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Ammonoids (Crioceratitinae, Hauterivian) from the Austral Basin, Chile

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Abstract. The low diversity of the Austral Basin ammonoid faunas was traditionally associated with a high degree of endemism. However, as reported herein, the ammonoids belonging to the Family Ancyloceratidae, Subfamily Crioceratitinae have affinities with European forms. Therefore, the Hauterivian ammonoids of the Austral Basin represent a mixture of endemic (*Favrella* Douvillé), with typical Tethyan examples (*Hemihoplites* Spath, *Crioceratites* Léveillé), and faunas that are characteristic of Northwestern Europe on the margins of the Boreal realm (*Protaconeceras* Casey, *Aegocrioceras* Spath), although the endemic forms dominate in number of specimens. The following species are described here: *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta, *Crioceratites* (*C.*) *apricum* (Giovine) and *Crioceratites* sp. aff. *C.* (*C.*) *schlagintweiti* (Giovine). This rare and localized appearance of taxa of the Northern Hemisphere suggests periods of sea level rise that permitted widespread migration from this region to peripheral basins.

Resumen. AMONOIDEOS (CRIOCERATITINAE, HAUTERIVIANO) DE LA CUENCA AUSTRAL, CHILE. La baja diversidad de las faunas de amonoideos de la cuenca Austral ha sido tradicionalmente asociada a su alto grado de endemismo. Sin embargo, aquí se describe una fauna de amonoideos de la Familia Ancyloceratidae, Subfamilia Crioceratitinae que muestra afinidades con formas europeas. De este modo, los amonoideos hauterivianos de la cuenca Austral representan una mezcla de géneros endémicos (*Favrella* Douvillé), con típicos ejemplos tethyanos (*Hemihoplites* Spath, *Crioceratites* Léveillé) y faunas características del noroeste de Europa en los márgenes del reino Boreal (*Protaconoceras* Casey, *Aegocrioceras* Spath), aunque las formas endémicas dominan en número de ejemplares. Se describen las siguientes especies: *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta, *Crioceratites* (*C.*) *apricum* (Giovine) y *Crioceratites* sp. aff. *C.* (*C.*) *schlagintweiti* (Giovine). Esta rara y localizada aparición de taxones del Hemisferio Norte sugiere períodos de nivel del mar global alto, lo que habría permitido la migración desde esta región a cuencas periféricas.

Key words. Ammonoids. Crioceratitinae. Hauterivian. Austral Basin. Chile.

Palabras clave. Amonoideos. Crioceratitinae. Hauteriviano. Cuenca Austral. Chile.

Introduction

The Austral Basin of Southern Patagonia was a retroarc basin open to the Pacific Ocean during most of the Cretaceous (figure 1.A). The early stages of the basin are characterized by a clastic nearshore platform during Berriasian to Early Hauterivian times followed or interbedded with dark shales with abundant calcareous nodules of a basinal setting spanning from the Valanginian to the Albian (Hatcher, 1900; Riccardi and Rolleri, 1980). Ammonoids are abundant in the shaly facies, although the faunas show a low diversity (Aguirre-Urreta, 2002a).

In this article we describe an assemblage of ammonoids in Patagonia; while one genus is of Tethyan origin, the other is only known in the margins of the Boreal realm. These ammonoids occur in outcrops of the Katterfeld Formation exposed in the headwaters of Estero Lechoso, to the north of Puerto Ibáñez, on the northern side of lago General Carrera in Chile (figure 1.B). The fauna is represented by *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta, *Crioceratites* (*C.*) *apricum* (Giovine) and *Crioceratites* sp. aff. *C.* (*C.*) *schlagintweiti* (Giovine).

Consequently, a new biogeographic scheme is proposed here for the Hauterivian of the Austral Basin, based on the correlation of present fauna with coeval elements in the Tethyan and Boreal realms. A brief summary on the biostratigraphy of this interval was advanced elsewhere (Aguirre-Urreta *et al.*, 2000).

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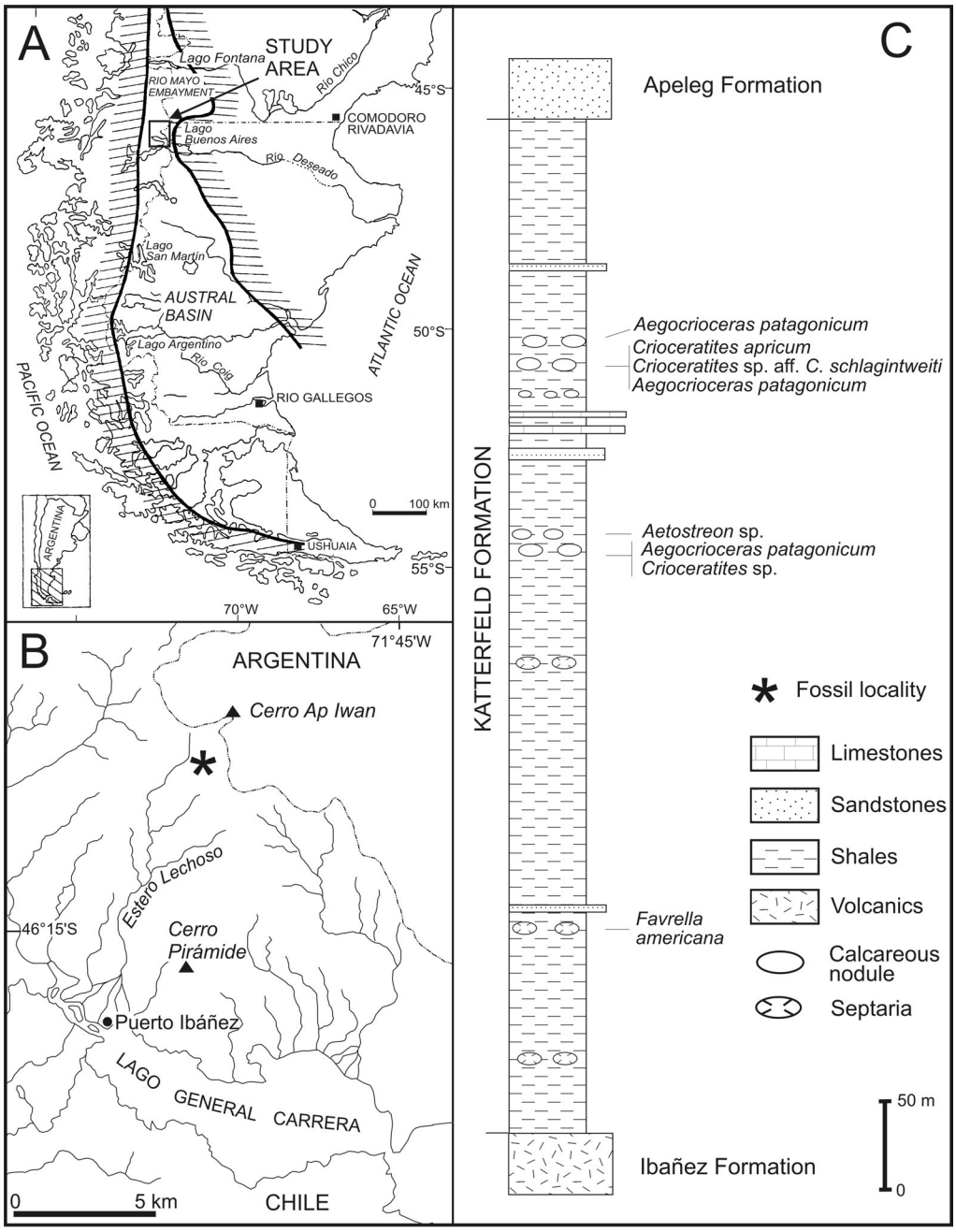


Figure 1. A, Map of the Austral Basin and the Río Mayo Embayment with indication of the study area; **B,** Locality map of Estero Lechoso on the northern shore of Lago General Carrera, Chile; **C,** Stratigraphic section of the Katterfeld Formation with location of ammonoid levels / ***A,*** *Mapa de la cuenca Austral y el engolfamiento de Río Mayo con indicación del área estudiada;* ***B,*** *Mapa de ubicación de Estero Lechoso en la margen norte del lago General Carrera, Chile;* ***C,*** *Sección estratigráfica de la Formación Kotterfeld con ubicación de los niveles con amonoideos.*

Geological setting

The northwestern sector of the oil-bearing late Mesozoic Austral Basin of southern Chile and Argentina (e.g. Biddle *et al*., 1986), is exposed in the area of present day central Patagonian Cordillera. The eastern margin of the basin expands to the east between 45º-47º S latitude, forming the Río Mayo Embayment (Aguirre-Urreta and Ramos, 1981; Ramos and Aguirre-Urreta, 1994). The cordilleran outcrops studied by Suárez *et al*. (1996) and Bell and Suárez (1997) represent a retroarc basin developed on continental crust to the east of a magmatic arc. This arc, which is now represented by the Patagonian batholith and Late Jurassic and Early Cretaceous volcanic rocks, was formed by the subduction of a Pacific oceanic plate beneath the South American continental margin (Hervé *et al*., 2000; Suárez and De La Cruz, 2001).

The northwestern part of the basin was partially filled by the Coyhaique Group (Haller and Lapido, 1980; De La Cruz *et al*., 2003), a marine succession diachronically overlying a Middle to Late Jurassic volcanic succession of the Ibáñez Formation of the Lago La Plata Group, and underlying Late Aptian subaerial volcanic rocks of the Divisadero Group.

The early stages of the basin are characterized by a clastic nearshore platform of the Springhill Formation developed as a stable shelf in the eastern margin during Berriasian to Early Hauterivian times. In the inner western part of the basin the oyster beds, submarine pyroclastic deposits, volcanic turbidites, and tuffites (ash siltstones and sandstones) of the 100 m thick Toqui Formation (Suárez *et al*., 1996) equivalent to the Springhill Formation, were deposited on high-energy shorelines and near-shore environments adjacent to the active volcanic arc.

The Katterfeld Formation, a succession of marine dark shales up to 500 m thick was deposited in still-water anoxic conditions during Valanginian to Hauterivian times (Ramos, 1981; Olivero and Aguirre-Urreta, 2002). The Katterfeld Formation, the deepest facies of the sedimentary infilling of the Late Jurassic-Early Cretaceous Río Mayo Embayment is characterized by a low diversity of its fossil fauna. This formation is represented by a geographically widespread unit of black shales, commonly bearing the ammonoids *Favrella* sp. aff. *F. steinmanni* (Favre) and *Favrella americana* (Favre) of Hauterivian age, of local character and endemic of the Austral Basin (Riccardi, 1988).

In the uppermost levels of the Katterfeld Formation near Puerto Ibáñez, Chile, *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta, *Crioceratites* (*C.*) *apricum* (Giovine) and *Crioceratites* sp. aff. *C.* (*C.*) *schlagintweiti* (Giovine) form a distinctive association. This assemblage is present in a single locality within 120 m of black shales, and located more than 200 m above the widespread ammonoid *Favrella americana* (Favre).

The Apeleg Formation, of Middle to Late Hauterivian to Early Aptian age, is the youngest of the three formations of the Coyahique Group (Ramos, 1981). It is a succession up to 1,200 m thick of well-sorted sandstones and mudstones characterized by mud-draped ripples and a well preserved, and varied trace fossil assemblage (Bell and Suárez, 1997). The sediments were mainly deposited as offshore tidal sandbars or sand ridges on a shallow marine shelf (Bell and Suárez, 1997), and locally they represent easterly-derived deltaic facies (Ramos, 1981; González-Bonorino and Suárez, 1995). Sediment accumulation was terminated by Late Aptian deformation, tectonic inversion, uplift and erosion. This tectonic episode was followed in the Late Aptian, by a major dacitic to andesitic volcanic event which produced the unconformably/paraconformably overlying Divisadero Group.

Lithostratigraphy and fossil locality

In the study area the black shales of the Katterfeld Formation rest directly on the Ibáñez Formation and crop out over a large area in the catchments of Estero Lechoso, reaching a thickness of 500 m (Bruce, 2001). The underlying Ibáñez Formation in the area is composed of silicic tuffs, mainly ignimbrites, surge and ash fall deposits, silicic extrusive and subvolcanic rocks, and intercalations of lacustrine, fluvial and deltaic deposits. Extrusive basaltic and andesitic rocks form a minor part of this formation. The contact of the Katterfeld Formation with the Ibáñez Formation is not well exposed, but both units occur very closely, suggesting a direct contact relationship (Bruce, 2001). In turn the Katterfeld Formation is conformably overlain by the Apeleg Formation.

A section surveyed in the Katterfeld Formation at the headwaters of Estero Lechoso (46°11′53″S, 71°52′48″W) is shown in figure 1.C (see also the appendix).

Systematic palaeontology

The material described here has been collected by the authors and is stored in the Palaeontological collections of the Geological Survey of Chile (SERNAGEOMIN). Type material has been examined in the Palaeontological collections of the University of Buenos Aires. This systematic part is by the senior author (B.A-U).

Dimensions of specimens are indicated as follows: D = diameter; H = whorl height; W = whorl breath; U = umbilical diameter. Figures in parentheses are ratios expressed as a percentage of the total diameter. The suture terminology followed here is: I = internal lobe; U = umbilical lobe; L = lateral lobe; E = external lobe.

Order AMMONOIDEA Zittel, 1884
Suborder ANCYLOCERATINA Wiedmann, 1966
Family ANCYLOCERATIDAE Gill, 1871
Subfamily CRIOCETATITINAE Gill, 1871

Genus ***Aegocrioceras*** Spath, 1924

Type species. *Hamites capricornu* Roemer, 1841, by original designation.

Diagnosis. A genus with crioceratitid coiling and

strong, single, radial ribs. Tubercles, mainly ventrolateral, are common in juveniles but disappear with growth (Rawson, 1975, p. 137).

Comments. *Aegocrioceras* was the dominant ammonoid across the whole NW Europe (Rawson, 1995), occurring in both the north German and English "middle" Hauterivian. It is a very distinctive genus due to its simple, strong ribbing, which clearly differentiates it from *Crioceratites* and allied forms. It appears suddenly, and according to Rawson (1995), it arose by allopatric speciation from a Tethyan *Crioceratites* immigrant in the margins of the Boreal realm. Rawson (1970, 1975) has extensively monographed the species of *Aegocrioceras* especially from Speeton Clay in England, and although there are no modern reviews of the German material, new illustrations by Kemper (1992) and the multiple references to those species from Rawson (1975) are useful to have a good general picture of this peculiar crioceratitid.

Aegocrioceras patagonicum sp. nov. Aguirre-Urreta
Figures 2.A-K

Holotype. The specimen SERNAGEOMIN 1650, headwaters of Estero Lechoso, Puerto Ibáñez, Chile.

Type locality. Headwaters of Estero Lechoso, Puerto Ibáñez, Chile.

Material. Besides the holotype, 17 specimens comprising the body chamber and crushed phragmocones (SERNAGEOMIN 1648-49, 1651-65), 1 specimen comprising an incomplete phragmocone and incomplete body chamber (1666) and more than 25 fragments of whorls.

Diagnosis. A slightly compressed species with rounded whorl section; radial, usually non-tuberculated ribs, with some very rarely bifurcating on the flank or at the umbilical edge.

Description. The coiling is crioceratitid, in an open spire, with whorls in contact. The whorl section is nearly equidimensional. The dorsum is concave, the umbilical edge rounded to slightly angular, the flanks slightly arched, and the venter broad and rounded. The maximum width is at mid-flank. The ornamentation consists of dense, simple ribs. At intermediate growth stages there are 21-23 ribs per half whorl, becoming denser with growth (26-31 ribs per half whorl). They are represented as striae concave to the aperture in the dorsum. They arise at the umbilical edge and turn slightly backwards and forwards on the flank and cross the venter without interruption. Some rare bifurcations occur at the umbilical edge or in the middle of the flank. No tubercles are noticeable in most of the specimens, but a single specimen with innermost whorls preserved (D = 7 mm, SERNAGEOMIN 1666) shows at least two rows of tubercles, ventral and ventrolateral on each rib. The suture line is not well preserved but is quadrilobate, typically crioceratitid, quite simple, with L the largest lobe.

Dimension of figured specimens (in mm)

Specimen	D	H	W	H/W	U
1650 holotype	67.2	23.7 (0.35)	21.3 (0.32)	1.11	*32.0 (0.48)
1653	43.9	15.7 (0.36)	15.7 (0.36)	1.00	18.5 (0.42)
1651	52.8	18.3 (0.35)	16.4 (0.31)	1.12	25.2 (0.48)
1652	54.8	17.3 (0.32)	18.5 (0.34)	0.95	28.1 (0.51)
1656	67.9	21.6 (0.32)	19.4 (0.29)	1.11	*33.2 (0.49)
1657	68.4	23.5 (0.34)	22.6 (0.33)	1.04	33.4 (0.49)
1655	68.9	22.6 (0.33)	21.8 (0.32)	1.04	*33.7 (0.49)
1654	88.2	28.4 (0.32)	26.8 (0.30)	1.06	*43.8 (0.50)

* approximate measurement

Discussion. *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta is very close to *Aegocrioceras quadratum* (Crick, 1898) regarding degree of coiling and style and density of ribbing, but differs in the whorl section which is quadrate in this species (Crick, 1898; Rawson, 1975). *A. spathi* Rawson differs from *A. patagonicum* sp. nov. Aguirre-Urreta in the degree of evolution and in having a much more compressed, subrectangular whorl section with flat dorsum. Several other species have been described in detail from Speeton Clay but all of them differ from *A. patagonicum* sp. nov. Aguirre-Urreta in at least one morphological character (Rawson, 1970, 1975).

Etymology. For Patagonia, the geographic region where the species is recorded.

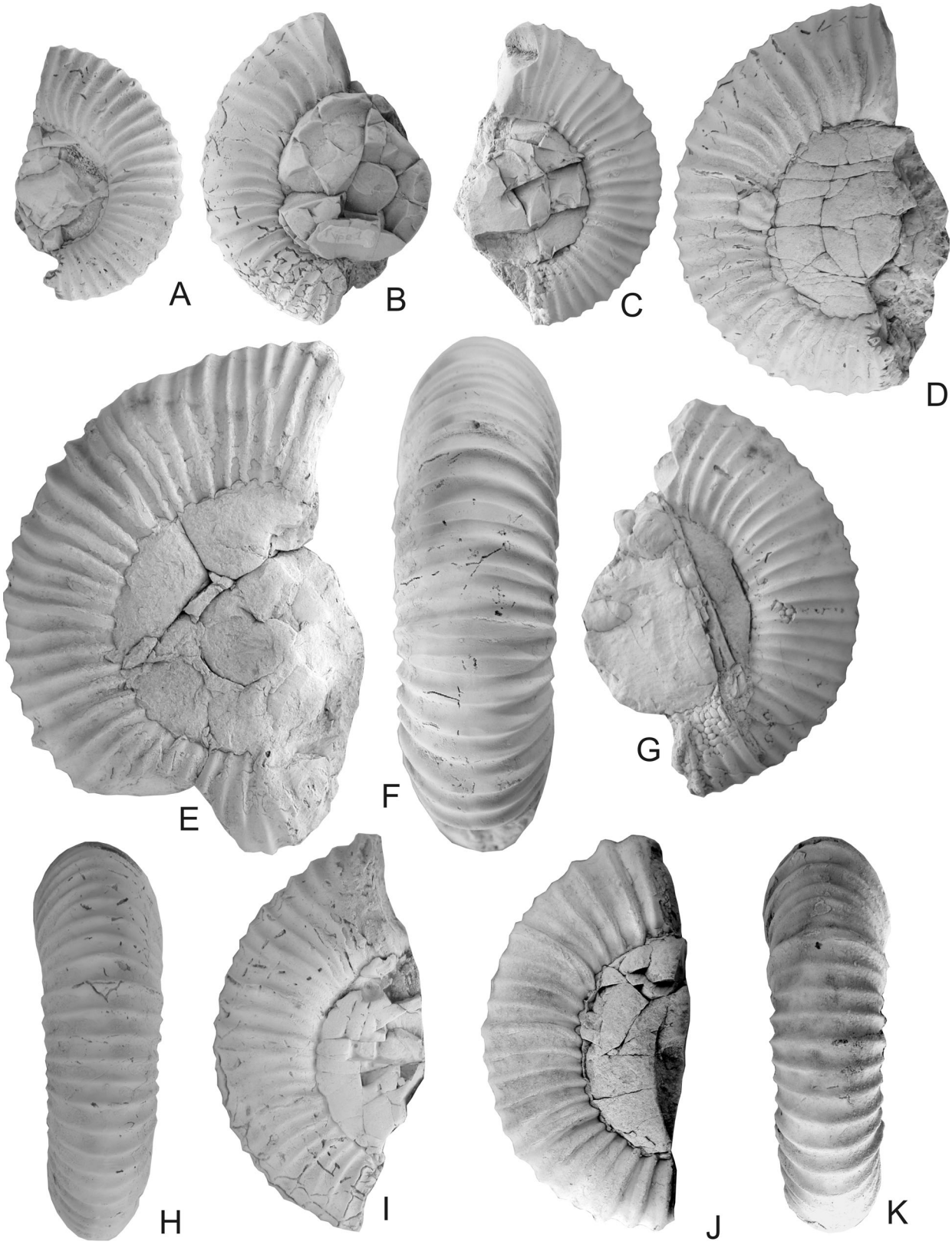
Occurrence. *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta is only known from the headwaters of Estero Lechoso, upper part of Katterfeld Formation, late Early-early Late Hauterivian.

Genus ***Crioceratites*** Léveillé, 1837

Type species. *Crioceratites duvalii* Léveillé by subsequent designation of Diener (1925, p. 191).

Diagnosis. Typically coiled in equiangular spiral, but spiral angle may increase with age; whorl oval to subquadrate; ribs generally dense, rounded, single or bundled at umbilical edge and nontuberculate; stronger major ribs with ventrolateral or umbilical, lateral and ventrolateral spines; constrictions may be present (modified from Wright, 1996, p. 211).

Figure 2. ***Aegocrioceras patagonicum*** sp. nov. Aguirre-Urreta, Estero Lechoso, Austral Basin, Chile / *Estero Lechoso, cuenca Austral, Chile.* **A-C,** lateral views of body chambers / *vistas laterales de cámaras habitaciones* (SERNAGEOMIN 1653-1652-1651 respectively / *respectivamente*) ; **D,** lateral view of holotype corresponding to an almost complete body chamber / *vista lateral del holotipo que corresponde a una cá-*



mara habitación casi completa (SERNAGEOMIN 1650); **E-F,** lateral and ventral views of body chamber / *vistas lateral y ventral de la cámara habitación* (SERNAGEOMIN 1654); **G,** lateral view of body chamber / *vista lateral de cámara habitación* (SERNAGEOMIN 1657); **H-I,** ventral and lateral views of body chamber / *vistas ventral y lateral de cámara habitación* (SERNAGEOMIN 1655); **J-K,** lateral and ventral view of body chamber / *vistas lateral y ventral de cámara habitación* (SERNAGEOMIN 1656). All specimens coated with ammonium chloride. Natural size / *todos los ejemplares cubiertos con cloruro de amonio. Tamaño natural.*

Comments. Léveillé (1837) erected the genus *Crioceratites* for three species of France. Briefly after that, d'Orbigny (1840) referred to *Crioceras* instead, and the generic name was afterwards extensively employed for Hauterivian and Barremian (frequently only referred as Neocomian) European species, although sometimes confused as initial spires of the uncoiled Barremian-Aptian *Ancyloceras* d'Orbigny. The confusion was cleared when Pictet (1863, p. 9, pl. 1, fig. 2) illustrated a complete specimen of "*Crioceras*" *duvalii* with the aperture preserved. Interpretation of *Crioceratites* is difficult, especially when there are numerous names for Hauterivian and Barremian forms both from the Boreal and Tethyan realms.

The wide range of morphological variation of *Crioceratites sensu latu* led Wiedmann (1962) to include the genera *Emericiceras* Sarkar and *Paracrioceras* Spath as junior synonyms of *Crioceratites*, but *Pseudothurmannia* Spath was retained as a subgenus of *Crioceratites*. Subsequently Immel (1978, 1979a, 1979b) and Klinger and Kennedy (1992) followed Wiedmann's views. Although a thorough discussion on the status of *Crioceratites* is beyond the scope of this paper, the inclusion of this myriad of forms in a single genus may be an oversimplification.

Crioceratites (Crioceratites) apricum (Giovine, 1952)
Figures 3.A-H

1950. *Paracrioceras* cf. *emerici* Léveillé. Giovine, p. 59, pl. 5, fig. 5.
1952. *Crioceras apricum* n.sp.: Giovine, p. 72, pl. 1, figs. 1-5.
1988. *Crioceratites apricus* (Giovine). Riccardi, pl. 7, figs. 3-5.
1997. *Crioceratites apricus* (Giovine). Aguirre-Urreta and Rawson, fig. 7 c.
1999. *Crioceratites apricum* (Giovine). Aguirre-Urreta *et al*., pl. 1, figs. 5-6.

Material. 7 specimens comprising phragmocones and incomplete body chambers (SERNAGEOMIN 1636-38, 1643-46), 4 specimens comprising incomplete phragmocones (SERNAGEOMIN 1639-42) and 10 fragments from the headwaters of Estero Lechoso, Puerto Ibáñez, Chile.

Description. The coiling is crioceratitid, open, with whorls not in contact. The whorl section is slightly depressed to slightly compressed (H/W = 0.93-1.04), rounded, with flat to slightly concave dorsum, angular umbilical border passing to rounded flanks and arched broad venter. The ornament is composed of single ribs that arise at the umbilical edge, bend backwards in the flanks with a feeble curve and cross the venter without interruption. There are two kinds of ribs: fine, simple, dense ribs, intercalated with stronger trituberculated ones. In the inner whorls the trituberculate ribs are much thicker, and only one or two fine intermediaries occur. With increasing diameter, the tubercles are more pronounced: the smallest is on the umbilical edge, a stronger one has a ventro lateral position and the third, and strongest, is on the edge of the siphonal line. In well preserved specimens, there are spines instead of tubercles. The number of intercalatories is now 2-4. With increasing diameter, and up to the largest preserved diameter, the tubercles diminish in size and nearly disappear, but the ribs are still strong, and the fine intercalated ribs vary from 4 to 6. The suture line is typically crioceratitid, not very complicated, with large and trifid L, longer than E and U; U longer than E. Saddle between U/L taller than that between L/E.

Dimension of figured specimens (in mm)

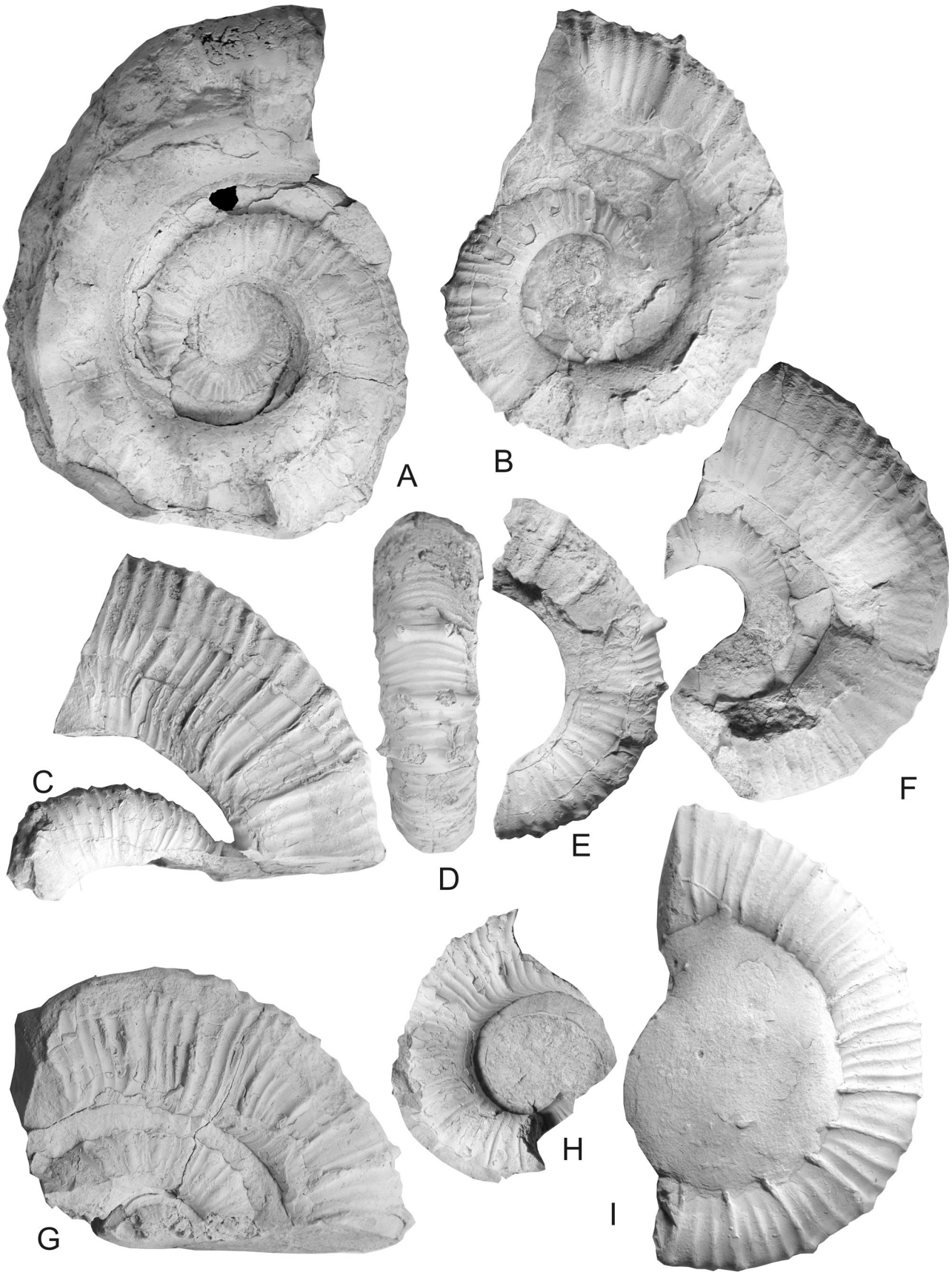
Specimen	D	H	W	H/W	U
1636	100	30.9 (0.31)	29.7 (0.30)	1.04	47.4 (0.47)
1637	80.4	25.9 (0.32)	*24 (0.30)	0.93	39.5 (0.49)
1639	81.9	26.3 (0.32)	*26.2 (0.32)	1.00	40.4 (0.49)
1641	61.0	18.3 (0.30)	19.1 (0.31)	0.96	29.4 (0.48)

* approximate measurement

Discussion. *Crioceratites* (*Crioceratites*) *apricum* compares well with *C.* (*C.*). *nolani* (Kilian, 1910) and allied species in coiling, whorl section, and ornamentation. This group presents a widespread and nearly cosmopolitan distribution, and the stratigraphic position is somewhat restricted to the lower-upper Hauterivian boundary (Kemper *et al*., 1981).

Occurrence. This species is known from several localities of the Neuquén Basin (west-central Argentina) in the lower part of the Agua de la Mula Member of the Agrio Formation, (*Crioceratites schlagintweiti* assemblage zone) (Aguirre-Urreta and Rawson, 1997; Aguirre-Urreta *et al*., 2005); from a single specimen recovered in a core from the Springhill Formation in the eastern side of the Austral Basin (Aguirre-Urreta and Erlicher, 2003) and in the upper part of the Katterfeld Formation, western side of the Austral Basin. Its age is early Late Hauterivian.

Figure 3. A-H, *Crioceratites (C.) apricum* (Giovine). Estero Lechoso, Austral Basin, Chile / *Estero Lechoso, cuenca Austral, Chile.* **A-C,** lateral views of phragmocones and incomplete body chambers /*vistas laterales de fragmoconos y cámaras habitaciones incompletas* (SERNAGEOMIN 1636, 1637, 1638 respectively / *respectivamente*); **D-E,** ventral and lateral views of incomplete phragmocone / *vistas ventral y lateral de fragmocono incompleto* (SERNAGEOMIN 1641); **F-H,** lateral views of incomplete phragmocones / *vistas laterales de fragmoconos incompletos* (SERNAGEOMIN 1639, 1635, 1640); **I, *Crioceratites* sp. aff. *C. (C.) schlagintweiti*** (Giovine)**.** Estero Lechoso, Austral Basin, Chile, lateral view of body chamber / *Estero Lechoso, cuenca Austral, Chile, vista lateral de cámara habitación* (SERNAGEOMIN 1634). All specimens coated with ammonium chloride. Natural size / *todos los ejemplares cubiertos con cloruro de amonio. Tamaño natural.*


A
B
C
D
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Crioceratites* (*Crioceratites*) sp. aff. *C. schlagintweiti (Giovine, 1950)
Figure 3.I

1950. *Crioceras schlagintweiti* n. sp. Giovine, p. 51, pl. 3, fig. 1; pl. 5, figs. 2-4; text-fig. 3.
1988. *Crioceratites schlagintweiti* (Giovine). Riccardi, pl. 8, figs. 1-2.
2004. *Crioceratites* aff. *schlagintweiti* (Giovine). Mourgues, fig. 5a.
2005. *Crioceratites schlagintweiti* (Giovine). Aguirre-Urreta *et al*., fig. 7i.

Material. Four incomplete specimens corresponding to incomplete phragmocones and body chambers (SERNAGEOMIN 1632-1635) from the headwaters of Estero Lechoso, Puerto Ibáñez, Chile.

Description. The coiling is crioceratitid, in an open spire, with whorls not in contact, becoming more uncoiled with growth. The whorl section is equidimensional at first, but tends to become more compressed with growth. The dorsum is flat, the umbilical edge rounded to slightly angular, the flanks slightly arched, and the venter, narrow and rounded. The maximum width is at mid-flank. The ribs are simple, arise at the umbilical edge, turn slightly backwards and forwards on the flank, and cross the venter without interruption. Tubercles are absent. With increasing diameter paired strong ribs, separated by a constriction appear. The posterior rib of each pair is always the strongest and these ribs are separated by 2-3 fine ribs at first but with increasing diameter up to 5 simple ribs are intercalated. All the ribs are straight on the flanks and cross the venter with a slight apertural bend. Sporadically weak, pointed umbilical tubercles can be seen on the posterior strong rib.

Dimension of figured specimen (in mm)

Specimen	D	H	W	H/W	U
1634	85.7	25.5 (0.30)	22.3 (0.26)	1.14	*43.9 (0.51)

* approximate measurement

Discussion. *Crioceratites* (*Crioceratites*) *schlagintweiti* is very close to the type species *C.* (*C.*). *duvalii* (Léveillé) and similar species in coiling, whorl section, and ornamentation. This group, together with the *C.* (*C.*) *nolani* group presents an extensive distribution, and a defined stratigraphic position limited to the lower-upper Hauterivian boundary (Kemper *et al*., 1981).

Occurrence. This species is known in the Neuquén Basin (west-central Argentina) where it characterizes the second ammonoid zone of the Agua de la Mula Member of the Agrio Formation (*Crioceratites schlagintweiti* assemblage zone) (Aguirre-Urreta and Rawson, 1997; Aguirre-Urreta *et al*., 2005). Mourgues (2004) illustrated one specimen with open nomenclature from the Chañarcillo (formerly Atacama) Basin from northern Chile. Here it is reported in the upper part of the Katterfeld Formation, western side of the Austral Basin. Its age is early Late Hauterivian.

Biostratigraphy and palaeobiogeography

The ammonoids recovered in the study section have been dated as Hauterivian in several regions of the world, but their relative position within the Austral Basin permits to suggest some precisions regarding their age.

Crioceratites (*C.*) *apricum* (Giovine) and *C.* (*C.*) *schlagintweiti* (Giovine) are known from the lower Upper Hauterivian in the Neuquén Basin where they characterize the *Crioceratites schlagintweiti* zone (Aguirre-Urreta and Rawson, 1997; Aguirre-Urreta *et al*., 2005). In the Austral Basin, *Crioceratites* (*C.*) *apricum* was previously known from a single specimen recovered from a core of the Springhill Formation (Aguirre-Urreta, 1998; Aguirre-Urreta and Erlicher, 2003). These Argentine species are very close to the European *Crioceratites* (*C.*) *nolani* (Kilian) and *C.* (*C.*) *duvalii* (Léveillé) that are typical of the base of the Upper Hauterivian (*sayni* zone) of the Tethyan realm (Kemper *et al*., 1981; Rawson, 1995).

Aegocrioceras is a genus restricted to the *inversum* and *speetonensis/staffi* zones of the late Early Hauterivian-early Late Hauterivian of England and Germany. A single dubious specimen is referred from the base of the *sayni* zone in the Tethys (Kemper *et al*., 1981) and *Aegocrioceras* sp. has also been recorded from the Argentine side of the Austral Basin in the *Favrella americana* assemblage zone (Riccardi, 1984; Riccardi *et al*., 1987), although none of these two records were described or figured.

Thus, the association of *Aegocrioceras* and species of *Crioceratites* places the fauna as latest Early Hauterivian-early Late Hauterivian.

Previously, Hauterivian ammonoids of the Austral Basin were grouped in two zones: a basal *Favrella americana* assemblage zone assigned as late Early Hauterivian to early Late Hauterivian and an upper "*Favrella*" *wilckensi* assemblage zone assigned as Late Hauterivian (Riccardi, 1984, 1988; Riccardi *et al*., 1987; Aguirre-Urreta, 2002a, 2002b). The former included, besides the nominal species, *Aegocrioceras* sp. and *Hemihoplites ploskiewickzi* Riccardi and Aguirre-Urreta, and the latter contained "*Favrella*" *wilckensi* (Favre), *Protaconeceras patagoniense* (Favre), and *Hemihoplites varicostatus* Riccardi and Aguirre-Urreta.

Thus, the presence of *Aegocrioceras* and *Crioceratites* above *Favrella americana* (Favre) indicates that the *F. americana* assemblage zone is best placed as Early Hauterivian. "*Favrella*" *wilckensi* (Favre), although not recorded in the study section, is assigned

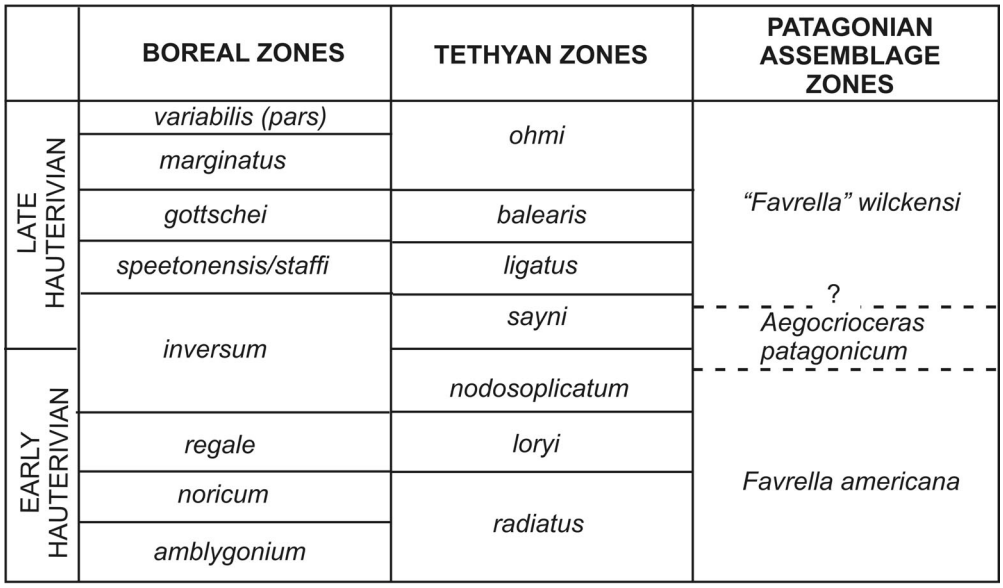

Figure 4. Hauterivian correlation chart among the Boreal and Tethyan standard zones and the Patagonian assemblage zones. Boreal zones from Kemper *et al*. (1981) and Rawson (1995), Tethyan zones from Hoedemaeker *et al*. (2003) / *cuadro de correlación de las zonas estándar boreales y tethyanas y las zonas de asociación de Patagonia en el Hauteriviano. Zonas boreales de Kemper* et al. *(1981) y Rawson (1995), zonas tethyanas de Hoedemaeker* et al. *(2003).*

to the Late Hauterivian because of its association with *Protaconeceras patagoniense* (Favre). *Protaconeceras* is a moderately common genus in the *gottschei* zone of England (beds C4 of Speeton) (Casey, 1954; Kemper *et al*., 1981; Riccardi, 1984; Riccardi *et al*., 1987). Figure 4 shows the proposed biostratigraphy for the Hauterivian of the Austral Basin and its correlation with the Boreal and Tethyan zones.

The proposed zonal sequence shows the fauna that dominated in successive periods of time in Patagonia. There, *Aegocrioceras* and *Crioceratites* occur in a clearly defined horizon, showing that their immigration was brief and that they did not evolve in news species in the area. Thus, these forms are of exceptional value in correlation as clearly pointed out by Kemper *et al.* (1981).

The low diversity of the Patagonian ammonoid faunas was traditionally associated with a high degree of endemism, but more recent studies have proved that some faunas show a more pandemic character with elements that are also present elsewhere in the Southern Hemisphere, or are related to Tethyan forms. Thus, the Hauterivian ammonoids of the Austral Basin of Patagonia represent a mixture of endemic taxa (*Favrella*), with Tethyan taxa (*Hemihoplites*, *Crioceratites*), and faunas from Northwestern Europe which was part of the margins of the Boreal realm (*Protaconeceras*, *Aegocrioceras*), although numerically dominated by the endemic forms. The rare and localized appearance of species abundant in the Northern Hemisphere points to periods of sea level rise that permitted widespread migrations (Kemper *et al*., 1981) to peripheral basins along the Pacific margin of western Gondwana.

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Appendix

Stratigraphic section of the Katterfeld Formation with ammonoid levels in the locality Estero Lechoso.

Top: Grey to greenish sandstones of Apeleg Formation.
90 m. Black shales partially covered.
2 m. Fine greenish sandstones.
37 m. Black shales.
40 m. Black shales with three fossiliferous levels: the upper one with *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta, an intermediate one with numerous carbonate nodules with *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta, *Crioceratites* (C.) *apricum* (Giovine), *Crioceratites* sp. aff. *C.* (C.) *schlagintweiti* (Giovine), *Entolium* sp. and other bivalves, and a lower level with calcareous nodules with indeterminate bivalves and carbonized wood.
25 m. Black shales interbedded with two thin calcareous horizons and one thicker bed of greenish to grey, coarse, laminated sandstones.
37 m. Black shales.
18 m. Black shales with at least two levels of calcareous nodules, the upper one with *Aetostreon* sp. and the lower one with *Aegocrioceras patagonicum* sp. nov. Aguirre-Urreta and *Crioceratites* sp.
85 m. Black shales, 26 meters above base a level with septarias.
87 m. Black shales partially covered.
30 m. Black shales.
1 m. Grey to greenish medium sandstones.
20 m. Black shales with calcareous nodules with *Favrella americana* (Favre) and septarias.
25 m. Black shales partially covered.
92 m. Black shales, 80 meters above base a level with septarias.
Base. Volcanic rocks of Ibáñez Formation.