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Middle Jurassic ammonites of the Los Molles, Lajas and Lotena Formations in Vega de la Veranada, Neuquén Basin, Argentina

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Abstract
In Vega de la Veranada (Neuquén Basin, Argentina) there is a good exposure of the Middle to Upper Jurassic sequence of Los Molles, Lajas, Lotena, La Manga, and Auquilco formations. The Bajocian, Bathonian and Callovian ammonites are scarce but a small representative collection obtained from a bed-by-bed sampling is described herein. The following species were recognized: *Megasphaeroceras*? sp. (Late Bajocian); *Caumontisphinctes* cf. *bifurcus* and *Lobosphinctes intersertus* (late Bajocian-earliest Bathonian); *Kheraiceras* sp. A, *Lilloettia steinmanni* and *Alcidellus tenuistriatus* (Late Bathonian); *Kheraiceras bullatum*, *Eurycephalites gottschei* and *Choffatia* cf. *subbakeriae* (Early Callovian); *Rehmannia patagoniensis* transient alpha (Late Callovian). Our chronostratigraphical results based on the biostratigraphy of the ammonite sequence, are time-correlated with a compilation of partial results formerly published.

Keywords
Late Bajocian-Late Oxfordian, Ammonite sequence, Vega de la Veranada, Neuquén Basin, Argentina.

1. INTRODUCTION

The outcrops of marine rocks of the Los Molles, Lajas, Lotena, La Manga and Auquilco formations in Vega de la Veranada (Fig. 1) range from, at least, the Upper Bajocian up to the Upper Oxfordian or Lower Kimmeridgian. Early information about the Jurassic of the study area was provided by Groeber (1929, 1946, 1953), and the complete description of the regional geology was given by Holmberg (1976). The succession of Vega de la Veranada was described, totally or in part by Groeber (1953), Stipanicic (1966), Stipanicic *et al.* (1976), Riccardi & Westermann (1991a), Parent (2006), and Parent & Garrido (2015). After the introduction of the genus *Araucanites* Westermann & Riccardi, 1976, the ammonite succession was studied by Parent (2006), and the stratigraphy and ammonite fauna of the La Manga Fm was described by Parent & Garrido (2015).

In this paper ammonites of the Los Molles, Lajas and Lotena formations of Vega de la Veranada are described for the first time, from a collection of Upper Bajocian to Upper (- Middle?) Callovian ammonites from the section shown in Fig. 2. The detailed stratigraphy of the study area is to be published elsewhere.

The ammonites were mostly collected by one of the authors (ACG) during a regional geological survey of the Los Molles, Lajas, Lotena, La Manga, and Auquilco formations. The detailed field-work yielded ammonites from levels never before collected in the area. Later all the authors visited the locality looking for additional material and information, including some of the samples used for the study of Alberti *et al.* (2020), as well as new ammonites from the La Manga Fm (to be published elsewhere). Some of the ammonites described below have been cited by Parent *et al.* (2020: 32) and Parent (2022).

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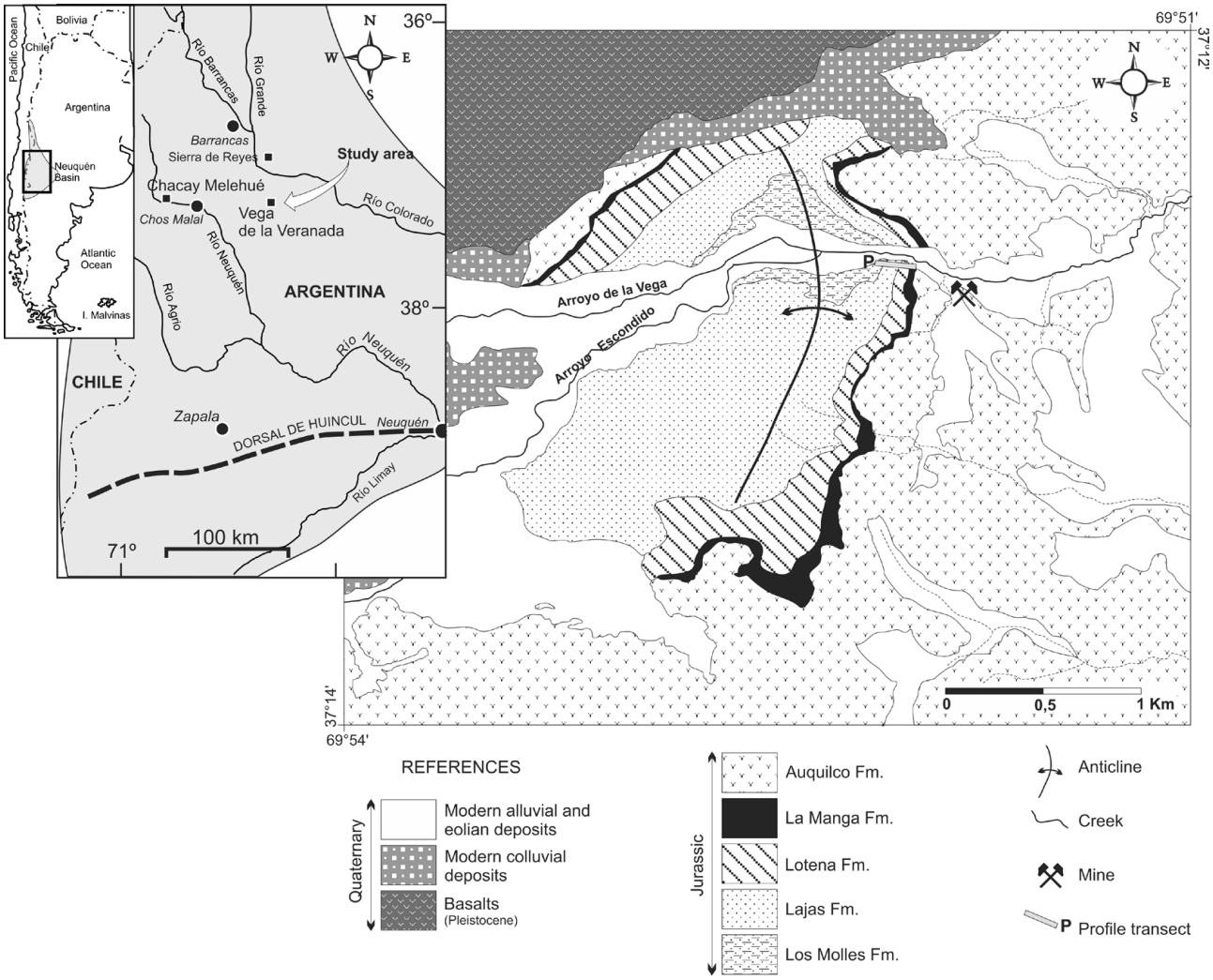

Fig. 1: Geologic map of the study area in Vega de la Veranada (Neuquén Basin, West-central Argentina, insets), with indication of the position of the profile transect studied shown in Figure 2.

2. SYSTEMATIC PALAEONTOLOGY

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 shell): [M], microconch (male shell): [m]. Measurements: diameter (D), diameter at the last adult septum (D_{ls}) and diameter at adult peristome (D_p), given in millimeters [mm]; umbilical width (U), whorl width (W), whorl height (H_1), and whorl ventral (or apertural) height (H_2), given as dimensionless proportions of D; length of bodychamber (L_{BC}) in degrees [°]. Number of primary (P) and ventral (V) ribs per half whorl. Levels of occurrence of the specimens denoted by the level number of the succession (Fig. 2) prefixed with VV for Vega de la Veranada.

Order Ammonitida Haeckel, 1866
Suborder Ammonitina Fischer, 1882
Superfamily Haploceratoidea Zittel, 1884
Family Oppeliidae Douvillé, 1890
Subfamily Oppeliinae Douvillé, 1890
Genus *Alcidellus* Westermann, 1958

Type species: *Ammonites tenuistriatus* De Grossouvre, 1888

Remarks: For concept of the genus see Parent *et al.* (2020).

***Alcidellus tenuistriatus* (Grossouvre, 1888)**
Fig. 3A-B

Material: Two well preserved, most likely adult, macroconch phragmocones (MOZ-PI-12217/1-2) from level VV-Lj-12.

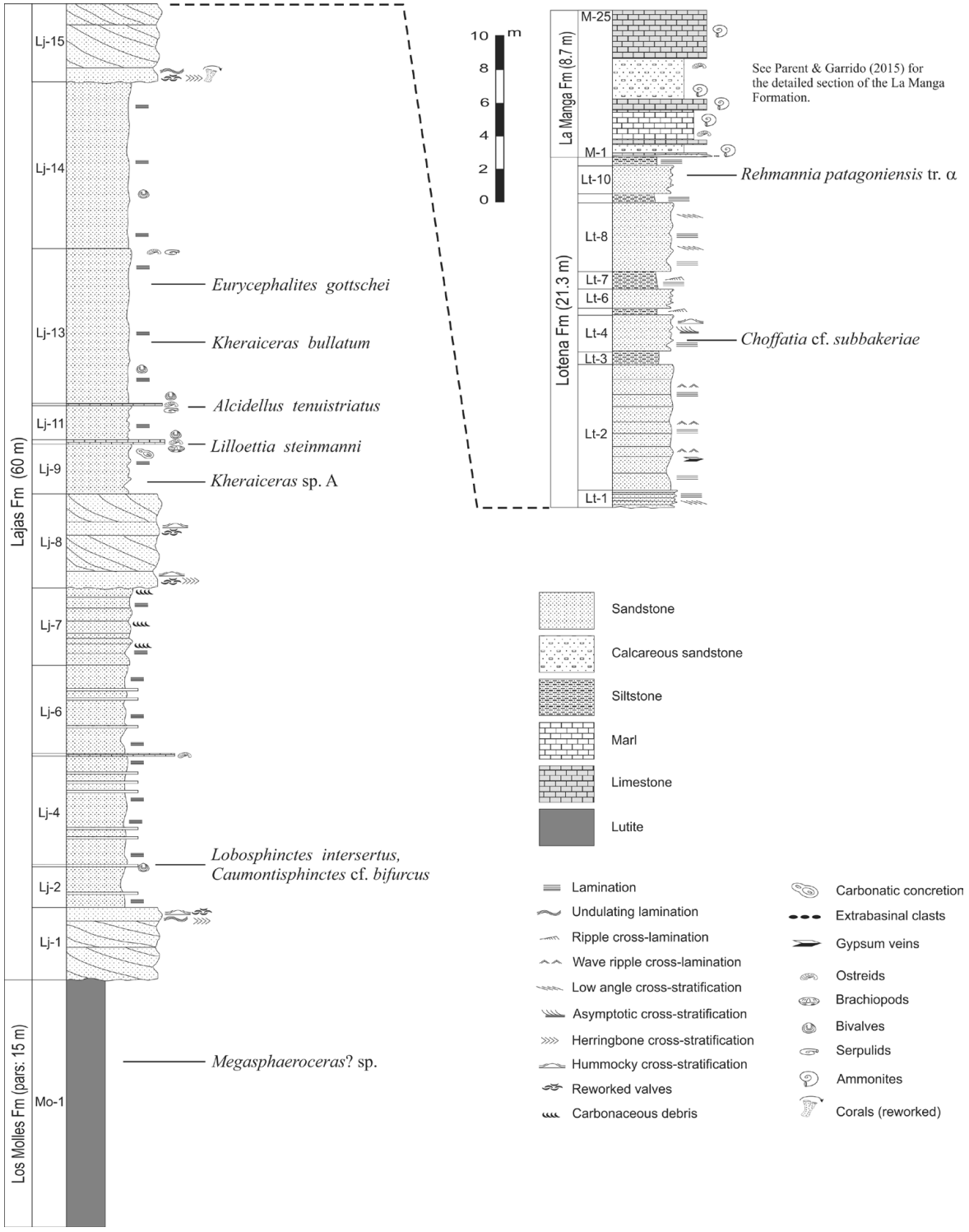

Fig. 2: Log of studied section at Vega de la Veranada with indication of the stratigraphic structures and sedimentological features, and the ammonite occurrences. Level numbers preceeded by the key of the lithostratigraphic formation (Mo: Los Molles Fm, Lj: Lajas Fm, Lt: Lotena Fm, M: La Manga Fm. The La Manga Fm is not included in the present study, it is shown for reference only (see description in Parent & Garrido, 2015).

Description: Compressed and involute (smaller specimen: maximum *D* = 90 mm: *W/D* = 0.22, *U/D* = 0.07), oxyconic with subtriangular whorl section, much higher than wide, gently convex flanks showing a weak mid-ventral ridge; venter weakly tricarinate passing to fastigate towards the bodychamber. Ribbing composed of well spaced, rursiradiate, wide and rounded lunuloid ribs in the upper half of the flank, fading-off in the uppermost part of the flank. Septal suture line poorly preserved, little frilled, with the typical structure of the subfamily.

Discussion: The combination of fastigate to blunt tricarinate venter with little frilled suture line, as in the present specimens, differentiates *Alcidellus* from *Oxycerites* Rollier, 1909 (Westermann & Callomon, 1988). The most similar species is the Upper Bathonian *A. tenuistriatus* as figured by Grossouvre (1888: pl. 4: 7, lectotype) and Westermann (1958).

Alcidellus n. sp. aff. *tenuistriatus* (in Parent *et al.*, 2020), from the upper Gerthi Subzone (Steinmanni Zone) of Chacay Melehué, is smaller in adult size, the lunuloid ribs (phragmocone) are more widely separated, and shows gentle ribbing in the lower half of the flanks. The specimens from the Gerthi Subzone of Chacay Melehué, described as *A. tenuistriatus* in Parent (1998: 76, fig. 5A-B), belong to *A*. n. sp. aff. *tenuistriatus*.

Alcidellus obsoletoides (Riccardi *et al.*, 1989) is smaller, more involute, and bears a well marked acute keel. The holotype of this species comes from the Bodenbenderi Zone of Caracoles, but in Mexico it seems to occur in the Steinmanni Zone. *Paroxycerites exoticus* (Steinmann, 1881), Steinmanni Zone, is somewhat similar in the ribbing of the adult phragmocone and beginning of the bodychamber, but is more compressed with an acute ventral keel (Riccardi *et al.,* 1989: pl. 4: 9-10), and the lunuloid ribs extend through the complete upper half of the flanks from a blunt mid-flank spiral ridge.

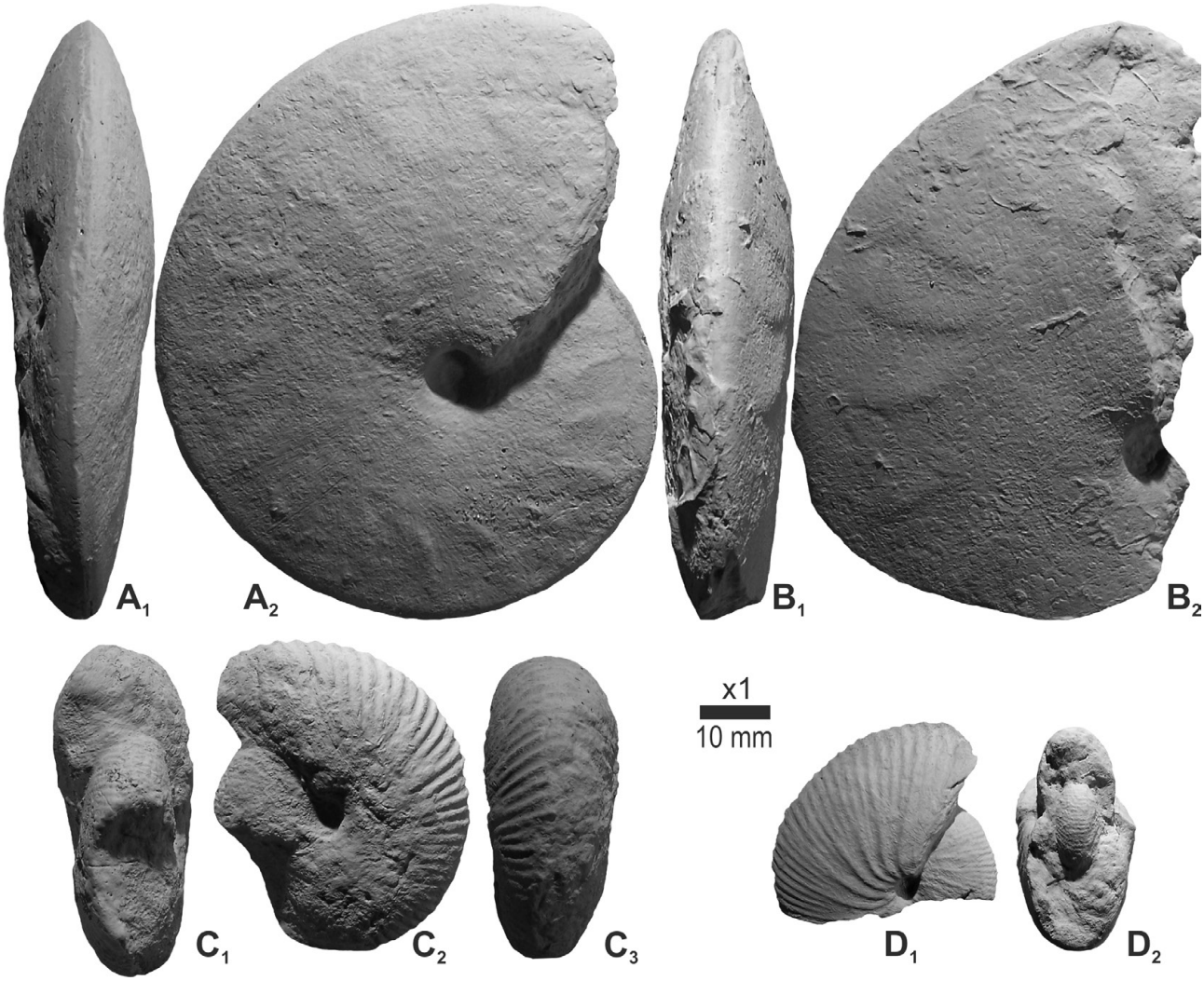

Fig. 3: A-B: *Alcidellus tenuistriatus* De Grossouvre, level VV-Lj-12, Steinmanni Zone (Upper Bathonian). A: macroconch phragmocone (MOZ-PI-12217/2). B: macroconch phragmocone (MOZ-PI-12217/1). C-D: *Lilloettia steinmanni* Spath, level VV-Lj-10, Steinmanni Subzone, Steinmanni Zone (Upper Bathonian). C: adult? phragmocone (MOZ-PI-12216/1). D: phragmocone (MOZ-PI-12216/2). All natural size (x1).

Age and distribution: The present specimens come from the level VV-Lj-12 (Lajas Fm), Steinmanni Zone, as they occur just above occurrences of *Lilloettia steinmanni* and underlying levels attributed to the Gottschei Zone (see below). *A. tenuistriatus* occurs in the Retrocostatum Zone in Europe (Westermann, 1958; Westermann & Callomon, 1988), the level VV-Lj-12 would be of this age, what agrees with the current time-correlation of the Steinmanni Zone (Riccardi *et al.*, 1989, updated in Parent, 2022).

Superfamily Stephanoceratoidea Neumayr, 1875
Family Sphaeroceratidae Buckman, 1920
Subfamily Eurycephalitinae Thierry, 1978
Genus *Lilloettia* Crickmay, 1930
Type species: *Lilloettia lilloetensis* Crickmay, 1930; by original designation

***Lilloettia steinmanni* (Spath, 1928)**
Fig. 3C-D

Material: Two phragmocones (MOZ-PI-11216/1-2) from level VV-Lj-10.
Description and discussion: Our specimens are involute with compressed subtriangular whorl section; the ribbing is typical for the species (cf. Riccardi & Westermann, 1991a). The early representatives of the species (Steinmanni Subzone) have the inner whorls more involute and compressed than the later forms of the Gerthi Subzone (Parent *et al.*, 2020) which are named *Lilloettia australis* Riccardi & Westermann, 1991a. The present specimens, very involute with compressed inner whorls, compare well with the early transient of the Steinmanni Subzone, suggesting they come from a level of this subzone. Additionally, a larger macroconch phragmocone, loose from the same level, perfectly matches the lectotype of *L. steinmanni* (Steinmann, 1881: pl. 11: 4) and the specimen from Lonquimay figured by Riccardi & Westermann (1991a: pl. 9: 4).

Genus *Eurycephalites* Spath, 1928
Type species: *Macrocephalites vergarensis* Burckhardt, 1903; by original designation (= *Macrocephalites gottschei* Tornquist, 1898, subj.: Parent, 1997).

***Eurycephalites gottschei* (Tornquist, 1898)**

Remarks: A single specimen, moderately involute and moderately densely ribbed, possibly a large microconch, collected from the level VV-Lj-13. This ammonite is provisionally assigned considering that the microconch of *Eurycephalites rotundus* (Tornquist, 1898) is smaller, more involute, and has tri- or quadrifurcate primaries (Parent, 1998: fig. 29K).

Genus *Megasphaeroceras* Imlay, 1961
Type species: *Megasphaeroceras rotundum* Imlay, 1961; by original designation.

***Megasphaeroceras*? sp.**

Remarks: One crushed specimen observed in the field (level VV-Mo-1): small umbilicus and fine, slightly flexuous ribs. *Megasphaeroceras* ranges from the "Humphriesianum" Zone up to the Magnum Zone.

Superfamily Perisphinctoidea Steinmann, 1890
Family Perisphinctidae Steinmann, 1890
Subfamily Leptosphinctinae Arkell, 1950

Genus *Lobosphinctes* Buckman, 1923
Type species: *Lobosphinctes intersertus* Buckman, 1923; by original designation.

Remarks: Macroconchiate *Lobosphinctes* can be differentiated from *Procerites* Siemiradzki, 1898 mainly by being more evolute, and by the occurrence of a mid-ventral smooth band in some parts of the ontogeny which is absent in *Procerites* (Arkell *et al.*, 1957; Riccardi & Westermann, 1999; Énay & Howarth, 2019). The microconchs (males) of the species of the genus are usually assigned to the genus *Planisphinctes* Buckman, 1922.

***Lobosphinctes intersertus* Buckman, 1923**
Fig. 4A

Material: One incomplete specimen (MOZ-PI-11214/1) from level VV-Lj-3.
Description: Maximum diameter preserved 105 mm, compressed (W/D = 0.24) and evolute (U/D = 0.47), subrectangular, higher than wide whorl section (W/H_1 = 0.83), with rounded umbilical shoulder. In the inner whorls the whorl section is more depressed. Ribbing increasing in density from inner whorls: P = 16 at D = 50 mm passing to P = 24 at D = 105 mm. Primary ribs slightly prosocline or subradial, most of them bifurcating around the mid-flank into narrowly splayed secondaries; ventral ribbing dense and evenly spaced, interrupted at D = 15-35 mm and in the last whorl preserved by a mid-ventral smooth band. The septal suture line is very poorly preserved.
Discussion: The shell shape and style of ribbing allow to assign the specimen to *Lobosphinctes*. Among the species of the genus, *L. intersertus*, as illustrated by the holotype (Buckman, 1923: pl. 547), matches our specimen. Another specimen of the species, coming from the Upper Bajocian of Chacay Melehué, was figured by Riccardi *et al.* (1989: pl. 1: 6; refigured in Westermann, 1992: pl. 61: 1).
Age and distribution: The present specimen comes from the level VV-Lj-3, associated with *Caumontisphinctes* cf. *bifurcus* Buckman, 1920. The stratigrahic position is considered Intersertus Zone, Upper Bajocian, time-correlated with the Parkinsoni Zone (see Riccardi *et al.*, 1989; Westermann, 1992; Parent, 2022).

Records of *Lobosphinctes* are also known from the Upper Bajocian of Quebrada San Pedro, Caracoles, and Aguada Colorada, Chile (Fernández-López *et al.*, 1994 and Fernández-López & Chong, 2014), and Río Pumani, Perú (Fernández-López *et al.*, 2014). These specimens from Peru and Chile could likely be Parkinsoni Zone in age, but they are all fragmentary, clearly attributable to *Lobosphinctes* but not confidently to *L. intersertus* (S. Fernández-López, pers. comm. 27/05/2022).

Genus *Caumontisphinctes* Buckman, 1920
Type species: *Caumontisphinctes polygyralis* Buckman, 1920; by original designation.

***Caumontisphinctes* cf. *bifurcus* Buckman, 1920**
Fig. 4B-C

Description and discussion: Two fragmentary specimens (MOZ-PI-11214/2-3; level VV-Lj-3), wholly septated, evolute with subrectangular whorls. The ribbing consists of strong, acute primary ribs, slightly prosocline, bifurcating on the upper half of flank from a small tubercle in narrowly splayed secondaries, projected forward and interrupted on the venter besides a wide smooth band. Some isolated primaries remain undivided. The diameter of the specimens can be roughly estimated as 70 and 90 mm.

The conspicuous style of ribbing and the morphology and coiling of the whorls of the present specimens point to *Caumontisphinctes*, and almost indistinguishable from *C. bifurcus* Buckman as illustrated by Pavia (1973: pl. 21: 4) from the Upper Bajocian Subfurcatum Zone (= Niortense Zone in the current usage) of Les Dourbes. The holotype of *C. bifurcus* (Énay & Howarth, 2019: fig. 4.1b-c) is virtually identical at comparable diameter. In Europe (Mediterranean and Sub-Mediterranean provinces), *Caumontisphinctes* occurs mainly at the base of the Upper Bajocian but our specimens seem to be somewhat younger.

The specimens show resemblance with *Parastrenoceras* Ochoterena, 1963 (type species *Parastrenoceras mixteca* Ochoterena, 1963) from the Upper Bajocian of Mexico.

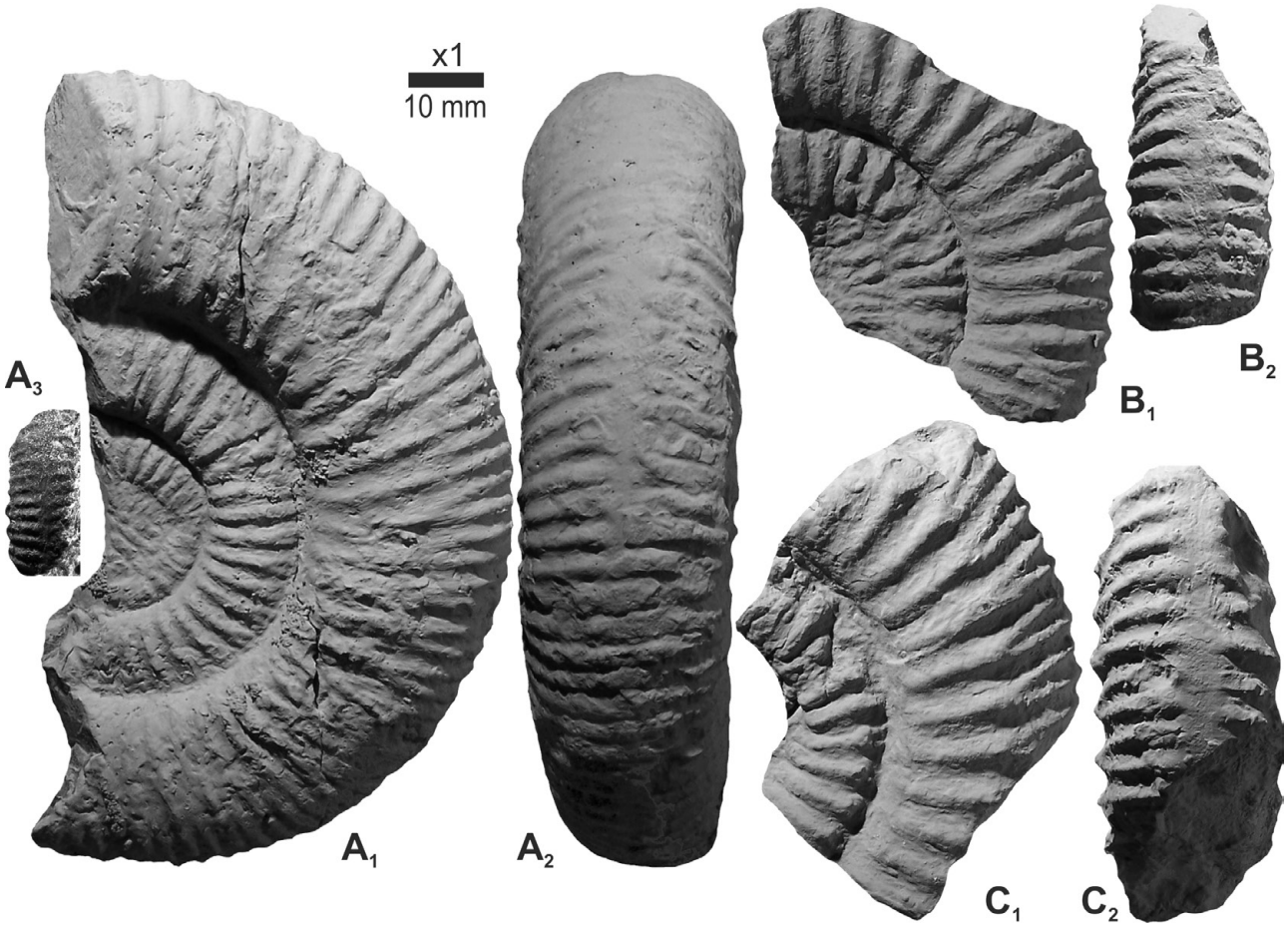

Fig. 4: A: *Lobosphinctes intersertus* Buckman, adult macroconch phragmocone (MOZ-PI-11214/1), level VV-Lj-3, Intersertus Zone (Upper Bajocian). A_3: ventral view of inner whorl. B-C: *Caumontisphinctes* cf. *bifurcus* Buckman, level VV-Lj-3, Intersertus Zone (Upper Bajocian). C: phragmocone with part of the bodychamber (MOZ-PI-11214/3). D: phragmocone with part of the bodychamber (MOZ-PI-11214/2). All natural size (x1).

However, the fibulate ribs and the elaborated ventral sculpture of *Parastrenoceras* make a very different ammonite.

Our fragmentary specimens do not allow a definite classification, but strongly suggest a late Bajocian age, in accord with the age suggested by *Lobosphinctes intersertus* with which they were collected from the level VV-Lj-3.

Hillebrandt (1993: 63) recorded *Caumontisphinctes*? aff. *rotula* (Parona, 1896) in northern Chile, from approximately the same stratigraphic position of the record of *Strenoceras* cf. *latisulcatum* (Quenstedt, 1886) by Westermann & Riccardi (1980) from Caracoles. Both species are Late Bajocian in Europe.

Subfamily Pseudoperisphinctinae Schindewolf, 1925

Genus *Choffatia* Siemiradzki, 1898

Type species: *Perisphinctes cobra* Waagen, 1875; by subsequent designation of Buckman (1920).

***Choffatia* cf. *subbakeriae* (d'Orbigny, 1850)**

Remarks: One poorly preserved specimen (MOZ-PI-11232; level VV-Lt-4); a compressed and finely ribbed perisphinctid comparable with the lectotype of *C. subbakeriae* (designated and refigured by Fischer, 1994: 136-137, pl. 55: 1, Upper? Callovian of Niort, France). This ammonite is provisionally assigned to the Lower Callovian, could be Gottschei or Bodenbenderi Zone.

Family Reineckeiidae Hyatt, 1900

Subfamily Reineckeiinae Hyatt, 1900

Genus *Rehmannia* Schirardin, 1956

Type species: *Ammonites rehmanni* Oppel, 1857

***Rehmannia patagoniensis* (Weaver, 1931) transient alpha**

Remarks: Lectotype designated and refigured by Riccardi & Westermann, 1991b: pl. 12: 1).

This species is widely distributed through the basin and has been profusely described and figured (see Riccardi & Westermann, 1991b; Parent, 2006; Garrido & Parent, 2013). Our colletion includes large macroconchs (D_p = 250-400 mm) of the transient alpha of the species, all from level VV-Lt-10 (see Garrido & Parent, 2013 for definition and characterization of the transients of this species); these specimens are identical to those of the *patagoniensis* Hz. in Picún Leufú (e.g. Riccardi & Westermann, 1991b: pl. 11: 1; Garrido & Parent, 2013: figs 8-10). The transient alpha (the earliest one) is consistently confined to the base of the Patagoniensis Zone, in the *patagoniensis* Hz.

Family Tulitidae Buckman, 1921

Remarks: Énay & Howarth (2019) described the genera of the family with no subdivision at the subfamily level. However, the family includes two groups which clearly seem to correspond to two independent lineages with significant morpho-ornamental differences, different mode of sexual dimorphism, and different biogeographic distributions (see Westermann & Callomon, 1988; Callomon *et al.*, 1992): the subfamily Tulitinae and the subfamily Bullatimorphitinae.

Subfamily Bullatimorphitinae Callomon, Dietl & Niederhöfer, 1992

Remarks: Within this subfamily we consider two genera: *Bullatimorphites* Buckman, 1921 (Bathonian) and *Kheraiceras* Spath, 1924 (Upper Bathonian-Lower Callovian), whose type species have macroconchs as type specimens. As expected, intermediate transitional forms, sometimes hard to classify, are known in the uppermost Bathonian-lowermost Callovian (see Mangold, 1993; Martin & Mangold, 2015; Galacz, 2021: fig. 2). The corresponding microconchs have been classified in different "microconch genera or subgenera" (see Enay, 1959; Sandoval, 1983; Mangold, 1993). *Bullatimorphites* is moderately involute, gradually uncoiling to moderately elliptical bodychamber, whereas *Kheraiceras* has highly involute and depressed septate whorls and a contracted, hook-shaped bodychamber (Pandey & Westermann, 1988; Enay & Howarth, 2019). On the other hand *Bullatimorphites* retains the ribbing in the bodychamber up to the peristome, whereas in *Kheraiceras* it tends to become smooth or very blunt (e.g. Courville, 1988; Énay & Howarth, 2019).

Genus *Kheraiceras* Spath, 1924

Type species: *Sphaeroceras cosmopolita* Parona & Bonarelli, 1897; by original designation.

***Kheraiceras* sp. A**

Fig. 5

Material: A single specimen (MOZ-PI-11215) from level VV-Lj-9.

Description and discussion: The specimen is a phragmocone, possibly adult. Spheroconic, involute with depressed suboval whorl section; the primary ribs born in the umbilical shoulder, tri- or bifurcating with occurrence of some intercalatories, all crossing the venter unchanged. It seems to be a transitional form between *Bullatimorphites* and *Kheraiceras*, but closer to the latter because of the coarse ribbing and the primaries born in the umbilical shoulder, higher than in *Bullatimorphites* where they are usually born in the umbilical seam. It is closely comparable with the Late Bathonian (Bremeri Zone) specimen from Verzé N du Mâconnais figured by Martin

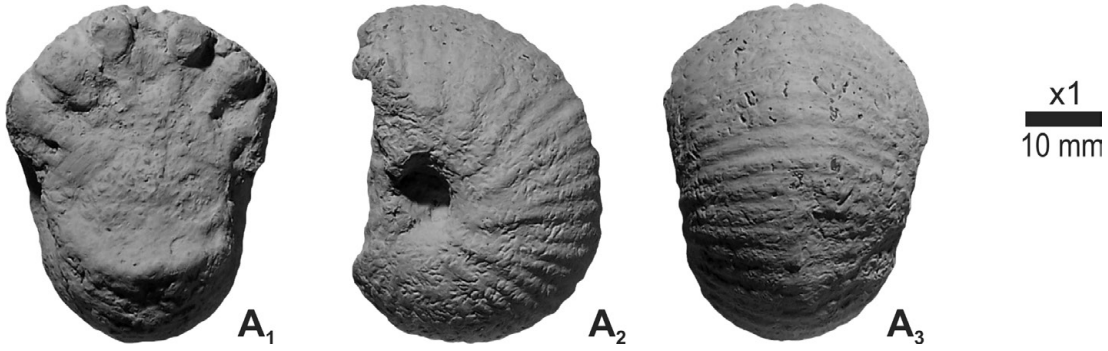

Fig. 5: *Kheraiceras* sp. A., phragmocone (MOZ-PI-11215), level VV-Lj-9, Steinmanni? Zone (Upper Bathonian). Natural size (x1).

& Mangold (2015: pl. 14: 7-8) as *Bullatimorphites* cf. *hannoveranus* (Roemer, 1911), whose adult stage seems to have been illustrated by Mangold (1971: figs 96-97) from Boyeux-Saint-Jerome (Ain), France. Also similar is the Late Bathonian specimen from Kandern, southwestern Germany figured by Hahn (1971: pl. 8: 3) as *Bullatimorphites bullatus* (d'Orbigny, 1846). According to Courville *et al.* (1999) these small forms, transitional from *Bullatimorphites* to *Kheraiceras*, are characteristic of the Late Bathonian Discus Zone.

Kheraiceras bullatum (d'Orbigny, 1846)

Fig. 6A-D

Material: Two moderately well preserved adult macroconchs (MOZ-PI-11218/1-2), one complete adult microconch (MOZ-PI-11823/1) and one microconch with incomplete bodychamber (MOZ-PI-11823/2); all from level VV-Lj-13.

Description: Macroconch. Involute, spheroconic phragmocone with strongly contracted and uncoiled bodychamber; adult size at peristome D_p = 68-74 mm. Last whorl of the phragmocone very involute with wide depressed, subelliptical whorl section. The bodychamber begins at D_{ls} = 52-55 mm, contracting and uncoiling, forming a straight segment (shaft) and then bending adorally up to the peristome. The ribbing is poorly preserved; it consists of wide, blunt slightly proverse to retroverse primaries in the flank, crossing the venter unchanged and fading off towards the peristome. The bodychamber, possibly complete, is 180-220° long.

Microconch. Involute sub-spheroconic phragmocone with contracted bodychamber. The bodychamber replicates the uncoiling pattern of the macroconch, forming a shaft or straight segment and bending adorally up to the peristome. Adult size at peristome D_p = 42 mm, D_{ls} about 23 mm. Last whorl of the phragmocone and bodychamber densely ribbed by subradial primaries which bifurcate in the lower half of the flank; some trifurcate before the weak constrictions which are three to four in the last whorl; all ribs cross the venter evenly spaced. The peristome is preceeded by a wide constriction and bears a pair of wide lappets in ventro-lateral position, very incompletely preserved in the figured specimen. The bodychamber is 320° long.

Discussion: The present macroconchs are assigned to *Kheraiceras* by having a very involute phragmocone with a shafted and contracted bodychamber, and the ribbing becoming blunt or disappearing in the bodychamber. The present macroconchs are very similar to the lectotype of *K. bullatum* (see Fischer, 1994: pl. 56: 1); the microconch with the peristome preserved is identical to the lectotype of the corresponding microconch morphospecies *Ammonites microstoma* d'Orbigny, 1846 (see Fischer, 1994: pl. 56: 2). There is no doubt that, as pointed out by Westermann & Callomon (1988) and Courville (1988), these two species conform to a well established dimorphic pair.

Álvarez (1997: pl. 11: H) figured a large macroconch as *Bullatimorphites* (*K.*) cf. *bullatus* from the Steinmanni Zone of Paso del Espinacito (San Juan Province, Argentina) which differs from the present macroconchs by being larger and having a longer bodychamber with an acute shaft; the umbilicus is covered by matrix but seems to be somewhat wider.

The specimen from Caracoles figured by Gottsche (1878: pl. 8: 1), a large phragmocone with marks of the umbilical seam of the very evolute bodychamber, is similar to the present specimens but larger. This specimen seems to have been collected associated with a fragment of a reineckeiid assigned to *Neuqueniceras antipodum* (Gottsche, 1878) by Riccardi & Westermann (1991b), a species known to occur in the Bodenbenderi and Proximum zones.

The macroconch *Kheraiceras v-costatum* (Burckhardt, 1927) figured by Riccardi *et al.* (1989: pl. 8: 3-4) from the Bodenbenderi Zone (Lower Callovian) of Caracoles, differs from our specimens in being somewhat larger, the ventral ribbing of the phragmocone chevron-like, and wider and more widely separated in the bodychamber; on the other hand the bodychamber is somewhat longer.

Considering the close resemblance with *K. bullatum* it is very possible that *K. v-costatum* represents a local late transient of the species as suspected by Riccardi *et al.* (1989: 569). The chevron-like or a forward convexity in ventral ribbing is already seen in late Bathonian *Kheraiceras* and *Bullatimorphites* (e.g. Géczy & Galácz, 1998: pl. 3: 6b; Martin & Mangold, 2015: pl. 14: 10, 14-15, 18).

The dimorphic pair (two macro- and two microconchs) described by Sandoval *et al.* (1990: pl. 9: 1-4) as *Bullatimorphites* (*K.*) *bullatus*, from the upper Steinmanni Zone of the Coauilote-Tecocoyunca area, Mexico, closely

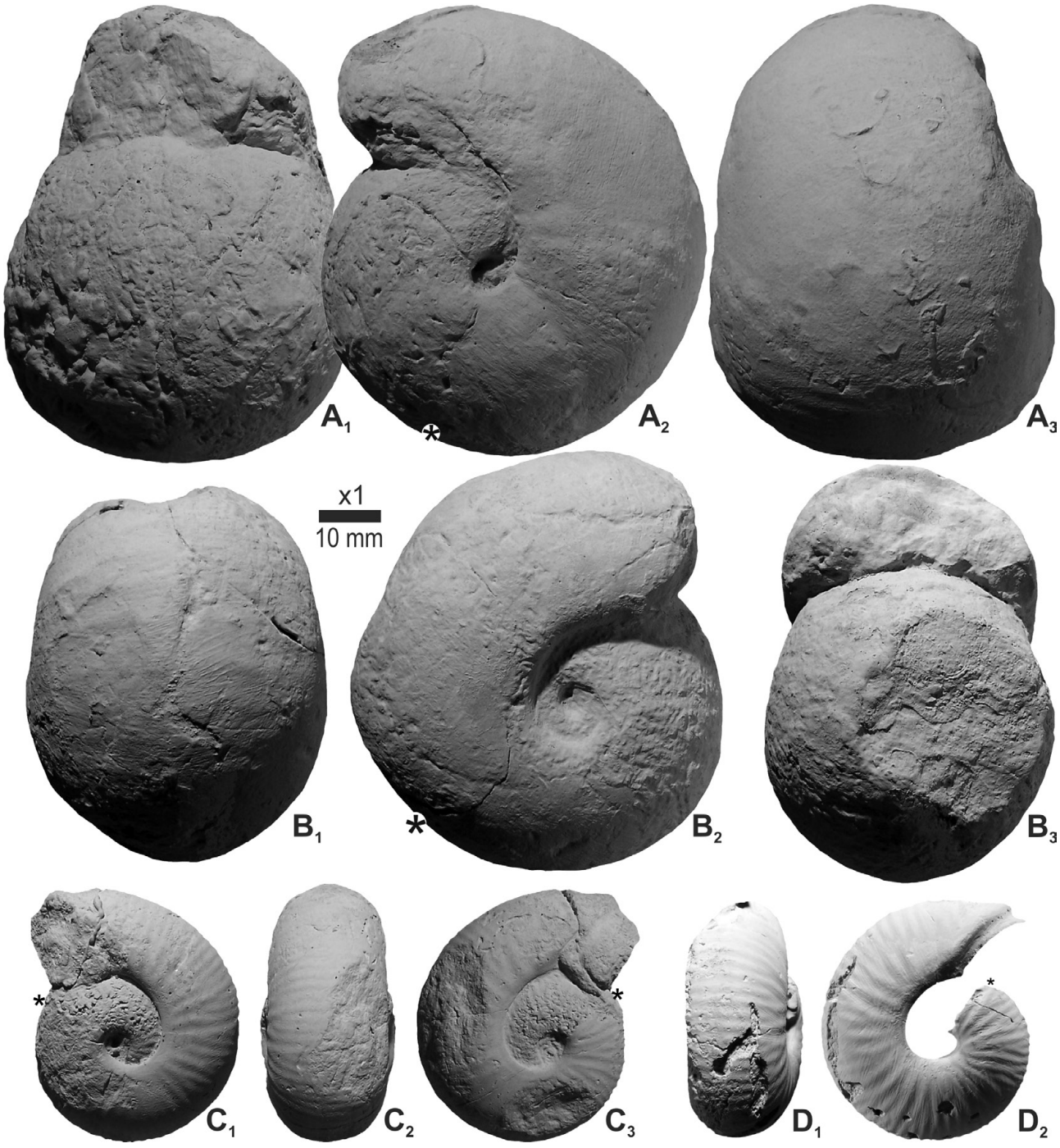

Fig. 6: A-C: *Kheraiceras bullatum* (d'Orbigny), level VV-Lj-13, Gottschei Zone (Lower Callovian). A: adult macroconch (MOZ-PI-11218/1). B: adult macroconch (MOZ-PI-11218/2). C: adult microconch (MOZ-PI-11823/1) with right lappet preserved (C_3). D: *Kheraiceras bullatum* (d'Orbigny), adult microconch bodychamber (MOZ-PI-03555/4), Chacay Melehué, Gottschei Zone. All natural size (x1). Asterisks at last septum.

resembles the present specimens, differing mainly in the larger size of the macroconchs and the slightly stronger ribbing.

The most significant resemblance we found among well dated Tethyan specimens, is with the dimorphic pair figured by Dietl *et al.* (2021: fig. 12.1-12.2, 12.4) from the *keppleri* Hz., basal Callovian of Albstadt-Pfeffingen, Germany. Our complete microconch in Fig. 6C is identical, and the macroconchs in Fig. 6A-B are almost indistinguishable but with shorter bodychambers (apparently complete). Our specimen in Fig. 6B clearly bears ventral ribbing in the bodychamber like the *K. bullatum* morph bullatum in Dietl *et al.* (2021: fig. 12.2), whereas our specimen in Fig. 6A is larger and smooth like the specimen labelled as *K. bullatum* morph hannoveranus in their fig. 12.1. These differences between the morphs are the diagnostics used by Westermann (1958) for distinguishing between *K. bullatum* and *K. hannoveranum*.

The dimorphic pair from the Bullatum Subzone, Macrocephalus (= Herveyi) Zone (Lower Callovian) of Pamproux (France) and Teruel (Spain), figured by Courville (1988: pl. 1: 1, 3) as *Bullatimorphites bullatus*, are so closely similar that they can be considered conspecific with our present specimens.

The close resemblance, even identity of our macro- and microconchs with these Tethyan specimens is very significant, suggesting a very similar or the same age.

Age and distribution: The specimens described (Fig. 6A-C) come from the level VV-Lj-13 (Lajas Fm). An identical, although incomplete microconch (Fig. 6D) was collected from the Gottschei Zone of Chacay Melehué. The stratigraphic range of *K. bullatum* [M&m] in the Mediterranean and Submediterranean Tethys is upper Discus to Bullatum zones (Westermann & Callomon, 1988; Courvillle, 1988; Branger, 2009; Dietl *et al.*, 2021). According to the close similarity with specimens from the earliest Callovian discussed above, this could likely be the age of the level VV-Lj-13, giving additional support to the earliest Callovian age attributed to the Gottschei (= Vergarensis) Zone (Riccardi *et al.*, 1989; Parent *et al.*, 2020; Parent, 2022).

Stipanicic (1966) cited *Kheraiceras* aff. *cosmopolita* (Parona & Bonarelli, 1897) in similar levels in the studied locality, associated with *Indocephalites* gr. *chrysoolithicus-kheraensis* what would likely be *Stehnocephalites gerthi* (Spath, 1928), thus likely from the Gerthi Subzone (Steinmanni Zone), slightly older than our material. Riccardi & Westermann (1991a: 13) cited from this same locality *Kheraiceras* cf. *bullatum* associated with *Eurycephalites extremus* (Tornquist, 1898) [M & m = *Xenocephalites stipanicici* Riccardi, Westermann & Elmi, 1989), *Eurycephalites involutus* (Riccardi & Westermann, 1991a), *Grossouvria* sp., and *Paroxycerites oxynotus* (Leanza, 1946). This assemblage indicates a higher stratigraphic position than the present specimens, most likely in some part of the interval Proximum-Chacaymelehuensis zones. Gerth (1925: 32) cited "*Sphaeroceras bullatum* d'Orbigny" associated with "*Macrocephalites vergarensis* Burckhardt" from the region between Paso de Vergara and Paso Villagra (southern Mendoza Province). This *M. vergarensis* should be a macroconchiate *Eurycephalites gottschei* (Tornquist, 1898) in modern taxonomy, a species which occurs mainly in the Gottschei Zone, thus close or the same age as the present specimens. Stehn (1923) cited the occurrence of "*Sphaeroceras bullatus*" in Lonquimay, Paso Vergara, Paposo (between Antofagasta and Taltal, northern Chile), and Caracoles, mostly associated with "*Macrocephalites vergarensis*", i.e. *E. gottschei* [M], Gottschei Zone as above.

In summary, *K. bullatum*, or close relatives, occur in the Andes (Neuquén and Tarapacá basins) with the following distribution:

(1) upper Sofanus Zone or lower Steinmanni Zone: *Kheraiceras* sp. A (Fig. 5),
(2) upper Steinmanni Zone: *K.* cf. *bullatum* and *K.* aff. *cosmopolita*,
(3) Gottschei Zone: *K. bullatum* (Fig. 6),
(4) Bodenbenderi-Chacaymelehuensis zones: *K.* cf. *bullatum* and *K. v-costatum*.

3. BIOSTRATIGRAPHY AND CHRONOSTRATIGRAPHY

The succession of faunal levels in the studied section is given in Fig. 2, and their estimated ages in Fig. 7. The ammonite fauna of the La Manga Fm was described by Parent & Garrido (2015). The complete succession was studied by Stipanicic (1966), and later by Parent (2006), including a single ammonite from the base of the Auquilco Fm described as *Orthosphinctes*? sp. A (this ammonite does not seem to belong to *Orthosphinctes* Schindewolf, 1925, but to a genus yet undescribed). From basal levels of the Auquilco Fm, a small collection of ammonites was recently discovered, currently under study.

According with the descriptions above (with references), the ammonites indicate that the studied succession of the Los Molles, Lajas, and Lotena formations was depostied during the interval late Early Bajocian-early Late Callovian, i.e. "Humphriesianum" to Patagoniensis zones in the study area (cf. Spalletti *et al.*, 2012).

(1) The occurrence of *Megasphaeroceras*? sp. (level VV-Mo-1) strongly suggests the upper part of the Los Molles Fm was deposited during the late Early to Late Bajocian.
(2) Few metres above, in the lower part of the Lajas Fm (level VV-Lj-3) occur *L. intersertus* and *C.* cf. *bifurcus*. *L. intersertus* strongly suggests the Intersertus Zone (see Parent, 2022); this species is well documented in Europe in the uppermost Bajocian Parkinsoni Zone, and possibly in the lower Zigzag Zone at the base of the Lower Bathonian.

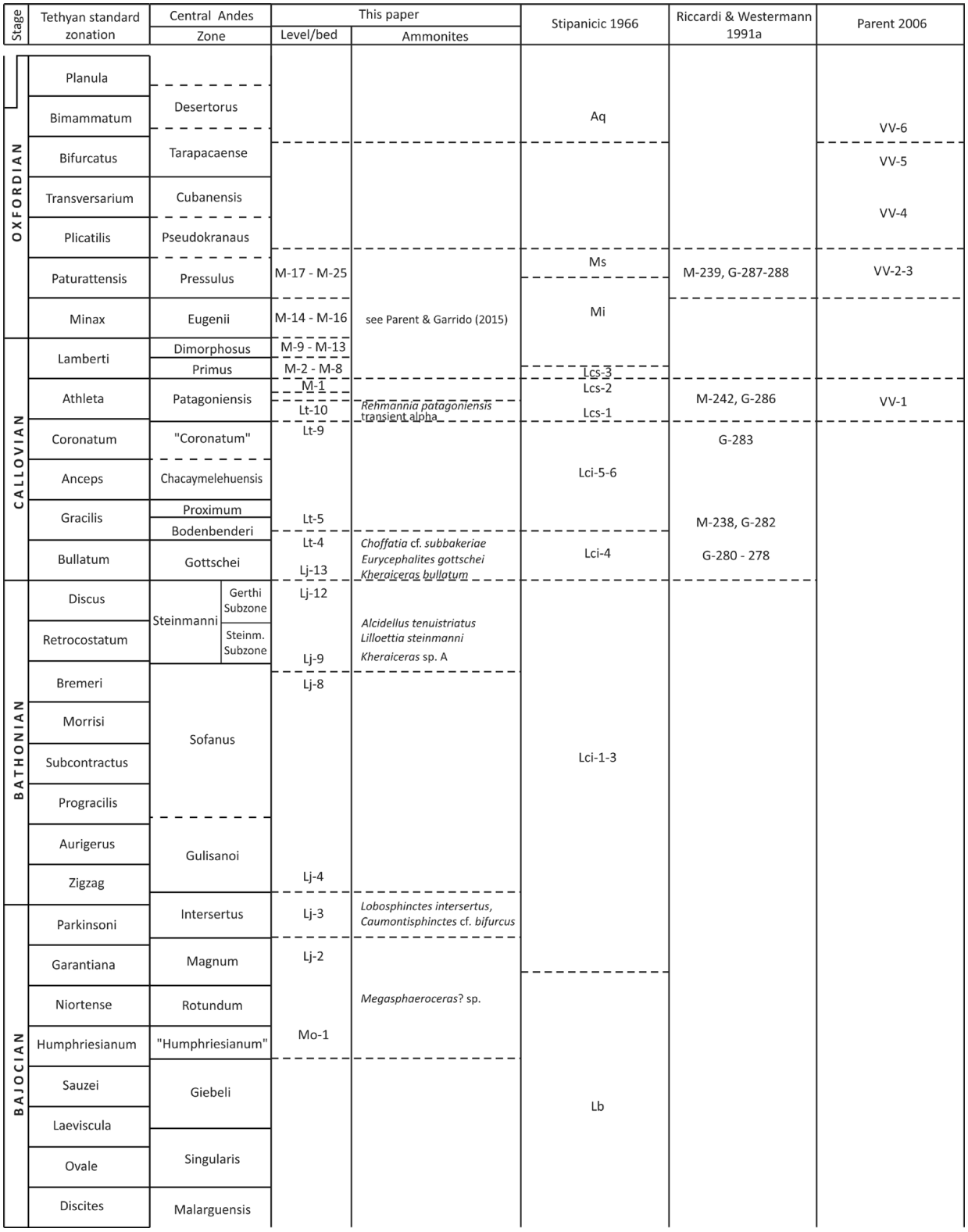

Fig. 7: Chronostratigraphic classification of the studied section based on the ammonites described, and time-correlation of the successions studied by Stipanici (1966), Riccardi & Westermann (1991a: 13) according to the ammonites cited in these papers and those described in Parent (2006). The fauna of the La Manga Fm was described in Parent & Garrido (2015). Andean ammonite zonation after Parent (2022) and the references therein.

(3) *Kheraiceras* sp. A (level VV-Lj-9) best compare with forms of Tethyan Late Bathonian, strongly suggesting the lower Steinmanni Subzone, Steinmanni Zone (Late Bathonian).
(4) *K. bullatum* and *E. gottschei* (above) occur in the thick sand bank level VV-Lj-13, Gottschei Zone. The former matches the earliest Callovian transient of the species known in France and Germany, providing additional support to the earliest Callovian age of the Gottschei Zone.
(5) The *C.* cf. *subbakeriae* from level VV-Lt-4 suggests the Lower Callovian, likely a level within the Gottschei-Bodenbenderi zones interval.
(6) *R. patagoniensis* transient alpha is an ammonite which is known only in the lower part of Patagoniensis Zone of the Upper Callovian, correlatable with the lower Athleta Zone.

In Fig. 7 the ammonite succession studied is compared with results of Stipanicic (1966), Riccardi & Westermann (1991a), and Parent (2006). The Andean chronostratigraphic zonation and time-correlation with the Primary Standard is based on the recent revision by Parent *et al.* (2020) and Parent (2022) and references therein.

4. CONCLUDING REMARKS

In Vega de la Veranada the black shales of the Los Molles Fm are partially exposed and poorly fossiliferous, only an impression of *Megasphaeroceras*? sp. (upper Middle to lower Upper Bajocian) was recorded.
The Lajas (60 m) and Lotena (21.3 m) formations consist of sandstone banks with few thin levels of calcareous sandstones. In the succesion occur scattered levels with scarce ammonites. In these levels occur also bivalves (mostly oysters), and rarely brachiopods, corals, and serpulids. The ammonites indicate an age-range Upper Bajocian-lowermost Upper Callovian. The ammonite succession is shown in Fig. 2 and its chronostratigraphic interpretation is in Fig. 7.
The position of the studied locality in the basin is proximal, so the lithology dominated by light coloured sandstones with cross-bedding banks. The ammonites are scarce and not well preserved, some could have arrived after drifting from somewhat deeper areas, closer to the talus or even the depocentre, towards Chacay Melehué.

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