

New Tithonian ammonites from the southern Neuquén Basin (Argentina) – with a review of the ammonite succession of the Picunleufuense Zone

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Abstract. New ammonite collections from the lower part of the Vaca Muerta Formation (Portada Covunco Member) at Picún Leufú, Estancia María Juana and Carrín Curá provided new data about the species of the lower Tithonian Picunleufuense Standard Zone in the southern margin of the Neuquén Basin. The fauna is consistently composed of the four typical species (*Indansites picunleufuense*, *Choicensisphinctes platyconus*, *Catutosphinctes guenenakenensis*, and *Cianguiticeras perlaevis*), and here we add the aspidoceratid *Physodoceras* cf. *neoburgense* which is described based of two specimens from the new collections. The successive assemblages composed of different morphotypes (transients) of those species characterize the three biohorizons of the lower Picunleufuense Zone: *picunleufuense* alpha Hz. (base of the zone), *picunleufuense* beta Hz., and *picunleufuense* gamma Hz. (new). A new, earlier transient of *Indansites picunleufuense* is described, but the material is still scarce for the characterization of the adult macroconch. The ammonites from the locality Carrín Curá were collected from a section of the lower Vaca Muerta Formation: 17.1 m of sandy shales with thin intercalations of calcareous sandstones indicating a near-shore environment. Ammonites and bivalves occur in the calcareous sandstone levels.

Keywords: Tithonian • Picunleufuense Zone • Neuquén Basin • Argentina • Ammonites • Carrín Curá.

Resumen. *Nuevos amonites tithonianos del sur de la Cuenca Neuquina, Argentina - con una revisión de la sucesión de amonites de la Zona Picunleufuense.* Amonites provenientes de la parte inferior de la Formación Vaca Muerta (Miembro Portada Covunco) nos han permitido obtener nuevos datos de las especies de la Zona Estándar Picunleufuense (Tithoniano inferior basal) en el sur de la Cuenca Neuquén, i.e. Picún Leufú, Est. María Juana y Carrín Curá. La fauna de la Zona Picunleufuense está compuesta por las cuatro especies típicas (*Indansites picunleufuense*, *Choicensisphinctes platyconus*, *Catutosphinctes guenenakenensis*, y *Cianguiticeras perlaevis*), a las que se agrega *Physodoceras* cf. *neoburgense*. Esta última especie es descrita a partir de dos ejemplares de los nuevos muestreos. La sucesión de asociaciones compuestas por los diferentes transients de las especies típicas caracterizan tres biohorizontes hasta ahora reconocidos en la Zona Picunleufuense: Hz. *picunleufuense* alpha, Hz. *picunleufuense* beta, and Hz. *picunleufuense* gamma (nuevo). Se describe un nuevo transient de *I. picunleufuense*, pero sobre la base de material insuficiente para una caracterización adecuada de la macroconcha adulta. Los amonites de Carrín Curá fueron colectados en una sección de 17.1 m de espesor de la base de la Fm Vaca Muerta. Esta sucesión de pizarras arenosas con delgadas intercalaciones de areniscas calcáreas indican un ambiente deposicional proximal. Amonites y bivalvos fueron colectados en los niveles de areniscas calcáreas.

Palabras clave: Tithoniano • Zona Picunleufuense • Cuenca Neuquina • Argentina • Amonites • Carrín Curá.

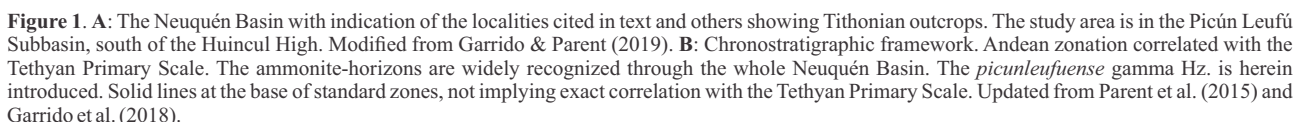
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INTRODUCTION

The basal beds of the Portada Covunco Mb (Parent et al. 2013b), lower member of the Vaca Muerta Fm, in Picún Leufú play an important role in the chronostratigraphy of the Tithonian of the Neuquén Basin (Fig. 1A). In these beds occurs an abundant ammonite fauna, just overlying the Quebrada del Sapo Fm (roughly time-equivalent of the Tordillo Fm north of the Huincul High) which had been overlooked by most authors – probably because of the difficulty in finding sections with well-preserved ammonites from these levels. It was recognized for the first time in localities of the Picún Leufú Subbasin, and after preliminar study of this fauna (Parent et al. 2006), it was

described in detail (Parent et al. 2011a) and used to define the basalmost chronostratigraphic unit of the Andean Tithonian: the Picunleufuense Zone (Fig. 1B). The base of this chronostratigraphic standard ammonite zone was established as the *picunleufuense* alpha Hz., the type locality of which is Picún Leufú. The Picunleufuense Zone has been recognized through virtually the entire Neuquén Basin (review in Parent et al 2015, Garrido et al. 2018). The base of the Portada Covunco Mb belongs to the Picunleufuense Zone everywhere in the basin, not only in the Picún Leufú Subbasin.

In the deposition area south of the Huincul High (Fig. 1A), which is usually denominated Picún Leufú Subbasin, there are some localities with good exposures of the Portada



The purposes of the present paper are (1) to summarize

THE STRATIGRAPHIC SUCCESSION OF CARRÍN CURÁ

Carrín Curá (CCU) is a locality in the southernmost part of the Neuquén Basin characterized during the Tithonian by a marine near-shore sedimentary environment (Leanza & Hugo, 1997). The geology of the region has been described in detail by Galli (1969) and Leanza & Leanza (1979). The

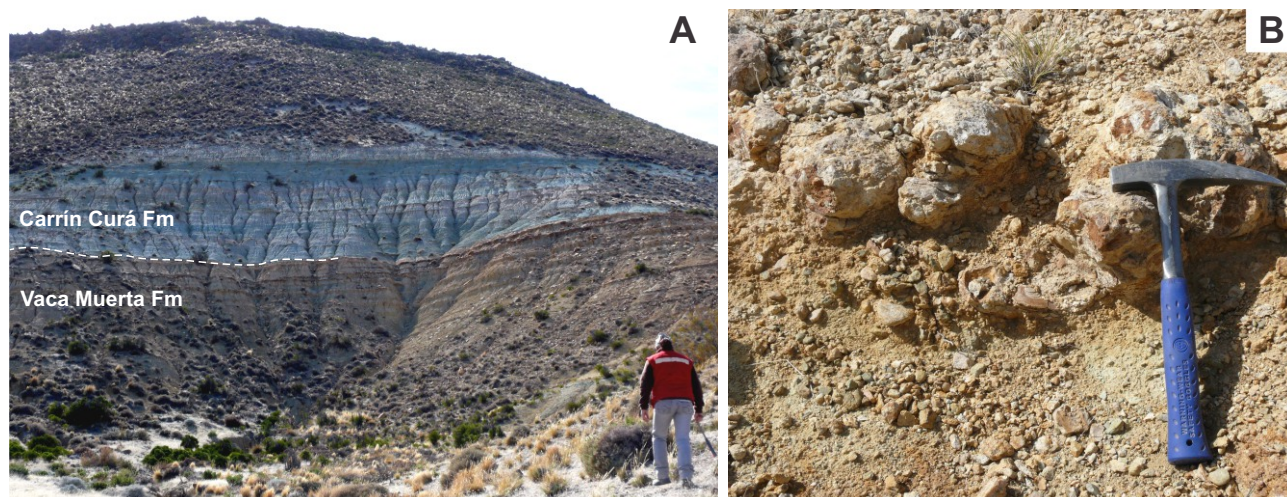


Figure 2. A. The studied section in Carrín Curá showing the contact between the Vaca Muerta and Carrín Curá formations. B. Close view of level CCU-1, *picunleufuense* alpha Hz., Picunleufuense Zone; the hammer is 320 mm in height.

rock succession and the fossiliferous levels we have recorded from the Portada Covunco Mb, lower Vaca Muerta Fm (Figs. 2-3) is as follows, from above:

Level CCU-7: 4.3 m, laminated sandy shale rich in organic matter, with intercalations of thin (< 2 cm), fine-grained calcareous sandstones.

Level CCU-6 [faunal level IV]: 0.17 m, laminated, fine-grained calcareous sandstone rich in fossils (bivalves).

Level CCU-5: 3.8 m, laminated sandy shale rich in organic matter, with intercalations of thin (< 2 cm), fine-grained calcareous sandstones.

Level CCU-4 [faunal level III]: 0.28 m, laminated, fine-grained calcareous sandstone rich in fossils (bivalves, ammonites). Ammonites: *Indansites picunleufuense* (Parent, Garrido, Schweigert & Scherzinger, 2011a) transient gamma. Although this is the only species recorded from this level, it could likely belong to the *picunleufuense* gamma Hz. (new, see below).

Level CCU-3: 7.6 m, laminated sandy shale rich in organic matter, with intercalations of thin (< 2 cm), fine-grained calcareous sandstones.

Level CCU-2 [faunal level II]: 0.3 m, laminated, fine-grained calcareous sandstone rich in fossils (bivalves, ammonites). Ammonites: *Indansites picunleufuense* tr. beta. Most likely *picunleufuense* beta Hz.

Level CCU-1 [faunal level I]: 0.55 m, texturally immature gravelly sandstone, with abundant calcareous cement. Rich in fossils (bivalves, ammonites). Ammonites: *Indansites picunleufuense* tr. alpha, and *Choicensisphinctes platyconus* Parent, Garrido, Schweigert & Scherzinger, 2011a tr. alpha. *Picunleufuense* alpha Hz.

THE AMMONITE SUCCESSION OF THE PICUNLEUFUENSE ZONE

According to previously published material (Parent et al. 2011a, 2013a, 2019, Vennari 2016) and that described below (Figs. 4-10), the succession of ammonite assemblages recorded from the Picunleufuense Zone in the Picun Leufú Subbasin is the following, from above:

– **level PL-7e (Picún Leufú section: Fig. 3):** *I. picunleufuense* (Fig. 6). The transient of these levels (described below) is somewhat distinctive from transients beta and gamma (new). On the other hand, they are very similar to specimens from rather equivalent levels MQ-IV-11-13 of Mallín Quemado (Garrido et al. 2018: figs. 3, 16). The stratigraphic position above the *picunleufuense* gamma Hz. (new) is suggested by (1) the very likely assignment of the underlying levels (PL-7a-d in Fig. 3) to the *picunleufuense* gamma Hz. (new), and (2) the succession in Mallín Quemado, where the fauna of this latter biohorizon (discussed in Parent et al. 2019) occurs below the specimens comparable with those of level PL-7e (described below).

– ***picunleufuense* gamma Hz. (new):** levels CCU-3, EMJ-10, and most likely PL-7a-d. The level EMJ-10 have yielded plenty well-preserved macroconchs of a very densely ribbed transient of *I. Picunleufuense*, which is here designated as transient gamma (it was formerly denominated transient EMJ-10 in Parent et al. 2019). This level with its ammonites is here taken to establish the *picunleufuense* gamma Hz. (new) on the basis of its characteristic fauna: *I. picunleufuense* tr. gamma (very abundant) associated with an evolute, densely ribbed morphotype of *C. platyconus* (see Parent et al. 2019: fig. 11). In the levels PL-7a-d occurs a yet poorly known fauna including *C. cf./aff. platyconus*, *Choicensisphinctes cf. windhausenii* (Weaver, 1931), and *Catutosphinctes cf./aff. guenenakenensis*; some specimens were figured in Parent et

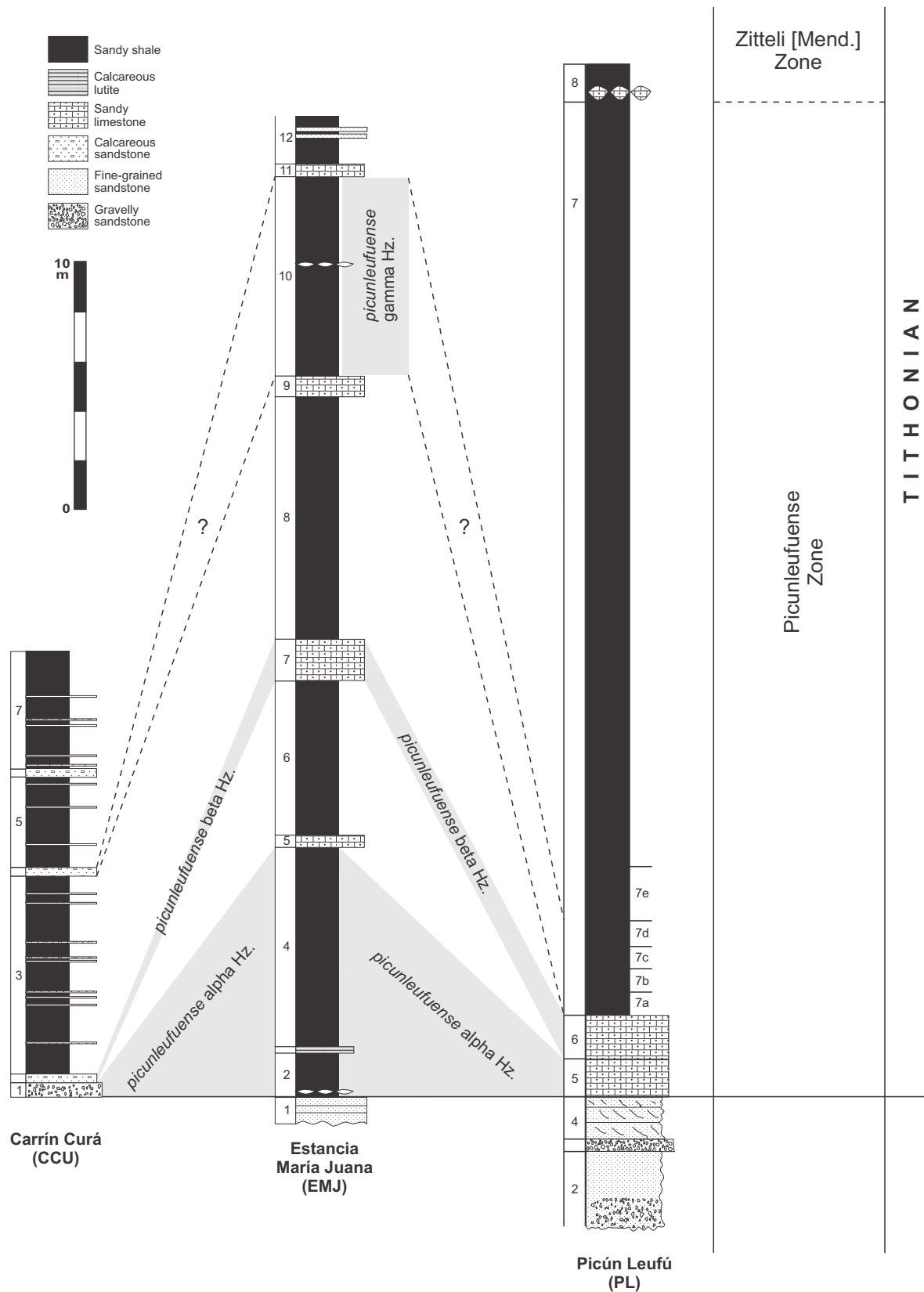


Figure 3. Time-correlation of the log-sections of lower parts of the Vaca Muerta Fm at Carrín Curá, Estancia María Juana and Picún Leufú, based on the recognition of ammonite biohorizons as time-planes. The Carrín Cura section and its fauna are summarized in the text, the section of Estancia María Juana is described in Parent et al. (2019), and the section of Picún Leufú described in Parent et al. (2011a). The base of the standard Picunleufuense Zone (standard base of the Andean Tithonian) is indicated by a solid line, the base of the non-standardized Zitteli [Mendozanus] Zone by a broken line.

al. (2011a: figs. 23, 30B, 31).

– ***picunleufuense* beta Hz.**: *I. picunleufuense* tr. beta, *C. platyconus* tr. beta, *Catutosphinctes guenenakenensis* Parent, Garrido, Schweigert & Scherzinger, 2011a, and *Cieneguiticeras perlaevis* (Steuer, 1897).

– ***picunleufuense* alpha Hz. (standard base of the Picunleufuense Zone)**: *I. picunleufuense* tr. alpha, *C. platyconus* tr. alpha, *C. guenenakenensis*, *Physodoceras* cf. *neoburgense* (Oppel, 1863), and *C. perlaevis*.

REGIONAL TIME-CORRELATION SOUTH OF THE HUINCUL HIGH

The sections of the localities Carrín Curá (Fig. 3), Estancia María Juana (stratigraphy in Parent et al. 2019), and Picún Leufú (stratigraphy in Parent et al. 2011a) can be correlated at the level of the ammonite biohorizon as shown in Fig. 3.

SYSTEMATIC PALAEONTOLOGY

Conventions. The material described is housed at the Museo Provincial de Ciencias Naturales “Prof. Dr. Juan A. Olsacher”, Zapala (MOZ-PI). Bodychamber is abbreviated with Bc and phragmocone with Ph; macroconch (female): [M], microconch (male): [m]. Measurements are indicated as follows: diameter (D), diameter at the last adult septum (D_{ls}) and diameter at adult peristome (D_p), all given in millimeters [mm]; umbilical width (U), whorl width (W), whorl height (H_1), and whorl ventral (or apertural) height (H_2), all given as dimensionless proportions of D ; length of bodychamber (L_{bc}) in degrees [$^\circ$]. Number of primary (P) and ventral (V) ribs per half whorl. Levels of occurrence of the specimens denoted by the level number in Fig. 3 and a prefix, PL (Picún Leufú), EMJ (Estancia María Juana) or CCU (Carrín Curá). Zones and biohorizons referred to Fig. 1B.

Order Ammonotida Fischer, 1882

Suborder Ammonitina Fischer, 1882

Superfamily Perisphinctoidea Steinmann, 1890

Family Ataxioceratidae Buckman, 1921

Subfamily Zapaliinae Parent, Schweigert, Scherzinger & Garrido, 2017

Genus *Indansites* Vennari, 2016

Type species. *Subplanites malarguensis* Spath, 1931, by original designation.

Indansites picunleufuense (Parent, Garrido, Schweigert & Scherzinger, 2011a)

Figs. 4-6

Synonymy. See Parent et al. (2019).

Transient alpha (Fig. 4). The innermost whorls were known only from specimens from Pampa Tril (see Parent et al. 2015: figs. 6A, 7, 8B, and Parent et al. 2019: fig. 9), more

than 300 km north of Picún Leufú. The specimen in Fig. 4C shows that they are evolute and already ornamented with sharp primary ribs, which bifurcate in the upper flank, thus perfectly matching the material known from Pampa Tril. On the other hand, the rib density is lower than in the transient beta. However, some macroconchs of the transient alpha can exhibit somewhat more densely ribbed median whorls of the phragmocone (Fig. 4A, E), resembling the transient beta.

The new microconchs (Fig. 4B, D, F) add even more variation to that reported in Parent et al. (2019). There are some large specimens with a macroconchiate ornamentation but ending in lappets; thus, these males are supposed to have changed their sex. The specimen illustrated in Fig. 4D is a new example of this case, suggesting it was not very unusual, at least in the earliest history of the species. Contrary, other males retain the simple bifurcating ribbing up to the peristome at large sizes, about $D = 70\text{--}80$ mm (Fig. 4F).

Transient beta (Fig. 5). The macroconch in Fig. 5 is one of the more coarsely ribbed examples of this transient. The most densely and finely ribbed example has been figured in Parent et al. (2011a: fig. 10) which, on the other hand, is identical to a specimen of this transient from Casa Pincheira (Parent 2003: fig. 6A).

Transient gamma. These are the specimens from level EMJ-10 (see Parent et al. 2019: figs. 5-8) formerly denominated “transient EMJ-10”. They are characterized by an extremely fine and dense ribbing in the phragmocone, occurring as a single morphotypic variant in the assemblage. Unfortunately no corresponding microconchs have been recorded yet. The stratigraphic position of this assemblage is discussed above.

Specimens from level PL-7e (Fig. 6). Several fragmentary macroconchs. Although the specimens are incomplete, they overlap sufficiently to allow most of the ontogeny to be composed. The inner and median whorls ($D < 90$ mm) are suboval to subrectangular, higher than wide, evolute, densely and finely ribbed with slightly prosocline primaries bifurcating in the upper half of the flank. The adult phragmocone up to the bodychamber is evolute, its whorl section subrectangular, higher than wide. The last half whorl of the adult phragmocone ($D = 90\text{--}120$ mm; $D_{ls} = 100\text{--}110$ mm) shows the characteristic short stage of trifurcate primaries in a strictly virgatotomic style. In the beginning of the bodychamber the ribbing becomes polyfurcated, with strong acute primaries, which divide into three or four finer secondaries. In the last portion of the bodychamber the primaries are reinforced and wider spaced; the secondaries and the several intercalatories are finer. The fragment of the largest macroconch suggests a maximum size of more than $D = 150$ mm.

The most closely comparable specimens are known from rather equivalent levels of Mallín Quemado (Garrido et al. 2018: figs. 9, 10A-B). The phragmocones are identical with moderately dense primary ribbing and a well-developed ontogenetic stage of trifurcate virgatotomes (sensu stricto) through a half whorl at $D = 110\text{--}130$ mm. However, the bodychamber of all these specimens is only partially preserved, thus hampering a closer comparison.

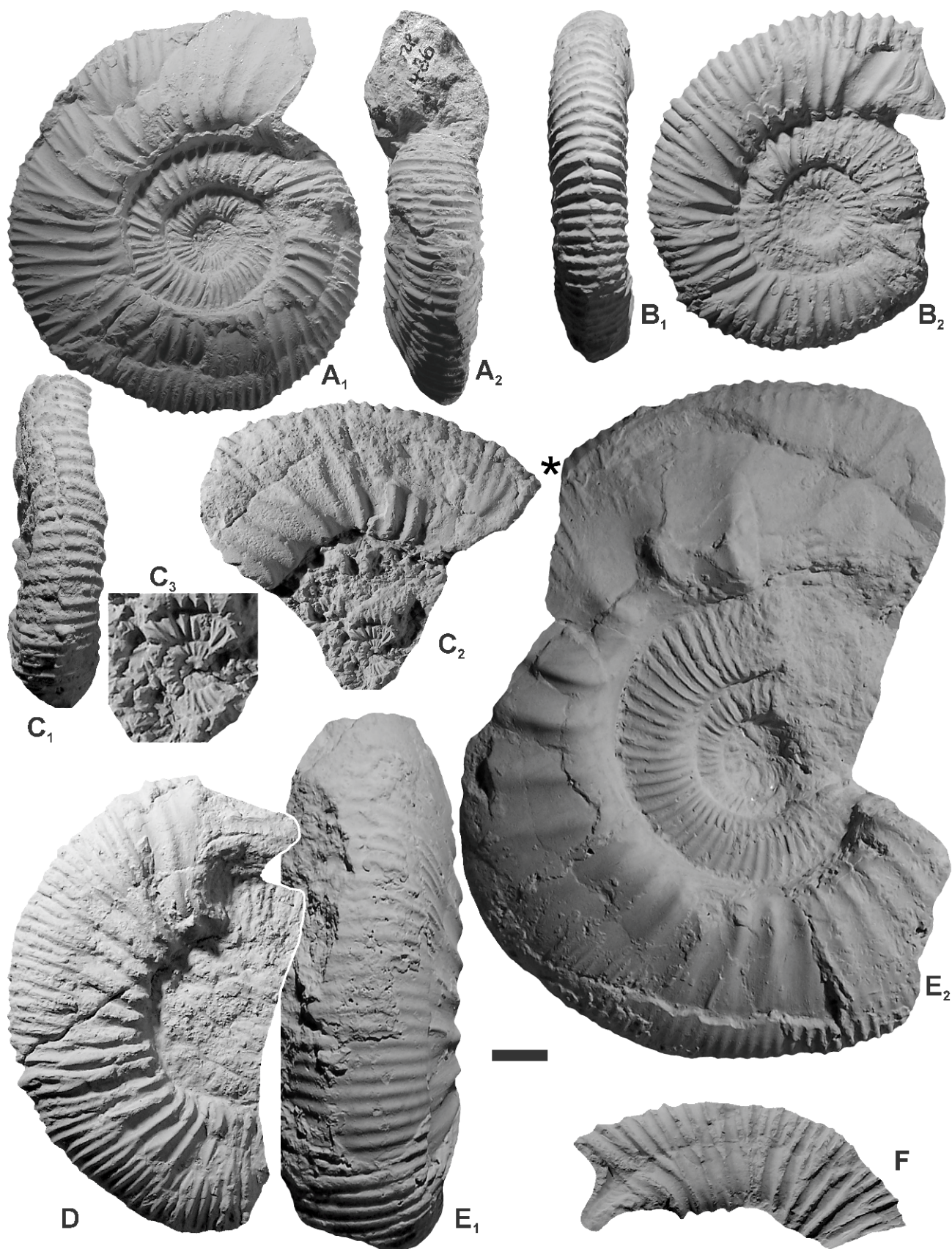


Figure 4. *Indansites picunleufuense* Parent, Garrido, Schweigert & Scherzinger, 2011a, transient alpha; *picunleufuense* alpha Hz., Picunleufuense Zone, Picún Leufú PL-5 (A-E) and E. María Juana EMJ-4 (F). **A:** macroconch phragmocone (MOZ-PI-7281/2). **B:** complete adult microconch (MOZ-PI-7473/2). **C:** incomplete macroconch (MOZ-PI-7473/3) with well preserved innermost whorls (**C₃**, x2). **D:** adult microconch (MOZ-PI-7473/1) with ornamentation of adult macroconch in the bodychamber. **E:** adult macroconch (MOZ-PI-7799/2) with beginning of bodychamber. **F:** adult end of microconch bodychamber (MOZ-PI-2293/2). - All natural size (x1) except **C₃** (x2). Asterisk at last septum. The bar represents 10 mm except for **C₃** (5 mm).

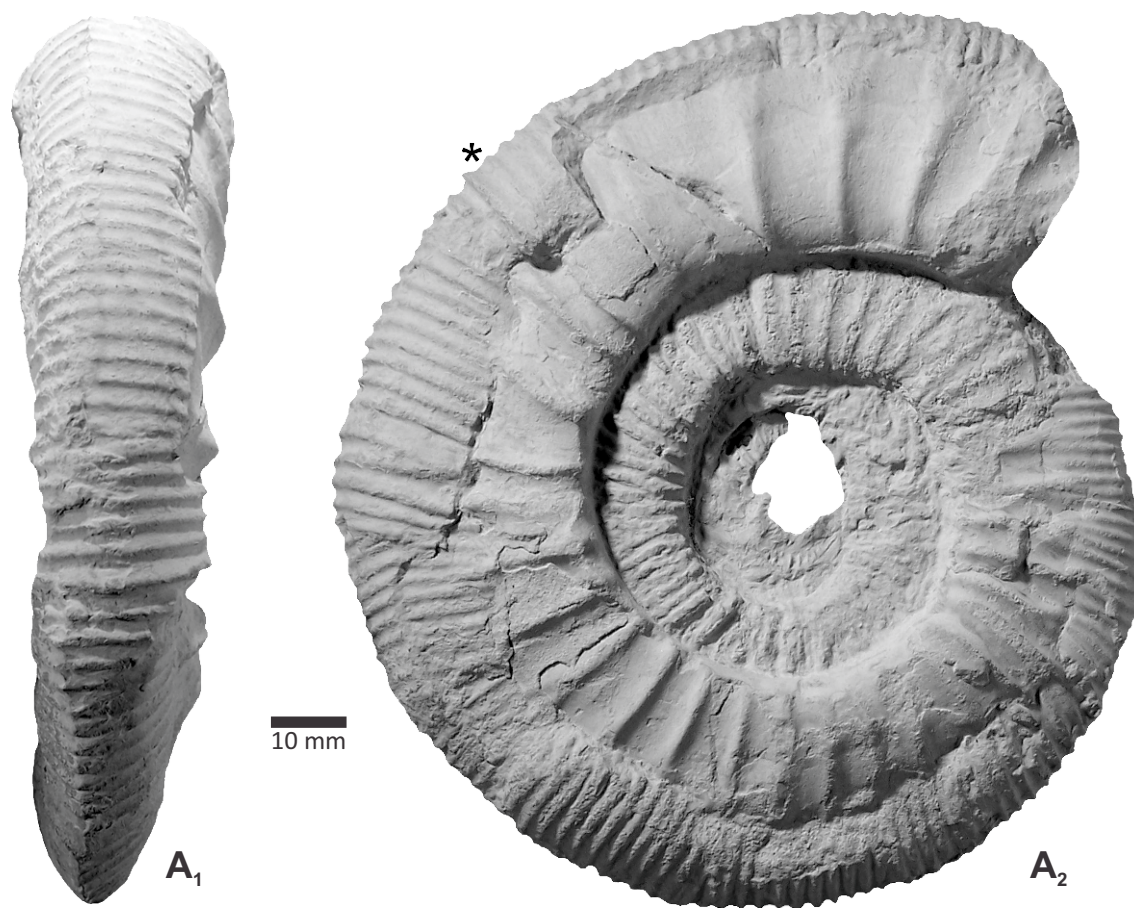


Figure 5. *Indansites picunleufuense* Parent, Garrido, Schweigert & Scherzinger, 2011a, transient beta; *picunleufuense* beta Hz., Picunleufuense Zone, Picún Leufú PL-6. Almost complete adult macroconch (MOZ-PI-7760). Same specimen figured in Parent et al. (2011a: fig. 12A) with additional preparation. - Natural size (x1). Asterisk at last septum.

Genus *Choicensisphinctes* Leanza, 1980

Type species. *Perisphinctes choicensis* Burckhardt, 1903, by original designation.

***Choicensisphinctes platyconus* Parent, Garrido, Schweigert & Scherzinger, 2011a**
Figs. 7-8

Synonymy. See Parent et al. (2019).

Transient alpha (Fig. 7). The range of variation of this species in the *picunleufuense* alpha Hz. was described as four macroconch morphotypes A-D (Parent et al. 2011a). The coarsely ribbed and evolute morph A is very rare in the study area, hardly present in small samples. The more abundant one is morph B, which includes the holotype. Morph C is moderately abundant, consisting of finely ribbed, compressed specimens from the inner whorls up to the bodychamber, which shows stronger primaries. Morph D differs from morph C just by some irregular ribbing on the bodychamber, but this does not seem to be a consistent difference. Thus, the range of variation can be well described by means of only the three macroconch morphs A-C.

The new examples in Fig. 7A-C illustrate the ontogeny of the macroconch phragmocone, finely and densely ribbed by regularly bifurcated ribs from the innermost whorls, with the occurrence of few single isolated virgatotomes from about $D=25-30$ mm.

The small macroconch in Fig. 7D must be considered adult for its incipient uncoiling and the strong variocostation from the beginning of the bodychamber (the remaining whorl is not preserved). The innermost whorls are more evolute and stronger ribbed than those of morphs B and C. Comparable small adult macroconchs have been recorded from the Zitteli [incl. *Mendozanus*] Zone in Cerro Lotena and Cerro Granito (to be published elsewhere).

The almost complete adult macroconch from Carrín Curá, level CCU-1 (Fig. 7E) looks identical to the holotype. This new specimen shows the gross, widely spaced cuneiform primary ribs of the bodychamber which are not well preserved in the slightly crushed holotype.

Morph C is compressed-platyconic and densely, finely ribbed from the inner whorls onwards (Parent et al. 2011a: fig. 16A-E). The new specimens illustrate the ornamentation of the adult phragmocone and the beginning of the bodychamber. In this ontogenetic stage the primaries become stronger and divide into five to ten or even more extremely fine secondaries in a palmate style, crossing the

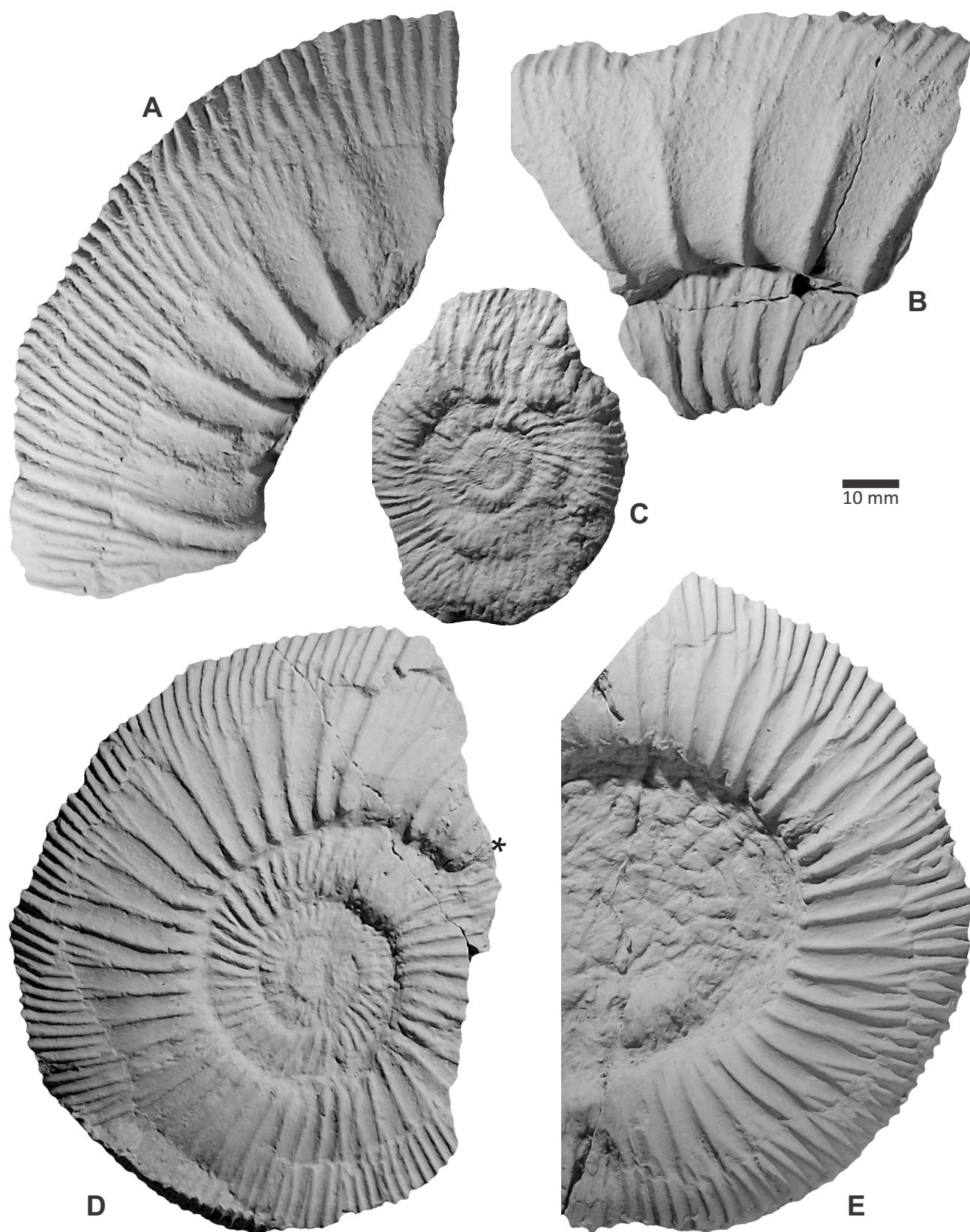


Figure 6. *Indansites picunleufuense* Parent, Garrido, Schweigert & Scherzinger, 2011a, Picunleufuense Zone, Picún Leufú level PL-7e. **A:** portion of adult macroconch bodychamber (MOZ-PI-7270/5). **B:** terminal portion of adult macroconch (MOZ-PI-7270/4). **C:** macroconch phragmocone (MOZ-PI-7270/3). **D:** complete adult macroconch phragmocone (MOZ-PI-7270/2). **E:** adult macroconch phragmocone (MOZ-PI-7270/1). - All natural size (x1). Asterisk at last septum.

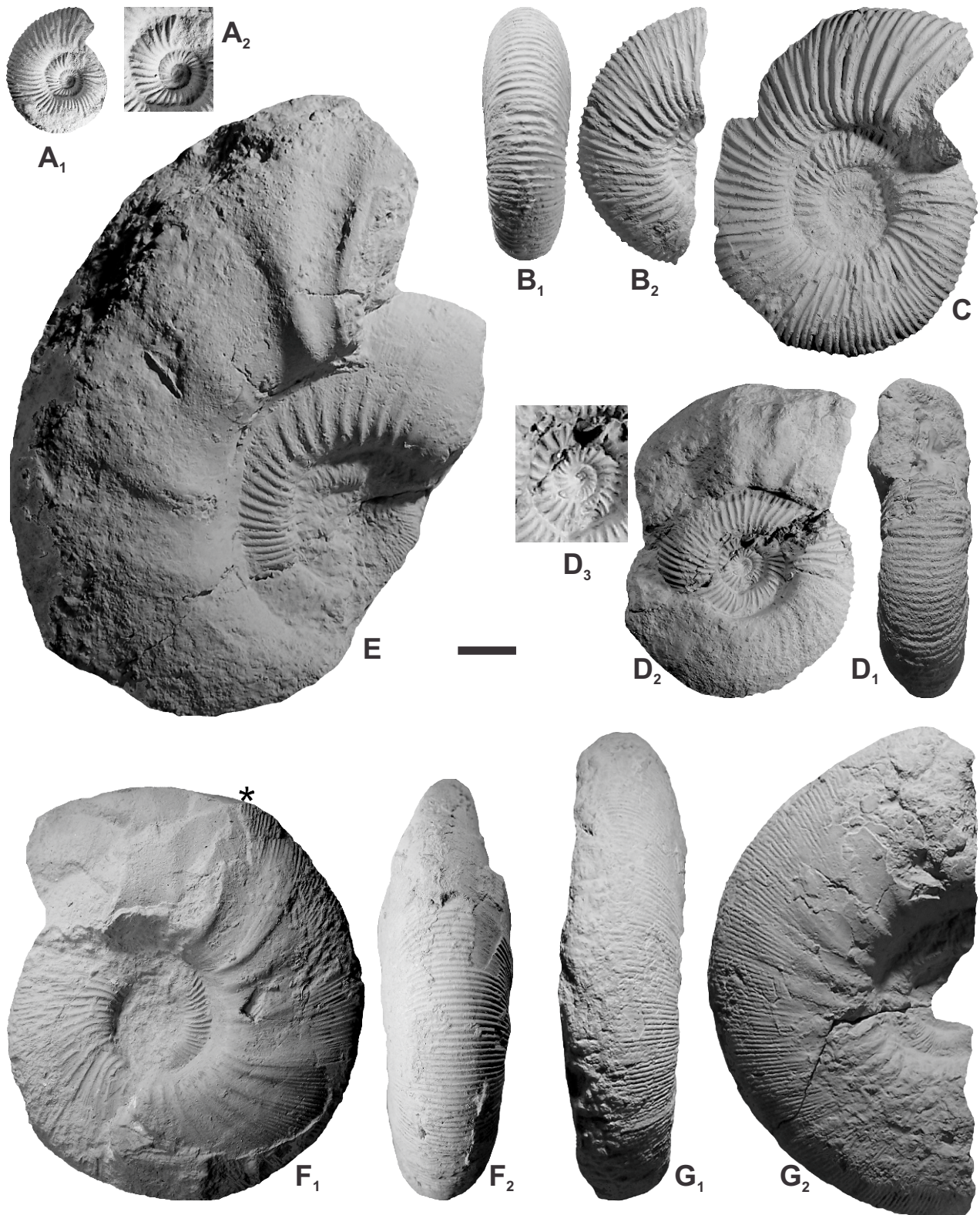


Figure 7. *Choicensisphinctes platyconus* Parent, Garrido, Schweigert & Scherzinger, 2011a, transient alpha, Picún Leufú level PL-5 (A-D, F-G) and Carrín Curá level CCU-1 (E), *picunleufuense* alpha Hz., Picunleufuense Zone. **A:** inner whorls of a macroconch (MOZ-PI-6395/3), morph B, **A₂:** innermost whorls, enlarged view (x2). **B:** middle whorls of an adult macroconch phragmocone (MOZ-PI-6395/2), morph B. **C:** adult macroconch phragmocone (MOZ-PI-7469/1), morph B with very finely ribbed inner whorls. **D:** small adult macroconch with incomplete bodychamber (MOZ-PI-7797/4), morph B; **D₃:** enlarged view of the innermost whorls (x2). **E:** almost complete adult macroconch (MOZ-PI-11197), transitional between morphs B and C for the finely and densely ribbed phragmocone. **F:** adult macroconch phragmocone (MOZ-PI-7388/3), morph C. **G:** adult macroconch phragmocone (MOZ-PI-7388/2), morph C. - All natural size (x1), except A₂ and D₃ (x2). The scale bar represents 10 mm, except for A₂ and D₃ (5 mm).

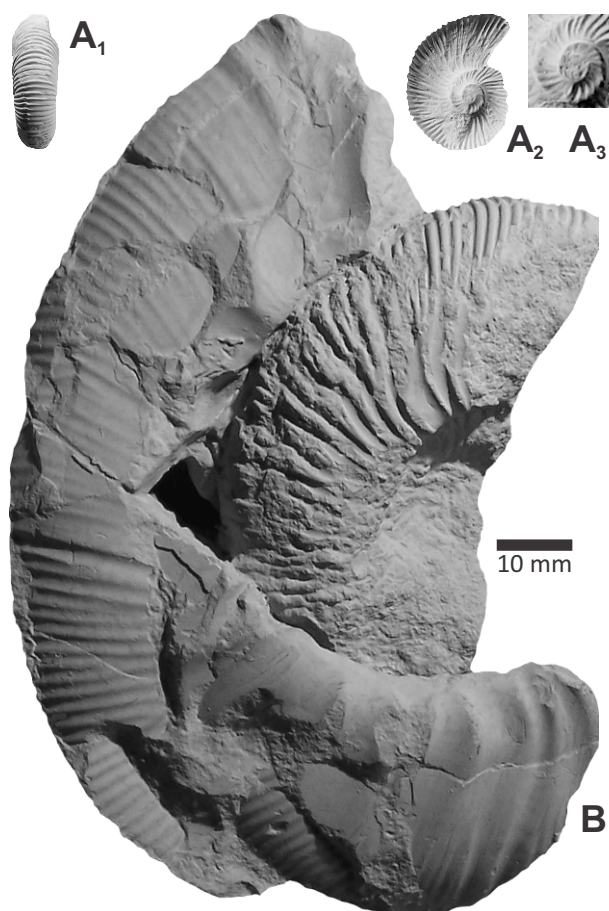


Figure 8. *Choicensisphinctes platyconus* Parent, Garrido, Schweigert & Scherzinger, 2011a, transient beta, Picún Leufú, level PL-6, *picunleufuense* beta Hz., Picunleufuense Zone. **A:** inner whorls of an adult macroconch (MOZ-PI-7762/3), ventral (**A₁**) and lateral (**A₂**) views; **A₃**: innermost whorls x2. **B:** almost complete adult macroconch (MOZ-PI-7762/2), last whorl bodychamber. - All natural size (x1) except **A₃** (x2). The scale bar represents 10 mm, except for **A₃** (5 mm).

venter unchanged and evenly spaced (Fig. 7F-G).

Transient beta (Fig. 8). This transient is scarce in the localities, where it has been recorded (Picún Leufú and Pampa Tril). The new examples are identical to the few other known specimens, suggesting that the macroconch of this transient has a low variability; microconchs are not known yet. The phragmocone of the macroconch in Fig. 8B is identical to that of the transient alpha (Fig. 7B-C); the differentiation is expressed in the different ornamentation of the bodychamber.

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

Type species. *Catutosphinctes rafaeli* Leanza & Zeiss, 1992, by original designation.

***Catutosphinctes guenenakenensis* Parent, Garrido, Schweigert & Scherzinger, 2011a**

Fig. 9

Remarks. The adult macroconch bodychamber of this species was known only partially from the holotype, which preserves only the last portion. The macroconchs in Fig. 9A-B show other parts of the adult bodychamber from which can be observed that the typical variocostation of this species is not only strong, but also abrupt, from about $D_{is} = 70$ mm onwards. The adult macroconch size seems to be less variable in this species, what contrasts with the representatives of the genus in the Zitteli [incl. *Mendozanus*], *Proximus* and *Internispinosum* zones which are widely variable in this feature.

The incomplete specimen in Fig. 9C, coming from level PL-6, *picunleufuense* beta Hz., allows to compare the innermost whorls with the more strongly ribbed representatives of the species in the *picunleufuense* alpha Hz. (e.g. Parent et al. 2011a: figs. 28, 29A-B).

Family Aspidoceratidae Zittel, 1895
Subfamily Aspidoceratinae Zittel, 1895
Genus *Physodoceras* Hyatt, 1900

Type species. *Ammonites circumspinosus* Oppel, 1863, by original designation (subjective junior synonym of *Ammonites inflatus circumspinosus* Quenstedt, 1857), by original designation.

Remarks. The concept of the genus follows Scherzinger et al. (2018).

***Physodoceras* cf. *neoburgense* (Oppel, 1863)**
 Fig. 10

Material. One almost complete adult macroconch and one macroconch phragmocone, both inner moulds from Picún Leufú, level PL-5.

Description. Small globular spherococone, very involute and narrowly umbilicate throughout the ontogeny ($U/D = 0.10$ at $D = 42$ mm).

Phragmocone: whorl section oval depressed ($W/D = 0.71-75$), with high umbilical wall and wide, rounded venter. Smooth from at least $D = 20$ mm.

Bodychamber: it begins at $D_{is} = 42$ mm and extends for at least 240° . The whorl section becomes compressed gradually towards the end, passing from $W/D = 0.71$ at D_{is} to $W/D = 0.55$ at the maximum preserved diameter of 64 mm (possible peristome). The ornamentation consists of wide mild undulations and closely spaced, regularly distributed gross growth lines.

Remarks and comparison. Our material consists of only two macroconchs. This scarce material of only macroconchs hampers a closer comparison with known species, many of which need to be compared considering the corresponding microconch due to frequent homoeomorphism in macroconchiate aspidoceratids (Scherzinger et al. 2018). The present species shows two conspicuous features of the adult macroconch bodychamber: (1) the strong contraction and uncoiling, and (2) the undulations combined with gross growth lines, both evenly distributed. It is very likely that these ornamental elements observed in the inner mould would be somewhat

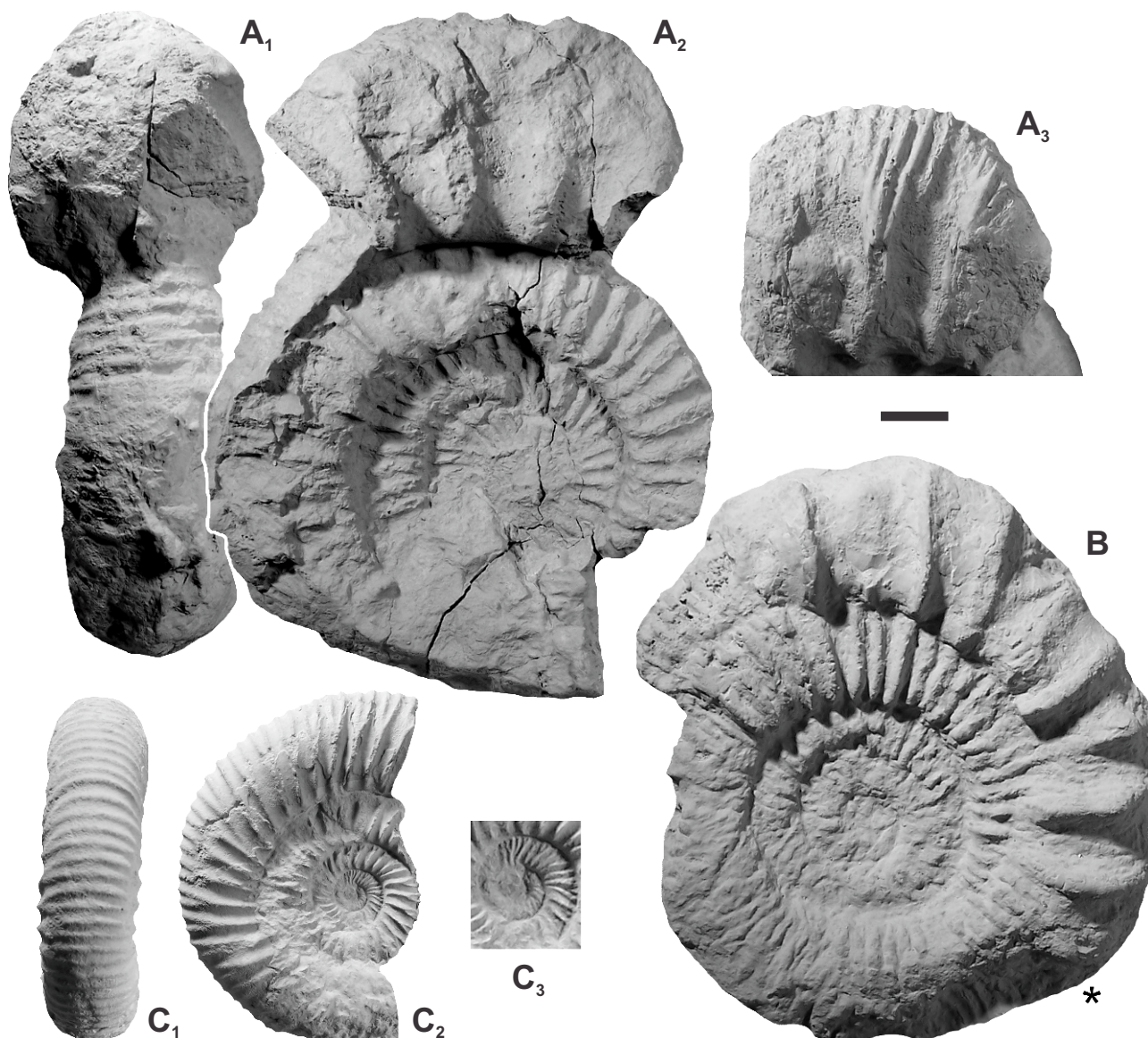


Figure 9. *Catutosphinctes guenenakenensis* Parent, Garrido, Schweigert & Scherzinger, 2011a, Picún Leufú, levels PL-5, *picunleufuense* alpha Hz. (A-B) and PL-6, *picunleufuense* beta Hz. (C), Picunleufuense Zone. A: almost complete adult macroconch (MOZ-PI-7492/2), last portion of whorl is bodychamber; A₃: opposite face of the portion of bodychamber showing the formation of the secondary ribs as incisions on the primary rib. B: almost complete adult macroconch (MOZ-PI-7492/1). C: macroconch? phragmocone (MOZ-PI-7801/1), C₃: enlarged view of the innermost whorls (x2). - All natural size (x1), except C₃ (x2). The scale bar represents 10 mm, except for C₃ (5 mm).

more prominent in the test.

Records from the Caribbean area are scarce. The specimen illustrated in Villaseñor et al. (2005: fig. 4e-g), from approximately the Darwini Zone of the Cucurpe Fm, Sonora (Mexico), is very similar to the present ones, but somewhat larger and more inflated.

According to the recent revision by Scherzinger et al. (2018), the dimorphic pair *P. neoburgense* [M]/*Sutneria asema* (Oppel, 1865) [m] ranges through the Vimineus and Ciliata zones, correlatable with the Semiforme and Fallauxi zones (see Schweigert et al. 2002, Schweigert & Scherzinger 2004). The neotype of *P. neoburgense* (Schlegelmilch 1994: pl. 72: 4), from the Ciliata Zone of Unterhausen near Neuburg a. d. Donau, Franconia, differs

from our specimens by its larger adult size.

There are well-dated Tethyan specimens comparable with the PL-5 specimens. For example, the two shown in Fig. 11 from the upper Hybonotum and upper Darwini-Semiforme zones of Rogoźnik, Poland. These specimens have been assigned to *P. neoburgense* by Kutek & Wierzbowski (1986). Nevertheless, the specimen of Fig. 11A was said to come from the Hybonotum Zone (Kutek & Wierzbowski 1986: tab. 2), below the known stratigraphic range of this species and below the occurrences, in the same section, of its corresponding microconch *S. asema*. Many other authors have figured similar specimens from the Hybonotum and Darwini zones labelled as *P. neoburgense* (e.g. Olóriz 1978, Checa 1985, Fözy & Scherzinger 2011),

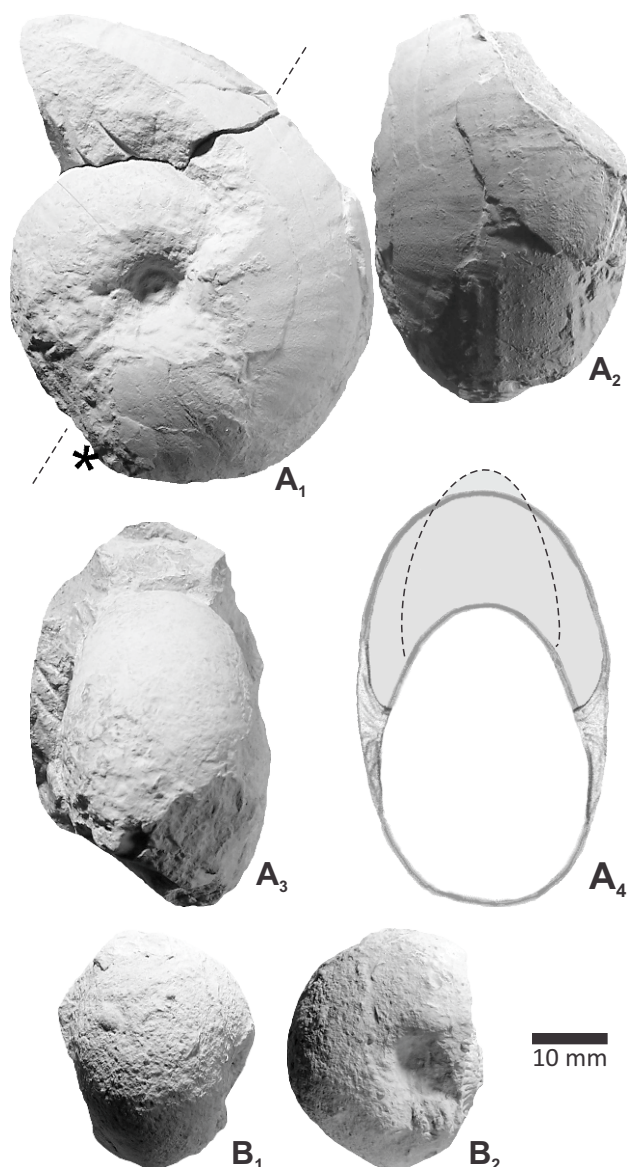


Figure 10. *Physodoceras* cf. *neoburgense* (Oppel, 1863), Picún Leufú, level PL-5, *picunleufuense alpha* Hz., Picunleufuense Zone. **A:** adult macroconch (MOZ-PI-7343/1) with bodychamber; lateral (**A₁**) and ventral (**A₂**) views; **A₃**: apertural view, last part of bodychamber removed; **A₄**: schematic apertural view through the plane indicated by the broken line in **A₁** (bodychamber gray); whorl section at peristome indicated by the broken line. **B:** macroconch? phragmocone (MOZ-PI-7343/2). - All natural size (x1). Asterisk at last septum.

but for an accurate identification both sexual dimorphs should be recorded and more complete material is necessary. These ammonites could be, in most cases, either small adults or nuclei of *Physodoceras pipini* (Oppel, 1863) in which the periumbilical tubercles appear at larger sizes. On the other hand, few specimens among the *pipini*-population (with spines) in the latest Hybonotum and Darwini Zone in the Mediterranean Province and in the Submediterranean Mucronatum Zone are smooth. In the Semiforme and Fallauxi / Vimineus and Ciliata zones all *Physodoceras* populations are smooth, without spines and would belong to *P. neoburgense*.

The currently incipient record of only macroconch

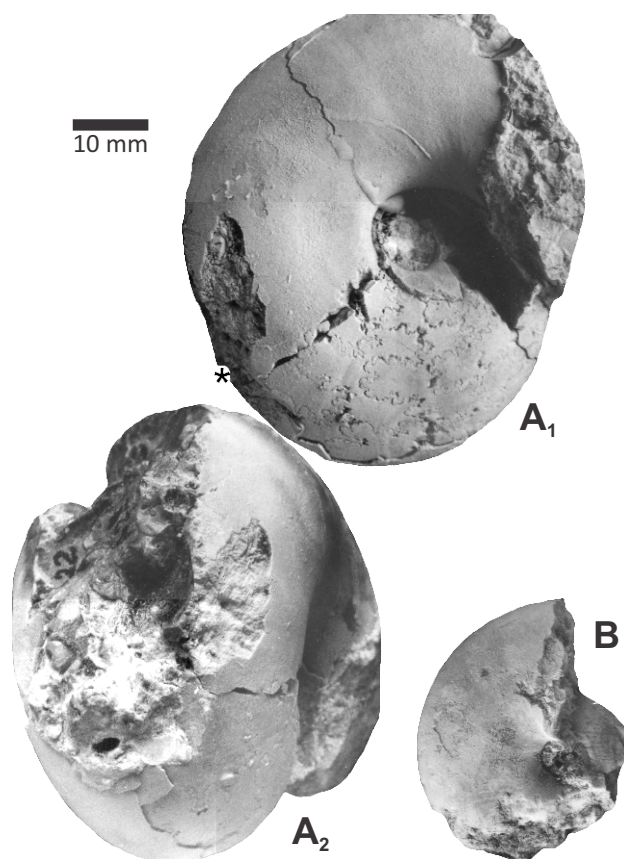


Figure 11. Specimens of *Physodoceras* from the Coquina Member in Kutek et al. (1986), Rogoznik, Poland, Lower (to lower Middle in tripartite subdivision) Tithonian. **A:** *Physodoceras* cf. *neoburgense* (Oppel, 1863), adult macroconch (MWG-UW-A/19/037-1) from level 22, Hybonotum Zone. **B:** *Physodoceras neoburgense*, macroconch phragmocone (MWG-UW-A/19/037-2) from level 19, upper Darwini-lower Semiforme zones. Photographs courtesy of A. Wierzbowski. Specimens housed at the Museum of the Geological Faculty, University of Warsaw. - All natural size (x1). Asterisk at last septum.

Physodoceras in the Picunleufuense Zone, besides the lack of any record of similar forms in the neighbourhood of the Neuquén Basin, prevents a closer identification of our specimens.

Distribution. This is the first record of this species from the Picunleufuense Zone. However, *P. neoburgense* is well represented through the Zitteli [incl. Mendozanus] Zone of Arroyo Cieneguita (Steuer 1897: pl. 6: 5; refigured in Parent et al. 2011b: fig. 38A) and Cerro Granito (unpublished).

CONCLUSIONS

The earliest ammonite fauna recorded from the Andean Tithonian of the Picún Leufú Subbasin is composed by the species of the Picunleufuense Zone: *Indansites picunleufuense*, *Choicensisphinctes platyconus*, *Catutosphinctes guenenakenensis*, *Physodoceras* cf. *neoburgense*, and *Cieneguiticeras perlaevis*. This lower number of species makes of this fauna a biome with low diversity.

In *I. picunleufuense*, the dominant element in this fauna,

there are consistent changes in the successive assemblages, mainly expressed as changes in the rib-density of the subadult-adult macroconch phragmocone. These changes, expressed as the domination of particular morphotypes in the succession, represent a slow phyletic evolution of the lineage, described informally as the transients alpha, beta and gamma.

We took these transients to label three successive ammonite biohorizons characterized by association of different morphotypes of the occurring species: *picunleufuense* alpha Hz., *picunleufuense* beta Hz., and *picunleufuense* gamma Hz. (new). Ammonite resampling in the base of the Portada Covunco Mb (lower Vaca Muerta Fm) in different localities of the Picún Leufú Subbasin shows consistently the succession of these biohorizons.

The very fine, biohorizon-based subdivision of the lower Picunleufuense Zone allows the highest resolution time-correlation possible within the Neuquén Basin, where the biohorizons are broadly recognized. However, a time-correlation with the Primary Standard Scale of the Tethys is still only approximated. Numerical ages (geochronometry) obtained from isotopic measurements help in nothing to time-correlation because of their instability and lack of precision (i.e., incoherence between different measurements).

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