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Editores

Oscar A. Albert
Horacio Parent

Ilustración de cubierta: *Torquatisphinctes proximus* (Steuer, 1897), Tithoniano Medio, Jurásico Superior, Cañadón de los Alazanes, Neuquén, Argentina (ver Figura 8G en página 31).

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ANOMALOUS UPPER MANTLE BENEATH THE CENTRAL ANDES. ISOSTASY AND ANDEAN UPLIFT.

Antonio INTROCASO

**Boletín
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Fisiografía y Geología**

Introcaso A., 2001. Anomalous upper mantle beneath the Central Andes. Isostasy and Andean uplift. [*Manto superior anómalo debajo de los Andes Centrales. Isostasia y levantamiento andino*]. *Boletín del Instituto de Fisiografía y Geología*, Volúmen 71, Números 1-2, pp. 1-12. Rosario, 25-12-2001. ISSN 1666-115X.

Abstract.- Four theoretical models isostatically compensated were prepared and compared between themselves in order to analyze either the isostatic equilibrium or the probable mechanisms for justifying the Central Andean uplift. They are: Model 1, or Airy Model: in this classical model the isostatic compensation would take place at the maximum Moho depth's level: 61.7 km. Model 2: this model justifies the Andean elevation by means of a combination of lithospherical thermal root and crustal root. In this case, the last one is diminished 5.3 km respect to crustal root's thickness of Model 1. Isostatic compensation takes place here at the bottom of thermal lithosphere: 140 km deep. Model 3: this model explains the elevation by means of a combination of the subsidence that the subducted Nazca Plate could produce, and the crustal root effect, that is 6 km thicker than the first model's root. The isostatic compensation could take place at a depth of 300 km. Model 4: this model involves Models 1, 2 and 3 mechanisms; the isostatic compensation takes place at a depth of 300 km. Crustal shortenings S_h are sensitive to the upper mantle's heterogeneity, varying from 17% to +18%, as it is shown by the following values: $S_h = 278$ km (Model 1), $S_h = 230$ km (Model 2), $S_h = 338$ km (Model 3) and $S_h = 288$ km (Model 4).

We also demonstrate that the model selected for evaluating the Andean isostatic equilibrium in this zone of the anomalous upper mantle is not critical. The analysis of the two EW gravity sections at 22°S and 24.5°S latitudes favors Model 2 as the most likely, since the crustal thickness found from it is clearly consistent with seismic data available at 24.5°S. Nevertheless, we can admit other gravimetric models.

Key-Words: Central Andean uplift, Isostatic equilibrium, Gravimetric models, Thermal root, Crustal root.

Resumen.- Manto superior anómalo debajo de los Andes Centrales. Isostasia y levantamiento andino. Fueron preparados cuatro modelos teóricos compensados isostáticamente que al ser comparados entre sí, permitieron analizar el equilibrio isostático y los mecanismos probables que justifican el levantamiento de los Andes Centrales. Ellos son: Modelo 1 o Modelo de Airy: En este clásico modelo la compensación isostática se realiza en la máxima profundidad del Moho, a 61.7 km. Modelo 2: Este modelo justifica la elevación andina por medio de una combinación de una raíz térmica litosférica y de una raíz cortical. En este caso, la última raíz disminuye 5.3 km respecto de la raíz cortical del Modelo 1. La compensación isostática toma lugar en el fondo de la litosfera térmica a 140 km de profundidad. Modelo 3: En este modelo la compensación isostática se explica por medio de una combinación de la subsidencia que la subducción de la Placa de Nazca podría producir y del efecto de la raíz cortical que se incrementa en 6 km respecto de la raíz del primer modelo. La compensación isostática se realizaría a 300 km de profundidad. Modelo 4: Este modelo involucra los mecanismos de los Modelos 1, 2 y 3. También en este modelo la compensación isostática se realiza a 300 km de profundidad. Los acortamientos corticales S_h son sensibles a las heterogeneidades del manto superior, variando entre 17% a +18% como se demuestra con los siguientes valores: $S_h = 278$ km (Modelo 1), $S_h = 230$ km (Modelo 2), $S_h = 338$ km (Modelo 3) y $S_h = 288$ km (Modelo 4).

Demostramos también que el modelo seleccionado para evaluar el equilibrio isostático andino no es crítico. El análisis de dos secciones gravimétricas EW en 22° y 24.5° de latitud Sur señala al Modelo 2 como el mas probable, debido a que el espesor cortical de ellos es claramente consistente con los datos sísmicos disponibles en 24.5°S. No obstante es posible admitir otros modelos gravimétricos.

Palabras clave: Levantamiento de los Andes Centrales, Equilibrio isostático, Modelos gravimétricos, Raíz térmica, Raíz cortical.

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INTRODUCTION

It has been pointed out that beneath the Central Andes, there could be: (1) cooling produced by the Nazca Plate subduction beneath the continental lithosphere (Grow and Bowin 1975; Introcaso and Pacino 1988) and (2) significant heating on the lithospheric mantle (Froideveaux and Isacks 1984; Introcaso and Pacino 1988; Isacks 1988). Here, we have analyzed the (1) and (2) density anomaly effects either on the gravity or on the Andean uplift. From (1), there would be high gravity and subsidence ε_{ci}, whereas from (2) there would be gravity diminution and elevation ε_{ei}.

Let us consider mechanism (1). The subducted plate may produce subsidence due to the following two facts: (a) the oceanic plate mean temperature is about 350°C (0°C on the top and 700°C on the bottom). When subduction takes place, the plate is located at the hot mantle, lower than 70 or 80 km deep. Temperatures there reach 1 200°C at depths of 140 km. Thus, a relative cooling is produced; (b) moreover, petrologic phase changes are probable, at adequate pressure and temperature. So, oceanic crust may become eclogite (density of about 3.5-3.6 $g\cdot cm^{-3}$) or gardnet-peridotite ($\approx$ 3.38 $g\cdot cm^{-3}$). Both circumstances produce contraction, subsiding the column that contains the subducted plate masses anomalies. According to Grow and Bowin (1975) and Dorman and Lewis (1972), the anomalous effects have been considered for isostatic evaluation until 300 km and 400 km respectively.

For better understanding, let us think that the relative cooling mentioned in (a) results in a density increase of +0.03 $g\cdot cm^{-3}$ for the mantle normal density (estimated to be 3.3 $g\cdot cm^{-3}$). If the length of a vertical column that intersects the subducted oceanic lithosphere were 80 km, the contraction ε_c would be $80\cdot(1 - 3.30/3.33) = 0.72$ km. Under such conditions, if a phase change on the oceanic crust 7 km thick took place, basalt with a density of 2.9 $g\cdot cm^{-3}$ would become, for example, eclogite with a density of 3.5 $g\cdot cm^{-3}$, producing a subsidence of $7\cdot(0.6/3.50) = 1.2$ km by contraction.

Let us return to point (2). It is well known that the large magmatic activity consistent with the highest elevation below the Central Andes strongly supports the existence of a thermal root (Froideveaux and Isacks 1984) although a thermal anomaly can justify only part of a great mountain's elevation (Froideveaux and Ricard 1987). So we need at least one additional method.

In order to explain part of the Central Andean uplift, we assume lithospherical heating from the large recognized Quaternary volcanism, associated with subduction (Froideveaux and Isacks 1984; Introcaso and Pacino 1988; Introcaso 1991). Moreover, Isacks' data (1988) obtained from 22 transversal Andean sections, topography was assumed by the mentioned author as the result of a combination of crustal shortening and lithospherical heating due to a thermal anomaly, agreeing with the Quaternary volcanic arc located over 27°S latitude.

For better understanding, let us consider a thermal anomaly with $\Delta T = 300$°C located on the lower half of the thermal lithosphere, 140 km thick. To keep the isostatic equilibrium of the column, the expansion will produce an elevation $\varsigma = (0.03/3.27)\cdot 70$ km $= 0.64$ km. In this expression we assume lithospherical density as 3.3 $g\cdot cm^{-3}$, diminishing to 3.27 $g\cdot cm^{-3} = (3.30 - 0.03)$ $g\cdot cm^{-3}$ when heating is present.

In order to analyze the heating below the Central Andes, Introcaso and Pacino (1992) prepared an isostatic correction chart, under the thermal hypothesis, or Pratt's hypothesis. The chart, with maximum corrections of +60 mGals, was prepared assuming a thermal expansion coefficient $\alpha = 3\cdot 10^{-5}$/°C. Using this chart, the corrections can be carried out in a few minutes.

In this paper we analyze four theoretical models inspired on the Central Andes. They are all isostatically compensated and their main features are the following: (a) Classical crustal model (or Airy model); (b) model with crustal heterogeneities (Andean masses and crustal root) and subcrustal heterogeneities (lithospherical thermal root); (c) model that combines crustal thickening with thermal contraction effect due to the subducted plate; (d) model which combines all the anomalous effects mentioned before. From them, we demonstrate that:

- The model adopted for evaluating isostatic equilibrium below the Central Andes is not critical.
- Bouguer anomalies are principally controlled by crustal roots beneath the Andes. If we admit a less significant incidence of the magmatic addition mechanism, the chief mechanism for explaining the Andean uplift is the crustal shortening.
- If there exist anomalous thermal effects on the upper mantle, they could produce variations of less than 10% (5 to 6 km) on the crustal roots; changes of 16% (thermal expansion) and +18% (thermal contraction) on the crustal shortenings respect to the classic Airy model.
- Finally, two Andean gravity models located at 22°S and 24.5°S latitude with peak Bouguer anomalies of 400 mGals, can be explained better by a model like model 2 (for example, it is consistent with seismic data at 24.5°S latitude). Yet inadequate changes in the initial conditions: normal crustal thickness, difference of density between lower crust and upper mantle, etc. allow us to show that other alternative models can also work, for example model 1.

HETEROGENEITIES ON THE UPPER MANTLE THEORETICAL MODELS

As we have just pointed out, there would exist anomalous effects below the Central Andes, produced by heating on the lower part of the crustal lithosphere, and by cooling due to the cold subduction of the Nazca Plate. For better analyzing these effects, we have prepared four theoretical models accurately isostatically compensated at different levels.

These models are preliminary models, in the sense that they only admit density variations with temperature changes. Relationships between temperature and mantle viscosity, changes in lithosphere-astenosphere density and changes in the pressure gradient, have not been taken into account.

All models assume isostatic compensation, and since the Andean excedent cannot be modified, the redistribution of the masses which tend to keep the equilibrium demands the crustal root to be thickened respect to the Airy model, in -20% to +20%.

Our models show the following characteristics (Fig. 1):

- Model 1 (for Airy model) (Fig. 1A): Andean masses, *ma* (ABCDA), width: 350 km; density σ_t = 2.67 g·cm^{-3}; maximum altitude h_t = 4 km; topographic section area: 1270 km^2, normal crustal density (below the sea level) σ_c = 2.90 g·cm^{-3}; normal crustal thickness T_n = 35 km; upper mantle normal density σ_m = 3.30 g·cm^{-3}; root that compensates the topographic excess ΔR_1 = 26.7 km, where

$$\text{(1)} \qquad \Delta R_1 = \frac{\sigma_t}{\sigma_m - \sigma_c} \text{ x } h_t = 6.675 \text{ x } h_t$$

with differential density $\sigma_m - \sigma_c$ = 0.4 g·cm^{-3} = (2.90 - 3.30) g·cm^{-3}. The shortening in this model is 278 km, as we will see when addressing the subject more specifically.

- Model 2 (Fig. 1B): The Andean masses *ma* are now perfectly balanced by a combination of a crustal root (26.7 - 5.3) km = 21.4 km thick at the central zone, and a thermal root EFGHE located at the lower half of the thermal lithosphere 140 km thick, where pressures are equal. Differential density $\sigma'_m - \sigma_m$ = -0.03 g·cm^{-3}, *i.e.*, with σ'_m = 3.27 g·cm^{-3}, assuming a thermal expansion coefficient α = 3·10^{-5}/°C. The isostatic compensation in this model takes place at the bottom of the thermal lithosphere, that is at a depth of 140 km. Shortening in this model is 230 km. The equation for defining the crustal root is:

$$\text{(2)} \qquad \Delta R_{2i} = \frac{\sigma_t}{\sigma_m - \sigma_c} \times h_{ti} - H_T \frac{\sigma_m - \sigma'_m}{\sigma_m - \sigma_c} \times \frac{\sigma_m}{\sigma'_m}$$

where H_T is the lithospherical column piece thickness before heating. After heating, the thickness will be $H_{Ti} = H_T \cdot \sigma_m / \sigma'_m$. Partial melt may take place from an abnormally heated zone. Since that, magmatic addition in the crust is probable. We will see this when focusing on shortenings.

- Model 3 (Fig. 1C): Isostatic balance of the Andean masses *ma* takes place at a depth of 300 km, where pressures balance. It involves a crustal root with maximum thickness R_{3i} = (26.7 + 6.0) km = 32.7 km combined with an effect produced by the cold subduction (IJKLI) of the plate dipping α = 30° between 100 km and 300 km; we have assumed a density contrast of +0.03 g·cm^{-3} = $\sigma''_m - \sigma_m$, where σ''_m is the anomalous density = 3.33 g·cm^{-3}. Crustal root R_{3i} is here defined by

$$\text{(3)} \qquad \Delta R_{3i} = \frac{\sigma_t}{\sigma_m - \sigma_c} h_{ti} + H_C \frac{\sigma''_m - \sigma_m}{\sigma_m - \sigma_c} \times \frac{\sigma_m}{\sigma''_m}$$

where H_C is the subducted Nazca Plate vertical column thickness before contraction. After contraction, thickness will be $H_{Ci} = H_C \cdot \sigma_m / \sigma''_m$. Shortening in this model is 338 km.

- Model 4 (Fig. 1D): It involves crustal thickening, thermal expansion and contraction produced by the Nazca Plate. Isostatic compensation takes place at a depth of 300 km, and crustal thickness would be defined from R_{2i} and R_{3i} by:

$$\text{(4)} \qquad \Delta R_{4i} = \frac{\sigma_t}{\sigma_m - \sigma_c} h_{ti} + \left(\frac{H_C}{\sigma''_m} - \frac{H_T}{\sigma'_m} \right) \times \frac{\Delta\sigma}{\sigma_m - \sigma_c} \times \sigma_m$$

if: $\Delta\sigma = \sigma_m - \sigma'_m = \sigma''_m - \sigma_m$. Shortening in model (4) is 288 km.

Fig. 2 shows the differences among the root thicknesses of the different models. The maximum root thickness in model 1 (Fig. 2A) is 26.7 km. In model 2 (Fig. 2B), it is reduced to 21.4 km at great part of the root. In model 3 (Fig. 2C), on the contrary, it increases reaching 32.7 km. As we can see in Fig. 2D, differences of about 11 km between models 2 and 3 show that the probable upper mantle heterogeneities may produce significant changes in crustal thickness, since the isostatic equilibrium must be kept without modifying the exposed distribution of the Andean masses.

BOUGUER ANOMALIES AND ISOSTATIC ANOMALIES ORIGINATED BY THE MODELS

Fig. 3A shows the Bouguer anomalies (effects from all the anomalous masses located below the sea level) produced by the four described models. They present approximately the same wavelengths and maximum differences (model 3 - model 2) of 42 mGal, *i.e.*, 11% respect to the mean Bouguer anomaly. These results anticipate the idea that the model chosen to evaluate the isostatic equilibrium is not critical. In fact, Fig. 3B shows the isostatic anomalies corresponding to models 2, 3 and 4 obtained after performing the isostatic corrections obtained from the Airy model's crustal root gravimetric effects with opposite sign.

The isostatic anomalies present a clear decreasing respect to the great Bouguer anomalies (about 10%). This decreasing points out:

- an isostatic equilibrium tendency in all the models, and
- that the model chosen to evaluate isostatic equilibrium is not critical.

SHORTENING BACKGROUNDS

Shortening is no doubt present in the Andean elevation, as it is confirmed by the following values: 115 km in Central Perú (Megard 1978); 190 km in the Peruvian Andes (Suarez et al. 1983); 150 km to 225 km at 18°S latitude (Sheffels et al. 1986); 185 km for the Andean latitudes 21°S-22°S (Giesse and Reutter 1987); 250 km at 22°S combined with heating (Isacks 1988). In Andean sections located at 30°S, 32°S (and 33°S) and 35°S, Introcaso et al. (1992) report shortenings of 150 km, 130 km and 90 km respectively.

Based on the areas of 22 sections of the Andean excedents (in km^2), Isacks (1988) found a gap on the seismic attenuation (Q) transversal section between 27°S and 15°S latitudes, respect to the values located between 35°S and 27°S latitudes that in his graph (fig. 6 in his paper) follow a regular sequence. He attributed this excess to heating at the lower half of the thermal lithosphere 140 km thick. Discounting this effect, the maximum shortening diminishes from about 320 km to 250 km in the South American elbow. His model does not involve magmatic

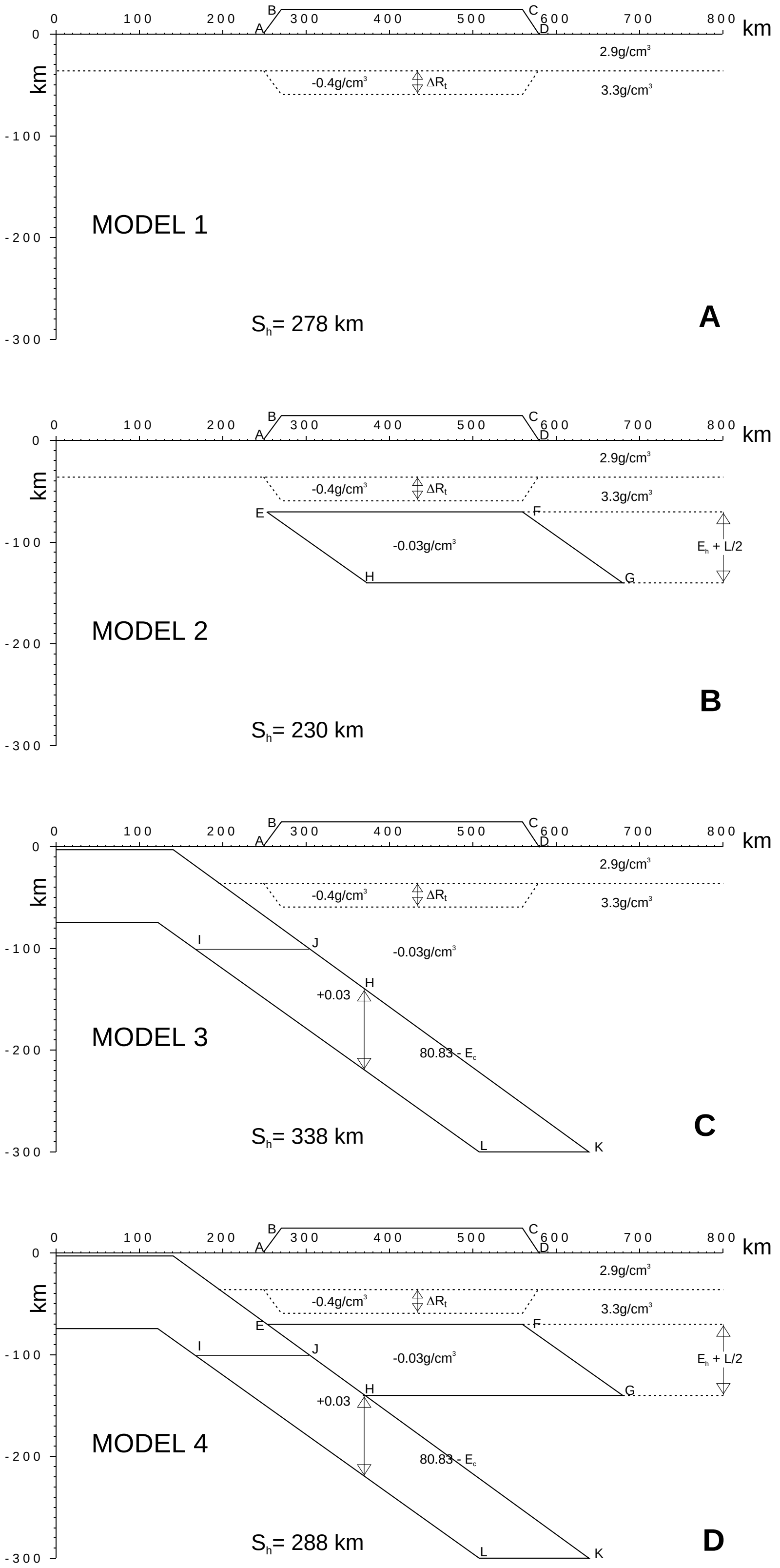

Figure 1. Theoretical models that explain the Central Andean uplift (ABCD). A: Model 1 or Airy Model; B: Model 2 that compensates the Andean masses by means of a combination of a crustal root (ΔR_t) and a lithospherical thermal root (EFGH); C: Model 3 that compensates the Andean masses by means of a combination of a crustal root and the Nazca Plate cold subduction effect (IJKL); D: Model 4 that compensates the Andean masses by means of a combination of a crustal root and the upper mantle heterogenities effects (Models 2 and 3). ***Figura 1.*** *Modelos teóricos que explican el levantamiento andino (ABCD). A: Modelo 1 o Modelo de Airy; B: Modelo 2 que compensa las masas andinas por medio de la combinación de una raíz cortical (ΔR_t) y una raíz térmica litosférica (EFGH); C: Modelo 3 que compensa las masas andinas por medio de la combinación de una raíz cortical y el efecto frío de la subducción de la Placa de Nazca (IJKL); D: Modelo 4 que compensa las masas andinas por medio de la combinación de una raíz cortical y los efectos de las heterogeneidades del manto superior (Modelos 2 y 3).*

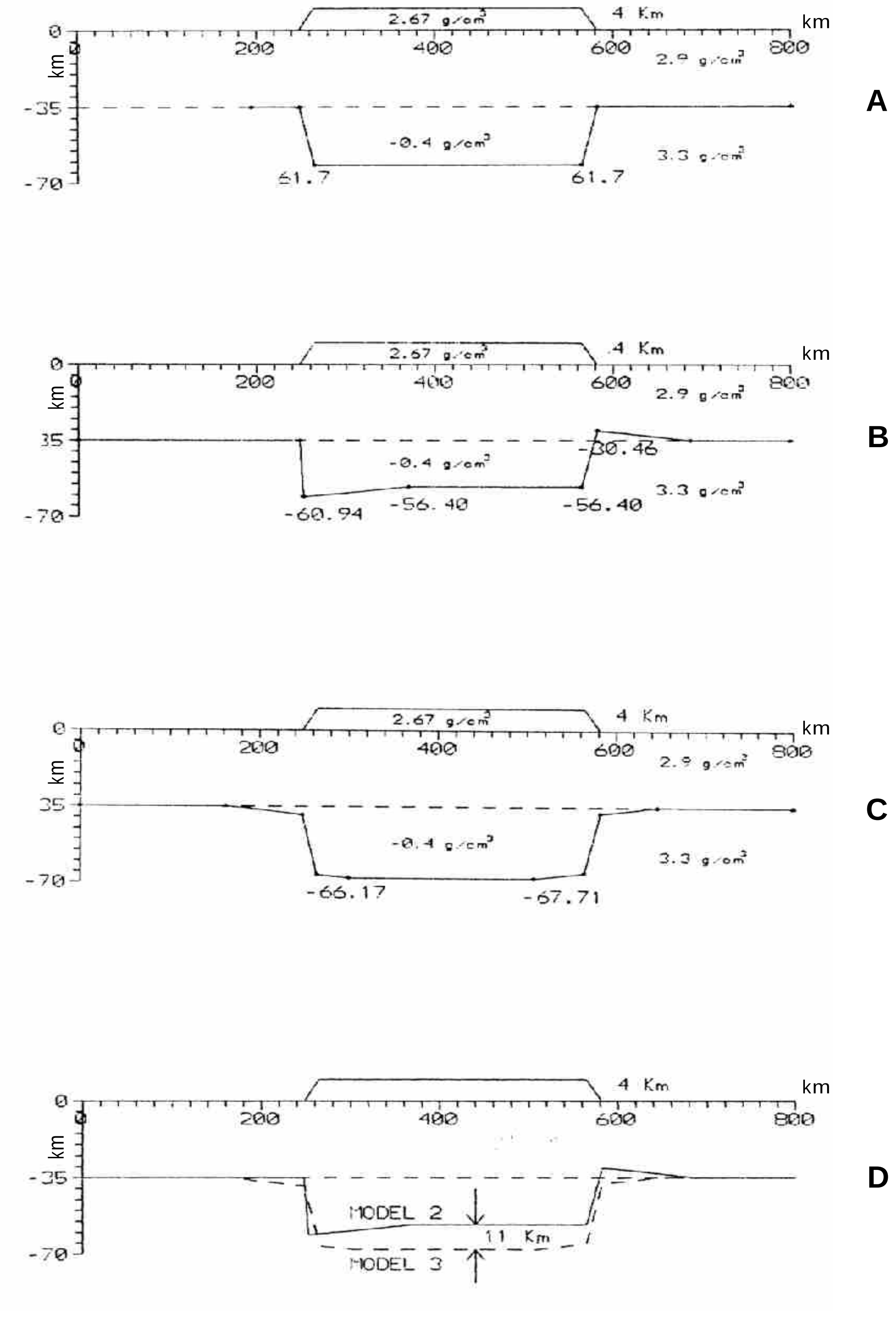

Figure 2. Crustal thicknesses of models 1, 2, 3 and 4 (see Fig. 1) to keep the Andean masses isostatic equilibrium. A: crustal thickness (61.7 km) corresponding to model 1 (Fig.1A); B: diminished crustal thickness (maximun values: 60.9 km and 56.4 km) corresponding to model 2 (Fig. 1B); C: increased crustal thickness (maximun values 67.7 km and 66.2 km) corresponding to model 3 (Fig. 1C); D: difference between the crustal thickness corresponding to models 3 and 2 (maximun: 11 km). ***Figura 2.*** *Modelos 1, 2, 3 y 4 de espesores corticales andinos (véase Fig. 1) manteniendo el equilibrio isostático de las masas andinas. A: espesor cortical (61.7 km) correspondiente al modelo 1 (Fig.1A); B: espesor cortical disminuído (valores máximos: 60.9 km y 56.4 km) correspondiente al modelo 2 (Fig. 1B); C: espesor cortical incrementado (valores máximos: 67.7 km y 66.2 km) correspondiente al modelo 3 (Fig. 1C); D: diferencia entre el espesor correspondiente a los modelos 3 y 2 (máximo: 11 km).*

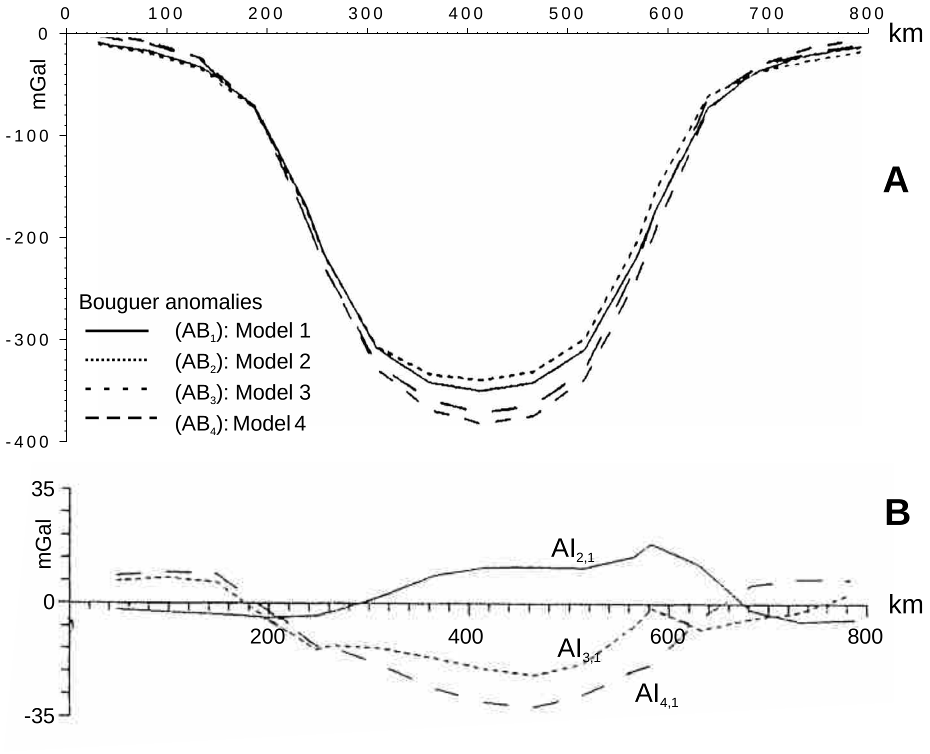

Figure 3. A: Bouguer anomalies of Models 1, 2, 3 and 4 (see Fig. 1). They present the same wavelengths but little differences in amplitude: maximun 11% between Models 3 and 2 (Fig. 1C and 1B); B: Isostatic anomalies $AI_{2,1}$, $AI_{3,1}$ and $AI_{4,1}$ of Models 2, 3 and 4 (Fig. 1 B-D) calculated from the classic Airy Model (Fig. 1A). They differ very little between them (maximun difference of less than 10%) pointing out the existence of isostatic equilibrium. ***Figura 3.*** *A: Anomalías de Bouguer de los Modelos 1, 2, 3 y 4 (véase Fig. 1). Estos presentan las mismas longitudes de onda pero ligeras diferencias en amplitud: máximo 11% entre los Modelos 3 y 2 (Fig. 1C y 1B); B: Anomalías isostáticas* $AI_{2,1}$, $AI_{3,1}$ *y* $AI_{4,1}$ *de los Modelos 2, 3 y 4 (Fig. 1 B-D) calculadas a partir del Modelo de Airy clásico (Fig. 1A). Estas difieren muy poco entre sí (máxima diferencia por debajo del 10%) resaltando la existencia de equilibrio isostático.*

addition.

We have considered Isacks' proposal (1988) in the analysis of our models on 22°S and 24.5°S, finding that Isacks' lithospheric and gravimetrical results will be consistent if the crustal model presents a crustal density excess of 1.3% at 22°S, respect to the averaged density of all the crust, and of 2.7% at the lower crust (root) respect to the model located at 24.5°S.

Let us now return to our theoretical models. Model 1 gives a shortening of $S_h = (A_t + A_R)/T_n = 278$ km; where A_t is the transversal area of the topographic excedent (in km^2); A_R is the compensating root (= $6.675 \cdot A_t$, Introcaso et al. 1992) and T_n is the initial crustal thickness (= 35 km). Since A_t = 1270 km^2, $A_t + A_R = 7.675 \cdot A_t$.

If we admit that the crustal thickening can be due, in part, to magmatic addition, there will be less necessary shortenings. In fact, Kono et al. (1989) considered that the material incorporated to the crust in the Peruvian Andes would be 15% of the anomalous heated zone of about 30 000 km^2. So, for our model 2, the crust would incorporate approximately 4 500 km^2 of materials of the upper mantle (since the anomalous heated zone is 23 450 km^2), and it would suffer a thickening of (3 518 / 335) km ≈ 10.5 km for our theoretical models. For this shortening, and assuming a constant crustal density, the isostatic equilibrium requires an elevation of (10.5 / 7.675) km = 1.368 km. So, the whole crustal thickening (10.5 km) is distributed between 1.368 km (topographic uplift) and 9.132 km (root).

Rigorously, Isacks (1988) considered that magmatic addition is not significant, and Ramos (pers. comm. 1992) estimates that it could be only 5%, so that the average thickening added would be only 3.5 km, contributing to the Andean elevation in only (3.5 / 7.675) km = 0.456 km.

Considering the four theoretical models, with and without magmatic addition, we will have the shortening values of Table 1. Both the root area variations A_R (column 3) and the coefficients A_R/A_t (column 4) anticipate the shortening S_h changes (columns 5 and 6). Finally, magmatic addition justifies part of the crustal thickening and diminishes the shortenings (column7).

In what we have seen we have assumed - simplifying the problem- that the intrusion used to keep the same density as the medium crustal density $\overline{\sigma}_c$. If we consider intrusions whose densities are different to $\overline{\sigma}_c$ (for example acid or basic intrusions) medium crustal density will change, since as we have seen, the intruded volume is not considered as very significant.

Assuming changes in the density, it is easy to demonstrate that the relationship

$$\frac{\Delta R_i}{h_i} = \frac{\overline{\sigma}_c}{\sigma_m - \overline{\sigma}_c}$$

changes, although only a little.

MODEL BACKGROUNDS

Schmitz et al. (1993) presented a seismic model on 24.5°S latitude, with a maximum Moho depth of 60 km. High and

Table 1. Column 1: Models 1, 2, 3 and 4 (Fig. 1); column 2: Area A_t of the Andean excedent; column 3: areas A_R of the roots; column 4: relationship A_R/A_t; column 5: shortenings S_h; column 6: Model 1 shortening porcentual variations respect to S_h. ***Tabla 1.*** *Columna 1: Modelos 1, 2, 3 y 4 (Fig. 1); columna 2: Area* A_t *del excedente andino; columna 3: áreas* A_R *de las raíces; columna 4: relación* A_R/A_t*; columna 5: acortamientos* S_h*; columna 6: variaciones de acortamiento porcentual del Modelo 1 respecto a* S_h*.*

Model	A_t **[km²]**	A_R **[km²]**	A_R/A_t	S_h **[km]**	**ε (%)**	**With magmatic addition of 5% 1 200km²**
1	1 270	8 877	6 675	278	-	244
2	1 270	6 795	5 350	230	-17	196
3	1 270	10 559	8 314	338	+18	304
4	1 270	8 823	6 947	288	-3.6	254

low velocity changes in lower crust are significant in this model.

Northward this section, on 21°S, Schmitz (1993) and Wigger et al. (1993) found a maximum Moho depth of about 65 km. On 22°10'S between 67.7°W and 71.5°W longitudes (Porth et al. 1990) they have also found low and high velocities, whose average in the lower crust is 6.2 km/s. This zone continues downwards until at least 65 km. They have found the following sequence of velocities and densities in the continental area:

22°10'S (only from Chile to the occidental Cordillera)

-Crust	
6 to 6.2 km·s^{-1} (upper crust)	2.78 g·cm^{-3}
6.2 km·s^{-1} (lower crust)	2.90 g·cm^{-3}
6.7 to 7.4 km·s^{-1} (intermediate crust)	2.90 to 3.10 g·cm^{-3}
-Upper mantle	
8.2 km·s^{-1}	3.25 g·cm^{-3}

24.5°S

-Crust	
6 to 6.2 km·s^{-1} (upper crust)	2.66 to 2.75 g·cm^{-3}
6 to 6.6 km·s^{-1} (lower crust)	2.90 g·cm^{-3}
6.7 to 7.2 km·s^{-1} (intermediate crust)	2.94 g·cm^{-3}
-Upper mantle	
8.1 km·s^{-1}	3.26 to 3.28 g·cm^{-3}

Density contrasts between lower crust and upper mantle are from 0.35 g·cm^{-3} to 0.38 g·cm^{-3}.

22°S and 24.5°S latitudes sections, compiled by Porth et al. (1990) present as a capital fact, low velocities of 6 km·s^{-1}, 6.2 km·s^{-1} and 6.6 km·s^{-1} in lower crust. According to the expression of Birch (1961):

$$\sigma = \frac{V_P + 2.55}{3.31}$$

and with Woollard (1959) relationships, a velocity decreasing of 0.1 km·s^{-1} would produce a density decreasing of 0.03 g·cm^{-3}.

At this point, we must take into account that these direct relationships not always hold. In fact, Woollard (1970) pointed out that the amount of Fe/Mg will play a decisive role, since a decreasing in the amount of Fe would produce a decreasing in density, while velocity V_P would increase.

Moreover, it is useful to point out that Araneda et al. (1985) have found high conductivity with high gravity in the zone that we are analyzing, between 68°W and 69°W. Speculatively, they explain this by basic material intrusion (high density with high gravity) and high conductivity by strong mineralization near the intrusive margin. Another alternative proposed by the mentioned authors is that there would exist two consecutive intrusions. A first one, more basic, that would affect gravity, and a second one younger and acid, over the basic complex that would have affected conductivity.

As we have seen, the value adopted by the German workers for the lower crust density is 2.90 g·cm^{-3}. This value agrees with the one adopted by Introcaso and Pacino (1988) and Introcaso et al. (1990). These authors have considered a value of 3.30 g·cm^{-3} for the upper mantle density. Fortunately, the gravity models mainly depend on the difference of density between crust and upper mantle. So, Haak and Giesse (1986) pointed out that the Bouguer anomaly maximum amplitude of 400 mGal below the central Andes, may be wholly justified by means of the lower crust-upper mantle differential density without the necessity of other contributions, as for instance the intermediate or upper crust contributions. At the same time, these models allow us to explore different alternatives. The choice of one or another depends -as we will see- on the crustal thickness obtained from the seismic method.

Our gravimetric models correspond to 22°S and 24.5°S sections (see location in Fig. 4). The gravimetric values of both sections were obtained from Abriata and Introcaso (1990) and Introcaso and Pacino (1988).

Let us see the main characteristics of these profiles.

Gravity Section on 22° South Latitude (Fig. 4a)

The section is located near 22°S latitude (see Fig. 4a). It extends westwards from 62°W meridian, crossing Tarija city (Ta), Tupiza city (Tu) and San Pablo city (SP) until the International boundary with Chile, where it continues passing Chuquicamata and reaching the Coast at Tocopilla city (To), penetrating into the Pacific Ocean until 73°W longitude.

The whole extension of the itinerary is approximately 1 200 km, involving:

a) Pacific ocean sector	300 km
b) Chilean continental sector	200 km
c) Bolivian oceanic sector	700 km

The profile crosses: (1) Coast Cordillera; (2) Central Valley (Chilean Precordillera); (3) Andes Cordillera or Principal Cordillera; (4) Altiplano-Puna; (5) Oriental Cordillera; (6) Subandean Ranges; (7) Chaco-

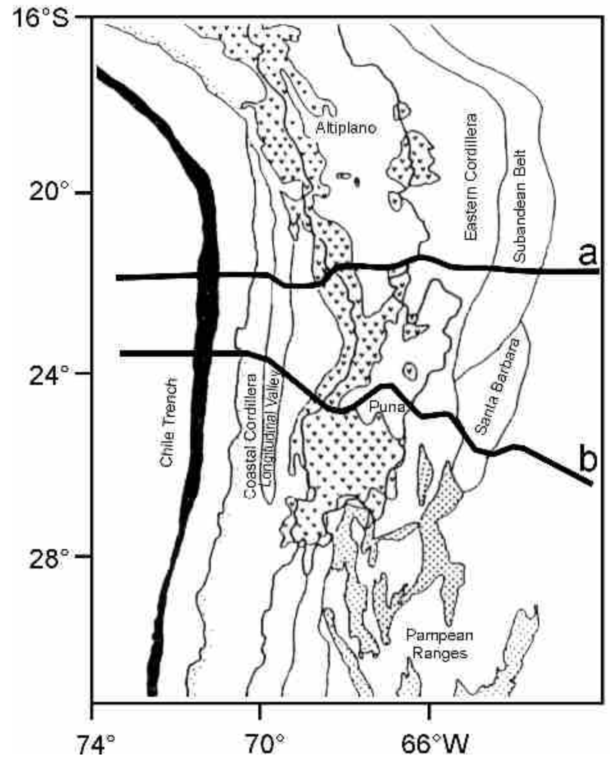

Figure 4. Andean gravimetric sections itinerary, located at 22°S (a) and 24.5°S (b) latitudes. ***Figura 4.*** *Secciones gravimétricas andinas localizadas en latitudes 22°S (a) y 24.5°S (b).*

Pampean flatness.

Free air and Bouguer anomalies in Bolivia were taken from the Bolivian gravity charts presented by Tellería (1992). Bouguer anomalies are simple, without topographic corrections. Because of this, models are preliminary. Altitudes arise from satellite-measured computer files, given by Argentine Antarctic Institute. At the Chilean continental sector, Götze et al. (1987) and Draguicevic (1970) values were taken.

In the Pacific Ocean sector, bathimetry and Free Air anomalies values were taken from Bowin et al. (1981), Hayes (1966), and Fisher and Raitt (1962).

In these sections we detach the following values:
Oceanic Sector: maximum depth of the Chile trench, 7 430 m; maximum free air anomaly under the trench, -228 mGal. Free Air anomalies were changed into Bouguer anomalies, replacing the sea water by continental masses, as we have just done on other sections (Introcaso et al. 1992).
Continental (Andean) Sector: maximum altitude of measure, 4 669 m; maximum Bouguer anomaly, -414 mGal; maximum free air anomalies, +100 mGal at the Central Andes and +150 mGal near the Oriental Cordillera.

Isostatic compensation was analyzed using an Airy model as model 1 (Figs. 1A and 2A). From the compensating masses or crustal roots obtained with $\Delta R = 6675 \cdot h_t$ where h_t is the topographic altitude. As it was demonstrated by Introcaso (1993) and here (Fig. 3B) the selected model is not critical to evaluate the isostatic equilibrium. Once Bouguer anomalies are corrected by gravimetric effects that compensating masses originate the resulting isostatic anomalies are small enough. Fig. 5A shows the isostatic anomalies in the continental sector and the free air anomalies -as usually- in the sea. We must note that the gravimetric section in Fig. 5A presents two significant exceptions: (1) under the Chile trench zone, where they are strongly negative (≈ -100mGal) as it was previously recognized by Introcaso and Pacino (1988) and (2) in the Oriental Cordillera zone, where it is significantly positive (+80mGal). A similar case was found by Kono et al. (1989) for the Peruvian Andes section (Nazca-Punta Maldonado). They have pointed out decompensation in the Eastern Cordillera, and compensation in the Western Cordillera. Here, it would exist a lack of crustal root, estimated in 5 to 10 km (Abriata and Introcaso, 1990). Giesse and Reuter (1987) have admitted crustal delamination originated by an ascending heating counterflow caused by the oceanic plate subduction.

Gravity Section on 24.5°S (Fig. 4b)

This section also extends in EW direction, about 300 km inside the sea, from the Chilean coast passing Socompa and going on with a small dip towards S-SE through the same geological provinces from W to E, until reaching after crossing Santa Bárbara range (Fig. 4b) the foreland sector.

Gravity, altitudes and marine depths values were obtained from the following sources: for the oceanic sector Hayes (1966), Fisher and Raitt (1962); for the continental sector in Chile Wuenschell (1955), Götze et al. (1990). The satellite-measured elevation computer files given by the Argentine Antarctic Institute were also used.

The most significant results are:
In the oceanic sector: maximum trench depth 8 200 m; maximum free air anomaly under the trench -252 mGal. As in the former cases, Bouguer anomalies were also calculated in the sea.
In the continental sector: maximum Bouguer anomaly below the Andean axis -400 mGal; maximum altitude of measuring 3 889 m (Cerrato 1975).

The isostatic equilibrium evaluation in the oceanic zone also shows a remarkable negative free air anomaly, as in the 22°S. As it is well known, in both cases the trench region is decompensated in isostasy usual terms. In the continental zone, the isostatic anomalies are small, pointing out that -in general terms- the equilibrium predominates (Fig. 5B).

For both models, we have begun inverting the regionalized Bouguer anomalies with the following initial conditions:

- "Normal" crust thickness $T_n = 35$ km, agreeing with the values adopted by Kono et al. (1989) and Giesse and Reuter (1987).
- Differential density lower crust-upper mantle -0.40 $g \cdot cm^{-3}$, according to Introcaso et al. (1992), and less than 5% with the values adopted by Grow and Bowin (1975), Woollard (1969) and Draguicevic (1970).

In order to separate the regional values, the observed Bouguer anomalies were processed by the filter method proposed by Pacino and Introcaso (1987). The method is based on upward continuation and inversion. Inversions were performed using Talwani et al. (1959) method, optimized by Marquardt (1963) algorithm. An analogous procedure was followed and commented when

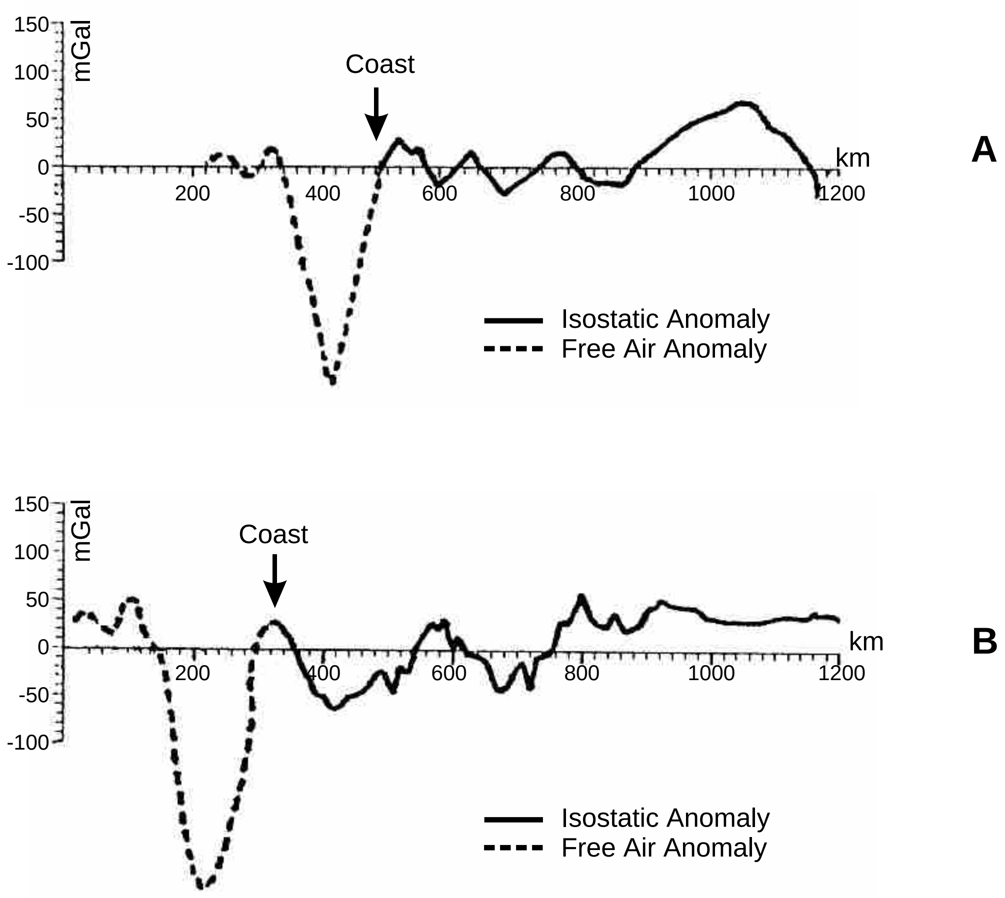

Figure 5. Isostatic and Free Air anomalies on the oceanic sector, corresponding to gravimetric sections located at 22° (A) and 24.5° (B) South latitudes (see Fig. 4). ***Figura 5.*** *Anomalías isostáticas y de aire libre en el sector oceánico, correspondientes a secciones gravimétricas localizadas a 22° (A) and 24.5° (B) latitud Sur (véase Fig. 4).*

analyzing the sections located at 30°S, 32°S, 33°S and 35°S (Introcaso et al. 1992).

Our first models, exclusively gravimetric models, that do not involve anomalous upper mantle, present as maximum Moho depths (Figs. 6 and 7): 65 km in 24.5°S and 68 km in 22°S.

In 24.5°S section, where we fortunately have achieved recent seismic data (Schmitz et al. 1993), maximum Moho depths are 60 km (Fig. 6).

On this EW section, Introcaso et al. (1997) found that 5 km of material located on the crustal bottom (Fig. 7) have been delaminated. Nevertheless, controversial results over heating in lithosphere mantle below Andean belt yet exists.

If we now consider a model like model 2 (Fig. 1B) with anomalous upper mantle also assumed by Isacks (1988), we will obtain a crustal model with maximum Moho depth 60 km, well agreeing with the seismic data. Similarly, from a model like model 2 (Fig. 1B) the maximum crustal thickness on 22°S is 63 km. Although the results seem to be consistent with a model that compensates the Andean excedent m_t by means of a combination of crustal root and lithospherical thermal root, we cannot be conclusive due to the uncertainties of the gravimetric models just pointed out. In fact, for the Andean gravimetric models located at 30°S, 32°S, 33°S and 35°S, Introcaso et al. (1992) pointed out uncertainties in the thicknesses determination of not less than 10%. Also Pardo and Fuenzalida (1988) have found seismic thicknesses between 32°S and 34°S, with ±10%, and velocities V_P with 5% of uncertainty.

In order to complete what we have said, we must add that the uncertainties in the density choice, for instance significant dispersion in the relationship V_P - σ (Nafe and Drake, 1965) or inversions of these relationships with the just mentioned by Woollard (1959), would produce significant changes in crustal thicknesses.

So, both alternative models: one exclusively crustal model (like model 1); the other with two roots: crustal root and lithospherical thermal root (like model 2), satisfy seismic data in 24.5°S and open perspectives for 22°S model, where unfortunately we do not have complete seismic data available yet.

Models like model 3, that combines the positive effect of the subducted plate with a crustal root 6 km exceeded, do not agree with seismic data.

Models like model 4 cannot be discarded, although we need to make sure about the existence of gravimetric effects, originated by subduction (Introcaso and Pacino, 1988 and Introcaso et al., 1992).

Definitely, upper mantle heterogeneities would play a role in the Andean elevation. For example, heating at the lower half of the thermal lithosphere would contribute with a 16% of the Central Andes elevation.

Nevertheless, it is clear that the Andean elevation is originated principally by crustal thickening leaded by isostasy. The main factor responsible for this thickening is the strong crustal compressive shortening, since magmatic addition is not considered as too much significant. If upper mantle heterogeneities exist, these shortenings will change.

Taking the topographic excedents and the crustal roots defined by observed and regionalized Bouguer anomalies inversion of both essentially crustal gravimetrical models (Figs. 6-7), shortenings will be:

$$S_h\,(22°\text{S}) = (1\,830 + 12\,900)\ \text{km} / 35 = 420\ \text{km}$$
$$S_h\,(24.5°\text{S}) = (1\,500 + 11\,800)\ \text{km} / 35 = 380\ \text{km}$$

The values found by Isacks (1988) for his model without lithospherical heating, agree with these results. Considering model 2 with 16% by thermal expansion, 9% by magmatic addition, shortenings will decrease 25% that is 315 km and 285 km respectively. In fact, these will be apparent shortenings, due to the uncertainties in:

- the initial crustal conditions choice. (Note that if initial crustal thickness is (35±5) km, uncertainty of approximately 14%, shortenings will be 490 km to 368 km, and 443 km to 332 km for the respective sections. The variation range is 110 km to 122 km).
- Introcaso et al. (1992) have pointed out that the gravimetric models, and also seismic-gravimetric models, give crustal thicknesses with at least 10% of uncertainty.
- as it can be seen in Table 1, both magmatic addition and upper mantle heterogeneities produce changes in the shortenings.

Nevertheless, shortening apparent values found in 22°S and 24.5°S reveal a diminution of 40 km in the shortening southwards, and as it was pointed out by Schmidt et al. (1993) and by us in this paper (see crustal gravimetric models) crustal characteristics change southwards.

CONCLUSIONS

From the preliminary theoretical models presented in this paper, we have shown that:

(1) The anomalous upper mantle below the Central Andes would produce: (a) additional elevation of about 16% caused by heating at the lower half of the thermal lithosphere, and (b) subsidence of about 18% caused by "cool" Nazca Plate subduction. To keep the isostatic equilibrium in these conditions, leaving observed Andean masses fixed, the crust would have to change its thickness. For case (a), crustal thickness would have to diminish about 5 km maximum, which is 8% of the thickness without heating. For case (b), the thickness would have to increase about 6 km, which is 9% of the thickness without anomalous upper mantle effects. These effects, being taken individually, modify shortenings in not neglectable values. In fact, the amount of crustal shortenings change, according to the involved mechanisms.

If we admit a model like model 2, involving thermal expansion, crustal shortening will diminish 17% respect to the Airy model. If we also consider heating inducing magmatic intrusion in the crust, and this intrusion is 5% of the materials of the heated zone, crustal shortening will diminish 29% respect to the classic Airy model shortening, by the influence of both mechanisms magmatic addition in crust and heating in the thermal lithosphere.

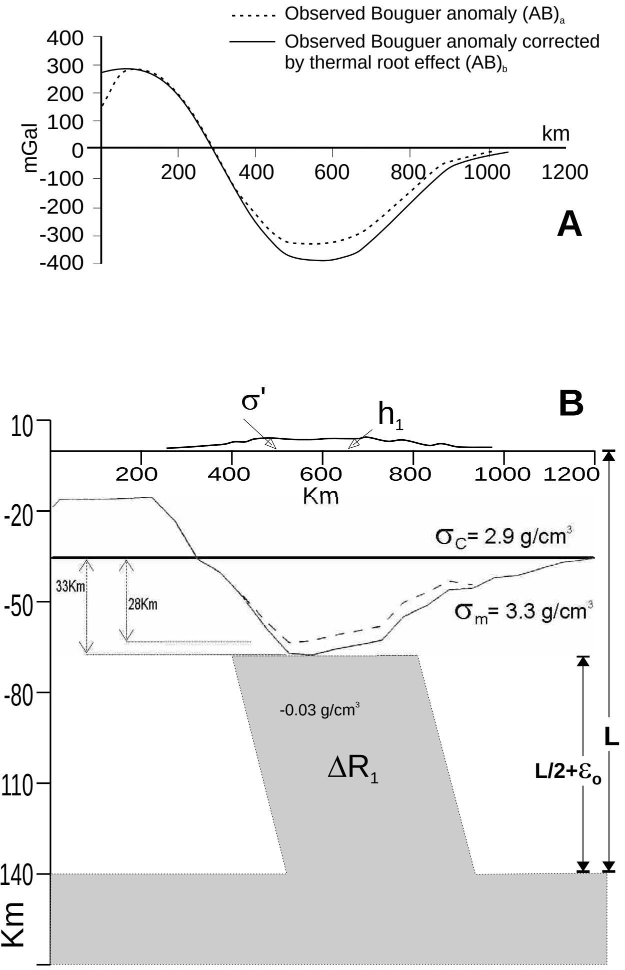

Figure 6. A: Regional observed Bouguer anomaly on 22° S latitude and regional observed Bouguer anomaly corrected by the gravimetric effect due to the lithospherical thermal root; B: Crustal thicknesses correponding to Models 1 and 2 (see Fig. 1A-B). ***Figura 6.*** *A: Anomalía regional de Bouguer observada en latitud 22° S y anomalía regional de Bouguer corregida por el efecto gravimétrico de la raíz térmica litosférica; B: Espesores corticales correspondientes a los Modelos 1 y 2 (véase Fig. 1A-B).*

On the contrary, for model 3 involving subduction effects, shortening will be 18% respect to the Airy model. Finally, admitting all mentioned mechanisms are present, crustal shortening will diminish 9% respect to the Airy model.

The observed shortenings involve uncertainties in the evaluations of either the topographic areas or the compensating roots (Introcaso et al. 1992). They also depend on the initial conditions, for example on the "normal" crustal thickness and on probable density changes produced by metamorphism. Because of this, they would have to be named as apparent shortenings.

(2) The system chosen to evaluate isostatic equilibrium is not critical. So, taking a classic isostatic model like Airy model (model 1), maximum amplitudes of isostatic anomalies found over models rigorously compensated at a depth of 140 km (model 2) and 300 km (models 3 and 4) are

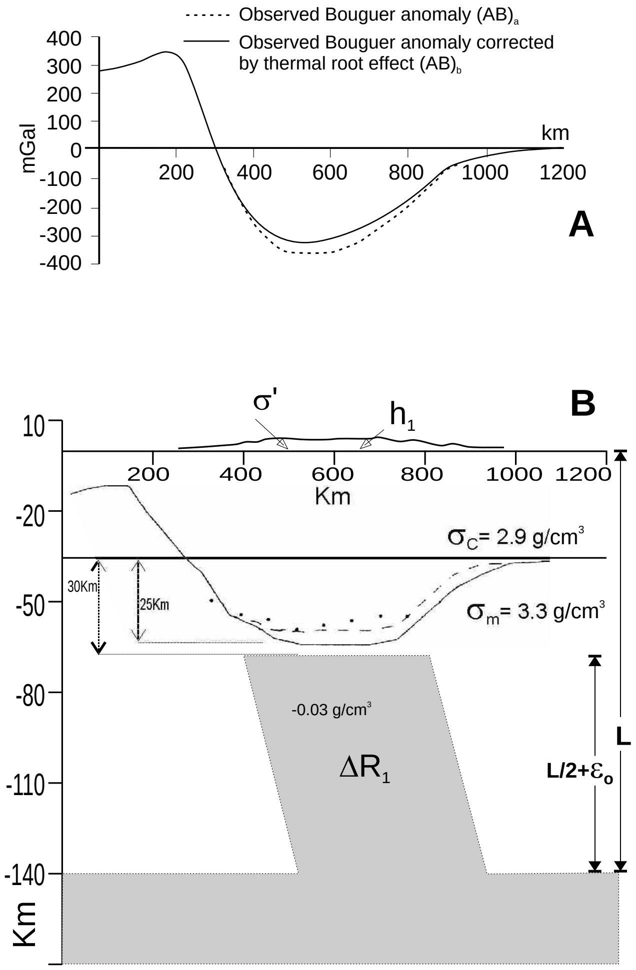

Figure 7. A: Regional observed Bouguer anomaly on 24.5° S latitude and regional observed Bouguer anomaly corrected by the gravimetric effect due to the lithospherical thermal root; B: Crustal thicknesses correponding to Models 1 and 2 (see Fig. 1A-B). Note the consistence between the crustal thickness of Model 2 and the seismic data indicated by black points. ***Figura 7.*** *A: Anomalía regional de Bouguer observada en latitud 24.5° S y anomalía regional de Bouguer corregida por el efecto gravimétrico de la raíz térmica litosférica; B: Espesores corticales correspondientes a los Modelos 1 y 2 (véase Fig. 1A-B). Notar la consistencia entre los espesores corticales del Modelo 2 y los datos sísmicos indicados por puntos negros.*

very small, less than 10% of the Bouguer anomalies. This guarantees that the isostatic equilibrium state can be analyzed independently of the selected model.

For 22°S and 24.5°S sections of this paper, the isostatic anomalies in continental zone -using an Airy system- are small, in general terms, respect to the Bouguer anomalies, pointing out a tendency to compensation.

(3) For the section located at 24.5°S, the seismic crustal model with a maximum depth of 60 km is consistent with the gravimetric crustal model involving heating at the lower half of the lithosphere, combined with crustal shortening. Since lithospheric heating may be a regional phenomena, it would also affect the section located at 22°S. In this case, the classic model without heating would give a maximum Moho depth of 68 km and 63 km with a thermal root located at the lower half of the lithosphere.

From the mentioned heating, it is possible that partial melt and magmatic intrusion of 5% of the thermal root area, could exist.

Finally, we point out that gravimetric models satisfying seismic depths (for example 60 km on 24.5°S latitude) are not the only ones, because of the well known ambiguities of the potential field.

(4) Great crustal increasing in thickness and width have been found out from the observed Bouguer anomalies on 22°S and 24.5°S latitudes. Using them, we have computed great rough shortenings of 420 km and 380 km respectively.

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LOWER AND MIDDLE TITHONIAN MARINE GASTROPODS FROM THE NEUQUÉN-MENDOZA BASIN, ARGENTINA.

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Boletín del Instituto de Fisiografía y Geología

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Abstract. Samples of marine Lower and Middle Tithonian gastropods from Picún Leufú, Cañadón de los Alazanes, Cerro La Parva (Neuquén) and Casa Pincheira (Mendoza) have provided three undescribed species. These are: *Exelissa? arcuatoconcava* nov. sp. (*Mendozanus* Biozone), *Sinuarbullina melehuensis* nov. sp. (*Zitteli* Biozone) and *Dicroloma?* sp. (*Mendozanus* Biozone).
Key-Words: Tithonian, Gastropods, Neuquén-Mendoza basin, Argentina.

Resúmen. Gastrópodos marinos del Tithoniano Inferior y Medio de la cuenca Neuquén-Mendoza, Argentina. Muestras de gastrópodos marinos del Tithoniano Inferior y Medio de Picún Leufú, Cañadón de los Alazanes, Cerro La Parva (Neuquén) y Casa Pincheira (Mendoza) contienen las siguientes especies: *Exelissa? arcuatoconcava* nov. sp. (*Mendozanus* Biozone), *Sinuarbullina melehuensis* nov. sp. (*Zitteli* Biozone) and *Dicroloma?* sp. (*Mendozanus* Biozone).
Palabras clave: Tithoniano, Gastrópodos, Cuenca Neuquén-Mendoza, Argentina.

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INTRODUCTION

Marine Upper Jurassic gastropods of the Neuquén-Mendoza basin are recorded only by sparse citations or descriptions in literature (*e.g.*, Behrendsen 1922). Nevertheless, these mollusks are common in distal and proximal facies at several localities of the basin. Gastropods frequently occur associated with ammonites and bivalves (sometimes abundant and apparently diverse).

In the present report we describe gastropods from marine Tithonian sediments belonging to the *Mendozanus* and *Zitteli* Biozones which were collected in last years. The samples are dated by the associated ammonites.

Palaeoecological implications can not be drawn from this first study, mainly due to the unknown protoconch and thus data on the life histories of the new species.

MATERIAL

The gastropods studied come from four localities of the Neuquén-Mendoza basin, from South to North (Fig. 1):

Picún Leufú, Neuquén (Figs. 1-2).- These specimens were extracted from the bodychambers of specimens of the ammonites *Euvirgalithacoceras malarguense* (Spath), *Torquatisphinctes* cf. *mendozanus* (Burckhardt) and *Neochetoceras*? sp. Gastropods are relatively abundant in the bodychamber of many of the ammonites occurring associated within a single level, at the top of the Tordillo Fm. (= Quebrada del Sapo Fm., Digregorio 1972). This level is a basal bed of the Lower Tithonian *Mendozanus* Biozone, approximately Hybonotum Zone in age.

Cañadón de los Alazanes (Figs. 1-2).- Four specimens obtained from nodules of level CA02 of the section described in Parent (2001), belonging to the *Zitteli* Biozone and containing the ammonite *Pseudolissoceras zitteli*, lamellaptychus, bivalves, and the gastropods.

Cerro de La Parva, Neuquén (Figs. 1-2).- These specimens were extracted from the bodychamber of a juvenil macroconch specimen of *Pseudolissoceras zitteli* (Burckhardt). The ammonite was collected at about 15 meters above the base of the Vaca Muerta Fm., in a bed of bituminous shales containing exclusively small specimens of *P. zitteli*; below, some Lithacoceratines occur in bituminous dark, fine sandstones. The vertical range of *P. zitteli* defines the homonymous biozone throughout the basin (Leanza 1980) and should be Semiforme Zone in age, although the age is expected to differ in distinct areas of the basin (Parent & Capello 1999).

Casa Pincheira, Mendoza (Figs. 1-2).- These specimens were extracted from the bodychamber of specimens of *Euvirgalithacoceras malarguense* (Spath). These ammonites were collected in level G15 of the local section (Parent *in press*, Parent & Capello 1999). This level is a bed at the top of the Tordillo Fm., belonging to the base of the Lower Tithonian *Mendozanus* Biozone, approximately Hybonotum Zone in age.

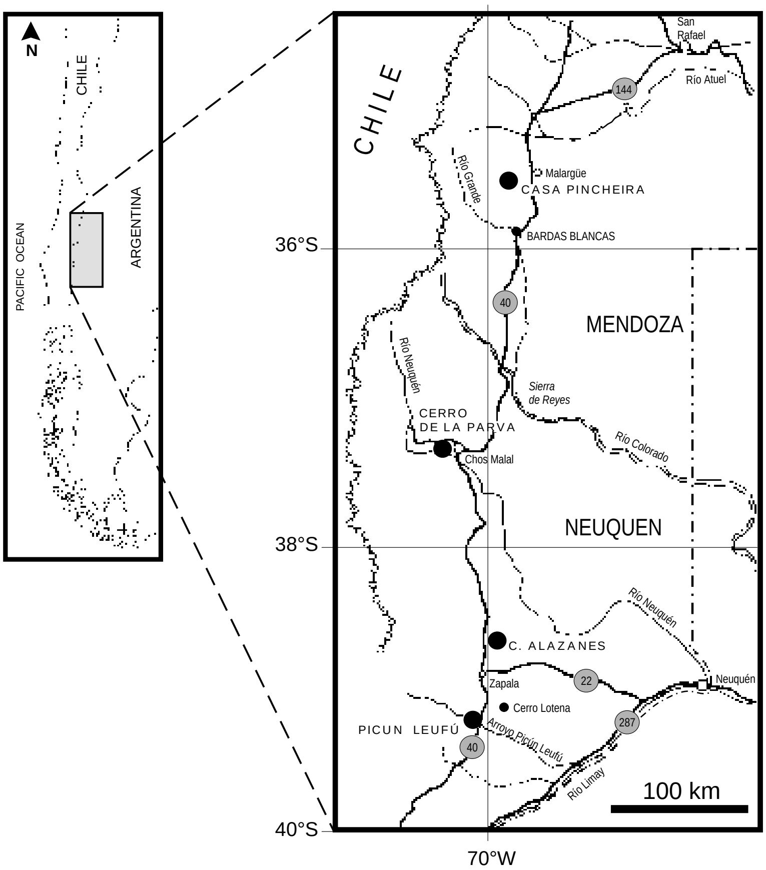

Figure 1. Reference map. Southern sector of the Neuquén-Mendoza basin. ***Figura 1***. *Mapa de referencia. Sector sur de la cuenca Neuquén-Mendoza.*

SYSTEMATIC PALEONTOLOGY

The specimens are housed at Laboratorio de Paleontología y Biocronología (LPB), Universidad Nacional de Rosario, and Museo Olsacher (MOZP), Zapala, Neuquén.

Subclass Caenogastropoda Cox, 1959
Order Cerithimorpha Golikov & Starobogatov, 1975
Superfamily Cerithoidea Fleming, 1823
Family Procerithiidae Cossmann 1905
Genus *Exelissa* Piette, 1860

Exelissa? arcuatoconcava nov. sp.

Fig. 3A-D

Derivatio nominis. Lat. *arcuatus* - bent and concavus - concave; after the opisthocyrt axial ribs.
Holotype. The specimen on Fig. 3A-C (MOZP 6419/1).
Locus typicus. Picún Leufú, Neuquén, Argentina.
Stratum typicum. Lower Tithonian *Mendozanus* Biozone.
Paratypes. Five specimens, one from Picún Leufú (MOZP 6419/1) and four from Casa Pincheira, Mendoza (LPB 193/1-4).
Diagnosis. The slender shell has convex teleoconch whorls with distinct sutures. Last whorl with about 10 axial ribs. The ribs are strongly and asymmetrically opisthocyrt and are apically thickened and bend abapical strongly toward the aperture. On the abapical part of the whorls and on the base 8-10 spiral furrows are developed.

Description. The material is badly preserved. Only the holotype shows details of the sculpture. It consists of 5 teleoconch whorls (the top of the shell is lacking) and is 4.2 mm high and 1.6 mm broad. The shell is slender and has convex whorls with distinct sutures. On the whorls about 8-10 axial ribs are developed. The ribs are strongly and asymmetrically opisthocyrt and strongest in their apical third. On the last whorl they have nodes on their apical end. Abapically the ribs weaken and become indistinct. The growth lines run parallel to the axial ribs. In the abapical part of the whorls 4-5 spiral furrows are recognizable. Two furrows above the suture are particularly clear visible. The base is convex and without axial ribs but with further 4-5 spiral furrows. The growth lines are prosocyrt on the base. The aperture is not preserved.

Remarks. The assignment of the species to the genus *Exelissa* is provisional. The teleoconch sculpture is unusual for the genus, but some *Exelissa* species have a similar pattern of axial and spiral ribs [for example, *E. costaminuera* Gründel, Pélissié & Guérin, 2000 from the Middle Jurassic of France, or *Procerithium (Rhabdocolpus) carbonarium* (F.A. Roemer) according to Huckriede 1967 from the Wealden of northwestern Germany (=*Exelissa*?)]. The last mentioned species has higher whorls and more (nearly 20) spiral furrows. *Cerithium diadematum* Quenstedt, uppermost Jurassic of Germany, has straighter whorl flanks, the axial ribs are more numerous and the spiral furrows cover the whole whorl surface (Kuhn 1939). The taxonomical position of *E.? arcuatoconcava* remains unresolved since the protoconch and the aperture are unknown.

Occurrence. Lower Tithonian *Mendozanus* Biozone.

Order "Meta-Mesogastropoda" Bandel, 1994
Superfamily Stromboidea Rafinesque, 1815
Family Aporrhaidae Philippi, 1836
Genus *Dicroloma* Gabb, 1868

Dicroloma? sp.

Fig. 3E-G

Material. A single specimen from Picún Leufú, Neuquén.
Description. The incomplete shell consists of 3.5 whorls and is 11.5 mm high and 8.0 mm wide. The early whorls of the shell and the adult aperture are missing. The specimen is a steinkern with some remains of the shell preserved. The

Andean Biozonation	Picún Leufú	Cañadón de los Alazanes	Chacay Melehué (Cerro de la Parva)	Casa Pincheira
Zitteli Biozone		Gastropods: *?S. melehuensis* n. sp. Ammonites: *P. zitteli* [M&m] **Semiforme Zone**	Gastropods: *S. melehuensis* n. sp. Ammonites: *P. zitteli* [M&m] **Semiforme Zone**	Ammonites: *P. zitteli* **Semiforme Zone**
Mendozanus Biozone	Gastropods: *E.? arcuatoconcava* n. sp., *Dicroloma*? sp. Ammonites: *E. malarguense* [M&m], *T.* cf. *mendozanus*, *Neochetoceras*? sp. **Hybonotum Zone**		Ammonites: *Euvirgalithacoceras sp.* *Choicensisphinctes? sp.* **Hybonotum-Darwini? Zones**	Gastropods: *E.? arcuatoconcava* n. sp. Ammonites: *E. malarguense* [M&m] **Hybonotum Zone**

Figure 2. Summary of stratigraphic and geographic distribution of described gastropods and the associated ammonites. ***Figura 2****. Sumario de la distribución estratigráfica y geográfica de los gastrópodos descriptos y de los amonites asociados.*

flanks of the whorls have a strong keel at about mid-whorl. The part of the whorl apically of the keel is bent against the apex and is not ornamented. The part between keel and abapical suture is nearly vertical and concave. On it two weak spiral ribs are recognizable. Growth lines are strongly opisthocyrt and weakly opistocline. Their abapical section is strongly bent forward. A second keel forms the transition to the convex base that, apparently, is unsculptured.

Remarks. The shape and sculpture of the shell are very similar to those of *Dicroloma* and *Bicorempterus* (Gründel 2001). But the protoconch and first teleoconch whorls are unknown, therefore the generic assignment is uncertain.

Occurrence. Lower Tithonian *Mendozanus* Biozone.

Subclass Heterostropha Fischer, 1885
Order Opisthobranchia Milne-Edwards, 1848
Superfamily Cylindrobullinoidea Wenz, 1947
Family Cylindrobullinidae Wenz, 1947

Genus *Sinuarbullina* Gründel, 1997

Remarks. The genus is known with a few species from the Lower and Middle Jurassic of Central Europe. The main diagnostic feature in relation to *Actaeonina* and *Cylindrobullina* are the growth lines with their strong opisthocyrt sinus below the apical suture. The known species from Europe are completely smooth. Only the growth lines may be partly strengthened. In contrast, the here described species has spiral furrows on the base.

Differences. Very similar is *Ptychostylus* Sandberger, 1870. This genus is known from brackish water sediments (Arkell, 1941; Huckriede, 1967; Bandel, 1991). The type species has a columellar fold and axial ribs.

Sinuarbullina melehuensis nov. sp.

Fig. 3H-N

Derivatio nominis. After the type locality.
Holotype. The specimen in Fig. 3K-N (LPB 418/1).
Locus typicus. Cerro La Parva, Chacay Melehué area, Neuquén.
Stratum typicum. Middle Tithonian *Zitteli* Biozone.
Paratypes. Two specimens (LPB 418/2-3).
Diagnosis. The shell is rather broad for the genus. The teleoconch whorls have a broad and sloping ramp. The base of the shell is covered with more than 10 spiral furrows. The aperture is apically narrowly rounded.

Description. The shell with about three teleoconch whorls is nearly 4.5 mm high. The width is variable, the specimens are slender to rather broad. The heterostrophic protoconch forms an angle with the axis of the teleoconch. Its diameter is 0.4 mm. The teleoconch whorls have a distinct and sloping ramp. A rounded edge forms the transition to the flanks of the whorls which are weakly convex. Sculpture is missing on this part of the shell; only the growth lines are somewhat strengthened. They are strongly opisthocyrt in their apical part and form here a distinct sinus. More abapically and on the base they are prosocyrt. The base is strongly convex and covered with more than 10 spiral furrows. The apical furrows are only weakly developed and they become stronger near the centre of the base. The aperture is highly oval and apically narrowly rounded. The outer lip is only weakly convex. The inner lip is divided in a parietal and a columellar part. A fold is not recognizable, but the aperture is filled with matrix.

Remarks. A concretion from the *Zitteli* Biozone of Cañadón Los Alazanes, Neuquén yielded a steinkern with external mold and an external mold of a specimen which almost certainly belongs to *Sinuarbullina melehuensis*; but growth lines and spiral furrows are not visible, thus the identification with *S. melehuensis* is uncertain.

Differences. Sinuarbullina ansorgi Gründel, 1997 is similar but older (Bathonian), smaller (about 1.6 mm high) and has no spiral sculpture. *Sulcoactaeon leblanci* (Loriol, 1875) from the uppermost Jurassic of Europe, is smaller, has no ramp; moreover *S. leblanci* has a sub-sutural spiral furrow and the shape of the aperture is different (Hägele 1997). *Acteonina collina* according to Thurman & Etallon (1881-1884) (Kimmeridgian) is very similar but has no sculpture. *Cylindrobullina miliola* d'Orbigny, from the Oxfordian of Europe, is smaller, the ramp is indistinct and spiral furrows are lacking (Cossmann 1895). *Ptychostylus guimarotensis* Bandel, 1991 (transition Jurassic / Cretaceous, brackish water sediments) is smaller, the greatest width of the whorls is situated near the ramp, the growth lines are not so strongly sinuous, spiral furrows are lacking and a columellar fold is developed.

Occurrence. Middle Tithonian *Zitteli* Biozone.

Figure 3. A-C: *Exelissa*? *arcuatoconcava* nov. sp., holotype (MOZP 6419/1), Picún Leufú, Neuquén, Argentina; Lower Tithonian *Mendozanus* Biozone. **A:** Shell in side view (height 4.2 mm); **B-C:** Part of the shell in side views (heights of the sections 3.7 mm and 3.2 mm). **D:** *Exelissa*? *arcuatoconcava* nov. sp., paratype (LPB 193/2), Casa Pincheira, Mendoza, Argentina; Lower Tithonian *Mendozanus* Biozone. Shell in side view (height 4.0 mm). **E-G:** *Dicroloma*? sp. (LPB 622), Picún Leufú, Neuquén, Argentina; Lower Tithonian *Mendozanus* Biozone. **E-F:** Shell in two side views (height 11.2 mm); **G:** Part of the shell enlarged with sculpture details (width of the teleoconch whorl 4.3 mm). **H-J:** *Sinuarbullina melehuensis* nov. sp., paratype (LPB 418/2), Cerro La Parva, Chacay Melehué area, Neuquén, Argentina; Middle Tithonian *Zitteli* Biozone. Shell in three side views (height 5.0 mm). **K-N:** *Sinuarbullina melehuensis* nov. sp., holotype (LPB 418/1); Cerro La Parva, Chacay Melehué area, Neuquén, Argentina; Middle Tithonian *Zitteli* Biozone. **K:** Growth lines (height of the section 0.9 mm); **L:** Protoconch (diameter 0.4 mm); **M:** Shell in side view (height 4.0 mm); **N:** Last whorl with sculpture (spiral furrows) on the base (height of the section 2.5 mm). **Figura 3. A-C:** *Exelissa*? *arcuatoconcava* nov. sp., holotipo (MOZP 6419/1), Picún Leufú, Neuquén, Argentina; Tithoniano Inferior, Biozona *Mendozanus*. **A:** Vista lateral de la concha (altura 4.2 mm); **B-C:** Vistas laterales de parte de la concha (alturas de las secciones 3.7 mm y 3.2 mm). **D:** *Exelissa*? *arcuatoconcava* nov. sp., paratipo (LPB 193/2), Casa Pincheira, Mendoza, Argentina; Tithoniano Inferior, Biozona *Mendozanus*. Vista lateral de la concha (altura 4.0 mm). **E-G:** *Dicroloma*? sp. (LPB 622), Picún Leufú, Neuquén, Argentina; Tithoniano Inferior, Biozona *Mendozanus*. **E-F:** Vistas laterales de la concha (altura 11.2 mm); **G:** Ampliación parcial de la concha mostrando detalles de la ornamentación (ancho de la vuelta de teleoconcha 4.3 mm). **H-J:** *Sinuarbullina melehuensis* nov. sp., paratipo (LPB 418/2), Cerro La Parva, Chacay Melehué area, Neuquén, Argentina; Tithoniano Medio, Biozona *Zitteli*. Tres vistas laterales de la concha (altura 5.0 mm). **K-N:** *Sinuarbullina melehuensis* nov. sp., holotipo (LPB 418/1); Cerro La Parva, Chacay Melehué area, Neuquén, Argentina; Tithoniano Medio, Biozona *Zitteli*. **K:** Líneas de crecimiento (altura de la sección 0.9 mm); **L:** Protoconcha (diámetro 0.4 mm); **M:** Vista lateral de la concha (altura 4.0 mm); **N:** Última vuelta con ornamentación (surcos espirales) en la base (altura de la sección 2.5 mm).

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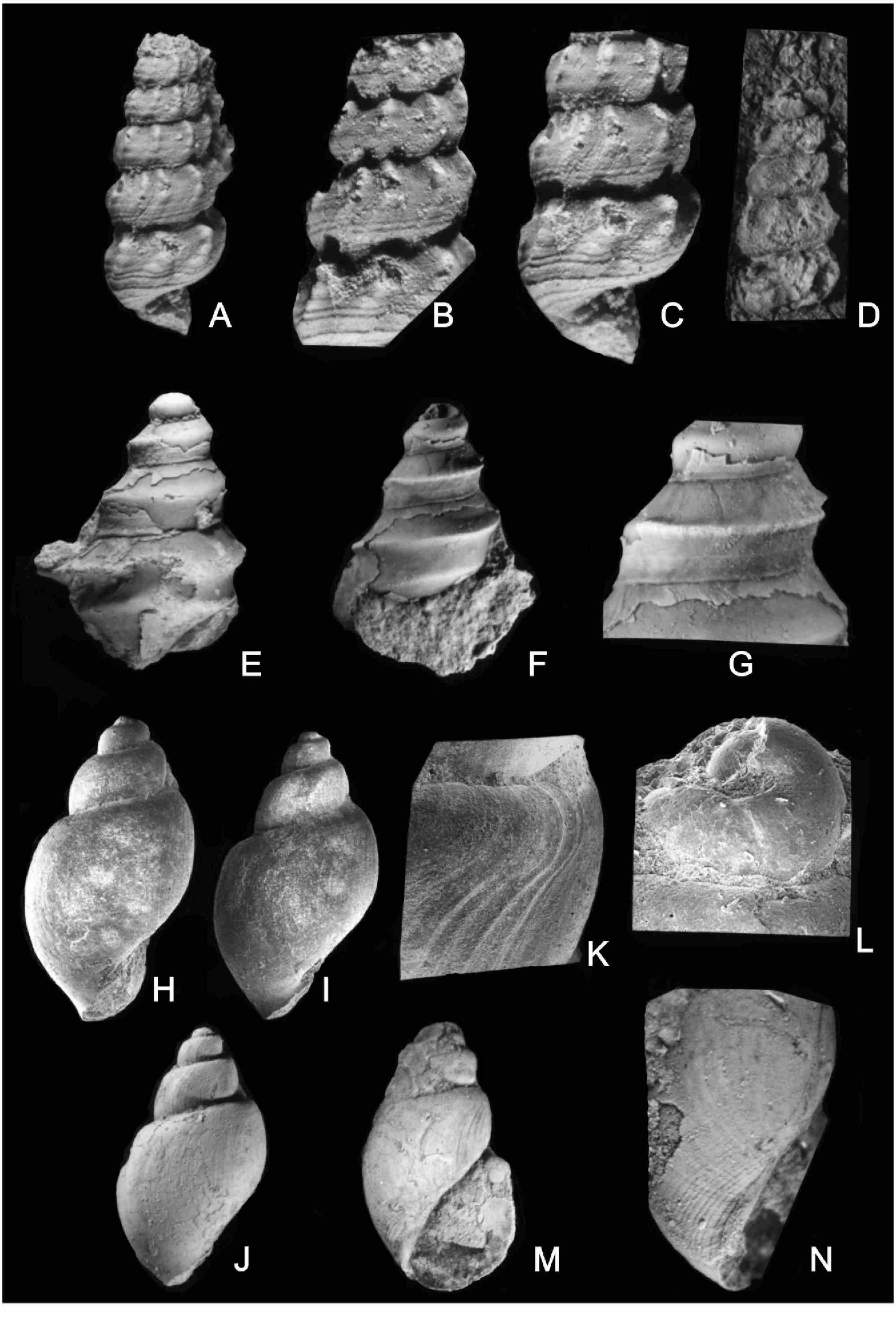
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THE MIDDLE TITHONIAN (UPPER JURASSIC) AMMONOID FAUNA OF CAÑADÓN DE LOS ALAZANES, SOUTHERN NEUQUÉN-MENDOZA BASIN, ARGENTINA.

Horacio PARENT

Boletín del Instituto de Fisiografía y Geología

Parent H., 2001. The Middle Tithonian (Upper Jurassic) ammonoid fauna of Cañadón de los Alazanes, Southern Neuquén-Mendoza Basin (Argentina). [*La fauna del Tithoniano Medio de Cañadón de los Alazanes, sur de la cuenca Neuqúen-Mendoza (Argentina)*]. *Boletín del Instituto de Fisiografía y Geología*, Volúmen 71, Números 1-2, pp. 19-38. Rosario, 25-12-2001. ISSN 1666-115X.

Abstract.- The Middle Tithonian rock and ammonite successions of Cañadón de los Alazanes (southern Neuquén-Mendoza Basin, Argentina), sampled for the first time, correlate almost exactly with those of the close localities Mallín de los Caballos and Mallín Quemado, but showing a comparatively reduced thickness. The studied fauna comprises: *Pseudolissoceras zitteli* (Burckhardt) [M&m], *Neochetoceras*? sp., *Pseudhimalayites subpretiosus* (Uhlig) [M, = *P. steinmanni* (Haupt)], *Torquatisphinctes proximus* (Steuer) transient α and transient β, and *Corongoceras* cf. *alternans* (Gerth) [M]. This fauna shows strong Tethyan affinities enabling close time-correlation with the European standard chronostratigraphic scale. The type specimens of *P. zitteli*, *P. planiusculum* (Zittel), *P. rasile* (Zittel), *C. alternans* and *C. lotenoense* (Spath) are figured. The Haploceratid genus *Pseudolissoceras* Spath most probably originated in Early Tithonian Hybonotum Zone populations of *Haploceras carachtheis* of Crussol (France), widely expanded its biogeographic distribution in the Semiforme Zone in the form of *P. zitteli*, prior to the diachronous disappearence of local adaptations in the Neuquén-Mendoza basin [*P. pseudoolithicum* (Haupt)] and northern Central Tethys (*P. concorsi* Donze and Enay = *P. bavaricum* Barthel). *P. subpretiosus* occurs in the lower Proximus *Biozone* (approximately upper Semiforme-lower Fallauxi Zones), although it appears to range, with its local microconch *Simocosmoceras adversum andinum* Leanza and Olóriz, through the upper *Zitteli* and lower *Proximus* Biozones in other localities of the basin. *T. proximus* occurs abundantly, differentiated in transients α and β, the latter giving gradually origin to the early Andean himalayitids [e.g., *Windhauseniceras internispinosum* (Krantz)] via *Torquatisphinctes*? *windhauseni* (Weaver *sensu* Leanza), a form close to *"Burckhardticeras" peroni* (Roman). Both transients of *T. proximus* are mainly confined to the *Proximus* Biozone and their sexual dimorphism remains unrecognized.

Key words: Middle Tithonian, Neuquén-Mendoza Basin, Ammonoidea, Biogeography, Time-correlation.

Resúmen.- La fauna de ammonoideos del Tithoniano Medio (Jurásico Superior) de Cañadón de los Alazanes, sur de la Cuenca Neuquén-Mendoza (Argentina). Las sucesiones estratigráfica y fáunica de Cañadón de los Alazanes (sur de la cuenca Neuquén-Mendoza, Argentina), muestreadas por primera vez, correlacionan muy estrechamente con las de Mallín de los Caballos y Mallín Quemado, aunque con un espesor comparativamente reducido. La fauna estudiada comprende: *Pseudolissoceras zitteli* (Burckhardt) [M&m], *Neochetoceras*? sp., *Pseudhimalayites subpretiosus* (Uhlig) [M, = *P. steinmanni* (Haupt)], *Torquatisphinctes proximus* (Steuer) transient α y transient β, y *Corongoceras* cf. *alternans* (Gerth) [M]. Esta fauna muestra fuertes afinidades tethysianas lo cual permite establecer correlaciones temporales bastante confiables con la escala cronoestratigráfica europea. Los especímenes tipo de *P. zitteli*, *P. planiusculum* (Zittel), *P. rasile* (Zittel), *C. alternans* y *C. lotenoense* (Spath) son figurados. El género *Pseudolissoceras* Spath, probablemente originado en poblaciones de *Haploceras carachtheis* de Crussol (Francia), expandió ampliamente su distribución biogeográfica durante la Zona Semiforme bajo la forma de *P. zitteli*. Siguiendo un patrón de desaparición diacrónica los últimos representantes del género se conocen en la cuenca Neuquén-Mendoza [*P. pseudoolithicum* (Haupt)] y en el norte del Tethys Central (*P. concorsi* Donze y Enay = *P. bavaricum* Barthel) como adaptaciones locales. *P. subpretiosus* (Uhlig) ocurre en la parte inferior de la Biozona *Proximus* (aproximadamente Zona Semiforme superior-Fallauxi inferior), aunque parece extenderse, junto con su microconcha local, *Simocosmoceras adversum andinum* Leanza y Olóriz, desde la parte alta de la Biozona *Zitteli* en otras localidades de la cuenca. *T. proximus* ocurre abundantemente diferenciado en dos formas transicionales (transients α y β), la mas tardía dando orígen gradual a los himalayítidos andinos tempranos [e.g., *Windhauseniceras internispinosum* (Krantz)] via *Torquatisphinctes*? *windhauseni* (Weaver *sensu* Leanza), forma muy cercana a *"Burckhardticeras" peroni* (Roman). Ambos transients de *T. proximus* están principalmente confinados en la Biozona *Proximus* y su dimorfismo sexual no ha sido aún reconocido con certeza.

Palabras clave: Tithoniano Medio, Cuenca Neuquén-Mendoza, Ammonoidea, Biogeografía, Correlación temporal.

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INTRODUCTION

During petroleum prospection in Neuquén Province, a new section of the Andean Tithonian was recently exposed in Cañadón de Los Alazanes (Fig. 1), near Manzano Escondido at the southern tip of Cordón Curymil, Sierra Vaca Muerta (Hoja Geológica 35b Zapala, Lambert 1956). In a recent field work Middle and Upper Tithonian and typically Perigondwanic ammonites were collected in that section. Tithonian ammonites from this locality were never described, only some indirect references may be found in Lambert (1956). Although the material is scarce its description is useful both paleontologically and biostratigraphically on the basis of the precise sampling of the succession and the occurrence of some taxa which need revision or are poorly known.

The associated gastropod fauna from beds CA02-04 (Fig. 2) is described by Gründel and Parent (2001).

The aim of this paper is to describe the new section and its ammonite fauna and to discuss the biostratigraphical and chronostratigraphical implications of the faunal succession and assemblages.

STRATIGRAPHY

Through the transect Mallín Quemado-Portada Covunco (Fig. 1), the Middle Tithonian spreads through about 100 to 200 m, whereas the whole Tithonian may reach a thickness of 833 m in Mallín Quemado and 1000 m near Mallín de los Caballos, of which no more than 100 to 150 m belong to the Lower Tithonian *Mendozanus* Biozone (cf. Leanza 1973, Leanza and Hugo 1977).

The studied section is shown in Figure 2. The lowermost part (*Mendozanus* Biozone) is covered, and therefore only some loose fragments of Lithacoceratids were seen in the field. The Middle Tithonian strata (*Zitteli*, *Proximus* and *Internispinosum* Biozones) span about 35 m in the Vaca Muerta Fm. They consist of black shales with limestone concretions at the base, and limestone and mudstone banks upwards in the section. The lithologic and ammonite successions of Cañadón de los Alazanes (Fig. 2) are the same as at Mallín Quemado and Mallín de los Caballos (cf. Leanza 1973, Leanza 1975, Leanza and Hugo 1977), but it is a half of the thickness, decreasing from Mallín de Los Caballos, surely in relation with the proximity to the shelf edge at Cañadón de los Alazanes. At the top, the Picún Leufú Fm. consisting of yellow massive limestones overlies the black shales and marls of the upper part of the Vaca Muerta Fm. (see Lambert 1956: fig. 4, Leanza 1973, Leanza and Zeiss 1990, 1992) from which were collected Berriasian ammonites near Los Catutos (between Zapala and Portada Covunco). These yellow limestones must correpond to the distal lens of the Picún Leufú Fm. described by Leanza (1973).

The lithology suggests a relatively deep and poorly oxigenated environment, becoming somewhat shallower and more oxigenated towards the upper part, in which the proportion of limestone beds increases. The oxidation of Iron ($Fe^{2+} \rightarrow Fe^{3+}$) by weathering results in a reddish-brown coloration of the limestones, and there is no shell debris, thus indicating deposition in a poorly oxigenated, confined environment. These depositational conditions suggest distal platform, close to the talus, which fits well with the facies maps given by Gulisano (*in* Riccardi et al. 1992), Leanza et al. [1977: 200 (fig. 2)], and to the above indicated gradient of thickness, showing a decreasing trend from Mallín de Los Caballos (talus to central basin) towards Cañadón de los Alazanes (shelf edge).

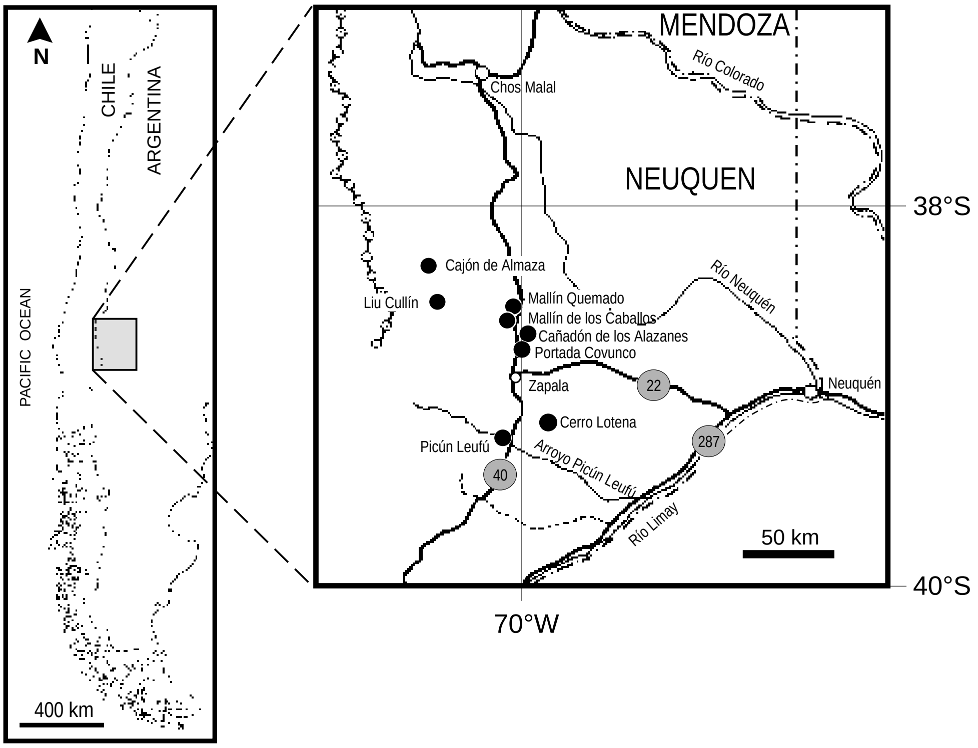


Figure 1. Reference map. Southern Neuquén-Mendoza basin. ***Figura 1.*** *Mapa de referencia. Sur de la cuenca Neuquén-Mendoza.*

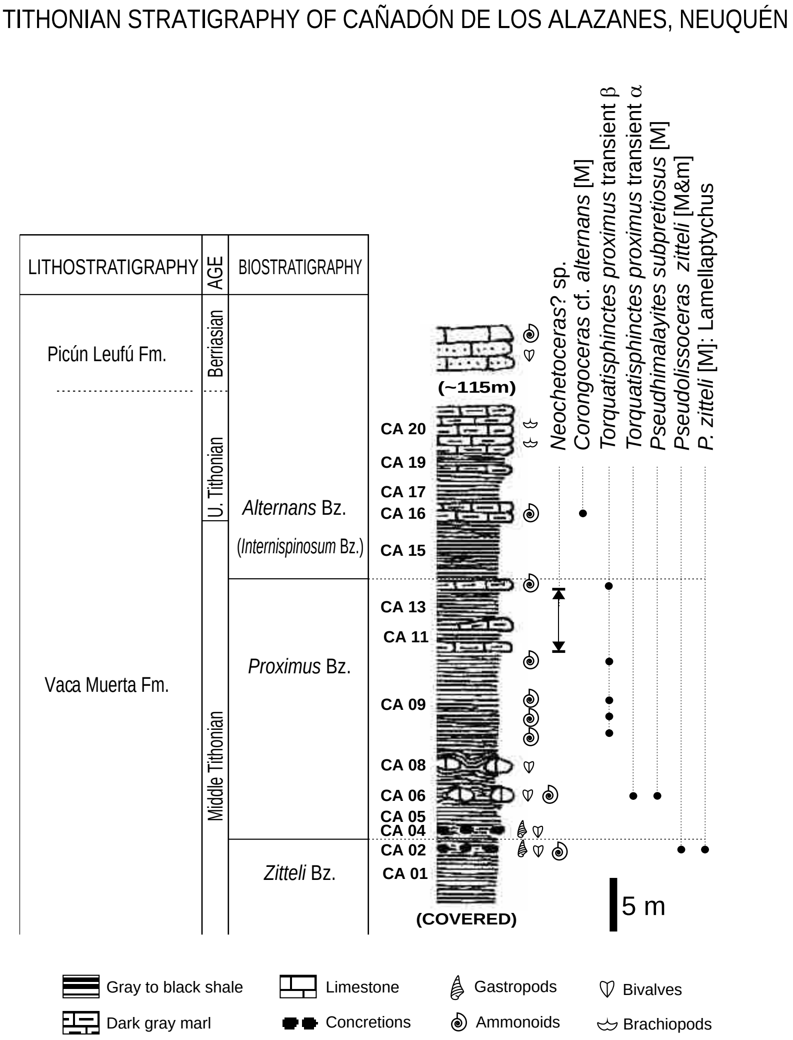


Figure 2. Log-section and ammonites of Cañadón de los Alazanes, southern end of Cordón Curymil, Sierra de Vaca Muerta, Neuquén. Lito- and biostratigraphic classifications modificated from Leanza (1981) as indicated in text and Figure 10. ***Figura 2.*** *Columna litológica y amonites de Cañadón de los Alazanes, extremo sur del Cordón Curymil, Sierra de Vaca Muerta, Neuquén. Clasificaciones lito- y bioestratigráfica modificadas de Leanza (1981) como se indica en el texto y en Figura 10.*

SYSTEMATIC PALEONTOLOGY

The studied material is housed at the Laboratorio de Paleontología y Biocronología (LPB), Universidad Nacional de Rosario and Museo Prof. Olsacher (MOZP), Zapala, Neuquén. Photographs and casts of type and other specimens were kindly provided by Martin Sander (Paläontologisches Institut der Universität Bonn, GPIBO) and Gerhard Schairer (Bayerische Staatssammlung für Paläontologie und Geologie, BSPM). Measurements are indicated as follows: diameter (*D*), diameter at the last adult septum (*D*ls), final adult diameter at peristome (*D*p), umbilical width (*U*), whorl width (*W*), whorl height (H_1), and whorl ventral height (H_2), all given in millimeters [mm]; counts of number of primary (*P*) and ventral (*V*) ribs per half-whorl; length of bodychamber (*LBC*) in degrees [°]. Bodychamber is abbreviated with BC and phragmocone with Ph; female (macroconch): [M], male (microconch): [m].

Superfamily Haplocerataceae Zittel, 1884

Family Haploceratidae Zittel, 1884

Genus *Pseudolissoceras* Spath, 1925

Type species. Neumayria zitteli Burckhardt, 1903 by SD Roman (1938); Middle Tithonian of Argentina.

Discussion. The genus has been treated in some detail by Barthel (1962) and Olóriz (1978). Recently published data and new stratigraphically well located material from Cañadón de los Alazanes, Cerro Lotena and Chacay Melehué (Neuquén-Mendoza Basin) allow to review briefly the taxonomy and biostratigraphy of the species of the genus. The first step in support of the discussion below is to figure photographically the type specimens of the oldest nominal species whose type specimens were originally figured by hand-drawing pictures: *P. zitteli* (Burckhardt, 1903) (Fig. 3A-B, Table 1), *P. planiusculum* (Zittel, 1870) (Fig. 3C-D, Table 1), and *P. rasile* (Zittel, 1870) (Fig. 3E, Table 1).

The genus is widely distributed (see Cecca 1999 for references) through the Central Tethys (*sensu* Cecca 1999), Kurdistan (Northern Iran), the Caribbean Province (Mexico and Cuba), the Neuquén-Mendoza Basin (Argentina), and South Primorie (Far East Russia). There are few, bad preserved specimens from Alexander Island, Antarctica described as *Pseudolissoceras*? sp. by Thomson (1979: 12, pl. 3: b) which most probably belong to *Haploceras* taking in consideration the aspect of the suture line (Thomson 1979: fig. 4c), which is the most consistent diagnostic feature of the genus *Pseudolissoceras*. Derivation of *Pseudolissoceras* from *Haploceras* Zittel, in the Lower Tithonian Hybonotum Zone, appears to be the most plausible hypothesis accounting for: 1) sutures differ only in the broader first lateral lobe and lower lateral saddle of *Pseudolissoceras*, 2) inner whorls of *P. zitteli* (described below) are closely comparable with those of *Haploceras*, 3) lower mandibles described for the species of both genera are of the same type (Lamellaptychus = Laevilamellaptychus), 4) sexual dimorphism is similar in both genera (see description of *P. zitteli* below). The most probable ancestor by stratigraphic position and morphological aspect appears to be the Hybonotum Zone *Haploceras carachtheis* (Zeuschner, 1846) [M&m] from Crussol (France) described by Enay and Cecca (1986: pl. 2: 10, pl. 4: 3). In the Mediterranean and Submediterranean domaines of the Tethys the most complete succession of morphospecies of *Pseudolissoceras* is recorded which may be compiled from Barthel (1962), Olóriz (1978), Cecca and Santantonio (1988), and Fözy (1988). These morphospecies have in common the inner whorls rounded, depressed and widely umbilicated (Figs. 4A-B, 5E); by the aspect of the outer whorls they are commonly separated in the *P. zitteli*-group and *P. rasile*-group, the latter including the forms with more inflated and widely umbilicated subadult and adult shells (Figs. 3E, 4A-B). Thus, the current structure of the genus is that of a group of sculptureless ammonite morphospecies, having all of them variable vertical range (black vertical bars in Fig. 6). This vertical classification of paralell ranging morphospecies may be converted in a horizontal classification (Simpson 1937, Tintant 1952, Callomon 1985) of chronospecies (labelled by the names in white boxes in Fig. 6) by assuming a broad range of intraspecific variation within essentially monospecific assemblages. The meaning of the vertical range of each morphospecies then become to represent merely the temporal persistence of the morphotype in the clade, as part of the total variation of the chronospecies. The resulting evolutionary sequence of chronospecies could be as follows (Fig. 6):

Pseudolissoceras olorizi Fözy, 1988. The earliest occurrences of the genus are confined to the Hybonotum Zone of Central Tethys: 1) the "Lithographicum Zone" specimen of *Pseudolissoceras* originally included in *Haploceras subelimatum* Fontannes, 1879 (Huguenin's collection at Faculté des Sciences de Lyon; see Donze and Enay 1961: 47), 2) *P. olorizi* Fözy, 1988 [M] from Hungary (see Fig. 5E), and 3) *P. rasile* (Zittel) and *P.* aff. *rasile* from Spain (Olóriz 1978: pl. 2: 6, 11), two macroconchs that could be included in *P. olorizi*.

Pseudolissoceras rasile (Zittel, 1870). In the Darwini Zone of Italy and Spain occurs mainly *P. rasile* (Olóriz 1978; Cecca and Santantonio 1988); *P. olorizi* may persist locally (Fözy 1988).

Pseudolissoceras zitteli (Burckhardt, 1903). Nominally, *P. zitteli* and/or close forms are cited all along the area of geographic distribution of the genus through the interval Semiforme-lower Fallauxi Zones. Most reliable records from European localities appear to indicate Semiforme Zone as the most consistent biochron for *P. zitteli*; the lectotype (Fig. 3A-B) comes from an unknown level of the *Zitteli* Biozone of western Mendoza, most likely Semiforme Zone in age (see below). In these forms the most notorious morphologic change in the evolution of the genus occurs, that is greater involution combined with a moderately variable periumbilical depression on the lower third of the flanks of the last whorls (Figs. 4A-B, 6). Concurrently with this change in modal morphology the genus shortly expands its geographic distribution into Northern Iran (in the form of *P. zitteli* and *P. advena* Spath, 1950 [M], most probably synonyms), Cuba (Myczynski 1989, 1994; Myczynski and Pszczolkowski 1994; Imlay 1942), Mexico (*P. subrasilis* [M], *P.* aff. *subrasilis* Burckhardt 1906 [m], *P. zitteli* [M&m], see Cantu-Chapa 1967, Verma and Westermann 1973, Olóriz et al. 1999, Villaseñor et al. 2000), the Neuquén-Mendoza Basin and South Primorie (*P. zitteli* in Sey and Kalacheva 1996, 1997; Sey et al. 1988). In the upper *Zitteli* Biozone of Neuquén, Argentina, occurs the poorly known *P. pseudoolithicum* (Haupt, 1907), morphologically very close to *P. rasile* (Fig. 6), and here considered as a local adaptation of *P. zitteli*, thus the terminal form of the genus in the Neuquén-Mendoza Basin. Some specimens from the upper *Zitteli* Biozone of Chacay Melehué and Cerro Lotena (Leanza 1980: pl. 1: 5) are transitional in coiling and whorl section between *P. zitteli* and *P. pseudoolithicum*. Arnould-Saget (1951a, 1951b) figured three small specimens from Central Tunisie which belong, in morphologic terms, to *P. rasile-pseudoolithicum*, but they are not useful in the present analysis due to uncertain stratigraphic position within the Tithonian. Similar consideration is applied to several later citations of *Pseudolissoceras* by Memmi (1967) within the Upper Tithonian and Lower Berriasian of Central Tunisie. A complete characterization of *P. zitteli* in the Neuquén-Mendoza Basin is given below.

P. concorsi Donze and Enay, 1961. *P. bavaricum* Barthel, 1962 and *P. concorsi* (northernmost Central Tethys) are defined by almost identical holotypes from the interval upper Semiforme-lower Fallauxi Zones; the stratigraphic position of the holotype of *P. bavaricum* in the lower Fallauxi Zone was recently defined by Scherzinger and Schweigert (1999). These forms show the most accentuated periumbilical depression and more simple suture line (less developed auxiliar elements); the "ceratitic aspect" of the sutures was noted by Barthel (1962: 15), Olóriz (1978: 38) and by G. Schweigert (*pers. comm.* 24-10-2001) and A. Scherzinger (*pers. comm.* 23-11-2001). Moreover, there appears to exist a positive correlation between the simplification of sutures and the accentuation of periumbilical depression, although the basic sutural plan remains unchanged. Transitional in morphology between *P. zitteli* and *P. concorsi-bavaricum*, showing a weak periumbilical depression, are specimens such as those figured as *P.* gr. *bavaricum* (Cecca et al. 1983-1984: pl. 6: 4) and *P. zitteli* (Haupt 1907: pl. 7: 4b). *P. concorsi* is the terminal chronospecies of the genus, probably of the same age like *P.* aff. *zitteli* (*in* Cecca and Santantonio 1988), cited

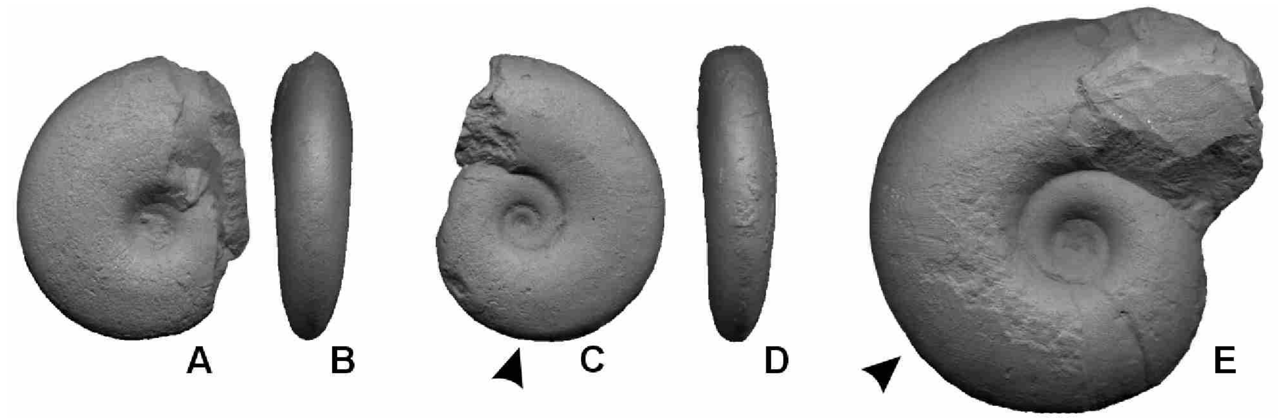


Figure 3. A-B: *Pseudolissoceras zitteli* (Burckhardt, 1903) [M?], lateral (A) and ventral (B) views of a cast (LPB-M 102) of the lectotype (BSPM - ASI616) figured by Burckhardt (1903: pl. 10: 6-7); completely septated specimen from Paso entre Cajón del Burro y Río Choica[s], Mendoza, Argentina; middle Tithonian. C-D: *Pseudolissoceras planiusculum* (Zittel, 1870) [m], lateral (C) and ventral views (D) of a cast (LPB-M 103) of the holotype (BSPM - ASIII56) figured by Zittel (1870: pl. 28: 3); adult specimen with bodychamber lacking peristome from Rogoznik, Poland; middle Tithonian. E: *Pseudolissoceras rasile* (Zittel, 1870) [M], lateral view of a cast (LPB-M 101) of the holotype (BSPM - 1868X504) figured by Zittel (1870: pl. 28: 2); specimen with incomplete bodychamber, probably adult from Monte Catria, Apennines, Italy; middle Tithonian. All natural size (x1); arrows denoting the base of the bodychamber. Whorl sections in Fig. 6B, F, K. ***Figura 3.*** *A-B:* Pseudolissoceras zitteli *(Burckhardt, 1903) [M?], vistas lateral (A) y ventral (B) de un molde (LPB-M 102) del lectotipo (BSPM - ASI616) figurado por Burckhardt (1903: pl. 10: 6-7); especímen completamente tabicado proveniente de Paso entre Cajón del Burro y Río Choica[s], Mendoza, Argentina; Tithoniano medio. C-D:* Pseudolissoceras planiusculum *(Zittel, 1870) [m], vistas lateral (C) y ventral (D) de un molde (LPB-M 103) del holotipo (BSPM - ASIII56) figurado por Zittel (1870: pl. 28: 3); especímen con cámara habitacional sin peristoma proveniente de Rogoznik, Polonia; Tithoniano medio. E:* Pseudolissoceras rasile *(Zittel, 1870) [M], vista lateral de un molde (LPB-M 101) del holotipo (BSPM - 1868X504) figurado por Zittel (1870: pl. 28: 2); especímen con cámara habitacional incompleta, probablemente un adulto proveniente de Monte Catria, Apeninos, Italia; Tithoniano medio. Todos en tamaño natural (x1); las flechas indican la base de la cámara habitacional. Secciones de vuelta en Fig. 6B, F, K.*

for the Fallauxi Zone of the Umbria-Marchese-Sabine Apennines of Central Italy, but unfortunately the material is lost (F. Cecca, *pers. comm.* 05/11/01).

P. planiusculum (Figs. 3C-D, 4A-B, 6) has been cited through the Darwini-lower Fallauxi Zones of the Central Tethys, and most probably includes the microconch of the forms of this interval. Figured Tethyan specimens attributed to *P. planiusculum* (the holotype, Fig. 3C-D; Bernoulli and Renz 1970: pl. 5: 3; Avram 1976; Olóriz 1978; Fözy 1994) range in adult diameter between 30-40 mm, are very evolute (U/D = 0.25-0.35), and the whorl section is rather compressed during juvenile and adult ontogeny (Fig. 4A-B) with flattish flanks in the bodychamber. All these features fit very well into the ontogenetic trajectories of the lappetted microconch of *P. zitteli* (Fig. 4A-B, 7C-F) described below, although lappeted specimens of *P. planiusculum* have not been described yet. Identical morphotypes occur in Mexico, like *P.* aff. *subrasilis* Burckhardt (1906: pl. 34: 12-14) and *P. zitteli* (*in* Cantu-Chapa 1967: pl. 1: 5, pl. 7: 9), from rocks that could be time-equivalent to the Semiforme Zone (cf. Olóriz et al. 1999). The stratigraphic distribution, covering almost the whole range of the genus, supports the sexual dimorphic correspondence.

In summary (Fig. 6), the genus may be interpreted as a succession of chronospecies with a paleobiogeographic distribution confined to Central Tethys during its early evolution (Hybonotum-Darwini Zones), and widely expanded through Central Tethys, Caribbean Province, Neuquén-Mendoza Basin and South Primorie during the Semiforme Zone. During the early Fallauxi Zone the latest, terminal forms -local adaptations- were restricted to northern Central Tethys and, probably, the Neuquén-Mendoza Basin (diachronous disappearence *sensu* Westermann 1992). The morphologic evolution follows a trend substained throughout the evolutionary sequence, from inflated evolute forms passing gradually into more compressed and involute suboxycones with a periumbilical depression and less developed auxiliar sutural elements. A marked step of this trend occurred at the early Semiforme Zone in coincidence with the biogeographic expansion event of the genus (Fig. 6). Excluiding the Andean terminal form *P. pseudoolithicum*, this pattern might be described as a peramorphocline (Fig. 6) -clinal occurrence of the ancestral adult morphology in successive descendant juvenile stages of the development (McNamara 1982, 1986; Dommergues et al. 1986)- driven in this case by an acceleration process. Sexual dimorphism, in the forms of the interval Darwini-Semiforme Zones results from a paedomorphic microconch by complex progenesis (*sensu* Landman et al. 1991; Parent 1997). This type of sexual dimorphism leads to a characteristic evolutionary trend, that is, microconchiate males changing slowly their morphology along peramorphic clades, in which macroconchs show evident changes in the adult morphology not reached by microconchs (Parent 1998; cf. Dommergues 1990).

Pseudolissoceras zitteli (Burckhardt, 1903) [M&m]

Figs. 2, 3A-B, 4A-B, 5A-E, 6, 7A-G; Table 1

?1900a *Oppelia* aff. *perlaevis* Steuer.- Burckhardt, p. 46, pl. 26: 5-6, pl. 29: 11.
*1903 *Neumayria Zitteli* n. sp.- Burckhardt, p. 55, pl. 10: 1-5, 6-7 [lectotype], 8.
?1946 *Neumayria zitteli* Burckh.- Sokolov, p. 9.
1967 *Pseudolissoceras zitteli* (Burckhardt).- Cantu-Chapa, p. 4, pl. 1: 5, pl. 7: 9.

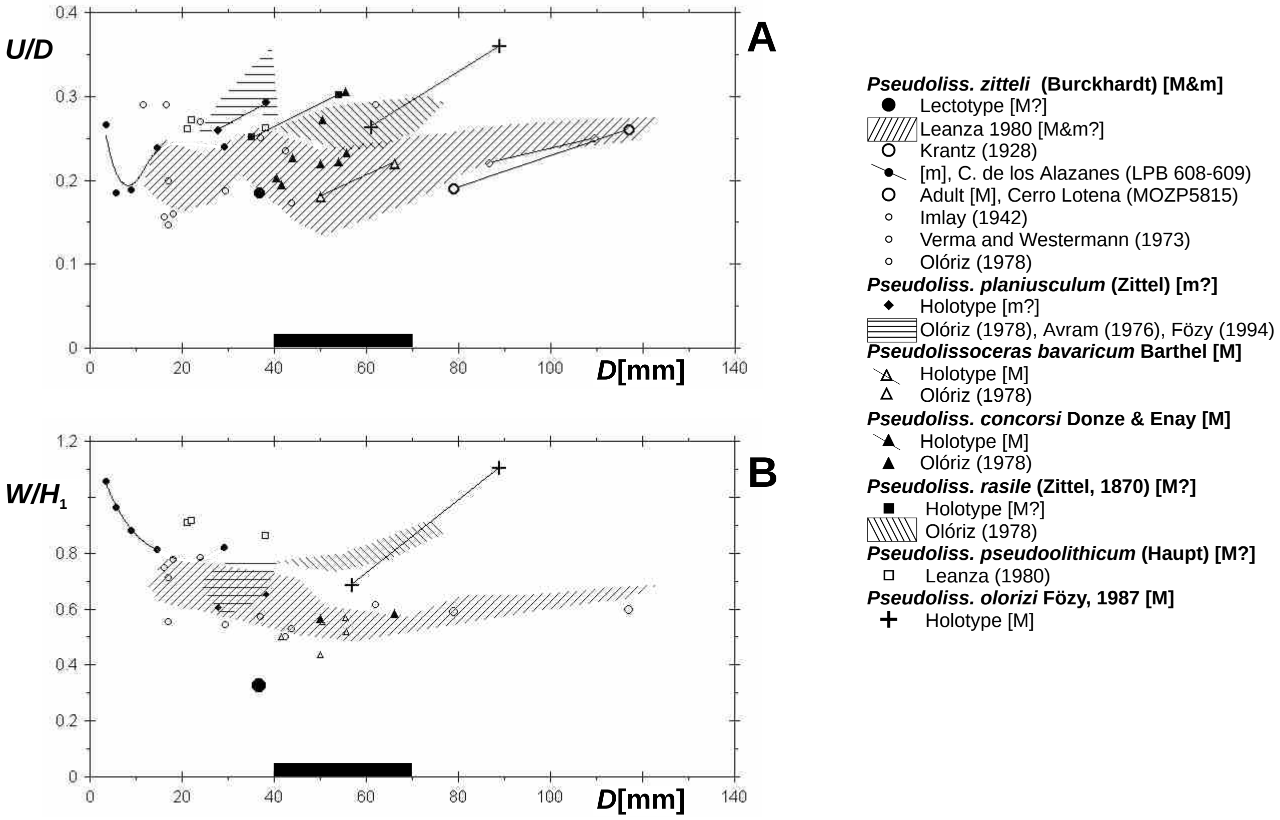


Figure 4. Variation of *U/D* (A) and W/H_1 (B) relative to *D* in *Pseudolissoceras zitteli* and the remaining nominal species of the genus. The black bold line on the D axe indicates the size range of maximum involution and periumbilical depression of *P. zitteli* and *P. concorsi-bavaricum*. ***Figura 4.*** *Variación de* U/D *(A) y* W/H_1 *(B) respecto a* D *en* Pseudolissoceras zitteli *y las demás especies nominales del género. La línea negra gruesa sobre el eje D indica el intervalo de talla de máximas involución y depresión periumbilical de* P. zitteli *and* P. concorsi-bavaricum.

1980 *Pseudolissoceras zitteli* (Burckhardt).- Leanza, p. 17, pl. 1: 1-2. [Complementary synonymy]

1989 *Pseudolissoceras zitteli* (Burckhardt).- Myczynski, p. 85, pl. 1: 2, pl. 5: 8, pl. 9:10b, pl. 10: 4b.

1990 *Pseudolissoceras zitteli* (Burckhardt).- Myczynski, pl. 1: 1b.

?1996 *Pseudolissoceras* ex. gr. *zitteli* (Oppel [*recte* Burckhardt]).- Sey and Kalacheva, p. 299, pl. 1: 1-2.

?1997 *Pseudolissoceras* ex. gr. *zitteli* (Burckhardt).- Sey and Kalacheva, p. 93, pl. 1: 13-17.

1999 *Pseudolissoceras zitteli* (Burckhardt).- Parent and Capello, p. 349.

Lectotype. The specimen from "Paso entre Cajón del Burro y Río Choica[s]", Mendoza, middle Tithonian, originally figured by Burckhardt (1903: pl. 10: 6-7, hand-drawing), refigurated herein photographically from a cast (Fig. 3A-B). Many of the ammonites figured by drawings in Burckhardt (1903) were formerly illustrated by excellent photographs in Burckhardt (1900a, 1900b); nevertheless none of the specimens figured by him as *Oppelia* aff. *perlaevis* Steuer (Burckhardt 1900a: pl. 26: 5-6) corresponds to the lectotype of *P. zitteli*.

Material. One fragmentary macroconch bodychamber (LPB608/1), one almost complete adult microconch (LPB608), two incomplete ?microconchs (LPB 608/2, 609); several pieces of Lamellaptychus (LPB 600, 611-613); all specimens collected from concretions of bed CA02, *Zitteli* Biozone (Middle Tithonian, Semiforme Zone).

Description. Macroconch: The poorly preserved bodychamber of the sample shows smooth, slightly convex flanks without sculpture preserved; umbilicus open about one fifth of the diameter on the umbilical shoulder of last whorl at $D \approx 60$ mm. Microconch: Inner whorls ($3 < D < 10$ mm) evolute and depressed with subcircular whorl section and almost smooth flanks, only gentle, flexuose growth lines are visible on the middle of the flank. The body chamber ($D > 18$ mm) is more evolute and compressed with much higher whorl section, rounded venter, and flattened flanks passing by a rounded shoulder to a convex and relatively high umbilical wall. The sculpture of the body chamber consists of flexuose growth lines which delineate the mid-flank-projected lappets towards the aperture. Growth lines are preserved on both the test and the internal mold and follow a pattern identical to that of adult macroconchs. Mandibles: Following Krantz (1928), Spath (1950), and Barthel (1962) mandibles are here described under the supposed species they belong to. The most appropiate name for the present specimens, among those described by Arkell (1957), is Lamellaptychus. After Arkell (1957: L439) Lamellaptychus is narrow-valved with the surface covered by soft oblique folds. Abundant nodules containing a single valve and a few with the two valves in anatomical connection, have been collected from level CA02; all of them appear to correspond to individuals of

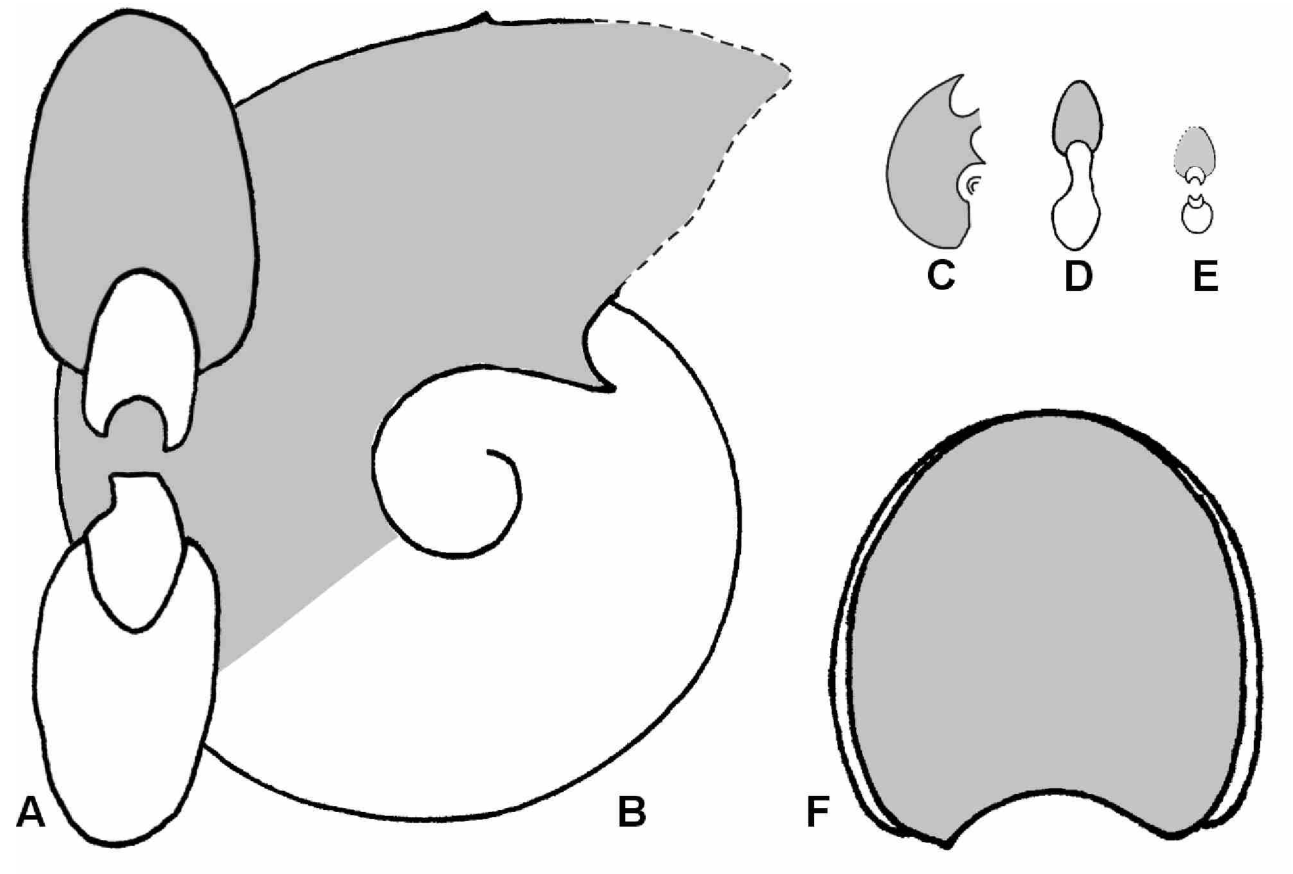


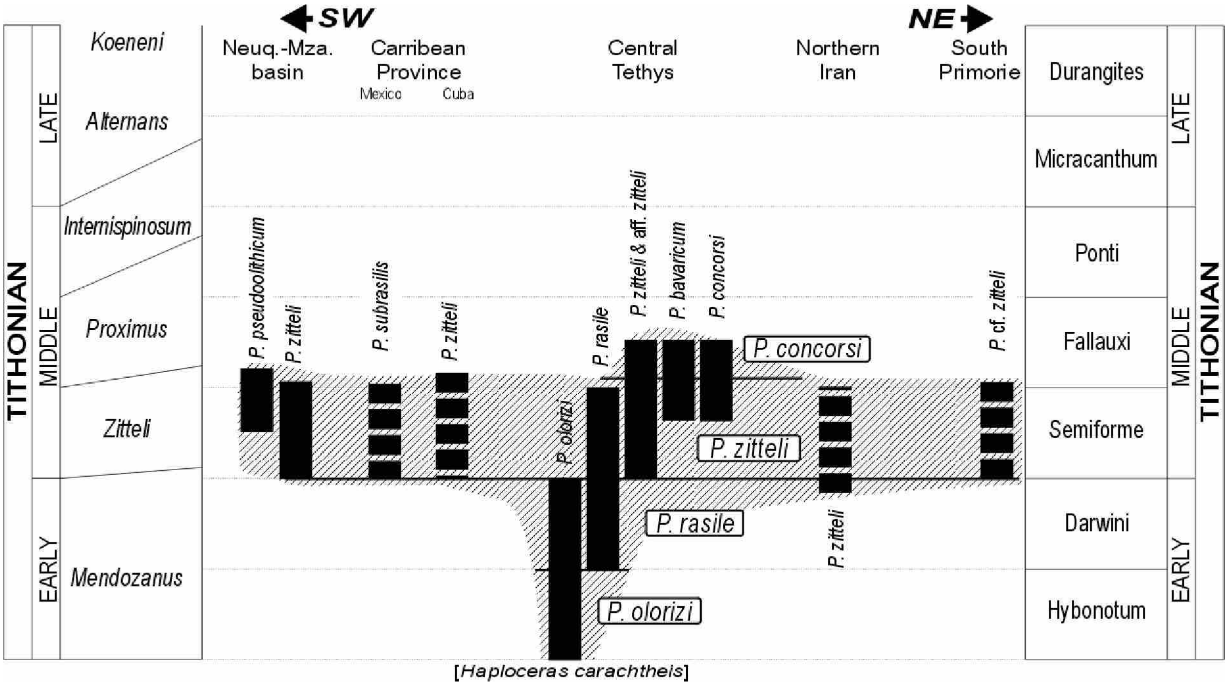
Figure 5. A-B: whorl section and lateral view of *Pseudolissoceras zitteli* [M], specimen MOZP5815; C-D: *Pseudolissoceras zitteli* [m], lateral view and whorl section of specimen LPB608; E: *Pseudolissoceras zitteli* [m], whorl section of specimen LPB609; F: whorl section of *Corongoceras* cf. *alternans* [M], specimen LPB605. All natural size (x1), bodychamber shaded. ***Figura 5.*** *A-B: sección de vuelta y vista lateral de* Pseudolissoceras zitteli *[M], especímen MOZP5815; C-D:* Pseudolissoceras zitteli *[m], vista lateral y sección de vuelta del especímen LPB608; E:* Pseudolissoceras zitteli *[m], sección de vuelta del especímen LPB609; F: sección de vuelta de* Corongoceras *cf.* alternans *[M], especímen LPB605. Todo en tamaño natural (x1), cámara habitacional sombreada.*

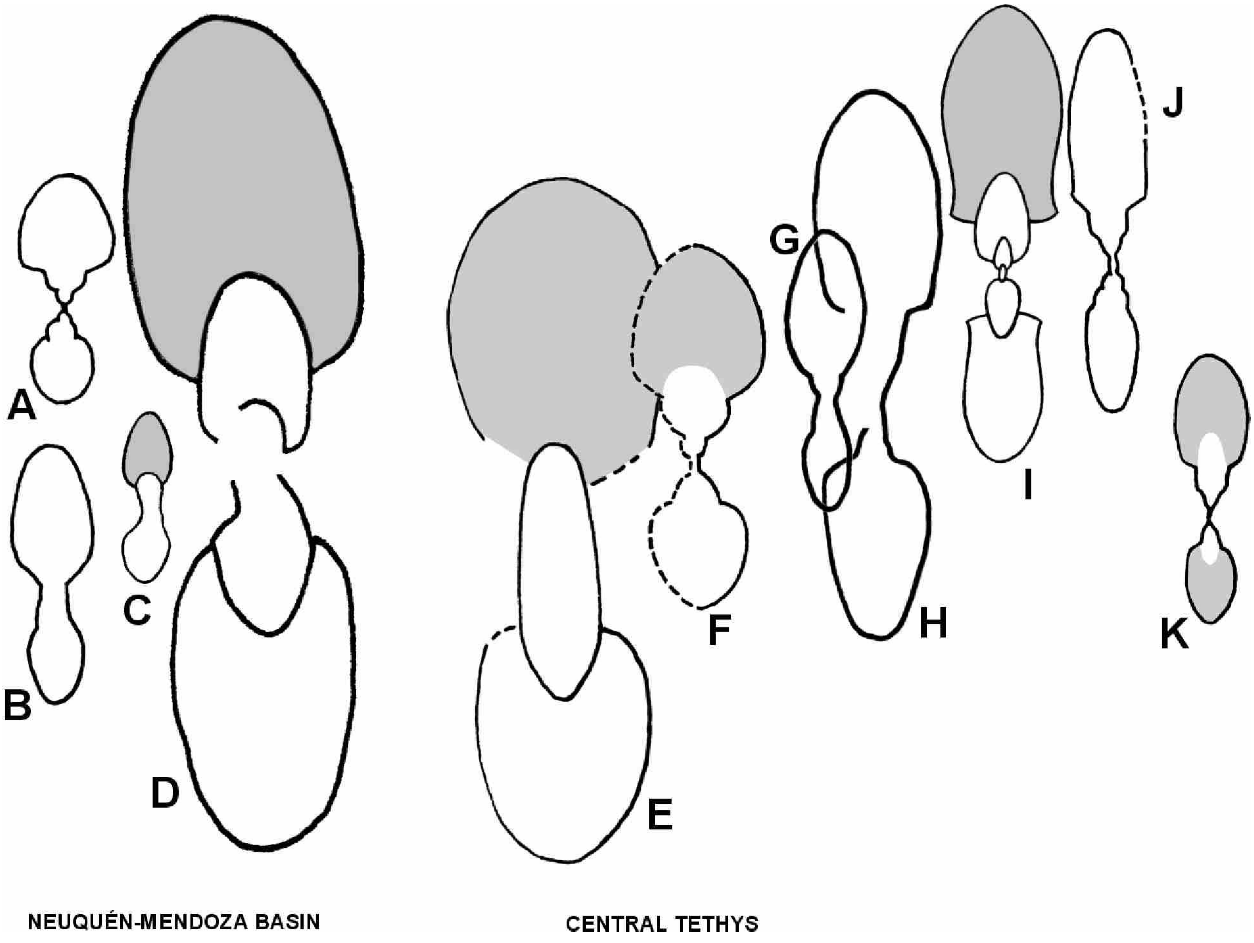
Pseudolissoceras zitteli [M] which occur in association in the same level and sometimes, in other localities, even in the same concretion. The size of the specimens corresponds to macroconchs of *P. zitteli*, much larger than the corresponding microconch as described above. Tithonian aptychi as small as to fit into the microconch bodychamber described above have not yet been described from the Neuquén-Mendoza Basin.

Discussion. The microconch is almost identical with the holotype of *P. planiusculum* (Fig. 3C-D) and those specimens figured by Avram (1976: pl. 7: 5, pl. 8: 2). The specimens of *P. zitteli* described by Cantu-Chapa (1967: pl. 1: 5, pl. 7: 9) from Mazatepec, Mexico (Semiforme Zone; cf. Olóriz et al. 1999), are microconchs which are indistinguishable from the present ones. The shape of the peristome of the described microconch matches many figured Kimmeridgian and Tithonian haplocerataceans such as those described as *Glochiceras carachtheis* (in Barthel 1962: pl. 2: 1, pl. 3: 1, 4; Olóriz 1978: pl. 10: 6), *Glochiceras planulatum* (in Ziegler 1958: pl. 15: 10; Berckhemer and Hölder 1959: pl. 26: 138), *Haploceras fialar* Oppel (in Burckhardt 1906: pl. 20: 15). The characteristic features that make our complete microconch a *P. zitteli* are not only the constraints of the recorded associated macroconch specimens but especially the smooth, rounded venter, the moderate involution, the flattened preapertural portion of the flanks, and, most importantly, the morphology of the inner whorls identical to that of *P. zitteli* [M]. Sexual dimorphism is not only related to different adult size between dimorphs as indicated by Verma and Westermann (1973), but moreover includes apertural lappets in the smaller microconchiate male.

Identical Tithonian pieces of Lamellaptychus were described by Cloos (1961: pl. 3: 6, pl. 4: 8-9) from some localities of Neuquén as *Laevaptychus crassissimus* (Haupt 1907), Cerro Lotena and Lamellaptychus, from Cerro Negro. Spath (1950: pl. 10: 12) figured "Lamellaptychus sp. indet." from the Tithonian of Kurdistan, which matches in every visible detail with the present pieces, although Spath suggested relationships with *Haploceras*. Barthel (1962) described under *Pseudolissoceras bavaricum* a piece of Laevilamellaptychus which strongly resembles the present ones.

A typical, almost complete adult macroconch (Figs. 5A-B, 7A-B, Table 1) from the *Zitteli* Biozone of Cerro Lotena (Fig. 1) is herein illustrated in order to give a complete picture of the species from both sexual dimorphs. This macroconch shows a ventral, transverse fold or ridge connected with a flexuose lateral fold or rib at *D* 110 mm, on the last preserved whorl, close to the peristome. The biological meaning, thus the taxonomic significance of this structure is not easy to assess from known material, but supports inclusion of *Pseudolissoceras* in Haploceratidae. Haploceratids which show consistently these folds are, e.g.


SW
NE
TITHONIAN
LATE
MIDDLE
EARLY
Koeneni
Alternans
Internispinosum
Proximus
Zitteli
Mendozanus
Neuq.-Mza. basin
Carribean Province
Mexico
Cuba
Central Tethys
Northern Iran
South Primorie
Durangites
Micracanthum
Ponti
Fallauxi
Semiforme
Darwini
Hybonotum
P. pseudoolithicum
P. zitteli
P. subrasilis
P. zitteli
P. olorizi
P. rasile
P. zitteli & aff. zitteli
P. bavaricum
P. concorsi
P. zitteli
P. cf. zitteli
P. concorsi
P. zitteli
P. rasile
P. olorizi
[Haploceras carachtheis]


A
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NEUQUÉN-MENDOZA BASIN
CENTRAL TETHYS

Haploceras verruciferum (Zittel, 1870), *H. staszycii* (Zeuschner, 1846) as noted by Olóriz (1978: 18), and *H. cassiferum* Főzy (1988: pl. 5: 2-3) besides many other examples in literature. Microconchs of *H. verruciferum* (Zittel), as described by Enay and Cecca (1986), show similar folds whereas they are lacking in the above described microconch specimens of *P. zitteli*.

The periumbilical depression of the flanks, typical of the morphospecies *P. concorsi* and *P. bavaricum*, is shown, in attenuated form, by some adult macroconchs of *P. zitteli* (Krantz 1928: pl. 1: 6, Leanza 1980: pl. 1: 1) as a flattening of the lower third of the flanks, in coincidence with the end of the phragmocone and the base of the bodychamber ($40 < D < 70$ mm). This flattening is associated with a contraction of the umbilical width, clearly evident in the graph *U/D-D* (Fig. 4A). *P. pseudoolithicum* Haupt, 1907 differs from *P. zitteli* in having a more inflated whorl section and a wider umbilicus through the late juvenil and adult ontogeny, but they have identical inner whorls ($D < 10$ mm).

Family Oppeliidae Douvillé, 1890
Subfamily Streblitinae Spath, 1925
Genus *Neochetoceras* Spath, 1925

Type species. *Ammonites steraspis* Oppel, 1863, OD; Lower Tithonian.

Neochetoceras? sp.

Figs. 2, 8A-C.

Material. One adult phragmocone (LPB 607), loose from beds CA10-13, *Proximus* Biozone (Middle Tithonian, Fallauxi Zone).

Description. Compressed subtriangular whorl section with smooth lower half of flanks; moderately open umbilicus; about 5 rounded and low primary ribs per half whorl appear to be confined to the upper half of flanks.

Remarks. The preliminar inclusion of the specimen into *Neochetoceras* Spath rather than in *Ochetoceras* Haug, 1885 (Type species: *Ammonites canaliculatus* von Buch, 1831; SD Munier-Chalmas, 1892) rests, not only in stratigraphic position, but on the apparently smooth lower half of the flanks and the rounded distant primary ribs only on the upper half, lacking any vestige of secondary or ancillary ribbing. Some species of *Streblites* have similar ornamentation but arising on the umbilical shoulder and their umbilicus is characteristically narrower. Within many similar specimens in literature, stands the closely comparable specimen of *Neochetoceras* sp. [M] figured by Cecca and Enay (1991: pl. 1: 9) from the Fallauxi Zone of Le Pouzin, France. Many older forms compare well too, for example, the latest Kimmeridgian *Ochetoceras irregulare* Beckhemer and Hölder (1959: pl. 23: 118, pl. 25: 130) and *Ochetoceras canaliferum* var. *tenuis* Beckhemer and Hölder (1959: pl. 25: 133). *Neochetoceras* has never been figured or cited for the Andean Tithonian. However, from material of Western Cuba, Myczynski (1989: pl. 1: 8-10) described as *Neochetoceras* aff. *steraspis* (Oppel) several specimens which are very similar to the present one, like that figured by Myczynski and Pszczolowski (1994: pl. 2: 1) as *Taramelliceras (Parastreblites)* sp. Kiessling et al. (1999: fig. 7A) have figured one specimen, assigned to the lower Tithonian of the Antarctic Peninsula, as *Neochetoceras*? sp., and Witham and Doyle (1989: fig. 6e) figured a minute specimen from the Tithonian of the Longing Member, northern Longing Gap as *Neochetoceras* sp.

Some morphotypes of *Semiformiceras semiforme* (Oppel, 1865) of the upper Semiforme Zone of Spain, France, Italy and Hungary, like those illustrated by Enay (1983: fig. 3.11-14), Olóriz (1978: pl. 3: 1-2), Cecca and Enay (1991: pl. 2: 18-19), Cecca et al. (1983-1984: pl. 6: 4) and Főzy (1988: pl. 1: 1-2, 4) show some resemblance with our specimen. The bodychamber of these forms is more inflated than the phragmocone, which is the part of the shell described above; the presence of the diagnostic groove of *Semiformiceras* cannot be evaluated.

Superfamily Perisphinctaceae Steinmann, 1890
Family Aspidoceratidae Zittel, 1895
Genus *Pseudhimalayites* Spath, 1925

Type species. *Aspidoceras steinmanni* Haupt, 1907 (= *Cosmoceras subpretiosum* Uhlig, 1878); Middle Tithonian.

Pseudhimalayites subpretiosus (Uhlig, 1878) [M]

Figs. 2, 8I-J

Figure 6. Chronologic-geographic-morphologic phylogenetic framework for the genus *Pseudolissoceras* Spath as probably originated from the early Tithonian *Haploceras carachtheis* (*sensu* Enay and Cecca 1986). Current morphospecies (black vertical bars, solid: controlled range, dotted: tentative range) may be considered variants within a succession of chronospecies (labelled by the names in the white boxes) by assuming a moderately broad range of intraspecific variation (plotted in Fig. 4A-B) around type specimens. The microconchs are nominally known as *P. planiusculum*, except for Andean *P. zitteli* whose microconch is herein described under the same name. Typical morphology indicated by whorl section of type specimens and a few additional ones, A: *P. pseudoolithicum* (Haupt), B: *P. zitteli* [M] (lectotype in Fig. 3A-B), C: *P. zitteli* [m] (Fig. 5D), D: *P. zitteli* [M] (Fig. 5A), E: *P. olorizi* [M] (holotype, drawn from Főzy 1988: pl. 6: 2), F: *P. rasile* [M] (holotype, see Fig. 3E), G-H: *P. zitteli* [M] (*in* Olóriz 1978: p. 43), I: *P. concorsi* [M] (holotype), J: *P. bavaricum* [M] (holotype), K: *P. planiusculum* [m] (holotype, Fig. 3C-D). All sections in natural size (x1); bodychamber shaded. B, F and K: after Barthel (1962); I: after Donze and Enay (1961). Geography depicted not at scale; time correlation of the Andean biozonation as in Figure 10 and text.

Figura 6. *Filogenia del género* Pseudolissoceras *Spath en un contexto temporal-geográfico-morfológico, supuestamente derivado de Haploceras carachtheis (sensu Enay y Cecca 1986) en el Tithoniano temprano. Las morfoespecies (barras negras verticales, continuas: rango controlado, punteadas: rango tentativo) pueden considerarse variantes dentro de una sucesión de cronoespecies (etiquetadas por los rectángulos blancos) asumiendo un moderamente amplio espectro de variabilidad intraspecífico (ploteado en Fig. 4A-B) alrededor de los especímenes tipo. Las microconchas son conocidas nominalmente como* P. planiusculum, *excepto para* P. zitteli *en los Andes cuya microconcha es descripta bajo el mismo nombre específico. La morphología típica indicada por la sección transversal de los especímenes tipo y algunos adicionales, A:* P. pseudoolithicum *(Haupt), B:* P. zitteli *[M] (lectotipo en Fig. 3A-B), C:* P. zitteli *[m] (en Fig. 5D), D:* P. zitteli *[M] (Fig. 5A), E:* P. olorizi *[M] (holotipo, dibujado a partir de Főzy 1988: pl. 6: 2), F:* P. rasile *[M] (holotipo en Fig. 3E), G-H:* P. zitteli *[M] (in Olóriz 1978: 43), I:* P. concorsi *[M] (holotipo), J:* P. bavaricum *[M] (holotipo), K:* P. planiusculum *[m] (holotipo en Fig. 3C-D). Todas las secciones en tamaño natural (x1); cámara habitacional sombreada. B, F y K: tomado de Barthel (1962); I: tomado de Donze y Enay (1961). Geografía fuera de escala; correlaciones temporales de la biozonación andina como en Figura 10 y el texto.*

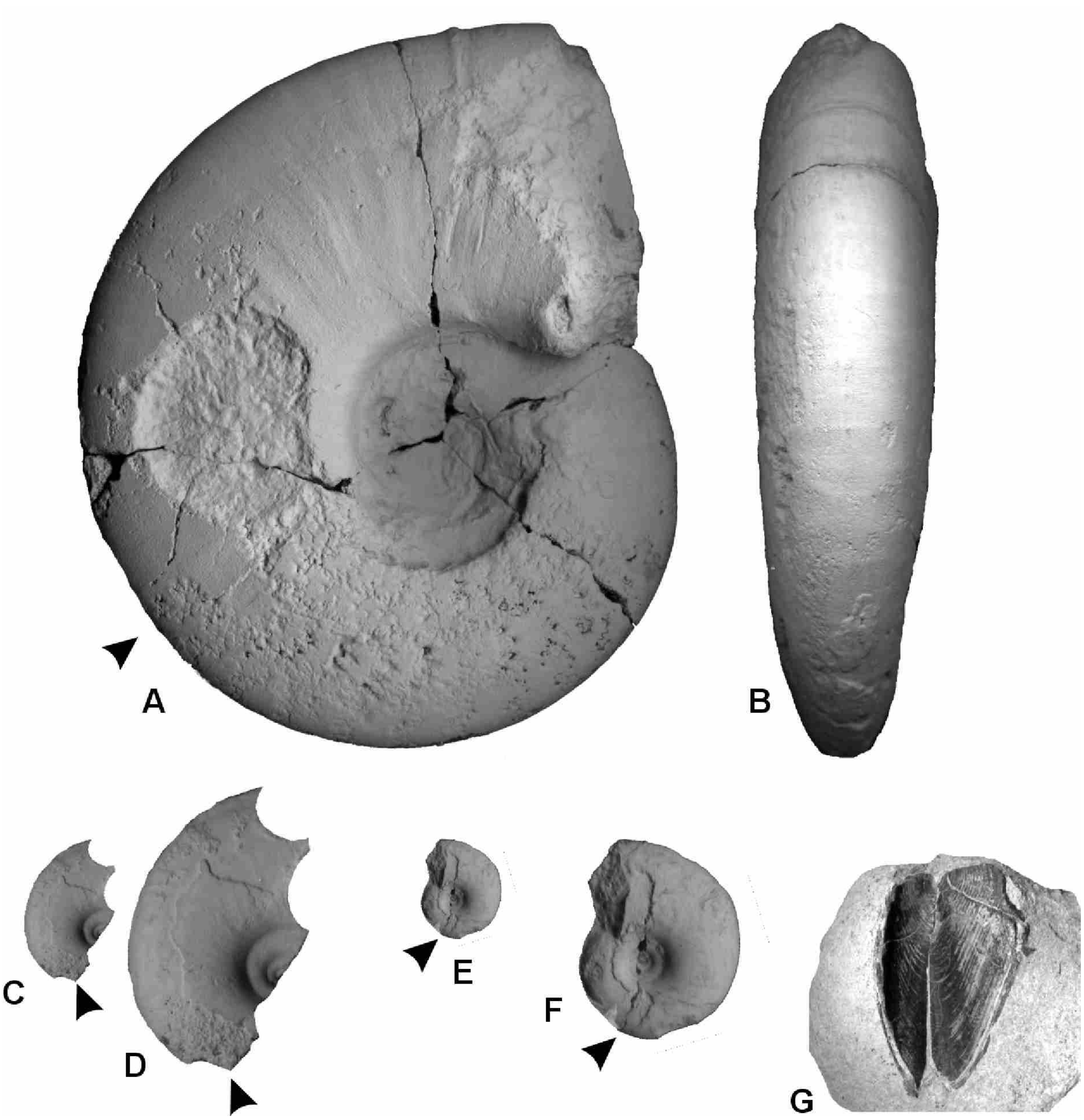

Figure 7. *Pseudolissoceras zitteli* (Burckhardt) [M&m]. A-B: lateral and ventral views (x1) of an almost complete adult macroconch (MOZP 5815) from Cerro Lotena, Neuquén, lower part of the *Zitteli* Biozone (probably from bed 3 in Leanza 1980: 9); C-D: lateral views of a virtually complete adult microconch (LPB608, C: x1, D: x2), bed CA02; E-F: lateral views of an almost complete microconch (LPB609, E: x1, F: x2), bed CA02; G: Lamellaptychus (upper face, concave), lower mandibles of a macroconch (LPB 600, x1), bed CA02. Arrows denoting the base of the bodychamber. ***Figura 7.*** Pseudolissoceras zitteli *(Burckhardt) [M&m]. A-B: vistas lateral y ventral (x1) de una macroconcha adulta casi completa (MOZP 5815) proveniente de Cerro Lotena, Neuquén, parte inferior de la Biozona* Zitteli *(probablemente del estrato 3 en Leanza 1980: 9); C-D: vistas laterales de una microconcha adulta virtualmente completa (LPB608, C: x1, D: x2), nivel CA02; E-F: vistas laterales de una microconcha adulta prácticamente completa (LPB609, E: x1, F: x2), nivel CA02; G: Lamellaptychus (cara superior, cóncava), mandíbulas inferiores de una macroconcha (LPB 600, x1), nivel CA02. Las flechas indican la base de la cámara habitacional.*

Macroconch

*1878 *Cosmoceras subpretiosum* n. sp.- Uhlig, p. 637 [non vidum], pl. 17: 8.
1907 *Aspidoceras Steinmanni* nov. sp.- Haupt, p. 189, pl. 7: 1 [lectotype of *P. steinmanni*].
1925 *Aspidoceras Steinmanni* Haupt.- Gerth, p. 39.
1928 *Aspidoceras (Pseudhimalayites) Steinmanni* Haupt.- Krantz, p. 13, 47-48.
1985 *Pseudhimalayites steinmanni* (Haupt).- Checa, p. 112, pl. 20: 2-5.
*1988 *Simocosmoceras subpretiosum* (Uhlig).- Malinowska, p. 481, pl. 143: 6.
*1997 *Pseudhimalayites subpretiosum* (Uhlig) (= *Aspidoceras steinmanni* Haupt).- Schweigert, p. 6, pl. 1: 4 [holotype], pl. 2: 1a-b [lectotype of *P. steinmanni*]; with synonyms.

Microconch

1987 *Simocosmoceras adversum* (Oppel) *andinum* n. ssp.- Leanza and Olóriz, p. 204, fig. 2.
1989 *Simocosmoceras pszczolkowskii* n. sp.- Myczyniski, p. 94, pl. 8: 4, pl. 10: 4a, 5.

Table 1. Measurements of type and studied specimens of *Pseudolissoceras*, *Torquatisphinctes* and *Corongoceras*. ***Tabla 1.*** *Medidas de especímenes tipo y material estudiado de los géneros* Pseudolissoceras, Torquatisphinctes y Corongoceras.

Specimen	[M/m]	Ph/BC	*D*	*U*	*U/D*	*W*	*W/D*	H_1	H_1/D	W/H_1	H_2	H_2/D	*P*	*V*	*LBC*[°]
Pseudolissoceras zitteli (Burckhardt)															
LPB 608	m	BC	29.1	7.0	0.24	10.5	0.36	12.8	0.44	0.81	-	-	0	0	190
LPB 609	m	BC	14.5	3.5	0.24	5.2	0.36	6.4	0.44	0.81	-	-	0	0	>180
		Ph	9.0	1.7	0.19	3.7	0.41	4.2	0.47	0.88	-	-	0	0	
		Ph	5.6	1.0	0.18	2.7	0.48	2.8	0.50	0.78	-	-	0	0	
		Ph	3.4	0.9	0.27	1.9	0.55	1.8	0.53	0.74	-	-	0	0	
MOZP 5815	M	BC	109.5	27.3	0.25	29.7	0.27	50.3	0.46	0.59	-	-	0	0	>190
		Ph-BC	86.8	18.8	0.22	27.1	0.34	44.0	0.51	0.62	-	-	0	0	
LECTOTYPE	M?	Ph	36.8	6.8	0.19	6.2	0.17	19.0	0.52	0.33	-	-	0	0	
(Fig. 3A-B)															
Pseudolissoceras rasile (Zittel)															
HOLOTYPE	M?	BC	54.0	16.3	0.30	-	-	-	-	-	-	-	0	0	
(Fig. 3E)		Ph	35.0	8.8	0.25	-	-	-	-	-	-	-	0	0	
Pseudolissoceras planiusculum (Zittel)															
HOLOTYPE	m	BC	38.3	11.2	0.29	10.1	0.26	15.5	0.41	0.65	13.8	0.36	0	0	200
(Fig. 3C-D)		Ph	27.8	7.2	0.26	7.8	0.28	12.9	0.46	0.61	-	-	0	0	
Torquatisphinctes proximus (Steuer) transient β															
LPB 606	?M	BC	40.2	18.5	0.46	12.2	0.30	12.1	0.30	1.01	10.4	0.26	16	31	>250
		Ph-BC	29.1	-	-	-	-	-	-	-	-	-	-	-	
Corongoceras lotenoense (Spath)															
HOLOTYPE		Ph	28.0	10.0	0.36	10.0	0.36	10.0	0.36	1.00	8.0	0.29	14	20	
(*in* Haupt 1907: pl. 9: 7a-b)		Ph	20.0	7.0	0.35	7.0	0.35	8.0	0.29	0.89	-	-	15	22	
Corongoceras alternans (Gerth)															
HOLOTYPE	M	BC	75.0	32.0	0.43	19.8	0.26	24.5	0.33	0.81	23.5	0.31	15	28	-
(*in* Gerth 1925: pl. 6: 3-3e)		Ph	39.0	13.0	0.33	-	-	15.0	0.38	-	13.0	0.33	14	-	

1993	*Simocosmoceras adversum andinum* Leanza and Olóriz.- Leanza, p. 76.
1997	*Simocosmoceras adversum* (Oppel).- Schweigert, p. 4-6, pl. 1: 2-3.

Holotype. The specimen figured by Uhlig (1878: pl. 17: 8), refigured by Malinowska (1988: pl. 143: 6) and Schweigert (1997: pl. 1: 4).

Material. One fragmentary bodychamber of an adult macroconch (LPB 603) from bed CA06, lower *Proximus* Biozone (Middle Tithonian, upper Semiforme-lower Fallauxi Zones).

Description. The specimen is an internal mold with remains of the shell, corresponding to the end of phragmocone and the base of the body chamber. The estimated dimensions are $D \approx 45$ mm, $W \approx 37$ mm. The umbilical wall is not completely preserved. The whorl section is very depressed with low flanks and a broad, rounded venter. The ornamentation is composed of three rows of tubercles: one of small top-stamped bullae at the umbilical shoulder; a second one of somewhat larger tubercles located just below the ventro-lateral shoulder; and a third row on the venter, composed of radially elongated bullae. Short undivided ribs connect the periumbilical and ventro-lateral tubercles. On the venter the two row of tubercles are separated by a smooth band. Sutures are too incompletely preserved for description.

Remarks. The subjective synonymy of the macrococnchs *P. steinmanni* (Haupt) with *P. subpretiosus* (Uhlig) as proposed by Schweigert (1997) is accepted herein, attending that both forms are of the same age and have identical inner whorls. The present specimen is very close to that one figured by Checa (1985: pl. 20: 4) at a comparable diameter, but the closest resemblance is with the specimen figured by Haupt (1907: pl. 7: 1, lectotype of *P. steinmanni*) and refigured by Schweigert (1997: pl. 2: 1a-b). The microconchs of the Middle Tithonian *Pseudhimalayites* are included in *Simocosmoceras* Spath, 1925 as pointed out by Schweigert (1997); Spath (1925: 132) had noted the aspidoceratid aspect of *Simocosmoceras*, stressing its superficial resemblance with *Sutneria* Zittel, 1884. In Cerro Lotena, Neuquén, in levels which contain *P. subpretiosus* occurs *Simocosmoceras adversum andinum* Leanza and Olóriz, 1987 [m]. The holotype of this latter form is very similar, if not identical, with inner whorls of *P. subpretiosus* so that there is little doubt that it represents the local microconchiate male as already suggested by Schweigert (1997: 5).

After the description by Haupt (1907) no other Andean specimen of *P. subpretiosus* was figured. Our specimen documents the association with *T. proximus* transient α in a single basal bed of the *Proximus* Biozone, above beds of the local *Zitteli* Biozone, thus fixing its stratigraphic position in the sequence (see discussion below in the biostratigraphic chapter). The morphological identity with the lectotype of *P. steinmanni* strongly suggests the same age for the two specimens, although the lectotype has hitherto not been precisely placed in the normal succession. *P. subpretiosus* has been recorded throughout most of the Neuquén-Mendoza Basin and although its stratigraphic position is not clearly established, it appears to have some range through the upper *Zitteli* and lower *Proximus* Biozones, documented by either one of the dimorphs, as follows:

Picún Leufú, Neuquén (Fig. 1): Leanza (1993: 76) cited the microconch *Simocosmoceras adversum andinum* Leanza and Olóriz.

Cerro Lotena, Neuquén (Fig. 1): Haupt (1907) originally described *P. steinmanni* on material from this locality but he did not give a precise indication of its stratigraphic position. Krantz (1928: 13) indicated the occurrence of the species in this locality without giving further information. Leanza and Hugo (1977: 253) indicated an occurrence apparently below beds containing *Windhauseniceras internispinosum* (Krantz, 1928), thus by definition within the *Proximus* Biozone. Leanza and Olóriz (1987: 203) recorded the type specimen of *Simocosmocers adversum andinum* [m] in the upper *Zitteli* Biozone, in association with *P. steinmanni* (Haupt), here interpreted as *P. subpretiosus* [M].

Cañadón de los Alazanes, Neuquén (Fig. 1): associated with *T. proximus* transient α, basal *Proximus* Biozone, this report.

Bardas Blancas, Mendoza (see fig. 1A in Parent, in press): Gerth (1925: 39-40) indicated the occurrence of *P. steinmanni* in this locality. Later, on this base, Krantz (1928: 47) listed the faunal content of the Middle Tithonian of this locality including, under current taxonomy: *P. subpretiosus*, *P. zitteli*, *Volanoceras krantzense* Cantu-Chapa [= *Simoceras* aff. *volanense* (Oppel) *in* Krantz (1928)], and *Taramelliceras waageni* (Zittel). The presence of *P. zitteli* indicates the homonymous biozone, and if the group of species is considered as an assemblage, it leaves little doubt of the Semiforme Zone age when compared with similar Tethyan assemblages (see Parent and Capello 1999), although *Taramelliceras* is said to end in the top of the Darwini Zone in Europe (Olóriz 1978, Kutek and Wierzbowski 1986).

Arroyo Cieneguitas, Mendoza (see fig. 1A in Parent, in press): Krantz (1928: 48) indicates the occurrence of *P. zitteli* and *P. subpretiosus* in the Middle Tithonian.

Family Ataxioceratidae Buckman, 1921

Subfamily Torquatisphinctinae Tavera, 1985

Remarks. Composition and scope of this subfamily following Parent (in press; cf. Tavera 1985).

Genus *Torquatisphinctes* Spath, 1924

Type species. Ammonites torquatus Sowerby, 1840; Kimmeridgian of Kachchh, India.

Torquatisphinctes proximus (Steuer, 1897)

Figs. 2, 8D-H; Table 1

Synonymy. See Parent (in press).

Material. One almost complete adult specimen (LPB606) from bed CA14; several crushed specimens from level CA09, several fragmentary and crushed specimens from nodules of level CA06 (LPB601-602, 616); *Proximus* Biozone (Middle Tithonian, upper Semiforme-Fallauxi Zones).

Remarks. The species was recently revised (Parent, in press) within the context of a taxonomic revision of the ataxioceratids of the Neuquén-Mendoza Basin. Two morphotypes were distinguished within the species. The new material confirms their vertical succession, as formerly suspected (Parent, in press), by which they must be regarded as transients of the species. *T. proximus* transient β [the younger and also the type transient since it includes the lectotype; see Fig. 8F-H; Parent, in press: fig. 9I-J (lectotype), fig. 13C; ?Leanza 1980: pl. 6: 4] has smaller adult size, shows a higher point of bifurcation of the ribs and a more evolute and compressed aspect than *T. proximus* transient α. This latter (see Parent, in press: Fig. 13A-B) is intermediate in morphology and age between *T. mendozanus* (see Burckhardt 1900a: pl. 25: 6-8, the type series originally described as *P*. aff. *lothari* Oppel) of the lower Tithonian *Mendozanus* Biozone and *T. proximus* transient β of the Middle Tithonian upper *Proximus* Biozone, but mostly resembling *T. mendozanus* in adult size, whorl section and coiling. *T. proximus* transient β strongly resembles "*Parapallasiceras* aff. *pseudocolubrinoides*" Olóriz (in Leanza 1980: pl. 8: 3) of the *Internispinosum* Biozone of Cerro Lotena in ribbing style and size, thus suggesting that the specimen of level CA14 (Fig. 8F-H) could already come from the base of that biozone. A specimen which resembles the present one was figured by Corvalán (1959: pl. 5: 20) as *Aulacosphinctes proximus* (Steuer) from bed B-2 (*Proximus* Biozone, sic) of Río Leñas, Chile.

The ventral groove or interruption of ribbing is a very variable feature in *T. proximus*, visible on the internal molds of either inner whorls or on the last whorl of the phragmocone. This variability appears to be the same in both transients by which an evolutionary pattern can not be described at present and the taxonomic importance can not be assessed. Furthermore, Guex (1970) has demonstrated that in dactylioceratids the variability of this feature is extremely wide, and, like in *T. proximus*, the groove is only observed in internal molds, so that its taxonomic value is very restricted.

Sexual dimorphism in the species is not yet recognized. Nevertheless, some undescribed, large variocostate macroconchs in the collection of the Museo Olsacher (Zapala), coming from the middle Tithonian of Cerro Lotena show identical inner whorls.

There is a close resemblance (homoeomorphy?) between late representatives of *T. proximus* with the upper Middle Tithonian *Parapallasiceras praecox* (Schneid, 1915). They compare very well in the evolute coiling, rounded whorl section and simple, rather straight prosocline ribbing, bifurcating in the upper half of the flanks, and with some trifurcations at constrictions.

Family Himalayitidae Spath, 1925

Remarks. In Europe, the earliest himalayitid "*Burckhardticeras*" *peroni* (Roman, 1936 *sensu* Olóriz 1978) may have arisen in the Ponti Zone (= Burckhardticeras Zone) from late representatives of the Torquatisphinctinae (cf. Donovan et al. 1981). In "*B.*" *peroni* the primary ribs become prominent at the point of bifurcation, conforming a lamelliform tuberculation (Olóriz 1978: 624: "tuberculación lameliforme") near the ventro-lateral shoulder that most probably gave origin to the diagnostic tuberculation of the early Late Tithonian Himalayitidae. In South America, the latest *T. proximus* transient β may represent, via *Torquatisphinctes? windhauseni* (Weaver, 1931 *in* Leanza 1980: pl. 8: 2), the origin of Andean himalayitids such as *Windhauseniceras internispinosum* (Krantz) and *Micracanthoceras mirum* (Leanza, 1945). Inner whorls of the lectotype of *T. proximus* (transient β) and *W. internispinosum* (*in* Leanza 1980: pl. 9: 1) are almost identical, characterized by an evolute coiling

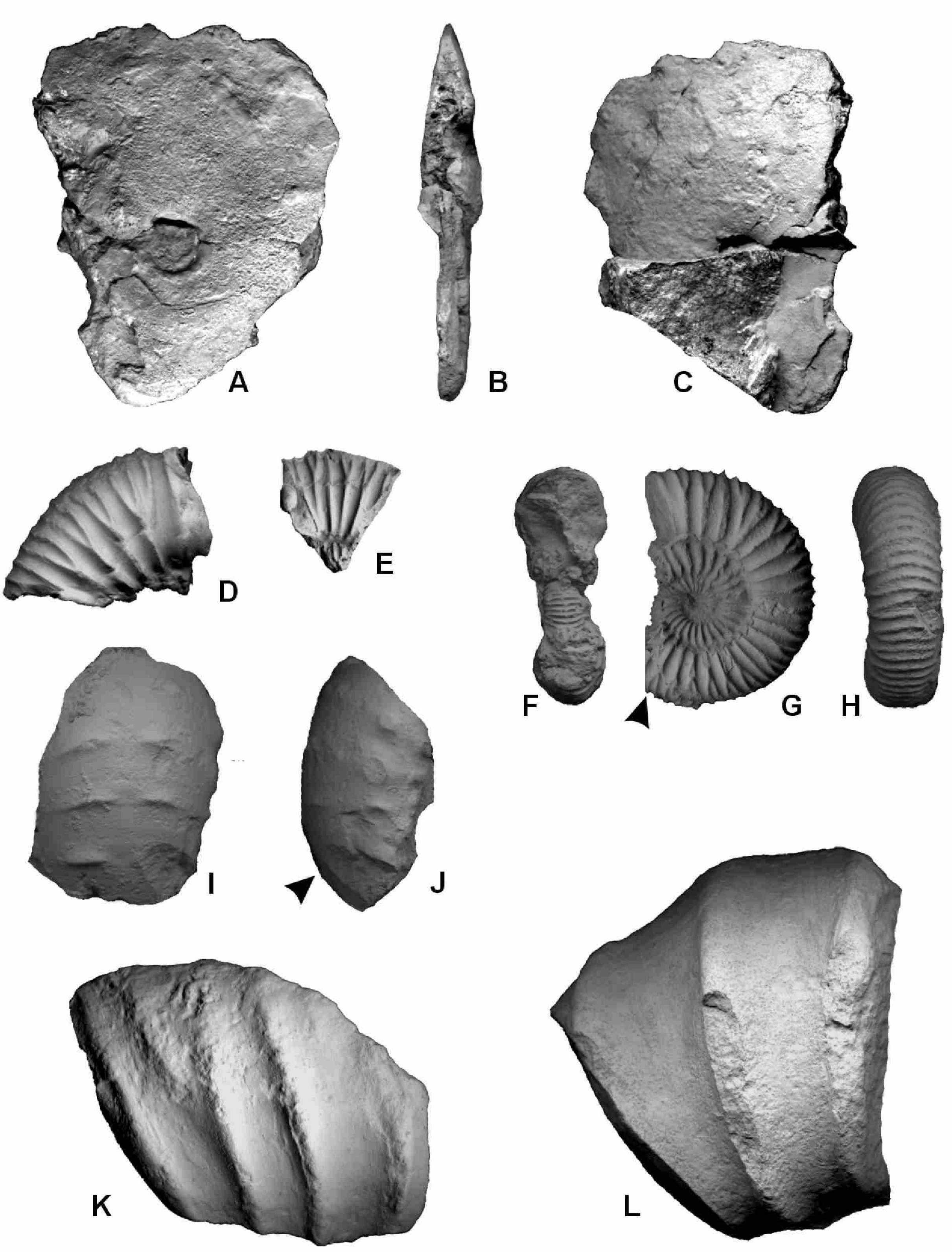

Figure 8. A-C: *Neochetoceras*? sp., adult phragmocone (LPB607), loose from beds CA10-13, A-B: lateral views, B: frontal view through the last septum; D-E: *Torquatisphinctes proximus* transient α (D: LPB601, E: LPB602) from bed CA06 (in a concretion with LPB 603); F-H: *Torquatisphinctes proximus* transient β, almost complete adult (LPB606) from bed CA14; I-J: *Pseudhimalayites subpretiosus* [M], adult bodychamber (LPB 603) from bed CA06; K-L: *Corongoceras* cf. *alternans* [M] (K: LPB604, L: LPB605) from bed CA16. All natural size (x1); arrows denoting the base of the bodychamber. ***Figura 8.*** *A-C:* Neochetoceras*? sp., fragmácono adulto (LPB607), desprendido de alguno de los estratos CA10-13, A-B: vistas laterales, B: vista frontal a través del último septo; D-E:* Torquatisphinctes proximus *transient* α *(D: LPB601, E: LPB602) del nivel CA06 (en la misma concreción que LPB 603); F-H:* Torquatisphinctes proximus *transient* β*, adulto casi completo (LPB606) del nivel CA14; I-J:* Pseudhimalayites subpretiosus *[M], cámara habitacional adulta (LPB 603) del nivel CA06; K-L:* Corongoceras *cf.* alternans *[M] (K: LPB604, L: LPB605) del nivel CA16. Todos en tamaño natural (x1); las flechas indican la base de la cámara habitacional.*

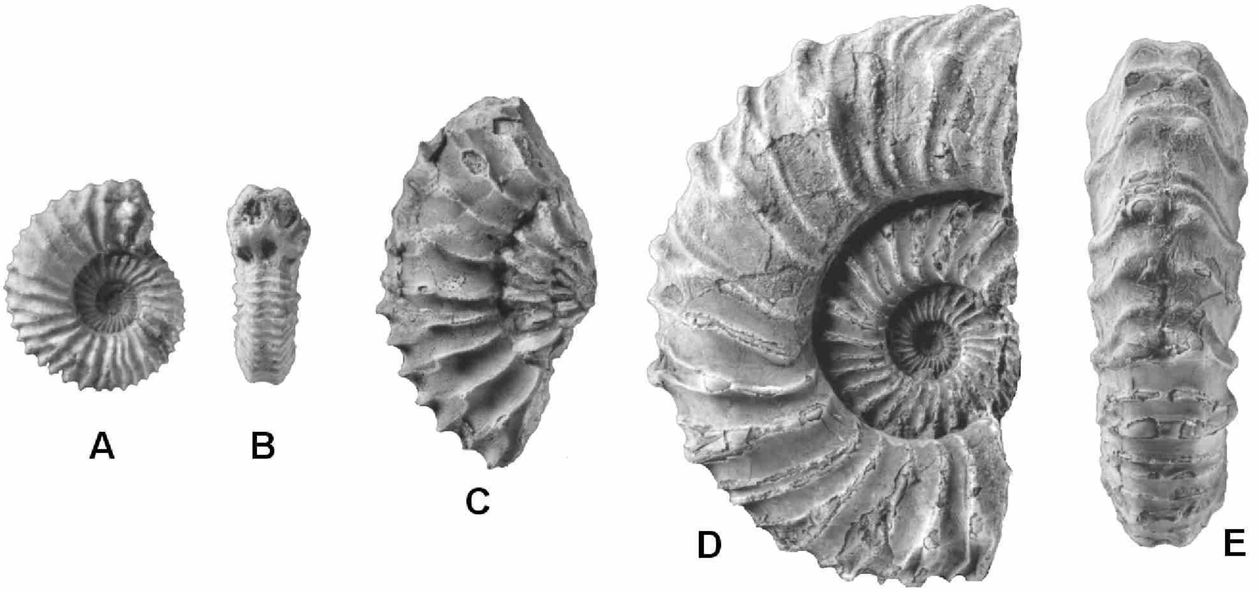

Figura 9. A-B: *Corongoceras lotenoense* (Spath), lateral (A) and ventral (B) views of the holotype figured by Haupt (1907: pl. 9: 7a-b), phragmocone; C: *Corongoceras lotenoense* (Spath), lateral view of the specimen figured by Haupt (1907: pl. 9: 7d), phragmocone with remains of bodychamber; D-E: *Corongoceras alternans* (Gerth) [M], lateral (D) and ventral (E) views of the holotype figured by Gerth (1925: pl. 6: 3-3a). All natural size (x1) specimens at the Paläontologisches Institut der Universität Bonn (GPIBO). ***Figura 9.*** *A-B:* Corongoceras lotenoense *(Spath), vistas lateral (A) y ventral (B) del holotipo figurado por Haupt (1907: pl. 9: 7a-b), fragmácono; C:* Corongoceras lotenoense *(Spath), vista lateral del especímen figurado por Haupt (1907: pl. 9: 7d), fragmácono con restos de cámara habitacional; D-E:* Corongoceras alternans *(Gerth) [M], vistas lateral (D) y ventral (E) del holotipo figurado por Gerth (1925: pl. 6: 3-3a). Todos los especímenes en tamaño natural (x1), depositados en el Instituto de Paleontología de la Universidad de Bonn.*

and a strong ribbing with bifurcations in the upper third of the flanks after a more or less notorious lamelliform tuberculation. The stratigraphic succession of these forms is evident in the material described by Leanza A.F. (1945) and Leanza H.A. (1980) which, in Cerro Lotena, occur inmediately above levels containing *T. proximus* (?transient β). This latter and *T.*? *windhauseni* show great resemblance with "*B.*" *peroni*, although their general aspect is still more that of a torquatisphinctid than himalayitid. Some specimens of *T. proximus* transient α develop an incipient ventro-lateral prominence of their primary ribs at the point of bifurcation on the innermost whorls ($3 < D < 10$ mm), anticipating the himalayitid-like sculpture which is seen more markedly in middle and outer whorls of later forms. The derivation of Himalayitidae from late *Torquatisphinctes* close to "*Burckhardticeras*" is in accord with the resemblance of some *Aulacosphinctes* Uhlig, 1910 (the microconchs of *Micracanthoceras* Spath, 1925) with those late *Torquatisphinctes*; this is clearly seen in the Andean faunas and could be the explanation for the common confusion assigning *T. proximus* (Steuer) to *Aulacosphinctes*. The specimens from Chacay Melehué, Neuquén, cited by Sokolov (1946) as *Hoplites microcanthus* Perón are probably related to these forms.

Genus *Corongoceras* Spath, 1925

Type species. *Corongoceras lotenoense*; pro *Hoplites köllikeri* Oppel, 1863 *sensu* Haupt, 1907. Upper Tithonian of Cerro Lotena, Argentina. The holotype (Fig. 9A-B, Table 1, the measurements given by Haupt 1907: 201 appear to be erroneous) consists of inner whorls, without bodychamber. This incomplete specimen has induced subjective interpetations of both, the species and the genus; an example appears to be *"Corongoceras" submendozanum* Krantz, 1928, a species defined by a typically Andean berriasellid ammonite (Krantz 1928: pl. 4: 6, holotype by monotypy) with compressed and finely, densely ribbed phragmocone.

***Corongoceras* cf. *alternans* (Gerth, 1925)**
Figs. 2, 5F, 8K-L, 9D-E, Table 1

Holotype. By monotypy, the specimen originally figured by Gerth (1925: pl. 6: 3) from Arroyo Durazno, West-Central Mendoza (SD Leanza 1945: 47), refigurated herein (Fig. 9D-E). The holotype of *C. lotenoense* (Fig. 9A-B, Table 1) is identical in every detail at a comparable diameter. The other specimen figured by Haupt (1907: pl. 9: 7d) (Fig. 9C) is very different in sculpture and whorl section.

Material. Two fragments of adult bodychambers (LPB 604-605) from bed C16, *Alternans*? Biozone (upper Middle Tithonian lower Upper Tithonian).

Description. Deduced maximum diameter about 200 mm. Whorl section stout suboval, slightly wider than high, with broad rounded venter and slightly arched flanks. The fragments are too short portions of the whorl to estimate the curvature ratio at the umbilical shoulder, but the umbilicus appears to have been moderately open. Ribs are strong, widely spaced, concave forwards, arising from the umbilical wall, and elevated on the umbilical shoulder. Bifurcation is in the upper half of the flanks with secondaries as strong as the primaries. The two last primaries of the bigger specimen remain undivided.

Remarks. The ribbing is typically himalayitid, especially resembling (but at larger size) that of the type species of *Aulacosphinctes* Uhlig 1910, as illustrated by Arkell (1957), and *"Djurjuriceras" mediterraneum* Tavera (1985: pl. 19: 1, holotype) from the lower Microcanthum Zone of Sierra Gorda, Spain. No closer comparisons are possible because of the fragmentary preservation of the described material. *C. alternans* is known from the holotype (Fig. 9D-

E) and other few figured specimens. Closely comparable is the specimen from Mallín Redondo figured by Leanza (1945: pl. 1: 2-3) which, moreover, is very similar to the holotype and almost identical with some specimens recently collected in Cajón de Almaza, Neuquén (Fig. 1). The studied specimens should represent adult macroconchs which are as large as those *Corongoceras alternans* figured as *Reineckeia köllikeri* Oppel by Burckhardt (1900b: pl. 20: 14-15, pl. 21: 1) from the Upper Tithonian of Liu Cullín, Neuquén (Fig. 1). A significant difference with the present specimens is the occurrence of tubercles at the points of furcation of ribs.

BIOSTRATIGRAPHY AND TIME-CORRELATION (Figs. 2, 10)

The described fauna is composed, at specific or generic taxonomic level, by taxa well known from the Central Tethys. This faunal affinity enables close time-correlation of Andean ammonite assemblages with the standard chronostratigraphic scale of Europe (Geyssant 1997) based on Leanza (1980, 1981), Olóriz and Tavera (1989) and Parent and Capello (1999). The equivalent zonation developped by Olóriz (1978) could be applied too in chronostratigraphic sense.

The occurrence of *P. zitteli* in the basal beds CA01-CA02, below *T. proximus* transient α, indicates the *Zitteli* Biozone. This biozone is commonly correlated with the lower Middle Tithonian Semiforme Zone of the European standard chronostratigraphic scale (Leanza 1980, 1981; Parent and Capello 1999; cf. Olóriz and Tavera 1989; Zeiss 1983).

The interval CA03-14 represents the *Proximus* Biozone, an interval biozone defined as the rocks comprised between the last occurrence of *P. zitteli* (top of the *Zitteli* Biozone) and the first occurrence of *Windhauseniceras internispinosum* (see Leanza 1980, 1981). The first occurrence of this latter species defines the base of the *Internispinosum* Biozone. The top of the *Proximus* Biozone in the studied section is supposed to be located around the beds CA14-15. However, the bed CA15 has not yielded fossils and is tentatively included in the *Internispinosum* Biozone accounting by the "early-himalayitid" aspect of the specimen of *T. proximus* transient β collected from bed CA14. The level CA06 is age significant by yielding *T. proximus* transient α and *P. subpretiosus* in a single concretion. This latter species has been widely recorded throughout the Tethys (see above and Schweigert 1997 for a review), Cuba (as the microconch *Simocosmoceras* Spath, Myczinski 1989, 1990) and Argentina. Its stratigraphic range in Europe appears to be confined to the Semiforme Zone judging by the ammonite assemblages described in literature. The association of *P. zitteli* with *Volanoceras krantzense* (Cantu-Chapa, 1990) is recorded at Bardas Blancas, Mendoza (Gerth 1925, Krantz 1928, Parent and Capello 1999) indicating the Semiforme Zone (work in progress by Schweigert, Parent and Scherzinger suggests the upper part of the Semiforme Zone). This is a solid indication that the base of the *Proximus* Biozone in Cañadón de los Alazanes lies in the upper Semiforme Zone, what is slightly lower than commonly advocated (cf. Leanza 1980, 1981; Callomon 1993; Parent and Capello 1999). As discussed above, *T. proximus* transient β shows some resemblance to *"Burckhardticeras" peroni* (Roman), and *W. internispinosum*, what suggests a late Middle Tithonian Ponti Zone age for the upper part of the *Proximus* Biozone and, probably, lower part of the *Internispinosum* Biozone. Biostratigraphically, the uppermost part of the range of *T. proximus* lies around the top of the *Proximus* and the base of *Internispinosum* Biozones, where it is more completely represented (e.g., Cañadón de los Alazanes, Cerro Lotena).

The record of a loose specimen of *Neochetoceras*? sp. coming from around the levels CA10-CA13 is interesting because it is the first record of such a form in the basin, although it contributes little for correlation. The resemblance with some forms of Fallauxi Zone age (see above) is suggestive of this Middle Tithonian interval within which may be approximately included in the *Proximus* Biozone in southern Neuquén-Mendoza Basin.

It is interesting to note, that if new sampling yields *P. zitteli* in beds higher than CA02, the boundary between the *Zitteli* and *Proximus* Biozones might be moved higher than traced herein. It is a consequence of the nature of biozones: rocks characterized by their fossil content, defined independently of time. The need for the development of a standard chronostratigraphic classification of the Andean Tithonian becomes evident when biostratigraphic time-correlation is intended (see Callomon 1985, 1995 for full general discussion).

There is no further sampled material from bed CA16 for correlation besides the fragments described as *Corongoceras* cf. *alternans*, which suggest some part of the homonymous biozone. Leanza (1980, 1981) and Parent and Capello (1999) have correlated the fauna of the *Alternans* Biozone with the lower Upper Tithonian Microcanthum Zone. In the Tithonian succession at Los Catutos (between Zapala city and Portada Covunco in the map of Fig. 1), Leanza and Zeiss (1990: fig. 4, table 1) indicate the occurrence of *Djurjuriceras catutosense* Leanza and Zeiss, 1990, *Djurjuriceras*? sp. and *Corongoceras* sp. in levels "x+a" to "y", top of *Proximus* and lower *Internispinosum* Biozones (cf. Leanza and Zeiss 1992). This succession suggests that bed CA16 could belong to the *Internispinosum* Biozone, although the expected lithographic limestones of Los Catutos, described by Leanza and Zeiss (1990, 1992), appear to be missing at Cañadón de los Alazanes.

CONCLUSION

The rock and ammonite successions at Cañadón de los Alazanes fit the general patterns seen through the basin and closely compare with those of Mallín de Los Caballos and Mallín Quemado. *Pseudolissoceras zitteli* [M&m] is more closely related to haploceratids than to oppeliids as indicated by the form of its sexual dimorphism, the tendency to flatten flanks and the development of ventral folds or ridges seen in macroconchs. In the Andes *P. zitteli* is nearly confined to rocks of Semiforme Zone age in correspondence with the range in Europe and the short biogeographic expansion of the genus during that time. The widely distributed, but typically scarce, *Pseudhimalayites subpretiosus*, here represented by a specimen identical to the lectotype of *P. steinmanni*, associated with *Torquatisphinctes proximus* transient α, indicates that the base of the *Proximus* Biozone may lie in the upper Semiforme-lower Fallauxi Zones. *T. proximus* transient α is

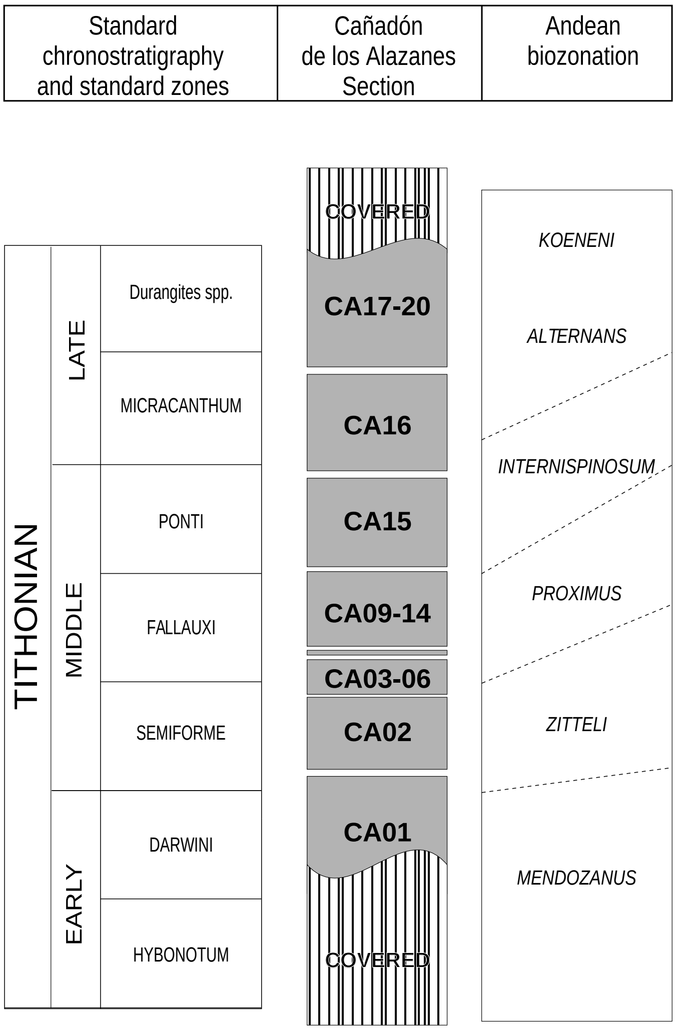

Figure 10. Correlation chart based on Leanza (1981), Parent & Capello (1999) and present results; shaded boxes indicate the estimated temporal range (age) of faunal levels based on the ammonoid fauna; inclined dotted lines in Andean biozonation denote the variation of the temporal limits of the biozones through the basin. Separation between boxes does not represent magnitud of time, but only probable gaps. ***Figura 10.*** *Carta de correlación basada en Leanza (1981), Parent & Capello (1999) y los presentes resultados; las cajas sombreadas indican el intervalo temporal estimado (edad) de los niveles fáunicos con base en la fauna de ammonoideos; las líneas punteadas inclinadas en la biozonación andina denotan la variación de los límites temporales de las biozonas a través de la cuenca. La separación entre las cajas sombreadas no representa magnitud de tiempo, sino simplemente probables discontinuidades temporales.*

close to the lower Tithonian *T. mendozanus*, and the late transient β strongly resembles early himalayitids, thus suggesting the origin of this family in the latter *T. proximus* (transient β). Sexual dimorphic status remains unclear, like for the whole genus *Torquatisphinctes*.

Direct faunal affinities between Andean and Central Tethyan Tithonian ammonite faunas are proved once again from samples of internal areas of the longitudinally arranged Neuquén-Mendoza Basin. Longitudinal-type and latitudinal-type basins are expected to generate very different paleobiogeographic patterns and scenarios. These faunal affinities, noted previously (Parent and Capello 1999; Parent, in press), allow direct intercontinental correlation of some Andean faunal assemblages with the standard time scale of Europe. Definition of faunal horizons containing associations of species also recognized in Europe may become the base for intercontinental time-correlations of a standard chronostratigraphic classification of the Andean Upper Jurassic (under current study).

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Boletín
del Instituto de
Fisiografía y Geología

"CARTOGRAFÍA TEMÁTICA"

Muestra Cartográfica
18-19 Octubre 2001
Rosario

Vista parcial de la muestra en el aula del Departamento de Ciencias Geológicas.

En ocasión de realizarse en la ciudad de Rosario un Seminario sobre "Cartografía Temática", se efectuó una muestra cartográfica en ámbitos del Departamento de Ciencias Geológicas y del Instituto de Fisiografía y Geología.

El seminario se desarrolló durante los días 18 y 19 de Octubre de 2001 en el Salón de Actos de la Facultad de Ciencias Exactas, Ingeniería y Agrimensura de la Universidad Nacional de Rosario, auspiciado por la citada Facultad por intermedio de su Decanato, la Escuela de Agrimensura y el Instituto de Fisiografía y Geología conjuntamente con el Colegio de Profesionales de la Agrimensura de la Provincia de Santa Fe, la Asociación Centro Argentino de Cartografía y la Fundaciòn Facultad de Ingeniería. En su transcurso se expusieron diversos aspectos relacionados con la cartografía, todos ellos seguidos con atención por mas de 150 asistentes, lo que demuestra el interés que la temática despierta.

En lo relativo a la muestra cartográfica, realizada con material cartográfico perteneciente a la mapoteca del Instituto, la misma consistió en la exhibición de mas de 150 cartas de países pertenecientes a los cinco continentes.

Pudieron apreciarse así cartas topográficas, geológicas, geomorfológicas, gravimétricas, mineralógicas, hidrogeológicas, geológicas militares (de campo traviesa), aeronáuticas, de riesgo sísmico, etc. También mapas carreteros, catastrales, de navegación y otros, algunos de antigua data. Entre estos mapas se detacó el Mapa Geológico Argentino de Brackebusch (1891) y considerado uno de los pocos que aún obran en mapotecas de instituciones oficiales argentinas.

Un importante número de maquetas de distintos tamaños y escalas, todas ellas ejecutadas en el Instituto, pudieron observarse conjuntamente con dos cartas topográficas en relieve -una de Guatemala y otra de Bariloche-. Tambien fué expuesto un antiguo globo terráqueo.

La muestra fué visitada por un considerable número de los asistentes al seminario, los que pudieron apreciar una verdadera exhibición de cartografía temática.

El Instituto de Fisiografía y Geología agradece al personal y en especial a su Director Agrim. Francisco Lattuca del Departamento de Ciencias Geológicas "Prof. Dra. P. Pasotti" por la colaboración prestada, así como por la cesión de su aula para la concreción de la muestra.

Referencia

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Boletín
del Instituto de
Fisiografía y Geología

RECORDATORIO

Juan Carlos Domingo Roberto Benvenuti

(25/05/1919 - 04/12/1999)

El 4 de Diciembre de 1999 falleció en Rosario el Dr. Juan Carlos Domingo Roberto Benvenuti. Había nacido en esta misma ciudad el 25 de Mayo de 1919 y obtenido el título de Doctor en Ciencias Naturales especializado en Geología en la Facultad de Ciencias Naturales, Universidad Nacional de La Plata, el 30 de Julio de 1947.

Desde sus inicios profesionales demostró su inclinación hacia los estudios petrográficos habiendo obtenido diversas becas de perfeccionamiento en distintos institutos nacionales y extranjeros; la mas importante de las cuales fué la que alcanzó, por concurso intenacional, para estudios de perfeccionamiento "Petrológicos y Geológicos" en la Universidad de San Pablo (Brasil) durante el año l955.

Fué miembro de numerosas instituciones científicas, tanto nacionales como extranjeras, habiendo sido designado en varias de ellas como socio honorario o vitalicio.

Ejerció la docencia tanto secundaria como terciaria y universitaria; la primera de ellas en la Escuela Industrial de la Nación (hoy Instituto Politécnico Superior "Gral. San Martín), dependiente de la Facultad de Ciencias Exactas, Ingeniería y Agrimensura, y en el colegio secundario del Instituto Dante Alighieri; en los segundos su tarea docente fue desarrollada en el Instituto Superior del Profesorado de la "Sagrada Familia" en donde organizó y dirigió, durante mas de 30 años, la carrera del Profesorado de Geografìa pero, fundamentalmente, en la Facultad de Ciencias Exactas, Ingenierìa y Agrimensura donde llegó a ser Profesor Titular en cátedras de su especialidad.

Fué en el Instituto de Fisiografía y Geología de esa misma Facultad, al que ingresara en Diciembre de 1947, poco después de su graduación, donde pudo desarrollar y demostrar su verdadera capacidad volcada en tareas de investigación y asentada en sus trabajos tanto éditos como inéditos.

Aún cuando se había retirado en el año 1985, continuó concurriendo al Instituto y prestando su colaboración siempre que se le requería.

Su presencia en las visitas que nos hacía constituía un verdadero momento de camaradería; de palabra amena, gesto amable y modales mesurados permitían pasar con él un momento agradable.

Hoy su ausencia es notoria, pero como si quisiera que su espíritu permaneciese con nosotros, sus sucesores -su esposa Liliana Dalvai, hijos Juan Carlos y Guillermo así como sus nietos- decidieron, en un gesto que mucho agradecemos, tanto en forma institucional como, fundamentalmente personal y cumpliendo con un expreso deseo de él donar la que fuera su biblioteca personal.

Oscar A. Albert

Bibiografía de J.C.D.R. Benvenuti

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Donación BENVENUTI

13 Julio 2001

El Ing. Asteggiano entrega su recordatorio a la Señora de Benvenuti.

Tal como lo manifestáramos en el recordatorio del Dr. Juan Carlos D. R. Benvenuti que publicamos en este mismo número, sus sucesores, cumpliendo con su expresa voluntad, donaron a la Facultad de Ciencias Exactas, Ingeniería y Agrimensura con destino específico al Instituto de Fisiografía y Geología "Dr. A. Castellanos", la biblioteca personal del citado profesional y ex-miembro investigador del Instituto.

La donaciòn se efectivizó el día 13 de Julio de 2001 en un acto realizado en el Decanato de la Facultad al cual asistieron la señora Liliana Dalvai -su esposa- y sus hijos Juan Carlos y Guillermo conjuntamente con algunos otros familiares del Dr. Benvenuti (nietos y sobrinos). En esa ocasión el Ing. David Asteggiano, Decano de la Facultad, agradeció la donación e hizo entrega, a los tres primeros, de un recordatorio consistente en un pequeño escudo de la Universidad Nacional de Rosario, a cada uno de ellos. La ocasión fué propicia para que entre los concurrentes se desarrollara una amable conversación que giró, fundamentalmente, en el recuerdo de la personalidad del desaparecido docente.

La biblioteca donada consiste en varios centenares de libros de Geología, Geomorfología y Geografía, así como de disciplinas afines a ellas, que pasan a engrosar el acervo bibliográfico del Instituto.

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1873 *Aspidoceras Beckeri* n. sp.- Neumayr, p. 202, pl. 18: 3.
1925 *Garantiana conjugata* Quenstedt.- Bentz, p. 162, pl. 6: 5, 6.

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Teichert C., 1987. An early German supporter of continental drift. - *Earth Sciences Review* 5(1): 134-136.
Arkell W.J., 1957. Jurassic ammonites. *In* Arkell W.J., Kummel B. and Wright C.W.: Treatise on Invertebrate Paleontology, (L) Mollusca 4, R.C. Moore (*ed.*). *University of Kansas Press and Geological Society of America, Kansas and New York*, 22+490p.
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