently studied by Armella et al. (2007, 2008). According to these authors the Picún Leufú Fm represents a shallow subtidal marine environment (inner shelf margin) associated to patch reefs deposits.

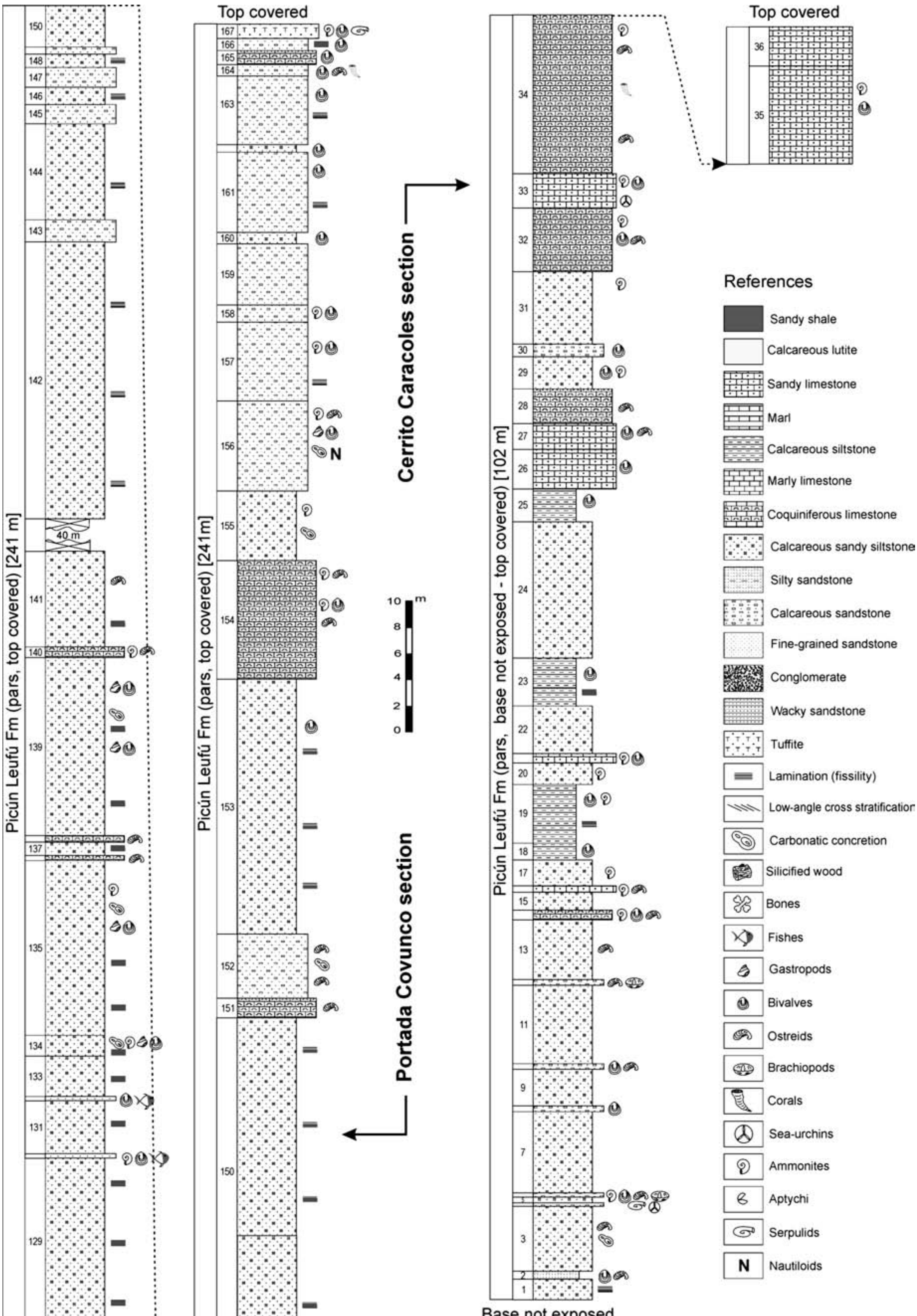

Fig. 4. Log-sections of the Picún Leufú Fm. at Portada Covunco (section 1 in Fig. 2; two segments, left hand) and Cerrito Caracoles (section 2 in Fig. 2; two segments, right hand).

Fig. 5. A: *Lithacoceras picunleufuense* Parent et al., 2011, portion of [M] bodychamber, P. Covunco, bed PC-2, lower Picunleufuense Z. **B-C**: *Choicensisphinctes platyconus* Parent et al., 2011, P. Covunco, lower Picunleufuense Z. **B**: Juvenile [M] with incomplete bodychamber (MOZ-PI 6882), bed PC-2; **C:** portion of phragmocone, plaster cast (LPB-M 129), bed PC-1. **D**: *Choicensisphinctes* cf./aff. *platyconus* Parent et al., 2011, almost complete adult [M], field photograph, P. Covunco, bed PC-3, Picunleufuense Z. – All natural size. The asterisk indicates the last septum.

3. Systematic palaeontology

Conventions: The described material is housed in the collections of the Museo Provincial de Ciencias Naturales "Prof. Dr. Juan A. Olsacher", Zapala (MOZ-PI) and Laboratorio de Paleontología y Biocronología, Universidad Nacional de Rosario (LPB). Macroconch (female): [M], microconch (male): [m]. Dimensions measured: diameter (D), diameter at the last adult septum (D_{ls}), final adult diameter at peristome (D_p), umbilical width (U), whorl width (W) and whorl height (H_1), all given in millimeters [mm]; length of body chamber (L_{BC}) in degrees [°]. Biometric features of shell shape are reported in the form of dimensionless numbers or "indexes", mainly relative to the size (D). This form of reporting has the advantage of giving a direct reference to the relative morphology, allowing comparisons of shape in a range of comparable sizes. The metric linear dimensions can be easily obtained using *D* which is reported besides. Number of primary (*P*) and ventral (*V*) ribs per half whorl. Codification of indicative marks on synonymy lists: figuration of type specimen (*), doubtful (?) and partial (p) synonymy, not belonging to the species (n). TS: type species, HT: holotype, LT: lectotype, MT: monotypy, TL: type locality, TH: type horizon. Collection numbers of the figured specimens are given in the figure captions. The stratigraphic position of the different species is explained below in the chapter Biostratigraphy. Open nomenclature follows Bengtson (1988) and the formula "sp. indet." is used when the material is scarce and/or poorly preserved which does not allow to discriminate if it is differentiable from known species.

Superfamily Perisphinctoidea Steinmann, 1890
Family Ataxioceratidae Buckman, 1921
Subfamily Lithacoceratinae Zeiss, 1968

Genus *Lithacoceras* Hyatt, 1900

Type species: *Ammonites ulmensis* Oppel, 1858, by OD.

Lithacoceras picunleufuense Parent, Garrido, Schweigert & Scherzinger, 2011
Fig. 5A

Remarks: The species occurs as impression through beds PC-1-PC-3. It was collected in association with *Choicensisphinctes platyconus* and *Catutosphinctes guenenakenensis* forming the typical assemblage of the Picunleufuense Z. (PGSS 2011). A fragment showing the typical adult [M] sculpture is illustrated in Fig. 5A.

L. picunleufuense was originally described as a "*Lithacoceras*" because the uncertainties derived from the apparent lack of record between the Andean region and the Tethys through the Caribbean area. Nevertheless, the definitive consideration of *Lithacoceras mexicanum* Burckhardt, 1906 as a true *Lithacoceras* and almost indistinguishable from *L. picunleufuense* can be considered to fill the palaeobiogeographic gap between the Andean species and the very close Submediterranean *Lithacoceras* (e.g., *L. eigeltingense* Ohmert & Zeiss, 1980; see Parent et al. 2006). This assumption is complementary to the strong evidence provided by the strong resemblance of sculpture ontogeny, shell shape and mode of sexual dimorphism between the Andean and Submediterranean *Lithacoceras* (see PGSS 2011).

Genus *Choicensisphinctes* Leanza, 1980

Type species: *Perisphinctes choicensis* Burckhardt, 1903, by OD.

Remarks: The ontogeny of *Choicensisphinctes* cf. *erinoides* (PSS 2011: 33) shows a succession of three ornamental stages: (1) *perisphinctoid*: evolute serpenticone, ribbing more or less dense, prosocline, mostly bifurcate, (2) *mendozanus*: subserpenticone, ribbing dense, polyfurcate with some polyschizotome (see Wright et al. 1996: 306), and (3) bullate: subplatyconic to stout suboxycone, primaries bullate, divided on sheaves, mainly on the bodychamber. However, these stages have been partially recognized in other species described below by which their use is useful for studying the evolutionary changes of the ontogeny of the species of the lineage. Much of the ornamental variation observed within and between the different species is mainly due to changes in the range of sizes (*D*) at which the perisphinctoid and *mendozanus* stages develop. The adult bullate stage seems to be diagnostic of *C.* cf. *erinoides* and similar morphotypes of the Zitteli Z., but is still absent in stratigraphically older species like *Choicensisphinctes platyconus*, *C.* cf/aff. *platyconus* (described below) and *Choicensisphinctes windhauseni* (Weaver, 1931), which show different ornamental styles on the adult phragmocone and bodychamber.

Choicensisphinctes platyconus Parent, Garrido, Schweigert & Scherzinger, 2011
Fig. 5B-C

Remarks: This species is abundant through beds PC-1-PC-3 and occurs as fragmentary and crushed specimens. The two figured specimens are poorly preserved but well comparable to specimens from the type locality (P. Leufú, cf. PGSS 2011: figs. 16F, 19B).

Choicensisphinctes cf./aff. *platyconus* Parent, Garrido, Schweigert & Scherzinger, 2011
Figs. 5D, 6, 7A-D, 8A-D

2003a *Choicensisphinctes choicensis* Burckhardt. – Parent, p. 154, fig. 8.
2011 *Choicensisphinctes* cf./aff. *platyconus* n. sp. – PGSS, p. 30, fig. 23B-E.
2011 *Choicensisphinctes* cf./aff. *platyconus* Parent et al. – PSS, p. 29, fig. 6D-E, ?C.

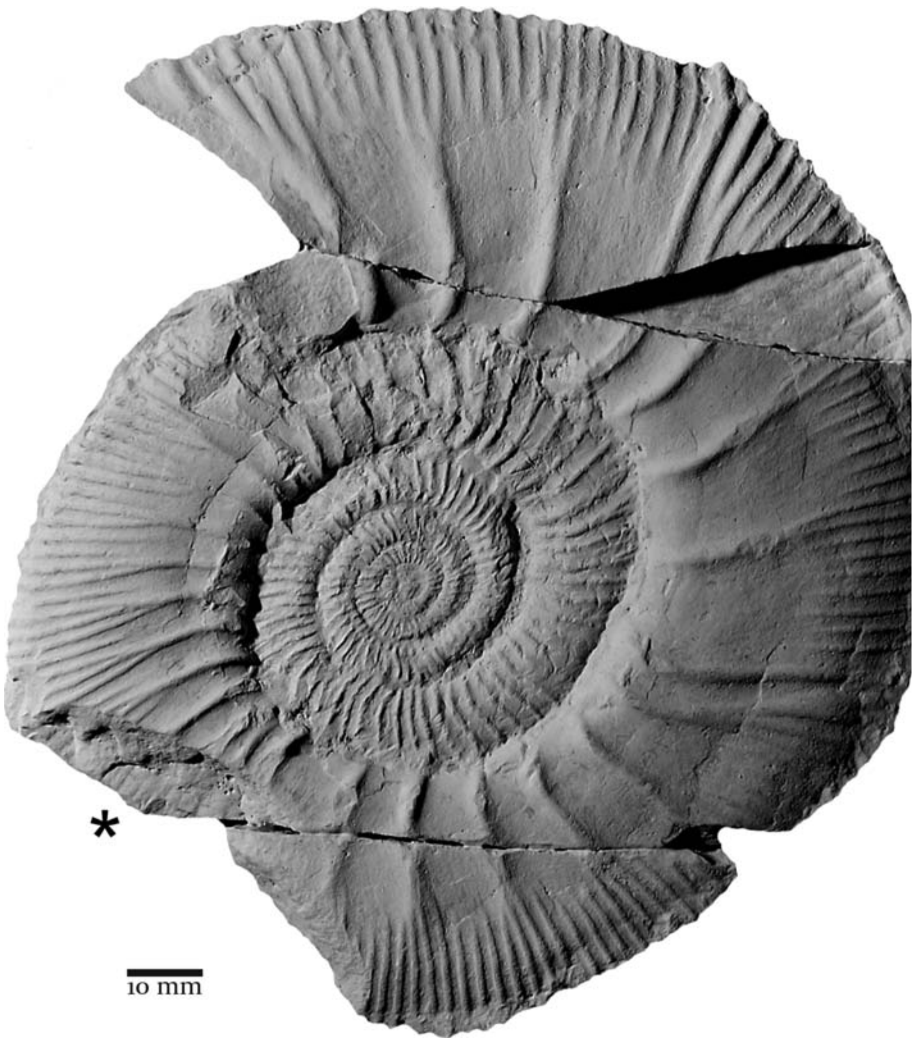

Fig. 6. *Choicensisphinctes* cf./aff. *platyconus* Parent et al., 2011. Almost complete adult [M] (MOZ-PI 7752), P. Covunco, bed PC-5, Picunleufuense Z. – Natural size. The asterisk indicates the last septum.

Material: One almost complete adult [M] and several incomplete or fragmentary specimens from bed PC-5. Material seen in the field but not collected (some shown as field-photographs) in beds PC-3 and PC-6.

Description: Compressed to moderately inflate and evolute platycone. Phragmocone with suboval whorl section passing to subrectangular with rounded venter in the last adult whorl and the bodychamber. Umbilicus moderately open in the phragmocone (U/D = 0.30-0.40 for D = 30-100 mm), and in the bodychamber (from D_{ls} = 100-110 mm) slightly uncoiling. The peristome, preserved partially, seems to be plain, slightly projected ventrally. The bodychamber is about 250-270° long. Adult size at peristome ranges from 130 to less than 180 mm in diameter. The sculpture shows characteristic and consistent changes during growth forming four ontogenetic stages (I-IV).

Stage I (inner whorls at D < 50-60 mm) – perisphinctoid stage: densely ribbed with narrow, slightly prosocline primaries bifurcate on the upper half of the flank in finer secondaries and with few intercalatories.

Stage II (middle whorls of phragmocone up to beginning of adult bodychamber) – mendozanus stage: primaries become slightly stronger on the lower flank and from mid-

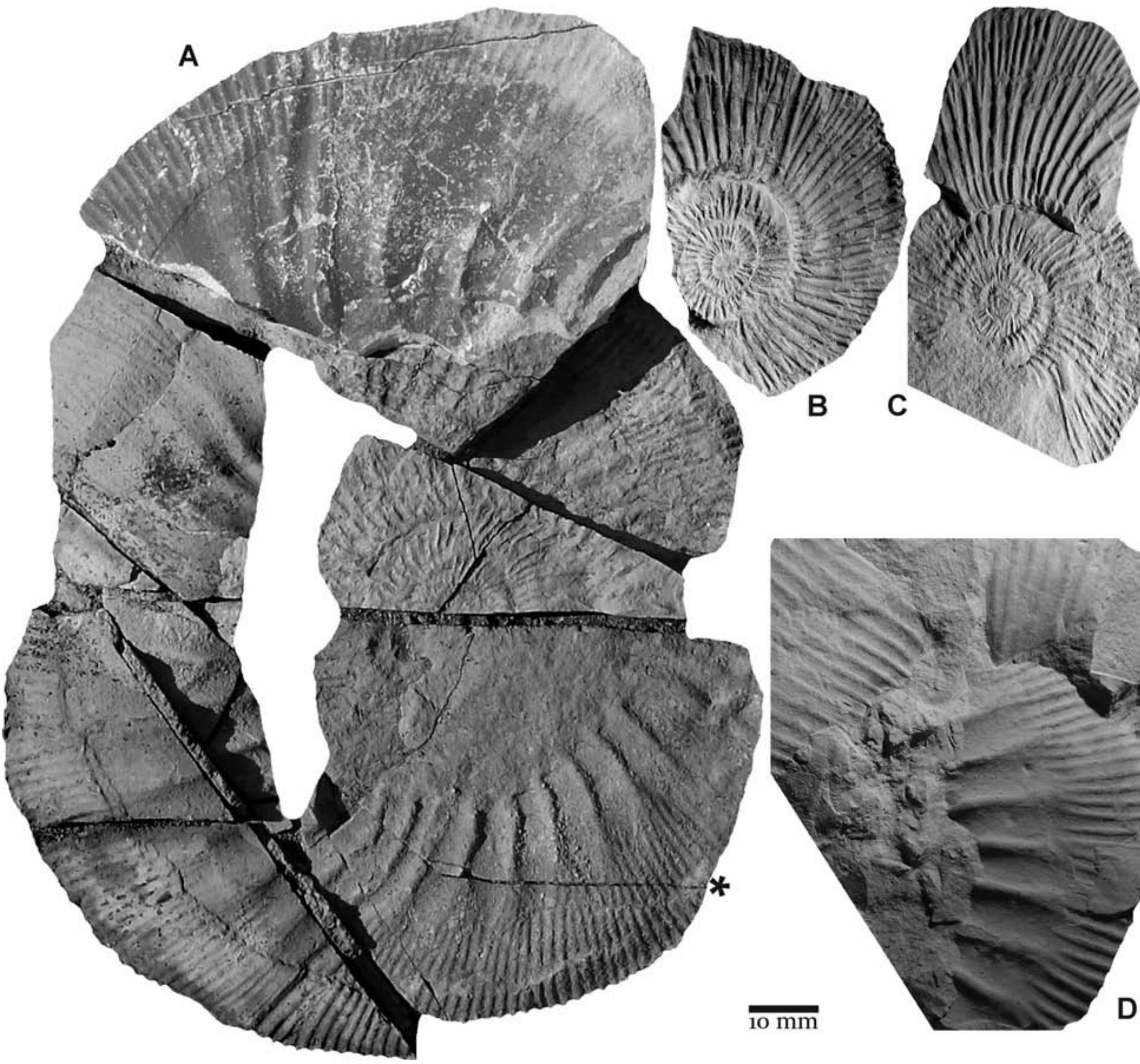

Fig. 7. A-D: *Choicensisphinctes* cf./aff. *platyconus* Parent et al., 2011, P. Covunco, Picunleufuense Z. **A:** Adult [M], field photograph, bed PC-6. **B-C**: Phragmocones (MOZ-PI 8571/1 and 8571/2, respectively), bed PC-5. **D**: Fragment of [M] bodychamber (MOZ-PI 8571/3, bed PC-5), showing the arrangement in beds PC-5-6, composed of abundant crushed fragments. – All natural size. The asterisk indicates the last septum.

flank onwards they bi- and then trifurcate in a virgatotomic style; intercalatory ribs appear towards the beginning of the bodychamber. The max $P = 30$ is reached at $D = 60\text{-}70$ mm.

Stage III (short stage at the beginning of the bodychamber, $D = 100\text{-}120$ mm) – palmate stage: primaries become more distant and profusely divided in the mid-flank in palm-like bundles of 5 to 10 secondaries; the ventral ribs are finer than primaries and cross the venter unchanged and evenly spaced.

Stage IV (adult bodychamber) – ataxioceratoid stage: primary ribs remain strong and rather acute and narrow ($P = 12\text{-}14$, $V = 70\text{-}100$); the bundles of secondary ribs have lost gradually the palm-like aspect by disconnection of the outer secondaries of the bundle becoming intercalatory ribs; towards the peristome the primaries are bi- or trifurcate and separated by several intercalatories. There are two constrictions per whorl (on the phragmocone and adult bodychamber), narrow and moderately deep to shallow, bounded by an engrossed undivided primary in front and proceeded by a polyfurcate primary rib.

Remarks: Fig. 8 summarizes de ontogenetic trends of involution and ribbing of the present sample of the species. The relative umbilical width follows a trend of gentle enlarge-

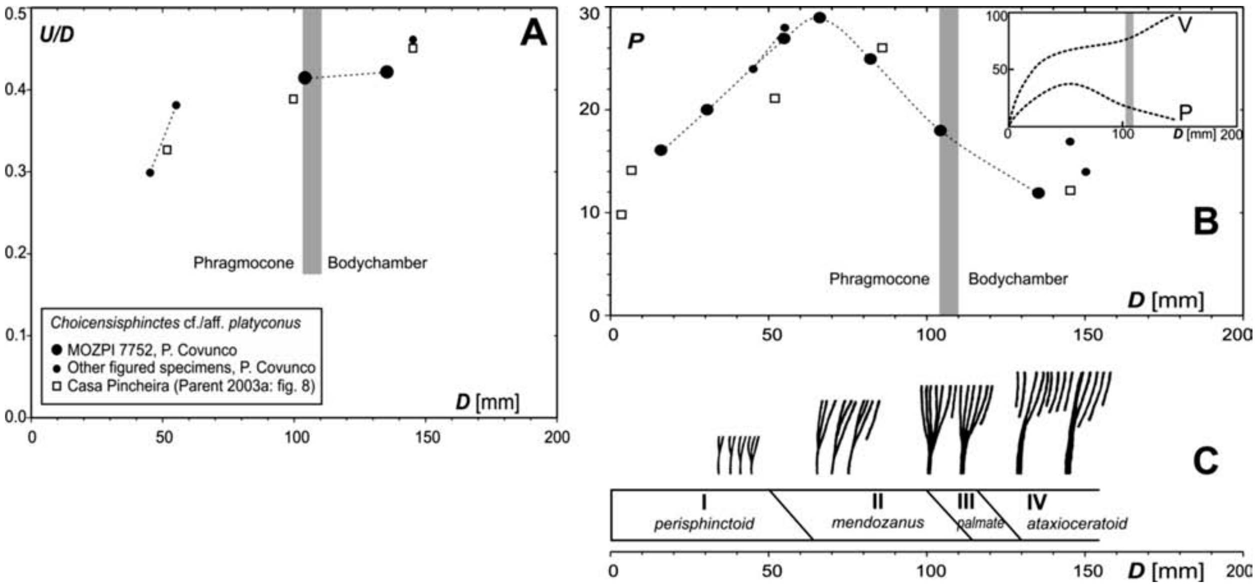

Fig. 8. *Choicensisphinctes* cf./aff. *platyconus* Parent et al., 2011 [M]. **A**: Ontogeny of the relative umbilical width (*U/D*) respect to size (*D*). **B**: Ontogeny of primary ribbing (*P*) in respect to size (*D*); Inset: comparison of the divergent ontogenetic trajectories of ventral (*V*) and primary ribbing. **C:** Ontogenetic sequence of sculptural stages (I-IV) described in text. The shaded bar indicates the approximate diameter of the last adult septum.

ment throughout the ontogeny. The number of primary ribs per half whorl increases markedly from the inner whorls, reaching a maximum of P = 30 at about D = 60-70 mm, and then reversing the trend from the adult phragmocone up to the end of the adult bodychamber. The conspicuous ornamental aspect of these ammonites is mainly originated by the divergent trends of primary and ventral ribbing density (Fig. 8B). Ventral ribbing shows a persistent trend of increasing density: V = 65 (D = 55 mm), 78 (D = 130 mm) and 95 (D = 145 mm).

This species is a conspicuous form which has been widely recorded in a horizon of the Picunleufuense Z., consistently located between the *picunleufuense* β Hz. (below) and the *malarguense* Hz. or *perlaevis* Hz. depending on the localitiy. Nevertheless, there is no adequate material available yet for a formal definition of a new species based on uncrushed specimens collected in succession. The present material is mostly crushed, so that the whorl section is barely observable, only in some fragments, and its dimensions cannot be accurately measured. There exists a well preserved and almost complete adult [M] from Casa Pincheira, but it was collected as a sole specimen (Parent 2003a: fig. 8). Other specimens from A. Cieneguita are poorly preserved and some of them are slightly different (PSS 2011), possibly representing intraspecific variation; and further material from P. Leufú is abundant but always fragmentary.

The [M] of the present species is somewhat similar to *C. platyconus* [M], especially to specimens from the *picunleufuense* β Hz. (PGSS 2011: fig. 21A). Differences are evident in the adult macroconch bodychamber. Indeed, in *C.* cf./aff. *platyconus* the sculpture of the bodychamber consists of widely spaced and acute primary ribs, divided in sheaves of several secondaries with abundant intercalatory ribs, whereas in *C. platyconus* the primaries are mostly bi- or trifurcate, tending to become simple, and the venter smoothens towards the aperture. The adult sizes are very similar. The phragmocone, and in some cases the beginning of the bodychamber look almost identical to some variants of *C. platyconus*, including the HT (cf. PGSS 2011: fig. 14A-B, 19). The close similarity and stratigraphic positions of these two species indicate a closest phyletic relationship within the lineage.

The macroconchs of *Choicensisphinctes windhauseni* (Weaver, 1931) coming from a somewhat higher stratigraphic position (see PGSS 2011) are more compressed and involute, with finer and denser ribbing in the phragmocone and the bodychamber.

The ribbing stage IV (Fig. 8C), the ataxioceratoid stage, is a common feature well known from Submediteranean Ataxioceratidae from the Early Kimmeridgian (e.g. "*Lithacoceras evolutus*" in Schairer 1974: pl. 10, fig. 2; *Ardescia desmoides* in Atrops 1982: pl. 5, figs. 1, 5), in the Late Kimmeridgian (e.g., *Euvirgalithacoceras*? *albulum* in Berckhemer & Hölder 1959: pl. 10, fig. 51) and still in the early (e.g. *Lithacoceras eigeltingense* Ohmert & Zeiss 1980: pl. 1, figs. 1-3) and Middle Tithonian (e.g., *Danubisphinctes palmatus* in Schweigert & Scherzinger 2004: pl. 1, fig. 6). This persistent and complex sculpture indicates

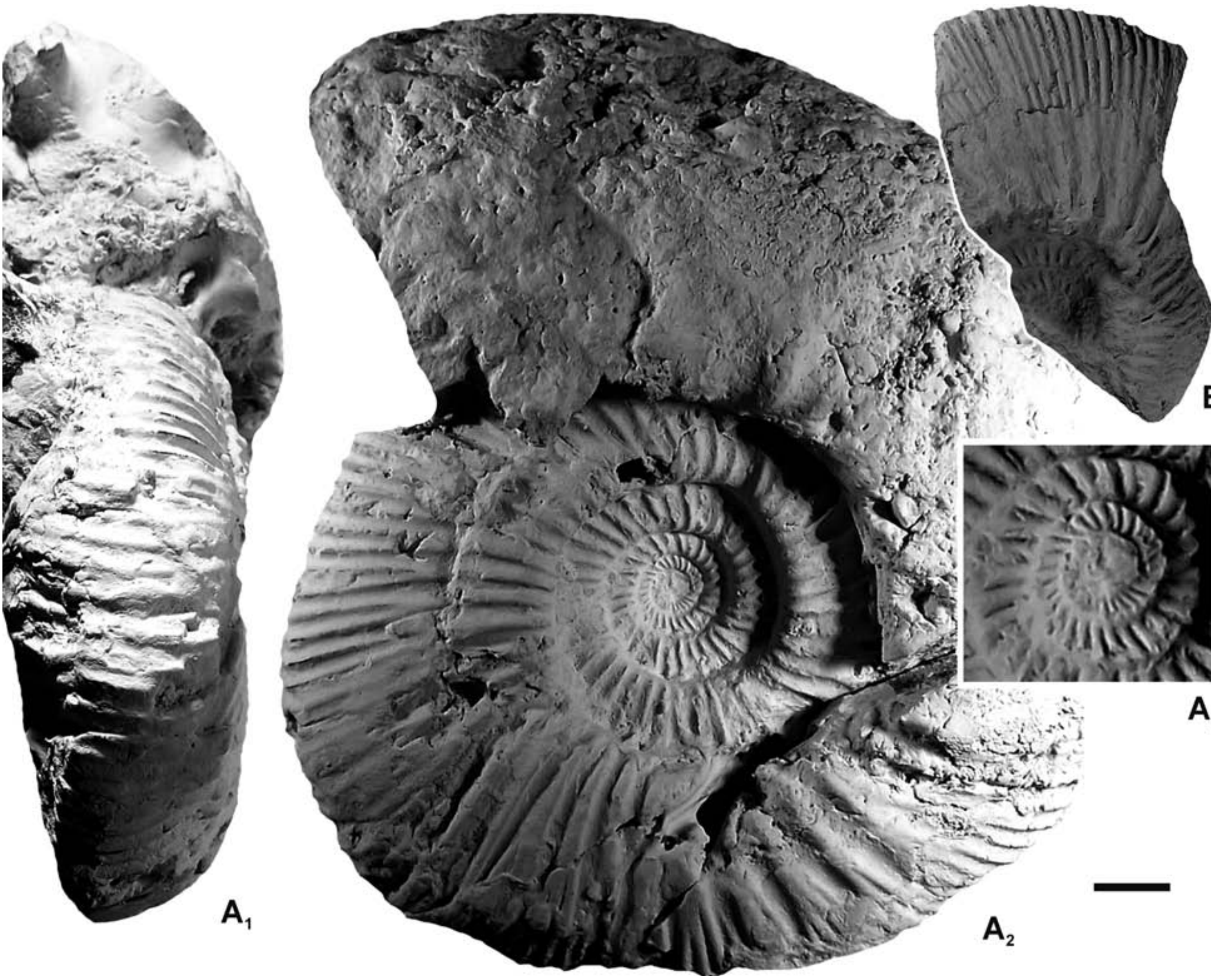

Fig. 9. A: *Choicensisphinctes* cf. *erinoides* (Burckhardt, 1903), adult [M] phragmocone (MOZ-PI 8553/1); inner whorls shown in double size (**A$_3$**), P. Covunco, bed PC-29, Zitteli Z. **B**: *Choicensisphinctes* cf. *limits* (Burckhardt, 1930), portion of phragmocone (MOZ-PI 8554), P. Covunco, bed PC-29, Zitteli Z. – All natural size, except **A$_3$**. The bar represents 10 mm length for natural size views.

close phyletic relationships between *Choicensisphinctes* and the Late Kimmeridgian-Early Tithonian lithacoceratids as discussed in PGSS (2011). However, the facipartite arrange of the stage III (Fig. 8C) is rather a distinctive feature of *Choicensisphinctes*, which on the other hand retains this feature in some later species of the lower middle Tithonian Zitteli Z. as for example in *Choicensisphinctes australis* in PGSS (2011: fig. 21B). On the other hand parabolic structures are completely unknown in *Choicensisphinctes*.

Uhlig (1910: pl. 60, fig. 1) figured a specimen of *Virgatosphinctes multifasciatus* Uhlig, 1910 from Jandu, India, almost identical to our specimen from bed PC-5 (Fig. 6). Uhlig (1910) listed four specimens but did not designate a type specimen, which is why we here designate the only figured specimen as the lectotype. The ribbing ontogeny and shell shape are so similar that it is almost impossible to separate them in morphological terms – the specimen from India is somewhat more evolute and compressed and shows an obscured short fascipartite ribbing stage (stage III). Enay (2009) has widely reviewed the genus *Virgatosphinctes* and although *V. multifasciatus* is not mentioned in his paper, we assume that the lectotype comes from beds of the *Virgatosphinctes*-*Aulacosphinctoides* assemblage zone of the Middle to lower Upper Tithonian, younger than the Picunleufuense Z. of the Andean Lower Tithonian. It is clear that significant comparisons are those based on successions of assemblages for considering the intraspecific variation and the evolutionary changes. Although these comparisons cannot be advanced, the strong similarity between the ontogenies suggests that *C.* cf./aff. *platyconus* and *V. multifasciatus* belong to closely related lineages. This assumption concurs with the hypothesis of Enay & Cariou (1997: 5) about a possible derivation of *Virgatosphinctes* from *Choicensisphinctes*.

Choicensisphinctes cf. *erinoides* (Burckhardt, 1903)
Fig. 9A; Appendix 1

Material: Several fragmentary specimens from beds PC-27, 29 and 32.

Description of two phragmocones from bed PC-29 (Fig. 9A): Inflate suboxyconic aspect, max preserved *D* = 140 mm; moderately involute with wide suboval whorl section. Primaries strong, slightly prosocline, closely spaced, bifurcated at about *D* = 100 mm and then trifurcated and tending to produce sheaves of five secondaries from below the mid-flank; ventral ribs finer than primaries and crossing the venter unchanged and evenly spaced. In the larger specimen, remains of umbilical seam of the next whorl which is not preserved seem to indicate the beginning of the adult uncoiling (bullate stage).

Middle whorls (30 < *D* < 80 mm) are relatively somewhat wider in whorl section, covered by primaries prosocline, bi- or trifurcated on mid-flank in finer secondaries which, with some intercalatories, cross unchanged and evenly spaced the widely rounded venter (mendozanus stage).

Inner whorls (*D* < 20 mm) evolute and moderately depressed with rounded whorl section, rather coarsely ribbed by prosocline primary ribs which bifurcate on the mid-flank (perisphinctoid stage).

Remarks: The described specimens are almost indistinguishable from the specimen figured by PSS (2011: fig. 10A) from about the same stratigraphic position, the cf.-*erinoides* horizon (Zitteli Z.) of A. Cieneguita. The only difference is the earlier, and likely insignificant, onset of variocostation, at about *D* = 90 mm, in the specimen of A. Cieneguita and at about *D* = 110 mm in the here described specimen (Fig. 9A). The HT of *C. erinoides* comes from a similar stratigraphic position (see PGSS 2011) and differs in the same way since its variocostation starts even earlier, at about *D* = 60 mm, whereas its shell morphology and sequence of ribbing stages are very similar. These differences seem to indicate gradual intraspecific variation. A well preserved adult macroconch phragmocone from Los Catutos is shown in Appendix 1. This specimen is identical to that of A. Cieneguita mentioned above. It was collected from an undefined horizon, but could be deduced it comes from the Zitteli Zone, most likely from a bed roughly equivalent to the level PC-32.

In the large concretions of the interval of beds PC-27-32 (Zitteli Z.) fragments of a large-growing ammonite species occur abundantly. It is more involute and compressed with short, strong primary ribs polyfurcating in sheaves from below the middle of the flank. In Fig. 9B one of these specimens is determined as *Choicensisphinctes* cf. *limits* (Burckhardt, 1930), a portion of phragmocone which is identical at comparable size to the specimen from A. Cieneguita figured in PSS (2011: fig. 11A), coming from about the same stratigraphic position (cf.-*erinoides* Hz.). Considering that both forms have identical inner whorls (cf. Fig. 9A, B) and intergrade in involution as the only feature which exhibits considerable variation, it was already pointed out (PSS 2011) that they could likely belong to a single species.

Occurrence: Zitteli Z. of P. Covunco. In old collections of the Museo Olsacher there are several large and well preserved macroconchs from the Los Catutos Mb of the locality Los Catutos resembling the material here described (see Appendix 1).

Subfamily Torquatisphinctinae Tavera, 1985
Genus *Catutosphinctes* Leanza & Zeiss, 1992

Type species: *Catutosphinctes rafaeli* Leanza & Zeiss, 1992, by OD.

Remarks: The HT of the type species is a poorly preserved, crushed specimen coming from Los Catutos (see Figs. 1-2). This specimen shows an incipient uncoiling and variocostation at the end of the outermost whorl (Leanza & Zeiss 1992: fig. 3) strongly suggesting it represents an adult macroconch with an incomplete bodychamber. In previous papers (Parent 2001, 2003a) several perisphinctids showing significant and consistent similarities in ribbing, adult size and sexual dimorphism, were preliminary assigned to "*Torquatisphinctes*". Later, collections of abundant material made by the authors in other localities (especially in C. Lotena-C. Granito or La Amarga, P. Tril, M. Quemado and A. Cieneguita) provided complete macroconchs and microconchs from the same stratigraphic position as *C. rafaeli* after which it could be organized a picture of the lineage including those forms in *Catutosphinctes*.

Catutosphinctes includes a succession of several forms throughout the Tithonian, conforming to a succession interpreted as an evolving lineage well represented all throughout the NB (PGSS 2011).

In a recent paper Zeiss & Leanza (2010) have included *Catutosphinctes* in the subfamily "Windhauseniceratinae Zeiss & Leanza, 2010". Unfortunately this subfamily name is invalid for preoccupation in Leanza & Zeiss (1992: 1845, 1848). On the other hand, "Windhauseniceratinae Leanza & Zeiss, 1992" is also invalid (Klein 2005: 2), since it was proposed without description (ICZN Art. 13.1) and between quotation marks and brackets with indication neither of the condition of a new taxon name nor of a type genus (ICZN Art. 16.1, 16.2). Furthermore, this name was used in Zeiss & Leanza (2008: 233) for a different group of ammonites than those included in Zeiss & Leanza (2010: 36).

This invalid "Windhauseniceratinae Zeiss & Leanza, 2010 non 1992" is a very heterogeneous group, including genera of the Himalayitidae (*Windhauseniceras*), Torquatisphinctinae (*Catutosphinctes* and *Mapuchesphinctes*) and Lithacoceratinae (*Zapalia* and *Parazapalia*). On the other hand, *Catutosphinctes proximus* (Steuer) has been recently revised with description of macro- and microconch topo-

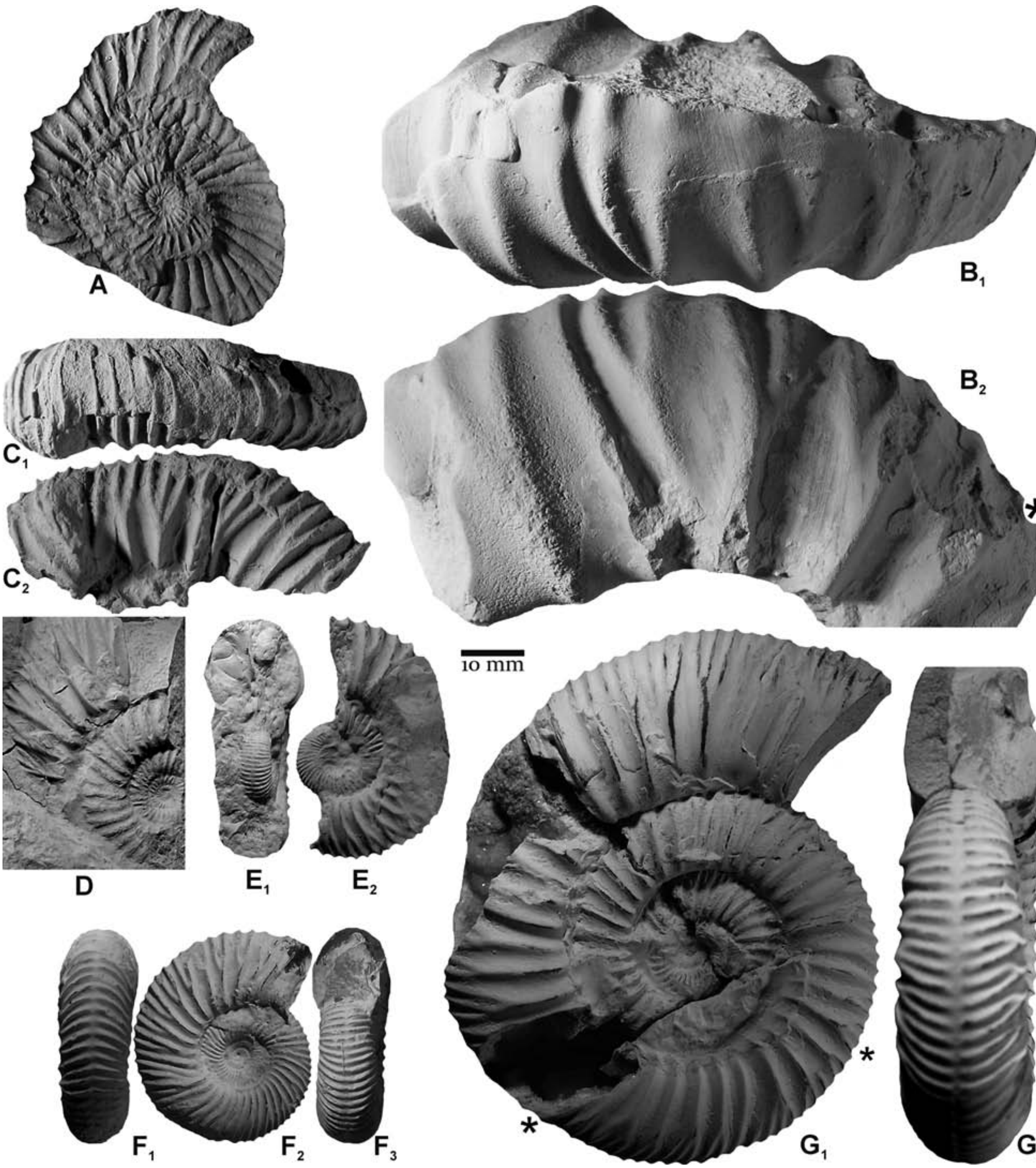

Fig. 10. A: *Catutosphinctes guenenakenensis* Parent et al., 2011, phragmocone (MOZ-PI X1), P. Covunco, bed PC-1, lower Picunleufuense Z. **B-D**: *Catutosphinctes* cf. *windhauseni* (Weaver, 1931), P. Covunco, bed PC-19, Zitteli Z.; **B**: portion of adult [M] bodychamber (MOZ-PI 7784/1); **C**: portion of phragmocone (MOZ-PI 7784/2); **D**: portion of phragmocone (MOZ-PI 7784/3). **E-G**: *Catutosphinctes* n. sp. A, P. Covunco, bed PC-37, Zitteli Z.; **E**: portion of phragmocone (MOZ-PI 6890/3); **F**: portion of phragmocone (MOZ-PI 6890/2); **G:** almost complete adult [m?] (MOZ-PI 6890/1). – All natural size. The asterisk indicates the last septum.

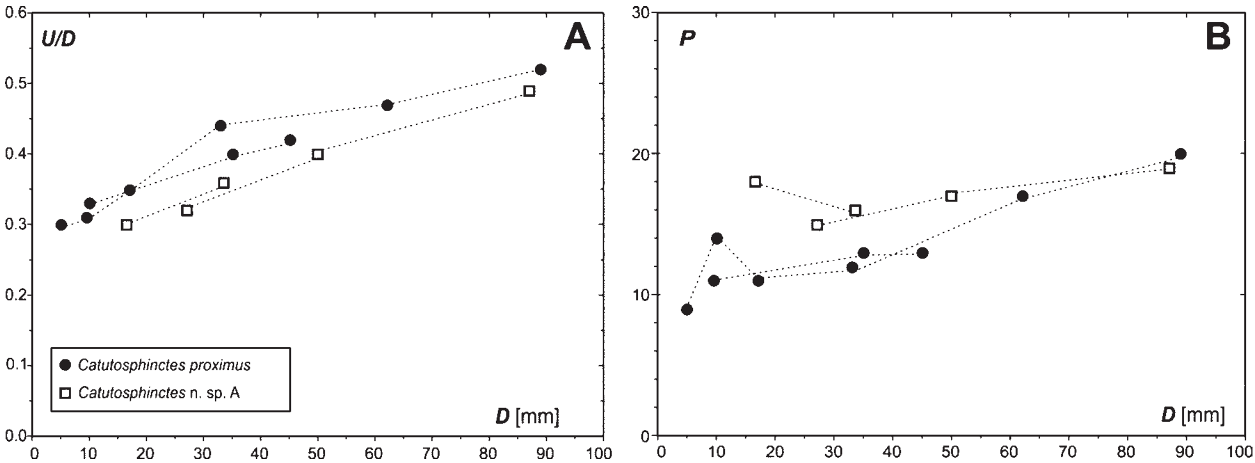

Fig. 11. *Catutosphinctes* n. sp. A and *Catutosphinctes proximus* (Steuer, 1897). **A**: Ontogeny of relative umbilical widht (*U/D*) respect to size (*D*). **B**: Ontogeny of primary ribbing (*P*) in respect to size (*D*). The specimens considered are those from Figs. 10F-G (*Catutosphinctes* n. sp. A) and 12B-C (*C. proximus*).

types in PSS (2011), where we demonstrated its generic assignation to *Catutosphinctes* and thus excluding closer phyletic relationships with *Aulacosphinctes* Uhlig, 1910 (Himalayitidae).

Catutosphinctes guenenakenensis Parent, Garrido, Schweigert & Scherzinger, 2011
Fig. 10A

Remarks: The species is rather abundant in beds PC-1 and PC-2 (Picunleufuense Z.) but occurs as impressions or very fragmentary specimens. An example of a moderately preserved specimen is figured, showing the typical juvenile morphology of this species.

Catutosphinctes cf. *windhauseni* (Weaver, 1931)
Fig. 10B-D

Material: Two incomplete phragmocones and a portion of adult [M] bodychamber, all from bed PC-19.

Description: The adult macroconch bodychamber (estimated *D* = 130-140 mm), with oval whorl section, is strongly ribbed by bi- or trifurcate ribs and few single primaries associated with a bifurcate rib; all ribs cross de rounded venter with a regular interruption or weakening.

The outer whorl of the phragmocone (estimated *D* = 60-70 mm), with subrectangular whorl section, is strongly sculptured by acute primary ribs which are bi- or trifurcate on mid-flank from a raised portion, then crossing evenly spaced the venter and describing a gentle arch. The inner whorls at *D* = 10-35 mm are widely umbilicate with a suboval to subrectangular whorl section. Ribbing is composed of radial primary ribs which bifurcate on the upper half of the flank.

Remarks: The described material is mostly fragmentary, but the ontogeny of this species can be reconstructed with some confidence, showing an intermediate morphology between *C. guenenakenensis* and *C. windhauseni*.

C. windhauseni has a very conspicuous morphology and apparently occurs within a short stratigraphic interval in the localities where is recorded, like in the type locality C. Granito (HT refigured in PGSS 2011: fig. 25A), C. Lotena, P. Tril and A. Cieneguita. Interestingly it occurs in beds of the upper Picunleufuense Z./lower Zitteli Z., above *C. guenenakenensis* and below *Catutosphinctes* n. sp. A (described below).

Catutosphinctes n. sp. A
Figs. 10E-G, 11

Material: Six well preserved juvenile specimens and one adult [m?] from a single concretion of bed PC-37.

Description: Inner whorls (5 < *D* < 20 mm) moderately inflate and involute with rounded to subrectangular whorl section; ribbing dense and fine, prosocline, alternating a simple primary with a bifurcate; ventral ribbing crossing the venter evenly spaced and unchanged. Middle whorls (20 < *D* < 30-35 mm) somewhat more compressed with suboval whorl section; finely ribbed with prosocline primaries regularly bifurcated on the upper half of the flank in two more or less widely splayed, equally strong secondaries; ventral

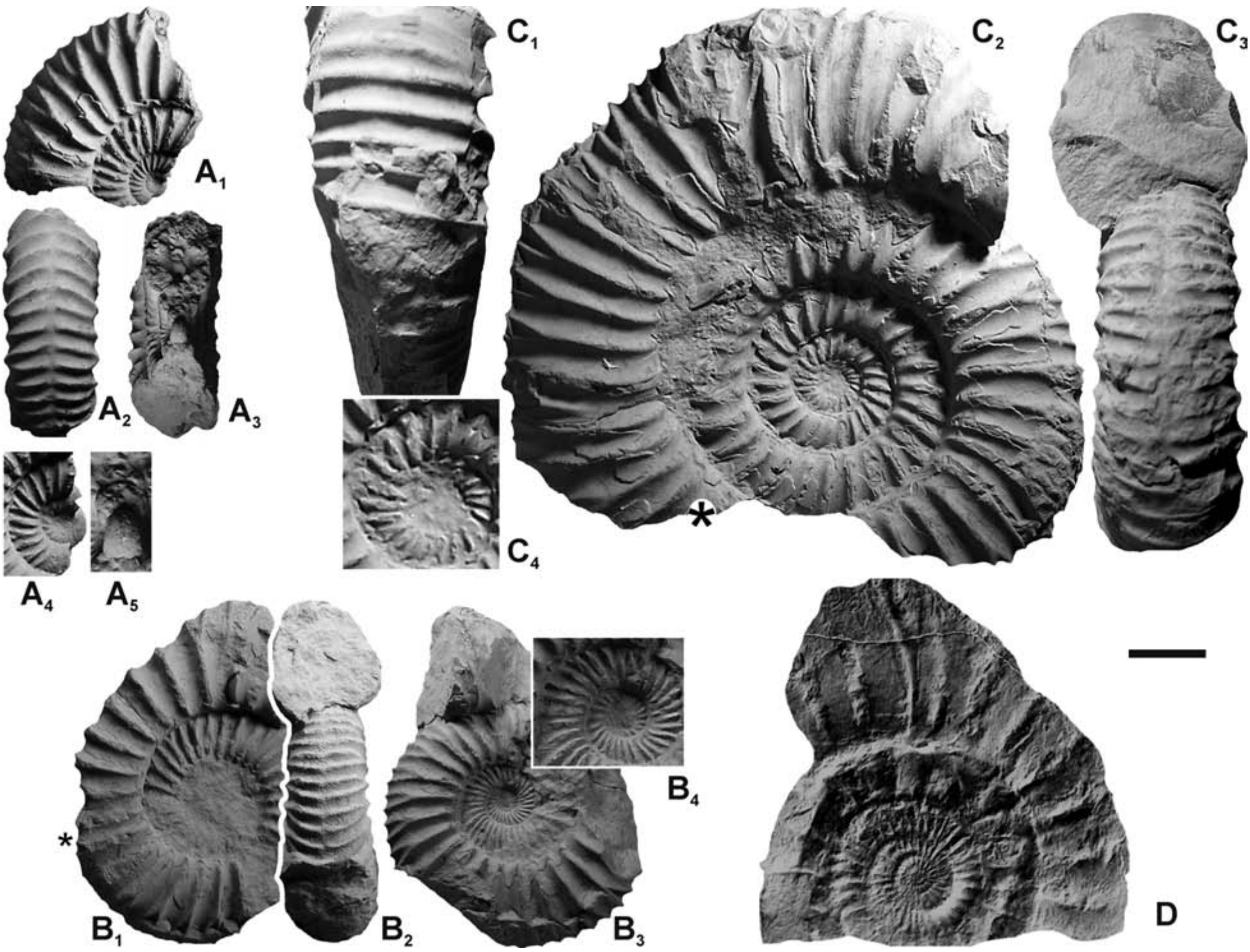

Fig. 12. A-C: *Catutosphinctes proximus* (STEUER, 1897), P. Covunco, bed PC-47, Proximus Z.; **A**: portion of phragmocone (MOZ-PI 7785/2) showing the whorl section (**A_2-A_3**) and the shell shape and sculpture of the innermost whorls (**A_4-A_5**, enlarged x2); **B**: phragmocone [m?] with beginning of bodychamber (MOZ-PI 7785/1); innermost whorls (**B_4**) enlarged (x2); **C:** juvenil? [M] with portion of bodychamber (MOZ-PI 7785/3); innermost whorls (**C_4**) enlarged (x2). **D**: *Catutosphinctes* aff. *rafaeli* LEANZA & ZEISS, 1992, phragmocone with beginning of bodychamber (MOZ-PI X2), P. Covunco, loose from bed PC-60, upper Proximus Z. – Natural size, otherwise indicated. The bar represents 10 mm length for natural size views. The asterisk indicates the last septum.

ribbing evenly spaced, interrupted on the mid-venter forming a narrow groove. Outer whorls (from *D* = 35 mm; max preserved *D* = 89 mm) evolute with suboval whorl section, becoming markedly uncoiled and higher than wide in whorl section towards the aperture. Ribbing strong, composed by acute ribs, at first bifurcated on a raised point in two widely splayed secondaries; from the beginning of the bodychamber bifurcate ribs alternate with subvirgatotomic trifurcate ribs which become predominant towards the peristome; ventral ribs are interrupted by a well-marked smooth band which fades off towards the peristome. The bodychamber begins at about *D* = 53 mm and extends along half a whorl, but it could be incomplete for there are no clear indications of the peristome. Septal suture line is not discernible.

Remarks: Outer whorls are typical for the genus: evolute and inflate serpenticone, subrectangular whorl section, persistent ventral groove and strong ribbing with the point of furcation raised. On the other hand, the inner (and in some the middle) whorls show a shell morphology and sculpture superficially similar to the inner whorls of some species of *Choicensisphinctes.* If only few incomplete phragmocones are considered it is difficult to make a convincing generic assignment.

The larger specimen (Fig. 10G) is adult, as denoted by the marked uncoiling of its bodychamber, and seems to be a microconch due to its small size and the absence of any variocostation typical for macroconchs of this genus.

The variants with strongly ribbed median whorls show a close similarity with material from A. Cieneguita and C. Lotena. Morphologically the specimens from A. Cieneguita (PSS 2011: fig. 19E-F) match perfectly but their stratigraphic position is higher, in the Proximus Z. The material from C. Lotena is not yet published, but in large samples of the upper Zitteli and lower Proximus zones several almost identical specimens occur as part of the wide range of variation of the lineage at these levels.

C. proximus from bed PC-47 is slightly more evolute and more coarsely ribbed in the juvenile phragmocone (D = 10-30 mm) than *Catutosphinctes* n. sp. A (Fig. 11).

In the literature there are only few ammonites with well-known stratigraphic position that could be assigned to this new species. One of them is a fragmentary ammonite from the Lower Tithonian "Mendozanus Zone" (?Zitteli Z.) of Paso Piuquenes, Mendoza, figured as *Virgatosphinctes denseplicatus rotundus* Spath by Aguirre-Urreta & Vennari (2009: fig. 5l).

Occurrence: Zitteli Zone of P. Covunco. Comparable material from C. Lotena also comes from the Zitteli Z.

Catutosphinctes proximus (Steuer, 1897)
Fig. 12A-C

Synonymy: See PSS (2011)

Material: Several more or less well preserved specimens from beds PC-44, 47 and 53-54. Best preserved are the specimens from bed PC-47: an adult macroconch with part of its bodychamber, a phragmocone and a juvenile macroconch, or, more likely, an adult microconch with incomplete bodychamber.

Description of material from bed PC-47: Macroconch. Innermost whorls (D < 4 mm) subcadiconic, moderately evolute. Inner whorls at 5 < D < 15 mm serpenticone evolute and depressed with oval whorl section. Outer whorls, up to the peristome, serpenticone evolute with wide umbilicus and suboval to subrectangular whorl section.

From the innermost whorls until the bodychamber there is a well defined ontogenetic trend in the shell morphology: the relative umbilical width (U/D) enlarges (Fig. 11A) whereas the relative width of the whorl section (W/D) becomes narrower.

Ribbing starts at about D = 3 mm in the form of feeble prosocline ribs confined to the flanks. At D = 4-6 mm primary ribs become strong and pass to the venter somewhat finer but not interrupted. From about D = 6 mm ribbing is more or less dense, composed by acute prosocline primaries which bifurcate on the upper third of the flanks from a raised point of furcation. Simple, undivided primaries are scarce. From about D = 25 mm the ventral ribbing shows a moderately marked forward projection (chevron) and well marked interruption forming a narrow smooth band. The ventral projection feature is more accentuated in those specimens, which are more densely ribbed in the inner whorls.

There is a trend of gentle increment of the number of primaries per half whorl from the inner whorls up to the bodychamber (Fig. 11B). However, at about D = 10-15 mm it is noted a short stage of wide variation: some specimens show strong primaries whereas in others they are finer and closely spaced. Subsequently all specimens develop a similar sculpture in design, strength and density. On the bodychamber the trend reverts by a more or less marked variocostation of stronger and more widely spaced primaries. The peristome is not preserved and the suture lines are not discernible.

Microconch?: The specimen shown in Fig. 12B seems to be an adult [m]. The last half whorl preserved, incipiently uncoiled, belongs to the bodychamber. Considering the larger size of the associated [M] described above and the adult condition of this specimen, as undoubtedly indicated by the uncoiling in a non-pathological specimen, it can be assumed it is a microconch, or, less likely, a small adult [M].

Remarks: The attribution to *C. proximus* cannot be soundly based on direct matching of specimens with the LT, because the latter, from A. Cieneguita, is incomplete and seems to be an adult microconch (see Parent 2003a; PSS 2011). Thus, some authors have labeled their specimens by superficial resemblance of material collected in beds which are consequently, but not always certain, assigned to the Proximus Z. Furthermore, as recently new material has been collected throughout all the Tithonian beds of the NB, it has become evident that the *Catutosphinctes* lineage evolves gradually with slight changes, whose patterns are just at the beginning to become understood. A significant step in this sense was the description of abundant topotypes from a stratigraphical interval including the type horizon. This has shown a rather extensive intraspecific variation (see PSS 2011: fig. 18).

The phragmocone of the largest macroconch available (Fig. 12C) is indistinguishable at similar diameters from the large adult microconch from A. Cieneguita figured by PSS (2011: fig. 18E). The spectrum of variation of the present material from bed PC-47 seems to be strongly similar to that of the samples from the *falculatum* Hz. of A. Cieneguita what concerns the specimens provisionally described as *C.* cf. *proximus* (PSS 2011: fig. 19D). This close similarity suggests the same stratigraphic position of bed PC-47, that is the *falculatum* Hz. of the Proximus Z. Nevertheless, further ammonite taxa typical of this horizon have not been recorded in that bed.

Occurrence: Proximus Z. of P. Covunco.

Catutosphinctes aff. *rafaeli* Leanza & Zeiss, 1992
Fig. 12D

Remarks: A single specimen (impression), bed PC-60, which can be attributed to the upper part of the local Proximus Z. because it occurs some meters below the lowermost record of *W. internispinosum* in bed PC-71 (base of the Internispinosum Zone).

Although the specimen is small for the genus, the long and notorious variocostation indicates it is a macroconch. Rather evolute, the inner whorls are moderately densely ribbed with radial primaries which from about D = 25-30

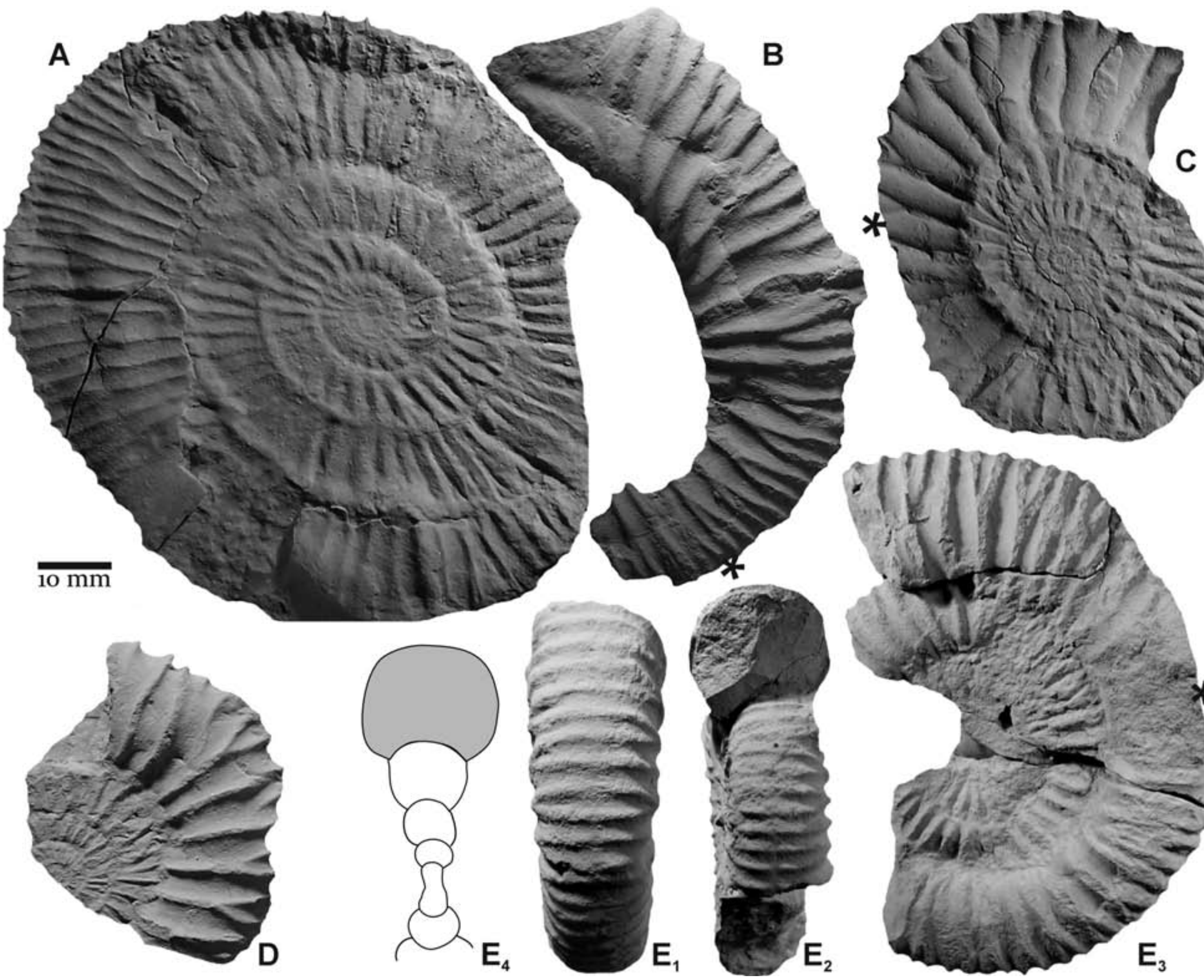

Fig. 13. A-B: *Catutosphinctes rafaeli* Leanza & Zeiss, 1992, P.Covunco, bed PC-72, Internispinosum Z.; **A:** incomplete [M] (MOZP 8840/1); **B**: [m] bodychamber with lappets (MOZ-PI 8840/2). **C-D**: *Catutosphinctes* cf. *rafaeli* Leanza & Zeiss, 1992, P. Covunco, bed PC-84, Internispinosum Z.; **C:** almost complete adult [m?] (MOZ-PI 8840/3); **D**: incomplete adult [m?] (MOZ-PI 8840/4). **E**: *Catutosphinctes araucanensis* (Leanza, 1980), almost complete adult [m] (MOZ-PI 8811/3), P. Covunco, bed PC-92, Internispinosum Z.; **E$_1$**: ventral view beginning of the bodychamber; **E$_2$**: apertural view with last part of bodychamber removed; **E$_3$**: lateral view; **E$_4$**: whorl section at the beginning of the bodychamber (grey). – All natural size. The asterisk indicates the last septum.

mm become stronger and more widely spaced. The specimen resembles *C. rafaeli* described below but significantly differs by the smaller adult size and by the early onset of variocostation in the phragmocone.

Catutosphinctes rafaeli Leanza & Zeiss, 1992
Fig. 13A-D

Material: Abundant crushed specimens and impressions from beds PC-72 to PC-84.

Remarks: The available specimens match with those already described and figured in Parent & Cocca (2007: fig. 3A-G) from the same section and stratigraphic position from the lower part of the local Internispinosum Z., the Rafaeli Subzone of Leanza & Zeiss (1992). The new material includes a comparatively large microconch bodychamber with lappets (Fig. 13B) which has fewer intercalatory ribs in comparison with other specimens of this species (cf. Parent & Cocca 2007: fig. 3A-C), and with *Catutosphinctes colubrinoides* (Burckhardt, 1903). The latter is morphologically indistinguishable from smaller *C. rafaeli* [m].

The HT of *C. rafaeli* is so poorly preserved that it is almost impossible to compare it with other specimens based

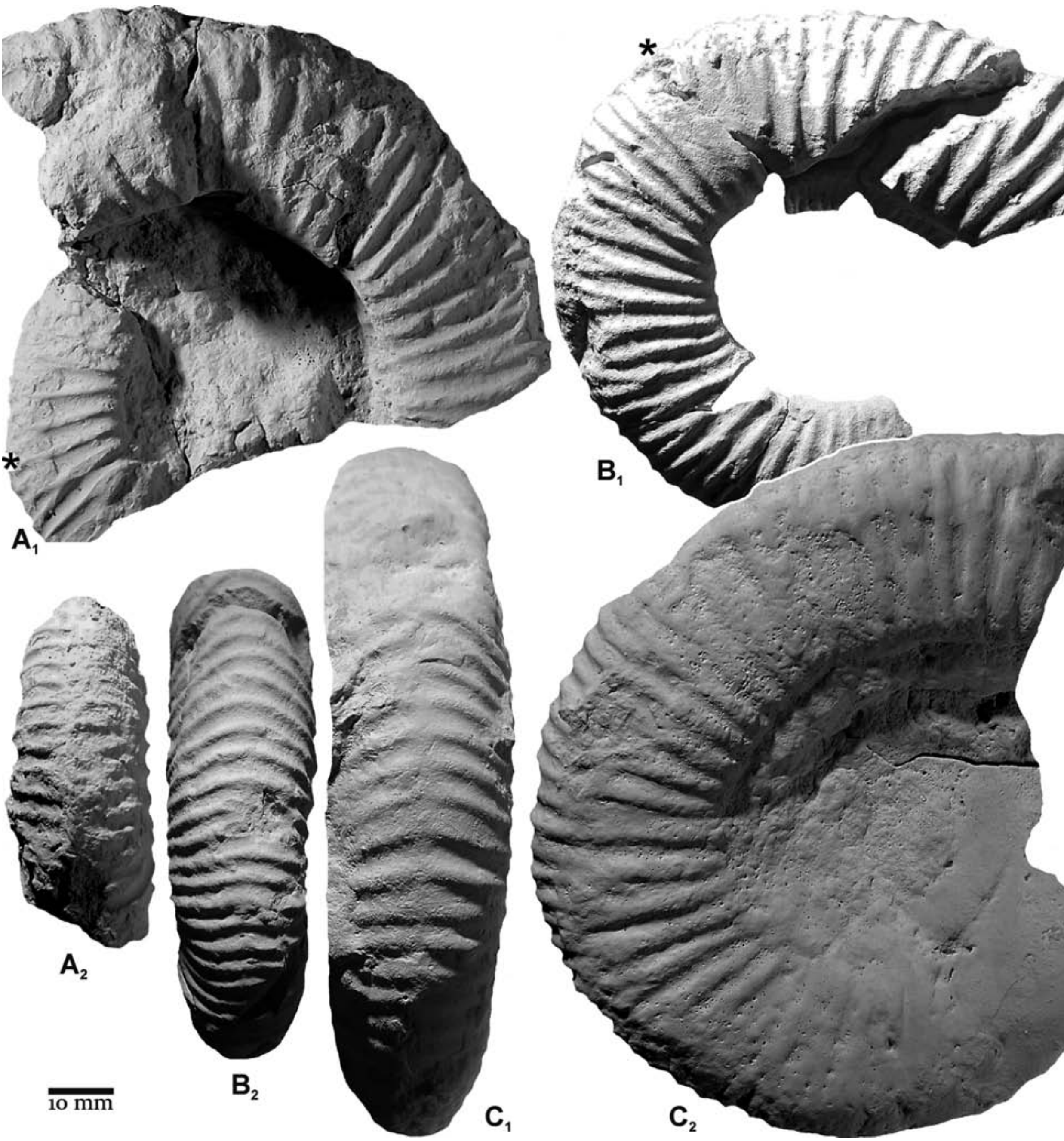

Fig. 14. *Catutosphinctes* n. sp. B, Cerrito Caracoles, Alternans Z.; **A**: fragmentary specimen with half whorl of bodychamber (MOZ-PI 8624), bed CC-19; **B**: last portion of phragmocone and beginning of the bodychamber (MOZ-PI 6887), bed CC-34; **C:** portion of adult? bodychamber (MOZ-PI 6559/2), bed CC-34. – All natural size. The asterisk indicates the last septum.

on morphology alone. Under this critical constraint the stratigraphic position and the knowledge of the evolution of the lineage become relevant criteria for assigning the newly collected material to *C. rafaeli*.

The two probable microconchs shown in Fig. 13C-D as *C.* cf. *rafaeli*, are evolute with septate whorls which are rather densely ribbed. The bodychamber is uncoiled and strongly variocostate with coarse primaries bifurcating from a raised point placed in the upper half or third of the flank as typical for the genus. Hitherto, there is no described taxon matching exactly with these specimens. The most similar, still unpublished specimens known to us come from the lowermost part of the Internispinosum Z. at C. Lotena, where they are associated with *Aspidoceras* cf. *euomphalum* (Steuer in Parent et al. 2007) and *Catutosphinctes* cf. *rafaeli*.

In the southernmost extension of the NB, the Picún Leufú Subbasin, similar specimens have also been observed in the P. Leufú Fm of the locality P. Leufú where they occur associated with *Aspidoceras* cf. *euomphalum* (Steuer in Parent et al. 2007) and smooth, globose nautiloids.

Occurrence: The first specimens, collected from bed PC-72, occur just above the lowermost record of *W. internispinosum* in bed PC-71, which indicates locally the base of the Internispinosum Z.

Catutosphinctes araucanensis (Leanza, 1980)
Fig. 13E

1980 *Subdichotomoceras araucanense* n. sp. – Leanza, p. 37, pl. 6, figs. 1, 3 (HT).
2007 *Catutosphinctes* cf. *araucanensis* Leanza. – Parent & Cocca, p. 26.

Material: A moderately preserved, almost complete specimen from bed PC-92.

Description: Evolute serpenticone. Max preserved D = 73 mm. Inner whorls rounded in whorl section. Outer whorls with subrectangular whorl section, flat venter and gently rounded flanks. Isocostate ribbing throughout the ontogeny. Primary ribs acute and well-marked, most of them bifurcate on the upper half of flanks in two secondaries as strong and acute as primaries; there is about one simple rib after each four to five, later after each two to three bifurcating ones; the point of furcation is raised, especially on the septate whorls. The ventral ribbing is evenly spaced, interrupted in the last whorl of phragmocone by a narrow groove which fades off towards the peristome. The bodychamber is incompletely preserved through a quarter whorl, beginning at about D_{ls} = 60 mm.

Remarks: The described specimen matches satisfactorily with the holotype of the species which is a complete microconch, showing the last part of the bodychamber with the aperture and lappets preserved as impressions. The diagnostic features of the microconchs of this species are the subrectangular whorl section with flat venter and an isocostate ribbing. The stratigraphic position of the holotype and paratype lies in the Internispinosum Z. of C. Lotena (bed 12 in Leanza 1980: 9). Our specimen has the same relative position within the Internispinosum Z.

Catutosphinctes n. sp. B
Fig. 14A-C

Material: Three fragmentary specimens, apparently macroconchs from beds CC-19 and CC-34.

Description: Evolute, subrectangular in whorl section with gently rounded venter. Primary ribs strong and acute, prosocline, most of them bifurcate on the upper half of the flanks. There is about one simple rib each following one to three bifurcates; the point of furcation is commonly raised. The ribbing cross the venter evenly spaced, interrupted irregularly on the phragmocone or on the bodychamber, forming an adapical arch.

Remarks: The evolute, serpenticonic to planulate shell with acute primary ribs divided into secondaries more or less widely splayed from a raised point (not clearly seen due to preservation) allow to assign these ammonites to *Catutosphinctes*. Nevertheless, they cannot be confidently assigned to any of the described species of the genus, although the subrectangular whorl section is similar in *C. araucanensis*.

Occurrence: Beds CC-19 and CC-34, Alternans Z.

Catutosphinctes cf. *inflatus* (Leanza, 1945)
Fig. 15A

Remarks: One poorly preserved adult [M] from bed PC-154. The last whorl of the phragmocone is evolute (as seen in dorsal face of the bodychamber), whorl section suboval, slightly higher than wide with by radial primary ribs, alternating one simple with one or two bifurcates which cross the venter unchanged. The last preserved whorl is part of the bodychamber, suboval to subrectangular higher than wide. Ribbing is composed by strong, undivided primaries, which cross the venter transversely and unchanged.

C. inflatus was recently reviewed (PSS 2011), based on abundant material from the *vetustum* Hz. of the Alternans Z. of A. Cieneguita.

Family Himalayitidae Spath, 1925
Genus *Windhauseniceras* Leanza, 1945

Type species: *Perisphinctes internispinosus* Krantz, 1926, by monotypy.

Windhauseniceras internispinosum (Krantz, 1926)

Remarks: *W. internispinosum* occurs abundantly in P. Covunco through the interval PC-71-PC-78, but is preserved as impressions or crushed specimens in the marly beds. This material does not provide further information to that what is already known from Leanza (1980), Parent (2003b) and Parent et al. (2007, including the description and illustration of the corresponding microconch of this species). The distinction between *C. rafaeli* and *W. internispinosum*, the most characteristic species of the Internispinosum Z., can be successfully done even from impressions on the basis of the coarse primary ribs with tubercles at the furcation point in the inner whorls of *W. internispinosum*. Moreover, the microconchs can be distinguished by the structure of their

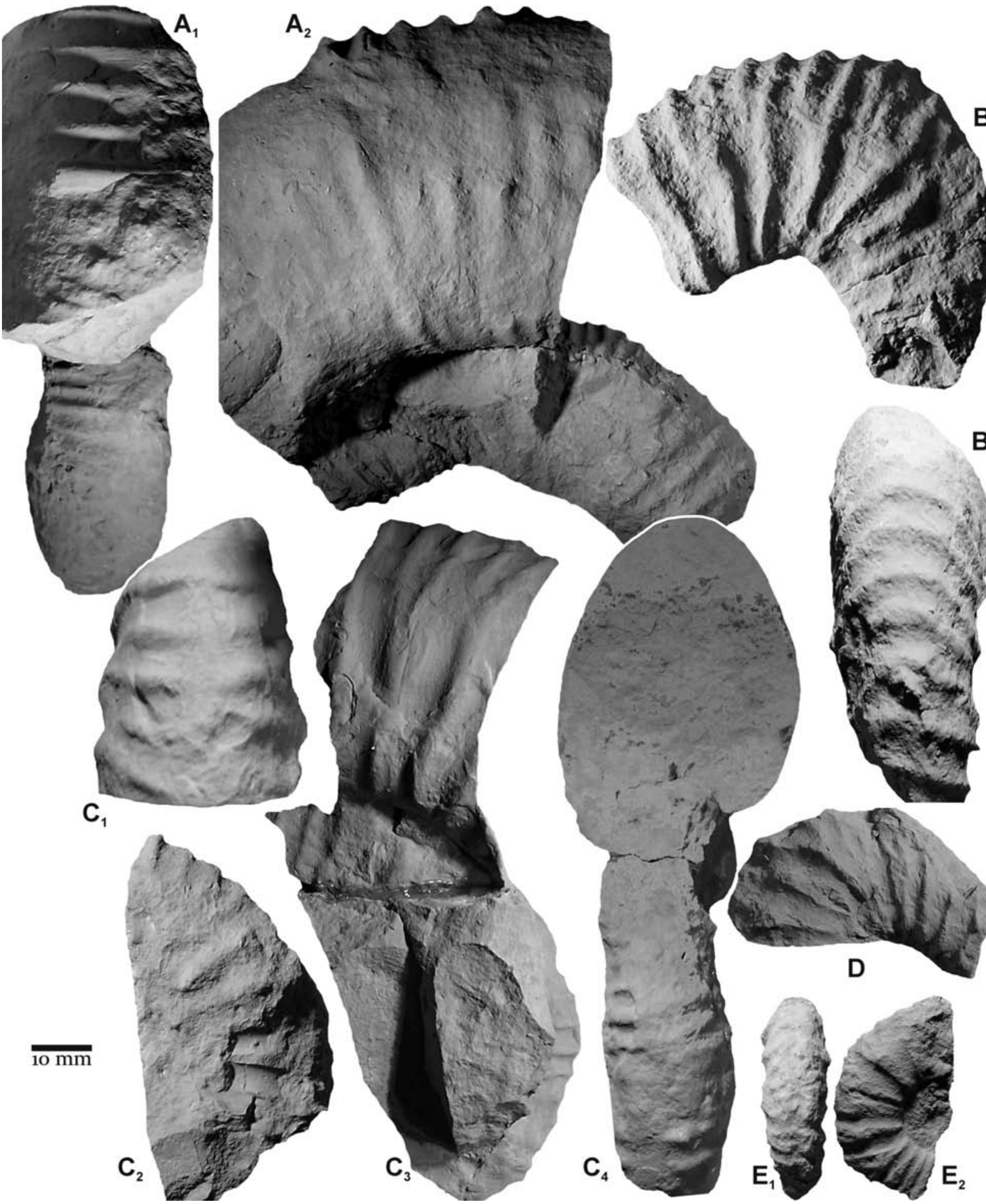

Fig. 15. A: *Catutosphinctes* cf. *inflatus* (LEANZA, 1945), portion of adult [M] phragmocone and beginning of bodychamber (MOZ-PI 8774), P. Covunco, PC-154, upper Alternans Z. **B-E**: *Corongoceras mendozanum* (BEHRENDSEN, 1891), Alternans Z.; **B**: portion of bodychamber (MOZ-PI X3), C. Caracoles, bed CC-33; **C:** fragmentary adult [M] with part of the bodychamber (MOZ-PI 8814), P. Covunco, bed PC-154; **D**: portion of phragmocone (MOZ-PI 8783/2), P. Covunco, bed PC-140; **E**: complete? phragmocone (MOZ-PI 8783/1), P. Covunco, bed PC-154. – All natural size. The asterisk indicates the last septum.

adult peristomes (cf. Parent et al. 2007: fig. 9A-B with Parent & Cocca 2007: fig. 3A-C and Fig. 13B herein).

The first occurrence of the species in bed PC-71 indicates the base of the Internispinosum Z.

Genus *Corongoceras* Spath, 1925

Type species: *Corongoceras lotenoense* Spath, 1925, by OD.

Corongoceras mendozanum (Behrendsen, 1891)
Fig. 15B-E

Remarks: This species is rather frequent within the interval of beds PC-140 to PC-154 (Alternans Z.). All material collected clear matches with the HT of *C. mendozanum* and the abundant material from A. Cieneguita figured in PSS (2011: figs. 33B-D, 34E-G) from the *vetustum* Hz. of the Alternans Z. One of the specimens (Fig. 15B) shows the venter rounded and covered with strong and uninterrupted ribs slightly raised on the ventrolateral shoulder, thus suggesting it is a small adult [M]. *C. mendozanum* [M] tends to retain the ventral interruption up to, at least, the beginning of the adult bodychamber.

In this sense the specimen is very similar to the HT of *Berriasella krantzi* Leanza, 1945 from the *bardense* horizon, Alternans Z. of M. Redondo, Mendoza. This species can be assigned to *Coronogoceras* rather than to *Berriasella* for its strong acute ribbing with small tubercles at the furcation point and slightly raised on the ventrolateral shoulder. *B. krantzi* is only known from a single specimen and more material is needed for observation of the ontogeny and sexual dimorphism which should lead to a conclusive generic assignment.

Genus *Steueria* Parent, Scherzinger & Schweigert, 2011

Type species: *Berriasella alternans* Gerth, 1921, by OD.

Steueria alternans (Gerth, 1921)
Figs. 16-18

Material: Six [M] phragmocones and one complete adult [m] from bed PC-140; three fragments from bed CC-32; a cf.-specimen, an adult [M] phragmocone from bed CC-34.

Description: Macroconch: Inner whorls ($D < 30$ mm) moderately involute with rounded whorl section. The sculpture consists of fine, narrowly spaced primary ribs which set on at the umbilical shoulder and run on the flanks in radial direction. One of each three to five primaries bear a tubercle. The venter is not visible. From about 30 mm in diameter up to the maximum preserved $D = 57$ mm, the inflation and sculpture become more widely variable. The relative umbilical width remains few variable, $U/D = 0.35$-0.40 at $D = 35$-57 mm. The more compressed specimens ($W/D = 0.21$ at $D = 57$ mm) are densely and finely ribbed (Fig. 17A-B); most primaries remain undivided bearing, one each two or four of them, a small tubercle on the upper third or half of flank; all ribs end on the ventrolateral shoulder by forming a small tubercle. The venter is narrow with a median groove. The more inflate specimens ($W/D = 0.41$ at $D = 44$ mm) have stronger sculpture. Primary ribs are slightly prosocline. Each three ribs, two of them remain simple and cross the wide venter adapically arched; the third one bifurcates on the uppermost flank from a tubercle, and the anterior secondary ends on a ventrolateral tubercle whereas the posterior one crosses the venter slightly arched.

Microconch: The phragmocone is identical in shell morphology and sculpture to the [M] at comparable diameter. The bodychamber begins at about $D_{ls} = 28$ mm and is about half a whorl long, evolute and inflated ($W/D = 0.32$ near peristome) with a subquadratic whorl section ($W/H_1 = 1$). Sculpture ontogeny as described for inflated variants with coarse ribs and tubercles. Peristome with minute lappets; $D_p = 37$ mm.

Remarks: The macroconchs are described from phragmocones only, but they can be safely assigned to *S. alternans* by considering the adult [M] phragmocone figured in PSS (2011: fig. 31) and especially the almost complete adult [M] shown in Fig. 16, both from the same horizon within the Alternans Z. of Cajón de Almanza. The adult [M] in Fig. 16 exhibits the inner whorls identical with the specimens of Fig. 17A-B, and the last whorl of phragmocone and the bodychamber show the same whorl section, involution and sculpture of the specimens in Fig. 17D-G.

The matching of different specimens at different sizes denotes variation in size at which the sculptural changes occur. These variations are interpreted as intraspecific as outlined in PSS (2011: 26, 65). This pattern of a more or less continuous intraspecific variation, based on slight to moderate differences in the timing of sculptural development and covariation between whorl inflation with strength of sculpture, can be described in practical terms as discrete morphotypes. Thus, the specimens illustrated in Figs. 16 and 17A-B could be designated *S. alternans* morph spinulosa (cf. PSS 2011: fig. 29A) and those in Fig. 18D-G as *S. alternans* morph alternans. This latter morphotype is centered around the HT of the species (see Parent 2001: fig. 9D-E) at one end of the range of variation. The opposite end of this range of variation, illustrated by the LT of *B. inaequicostata* Gerth, 1921 (= *S. alternans*, see PSS 2011: fig. 29D), is not represented in the material from bed PC-140.

A large portion of an adult [M] phragmocone ($D = 196$ mm) from bed CC-34 (Fig. 18) shows similar shell morphology and sculpture to that of the more inflated specimens described above. However, the ribbing slightly differs from the large [M] of C. Almanza by a denser and more rigid style on the flanks. This specimen is tentatively determined as *S.* cf. *alternans*.

Occurrence: Alternans Z. of P. Covunco and C. Caracoles.

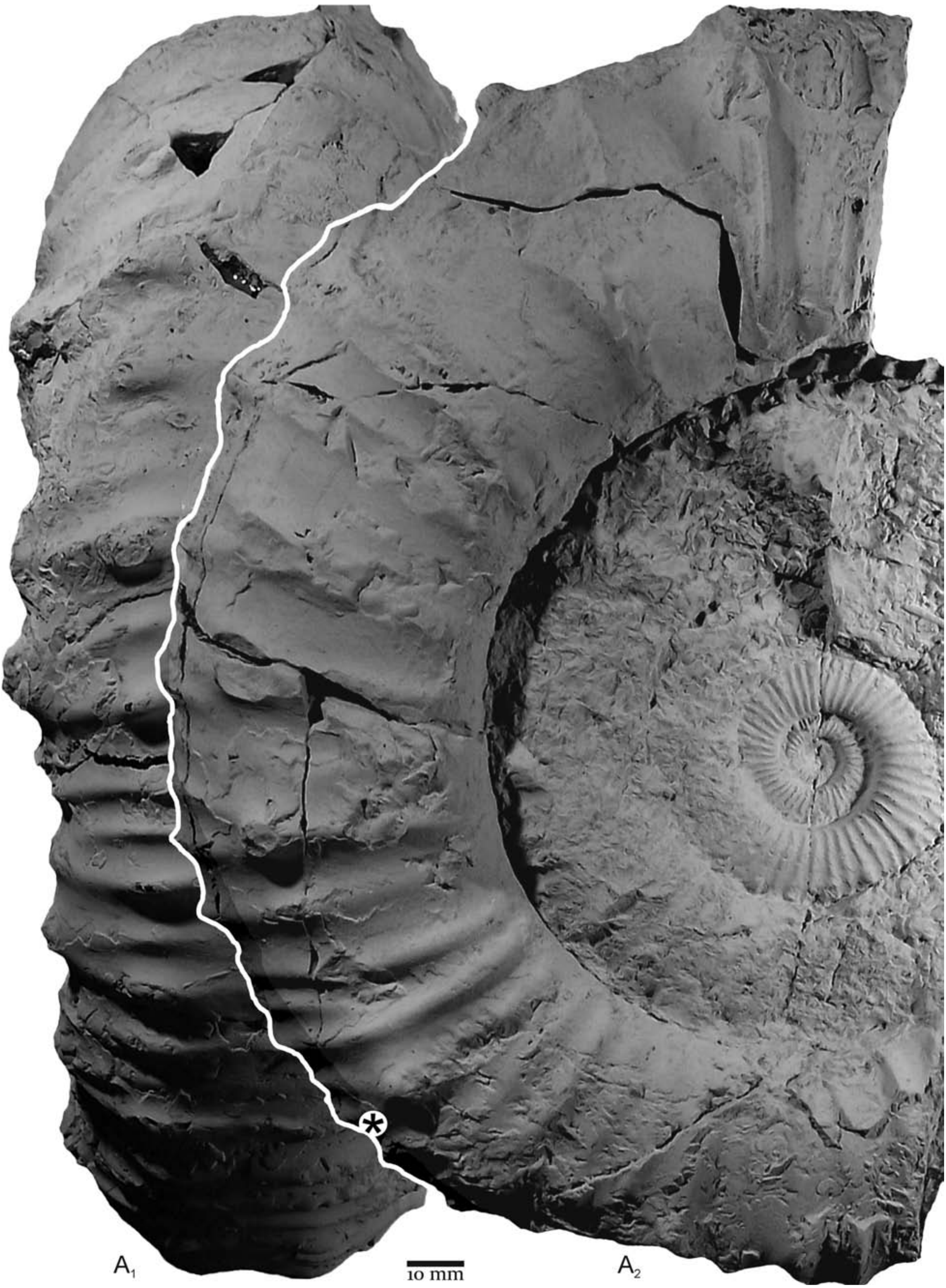

Fig. 16.

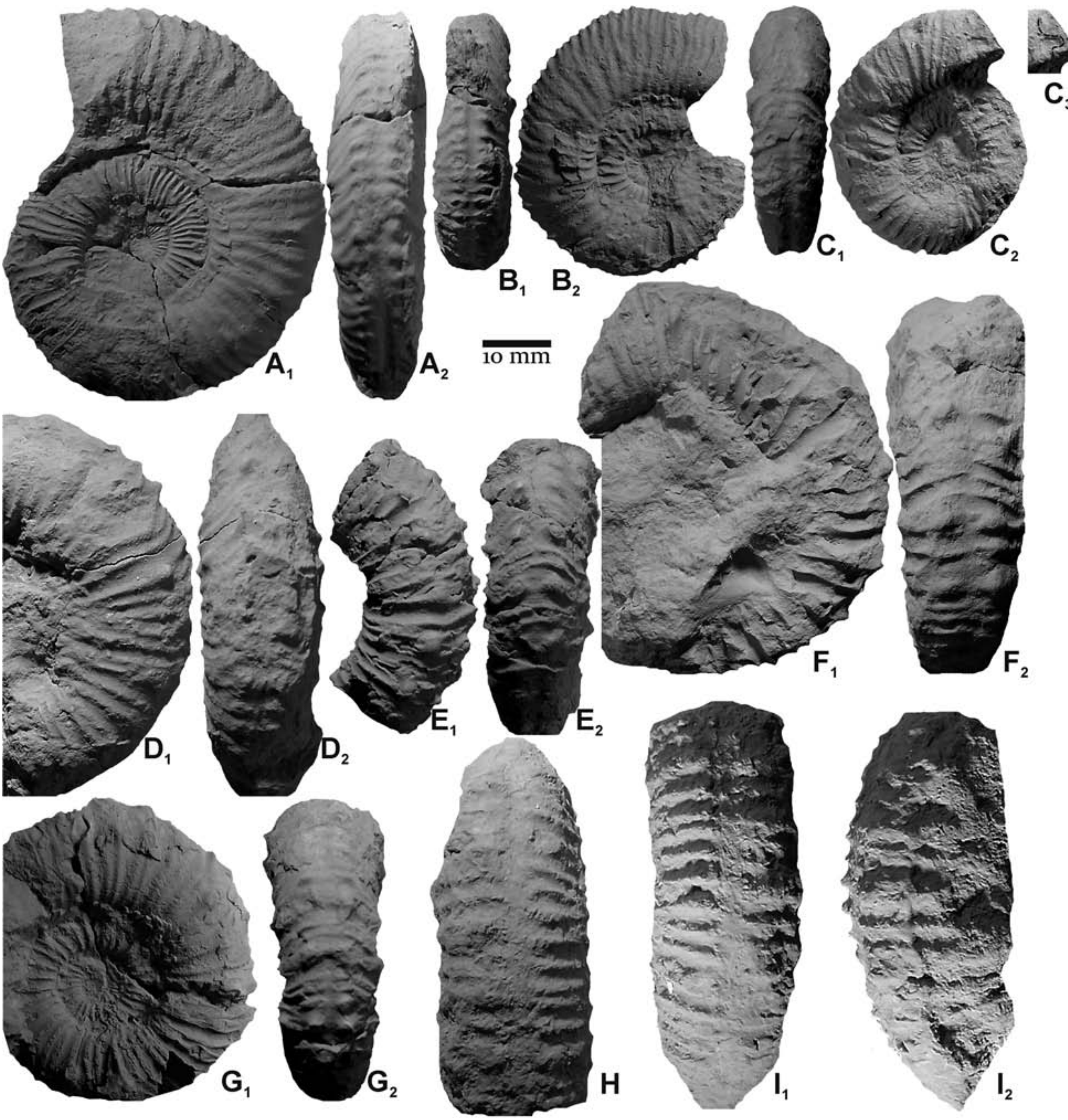

Fig. 17. *Steueria alternans* (GERTH, 1921), Alternans Z. **A-B**: [M] inner whorls of a finely ribbed morphotype (MOZ-PI 8794/2 and 8794/3), P. Covunco, bed PC-140. **C**: Complete adult [m] with lappets (MOZ-PI 8794/4), P. Covunco, bed PC-140. **D-G**: [M] inner whorls of strongly ornamented morphotype (MOZ-PI 8794/1, 5-7), P. Covunco, bed PC-140. **H-I**: Portions of [M] phragmocones (MOZ-PI 8716/1 and 8716/2), C. Caracoles, bed CC-32. – All natural size. The asterisk indicates the last septum.

Fig. 16. *Steueria alternans* (GERTH, 1921), nearly complet adult [M] (MOZ-PI 6549), Cajón de Almanza, Alternans Z. – Natural size. The asterisk indicates the last septum.

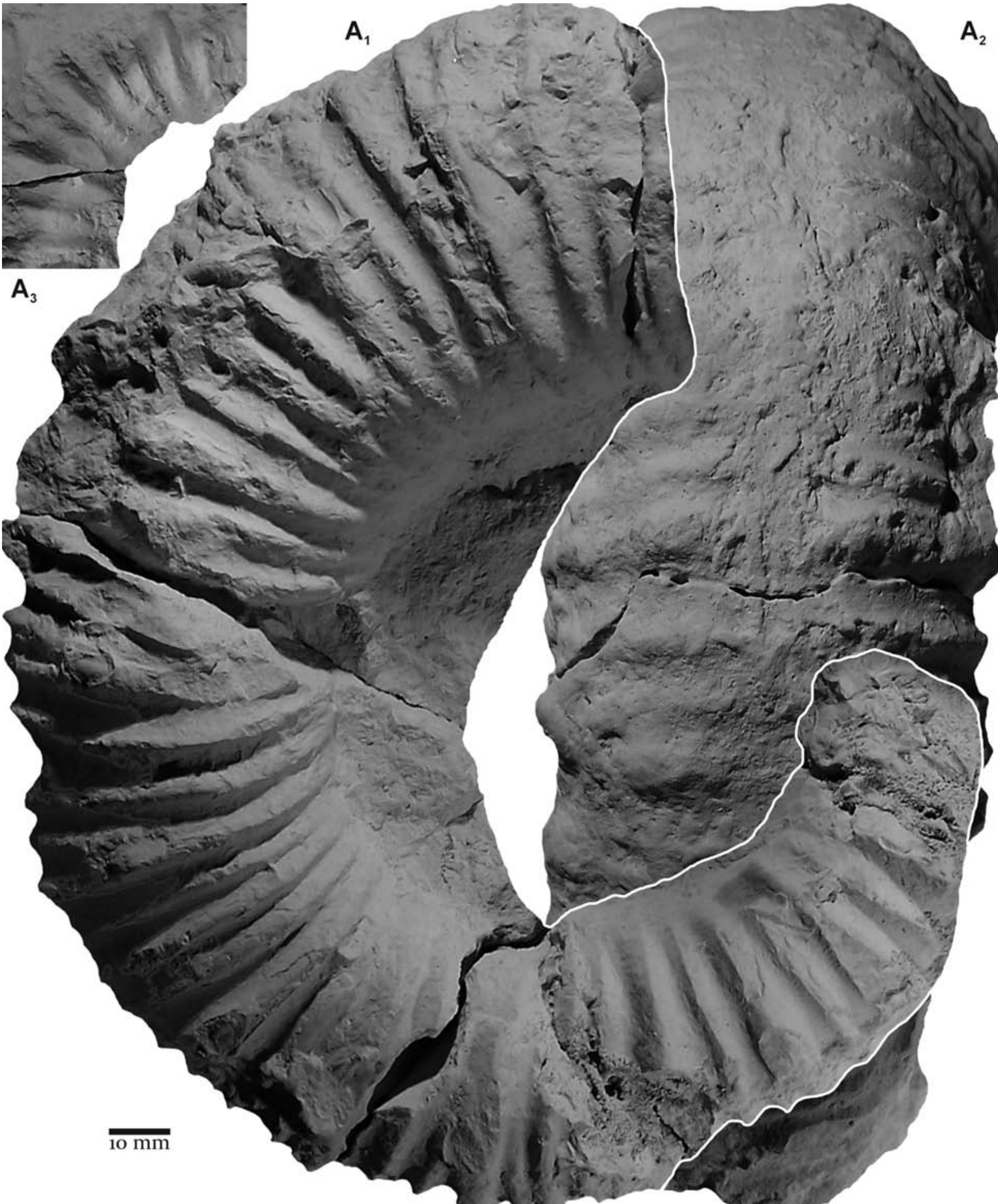

Fig. 18. *Steueria* cf. *alternans* (GERTH, 1921), adult [M] phragmocone (MOZ-PI 6559/1), C. Caracoles, bed CC-34, Alternans Z. **A_1-A_2**: lateral and ventral views left face (apertural view), **A_3**: lateral view of the penultimate whorl of rigth face. – Natural size.

Fig. 19. *Steueria* aff. *alternans* (GERTH, 1921), portion of an adult [M] bodychamber (MOZ-PI X4), P. Covunco, bed PC-130, Alternans Z. – Natural size. The asterisk indicates the last septum.

Steueria aff. *alternans* (Gerth, 1921)
Fig. 19

Remarks: The only available specimen (bed PC-130) consists of the half whorl of a large [M] bodychamber with remains of the phragmocone. It is stout, subtrapezoidal in whorl section with loosely spaced strong, acute primary ribs, which bifurcate on the upper third of the flank from a prominent tubercle. The secondaries, which begin with the same prominence as the primaries, reach the ventrolateral shoulder and form a well-marked, elongate tubercle in each of them, then crossing the venter somewhat weaker.

The adult bodychamber of *S. alternans* [M] is only known from the specimen of the Alternans Z. of C. de Almanza described above (Fig. 16). The present specimen has about the same adult size but differs in its more densely and evenly spaced ventral tubercles. The meaning of these differences in the pattern of sculpture cannot be evaluated from a single specimen but possibly the present specimen represents an older phyletic transient.

Occurrence: Bed PC-130, Alternans Z. In beds PC-134-PC-135 we have collected fragmentary specimens of the genus.

Family Neocomitidae Salfeld, 1921
Subfamily Berriasellinae Spath, 1922
Genus *Blanfordiceras* Cossmann, 1907

Type species: *Ammonites wallichi* Gray, 1832, by OD.

Blanfordiceras vetustum (Steuer, 1897)
Fig. 20B

Remarks: A single phragmocone from bed CC-33 (Alternans Z.) closely matching the more inflated and involute variants of the species in its type locality (see PSS 2011: fig. 26C-E). The species has been recently revised with abundant material of the Alternans Z. of A. Cieneguita (PSS 2011). Its occurrence in the study area expands the recorded geographic distribution of this species.

Blanfordiceras cf. *wallichi* (Gray, 1832)
Fig. 20C-D

Material: Several fragmentary specimens from bed PC-154.

Description: Compressed platycone (W/D = 0.21-0.26), moderately evolute (U/D = 0.36). Whorl section subrectangular, higher than wide, with flat flanks and a narrow venter. Ribbing irregular, mainly formed by somewhat flexuous primary ribs which appear on the umbilical shoulder where they are frequently raised and bifurcate on the upper half of the flank. Some few primaries remain simple, and few others are bifurcating close to the umbilical shoulder and again in the upper flank. Ventral ribbing evenly spaced, slightly raised on the ventrolateral shoulder by forming a lamellar tubercle or bulla, then clearly interrupted by a median groove on the venter which tends to fade out on the bodychamber, where all ribs form a forward projection.

Remarks: The material is rather abundant but fragmentary. However, some differences in respect to *B. vetustum* are considered as significant enough to separate this material as a different species. It differs from *B. vetustum* in being more compressed, with flexuous primary ribs bifurcating on a lower point of the flank, and by the occurrence of a more persistent ventral groove or forwardly projected ventral ribbing.

The present specimens are barely distinguishable from the HT of *B. wallichi* (Wright et al. 1996: fig. 38: 1). The only significant difference is that the HT does not show the adoral projection of the ventral ribbing.

Occurrence: Alternans Z. of P. Covunco.

"*Blanfordiceras*" *fraudans* (Steuer, 1897)
Fig. 20A

*1897 *Reineckeia fraudans* nov. sp. – Steuer, p. 35, pl. 9, figs. 4-6.
?1897 *Reineckeia pawlowi* nov. sp. – Steuer, p. 32, pl. 7, figs. 6-9.
*1921 *Reineckeia fraudans* nov. sp. – Steuer, p. 61, pl. 9, figs. 4-6.
?1921 *Reineckeia pawlowi* nov. sp. – Steuer, p. 59, pl. 7, figs. 6-9.
*2011 *Reineckeia fraudans* Steuer. – PGSS, p. 81, fig. 25D [LT refigured].
?2011 *Reineckeia pawlowi* Steuer. – PGSS, p. 81, fig. 25C.

Material: A well preserved, almost complete [M] and fragments seen in the field. Bed CC-32.

Description: Platycone moderately evolute with rounded to subrectangular, higher than wide whorl section. Max D = 147 mm, estimated at the end of the preserved part of the bodychamber.

Phragmocone: Inner whorls covered by subradial, moderately dense lateral ribs (P = 26 at D = 110 mm). The last septate whorl is equally densely ribbed by a regular alternation of one undivided primary rib with one bifurcated on the upper half of the flank, with the formation of a feeble tubercle on the furcation point; all ribs cross the venter uninterrupted, describing a gentle forward arch.

The portion of the bodychamber is proportionally wider and incipiently uncoiled (about U/D = 0.48 at D_{ls} = 140 mm); the ribbing shows a similar style but dominated by undivided primary ribs. Peristome not preserved. Sutures very poorly preserved.

Remarks: The specimen perfectly matches the LT. A partially similar specimen from the Alternans Z. of A. Ciene-

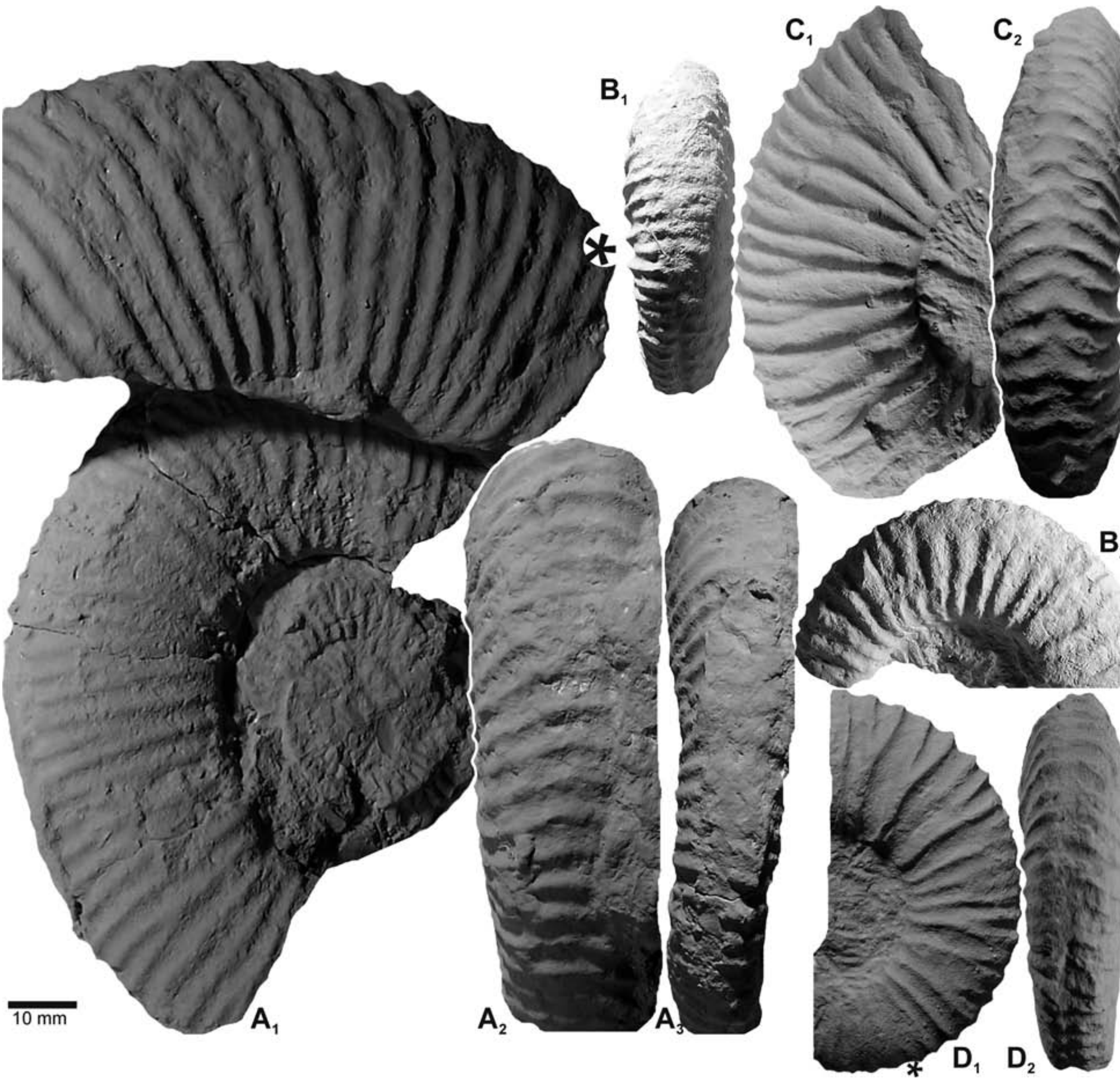

Fig. 20. A: "*Blanfordiceras*" *fraudans* (Steuer, 1897), adult [M] with incomplete bodychamber (MOZ-PI X5), C. Caracoles, bed CC-32, Alternans Z.; $\mathbf{A_1}$: lateral view, $\mathbf{A_2}$**:** ventral view of last portion preserved of the phragmocone, $\mathbf{A_3}$: ventral view of previous half whorl of phragmocone. **B**: *Blanfordiceras vetustum* (Steuer, 1897), portion of phragmocone (MOZ-PI 6886), C. Caracoles, bed CC-33, Alternans Z. **C-D**: *Blanfordiceras* cf. *wallichi* (Gray, 1832), portions of beginning of bodychamber (MOZ-PI 8783/1 and 8783/2 respectively), P. Covunco, bed PC-154, Alternans Z. – All natural size. The asterisk indicates the last septum.

guita (PSS 2011: fig. 27C) was described as *Blanfordiceras argentinum* (Krantz, 1926), but the present specimen is more evolute and does not show the well marked ventral smooth band seen in the material from A. Cieneguita.

The specimen from the Tithonian of A. de la Manga figured by Steuer (1897, transl. 1921: pl. 9, figs. 4-6) was believed to be the HT by monotypy (PGSS 2011: 81, fig. 25D, refigured), but the species was based on at least two specimens as can be interpreted from the original description (Steuer 1897: 35, transl. 1921: 62). Thus, the mentioned specimen and the only figured one is herein designated as the lectotype. As discussed below (under *Aspidoceras andinum*) the type horizon can be assumed to lie within the interval from the upper Internispinosum to Koeneni zones.

Fig. 21. A: *Chigaroceras*? *gerthi* (Krantz, 1926), adult [M?] phragmocone (MOZ-PI 8743), C. Caracoles, bed CC-33, Alternans Z. **B**: *Parodontoceras* cf. *storrsi* (Stanton, 1895), adult [M] phragmocone (MOZ-PI 8738), C. Caracoles, bed CC-33, Alternans Z. **C:** *Parodontoceras calistoides* (Behrendsen, 1891), portion of phragmocone (MOZ-PI 8638), C. Caracoles, bed CC-32, Alternans Z. **D**: *Berriasella* sp. A, almost complete adult [M?] specimen (MOZ-PI 8758), P. Covunco, bed PC-156, ?Koeneni Z. – All natural size. The asterisk indicates the last septum.

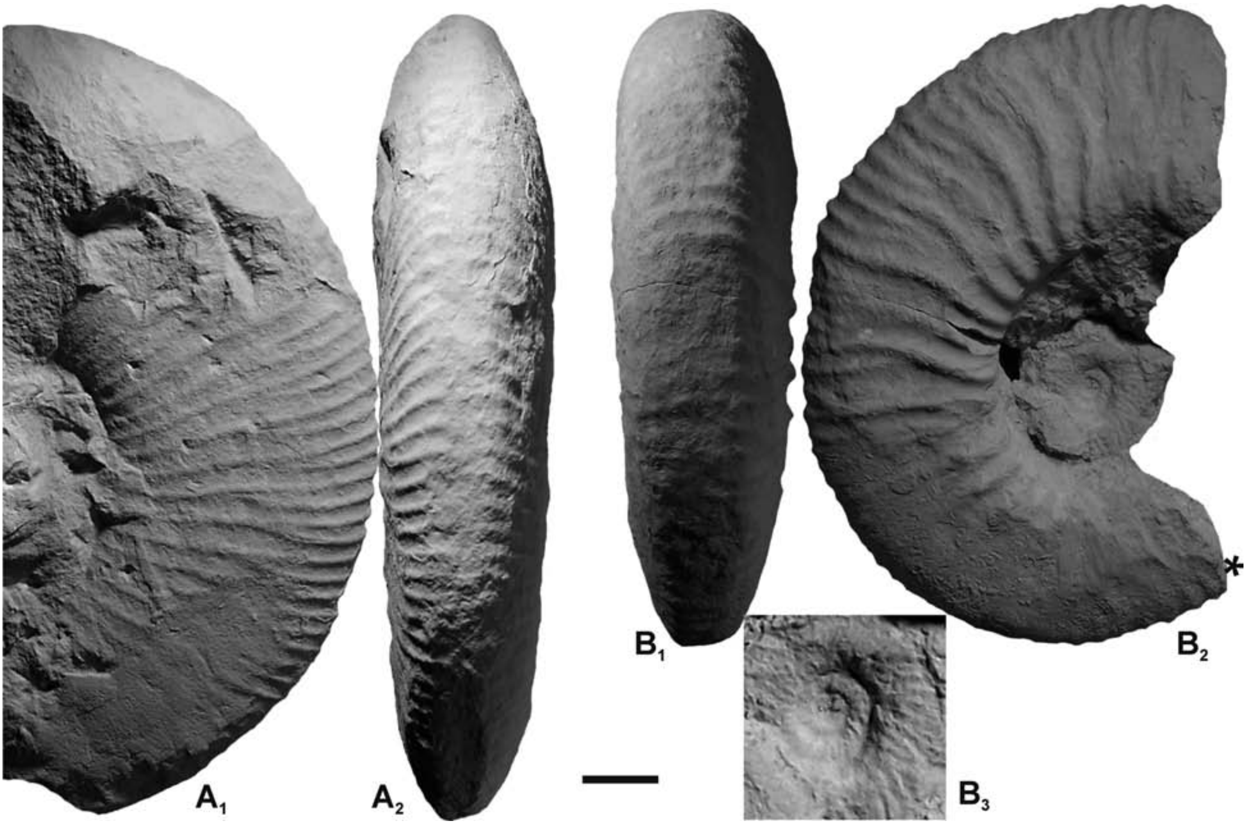

Fig. 22. A: *Parodontoceras calistoides* (BEHRENDSEN, 1891), [M?] portion of adult phragmocone (MOZ-PI 8785), P. Covunco, bed PC-157, Koeneni Z. **B:** *Subthurmannia*? sp. A, almost complete adult [m?] (LPB 669), C. Caracoles, bed CC-35, ?Koeneni Z.; inner whorls (**B**$_3$) enlarged (x2); all natural size, except **B**$_3$. – The scale bar represents 10 mm length for natural size views. The asterisk indicates the last septum.

This species has been widely cited from different Upper Tithonian stratigraphic horizons throughout the basin, but never been figured (e.g., WINDHAUSEN 1918; GERTH 1925, KRANTZ 1928; LEANZA & HUGO 1977; among others). It has been usually assigned to *Berriasella*, but this old-fashioned classification has been recently rejected (PGSS 2011: 81). For the time being there is no available genus for allocating satisfactorily this species, which likely belongs to a new genus.

Genus *Berriasella* UHLIG, 1905

Type species: *Ammonites privasensis* PICTET, 1867, by SD of ROMAN (1938).

Berriasella sp. A
Fig. 21D

Material: Three specimens from bed PC-156.

Description: Adult phragmocone and bodychamber compressed platycone and moderately involute (U/D = 0.37, W/D = 0.19 at D = 135 mm, bodychamber). The bodychamber begins at about D_{ls} = 100 mm. Whorl section suboval to subrectangular with a rounded, narrow venter and slightly curved to flat flanks. Densely ribbed (P = 23 at D = 135 mm) with radial primaries which appear on the upper umbilical wall, cross the umbilical shoulder well developed, and bifurcate on the uppermost flank. Some secondaries are loosely connected with its primary, and some few bifurcate just above the umbilical shoulder and again in the uppermost flank. Ribbing on the venter equally strong than in the primaries. In the phragmocone they are interrupted forming a well-defined ventral groove, which tends to fade off towards the peristome. The largest bodychamber available (not figured) from bed PC-156, although poorly preserved, shows that close to the peristome it is uncoiled and exhibits a strongly compressed rounded suboval whorl section. The ribbing becomes denser and more irregular with several primaries bifurcating on the umbilical shoulder.

Remarks: The specimens are adults (by terminal uncoiling) and seem to be [M] considering the terminal changes of ribbing towards a greater density and irregularity. The specimens described have the typical aspect of the earliest Berriasellinae which are certainly rooted in Late Tithonian Lithacoceratinae.

The specimen in Fig. 21D is very similar to the HT of *Berriasella grandis* Mazenot (1939: pl. 22: 6) from the Lower Berriasian of Chevallon, France. *B. grandis* has been cited for the lower Picún Leufú Fm of C. Caracoles by Armella et al. (2008: 65). The LT of *B. privasensis* (Mazenot 1939: pl. 2, fig. 3), a lappeted [m], is also very similar to the figured specimen but somewhat smaller. Indeed, its bodychamber is very compressed with high flanks covered by bifurcate ribs with some simple ribs and the ventral ribbing, of the same strength, is crossing the venter first slightly interrupted and then uninterrupted towards the peristome. Several additional examples of similar ammonites are figured by Tavera (1985: pls. 34-36) as different nominal species of *Berriasella*; nevertheless, considering the chaotic taxonomy within the genus *Berriasella*, where a very large number of morphospecies is included, it seems completely useless to seek for a specific identification of our material.

"*Berriasella*" *krantzi* Leanza, 1945 from the Alternans Z., *bardense* Hz. of M. Redondo (Fig. 1) is superficially similar to the present material but there are significant differences: it is more inflated with acute ribs and some trifurcate ribs, the ventral ribbing cross the venter unchanged and with a gently adapical projection (Leanza 1945: 32). These features, on the other hand, are not typical of *Berriasella*.

Genus *Parodontoceras* Spath, 1923

Type species: *Hoplites calistoides* Behrendsen, 1891, by OD.

Parodontoceras calistoides (Behrendsen, 1891)
Figs. 21C, 22A

Remarks: The available specimens (beds PC-157 and CC-32), although fragmentary, show the typical morphology and sculpture of the species as recently revised in PSS (2011). This species is very variable and has a rather long stratigraphical range through the Alternans and Koeneni zones and could range into the Noduliferum Z.

Parodontoceras cf. *storrsi* (Stanton, 1895)
Fig. 21B

Material: A single specimen from bed CC-33.

Description: The specimen is a phragmocone. Platycone, compressed (about W/D = 0.23) and involute (about U/D = 0.29), max D = 104 mm. Whorl section subrectangular with high flanks and a relatively narrow, tabulate venter. Ribbing irregular and moderately dense (P = 20, V = 42 at D = 97 mm), composed by flexuous primary ribs which born on the umbilical shoulder and bifurcate on the upper half or third of the flank. Ventral ribs are slightly projected forward and raised on the ventrolateral shoulder, and then crossing the venter unchanged or slightly weakened.

Remarks: This specimen differs from the HT of *P. calistoides* (Wright et al. 1996: fig. 36: 1c-d) and other typical material (PSS 2011: fig. 25A) by the coarser and irregular ribbing which, cross the venter uninterrupted. Best resemblance is with *P. storrsi* (HT refigured by Imlay & Jones 1970: pl. 12, figs. 11, 17-18) which, however, is somewhat finer ribbed, and exhibits a well-defined ventral smooth band. This species cannot be clearly distinguished from *P. calistoides* and could be a geographic variant. The specimen of *P. calistoides* from the lower Alternans Zone (*vetustum* Hz.) of *A. Cieneguita* (PSS 2011: 23A) is also similar but differs by the uninterrupted ventral ribbing.

Genus *Chigaroceras* Howarth, 1992

Type species: *Chigaroceras banikense* Howarth, 1992, by OD.

Chigaroceras? *gerthi* (Krantz, 1926)
Fig. 21A

Description: The only specimen available (bed CC-33) is a phragmocone of a probable adult [M] with the beginning of the bodychamber. It is a moderately involute platycone conch with well-rounded venter and a subrectangular to suboval whorl section. The outermost preserved whorl is compressed with a well-rounded but moderately narrow venter; moderately but clearly uncoiled. Inner whorls are covered with fine and densely arranged primaries, which bifurcate on the uppermost part of the flank. The outermost whorl is more coarsely ribbed by subradial primaries, which bifurcate irregularly on the upper third of the flank; some primaries remain undivided. All ribs cross the venter unchanged and evenly spaced.

Remarks: The assignment of the present specimen to *Chigaroceras* is based on its shell morphology and the lateral ribbing of the terminal phragmocone, composed by well-spaced, strong primaries which become stronger on the upper flank prior to furcation (cf. Leanza 1996). The present specimen slightly differs from the HT (refigured in PSS 2011: fig. 25C) by being slightly more densely ribbed. The stratigraphic position is nearly the same as for the HT and the specimen from the *vetustum* Hz. of A. Cieneguita (PSS 2011: fig. 26A).

Subfamily Neocomitinae Salfeld, 1921
Genus *Subthurmannia* Spath, 1939

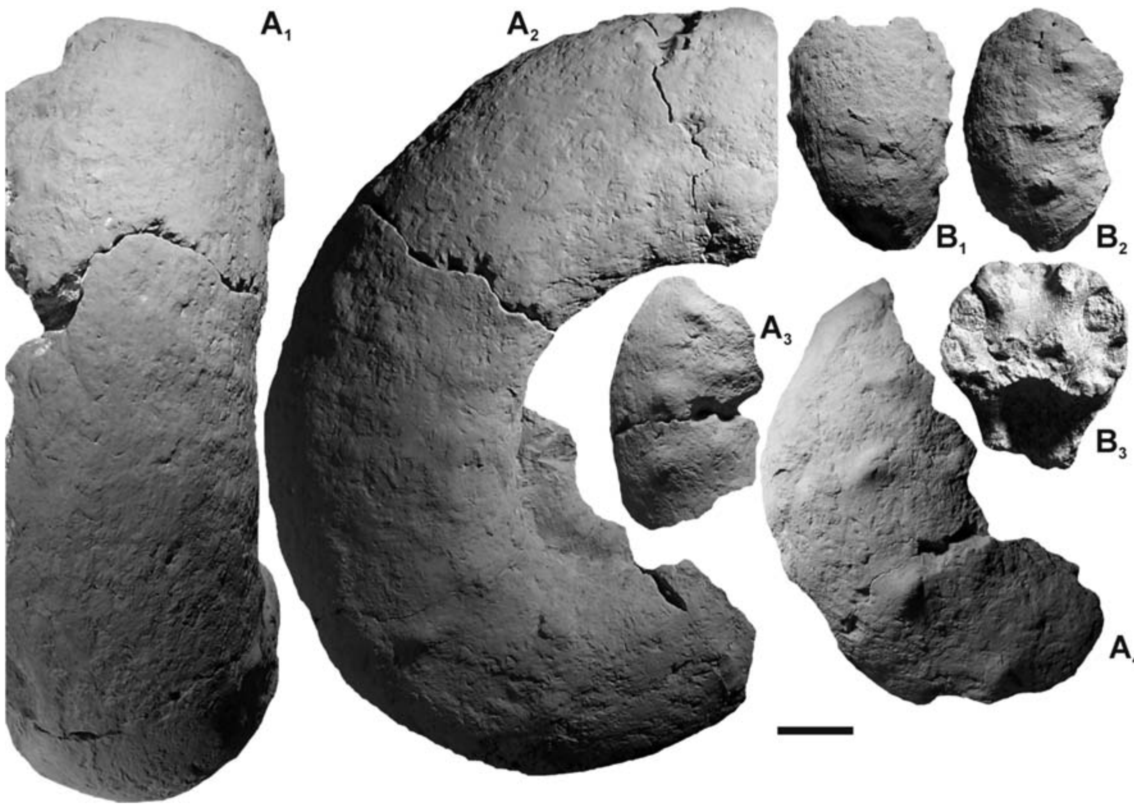

Fig. 23. A-B: *Aspidoceras andinum* Steuer, 1897, C. Caracoles, bed CC-33, upper Alternans to Koeneni Z.; half size views (x0.5). **A:** Adult [M] phragmocone (MOZ-PI 8750) with the last whorl (**A_1-A_2**) strongly uncoiled; **A_3** and **A_4** views of portions of inner whorls. **B**: Fragment of phragmocone (MOZ-PI 8745). – All x0.5. The bar represents 20 mm.

Type species: *Subthurmannia fermori* Spath, 1939, by OD.

Subthurmannia? sp. A
Fig. 22B

Material: One (?) adult specimen from bed CC-35.

Description: Moderately involute platycone, max D = 85 mm. Innermost whorls (D < 10 mm) rounded and evolute, inner whorls (10 < D < 20 mm) with higher than wide suboval whorl section; densely ribbed by prosocline ribs.

The bodychamber begins at D_{ls} = 58 mm and shows a short but marked uncoiling. Whorl section subtrapezoidal with tabulate venter. Ribbing rather irregular, composed of well spaced flexuous primary ribs, some bifurcate at midflank; they appear on the umbilical shoulder crossing the umbilical shoulder as strong as on the flanks. The secondary ribs are somewhat finer than the primaries. There are abundant intercalatory ribs irregularly distributed which, together with the secondaries, cross the flat venter unchanged. At the end of the phragmocone and beginning of the bodychamber occurs a short ornamental stage in which the ventral ribs reach the ventrolateral shoulder with the formation of a feeble tubercle and then cross the venter somewhat weakened.

Remarks and discussion: The platyconic shell with tabulate venter and ribs branching irregularly are typical features of the Neocomitinae. Among Neocomitinae the present specimen shows resemblance with some Tethyan species, especially *S. fermori*, for the irregular lateral ribbing and the narrow and flat venter on the beginning of the bodychamber, but in the present specimen there are no bifurcations from the umbilical shoulder. The specimen from the Berriasian of Muktinath in Nepal, figured by Helmstaedt (1969: pl. 3, fig. 6) as *Thurmanniceras* (?) sp. is very similar to the present specimen, differing by a more regular, bifurcate ribbing on the bodychamber. Another very similar specimen was figured by Fatmi (1977: pl. 6, fig. 3) as *S. fermori*. This latter specimen comes from the Berriasian of Chichali Pass, Trans Indus Range, Pakistan. It differs by its ventral ribbing which weakens on the flat venter at a larger size.

Occurrence: Probably upper Tithonian Koeneni Z., although it could be already Berriasian in age.

Family Aspidoceratidae Zittel, 1895
Subfamily Aspidoceratinae Zittel, 1895
Genus *Aspidoceras* Zittel, 1868

Type species: *Ammonites rogoznicensis* Zejszner, 1846, by monotypy.

Aspidoceras andinum Steuer, 1897
Fig. 23A-B

*1897 *Aspidoceras andinum* nov. sp. – Steuer, p. 70, pl. 5, figs. 5-6 [HT].
?1897 *Aspidoceras cieneguitense* nov. sp. – Steuer, p. 71, pl. 5, figs. 8-9.
*1921 *Aspidoceras andinum* nov. sp. – Steuer, p. 99, pl. 5, figs. 5-6 [HT refigured].
?1821 *Aspidoceras cieneguitense* nov. sp. – Steuer, p. 101, pl. 5, figs. 8-9.
?1977 *Aspidoceras cieneguitense* Steuer. – Leanza & Hugo, p. 261.
?1992 *Aspidoceras andinum* Steuer. – Riccardi in Westermann, pl. 81, fig. 1.
?2011 *Aspidoceras cieneguitense* Steuer. – PSS, p. 76, fig. 38B.

Material: Two [M] specimens, an adult phragmocone and a fragment from bed CC-33.

Description: The specimens are phragmocones, evolute and moderately depressed with suboval whorl section at D = 60 mm, passing to subrectangular with widely rounded venter on the last whorl at D = 206 mm. Sculpture composed by two rows of conical tubercles connected by a weak straight rib confined between them. One of the rows is in the lower flank, just over the umbilical shoulder; the other row (tubercles slightly larger than the periumbilicals) is in the upper flank, just below the ventrolateral shoulder. The connecting rib vanishes on the last whorl preserved and the tubercles fade off in the outer half of the outermost whorl preserved. Venter smooth throughout. Considering the strong uncoiling it can be assumed that the specimen is an adult [M].

Remarks: The present specimens come from the Alternans Z. (discussed below) and match the monotypic HT (a phragmocone) of *A. andinum* in shell morphology and sculpture at comparable diameter.

The type horizon in the succession of the TL (Arroyo de la Manga) is not precisely known since the fauna was presented by Steuer (1897: 144-145, transl. 1921: 43-45) without separation in stratigraphic horizons. It can be estimated only a wide chronostratigraphic range considering the full individual range of those species which can be reasonably identified by independent information from other localities. The available information is summarized and shortly discussed in Table 1, wherefrom it becomes evident that the type horizon must lie within the interval upper Internispinosum-Koeneni zones. Moreover, from the information by Krantz (1928) discussed in PSS (2011) and Table 1, it is very likely that the TH lies within the Alternans Z.

The specimen from Río Diamante (Mendoza) figured by Riccardi (in Westermann 1992: pl. 81, fig. 1) as *A. andinum* is very similar to the HT in the outermost whorl, but the inner whorls are much less densely tuberculate, closely resembling the HT of *Aspidoceras cieneguitense* Steuer, 1897 (revised and refigured in PSS 2011) from the level AC-II (Proximus-Internispinosum zones). The specimen from Río Diamante was said to come from the Proximus Z., but this cannot be evaluated because the lacking of any stratigraphic information.

In the Internispinosum and Alternans-Koeneni zones of the NB occur *Aspidoceras* cf. *euomphalum* Steuer, 1897 (in PSS 2011) and *Aspidoceras euomphalum*, respectively. The latter species differs from *A. andinum* by (1) the periumbilical tubercles being smaller and more abundant than the lateral ones, and (2) the subcircular whorl section.

The size, morphology and sculpture of the present material is more or less comparable with several of the nominal species of the genus *Aspidoceras* recorded from the Tithonian of Europe reviewed by Checa (1985), however, within these species the only one which comes from beds of comparable age is *Aspidoceras taverai*. Indeed, although the HT comes from the Jacobi Z. (Berriasian), there is another specimen figured by Checa (1985: pl. 19, fig. 2) which comes from the Durangites Z. (Upper Tithonian). The latter specimen (phragmocone) is somewhat similar to the inner whorls of the present material at comparable diameters, but like in *A. cieneguitense.*

Genus *Sutneria* Zittel, 1884

Type species: *Nautilus platynotus* Reinecke, 1818, by SD of Munier-Chalmas (1892).

Remarks: The use of this genus for assigning microconchiate aspidoceratids is merely provisional as discussed in PGSS (2011: 87).

Sutneria cf. *parabolistriatum* (Krantz, 1926)
Fig. 24B

Description and remarks: A single specimen (max D = 24 mm, bodychamber) from bed PC-19. Moderately involute (U/D = 0.31) and inflated, showing weak umbilical tubercles on the last whorl of the phragmocone and lingulatiform structures on the mid-flank. The short portion of bodychamber preserved is smooth. The specimen is very similar in shell morphology and sculpture to the outermost whorl in the HT of *S. parabolistriatum* (refigured in PGSS 2011: fig. 33).

Occurrence: Bed PC-19, lower Zitteli Z.

Sutneria sp. A
Fig. 24A

Table 1. Ammonite fauna of Arroyo de la Manga described by Steuer (1897, transl. 1921) with no indication of stratigraphic subdivisions or horizons. The column Zone range indicates the best possible independent assignation estimated from other material with well known stratigraphic position in different localities (column Remarks). HT: holotype, LT: lectotype, TL: type locality, TH: type horizon.

Steuer (1897, 1921)	This report	Zone range	Remarks
Reineckeia argentina Steuer	*Argentiniceras*? *argentinum*	–	Shell shape and sculpture suggest *Argentiniceras*
R. steinmanni Steuer	*Hemispiticeras steinmanni*	–	Type species of *Hemispiticeras* Spath, 1925
R. microcantha (Oppel)	*Micracanthoceras*? sp.	Alternans	Very similar to *M. microcanthum* of the Late Tithonian Microcanthum Z. of Europe. Probably closely related to *Micracanthoceras*? *mangaensis* (see below)
R. cf. stephanoides (Oppel)	*Windhauseniceras internispinosum* (Krantz)	upper Internispinosum	The early transients of the lower Internispinosum Z. have tubercles confined to the inner whorls; later transients become tuberculated on outer whorls (Parent et al. 2007). Refigurated in PSS (2011)
R. transitoria (Oppel)	*Krantziceras* cf. *compressum* Parent et al., 2011	?Koeneni	Previously supposed a variant of *C. striolatus* in Parent (2003a), it has been recently reinterpreted as *Krantziceras* cf. *compressum* resembling specimens of the Koeneni Z. of Pampa Tril (PSS 2011)
R. pawlowi Steuer	New genus?	-	HT refigurated in PGSS (2011). Probably an Andean Himalayitid.
R. mangaensis Steuer	*Micracanthoceras*? *mangaensis*	Alternans	The general aspect of the shell with small tubercles high on the flanks, confined to the inner whorls suggests this species is a *Micracanthoceras*, very similar to *M. microcanthum*. HT refigurated in Parent (2003a)
R. fraudans Steuer	New genus?	-	Revised and HT refigurated in PGSS (2011).
R. striolata Steuer	*Choicensisphinctes striolatus*	Koeneni	LT refigurated in Parent (2003a), discussed and transferred to *Choicensisphinctes* in PSS (2011)
R. striolatissima Steuer	*Choicensisphinctes striolatus*	Koeneni	LT herein designated, the specimen figured by Steuer (1897: pl. 14: 5-6). Refigured in Parent (2003a) and considered as an intraspecific variant of *C. striolatus*
Odontoceras koeneni Steuer	*Substeueroceras koeneni*	Koeneni	This specimen was not figured by Steuer (1897)
O. subcallisto (Toucas)	*Parodontoceras*? sp.	-	A small phragmocone seems to be the only material available. The style of ribbing and the shell shape suggest *Parodontoceras*
O. kayseri Steuer *O. tenerum* Steuer *O. gracile* Steuer	*Parodontoceras calistoides*	Alternans	Discussed in PSS (2011). The three species were defined from material collected in the succession of Arroyo de la Manga, thus the TL of the three species
Hoplites vetustus Steuer	*Blanfordiceras vetustum*	Alternans	Revised and LT refigurated in PSS (2011)
H. subvetustus Steuer	*Blanfordiceras vetustum*	Alternans	LT refigurated in PSS (2011), TL/TH: Rodeo Viejo/RV-III (wrongly indicated as AC in PSS 2011: table 1, but correct in App. 2)
H. mendozanus Behrendsen	*Corongoceras mendozanum*	Alternans	Revised in PSS (2011)
Aspidoceras andinum Steuer	*Aspidoceras andinum*	Alternans-?Koeneni	The only reliable, independent evidence about the stratigraphic position of *A. andinum* in its TL and Arroyo Durazno is in Krantz (1928: 10, 49-50), who cited several species very similar to those of Steuer (1897), Krantz (1928: 49, A. Durazno) and A. Cieneguita (reviewed in PSS 2011) assigned to the Alternans Z (*vetustum* hz.).

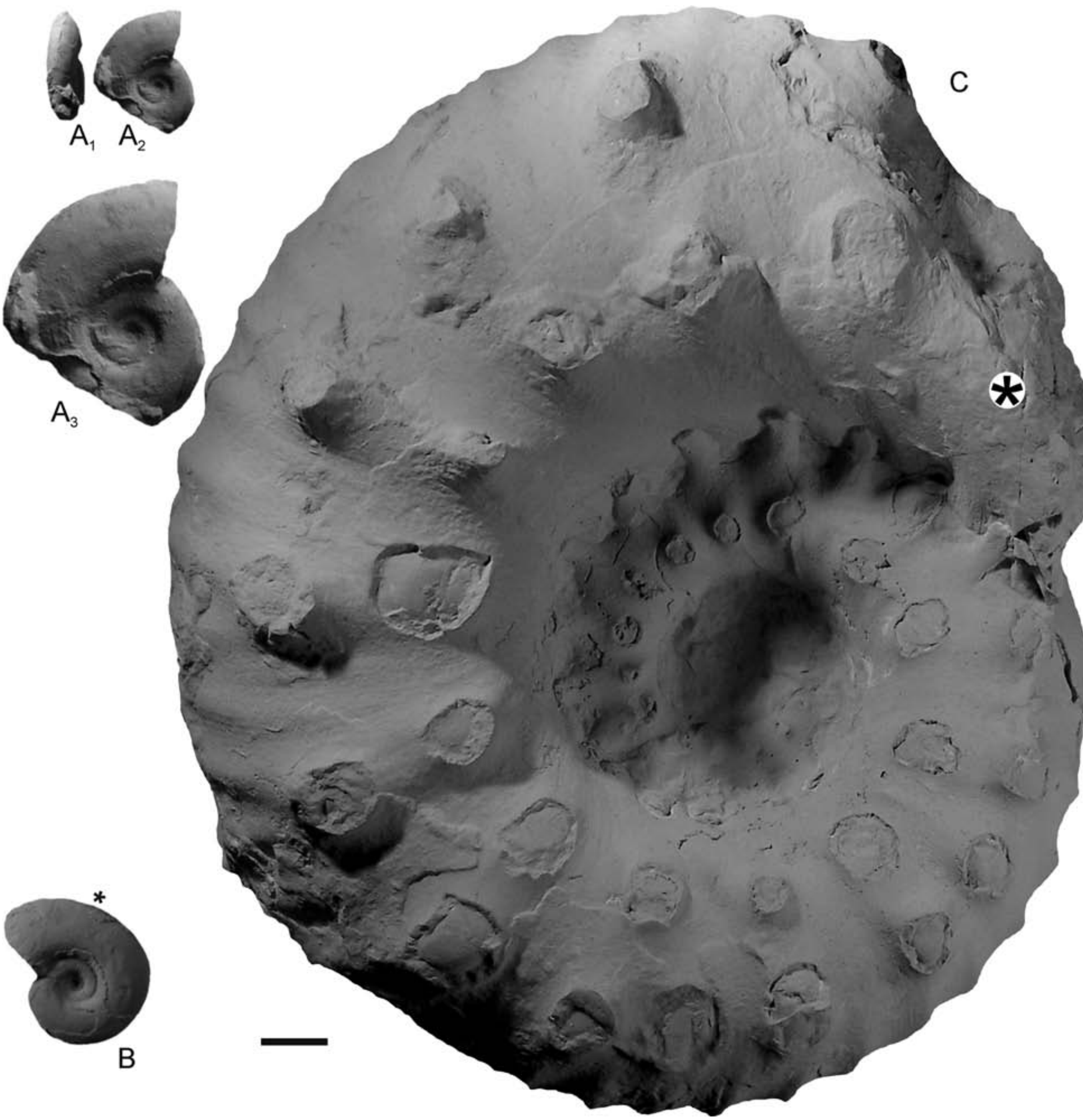

Fig. 24. A: *Sutneria* sp. A, almost complete adult microconch (MOZ-PI 7783/1) with incomplete bodychamber (A_3 double sized, A_1-A_2 natural size), P. Covunco, bed PC-39, Zitteli Z. **B**: *Sutneria* cf. *parabolistriatum* (Krantz, 1926), complete adult microconch (MOZ-PI X6), P. Covunco, bed PC-19, Zitteli Z. **C:** *Pseudhimalayites subpretiosus* (Uhlig, 1878), complete adult [M] phragmocone (MOZ-PI 1286), Cerro Lotena, lower Internispinosum Z. – All natural size, except A_3. The asterisk indicates the last septum.

Description: A single specimen (about max D = 20 mm, bodychamber) from bed PC-39. Evolute (U/D = 0.35) and compressed (W/D = 0.25) platycone, with subrectangular (phragmocone) to suboval (bodychamber) whorl section with narrow, rounded venter; flanks and venter smooth. The outer half whorl is bodychamber, smooth but showing two gentle sulci on the flank.

Remarks: Bed PC-39, upper Zitteli Z.

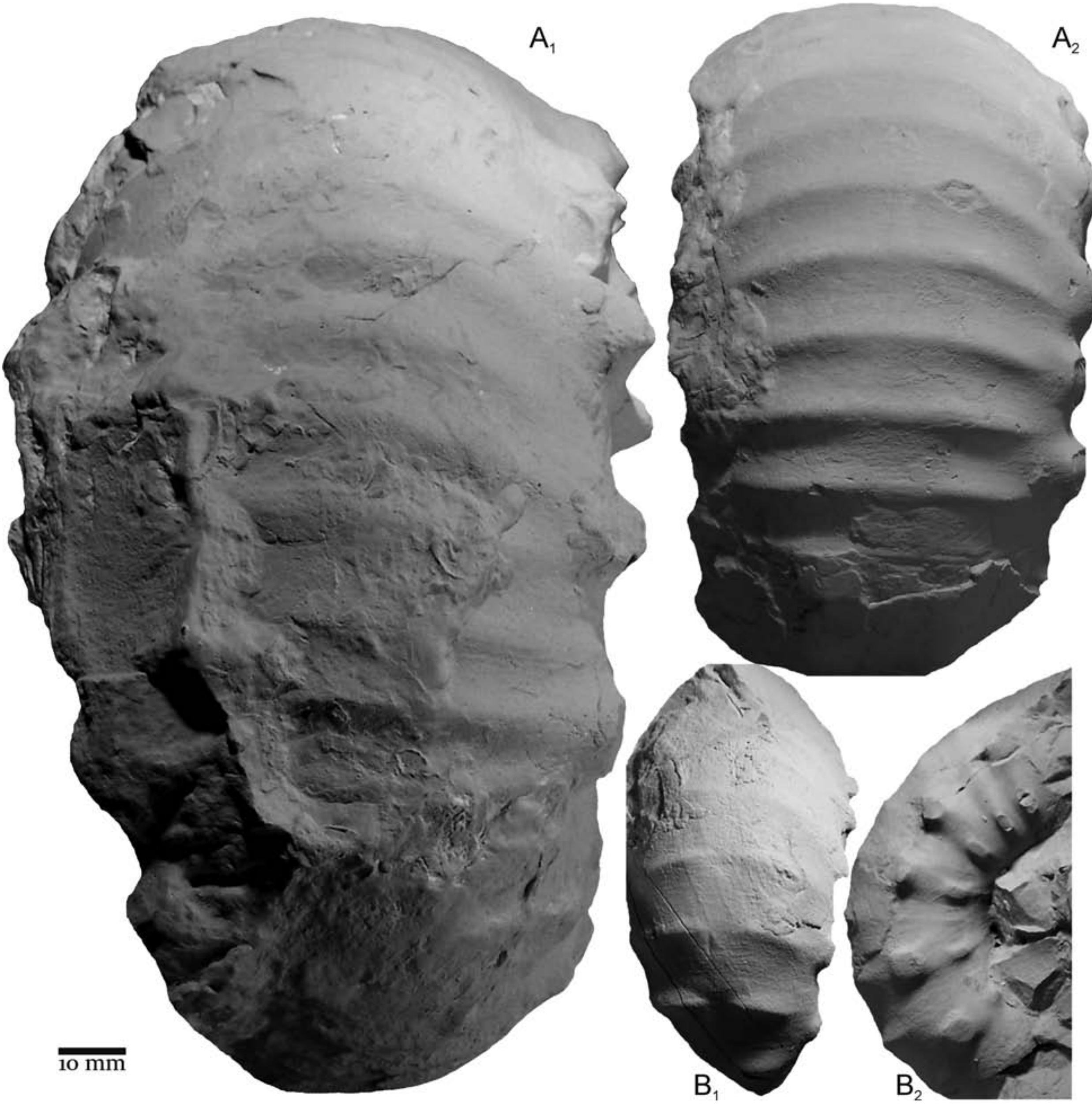

Fig. 25. A: *Pseudhimalayites subpretiosus* (Uhlig, 1878), ventral views of the complete adult [M] phragmocone shown in Figure 23C, C. Lotena, lower Internispinosum Z.; **A$_1$**: last whorl; **A$_2$**: beginning of the last whorl. **B**: *Pseudhimalayites subpretiosus* (Uhlig, 1878), portion of a (?) juvenile bodychamber (MOZ-PI 8587/2), P. Covunco, bed PC-55, upper Proximus Z. – All natural size.

Genus *Pseudhimalayites* Spath, 1925

Type species: *Aspidoceras steinmanni* Haupt, 1907, by OD (= *Cosmoceras subpretiosum* Uhlig, 1878).

Pseudhimalayites subpretiosus (Uhlig, 1878)
Figs. 24C, 25A-B

Remarks: A single specimen was collected from bed PC-55. It is a portion of a subadult [M], about 70 mm in diame-

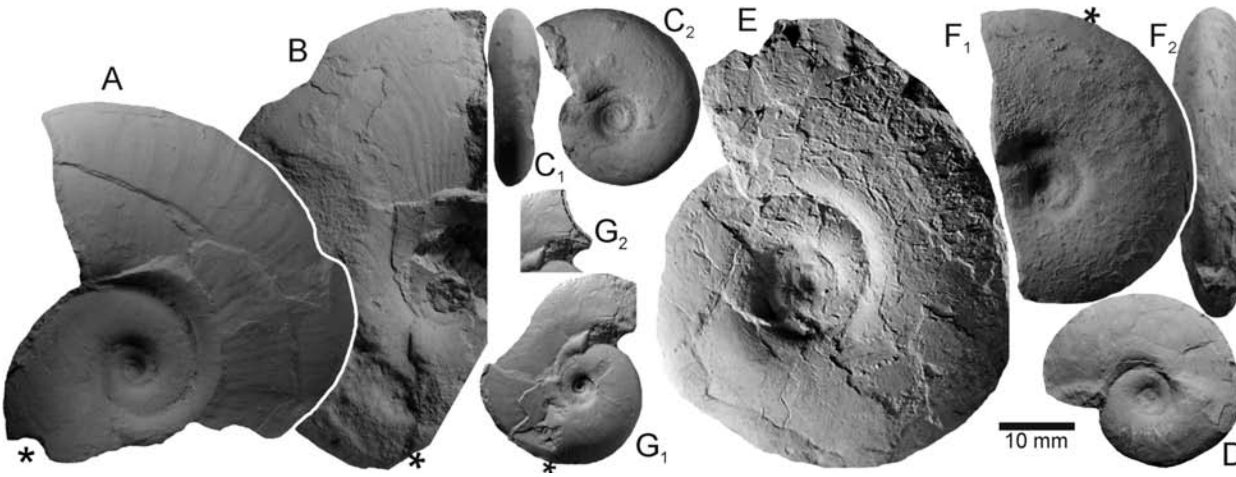

Fig. 26. A-E: *Pseudolissoceras zitteli* (Burckhardt, 1903), Portada Covunco, Zitteli Z. **A:** Complete adult [M] (LPB 1039/1), bed PC-12. **B**: Adult [M] (LPB 1039/2), bed PC-19. **C**: [M] phragmocone (MOZ-PI 7783/3), bed PC-27. **D**: Adult [m] (MOZ-PI X7) with peristome lacking lappets, bed PC-39; **E**: adult [M] with beginning of the bodychamber (MOZ-PI X8), bed PC-39. **F**: *Pasottia andina* Parent, Schweigert, Scherzinger & Enay, 2008 [M] with beginning of the bodychamber (MOZ-PI 7783/2), P. Covunco, bed PC-27, Zitteli Z. **G**: *Cieneguiticeras perlaevis* (Steuer, 1897), almost complete adult [m] (LPB-M 130), P. Covunco, bed PC-39, Zitteli Z; **G$_1$**: detailed view of the peristome with the lappet delineated. – All natural size. The asterisk indicates the last septum.

ter. Whorl section suboval depressed, with moderately wide umbilicus. The three rows of tubercles which characterize the genus are well-defined: a row of periumbilical bullae, a row of rounded stomped tubercles on the upper half of the flank and a third one of ventral bullae with the appearance of short ribs. The form of the ventral bullae indicates the subadult condition of the specimens. Indeed, the juvenile phragmocone of the [M] bears short and well-marked ventral bullae (see PSS 2011: fig. 37A-B), in the subadult phragmocone they are more elongate, and gradually they are merged in a ventral rib close to bodychamber.

We take the opportunity for a re-illustration of the specimen already poorly figured by Zeiss & Leanza (2010: pl. 15, fig. 5), as '*Aspidoceras*'. This specimen (Figs. 24C, 25A) is an adult [M] phragmocone collected from an unspecified horizon of the Vaca Muerta Fm in Cerro Lotena (see Fig. 1) which illustrates the subadult and adult ontogeny of the phragmocone of the species. Recent intensive sampling in this section has provided several specimens perfectly matching in morphology and matrix which allow assigning the specimen to the lowermost Internispinosum Zone. The ventral view of the subadult phragmocone (Fig. 25A$_2$) shows the gradual merging of pairs of ventral bullae into a rib. The markedly spatulate aspect of the lateral tubercles on the inner whorls (Fig. 24C) is another characteristic feature of this species.

Occurrence: Bed PC-55, upper Proximus Z.

Superfamily Haploceratoidea Zittel, 1884
Family Haploceratidae Zittel, 1884
Genus *Pseudolissoceras* Spath, 1925

Type species: *Neumayria zitteli* Burckhardt, 1903, by OD.

Pseudolissoceras zitteli (Burckhardt, 1903)
Fig. 26A-E

Remarks: The species occurs at several levels of the succession (PC-12-PC-39) but the material is scarce and moderately to poorly preserved. There are not evident changes between specimens of successive beds, but this is not conclusive from the available material. The species has been recently revised in detail by Parent (2001).

Occurrence: The interval of occurrence PC-12-PC-39 defines the local total-range biozone of the species, thus its conjugated non-standard chronostratigraphic zone (discussed below in the Biostratigraphy chapter).

Family Oppeliidae H. Douvillé, 1890
Subfamily Taramelliceratinae Spath, 1928
Genus *Pasottia* Parent, Schweigert, Scherzinger & Enay, 2008

Type species: *Pasottia andina* Parent, Schweigert, Scherzinger & Enay, 2008, by OD.

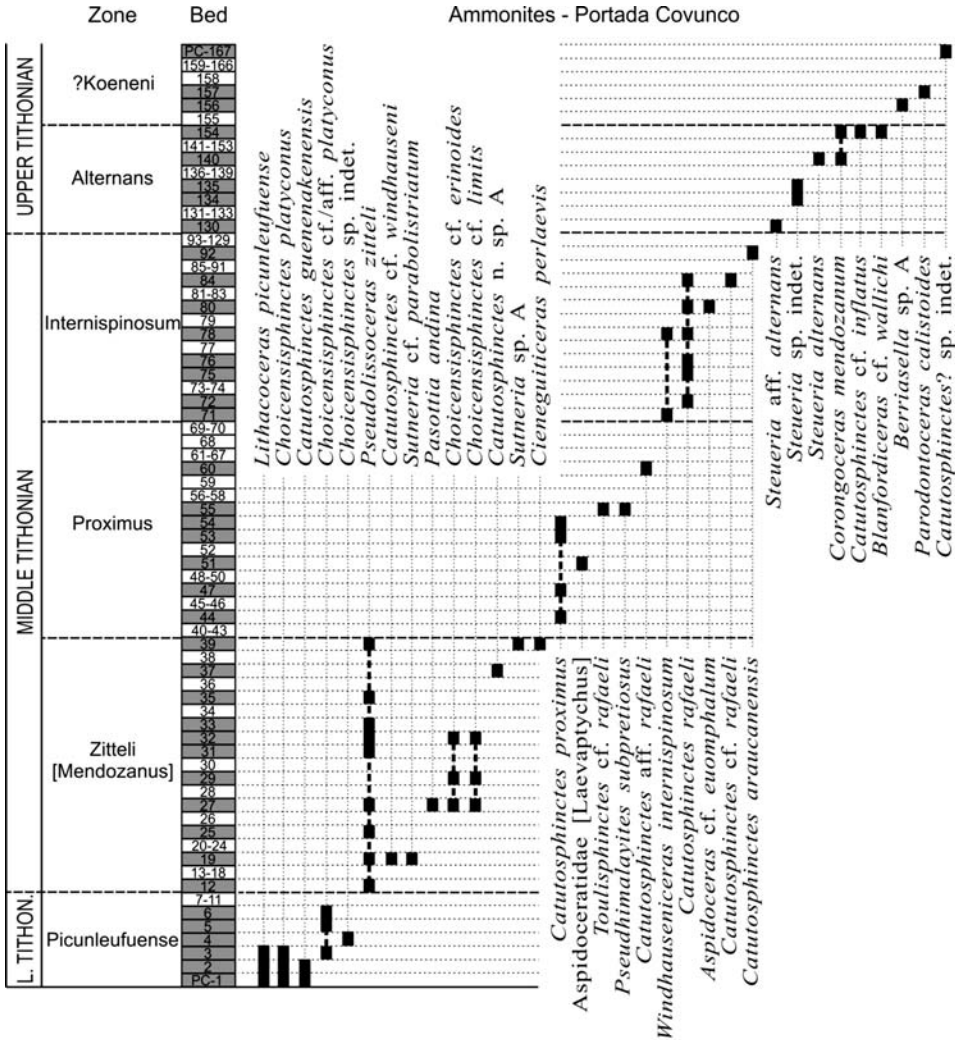

Fig. 27. Chronostratigraphic zonation of the Portada Covunco section based on the distribution of the ammonite fauna described. Chronostratigraphic zonation of the Andean Tithonian based on Leanza (1981) and Parent et al. (2011). Height of the subdivisions drawn on graphical convenience with neither implications on time duration nor bed thickness. Beds with ammonites recorded are shaded.

Pasottia andina Parent, Schweigert, Scherzinger & Enay, 2008
Fig. 26F

Remarks: The only specimen available comes from bed PC-27 (Zitteli Z.). It is a well preserved adult phragmocone with the beginning of the bodychamber, which shows incipient uncoiling. Compressed suboxycone with narrow, acute venter; rather flat flanks converging gently to the venter; sharp umbilical shoulder with a steep umbilical wall on the inner whorls from about $D = 10$ mm.

Differentiation in respect to *P. zitteli* is in the more compressed shell and the steep umbilical wall with sharp shoulders from the inner whorls. The most evident difference between these species lies in the suture lines, but this feature is not discernible in the herein described specimen.

Genus *Cieneguiticeras* Parent, Myczynski, Scherzinger & Schweigert, 2010

Type species: *Haploceras falculatum* Steuer, 1897, by OD.

Cieneguiticeras perlaevis (Steuer, 1897)
Fig. 26G

Remarks: The only available material (bed PC-39, Zitteli Z.) is the impression of a complete adult [m] with lappets at D_p = 25.5 mm. A plaster cast is shown in Fig. 26G.

C. perlaevis (Picunleufuense and Zitteli zones) and *C. falculatum* (Steuer, 1897) (Proximus Z.) are similar intergrading transients which are rather conventionally separated for their stratigraphic position. Nevertheless, some differences exist in the microconchs, the bodychamber of *C. falculatum* tends to be ventrally narrower, with the upper part of the flanks converging (see PMSS 2010: fig. 3C), than *C. perlaevis*. On the other hand, the macroconchs of *C. falculatum* tend to be more densely and strongly ribbed on the phragmocone than in *C. perlaevis*.

4. Biostratigraphy of the studied sections

The chronostratigraphic subdivision of the Andean Tithonian is based on a zonation derived from the different kinds of biozones originally proposed from Burckhardt (1900) onwards (see Leanza 1981; PGSS 2011). This zonation is not yet standarized in modern terms; only the basal Tithonian Picunleufuense Zone was defined originally as a standard chronostratigraphic zone (PGSS 2011). However, considering that the zones are recognized by their ammonite content (Callomon 2001; Parent 2006), the boundaries between the zones are herein traced by the base of the zone at the first occurrence of ammonites which are characteristic of the zone.

The biostratigraphy of the section of P. Covunco has been discussed previously from a preliminar collection of ammonites (Parent & Cocca 2007). Those results are completely concordant with the obtained herein on the basis of a much more detailed sampling and description of the fauna. The fauna described in the present report is generally poorly preserved preventing the confident recognition of ammonite-horizons among the many already defined for the Tithonian of the Neuquén Basin in other localities (see PSS 2011). The ammonite succession of P. Covunco is the most complete, ranging the interval Picunleufuense-?Koeneni (Noduliferum) zones (Fig. 27), whereas the section studied at C. Caracoles ranges from the Alternans Z. up to the ?Koeneni (Noduliferum) Z. (Fig. 28). The biostratigraphy of the rocks underlying our section at C. Caracoles was studied by Leanza & Zeiss (1992).

Picunleufuense (standard) Zone – Beds PC-1-PC-11. Beds PC-1-PC-3 yield the typical ammonites of the lower part of the zone (*L. picunleufuense, C. platyconus* and *C. guenenakenensis*). Beds PC-3-PC-6 yield abundant *C.* cf./aff. *platyconus* which indicates the upper part of the zone (PGSS 2011; PSS 2011). Beds PC-7-PC-11 which have not yielded ammonites are also included in this zone for lying below the first occurrence of *P. zitteli* in bed PC-12, which is taken as the base of the Zitteli Zone.

Zitteli (non-standard) Zone (including the Mendozanus Zone, see PGSS 2011; PSS 2011) – Beds PC-12-PC-39. The range biozone of *P. zitteli* is used for defining the *Zitteli* Biozone from which has been derived the conjugate Zitteli Zone (cf. Leanza 1981).

Proximus (non-standard) Zone – Beds PC-40-PC-70. Rocks between the last occurrence of *P. zitteli* and the first one of *W. internispinosum* are considered, in chronostratigraphical terms, the Proximus Z. (cf. Leanza 1981). The index species is abundant.

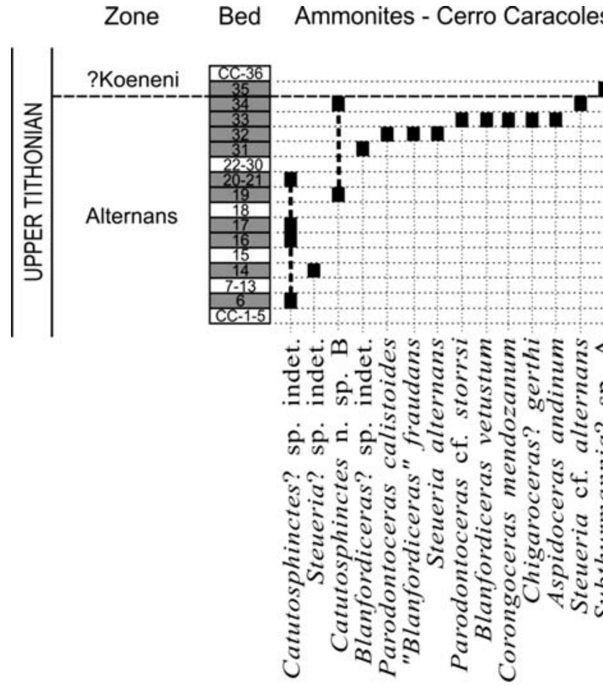

Fig. 28. Chronostratigraphic zonation of the Cerrito Caracoles section based on the distribution of the ammonite fauna described. Height of the subdivisions drawn on graphical convenience with neither implications on time duration nor bed thickness. Beds with ammonites recorded are shaded.

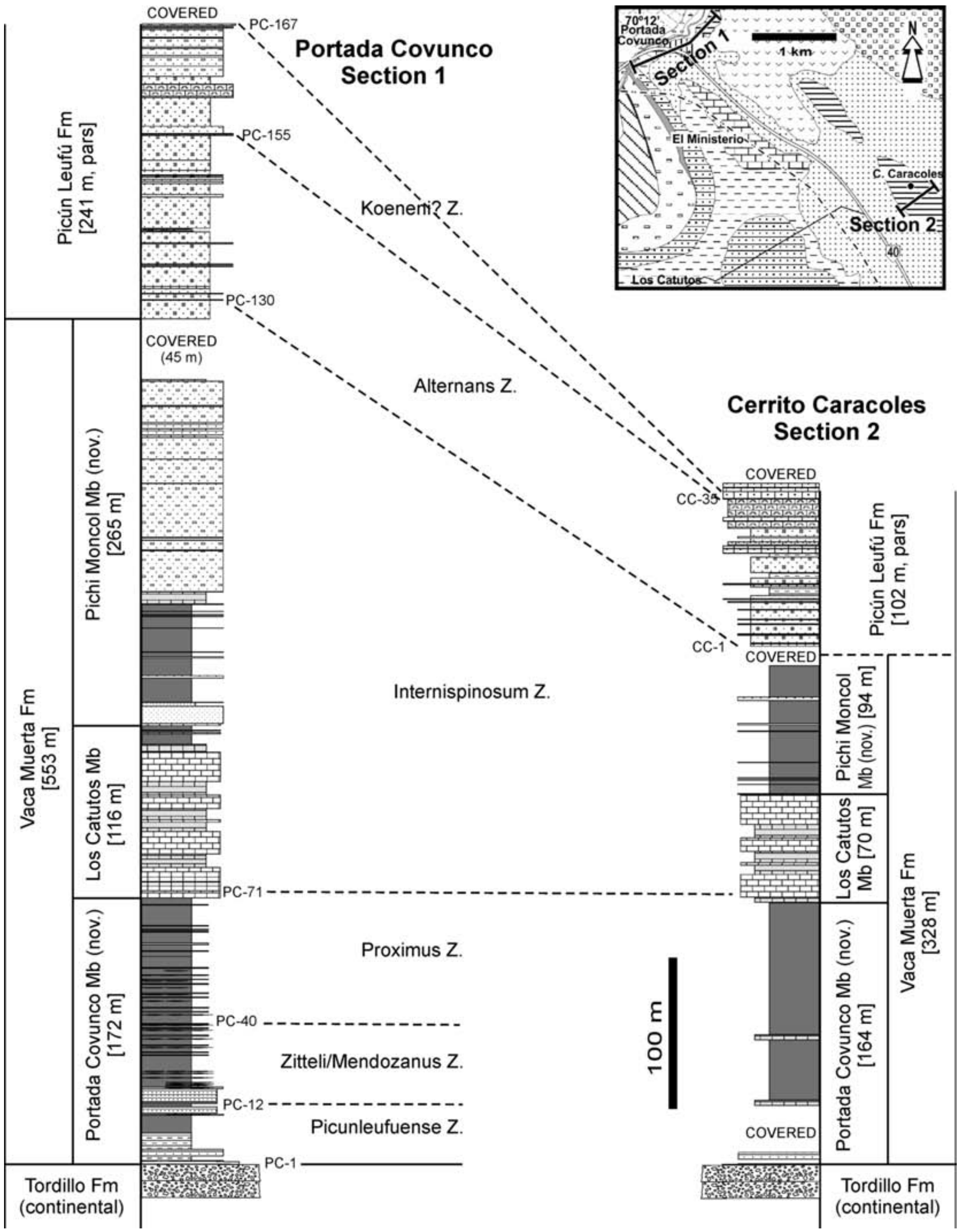

Fig. 29. Litho- and chronostratigraphic correlations between the studied sections at P. Covunco (Section 1 in Fig. 2) and Cerrito Caracoles (Section 2 in Fig. 2). Features of the Los Catutos Mb at Los Catutos section based on Leanza & Zeiss (1990, 1992), for the Portada Covunco and Pichi Moncol members there is no accurate biostratigraphic information available. Log-sections simplified from Figs. 3-4 and chronostratigraphy from Figs. 27-28. The reference map in the upper-right corner is part of the Fig. 2 in the same scale.

Internispinosum (non-standard) Zone – Beds PC-71-PC-129. The local range biozone of *W. internispinosum* spans the range PC-71-PC-78 fixing the base of the conjugate chronostratigraphic zone in the bed PC-71. The zone ranges up to the arbitrary base of the Alternans Z. in bed PC-130. The faunal content is similar to that of the nearby locality Los Catutos (see Zeiss & Leanza 2010). *C. rafaeli* is abundant in most of the zone but restricted below the occurrence of *C. araucanensis* (bed PC-92). *A.* cf. *euomphalum* Steuer (sensu Parent et al. 2007), some specimens still containing their laevaptychus in the bodychamber, was recorded only from bed PC-80 where it is rather abundant as impressions. The fauna is almost exactly the same in the lower part of the Internispinosum Z. in C. Lotena (cf. Leanza 1980) and Barda Negra (Parent et al. 2007).

In the transect of beds PC-93-PC-129 no ammonites were found; hence these beds are included in this zone only under the adopted criterium of extending a zone up to the base of the next following one.

The range of occurrence or biozone of *C. rafaeli* defines the Rafaeli Subzone (Leanza & Zeiss 1992) in Los Catutos and could be applied in the P. Covunco section for the beds PC-72-PC-84. However, it is inconvenient to use this subdivision of the Internispinosum Z. in other localities than the type locality for the material on which the subzone is based consists merely of impressions.

Alternans (non-standard) Zone – Beds PC-130-PC-154 and CC-1-CC-34. In bed PC-130 occurs the first representatives of *Steueria* (*S.* aff. *alternans*), overlying beds of the Internispinosum Z. Thus, considering that *Steueria* is known to occur in the Alternans Z. (Leanza 1945; PSS 2011) and has never been recorded below or associated with *W. internispinosum*, the bed PC-130 is taken locally as the base of the Alternans Z. in the section of P. Covunco. The fauna includes the most characteristic ammonites of the zone as recorded in A. Cieneguita (PSS 2011): *S. alternans, C. mendozanum* and representatives of *Blanfordiceras*.

In the C. Caracoles section the first *Steueria* occurs in bed CC-14, above some *Catutosphinctes*? sp. indet. in bed CC-6. The Internispinosum Z. of this section partially outcrops more than 50 m below the bed CC-1, in the locality Los Catutos (see Figs. 2, 29; cf. Leanza & Zeiss 1992: fig. 2).

?*Koeneni (non-standard) Zone – Beds PC-155-PC-167 and CC-35-CC-36*. There is a small number of ammonites (*Berriasella* sp. A, *P. calistoides*, *Subthurmannia*? sp. A), which could belong either to this zone or even to the Andean Lower Berriasian.

5. Conclusions

On the basis of their lithofacial features, two new members of the Vaca Muerta Formation have been formalized, the Portada Covunco and Pichi Moncol members, that join to Los Catutos Member (Leanza & Zeiss 1990).

Time correlation between the two sections studied (Fig. 29) shows very similar ammonite and lithological successions in the Lower-Middle Tithonian. From the Internispinosum Z. a remarkable differentiation in thicknesses and partially in lithofacies is evident. The section at P. Covunco is about three times thicker than the equivalent of the C. Caracoles section, but in the lowermost third both are identical. This differentiation is obviously related to the dynamics of the Huincul Arch.

The specific diversity of the ammonite fauna in P. Covunco is rather low in comparison with other localities like Picún Leufú, Pampa Tril and Arroyo Cieneguita, although in general the succession is poorly fossiliferous, especially in the Koeneni Z. In C. Caracoles the record is limited to the Upper Tithonian (Fig. 28), where the Alternans Z. shows a higher diversity in respect to P. Covunco.

In the studied transect both the Vaca Muerta Fm and the lower part of the Picún Leufú Fm are Tithonian in age.

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Addresses of the authors:

HORACIO PARENT, Laboratorio de Paleontología, IFG-FCE-IA, Universidad Nacional de Rosario, Pellegrini 250, 2000 Rosario, Argentina;
e-mail: parent@fceia.unr.edu.ar

ALBERTO CARLOS GARRIDO, Museo Provincial de Ciencias Naturales “Prof. Dr. Juan Olsacher”, Dirección General de Minería, Elena de Vega 472, 8340 Zapala, Argentina;
e-mail: albertocarlosgarrido@gmail.com

GÜNTER SCHWEIGERT, Staatliches Museum für Naturkunde, Rosenstein 1, 70191 Stuttgart, Germany;
e-mail: guenter.schweigert@smns-bw.de

ARMIN SCHERZINGER, Lämmerhalde 3, 71735 Eberdingen, Germany;
e-mail: armin.scherzinger@hotmail.de

Appendix 1.

Choicensisphinctes erinoides (Burckhardt, 1903). Adult macroconch phragmocone (MOZ-PI 508) from an undefined horizon within the Zitteli Zone of Los Catutos. Natural size.