

## Lower Cretaceous ammonites from the Neuquén Basin, Argentina: A new heteromorph fauna from the uppermost Agrio Formation

Beatriz Aguirre-Urreta<sup>a,\*</sup>, Peter F. Rawson<sup>b,c</sup>

<sup>a</sup> Instituto de Estudios Andinos “Don Pablo Groeber” (UBA-CONICET), Departamento de Ciencias Geológicas, Universidad de Buenos Aires, Pabellón II, Ciudad Universitaria, 1428 Buenos Aires, Argentina

<sup>b</sup> Centre for Environmental and Marine Sciences, University of Hull (Scarborough Campus), Filey Road, Scarborough, North Yorkshire YO11 3AZ, UK

<sup>c</sup> Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK

### ARTICLE INFO

#### Article history:

Received 17 October 2011

Accepted in revised form 10 January 2012

Available online 10 February 2012

#### Keywords:

Argentina  
Neuquén Basin  
Ammonites  
Biostratigraphy  
Hauterivian  
Barremian

### ABSTRACT

Although the Agrio Formation (Valanginian–Early Barremian) yields rich ammonite faunas at many levels, the highest beds are very sparsely fossiliferous. However, intensive collecting over the years has yielded a sparse fauna of heteromorph ammonites that are completely new to Argentina. Three taxa are represented, *Sabaudiella riverorum* sp. nov., *Curacoites rotundus* gen. et sp. nov. and *Hamulinites?* sp. The fauna is placed in a new ammonite zone of *Sabaudiella riverorum* and dated as latest Hauterivian–Early Barremian.

© 2012 Elsevier Ltd. All rights reserved.

### 1. Introduction

The Agrio Formation (Valanginian–Early Barremian) crops out extensively in the Neuquén Basin of west-central Argentina, and in the more basinal areas is over 1500 m thick (Spalletti et al., 2011). Here it can be divided into three members: the Pilmatué, Avilé and Agua de la Mula members (Leanza and Hugo, 2001). The formation has yielded rich ammonite faunas at many levels (Aguirre-Urreta et al., 2005, 2007). However, the highest beds (top part of the Agua de la Mula Member) are poorly fossiliferous and often poorly exposed, being hidden beneath talus derived from the overlying harder sediments of the predominantly non-marine Huitrin Formation. However, systematic collecting has yielded a sparse heteromorph ammonite fauna that is completely new to Argentina. Various elements of the fauna have been found at 11 localities in the northern part of the basin, in northern Neuquén and southern Mendoza provinces (Fig. 1), but nowhere is it common.

Preservation of specimens varies considerably from locality to locality and complete, well-preserved specimens are very rare. The fossils are usually represented by indifferently preserved material, either fragments of hooks or internal moulds of fragmentary coiled body chambers, but a few well-preserved, more complete

specimens occur in small calcareous nodules. The material indicates the presence of three species assigned to the genera *Sabaudiella*, *Curacoites* gen. nov. and *Hamulinites?* By comparison with the European faunas discussed below they indicate that the highest part of the Agrio Formation is probably no younger than Early Barremian.

### 2. Lithostratigraphy and fossil localities

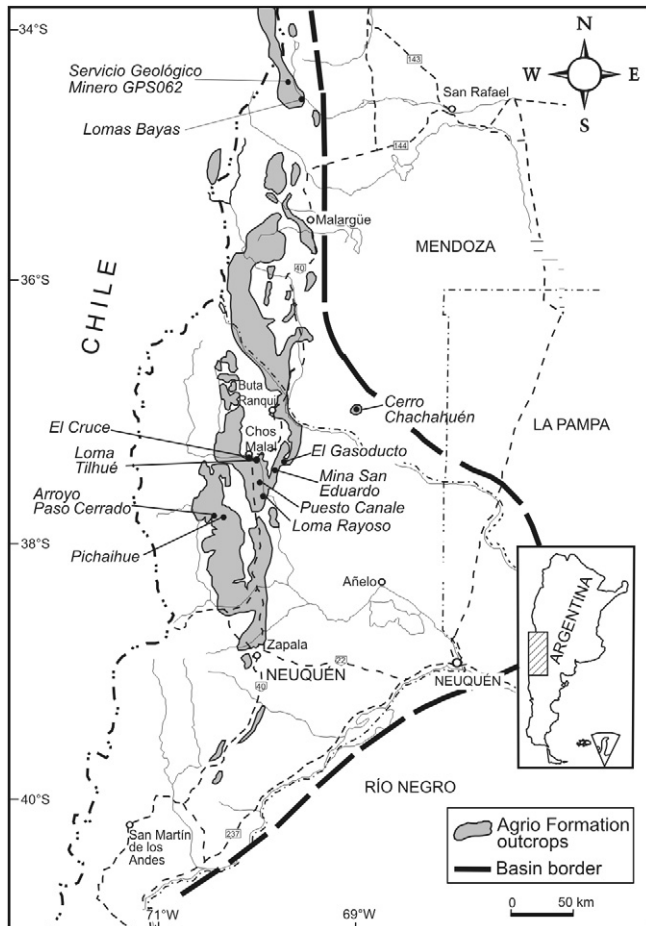
Of the 11 localities that have yielded this fauna (Fig. 1) we have measured sections in four of them: Lomas Bayas, Cerro Chachahuén, Mina San Eduardo and Pichaihue (Fig. 2). The localities are described below, from north to south. The first three are in Mendoza Province and are close to the basin margin where the Agrio Formation is quite condensed. They were examined only by BA-U; the remaining localities are in Neuquén Province and most of these have been visited by both of us.

#### 2.1. Servicio Geológico Minero GPS 062 (34° 37' S, 69° 34' W)

This section is named after a GPS point of the Argentine Geological Survey (SGM). It is very close to La Mala Dormida, one of Gerth's (1925) localities. It is reached along a winding, precarious rocky track from the settlement of Las Aucas in southern Mendoza. The section is poorly exposed, but the whole of the (condensed)

\* Corresponding author.

E-mail address: [aguirre@gl.fcen.uba.ar](mailto:aguirre@gl.fcen.uba.ar) (B. Aguirre-Urreta).



**Fig. 1.** Map showing localities for the *Sabaudiella riverorum* fauna in the Neuquén Basin.

Agrio Formation, less than 100 m thick, is composed of yellowish silty limestones. Two well-preserved internal moulds of shafts and hooks of *Hamulinites?* sp. (CPBA 18191, 18192) were collected from the top beds of the formation.

#### 2.2. Lomas Bayas (34°39'S, 69°31'W)

This locality is close to the south bank of the Río Diamante, a few kilometres northeast of Las Aucas. The complete Agrio Formation is 90 m thick here and consists of pale conglomerates and sandstones, yellowish silty limestones and coquinas. Poorly preserved *Hamulinites?* sp. (CPBA 18193.1–2, 18194) and a single poorly preserved fragment of *Sabaudiella?* sp. indet. (CPBA 18190) occur 8 m below the top of the formation, above *Paraspiticeras* and with echinoid spines, small oysters and sponges in association.

#### 2.3. Cerro Chachahuén (37°04'S, 68°54'W)

This locality has been known since the early work of Padula (1948) and Holmberg (1962). Access is very difficult; from Pata Mora bridge over the Río Colorado near Rincón de los Sauces, it is a 50 km drive northeast along local dirt trails and dry rivers. The Agrio Formation is exposed near Puesto Ojos de Agua, south of Cerro Corrales, and reaches more than 100 m in thickness. The succession, disturbed by Miocene andesitic sills, begins in the uppermost Pilmatué Member. The Avilé Member is not developed

but the complete Agua de la Mula Member is represented, although the uppermost 8–10 m are covered. Only one incomplete *Hamulinites?* sp. (CPBA 18217) has been collected from a yellowish silty coquina, some 3 m below the top of the covered section.

#### 2.4. Loma Tilhué (37°23'S, 70°14'W)

Loma Tilhué is close to the southern side of Chos Malal, near national road 40, some 1.2 km northwest of the bridge over the Río Neuquén, on the western limb of the Loma Tilhué anticline. The whole Agrio Formation crops out here, but fossils are very rare and mostly restricted to the uppermost part of the Agua de la Mula Member. *Sabaudiella riverorum* (CPBA 18202.1–4, 18205, MLP 20316.1–3) and *S. aff. riverorum* (CPBA 18203, 18204) occur in calcareous nodules in grey shales below an orange limestone bed.

#### 2.5. El Cruce (37°23'S, 70°15'W)

This locality is in Chos Malal, near national road 40, some 1.7 km west of Loma Tilhué. There are good, though patchy, exposures of the topmost Agua de la Mula Member of the Agrio Formation and the lower Troncoso Member of the overlying Huitrín Formation. *Sabaudiella riverorum* (CPBA 18218, 18245.1–3, 18246.1–2, 20599) was found in calcareous nodules in grey to green shales.

#### 2.6. El Gasoducto (37°25'S, 69°56'W)

The section is 9 km north of Curaco, 1.3 km northwest of the intersection of provincial road 9 with a gas pipeline. Only the upper part of the Agua de la Mula Member of the Agrio Formation is well exposed at this locality. Here the highest beds of the Agrio Formation are represented by orange limestones. Immediately beneath are dark shales that yield *Sabaudiella riverorum* (CPBA 18195–18196, 20799) and, a few metres above, *Curacoites rotundus* (CPBA 18197–18198, 18216.1–2).

#### 2.7. Mina San Eduardo (37°32'S, 70°00'W)

This section is close to the abandoned San Eduardo coal mine, 7 km west-southwest of Curaco. The whole Agrio Formation has been measured here, reaching 1150 m. One specimen of *Sabaudiella riverorum* (CPBA 18199) was found in a calcareous nodule in black shales 30 m below the base of the 2-m-thick orange limestones that represent the uppermost beds of the formation, and two fragments were found loose at a similar level (CPBA 18200–18201).

#### 2.8. Puesto Canale (37°36'S, 70°03'W)

This locality was not visited by us. The ammonites were collected during field work for a Master's project (Rodríguez, unpublished). The section is 30 km south of Chos Malal, 10 km east of the junction of a local dirt road with national road 40 at Naunauco, on the western bank of the Río Neuquén. Small pieces of *Sabaudiella riverorum* (CPBA 10207–10208) and *S. sp. indet.* were recovered from black shales of the top Agrio Formation.

#### 2.9. Loma Rayoso (37°39'S, 70°00'W)

This locality is 3.2 km west of Balsa Huitrín. Access is from provincial road 9, just south of Río Neuquén, 1 km along a track that ends in a small house. Three fragments of *Sabaudiella sp. indet.* (CPBA 18215.1–3) have been recovered from the shales of the uppermost Agrio Formation.

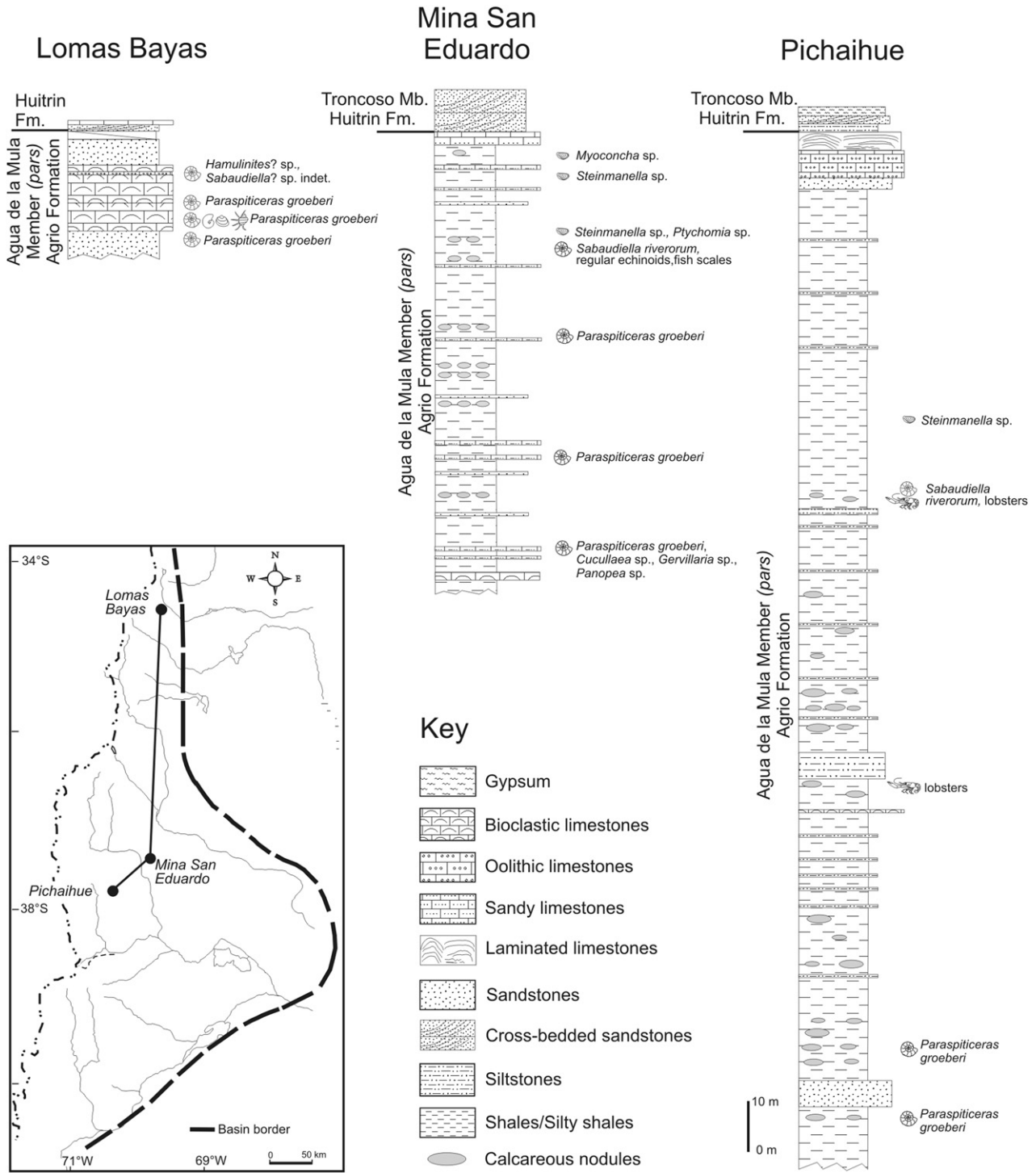


Fig. 2. Lithic logs of the highest beds of the Agrio Formation at Lomas Bayas, Mina San Eduardo and Pichaihue.

2.10. Pichaihue (37°47'S, 70°14'W)

The arroyo Pichaihue cuts a valley west of the Sierra de Chorriaca and the access to the section is along a track running due east off provincial road 4, 12 km east of Colipilli. The complete Agrio Formation is exposed on the western limb of the Chorriaca anticline. *Sabaudiella riverorum* (CPBA 18213.1–6, 18214.1–5) occurs in dark shales just below a band of very pale, cream-weathering, soft

siltstone that lies approximately 70 m below the top of the Agrio Formation.

2.11. Arroyo Paso Cerrado (37°47'S, 70°18'W)

The section is west of Pichaihue, along a track running south off provincial road 4, 9 km east of Colipilli, near the Arroyo Paso Cerrado. Loose specimens of *Sabaudiella riverorum* (CPBA

18209–18210, 18211.1–2), *S. aff. riverorum* (CPBA 18211.3) and *Curacoites rotundus* (CPBA 18212.1–2) have been collected from a level equivalent to that at Pichaihue.

### 3. Systematic palaeontology

The material described here is stored in the palaeontological collections of the Department of Geological Sciences in the University of Buenos Aires (CPBA) and the Invertebrate Paleontology collections of the La Plata Natural History Museum (MLP).

Suborder Ancyloceratina Wiedmann, 1966

Superfamily Ancylocerataceae Gill, 1871

Family Ancyloceratidae Gill, 1871

Subfamily Crioceratitinae Gill, 1871

Genus *Sabaudiella* Vašiček and Hoedemaeker, 2003

*Type species. Ancyloceras sabaudianus* Pictet and de Loriol, 1858.

**Remarks.** Vašiček and Hoedemaeker (2003, p. 19) defined *Sabaudiella* as “Small to medium sized, hooked to paraspinoid shells with a juvenile portion coiled in an open spiral. On the periphery of the adult, small marginal tubercles are present on the ribs, in which fibulation appears from time to time. The suture-line is complex with an asymmetrically trifid L and bipartite saddles.” They placed it in the Family Bochianitidae, Subfamily Protancyloceratinae and proposed *Ancyloceras sabaudianus* Pictet and de Loriol (1858) as the type species.

Busnardo (in Busnardo et al., 2003, p. 79) proposed the same generic name with the same type species just a month later, but included it in the Family Ancyloceratidae, as did Mourgues (2007). Busnardo also defined the genus more broadly to embrace forms both with and without tubercles or fibulation. We follow this broader definition as the microconchs of the Argentine material lack tuberculation but otherwise appear to resemble the tuberculate forms of *Sabaudiella*.

*Sabaudiella* is one of numerous small heteromorphs with ancyloceratid or paraspinoceratid coiling that appeared at various times through the Early Cretaceous, at least some of which may be microconchs of larger crioceratitid or ancyloceratid forms (e.g., Wright, 1996, p. 216). Neither Vašiček and Hoedemaeker (2003) nor Busnardo (in Busnardo et al., 2003) recognized dimorphism in their forms, whereas we suggest below that the macroconch of *Sabaudiella* is a crioceratitid form that co-occurs with it. Hence we place *Sabaudiella* in the Crioceratitinae.

As noted by Vašiček and Hoedemaeker (2003), the more complex suture of *Sabaudiella* distinguishes it from similar genera in the Leptoceratoidinae, which are characterized by a very simple suture, though Vermeulen (2006) grouped all of these forms together in a single family, Leptoceratoidinae.

*Sabaudiella riverorum* sp. nov.

Figs. 3A–O, 4A–E, 5

2011 *Sabaudiella* sp. Aguirre-Urreta et al., fig. 9d.

**Derivation of name.** For the Rivera family of Pichaihue valley, whose hospitality has helped our research for many years.

**Holotype.** CPBA 18195 (Fig. 3A, B), a microconch (m), from El Gasoducto.

**Allotype (Paratype).** CPBA 20599 (Fig. 3C), a macroconch (M), from El Cruce.

**Other paratypes.** 36 specimens: 8 from Loma Tilhue (CPBA 18202.1–4 m, 18205 M) (MLP 20316.1–3 m, Alberto Gutiérrez coll.); 6 from El Cruce (CPBA 18218 M, 18246.1–2 M, 18245.1–3 m); 2 from El Gasoducto (CPBA 18196 m, 20799 m); 3 from Mina San Eduardo (18199–18201 M); 2 from Puesto Canale (CPBA 10207–10208 M); 11 from Pichaihue (18213.1–6 m, 18214.1–5 M); 4 from Arroyo Paso Cerrado (18209–18210 m, 18211.1–2 M).

**Description.** A dimorphic form, with crioceratitid coiling in the macroconch and ancyloceratid coiling in the microconch.

**Macroconch.** Seventeen incomplete specimens and whorl fragments are loosely coiled; the coiling is more or less crioceratitid but three of the more complete examples indicate a narrowing of the space between the last preserved whorl and the previous one (Fig. 3C, E, F). The whorl height and thickness are similar; the dorsum is flat and smooth, the venter wide, flat and crossed transversely by sharp ribs in all but the most advanced growth stages. The earlier whorls have simple ribs, which develop very feeble ventro-lateral tubercles (Fig. 3C, E, F). During growth umbilical tubercles may also form and at a varying growth stage the rib pattern becomes more irregular: some ribs may branch in pairs or even threes from an umbilical tubercle, or may bifurcate at a mid-lateral tubercle or be intercalated at the same level. A slight ventro-lateral angularity may also develop, and tuberculate ribs may alternate with non-tuberculate ribs, which are slightly weaker on the lower flanks but equally strong towards and over the venter. The most complete specimen (Fig. 3C) shows that at the end of the body chamber the ribs nearly disappear. The suture is not visible in most specimens but an incomplete suture is visible in one large macroconch fragment (Fig. 5).

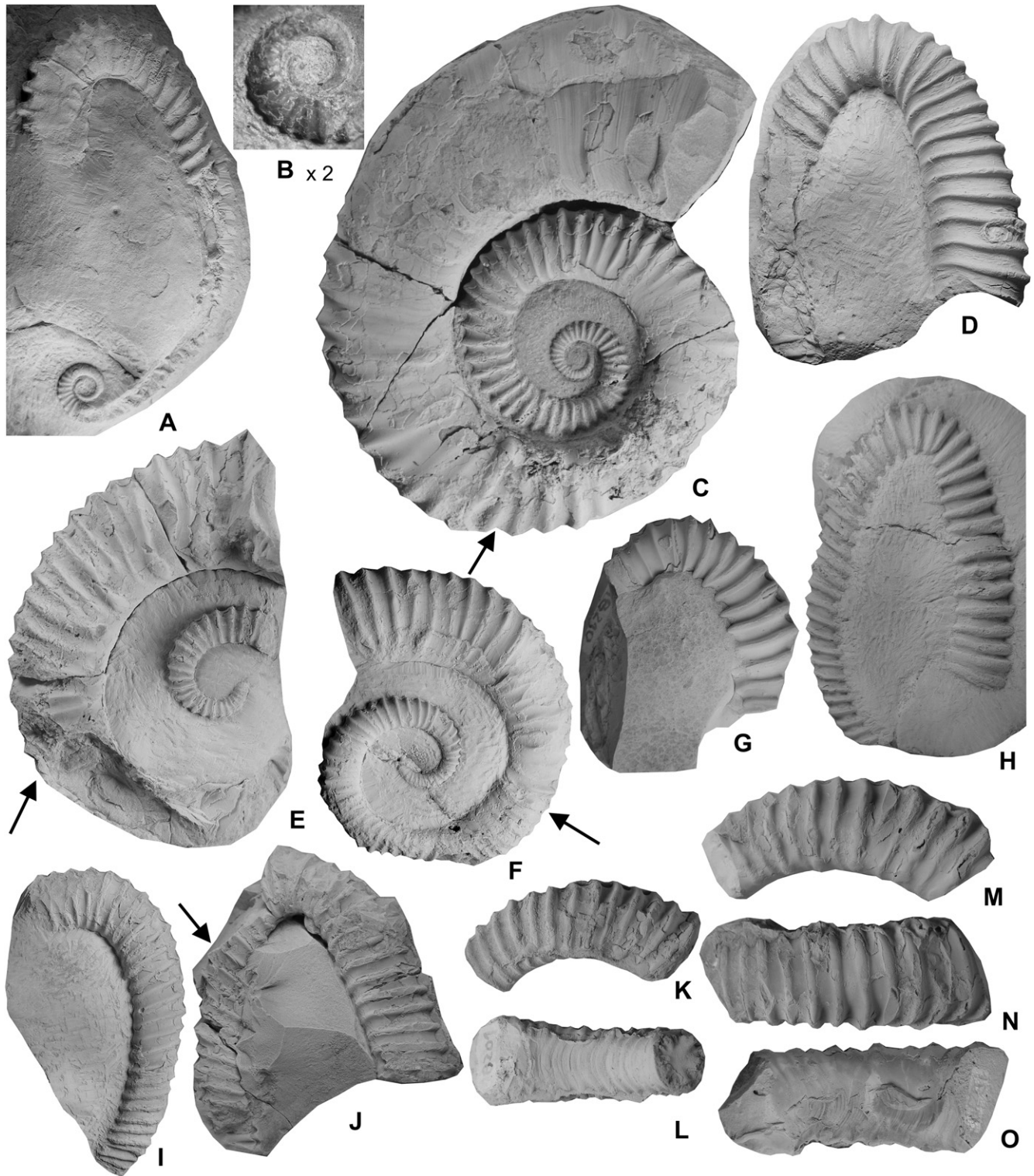
**Microconch.** Twenty-one specimens, mainly fragments. Moderately small (maximum dimension ca. 65 mm) ancyloceratid form. The earliest whorls show tight crioceratitid coiling to about 8 mm diameter (Fig. 3A, B). This stage is followed by a curved shaft, hook and final shaft, the last becoming almost straight (Fig. 3A, D, G–J). The whorl section is slightly to moderately compressed with a rounded or subrounded venter. The shell is ornamented with strong, narrowly rounded ribs that appear slightly sharp on internal moulds. The ribs remain single except at the apex of the hook where one or two bifurcate at the umbilical margin to maintain equal spacing of ribs on the flanks and venter (Fig. 3D, H). The ribs are moderately well-spaced, the interspaces being slightly wider than the ribs. The umbilical area is flat and smooth. Over most of the shell the ribs are strongly prorsiradial on the flanks but on the final shaft they become straight. They either extend straight over the venter or bend forward very slightly.

**Discussion.** As well as sharing morphological features, other than the style of coiling, some of the microconch and macroconch forms are from the same locality and level (Loma Tilhué, El Cruce and Pichaihue), which leads us to regard them as a dimorphic pair. In fact, some short fragments could be placed in either form.

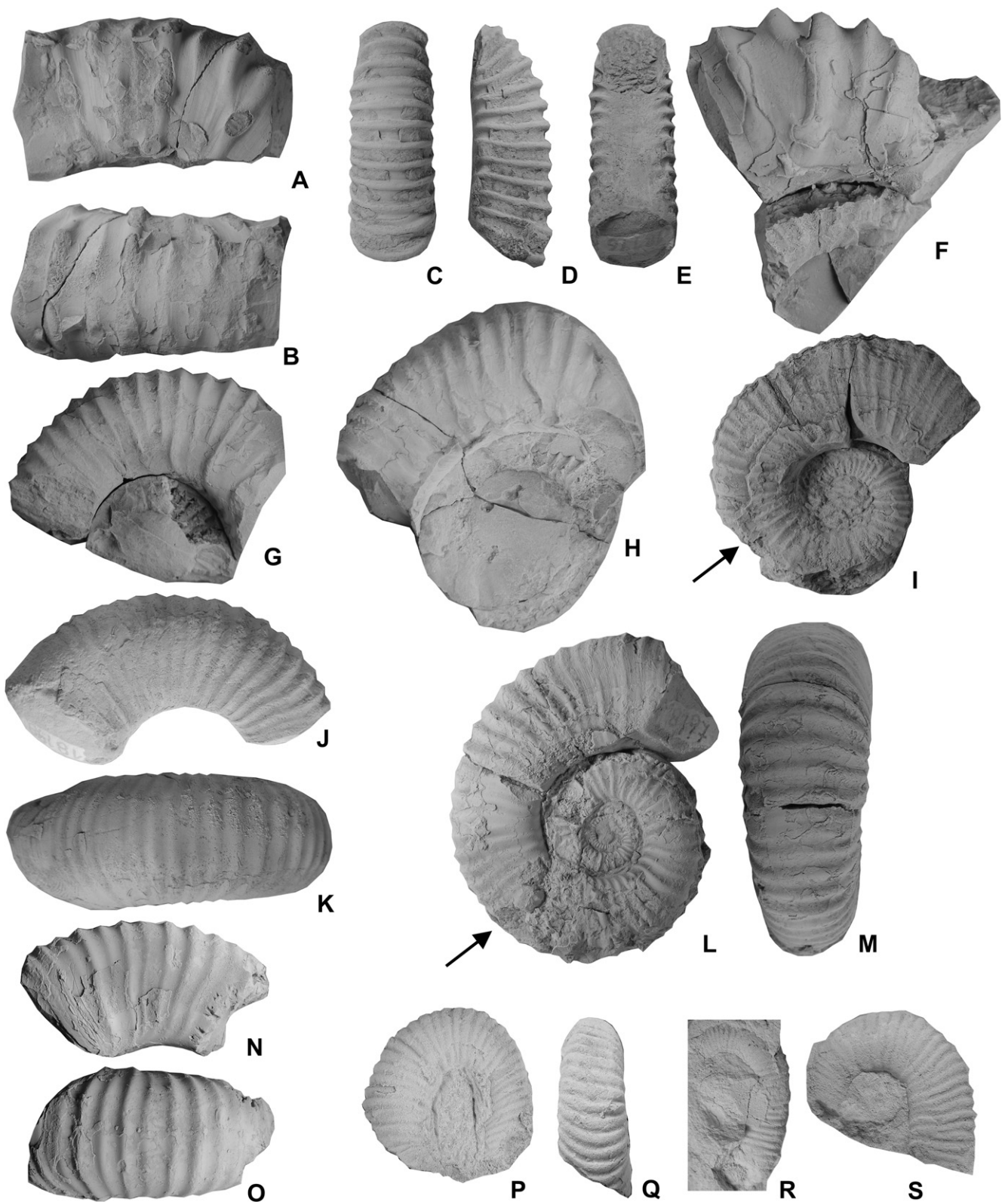
The microconch is more coarsely ribbed than the Swiss material described by Busnardo (in Busnardo et al., 2003) as *Sabaudiella simplex* or the Chilean ammonites figured by Mourgues (2007, fig. 2) under the same name, which also lack tubercles.

In addition to the material described above there are two fragmentary specimens from Loma Tilhué (CPBA 18204, Fig. 4G; 18203, Fig. 4H) and one from Arroyo Paso Cerrado (CPBA 18211.3, Fig. 4F) that are similar to the comparable growth stage of the macroconch of *Sabaudiella riverorum* but much more tightly coiled. They are provisionally identified as *S. aff. riverorum*. There are also three very short, crushed fragments from Loma Rayoso (CPBA 18215.1–3) that are identified as *Sabaudiella* sp. indet. and another fragment from Lomas Bayas (CPBA 18190) identified as *Sabaudiella?* sp. indet.





**Fig. 3.** *Sabaudiella riverorum* sp. nov. A, B, CPBA 18195, holotype, El Gasoducto. C, CPBA 20599, allotype, El Cruce. D, CPBA 18245.1, El Cruce. E, CPBA 18205, Loma Tilhue. F, CPBA 18246.1, El Cruce. G, CPBA 18210, Arroyo Paso Cerrado. H, CPBA 20799, El Gasoducto. I, CPBA 18245.2, El Cruce. J, CPBA 18202.3, Loma Tilhue. K, L, CPBA 18201, Mina San Eduardo. M–O, CPBA 18214.2, Pichaihue. All specimens apart from B coated with ammonium chloride. Arrow indicates beginning of body chamber. All  $\times 1$  except B, detail of inner whorls of holotype,  $\times 2$ .



**Fig. 4.** A–E, *Sabaudiella riverorum* sp. nov. A, B, CPBA 18214.1, Pichaihue. C–E, CPBA 18196, El Gasoducto. F–H, *Sabaudiella* aff. *riverorum* sp. nov. F, CPBA 18211.3, Arroyo Paso Cerrado; G, CPBA 18204, Loma Tilhue; H, CPBA 18203, Loma Tilhue. I–O, *Curacoites rotundus* gen. et sp. nov. I, CPBA 18216.1, El Gasoducto; J, K, CPBA 18198, El Gasoducto; L, M, CPBA 18197, holotype, El Gasoducto; N, O, CPBA 18212.2, Arroyo Paso Cerrado. P–S, ?*Hamulinites* sp. P, Q, CPBA 18127, Cerro Chachahuén; R, CPBA 18191, Servicio Geológico Minero GPS 062; S, CPBA 18192, Servicio Geológico Minero GPS 062. All specimens coated with ammonium chloride. Arrow indicates beginning of body chamber. All  $\times 1$ .

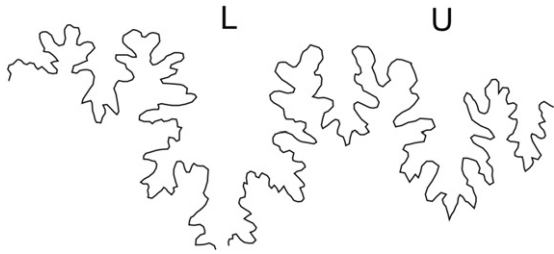


Fig. 5. Part of external suture-line of *Sabaudiella riverorum* (CPBA 18211.2 M) at 24 mm whorl height;  $\times 3$ .

Genus *Curacoites* gen. nov.

*Derivation of name.* From the Curaco Range, northern Neuquén.

*Type species.* *Curacoites rotundus* sp. nov.

*Diagnosis.* A crioceratitid with rounded whorl section in which the whorls are tightly coiled and bear strong, single or biplicate, radial ribs that are slightly flexuous on the flank.

*Discussion.* The combination of tight coiling and uniform, non-tuberculate ribbing of this form distinguishes it from the great majority of Hauterivian–Barremian heteromorphs. *Paraspiticeras* is another tightly coiled form, but it is characterised by ribbing of variable strength, the stronger ribs characteristically bearing from one to three tubercles. *Pedioceras* is again tightly coiled with ribbing similar to that of *Curacoites* in the earlier whorls, but it has a flat venter and ventro-lateral tubercles. The more tightly coiled Hemihoplitidae have a flat venter and tend to be slightly to moderately compressed. Some later Heteroceratidae, such as *Martelites*, are similar to *Curacoites* in their more advanced growth stages, but have helically coiled earlier whorls. Hence *Curacoites* is regarded as more closely related to the Crioceratitinae and placed in that subfamily.

*Curacoites rotundus* sp. nov.

Fig. 4I–O

*Derivation of name.* A reference to the rounded, almost circular nature of the whorl section.

*Holotype.* CPBA 18197 (Fig. 4L, M) from El Gasoducto.

*Paratypes.* 5 specimens: 3 from El Gasoducto (CPBA 18198, 18216.1–2); 2 from Arroyo Paso Cerrado (18212.1–2).

*Description.* Moderately small (maximum diameter probably ca. 65 mm) crioceratitid with a rounded, almost circular, whorl section. The venter is gently rounded and the dorsum is flat. The whorls are tightly coiled and there is only a very slight gap between the penultimate and last whorl. The shell bears quite strong radial ribs, which are very slightly flexuous across the flank and extend undiminished across the venter. The majority remain single but a few occasionally bifurcate at or a little above the umbilical margin, in which case one of the pair is sometimes less strong than the other. On the last part of the adult? body chamber of the holotype one or two fine ribs are intercalated between the main ones, and there is a very slight constriction. The umbilical area is flat and smooth.

*Discussion.* The preserved body chambers are of similar size, which suggests that they are probably adult. The development of some

finer ribs and a constriction at or near the end of the body chamber on the holotype would support this interpretation.

Subfamily Leptoceratoidinae Thieuloy, 1966

Genus *Hamulinites* Paquier, 1900

*Hamulinites?* sp.

Fig. 4P–S

*Material.* 6 specimens: 2 from Servicio Geológico Minero GPS 062 (CPBA 18191, 18192); 3 from Lomas Bayas (CPBA 18193.1–2, 18194); 1 from Cerro Chachahuén (CPBA 18217).

*Description.* Moderately small (estimated maximum dimension ca. 40 mm), ptychoceratid form. The material is incomplete; neither the earliest whorls nor the final growth stages are preserved. There is a straight shaft, hook and another straight shaft of unknown length. The whorl height increases moderately rapidly on the hook and succeeding shaft. The whorl section is slightly compressed with a rounded venter. The shell is ornamented with fine ribs that are prosiradiate on the first shaft and hook but more or less radial on the last preserved shaft: most remain single but some bifurcate low on the whorl flank of the hook. The ribs run straight over the venter.

*Discussion.* In general morphology this form appears to be close to European examples of *Hamulinites* (e.g., Vašiček and Wiedmann, 1994) but no sutures are visible: *Hamulinites* is characterized by a very simple suture. The whorls increase more rapidly in height than those of *Sabaudiella riverorum* and *Hamulinites?* sp. is more finely ribbed. It also has almost straight rather than gently curved shafts.

#### 4. Significance and age of the fauna

The *Sabaudiella*/*Curacoites*/*Hamulinites?* fauna is younger than any ammonite fauna previously recorded from the Agrio Formation and occurs in beds that, in the absence of evidence to the contrary, were provisionally placed in the higher part of the *Paraspiticeras groeberi* Zone (Aguirre-Urreta and Rawson, 1997). However, the new fauna forms a distinct assemblage several metres above the last *Paraspiticeras groeberi*. Although ammonites are not common at this level, elements of the fauna are widely distributed across the northern half of the Neuquén Basin. *Sabaudiella riverorum* occurs in several sections in northern Neuquén. We therefore propose a new ammonite zone of *Sabaudiella riverorum* to accommodate the fauna, with its base defined by the first appearance of the species. Because of the sparsity of material at any one locality and the apparent absence of ammonites in the highest few metres of the Agrio Formation it is not possible to determine the exact range of the index species so we provisionally take the top of the zone to coincide with the top of the formation.

At one locality (El Gasoducto), *Curacoites rotundus* appears a few metres above *S. riverorum*, but whether this is a general pattern of occurrence is uncertain because at the only other locality to yield this species (Arroyo Paso Cerrado) only two specimens were found, both loose though associated with *S. riverorum*.

In southern Mendoza, where the upper Agrio Formation is represented by a very near-shore, more calcareous facies, only a single fragment of *Sabaudiella?* sp. indet. has been found. Instead, *Hamulinites?* appears at a comparable level, just above *Paraspiticeras*, and can be used as an alternative marker for the *S. riverorum* Zone.

The age of the faunas in relation to the classic European sections is difficult to assess accurately, especially as one of the Argentine genera is new and another can only be identified provisionally. Our discussion therefore focuses principally on *Sabaudiella*. According

AGE	West Mediterranean Province (Reboulet et al. 2011)		Neuquén Basin (modified from Aguirre-Urreta et al. 2007)
	Biozone	Sub-Biozone	Biozone
BAR.	<i>Taveraidiscus hugii auctororum</i>	<i>Psilotissotia colombiana pars</i>	<i>Sabaudiella riverorum</i>
		<i>T. hugii auctororum</i>	
LATE HAUTERIVIAN	"Pseudothurmannia ohmi"	<i>Pseudothurmannia picteti</i>	-----
		<i>Pseudothurmannia catulloi</i>	<i>Paraspiticeras groeberi</i>
		"Pseudothurmannia ohmi"	-----
	<i>Balearites balearis</i>	<i>Spathioceras seitzi</i>	<i>Crioceratites diamantensis</i>
		<i>Crioceratites krenkeli</i>	
		<i>Binelliceras binelli</i>	
		<i>Binelliceras balearis</i>	
	<i>Plesiospitidiscus ligatus</i>		<i>Crioceratites schlagintweiti</i>
	<i>Subsaynella sayni</i>		<i>Spitidiscus riccardii</i>

Fig. 6. Late Hauterivian–earliest Barremian biostratigraphical correlation with the "standard" zonation of the West Mediterranean Province.

to Busnardo (in Busnardo et al., 2003, p. 79) the type species, *S. sabaudiana*, occurs in the highest Hauterivian "Pseudothurmannia angulicostata auct." Zone. This was based on both newly collected and museum material from Veveyse de Châtel, Switzerland, where its main occurrence is in bed 92.2 (Busnardo et al., 2003, table 4). Vašiček and Hoedemaeker (2003, p. 20) stated, however, that the type species of the genus is of ?Early Barremian age "according to the literature". This apparent contradiction reflects a differing interpretation of the position of the Hauterivian/Barremian boundary. At its meeting in 2002 (Hoedemaeker et al., 2003), The Kilian Group agreed that the "Pseudothurmannia angulicostata auct." Zone should be renamed the *Pseudothurmannia ohmi* Zone and retained in the Hauterivian. This is still the recognised situation (Reboulet et al., 2011). The zone was divided into three subzones, the middle of which is the *Pseudothurmannia catulloi* Subzone. A new species of *Sabaudiella*, *S. argosensis*, was described from this subzone by Vašiček and Hoedemaeker (2003), but the subzone was placed in the Lower Barremian. *Sabaudiella argosensis* occurs in the Río Argos section in southeast Spain. A third species, *S. simplex*, was described by Busnardo (in Busnardo et al., 2003). This co-occurs with *S. sabaudiana* bed 92.2 at Veveyse de Châtel, but first appears slightly lower in the sequence.

According to Vašiček and Hoedemaeker (2003), *Sabaudiella* also occurs in Italy, in the Lower Barremian zone of *Taveraidiscus hugii*: they placed the ammonites figured by Cecca et al. (1995, pl. 1, figs 13–16) as "*Paraspiticeras*" *evolutum* (Fallot and Termier) in synonymy with *Sabaudiella argosensis*, but the individuals with simple ribs throughout (Morphotype A in Cecca et al., 1995) may be better placed in *S. simplex*.

These records indicate that the European occurrences of *Sabaudiella* extend from the highest Hauterivian *Pseudothurmannia ohmi* Zone into the lowest Barremian *Taveraidiscus hugii* Zone, though it should be stressed that *Sabaudiella* is a recently described genus and further discoveries will probably show that, like other heteromorph genera, it has a more extensive range.

*Hamulinites* is a widely distributed genus that is generally regarded as Barremian in age (Wright, 1996), predominantly Early Barremian (Vašiček and Wiedmann, 1994), but Avram (1999), Busnardo (in Busnardo et al., 2003) and Company et al. (2005) all recorded it as first appearing within the *Pseudothurmannia ohmi* Zone in Romania, Switzerland and Spain respectively.

The only previous record of *Sabaudiella* outside Europe is from Chile, where Mourgues (2007) and Aguirre-Urreta et al. (2007) illustrated specimens assigned to *S. simplex* Busnardo that

apparently co-occur there with the last *Paraspiticeras groeberi*. Mourgues (2007, fig. 3) concluded that the whole of the *Paraspiticeras groeberi* Zone in Chile should, therefore, be correlated with the upper two subzones (*catulloi* and *picteti*) of the *Pseudothurmannia ohmi* Zone at the top of the Hauterivian, while we have regarded at least part of the *Paraspiticeras groeberi* Zone in Argentina as earliest Barremian (Aguirre-Urreta et al., 2005, 2007).

In conclusion, by comparison with the European faunas we suggest that the *Sabaudiella riverorum* Zone spans the Hauterivian/Barremian boundary and thus the underlying *Paraspiticeras groeberi* Zone as modified here is of very late Hauterivian age (Fig. 6).

## Acknowledgements

Our research in the Neuquén Basin was initially supported by grants from the British Council/Fundación Antorchas (1995–2001). Beatriz Aguirre-Urreta acknowledges partial support from grants ANPCYT PICT 0464/10 and UBACYT 100974. Peter Rawson acknowledges the award of a 2003 Leverhulme Emeritus Fellowship from the Leverhulme Trust which supported further field work in Argentina. We are grateful to Dario Lazo and Victor Ramos (University of Buenos Aires) and Sue Rawson for help in the field. We also acknowledge Santiago Reuil for his skill in preparing some of the specimens and an anonymous referee for his constructive comments. David Batten is thanked for carefully editing the paper. This is contribution R-48 of the Instituto de Estudios Andinos Don Pablo Groeber (UBA-CONICET).

## References

- Aguirre-Urreta, M.B., Rawson, P.F., 1997. The ammonite sequence in the Agrio Formation (Lower Cretaceous), Neuquén Basin, Argentina. *Geological Magazine* 134, 449–458.
- Aguirre-Urreta, M.B., Rawson, P.F., Concheyro, G.A., Bown, P.R., Ottone, E.G., 2005. Lower Cretaceous (Berriasian–Aptian) biostratigraphy of the Neuquén Basin. In: Veiga, G., Spalletti, L.A., Howell, L.A., Schwarz, E. (Eds.), *The Neuquén Basin: A Case Study in Sequence Stratigraphy and Basin Dynamics*. Geological Society, London, Special Publication, 252, 57–81.
- Aguirre-Urreta, M.B., Mourgues, F.A., Rawson, P.F., Bulot, L.G., Jaillard, E., 2007. The Lower Cretaceous Chañarcillo and Neuquén Andean basins: ammonoid biostratigraphy and correlations. *Geological Journal* 42, 143–173.
- Aguirre-Urreta, B., Lazo, D.G., Griffin, M., Vennari, V., Parras, A.M., Cataldo, C., Garberoglio, R., Luci, L., 2011. Mega invertebrados del Cretácico y su importancia bioestratigráfica. In: Leanza, H.A., Arregui, C., Carbone, O., Danieli, J.C., Vallés, J.M. (Eds.), *Geología y Recursos Naturales de la Provincia del Neuquén. Relatorio del XVIII Congreso Geológico Argentino*, pp. 465–488.
- Avram, E., 1999. Some new species of the subfamily 'Leptoceratoidinae' (Ancyloceratinae, Ammonoidea) in uppermost Hauterivian and lower Barremian deposits from Rumania. *Scripta Geologica Special Issue* 3, 31–43.
- Busnardo, R., Charollais, J., Weidmann, M., Clavel, B., 2003. Le Crétacé inférieur de la Veveyse de Châtel (Suisse). *Revue de Paléobiologie* 22, 1–174.
- Cecca, F., Faraoni, P., Marini, A., Pallini, G., 1995. Field-trip across the representative sections for the Upper Hauterivian–Barremian ammonite biostratigraphy in the Maiolica exposed at Monte Nerone, Monte Petrano and Monte Catria (Umbria-Marche Apennines). *Memorie Descrittive della Carta Geologica d'Italia* 51, 187–211.
- Company, M., Aguado, R., Sandoval, J., Tavera, J.M., Jiménez de Cisneros, C., Vera, J.A., 2005. Biotic changes linked to a minor anoxic event (Faraoni Level, latest Hauterivian, Early Cretaceous). *Palaeogeography, Palaeoclimatology, Palaeoecology* 224, 186–199.
- Gerth, E., 1925. La fauna neocomiana de la cordillera Argentina en la parte meridional de la provincia de Mendoza. *Actas de la Academia Nacional de Ciencias* 9 (2), 57–122.
- Gill, T., 1871. Arrangement of the families of mollusks. *Smithsonian Miscellaneous Collections* 227, 1–49.
- Hoedemaeker, P.J., Reboulet, S., Aguirre-Urreta, M.B., Alsen, P., Aoutem, M., Atrops, F., Barragan, R., Company, M., Gonzalez, C., Klein, J., Lukeneder, A., Ploch, I., Raisossadat, N., Rawson, P.F., Ropolo, P., Vašiček, Z., Vermeulen, J., Wippich, M.G.E., 2003. Report on the 1st International Workshop of the IUGS Lower Cretaceous Ammonite Working Group, the 'Kilian Group' (Lyon, 11 July 2002). *Cretaceous Research* 24, 89–94.
- Holmberg, E., 1962. Descripción geológica de la Hoja 32d Chachahuén, Prov. de Neuquén y Mendoza. *Boletín de la Dirección Nacional de Geología y Minería (Buenos Aires)* 91, 1–72.



- Leanza, H.A., Hugo, C., 2001. Hoja Geológica 3969-1 Zapala, Provincia de Neuquén. *Boletín del Instituto de Geología y Recursos Mineros (Buenos Aires)* 275, 1–128.
- Mourgues, F.A., 2007. *Sabaudiella* Vašiček & Hoedemaeker (Ancyloceratidae, Ammonoidea) in the Andean Lower Cretaceous Chañarcillo back-arc basin, northern Chile. *Cuadernos del Museo Geominero* 8, 267–271.
- Padula, E., 1948. Sobre la presencia del Hauterivense marino en la Sierra de Chachahuén. *Boletín de Informaciones Petroleras* 287, 49–53.
- Paquier, V., 1900. Recherches géologiques dans le Diois et les Barronnies orientales. *Bulletin de la Société de Statistique des Sciences Naturelles et des Arts Industriels de Département de l'Isère (Grenoble)* 5, 77–476.
- Pictet, F.-J., de Loriol, P., 1858. Description des fossiles contenus dans les terrains néocomiens des Voirons. *Matériaux Pour la Paléontologie Suisse (Genève)* 2, 1–64.
- Reboulet, S., Rawson, P.F., Moreno-Bedmar, J.A., Aguirre-Urreta, M.B., Barragan, R., Bogomolov, Y., Company, M., Gonzalez-Arreola, C., Stoyanova, V.I., Lukeneder, A., Matrimon, B., Mitter, V., Randrianaly, H., Vasicek, Z., Baraboshkin, E.J., Bert, D., Bersac, S., Bogdanova, T.N., Bulot, L.G., Latil, J.-L., Mikhailova, I.A., Ropolo, P., Szives, O., 2011. Report on the 4th International Meeting of the IUGS Lower Cretaceous Ammonite Working Group, the "Kilian Group" (Dijon, France, 30th August 2010). *Cretaceous Research* 32, 786–793.
- Rodríguez, M.C., 2005. Geología y bioestratigrafía de las proximidades de Loma Rayoso, provincia de Neuquén. Trabajo Final de Licenciatura, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, 137 pp., unpublished.
- Spalletti, L.A., Veiga, G.D., Schwarz, E., 2011. La Formación Agrio (Cretácico Temprano) en la Cuenca Neuquina. In: Leanza, H.A., Arregui, C., Carbone, O., Danieli, J.C., Vallés, J.M. (Eds.), *Geología y Recursos Naturales de la Provincia del Neuquén. Relatorio del XVIII Congreso Geológico Argentino*, pp. 145–160.
- Thieuloy, J.-P., 1966. Leptocères berriasiens du massif de la Grande-Chartreuse. *Geologie Alpine* 42, 281–295.
- Vašiček, Z., Hoedemaeker, P.J., 2003. Small Berriasian, lower Valanginian and Barremian heteromorphic ammonites from the Río Argos succession (Caravaca, southeast Spain). *Scripta Geologica* 125, 11–33.
- Vašiček, Z., Wiedmann, J., 1994. The Leptoceratoidinae: small heteromorph ammonites from the Barremian. *Palaeontology* 37, 203–239.
- Vermeulen, J., 2006. Nouvelle classification à fondement phylogénétique des ammonites hétéromorphes du Crétacé inférieur. *Annales du Muséum d'Histoire Naturelle de Nice* 21, 137–178.
- Wiedmann, J., 1966. Stammesgeschichte und System der posttriadischen Ammonoiten, ein Überblick (1. Teil). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 127, 13–81.
- Wright, C.W., 1996. *Treatise on Invertebrate Paleontology, Part I. Mollusca 4 (Revised)*. Volume 4 Cretaceous Ammonoidea (with contributions by J.H. Callomon and M.K. Howarth). Geological Society of America, Boulder, CO, and University of Kansas Press, Lawrence, KS, xx + 362 pp.