ON DARWIN'S FOOTSTEPS ACROSS THE ANDES: TITHONIAN-NEOCOMIAN FOSSIL INVERTEBRATES FROM THE PIUQUENES PASS

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ABSTRACT

The aim of this work is to summarize the modern knowledge of the geology of the Piuquenes Pass, in the Main Andes of Argentina and Chile, and to describe a small fauna of Tithonian-Neocomian invertebrates mostly represented by ammonites. The present knowledge of the region is compared with Darwin's, as expressed in his famous book on the Geology of South America.

Keywords: *Main Andes, Mesozoic, Ammonites, Piuquenes Pass, Darwin.*

RESUMEN: *Tras las huellas de Darwin a través de los Andes: invertebrados fósiles del Tithoniano-Neocomiano del paso de Piuquenes.* El objetivo de este trabajo es presentar una breve revisión moderna de la geología del Paso de Piuquenes en los Andes Principales de Chile y Argentina y describir una pequeña fauna de invertebrados del Tithoniano-Neocomiano compuesta principalmente por amonites. Se compara también el conocimiento de esta región con la referida por Darwin en su famoso libro sobre la geología de América del Sur.

Palabras clave: *Andes Principales, Mesozoico, Amonites, Paso de Piuquenes, Darwin.*

INTRODUCTION

During his 5 years' voyage around the world on board the HMS Beagle, Darwin spent more than 3 years on shore. This was most probably due to his interest in exploring new regions, but also to avoid the strong sea-sickness that annoyed him when sailing. During the Beagle years and some time later Darwin was foremost a geologist, though we are used to think of him as a pure biologist. Thus, his enormous collection of fauna and flora came second to his interest as can be seen in the fact that he gave most of it to different specialists after his return to England.

In March-April 1835, Darwin undertook a long ride to examine the geology of the Andes. He started the journey in Valparaiso on the Pacific coast, crossed the Andes along the Piuquenes and Portillo passes, reached Mendoza city and went back to Chile by the Cumbre or Uspallata Pass (Fig. 1). This trip was probably one of the most valuable to him from a scientific point of view as can be seen in the long and detailed letters he sent both to Professor Henslow and to his sister Susan. The letter to Henslow begins thus: "*I have just returned from Mendoza, having crossed the Cordilleras by two passes. This trip has added much to my knowledge of the geology of the country. Some of the facts, of*

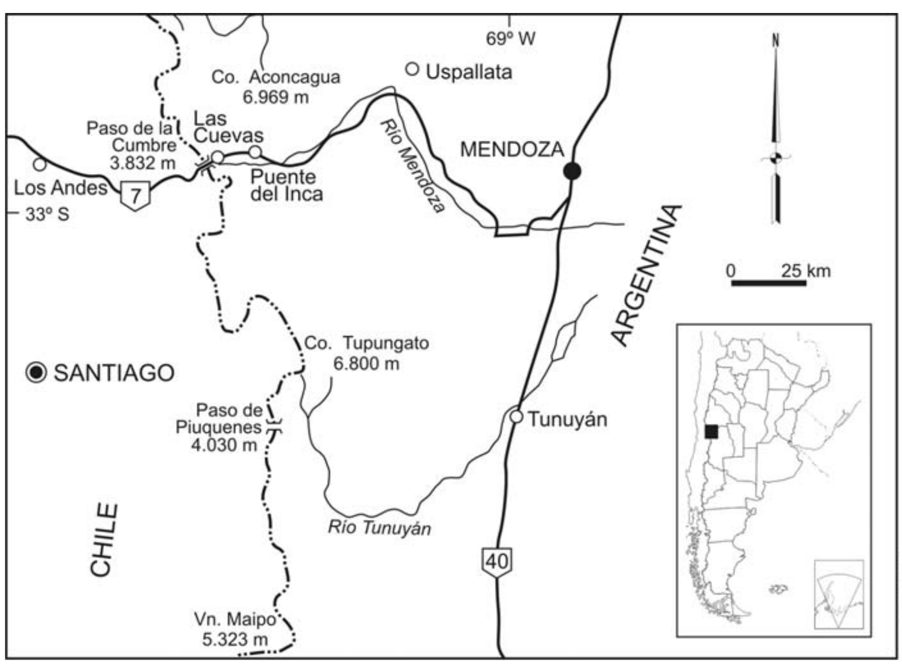


Figure 1: Location of the Piuquenes Pass in the Main Andes of Argentina and Chile.

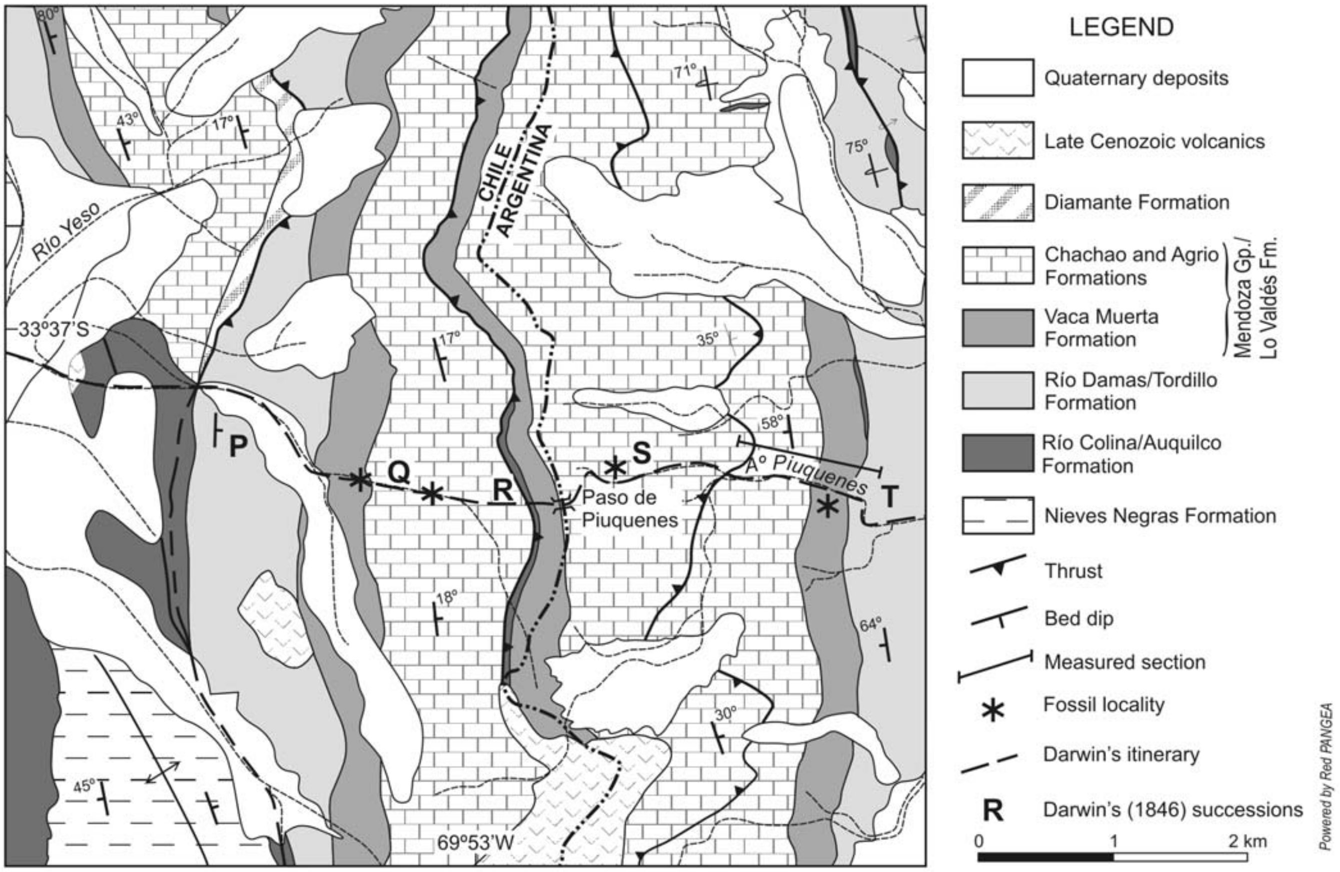


Figure 2: Geological map of the region of the Piuquenes Pass, Main Andes (from Pángaro *et al.* 1996).

the truth of which I in my own mind feel fully convinced, will appear to you quite absurd & incredible", followed by several paragraphs devoted to the structure of the cordillera (Burkhardt and Smith 1985).

One hundred and sixty years later, in the summer of 1995 one of us (BAU) followed the steps of Darwin along the Piuquenes Pass, checking the stratigraphy and collecting fossils. Thus, the objective of this work is to summarize the modern knowledge of the geology and palaeontology of the region of the Piuquenes Pass, in the Main Andes of Argentina and Chile, comparing these views with Darwin's (1846), as expressed in his famous book on the Geology of South America.

REGIONAL GEOLOGICAL SETTING

The Piuquenes (Darwin always spelled it as Peuquenes) Pass runs across the boundary between Argentina and Chile in the Main Central Andes (33°38'S, 69°52'W, Fig. 1). It reaches 4,030 m a.s.l., and though it is the international divide, the highest pass is Portillo, located some 24 km to the east, with 4,374 m a.s.l.

The geology of this part of the Main Andes was studied in detail by Polanski (1964) as part of the mapping program of the Geological Survey of Argentina. It is characterized by a normal subduction zone, where the oceanic Nazca plate subducts beneath South America at an angle of 30° (Jordan *et al.* 1983). As a result of that the Mesozoic sequence is heavily deformed in a series of thrust slices (see Giambiagi *et al.* 2009). These thrusts produced an imbricated sequence, where the strata are repeated several times, creating a complex structure.

The basement of the Andes at this latitude is composed of metamorphic rocks of Precambrian age. Carboniferous marine successions devoid of fossils and some rhyolitic tuffs and lavas of Permian and Triassic age are unconformably overlying the basement (Polanski 1964). The Mesozoic sequences, which record a Pacific marine transgression, constitute different stratigraphic cycles described by Groeber (1953), Malumián and Ramos (1984) and Riccardi (1983, 1988).

These sedimentary successions are covered by extensive Cenozoic volcanic and pyroclastic rocks, including some Recent volcanic centers, such as San José and Marmolejo volcanoes. Isolated patches of colluvial and alluvial deposits are widely distributed in the region (Fig. 2).

THE GEOLOGY OF THE PIUQUENES PASS

A geological map of the Piuquenes Pass region is shown in figure 2 (Pángaro *et al.* 1996), where Darwin's itinerary is marked, and the rock succession according to Darwin (1846) is also shown. He described the following:

"*The ridge of Peuquenes, which divides the waters flowing into the Pacific and Atlantic oceans, extends in a nearly N.N.W. and S.S.E. line; its strata dip eastward at an angle of between 30° and 45°, but in the higher peaks bending up and becoming almost vertical. Where the road crosses this range, the height is 13,210 feet above the sea-level, and I estimated the neighbouring pinnacles at from 14,000 to 15,000 feet. The lowest stratum visible in this ridge is a red stratified sandstone [P]; on it are superimposed two great masses [Q and S] of black, hard, compact, even having a conchoidal fracture, calcareous, more or less laminated shale, passing into limestone: this rock contains organic remains, presently to be enumerated. The compacter varieties fuse easily in a white glass; and this I may add is a very general character with all the sedimentary beds in the Cordillera: although this rock when broken is generally quite black, it everywhere weathers into an ash-grey tint. Between these two great masses [Q and S], a bed [R] of gypsum is interposed, about 300 feet in thickness, and having the same characters as heretofore described. I estimated the total thickness of these three beds [Q, R, S] at nearly 3000 feet; and to this must be added, as will be immediately seen, a great overlying mass of red sandstone.*

In descending the eastern slope of this great central range, the strata, which in the upper part dip eastward at about an angle of 40°, become more and more curved, till they are nearly vertical; and a little further onwards there is seen on the further side of a ravine, a thick mass of strata of bright red sandstone [T], with their upper extremities slightly curved, showing that they were once conformably prolonged over the beds [S]: on the southern and opposite side of the road, this red sandstone and the underlying black shaly rocks stand vertical, and in actual juxtaposition" (Darwin 1846, p. 179-180, pl. 1, sketch 1, see Giambiagi *et al.* 2009).

The red sandstones of P correspond to the Río Damas Formation in Chile (Tordillo Formation in Argentina). Q and S of Darwin (1846) are the Lo Valdés Formation in Chile or the Mendoza Group in Argentina, where it is composed by the Vaca Muerta, Chachao and Agrio Formations. R, the gypsum bed, is the Auquilco Formation of Argentina (Río Colina Formation in Chile) of Oxfordian-Kimmeridgian age, and T is again the Tordillo Formation. It is obvious now that Darwin did not quite understand the complex structure of the region, as can be seen in the geological map of figure 2, where a western back-thrust puts the Auquilco Formation on top of the Agrio Formation and a second fore-thrust repeats again the Agrio and Chachao Formations (Pángaro *et al.* 1996, Giambiagi *et al.* 2009).

A section was measured on the Argentinean slope (Fig. 3), along the northern bank of the Arroyo Piuquenes (Aguirre-Urreta 1996; see location in Fig. 2). The top beds of the Tordillo Formation (Kimmeridgian) are sandstones interbedded with siltstones and green shales. The Vaca Muerta Formation begins with a few meters of limestone with algal lamination, followed in its lower part by black papyraceous shales with abundant calcareous nodules with three fossiliferous levels, from bottom to top with: *Virgatosphinctes* aff. *V. denseplicatus rotundus* Spath, 1931, *Pseudolissoceras zitteli* (Burckhardt, 1903) and *Aulacosphinctes proximus* (Steuer, 1897). These shales grade upwards to dark grey, thinly laminated limestones, reaching more than 110 metres (Fig. 3). The age of the Vaca Muerta Formation in the area is Early to Middle-Late? Tithonian. The Chachao Formation - 40 metres thick - is composed by massive oyster coquinas interbedded with shales bearing *Parodontoceras calistoides* (Behrendsen, 1891) of Late Tithonian age in its lower part. The Agrio Formation is some 120 metres thick in the measured section but is incomplete, as it is cut by a thrust that puts the Chachao coquinas on top of its upper part. The lower part is mostly composed by intercalations of massive and finely laminated grey and yellowish limestones, bearing - in some levels- *Steinmanella* sp., *Thalassinoides* isp. and poorly preserved flattened ammonoids. In the upper part there are non-fossiliferous olive green shales, limestone with small oysters, silty limestones and black shales with *Spitidiscus riccardii* Leanza and Wiedmann, 1992 (Aguirre-Urreta 2001), *Protohemichenopus neuquensis* Camacho, 1953, Lucinidea indet., and callianassid crustaceans.

The fossils that Darwin collected in Q and S (presently Lo Valdés Formation/ Mendoza Group) were studied by d'Orbigny and cited by Darwin (1846, p. 181) as follows:

"*The fossils above alluded to in the black calcareous shales are few in number, and are in an imperfect condition; they consist, as named for me by M. d'Orbigny, of*

1. Ammonite, indeterminable, near to A. recticostatus, *D'Orbig. Pal. Franc. (Neocomian formation).*

2. Gryphæa, *near to* G. Couloni, *(Neocomian formations of France and Neufchatel).*

3. Natica, *indeterminable.*

4. Cyprina rostrata*, D'Orbig. Pal. Franc. (Neocomian formation).*

5. Rostellaria angulosa *(?), D'Orbig. Pal. de l'Amer. Mer.*

6. Terebratula ?"

However, it seems that d'Orbigny gave Darwin slightly different information (see fig. 4). According to his notes, the specimens collected by Darwin in the "*Cordillera Centrale du Chili*" comprised:

"*617/792.* Gryphaea - *Voisine du* Gryphaea Couloni, *du terrain Neocomien de France et de Neuchatel*

613. Natica *(indeterminable)*

*619. Ammonite indeterminable, voisine de l'*A. recticostatus, *d'Orb (Paleont. française) Du terrain Neocomien*

614. B. Cyprina rostrata*, d'Orb. Paleont. franç. Terrain Neocomien (non Lucina)*

C. Terebratula *?*

A. Rostellaria angulosa*, d'Orb. Paleont. de l'Am. Mer. Pl. 18 fig. 4 ?*"

d'Orbigny also listed :

"*790.* Arca *peut être* Arca gabrielis, *d' Orb. (Paleontologie francaise) du terrain Neocomien*"

This fossil is not mentioned by Darwin from the Piuquenes Pass, and is almost certainly from Puente del Inca (Darwin

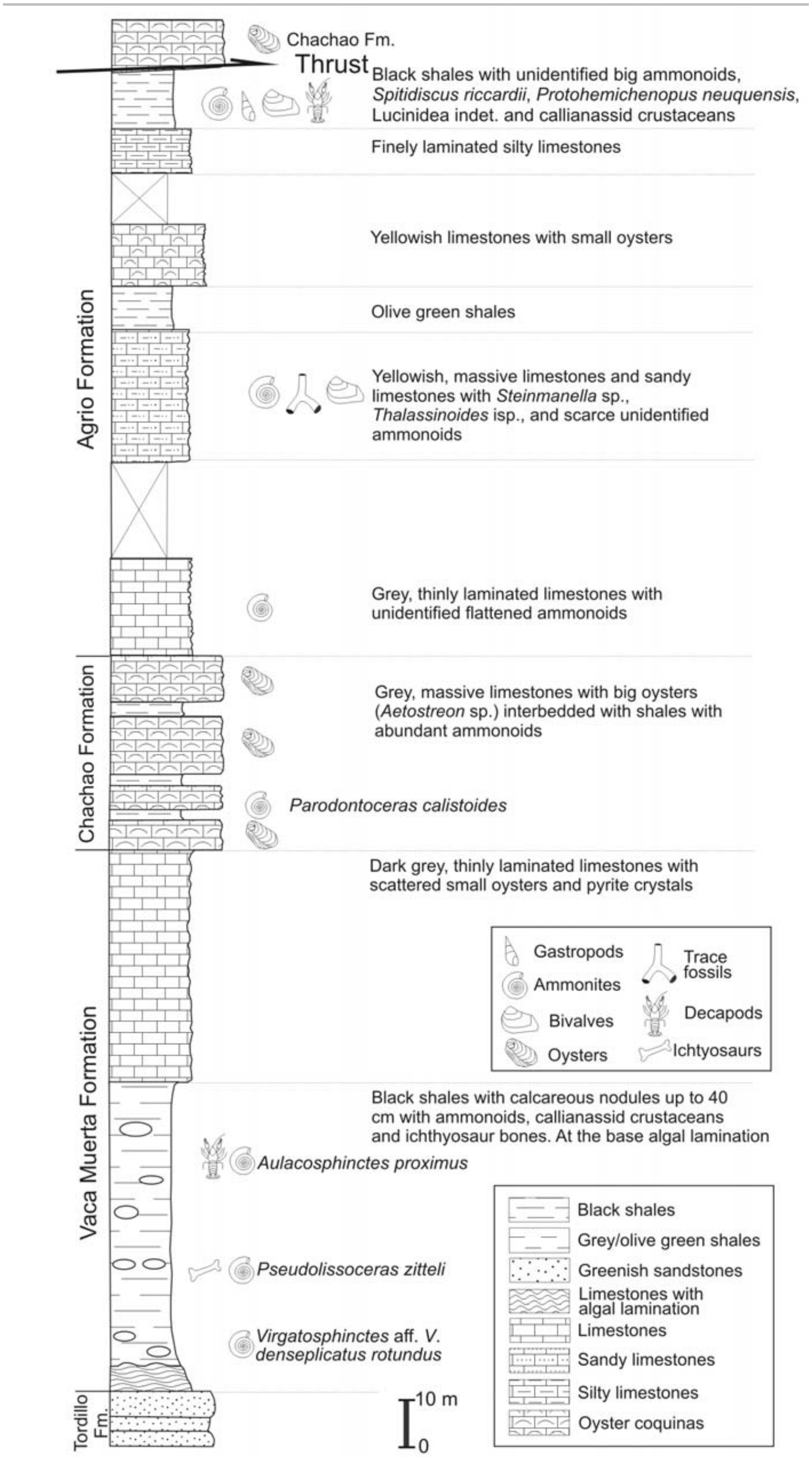


Figure 3: Stratigraphic section of the Mendoza Group in the Argentine slope of the Piuquenes Pass.

1846, p. 193), as this specimen and the "792 *(*Gryphaea - *Voisine du* Gryphaea Couloni)" have a note in the left margin stating *Cumbre*, probably handwritten by Darwin (Fig. 4).

D'Orbigny assigned a bivalve to *Cyprina rostrata* d'Orbigny, 1853 pointing out that this is not *Lucina* Lamarck, 1799, which is interesting as here this fossil is referred to Lucinidae indet. (D. Lazo, oral comm.) (Fig. 5, p-q). He also added the figure of *Rostellaria angulosa* d'Orbigny, 1842 (d'Orbigny 1842, p. 80, pl. 18, fig. 4) which was very helpful in the assignation of our specimens to *Protohemichenopus neuquensis* Camacho, 1953 (Fig. 5 o). It is worth mentioning here that, besides the ammonites that will be described in detail below, we have also found chelipeds of callianassid crustaceans in both the Vaca Muerta and Agrio Formations.

Besides Darwin (1846) the other only published mention of fossils in the Piuquenes range is that of Polanski (1964, p. 48) who listed the following Tithonian fossils: *Corongoceras* sp., *Aulacosphinctes* sp., *Trigonia carricurensis* Leanza, *Lucina* sp. and *Exogyra* sp.

SYSTEMATIC PALAEONTOLOGY

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

Pseudolissoceras zitteli (Burckhardt, 1903)
Figs. 5 a-h

? 1897 *Oppelia perlaevis* Steuer, p. 73, pl. 6, figs. 7-9
1900 *Oppelia* aff. *perlaevis* Steuer; Burckhardt, p. 46, pl. 26, figs. 5, 6; pl. 29, fig. 2
1903 *Neumayria zitteli* Burckhardt, p. 55, pl. 10, figs. 1-8
1907 *Neumayria zitteli* Burckhardt; Haupt, p. 200, pl. 7, figs. 3a, b, 4a-c
? 1921 *Oppelia perlaevis* Steuer, p. 102, pl. 6, figs. 7-9
? 1921 *Oppelia perglabra* Steuer, p. 104, pl. 7, figs. 13-15
1925 *Pseudolissoceras zitteli* (Burckhardt); Spath, p. 113 (Gen. nov.)
1926 *Pseudolissoceras zitteli* Burckhardt; Krantz, p. 436, pl. 17, figs. 4, 5
1928 *Pseudolissoceras zitteli* Burckhardt; Krantz, p. 18, pl. 1, fig. 6; pl. 4, figs. 9a, b

1931 *Pseudolissoceras zitteli* Burckhardt; Weaver, p. 401, pl. 43, fig. 291
1942 *Pseudolissoceras* cf. *Pseudolissoceras zitteli* (Burckhardt); Imlay, p. 1443, pl. 4, figs. 1-4, 7, 8, 11, 12
1980 *Pseudolissoceras zitteli* (Burckhardt); Leanza, p. 17, pl. 1, figs. 1a, b, 2a, b
2001 *Pseudolissoceras zitteli* (Burckhardt); Parent, p. 23, figs. 3a, b, 5a, b, 7a-f
Material: 10 specimens (CPBA 20552.1-20552.10) from the Piuquenes Pass, Mendoza.

Description: Well preserved, small to medium size specimens (largest specimen is 62.2 mm diameter); body chamber occupies at least half a whorl, usually laterally crushed. Shell discoidal, involute (U c. 21% of diameter) with deep umbilicus, rounded umbilical border and an abrupt umbilical slope on the outermost whorls while on the innermost it becomes gently inclined. Subelliptic transversal section with convex flanks converging on a rounded and slightly acuminated venter. Whorls always higher than wide, with maximum width near the middle of the flanks. Shell surface almost smooth. Only where test is preserved is it possible to distinguish extremely soft, falcoid ribs densely packed, that start at the base of the umbilical slope. No dimorphic sexual structures observed. Suture line not completely preserved.

Dimensions of specimens

Specimen (CPBA)	Diameter (D)	Umbilicus (U)	U/D	Whorl Height (H)	Whorl Width (W)	H/W
20552.1	62.2	12.3	0.20	30.3	-	-
20552.2	37.3*	7.4	0.20	17.9	9.2*	1.95
20552.3	44.5	9.4	0.20	22.9	14.2	1.61
20552.4	43	9.1*	0.20	19.8	15.0	1.32
20552.5	38.1	6.9	0.18	17.5	11.3	1.55
20552.6	28	6.1	0.22	13.0	7.8	1.67
20552.7	27.2	6.4	0.24	13.2	8.8	1.50
20552.8	20.5	4	0.20	10.3	8.1	1.27
20552.9	32	6	0.19	12.6	-	-
20552.10	41.1*	9.7	0.24	16.4*	-	-

* Indicates approximate measurement.

Remarks: Specimens described above can certainly be assigned to *Pseudolissoceras zitteli* (Burckhardt 1903, p. 55, pl. 10, figs. 1-8), and it is also possible that specimens figured as *Oppelia perlaevis* Steuer (1897, p. 73, pl. 6, figs. 7-9; 1921, Spanish translation of 1897 edition, p. 102, pl. 6, figs. 7-9) and *Oppelia perglabra* Steuer (1921, p. 104, pl. 7, figs. 13-15) from the lowermost Middle Tithonian of Mendoza, belong also in the same species. This is due to the fact that there is a strong similarity in general form, ornamentation, and suture line between them and Burckhardt's original form. Nevertheless, we can not confirm this until we have the chance of comparing our specimens with Steuer's holotypes, although we can confidently assert that they do not belong in *Oppelia* Waagen, 1869 because they show no trace of even a feeble keel preserved on the illustrated material.
Specimens described and figured by Haupt (1907, p. 200, pl. 7, fig. 3a, b, 4a-c), Krantz (1926, p. 436, pl. 17, figs. 4, 5; 1928, p. 18, pl. 1, fig. 6; pl. 4, fig. 9a, b), Weaver (1931, p. 401, pl. 43, fig. 291) and Leanza (1980, p. 17, pl. 1, figs. 1a, b, 2a, b), were all found at Cerro Lotena, Neuquén, although some specimens have also been recovered from Picún Leufú (Weaver), Rodeo Viejo, Bardas Blancas, Arroyo Cienaguitas and from a locality between Cajón del Burro and Río Choica, in Mendoza (Krantz 1926). Specimens studied by Parent (2001, p. 23, fig. 3a, b, 5a, b, 7a-f) are from Cañadón de los Alazanes, a locality exposed at the Vaca Muerta Range in Neuquén, while Imlay's material (1942, p. 1443, pl. 4, figs. 1-4, 7, 8, 11, 12) is from Cuba. In all cases specimens are highly similar; there is a notable concordance in U/D and H/W ratios with only some minimum differences in transversal section -which can be sometimes more inflated or depressed- or in having a more or less acuminate or rounded venter. In all cases, specimens are found in association with a similar fauna composed mainly of other haploceratid ammonoids, from which they can be generally differentiated by the absence of a marked groove on the flanks, as occurs in *Hildoglochiceras* Spath, 1924, or its rounded venter and lesser degree of involution than in *Parastreblites* Donze and Enay, 1961.
On the other hand, many authors (Haupt 1907, Krantz 1926, Weaver 1931, Leanza 1980) distinguish *Pseudolissoceras pseudoolithicum* (Haupt, 1907) recorded in the same beds that contain *Pseudolissoceras zitteli*. That species never exhibits an umbilical edge, it is only moderately involute, and its flanks are more inflated with whorls as high as wide in transverse section.

Ocurrence: Lowermost Middle Tithonian. *Pseudolissoceras zitteli* Zone.

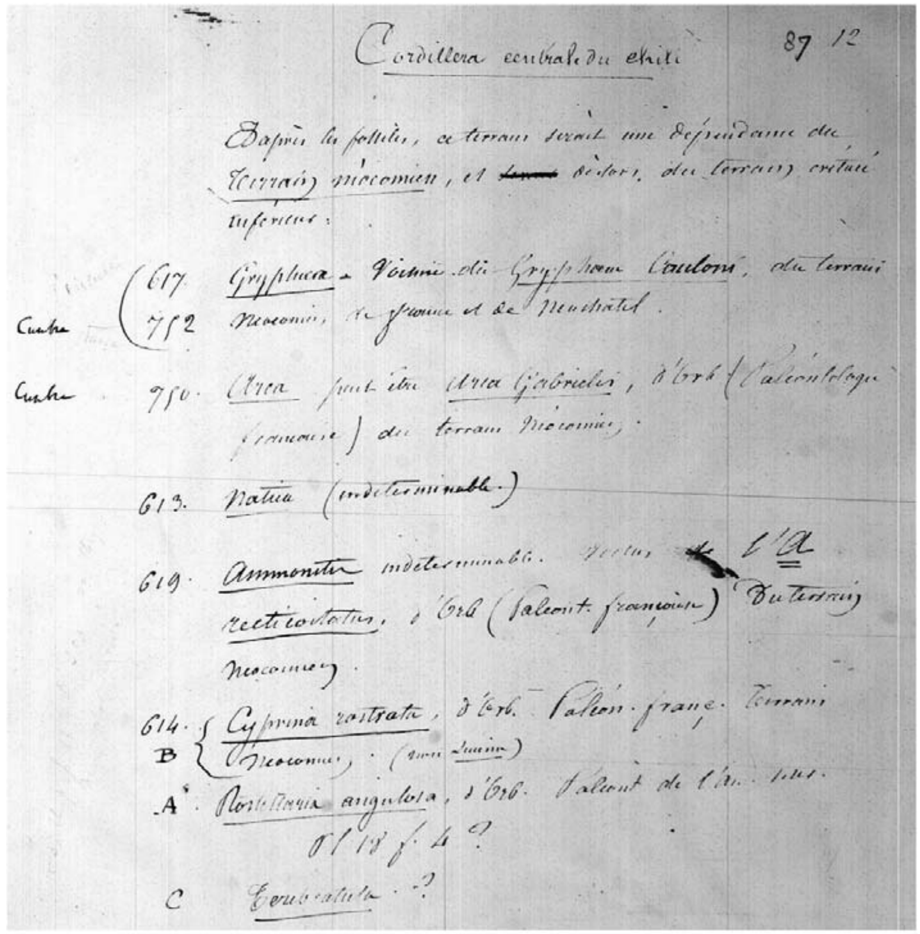
Family Perisphinctidae Steinmann, 1890
Subfamily Virgatosphinctinae Spath, 1923 a
Genus ***Virgatosphinctes*** Uhlig, 1910

Virgatosphinctes aff. ***Virgatosphinctes denseplicatus rotundus*** Spath, 1931
Figs. 5 i-m

? 1890 *Perisphinctes contiguus* Catullo; Toucas, p. 581, pl. 14, fig. 4
? 1900 *Perisphinctes contiguus* Catullo; Burckhardt, p. 45, pl. 24, fig. 1
1903 *Perisphinctes contiguus* Catullo; Burckhardt, p. 38, pl. 4, figs., 7-10
? 1931 *Virgatosphinctes denseplicatus* (waagen) var. *rotunda* Spath, p. 532, pl. 96, figs. 3a-b; pl. 102, fig 4.
1954 *Virgatosphinctes* cf. *denseplicatus* (Waagen) var. *rotunda* Spath; Indans, p. 106, pl. 21, fig. 1
1972 *Virgatosphinctes denseplicatus* Waagen; Fatmi, p. 346, pl. 8, figs. 5a, b
1980 *Virgatosphinctes denseplicatus rotundus* Spath; Leanza, p. 31, pl. 2, figs. 2, 3

Material: 6 specimens (CPBA 20551.1-20551.6) from the Piuquenes Pass, Mendoza.

Description: Medium size discoidal phragmacone (largest specimen is 45.9 mm in diameter), body chamber not preserved. Slightly involute (U c. 33% of diameter), with moderately deep umbilicus and umbilical border not very inclined. Venter slightly planar with gently curved flanks. Whorl section somewhat inflated, slightly wider than high, with maximum width at umbilical margin. Fine, sharp ribs, regularly distributed, beginning at the middle of the umbilical slope, with a slightly prorsiradiate tendency and then bifurcate at the external third of the flank, crossing the venter without interruption. A slight weakness occurs in the ribs in specimens that are less than 38 mm in diameter. At least two shallow constrictions are observed in the last whorl preserved, parallel to the rib pattern and bordered posteriorly by a simple asymmetrical rib. Suture line not observed.



Cordillera centrale du chili 87 12

D'après les fossiles, ce terrain serait une dépendance du terrain néocomien, et dès lors, des terrains crétacé inférieur.

617 / 752 Gryphaea - Voisine de Gryphaea Couloni, du terrain néocomien, de France et de Neuchatel.

750. Arca peut être Arca Gabrieli, d'Orb (Paléontologie française) du terrain néocomien.

613. Natica (indéterminable)

619. Ammonites indéterminable. ... recticostatus, d'Orb (Paléont. française) du terrain néocomien.

614. B Cyprina rostrata, d'Orb. Paléon. franç. terrain néocomien.

A. Rostellaria angulosa, d'Orb. Paléont. ...
Pl 18 f. 4?

C Terebratula ?

Figure 4 : List of fossils identified by d'Orbigny for Darwin from his collection of the Central Cordillera of Chile (from www.darwin-online.org.uk).

Dimensions of specimens

Specimen (CPBA)	Diameter (D)	Umbilicus (U)	U/D	Whorl Height (H)	Whorl Width (W)	H/W
20551.1	45.9	18.7*	0.41	16.1	17.2	0.94
20551.2	37.8	13.7	0.36	13.9	15.0	0.93
20551.3	35.5	14.7	0.41	12.2	12.7	0.96
20551.4	28.6	10.1	035	9.8	11.4	0.86
20551.5	18.0	5.1	0.28	6.3	8.8	0.72
20551.6	10.5	1.9	0.18	4.9	-	-

* Indicates approximate measurement.

Remarks: Specific assignation of the specimens to *Virgatosphinctes denseplicatus rotundus* Spath (1931, p. 532, pl. 96, figs. 3a-b; pl. 102, fig. 4) is quite difficult due to the fact that ornamentation suffers a radical change in the last whorl, just as illustrated by Waagen in *Virgatosphinctes denseplicatus* (1873, p. 201, pl. 46, fig. 3a, b; pl.55, figs. 1a. b), where the innermost fine ribs become stronger over the inner third of the last whorl, and then differentiate in the middle of the flank into a bundle of 4 to 10 secondary ribs that cross the venter without any interruption. It is important to state here that the gradual differentiation from biplicate ribs, into triplicate, virgatotome, and finally fasciculate ribs that constitutes a diagnostic character of *Virgatosphinctes* Uhlig, 1910 is not evident in Waagen's illustrated specimens from the Lower Tithonian of Kutch.

Perisphinctes contiguus Catullo (in Toucas 1890, p. 581, pl. 14, fig. 4, Burckhardt 1900, p. 45, pl. 24, fig. 1, Burckhardt 1903, p. 38, pl. 4, figs. 7-10) closely resembles the specimens described above, with similar rib pattern and alternation of triplicate ribs on one side with biplicate ribs on the other; there is also a slight attenuation of the ornamentation on the venter of some specimens. Toucas' material comes from the Lower Tithonian of the Carpathians, the Alps, the Apennines and from Andalucia, while Burkhardt's specimens are from the Lower Tithonian from Casa Pincheira in Mendoza.

Virgatosphinctes cf. *denseplicatus* (Waagen) var. *rotunda* Spath (in Indans 1954, p. 106, pl. 21, fig. 1) from Cerro Alto in southern Mendoza also resembles the studied specimens, as well as the specimen from western Pakistan identified as *Virgatosphinctes denseplicatus* Waagen by Fatmi (1972, p. 346, pl. 8, figs. 5a, b). However, there appears to be a difference in the ornamentation pattern with the Argentinian specimens, as there are simple pos-

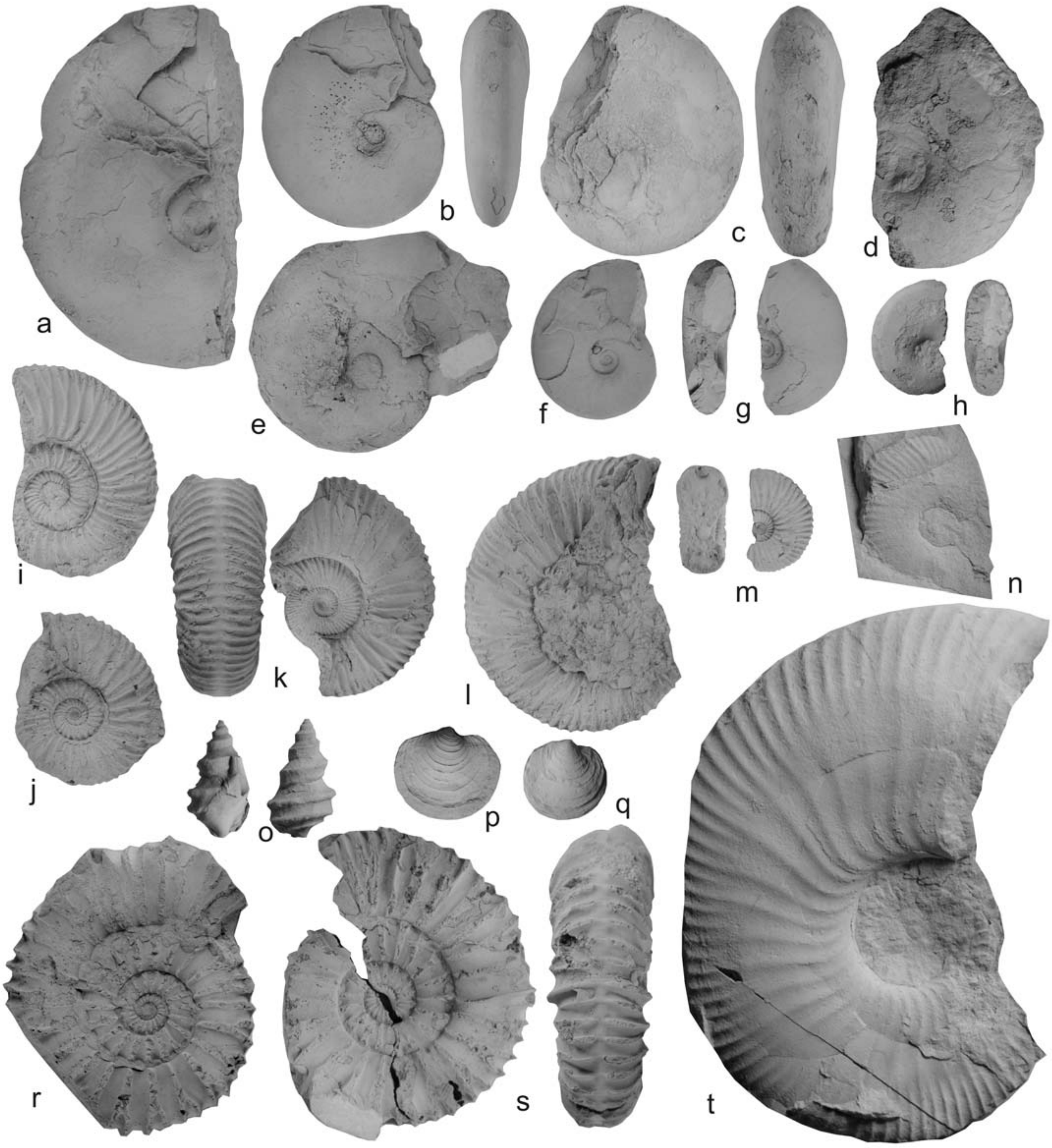


Figure 5: a-h) *Pseudolissoceras zitteli* (Burckhardt, 1903); a) lateral view CPBA 20552.1; b) lateral and ventral views CPBA 20552.5; c) lateral and ventral views CPBA 20552.4; d) lateral view CPBA 20552.3; e) lateral view CPBA 20552.2; f) lateral view CPBA 20552.6; g) apertural and lateral views CPBA 20552.7; h) lateral and ventral views CPBA 20552.8; i-m) *Virgatosphinctes* aff. *Virgatosphinctes denseplicatus rotundus* Spath, 1931; i) lateral view CPBA 20551.3; j) lateral view CPBA 20551.4; k) ventral and lateral views CPBA 20551.2; l) lateral view CPBA 20551.1; m) apertural and lateral views CPBA 20551.5; n) *Spitidiscus riccardii* Leanza and Wiedmann, 1992, lateral view CPBA 20557; o) *Protohemichenopus neuquensis* Camacho, 1953, apertural and lateral views CPBA 20556.1; p-q) Lucinidae indet. lateral views CPBA 20555.1-2; r-t) *Aulacosphinctes proximus* (Steuer, 1897); r) lateral view CPBA 20553.2; s) lateral and ventral views CPBA 20553.1; t) *Parodontoceras calistoides* (Behrendsen, 1891), lateral view CPBA 20554. All specimens from the Piuquenes Pass, Mendoza. All natural size. Specimens coated with ammonium chloride.

terior ribs bordering the constrictions, not joining the immediately anterior biplicate ribs.

Finally, there is a strong resemblance between the specimens studied here and *Virgatosphinctes denseplicatus rotundus* described and figured by Leanza from the Lower Tithonian of Cerro Lotena, Neuquén (1980, p. 31, pl. 2, figs. 2, 3), though his specimens show a more inclined umbilical slope and a more subelliptical whorl section.

Virgatosphinctes denseplicatus rotundus is usually found in association with other *Virgatosphinctes*, like *Virgatosphinctes andesensis* (Burckhardt), from which it can be differentiated due to its whorl section only slightly wider than high, its softer ornamentation and the lack of intercalatory ribs and primary ribs describing an inflection on the middle of the flanks.

Ocurrence: Basal section of Vaca Muerta Formation, just above the biolaminated carbonate levels. Lower Tithonian, *Virgatosphinctes mendozanus* Zone.

Family Perisphinctidae Steinmann, 1890
Subfamily Himalayitinae Spath, 1925
Genus ***Aulacosphinctes*** Uhlig, 1910

Aulacosphinctes proximus (Steuer, 1897)
Figs. 5 r-t

1897 *Reineckeia proxima* Steuer, p. 34, pl. 8, figs. 7-11

? 1897 *Perisphinctes colubrinus* Reinecke; Steuer p. 62, pl. 15, fig. 11

1900 *Perisphinctes colubrinus* Reinecke; Burckhardt, p. 44, pl. 24, figs. 5, 6; pl. 26, fig. 4

1907 *Perisphinctes proximus* Steuer; Haupt, p. 192

1921 *Reineckeia proxima* Steuer, p. 61, pl. 8, figs. 7-11

? 1921 *Perisphinctes colubrinus* Reinecke; Steuer, p. 90, pl. 15, fig. 11

1928 *Aulacosphinctes wanneri* Krantz, p. 42, pl. 2, figs. 6a, b

? 1931 *Aulacosphinctes proximus* (Steuer); Weaver, p. 411, pl. 44, figs. 298, 299

1931 *Aulacosphinctes colubrinus* (Reinecke); Weaver, p. 413, pl. 44, figs. 301-303

1980 *Aulacosphinctes proximus* (Steuer); Leanza, p. 44, pl. 6, figs. 2a, b, 4a, b, 5a, b

1981 *Aulacosphinctes proximus* (Steuer); Leanza, p. 587, pl. 2, figs. 9, 10

Material: 2 specimens (CPBA 20553.1-20553.2) from the Piuquenes Pass, Mendoza.

Description: Medium size planulate shell (largest specimen is 52.3 mm in diameter), body chamber partially preserved, of at least 1/4 whorl. Strongly evolute (U c. 45% of diameter), with shallow umbilicus, rounded umbilical border and gradually inclined umbilical slope. Subquadrate transversal section with slightly convex flanks and flat venter, whorls slightly higher than wide. Prominent, fine, sharp and distant ribs start at the base of the umbilical slope in a rursiradiated mode, at the umbilical margin they become prorsiradiated, crossing the flanks in a prorsiradiated to rectiradiated pattern. Number of ribs decreases as diameter increases; in a 52.3 mm diameter specimen there are 25 ribs in the last whorl and 20 in the preceding one. Ribs on the innermost whorls are interrupted over the venter by a narrow and shallow furrow, which tends to disappear in outer whorls although ornamentation there may suffer an important weakening. Simple primary ribs are irregularly intercalated with biplicate ribs that bifurcate at the middle of the flanks without developing any tubercle at the bifurcation point. Some intercalatory ribs are also observed, not extending beyond the middle part of the flanks. Two wide but shallow constrictions occur near the shell end; they are posteriorly bounded by a simple, acute and prominent primary rib. Suture line not visible.

Dimensions of specimens

Specimen (CPBA)	Diameter (D)	Umbilicus (U)	U/D	Whorl Height (H)	Whorl Width (W)	H/W
220553.1	48.1	22.9	0.48	13.8	12.6	1.1
20553.2	52.3	21.3	0.41	14.9	14.3	1.0

* Indicates approximate measurement.

Remarks: Diagnostic characters observed in the specimens studied, such as evolution degree, rib pattern and the presence of a ventral furrow allow its assignation to *Aulacosphinctes proximus* (Steuer 1897, p. 34, pl. 8, figs. 7-11 as *Reineckeia proxima*; 1921 Spanish translation, p. 61, pl. 8, figs. 7-11). However, in the same publication Steuer describes another species, from Arroyo Cienaguitas in Mendoza, and from contiguous beds. This species, (*Perisphinctes colubrinus* (Reinecke) p. 62, pl. 15, fig. 11), is very similar to *Aulacosphinctes proximus* (Steuer, 1897), both in general form and ornamentation pattern, but the ventral furrow is not visible on the last whorl preserved, although it is present on previous ones. Nevertheless the specimen illustrated is 83 mm in diameter, so this character may not be noticeable at that size, although it might be quite important in smaller shells as can be clearly seen on the specimens studied by Burckhardt (1900, p. 44, pl. 24, figs. 5, 6; pl. 26, fig. 4) and Weaver (1931, p. 413, pl. 44, figs. 301-303), from Mendoza and Neuquén, respectively.

Weaver (1931, p. 411, pl. 44, figs. 298, 299) also described a specimen that was assigned to *Aulacosphinctes proximus*. However, his description does not mention any rib interruption over the venter at any shell size, an important character in the definition of the genus that casts doubts on its assignation.

Aulacosphinctes wanneri Krantz (1928, p. 42, pl. 2, figs. 6a, b) from Arroyo La Manga, Mendoza, closely resembles *Aulacosphinctes proximus*. The development of a trifurcated rib is the only difference between the two species, an unimportant character that may be considered as intraspecific variation.

Finally, the studied specimens are comparable with those studied by Leanza (1980, p. 44, pl. 6, figs. 2a, b, 4a, b, 5a, b;

1981, p. 587, pl. 2, figs., 9, 10) from the Middle Tithonian of Cerro Lotena in Neuquén.

Ocurrence: Middle Tithonian, *Aulacosphinctes proximus* Zone.

Family Neocomitidae Salfeld, 1921
Subfamily Berriasellinae Spath, 1922
Genus ***Parodontoceras*** Spath, 1923 a

Parodontoceras calistoides (Behrendsen, 1891)
Fig. 5 t

1891 *Hoplites calistoides* Behrendsen, p. 402, pl. 23, figs. 1a, b
1897 *Odontoceras calistoides* Behrendsen; Steuer, p. 41, pl. 17, figs. 13-16
1921 *Odontoceras calistoides* Behrendsen; Steuer, p. 69, pl. 17, figs. 13-16
1922 *Hoplites calistoides* Behrendsen, p. 184, pl. 1, figs. 11a, b
1923a *Parodontoceras callistoides* Behrendsen; Spath, p. 305 (Gen. nov.)
1925 *Berriasella calistoides* Behrendsen; Gerth, p. 88
1928 *Berriasella (Parodontoceras) calistoides* (Behrendsen); Krantz, p. 24
1945 *Parodontoceras calistoides* (Behrendsen); Leanza, p. 41, pl. 5, figs. 5, 6
1988 *Paradontoceras calistoides* (Behrendsen); Riccardi, pl. 3, figs. 3, 4

Material: 1 specimen (CPBA 20554) from the Piuquenes Pass, Mendoza.

Description: Medium to large phragmacone (97.2 mm diameter), laterally crushed. Shell ellipticone, involute (U c. 22 % of diameter), with poorly developed umbilical border and quite inclined umbilical slope. Flanks are gently convex and venter somewhat flattened. Whorls are higher than wide, with the maximum width probably located at the umbilical border. The whorl height increases considerably with diameter, resulting in an eccentric shaped shell. Ornamentation consists of moderately strong ribs, regularly spaced, that begin at least from the middle part of the umbilical slope in a rursiradiate manner, then bend forwards at the umbilical border describing an inflection, and then another inflection at the bifurcation point in the middle of the flanks. These biplicate ribs are intercalated with simple ribs and some intercalatory ones do not go beyond the external third of the flank. All ribs are interrupted over the venter by a relatively wide and shallow furrow, which becomes less visible as diameter increases until it disappears completely. Suture line is very badly preserved.

Dimensions of specimen

Specimen (CPBA)	Diameter (D)	Umbilicus (U)	U/D	Whorl Height (H)	Whorl Width (W)	H/W
20554	97.2	21.1	0.22	43.2	19.7*	2.19

* Indicates approximate measurement.

Remarks: Specific assignation of the specimen to *Parodontoceras calistoides* (Behrendsen, 1891, p. 402, pl. 23, figs. 1a, b) is quite safe despite its rather poor preservation, especially taking into account its eccentric shape, rib pattern and ventral furrow. This species is known from many localities in Neuquén and Mendoza, almost always in association with *Substeueroceras koeneni* (Steuer, 1897) characterized by a finer and denser rib pattern than *Parodontoceras calistoides.* Nevertheless, they seem to be very close forms and only a future more detailed study will prove if they are not just morphotypes of the same species.

Ocurrence: Uppermost Tithonian, *Substeueroceras koeneni* Zone.

Family Holcodiscidae Spath, 1923 b
Genus ***Spitidiscus*** Kilian, 1910

Spitidiscus riccardii Leanza and Wiedmann, 1992
Fig. 5 n

1992 *Spitidiscus riccardii* Leanza and Wiedmann, p. 33, figs. 4a-b
1992 *Spitidiscus* aff. S. *rotula* (J. de C. Sowerby); Leanza and Wiedmann, p. 32, figs. 3a-b
1992 *Spitidiscus* aff. *S. gastaldianus* (d'Orbigny); Leanza and Wiedmann, p. 32, figs. 6a-b
1995 *Spitidiscus riccardii* Leanza and Wiedmann; Aguirre-Urreta, p. 407, pl. 1, figs. 1-23
1999 *Spitidiscus riccardii* Leanza and Wiedmann; Aguirre-Urreta *et al.*, pl. 1, fig. 4.
2005 *Spitidiscus riccardii* Leanza and Wiedmann; Aguirre-Urreta *et al.*, figs. 7 e-f

Material: 1 specimen (CPBA 20557) and several fragments and impressions from the Piuquenes Pass, Mendoza.

Description: Shell small, involute (approx. diameter 30 mm), with rounded umbilical slope and slightly rounded flanks converging towards a curved venter. Ornament is composed by ribs and constrictions. The ribs are fine, arise from the umbilical slope and bifurcate in the lower third of the flank where they curve into a falcoid shape. They cross the venter without interruption bending slightly towards the aperture. The constrictions are less curved than the ribs and they dissect them. Suture line not preserved.

Remarks: Although the preservation of the specimens is rather poor, they can be assigned to *Spitidiscus riccardii* Leanza and Wiedmann, 1992 due to the size, involution of the shell and ribbing pattern. The studied specimens are comparable with those studied by Aguirre-Urreta (1995, p. 407, pl. 1, figs. 1-23) from Agua de la Mula and Agrio del Medio in Neuquén where the species has been studied in detail.

Occurrence: Upper Hauterivian. *Spitidiscus riccardii* Zone.

CONCLUDING REMARKS

When one compares the geological section of the Piuquenes Pass by Darwin (1846, pl. 1, skecth 1) with the present knowledge of the area (Pángaro *et al.* 1996, Fig. 2 herein), it can be seen that Darwin was able to clearly identify the succession of Meso-Cenozoic rocks and some structural features. He only partially recognized the highly complex structure of thrusts that affects the sedimentary rocks, repeating parts of the sequence.

Regarding the fossil content, it must be understood that Darwin just rode along the trail, suffering the effects of high altitude and that he was being hurried by the "*baqueanos*" who were afraid of bad weather. He wrote to Henslow: "*It was late in the Season, & the situation particularly dangerous for Snow storms. I did not dare to delay, otherwise a grand harvest might have been reaped*" (Burkhardt and Smith 1985). He was able to collect the most common fossil, his big oyster *Exogyra (Gryphacea) couloni* (presently *Aetostreon*), other bivalves, some gastropods and ammonites. It is difficult to know precisely from where he got his specimens, though it seems he stopped several times along the trail collecting loose material, a fact that would explain why the fossils were poorly preserved.

D'Orbigny (manuscript, see Fig. 4, and also Darwin 1846) regarded the assemblage as Neocomian age, based not only in the oysters but also in the presence of an indeterminate ammonite resembling *Ammonites recticostatus* d'Orbigny, 1840. This species is presently assigned to the genus *Macroscaphites* Meek, 1876 of Barremian-Early Aptian age, and is completely unknown in the Neuquén Basin, where the youngest ammonites are of Early Barremian age (Aguirre-Urreta *et al.* 2005). Most probably d'Orbigny confused it with some Tithonian perisphinctids which are common in the area.

In spite of the poor preservation of the specimens and the lack of knowledge of faunas of this age in South America, it should be emphasized that Darwin was correct in assigning the whole succession to the Neocomian, following d'Orbigny's advice. This fauna was one of the first to be documented in the High Cordillera of the Main Andes, which now we know that also includes the Tithonian as seen by the ammonites described above.

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WORKS CITED IN THE TEXT

Aguirre-Urreta, M.B. 1995. *Spitidiscus riccardii* Leanza y Wiedmann (Ammonoidea) en el Hauteriviano del Neuquén. Ameghiniana 32: 407-410.

Aguirre-Urreta, M.B. 1996. El Tithoniano marino de la vertiente argentina del paso de Piuquenes, Mendoza. 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos (Buenos Aires), Actas 2: 185.

Aguirre-Urreta, M.B. 2001. Marine Upper Jurassic-Lower Cretaceous Stratigraphy and Biostratigraphy of the Aconcagua-Neuquén Basin, Argentina and Chile. Journal of Iberian Geology 27: 71-90.

Aguirre-Urreta, M.B., Concheyro, A., Lorenzo, M., Ottone, E.G. and Rawson, P.F. 1999. Advances in the biostratigraphy of the Agrio Formation (Lower Cretaceous) of the Neuquén basin, Argentina: ammonites, palynomorphs, and calcareous nannofossils. Paleogeography, Palaeoclimatology, Palaeoecology 150: 33-47.

Aguirre-Urreta, M.B., Rawson, P.F., Concheyro, G.A., Bown, P.R. and Ottone, E.G. 2005. Lower Cretaceous Biostratigraphy of the Neuquén Basin. In Veiga, G., Spalletti, L., Howell, J.A. and Schwarz, E. (eds.) The Neuquén Basin: A case study in sequence stratigraphy and basin dynamics. The Geological Society, Special Publication 252: 57-81, London.

Behrendsen, O. 1891-1892. Zur Geologie des Ostabhanges der argentinischen Kordillere. Deutsche Geologische Gesellschaft 43 (1891): 369-420; 44 (1892): 1-42.

Behrendsen, O. 1922. Contribución a la geología de la pendiente oriental de la Cordillera Argentina. Academia Nacional de Ciencias, Actas 7: 157-227, Córdoba.

Burckhardt, C. 1900. Profils géologiques transversaux de la Cordillère Argentino-Chilienne. Museo de La Plata, Sección Geológica y Mineralógica, Anales 2: 1-136.

Burckhardt, C. 1903. Beitrage zur Kenntniss der Jura und Kreide formation der Cordillere. Palaeontographica 50: 1-144.

Burkhardt, F. and Smith, S. 1985. The Complete Correspondence of Charles Darwin. Vol. 1. 1821-1836. Cambridge University Press, 752 p., Cambridge.

Camacho, H. H. 1953. Algunas consideraciones sobre los "Aporrhaidae" fósiles argentinos. Revista de la Asociaci´´on Geológica argentina 8: 183- 194.

Darwin, C. 1846. Geological observations on South America, being the third part of the geology of the voyage of the Beagle, under the command of Capt. FirtzRoy, RN, during the years 1832 to 1836. Smith, Elder and co., 268 p. London.

d'Orbigny, A. 1840-1841. Paléontologie Francaise. Description des Mollusques et Rayonnés Fossiles. Terrains Crétacés. Masson, 662 p., Paris.

d'Orbigny, A. 1842. Voyage dans L'Amérique Méridionale. Tome 3, 4° part: Paleontologie, 188 p., Paris & Strasbourg.

Fatmi, A.N. 1972. Stratigraphy of the Jurassic and Lower Cretaceous rocks and Jurassic ammonites from northern areas of West Pakistan. British Museum of Natural History 20: 297-380.

Gerth, E. 1925. La fauna Neocomiana de la Cordillera argentina, en la parte meridional de la provincia de Mendoza. Academia Nacional de Ciencias, Actas 9: 57-132, Córdoba.

Giambiagi, L., Tunik, M., Ramo, V. A. and Godoy, E. 2009. The High Andean Cordillera of Central Argentina and Chile along the Piuquenes Pass- Cordón del Portillo transect: Darwin´s pioueering observations compared with modern geology. Revista de la Asociación Geológica Argentina 64 (1): 44-54.

Groeber, P. 1953. Mesozoico. In Geografía de la República Argentina, Sociedad Argentina de

Estudios Geográficos GAEA 2(1): 9-541, Buenos Aires.

Haupt, O. 1907. Beiträge zur Fauna des oberen Malm und der unteren Kreide in der argentinischen Cordillere. Neues Jahrbuch für Mineralogie, Geologie und Paläontologie 23: 187-236.

Imlay, R.W. 1942. Late Jurassic fossils from Cuba and their economic significance. Geological Society of America, Bulletin 53: 1417-1478.

Indans, J. 1954. Eine Ammonitenfauna aus dem Untertithon der argentinischen Kordillere in Süd-Mendoza. Palaeontographica 105 A: 96-132.

Jordan, T., Isacks, B., Ramos, V.A. and Allmendinger, R.W. 1983. Mountain building model: The Central Andes. Episodes 1983(3): 20-26.

Kilian, W. 1910. Erste Abteilung: Unterkreide (Palaeocretacicum). Lieferung 2: Das bathyale Palaeocretacicum im südostlichen Frankreich; Valendis-Stufe; Hauterive-Stufe; Barreme-Stufe; Apt-Stufe. In Frech, F., Lethaea Geognostica. II. Das Mesozoicum, Band 3 (Kreide) (1907-1913), Schweizerbart, 169-288, pls. 1-8, Stuttgart.

Krantz, F. 1926. Die ammoniten des Mittel-und Obertithons. In Jaworski, E., Krantz, F. and Gerth, E. (eds.) Beiträge zur Paläontologie und Stratigraphie des Lias, Doggers, Tithons und der Unterkreide in der Kordillere im Süden der Provinz Mendoza (Argentinien). Geologische Rundschau 17a: 427-462.

Krantz, F. 1928. La fauna del Titono superior y medio en la parte meridional de la provincia de Mendoza. Academia Nacional de Ciencias, Actas 10: 1-57, Córdoba.

Leanza, A.F. 1945. Ammonites del Jurásico Superior y del Cretácico Inferior de la Sierra Azul, en la parte meridional de la provincia de Mendoza. Anales del Museo de La Plata NS 1: 1-99.

Leanza, H.A. 1980. The Lower and Middle Tithonian Ammonite Fauna from Cerro Lotena, Province of Neuquén, Argentina. Zitteliana 5: 3-49.

Leanza, H.A. 1981. Faunas de ammonites del Jurásico superior y del Cretácico inferior de América del Sur, con especial consideración de la Argentina. In Volkheimer, W. and Musacchio, E.A. (eds.) Cuencas sedimentarias del Jurásico y Cretácico de América del Sur. Comité Sudamericano del Jurásico y Cretácico 2: 559-597, Buenos Aires.

Leanza, H.A. and Wiedmann, J. 1992. Nuevos Holcodiscidae (Cephalopoda-Ammonoidea) del Barremiano de la Cuenca Neuquina, Argentina y su significado estratigráfico. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte 1992, 1: 24-38.

Malumián, N. and Ramos, V.A. 1984. Magmatic intervals, transgression regression cycles and oceanic events in the Cretaceous and Tertiary of Southern South America. Earth and Planetary Science Letters 67: 228 237.

Pángaro, F., Ramos, V.A. and Godoy, E. 1996. La Faja plegada y corrida de la Cordillera Principal de Argentina y Chile a la latitud del Cerro Palomares (33°35'S). 13° Congreso Geológico Argentino y 3° Congreso Exploración de Hidrocarburos (Buenos Aires), Actas 2: 315-324.

Parent, H. 2001. The Middle Tithonian (Upper Jurassic) ammonoid fauna of Cañadón de los Alazanes, southern Neuquén-Mendoza Basin, Argentina. Boletín del Instituto de Fisiografía y Geología 71: 19-38, Rosario.

Polanski, J. 1964. Descripción geológica de la Hoja 25a Volcán San José, provincia de Mendoza. Dirección Nacional de Geología y Minería, Boletín 98: 1-94, Buenos Aires.

Riccardi, A. 1983. The Jurassic of Argentina and Chile. In Moullade, M. and Nairn, A.E.M. (eds.) The Phanerozoic geology of the world II, The Mesozoic B, Elsevier, 201-263, Amsterdam.

Riccardi, A.C. 1988. The Cretaceous System of southern South America. Geological Society of America, Memoir 168: 1-161.

Salfeld, H. 1921. Kiel- und Furschenbildung auf der Schalenaussenseite der Ammonoifrrn in ihrer Bedeutung für die Systematik und Festlegung von Biozonen. Zentralblatt für Mineralogie, Geologie und Paläontologie 1921: 343-347.

Spath, L.F. 1922. On Cretaceous Ammonoidea from Angola, collected by Professor J.W. Gregory, D. Sc., F.R.S. Transactions of the Royal Society of Edinburgh 53: 91-160.

Spath, L.F. 1923 a. On ammonites from New Zealand. In Trechmann, Ch.T. (ed.) The Jurassic Rocks of New Zealand. Geological Society of London, Quarterly Journal 79: 246-312.

Spath, L.F. 1923 b. A monograph of the Ammonoidea of the Gault. Part 1. Palaeontographical Society, Monographs 75 (353): 1-72.

Spath, L.F. 1925. Ammonites and Aptychi. In Wyllie, B.N.K and Smellie, W.E. (eds.) The collection of fossils and rocks from Somaliland. Hunterian Museum, Glasgow University, Monograph 7: 111-164.

Spath, L.F. 1927-1933. Revision of the Jurassic Cephalopod Fauna of Kachh (Cutch). Paleontologia Indica, NS 9, 1 (1927): 1-72, 2 (1928): 73-161, 3 (1928): 163-278, 4 (1931): 279-550, 5 (1931): 551-658, 6 (1933): 659-945.

Steinmann, G. 1890. Cephalopoda. In G. Steinmann and L. Döderlein (eds.) Elemente der Paläontologie, 344-475, W. Engelmann, Leipzig.

Steuer, A. 1897. Argentinische Jura - Ablagerungen: Eine Beitrage zur Kenntniss der Geologie und Paleontologie der argentinischen Anden. Palaeontologische Abhandlungen NS 7: 127-222, Jena.

Steuer, A. 1921. Estratos Jurásicos Argentinos. Contribución al conocimiento de la Geología y Paleontología de los Andes Argentinos entre el Río Grande y el Río Atuel. Academia Nacional de Ciencias, Actas 7: 5-128, Córdoba.

Toucas, A. 1890. Étude sur la fauna des couches tihoniques de l'Ardèche. Bulletin de la Société Géologique de France (Serie 3) 18: 560-629.

Uhlig, V. 1910. The Fauna of the Spiti Shales. Palaeontologia Indica 15: 133-395.

Waagen, W. 1873-1875. Jurassic Fauna of Kutch. Palaeontologia Indica 1 (1873): 1-22, 2 (1875): 23-76, 3 (1875), 77-106, 4 (1875): 107-247.

Weaver, C. 1931. Paleontology of the Jurassic and Cretaceous of West Central Argentina. Memoirs of the University of Washington 1: 1-496.

Zittel, K.A. 1884. Cephalopoda. In Zittel, K.A. Handbuch der Palaeontologie, R.Oldenbourg, Band 1, Abteilung 2, Lieferung 3, 893 p., Munich and Leipzig..

Zittel, K.A. 1895. Grundzüge der Palaeontologie. R. Oldenbourg, viii + 971 p., 2.048 figs, Munich and Leipzig.

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