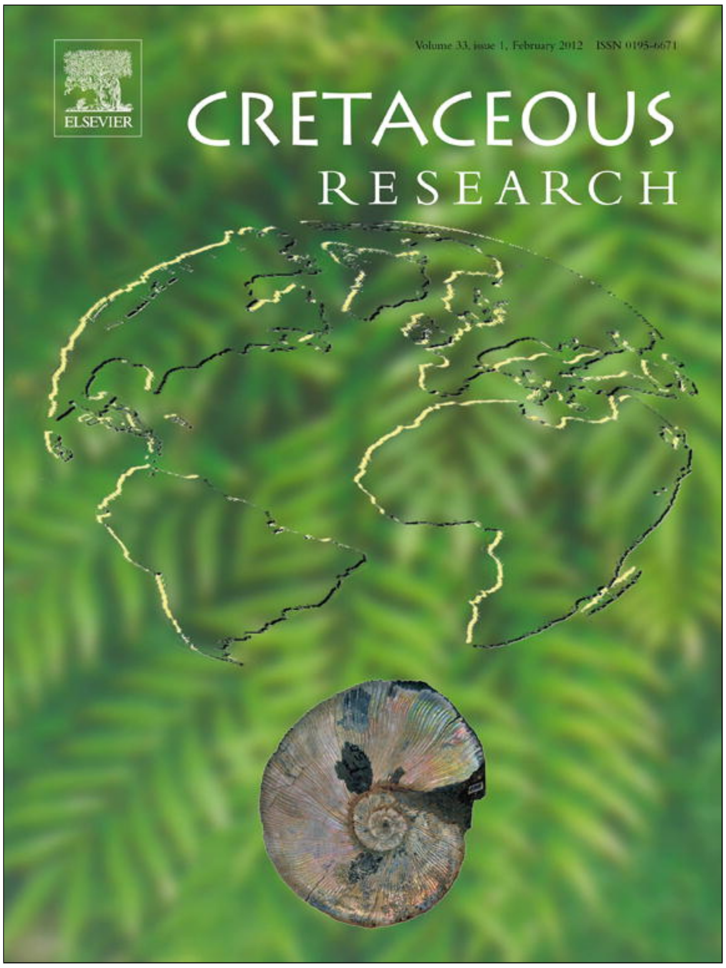
Volume 33, issue 1, February 2012 ISSN 0195-6671
ELSEVIER
CRETACEOUS
RESEARCH

Cretaceous Research 33 (2012) 97–105

Contents lists available at SciVerse ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

Lower Cretaceous ammonites from the Neuquén Basin, Argentina: The Hauterivian genus *Spitidiscus*

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A R T I C L E   I N F O

Article history:
Received 30 March 2011
Accepted in revised form 6 September 2011
Available online 10 September 2011

Keywords:
Argentina
Neuquén Basin
Ammonites
Spitidiscus
Biostratigraphy
Hauterivian

A B S T R A C T

Spitidiscus is a widely-distributed Hauterivian genus that briefly invaded the Neuquén Basin, Argentina, in mid Hauterivian times, well after it first evolved in the west Tethyan area. Its appearance in Argentina is linked with a globally-significant mid Hauterivian sea-level rise. This is marked in the basin by a sharp facies change in the Agrio Formation, from non-marine sandstones of the Avilé Member to marine sediments, often laminated black shales, with *Spitidiscus* at the base of the overlying Agua de la Mula Member. Our extensive field work has shown that *Spitidiscus* occurs across the whole basin, where it is represented by two species, *Spitidiscus riccardii* Leanza and Wiedmann and *Spitidiscus kilapiae* sp. nov. For most of its vertical range *Spitidiscus* occurs alone, characterising the *S. riccardii* Zone. But at the top of its range it is joined by the first crioceratitid ammonites, their appearance marking the base of the *Crioceratites schlagintweiti* Zone.

1. Introduction

This paper is the latest in a series dedicated to describing the rich Lower Cretaceous ammonite faunas of the Agrio Formation of the Neuquén Basin, Argentina. It focuses on the holcodiscid genus *Spitidiscus*, which here characterises the *Spitidiscus riccardii* Assemblage Biozone, of mid Hauterivian age. *Spitidiscus* is typically a Tethyan genus of Early to early Late Hauterivian age that was particularly characteristic of the Mediterranean Province. But at times it spread far beyond that area to reach marginal areas of the Boreal Realm (NW European Province) on the one hand, and the Neuquén Basin on the other. It thus provides an interesting link across these regions.

Spitidiscus was first described from Argentina by Leanza and Wiedmann (1992), who recorded it from a single locality, Agrio del Medio, in Neuquén Province, at a horizon that they believed lay high in the upper member (now Agua de la Mula Member) of the Agrio Formation. But Aguirre-Urreta et al. (1993) then showed that its true level was lower, at the base of the member and just above the non-marine sandstones of the Avilé Member. Subsequently, Aguirre-Urreta (1995) suggested that the three species identified by Leanza and Wiedmann (1992) were all variants of one taxon, *S. riccardii*. Aguirre-Urreta and Rawson (1997) recorded *Spitidiscus* from three additional localities in Neuquén Province and figured a second species, *Spitidiscus* sp. nov., which is described here as *Spitidiscus kilapiae*. Further field research shows that *Spitidiscus* is widely-distributed in the Neuquén Basin: it is here recorded from 14 localities in Neuquén and Mendoza provinces (Fig. 1).

2. Lithostratigraphy and fossil localities

Spitidiscus appears at the base of the upper, Agua de la Mula, member of the Agrio Formation, in a distinctive lithological unit that we refer to informally as the Spitidiscus shales. Its first appearance marks the base of the *S. riccardii* Zone. The underlying non-marine Avilé Member is without ammonites, so following normal biostratigraphical practice Aguirre-Urreta and Rawson (1997, fig. 5) included it within the underlying *Weavericeras vacaensis* Zone. It should be noted that Archuby and Fürsich (2010) mistakenly placed the Avilé Member in the *S. riccardii* Zone.

The Spitidiscus shales are widely-distributed across the Neuquén Basin and form a significant hydrocarbon source rock (Cruz et al., 1996; Kozlowski et al., 1998). There is usually a very sharp basal contact with the yellowish, fluviatile sandstones of the Avilé Member beneath. The boundary represents a major transgressive surface that appears to be the local representative of a significant mid Hauterivian global rise in sea level that had a marked influence on ammonite migration and evolution (Rawson, 1993).

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doi:10.1016/j.cretres.2011.09.004

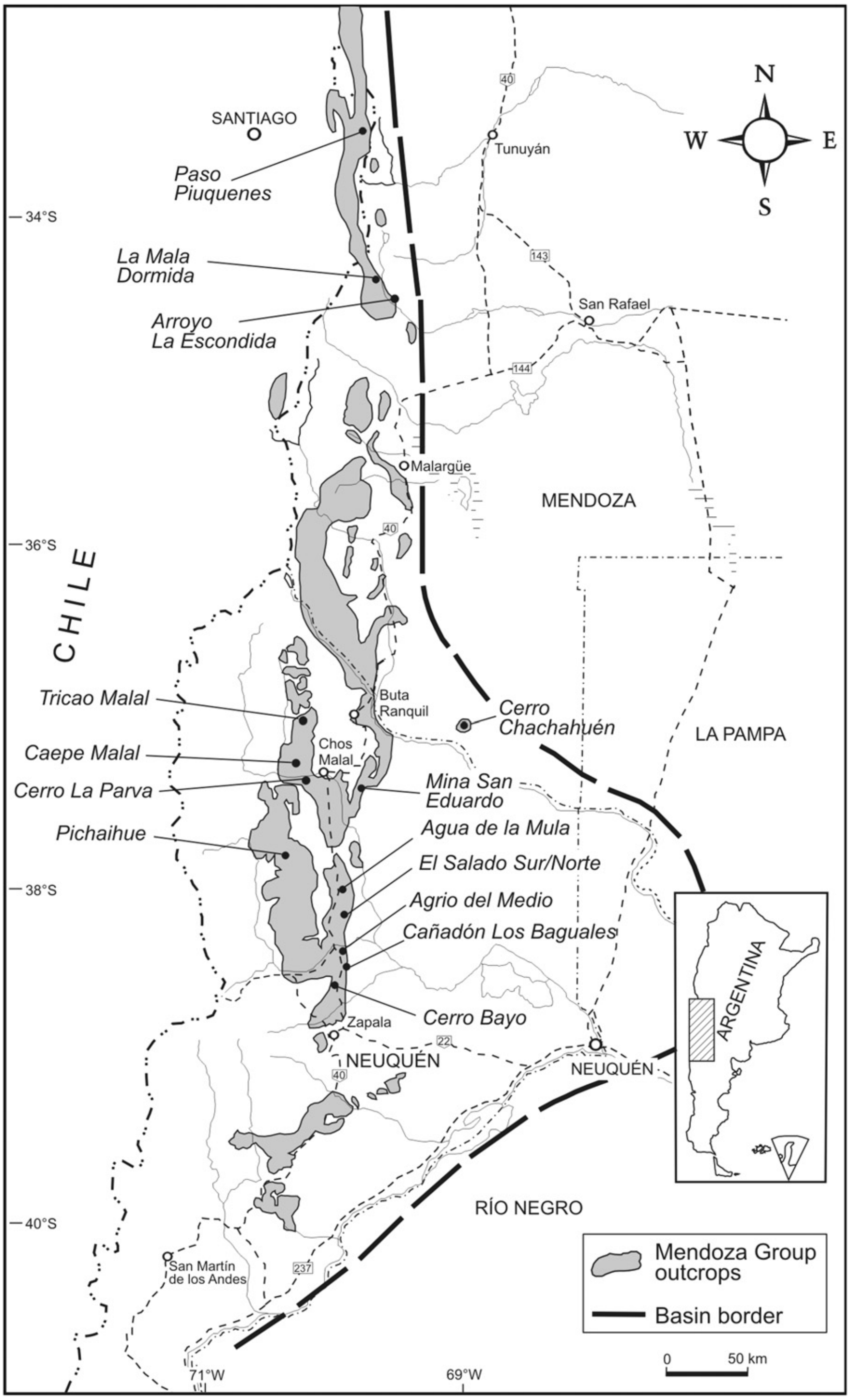

Fig. 1. *Spitidiscus* localities in the Neuquén Basin.

The Spitidiscus shales are predominantly black, organic-rich shales that reach a maximum thickness of some 50 m. We can find no evidence to support Archuby and Fürsich's (2010) record of a much thicker sequence at Agua de la Mula or Bajada del Agrio. The lower beds are often hard, calcareous and/or silty, splintery-weathering, and weather to a distinctive blue-grey colour. These and the underlying yellowish sandstones together form clear markers over an extensive area of the basin. Above come several metres of finely-laminated shales. Towards the top of these, brown-weathering, slightly silty interbeds appear and the sequence grades upwards into a more typical upper Agrio sequence of silty shales with thin interbedded calcareous sandstones. The last *Spitidiscus* co-occur at this level with earliest *Crioceratites* of the *Crioceratites schlagintweiti* Zone.

In the southern part of the basin, where the Avilé Member is not developed, the sediments with *Spitidiscus* are yellowish shales with gypsum crystals. In Mendoza, north of the embayment, the sequence with *Spitidiscus* is represented by either dark mudstones (at Paso Piuquenes), black shales (at Cerro Chachahuén) or yellowish silty limestones (at Arroyo La Escondida and La Mala Dormida).

The Spitidiscus shales yield only a low diversity benthic macrofauna, of which the most common constituent is an unnamed, very small, turreted gastropod which is locally abundant. Other elements include a slightly larger gastropod with winged aperture, *Protohemichenopus neuquensis* Camacho, and a small bivalve, *Grammatodon* sp. The fine lamination of much of the shales testifies to the lack of bioturbation. But while the gastropods are widespread in their geographical distribution, *Spitidiscus* is more patchily distributed.

We record here 382 ammonites from the 14 localities and we have measured sections through at least part of the zone in 9 of them, Paso Piuquenes, Arroyo La Escondida, Cerro Chachahuén, Caepe Malal, El Salado, Agua de la Mula, Mina San Eduardo, Agrio del Medio and Pichaihue. The localities are described below, from north to south. The first four are in Mendoza Province and were visited only by M. B. Aguirre-Urreta; the remainders are in Neuquén Province and most have been visited by both authors.

Preservation of specimens varies considerably from horizon to horizon and from locality to locality, varying from flattened, poorly preserved impressions to 3-dimensional body chambers with shell preserved. Despite extensive search over many years, complete well-preserved specimens are rare.

2.1. Paso Piuquenes (33°38′S, 69°52′W)

This is a classic locality already visited by Darwin in 1835. The pass, located 4030 m above sea level, runs across the boundary between Argentina and Chile in the Main Central Andes. The Agrio Formation is some 120 m thick here but is incomplete, as it is cut by a thrust. The lower part is mostly composed of intercalations of massive and finely-laminated grey and yellowish limestones, bearing in some levels *Steinmanella* sp., *Thalassinoides* sp. and poorly preserved flattened ammonites. In the upper part there are non-fossiliferous olive green shales, limestones with small oysters, silty limestones and black shales with poorly preserved *S. kilapiae*, *P. neuquensis* Camacho, Lucinidea indet., and callianassid crustaceans (Aguirre-Urreta and Vennari, 2009).

2.2. La Mala Dormida (34°35′S, 69°36′W)

This is one of Gerth's (1925, fig. 17) localities. It lies 10 km north of El Perdido Pass and is reached by foot after a winding, precarious rocky track from Las Aucas settlement. A condensed section of the complete Agrio Formation is composed of yellowish silty limestones reaching some 150 m. Although the section is quite covered, well preserved internal moulds of *S. kilapiae* were collected.

2.3. Arroyo La Escondida (34°38′S, 69°30′W)

This locality is close to the northern margin of the Río Diamante, a few kilometres northeast of Las Aucas in southern Mendoza. A partial Agrio Formation is only 75 m thick here (base not exposed), as this locality represents the easternmost border of the basin at these latitudes. *S. kilapiae* was recovered in yellowish silty limestones.

2.4. Cerro Chachahuén (37°04′S, 68°54′W)

This is a locality know since the work of Padula (1948) and Holmberg (1962). Access is very difficult: the section lies 50 km northeast from Pata Mora bridge over the Río Colorado near Rincón de los Sauces, and is accessed along local dirt trails and dry rivers. The Agrio Formation is exposed nearby Puesto Ojos de Agua south of Cerro Corrales and reaches more than 100 m. The succession, disturbed by Miocene andesitic sills, starts in the uppermost Pilmatué Member. The Avilé Member is not developed and the typical Spitidiscus shales are immediately above a coquina with *Weavericeras*. Only three poorly preserved moulds of *Spitidiscus* sp. indet. have been recovered.

2.5. Tricao Malal (37°01′S, 70°17′W)

Access to the small settlement of Tricao Malal is 38 km north of Chos Malal along the provincial road 2. The Agrio Formation crops out in a series of north-south trending synclines and anticlines. *S. kilapiae* was recovered from a section of the Agrio Formation east of Cerro de los Buitres.

2.6. Caepe Malal (37°11′S, 70°23′W)

This locality is along the provincial road 2 from Chos Malal to Tricao Malal in northern Neuquén. The Avilé and Agua de la Mula Members of the Agrio Formation crop out on the western side of the road while the Pilmatué Member lies between the road and the Curileuvú river. *S. kilapiae* is restricted to 15 m of black shales at the base of the Agua de la Mula Member.

2.7. Cerro La Parva (37°16′S, 70°26′W)

The Cerro La Parva is approximately 25 km northwest of Chos Malal, on the southern side of the provincial road 43 to Andacollo. The whole of the Agrio Formation crops out, though some parts are covered. This is the most “basinal” exposure in which we have found *Spitidiscus*, represented by 6 flattened *Spitidiscus* sp. indet. All were on or close to one bedding plane.

2.8. Mina San Eduardo (37°32′S, 70°00′W)

The section is adjacent to the abandoned San Eduardo coal mine, 7 km west-southwest of Curaco. The whole Agrio Formation has been measured here, reaching 1150 m. *S. kilapiae* appears immediately above the top of the Avilé Member in a bioturbated sandy limestone that forms the lowest 0.2 m of the Agua de la Mula Member, where it is associated with the gastropod *P. neuquensis* Camacho.

2.9. Pichaihue (37°47′S, 70°12′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 is exposed on the western flank of the Chorriaca anticline. There are very extensive exposures of the Spitidiscus shales here, but only a few *S. kilapiae* have been recovered from nodules high in the shales, co-occurring with fragments of the first *Crioceratites*.

2.10. Agua de la Mula (38°03′S, 70°01′W)

Access is from the east side of national road 40, 80 km south of Chos Malal, along a track to a dry oil well and barite mines. The section lies on the western flank of the Cordillera del Salado anticline and comprises the whole Agrio Formation with a thickness of 1235 m. *S. kilapiae* is preserved both as fragmentary impressions and 3-dimensional specimens in the shales forming the lowest 38 m of the Agua de la Mula Member: from 22.5 m upwards it is associated with *Crioceratites*.

2.11. El Salado (38°11′S, 70°03′W)

The section lies 15 km south of Agua de la Mula; access is eastward from national road 40 along a track leading to the Pampa Amarga oil wells. About 1 km south of the track there are extensive exposures of the Agrio Formation, dissected by several gullies. The lowest part of the Agua de la Mula Member is very well exposed here and was measured. The basal 14 m consist of laminated black shales and slightly silty, calcareous shales weathering bright blue-grey, the more silty levels forming slightly harder courses in the lower half. Above are many metres of black shales weathering dark grey. Small, very sparsely scattered calcareous nodules occur from about 11.5 to 25 m above the base, while at about16.5 m is a more or less continuous band of small irregularly shaped nodules. *S. kilapiae* first appears in this nodular bed and becomes increasingly abundant up to about the 25 m interval. Fragments of the same form reappear higher in the sequence, just below and just above the first band of very large reddish-weathering concretions: just above the concretions it is found with the first fragments of a coarsely tuberculate *Crioceratites* indicating the base of the *C. schlagintweiti* Zone.

2.12. Agrio del Medio (38°21′S, 69°57′W)

The Agua de la Mula Member is well exposed on the eastern flank of the Agrio Anticline, immediately east of regional road 10, about 3 km southwest of Agrio del Medio settlement (see Aguirre-Urreta et al., 1993, figs. 2 and 3). The Spitidiscus shales are patchily exposed here, but several metres above the base is a horizon with small nodules and numerous *S. riccardii* body chambers.

2.13. Cañadón de los Baguales (38°28′S, 69°58′W)

The section lies 50 km north of Zapala and 6.8 km north of Cañadón de los Baguales, access is 0.4 km eastward of provincial road 14 along seismic line 20088/06157. A partial exposure of the Agrio Formation includes the Avilé Member and the base of the Agua de la Mula Member where several well preserved *S. riccardii* were recovered from poorly exposed black shales, associated with the gastropod *P. neuquensis*.

2.14. Cerro Bayo, NW flank (38°41′S, 70°04′W)

Access to the section is from provincial road 14, 28 km north of Zapala, and then 4 km west on a gravel road along the cañadón de la Vaca Muerta, then along a seismic line. A partial section of the Agrio Formation is well exposed. The Avilé Member is not developed as a distinctive unit here, but its approximate level appears to be represented by a soft sand with gypsum – so deeply weathered that the lithology remains uncertain. Above, the Spitidiscus shales are represented by a few metres of grey silty shales with gypsum, overlain by paler-weathering, light brown very silty shales containing calcareous nodules with small gastropods and rare *S. riccardii*.

3. Systematic palaeontology

The material described here is stored in the Palaeontological collections of the University of Buenos Aires (CPBA).

Dimensions of specimens are indicated as follows: d = diameter; wh = whorl height; wt = whorl thickness; wu = width of umbilicus.

Superfamily: Perisphinctaceae Steinmann, 1890
Family: Holcodiscidae Spath, 1923

Remarks. The taxonomic position of the Holcodiscidae has oscillated between the Desmocerataceae and the Perisphinctaceae, the uncertainty reflecting at least in part different authors' interpretation of the range of genera to be included within the family. In our review of the Argentine genus *Holcoptychites* (Aguirre-Urreta and Rawson, 2003) the suprafamilial placement of the Holcodiscidae and the generic content of the family were discussed in detail. We agreed with Hoedemaeker (1995) and Bulot (1995) that the Holcodiscidae formed a link between the Perisphinctaceae and the Desmocerataceae and concluded that they were closer to the former because of the strong ornament seen in many forms. That position is followed here.

The familial/subfamilial placement of *Spitidiscus* has also varied considerably. Spath (1923, p. 35) apparently included it in his new family Holcodiscidae, though he neither defined the family nor indicated clearly its generic content. Wright (1955, 1957) followed this, but later (Wright, 1981, p. 161) transferred *Spitidiscus* to the Desmocerataceae, linking it with *Eodesmoceras* and presumably therefore regarding it as a member of the Eodesmoceratinae which also embraced Breskovski's (1977) Barremitinae. But *Eodesmoceras*, supposedly Valanginian, is now known to be based on much younger (Albian) fragments of *Desmoceras* and *Puzosia* (Busnardo and Thieuloy, 1989, p. 121). So in the new edition of the Treatise (Wright, 1996, p. 69) Barremitinae replaced Eodesmoceratinae as the subfamily name, and *Spitidiscus* was treated as the earliest member of the subfamily.

However, Tzankov and Breskowski (1982) and Leanza and Wiedmann (1992) returned to Wright's (1957) original Treatise classification, by retaining *Spitidiscus* in the Holcodiscidae. That position was followed by Bulot (1995) and Aguirre-Urreta and Rawson (2003). The latter authors recognised two subfamilies within the Holcodiscidae, the Spitidiscinae and the Holcodiscinae, linked by *Abrytusites* and *Plesiospitidiscus*.

Subfamily: Spitidiscinae Vermeulen and Thieuloy, 1999.

Diagnosis. "Moderately evolute to moderately involute holcodiscids with inflated to moderately compressed shells. Venter normally gently rounded. Ribs quite strong, varying from coarse to fine. Constrictions generally broad and only slightly sinuous" (Aguirre-Urreta and Rawson, 2003, p. 594).

Discussion. As interpreted by Aguirre-Urreta and Rawson (2003) the subfamily embraces three genera. The earliest is *Jeanthieuloyites*, which is characterised by a smooth ventral band. At about the beginning of the Hauterivian this gave rise to both *Holcoptychites*, which embraces more coarsely ribbed forms that are known so far only from Argentina, and *Spitidiscus*, which is generally more finely ribbed. Both genera have a gently rounded venter that is uninterrupted by a smooth band.

Genus: *Spitidiscus* Kilian, 1910

Spitidiscus riccardii Leanza and Wiedmann, 1992
Fig. 2A–T

v* 1992 *Spitidiscus riccardii* Leanza and Wiedmann, p. 33, fig. 4a, b (Refigured Aguirre-Urreta, 1995, pl. 1, figs. 8, 9; Aguirre-Urreta and Rawson, 1997, fig. 6d, e).
v 1992 *Spitidiscus* aff. S. *rotula* (J de C Sowerby); Leanza and Wiedmann, p. 32, fig. 3a, b.
v 1992 *Spitidiscus* aff. *gastaldianus* (d'Orbigny); Leanza and Wiedmann p. 32, fig. 6a, b.
v 1993 *Spitidiscus* sp. nov. Aguirre-Urreta, pl. 3, figs 3, 4.
v 1995 *Spitidiscus riccardii* Leanza and Wiedmann; Aguirre-Urreta, p. 407, pl. 1 figs. 1–23. (Fig. 17 refigured Aguirre-Urreta et al., 1999, pl. 1, fig. 4; Fig. 15 refigured Aguirre-Urreta et al., 2005, fig. 7e).
v 2005 *Spitidiscus riccardii* Leanza and Wiedmann; Aguirre-Urreta et al., Fig. 7e, f.
non 2009 *Spitidiscus riccardii* Leanza and Wiedmann; Aguirre-Urreta and Vennari, p. 40, fig. 5n.

Holotype. By original designation, the specimen figured by Leanza and Wiedmann (1992), p. 33, figs 4a, b, P 1749 M.O.Z. (Museo Olsacher, Zapala).

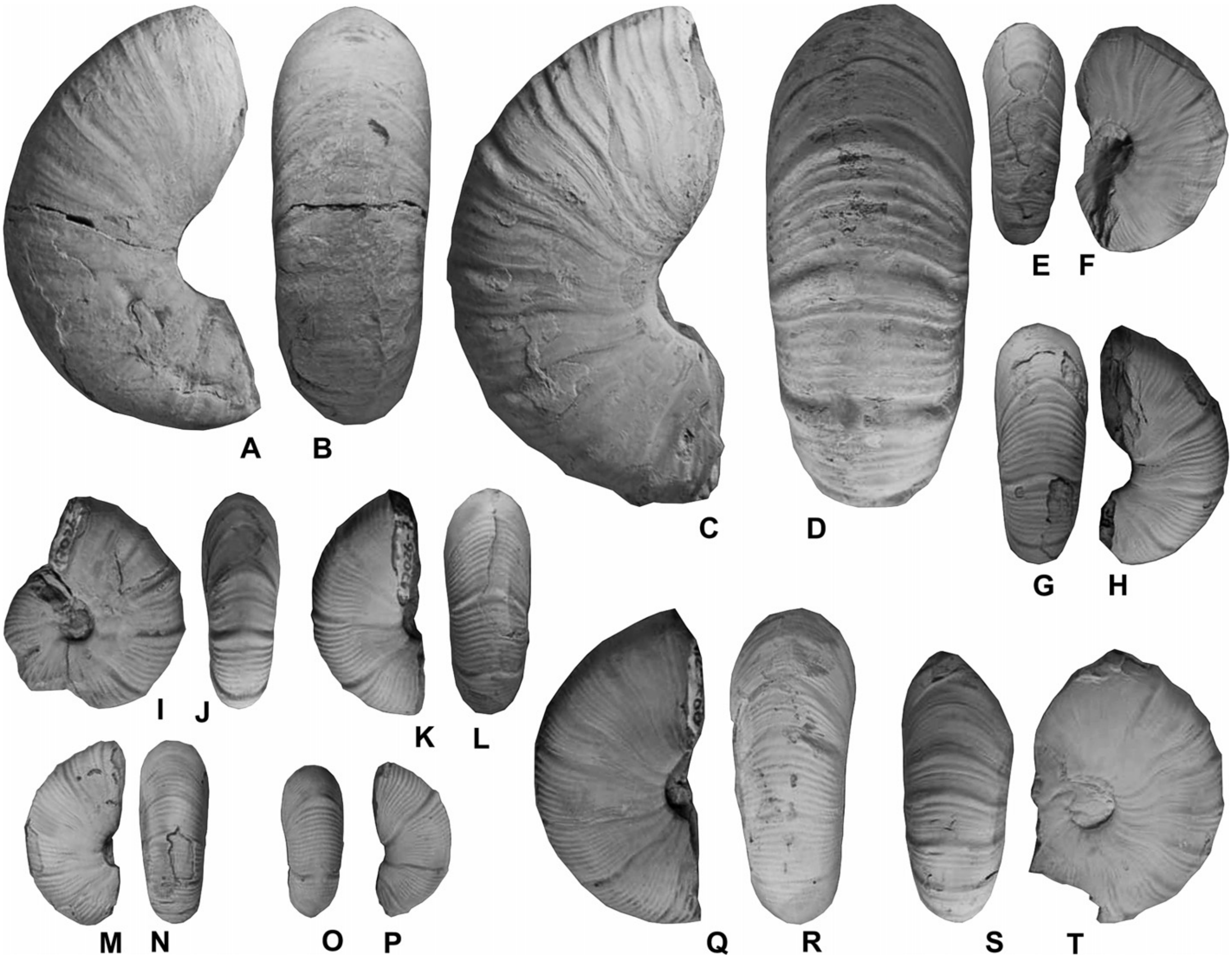

Fig. 2. *Spitidiscus riccardii* Leanza and Wiedmann. A–L, Q–T from Agua del Medio, M–P from Cañadón de los Baguales. A-B, CPBA 20025.2; C-D, CPBA 20025.1; E-F, CPBA 17026.17; G-H, CPBA 17026.26; I-J, CPBA 17026.22; K-L, CPBA 17026.7; M-N, CPBA 20033.13; O-P, CPBA 20033.2; Q-R, CPBA 17026.24; S-T, CPBA 17026.2. All specimens x 1, coated with ammonium chloride. [F–K, Q–T previously figured by Aguirre-Urreta (1995)].

Material. 97 specimens. 65 from Agrio del Medio (CPBA 17026. 1-53, 19841.1-7, 20025.1-5), 28 from Cañadón de los Baguales (CPBA 20033.1-28) and 4 from Cerro Bayo (CPBA 18179.1-3, 18180).

Description. The species is known mainly from body chambers up to about 70 mm diameter. The shell is moderately involute, slightly to moderately compressed, the whorl height being consistently greater than the thickness. The whorl section is arched, the flanks merging into the narrowly rounded venter and rounded umbilical wall. There are numerous slightly sinuous, very shallow constrictions; in some specimens these are feeble on the lower flank but become more marked on the outer flank and venter. Very fine radial striae occur within some constrictions. Between adjacent constrictions are a variable number of very fine, bundled ribs and/or striae. Each "bundle" starts with a wide, smooth, flat or slightly raised rib on the umbilical margin and running over the lowest flank, then branches into a sheath of secondaries. The rib that forms the posterior margin to a constriction is usually more prominent and often swells slightly across the outer flank and ventral area, where it truncates immediately adjacent ribs. Fine radial striae may also occur between ribs and at a varying growth stage the fine ribbing often "degenerates" into striae. In some specimens at this stage the constrictions disappear but the "posterior rib" may remain slightly more raised, especially over the venter.

Dimensions of figured specimens (in mm).

	d	wh	wh%d	wt	wt%d	wu	wu%d
CPBA 20025.1	74.1	33.3	0.45	29.5	0.40	17.4	0.23
CPBA 20025.2	61.1	28.1	0.46	23.1	0.38	13.9	0.23
CPBA 17026.24	46.0	21.3	0.46	17.6	0.38	8.0	0.17
CPBA 17026.2	41.1	19.3	0.47	15.9	0.39	8.0	0.19
CPBA 17026.26	35.2	17.1	0.48	13.3	0.38	6.4	0.18
CPBA 17026.7	33.9	15.8	0.47	13.0	0.38	5.7	0.17
CPBA 17026.17	33.7	16.2	0.48	11.7	0.35	7.0	0.21
CPBA 17026.22	30.7	15.1	0.49	10.9	0.35	5.6	0.18
CPBA 20033.13	32.0	16.3	0.51	11.7	0.36	4.9	0.15
CPBA 20033.2	28.3	14.8	0.52	11.1	0.39	3.8	0.13

Discussion. There is some variation in these forms, especially in strength and density of ribbing (see Aguirre-Urreta, 1995, pl. 1, and Fig. 2 here), and the holotype of *Spitidiscus riccardii* is towards one extreme – less compressed and slightly more coarsely ribbed. It is also apparent that the larger body chambers (Fig. 3A–D; Aguirre-Urreta, 1995, pl. 1, figs 19–22) tend to have reduced ornament, while many of the smaller body chambers are more strongly ribbed at first, becoming striate on

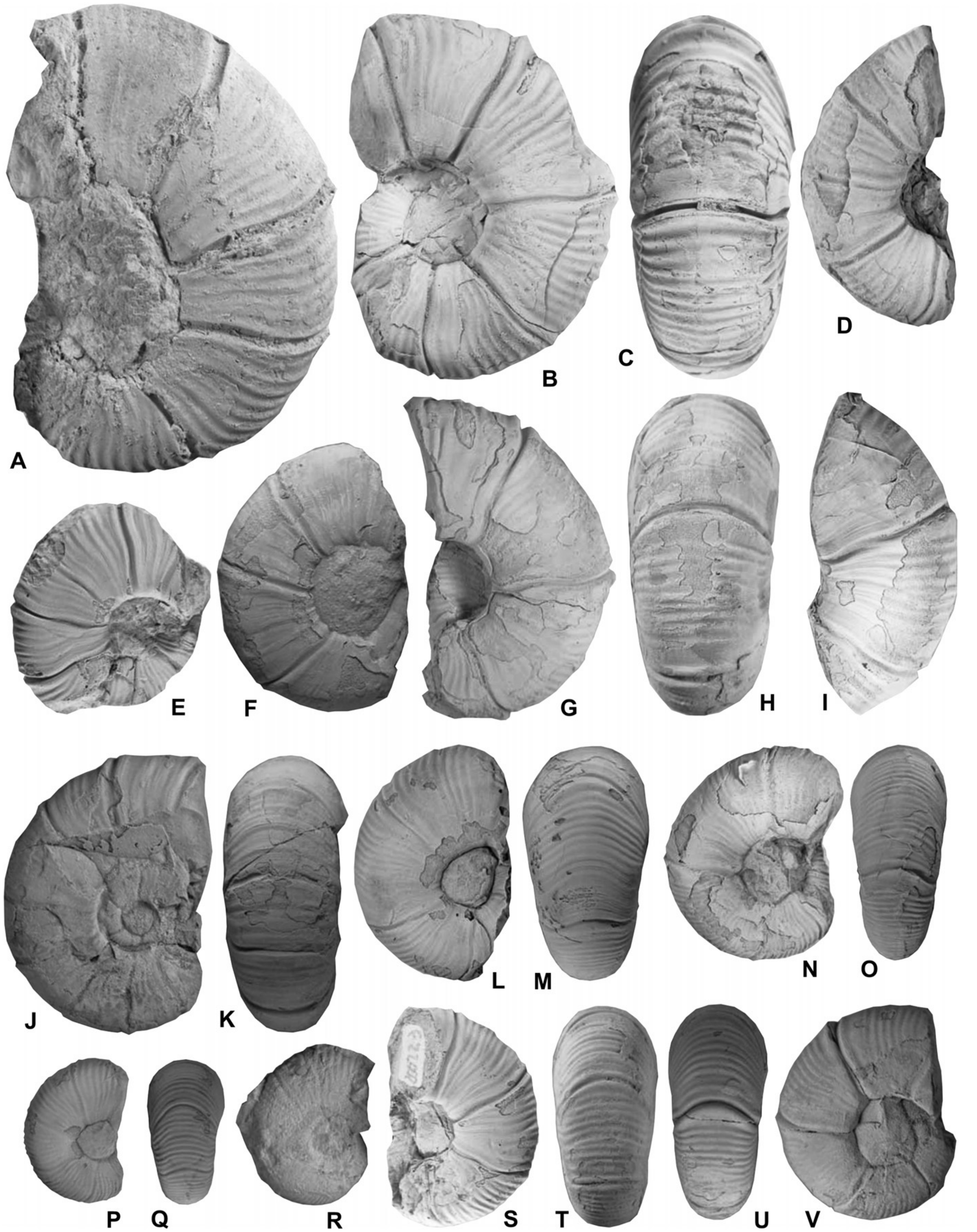

Fig. 3. *Spitidiscus kilapiae* sp. nov. A from Arroyo La Escondida, B-Q, S-V from El Salado, R from La Mala Dormida. A, CPBA 18178.7; B-C, holotype, CPBA 20022.5; D, CPBA 20022.9; E, CPBA 20022.8; F, CPBA 18185.43; G, CPBA 20022.4; H-I, CPBA 20022.6; J-K, CPBA 20032.5; L-M, CPBA 20022.7; N-O, CPBA 20022.2; P-Q, CPBA 20028.17; R, CPBA 18177.2; S-T, CPBA 20022.3; U-V, CPBA 20028.10. All specimens × 1, coated with ammonium chloride.

the last part of the whorl, and bearing prominent ventral swellings on the rib bounding the posterior part of a constriction (e.g. Fig. 2G–P, S, T). In addition, the constrictions often get closer together towards the aperture. It is probable that these differences reflect a dimorphic pair.

The bundled ribs, feeble constrictions and slightly raised ribs adjacent to the constrictions are characteristic also of *Spitidiscus fasciger* Thieuloy (1972, p. 35, pl. 3, figs. 4–9) from south-east France. But *S. fasciger* is more compressed than *S. riccardii*, the ribs are less flexuous and it has an almost flat venter. The bundling of ribs distinguishes *S. riccardii* from *Spitidiscus kilapiae* sp. nov., and the latter species is also more inflated, with stronger constrictions and more regular ribbing.

Spitidiscus kilapiae sp. nov
Fig. 3A–V

v 1997 *Spitidiscus* sp. nov. Aguirre-Urreta & Rawson, p. 453, fig. 6f, g.
v 1999 *Spitidiscus* sp. nov. Aguirre-Urreta et al., pl. 1, figs. 7, 8.
2007 *Spitidiscus* sp. Aguirre-Urreta et al., fig. 12C, D.
2009 *Spitidiscus riccardii* Leanza and Wiedmann; Aguirre-Urreta and Vennari, p. 40, fig. 5n.

Derivation of name: After Doña Marta Kilapi, for her hospitality during our visits to El Salado, the locality where *S. kilapiae* is most abundant.

Holotype. CPBA 20022.5 from El Salado, Fig. 3B, C here.

Paratypes. 285 specimens. 1 from the Paso Piuquenes (CPBA 20557), 2 from La Mala Dormida (CPBA 18177.1-2), 7 from Arroyo La Escondida (CPBA 18178.1-7), 1 from Tricao Malal (CPBA 18188), 2 from Caepe Malal (CPBA 18189.1-2), , 8 from Mina San Eduardo (CPBA 18181.1-8), 2 from Pichaihue (CPBA 18182.1-2), 14 from Agua la Mula (CPBA 17025, 18183.1-6, 18184.1-6) and 248 from El Salado (CPBA 18049.1-9, 18185.1-48, 18186.1-3, 18187.1-3, 20016.1-31, 20020.1-32, 20021.1-20, 20022.1-9, 20027.1-4, 20028.1-21, 20029.1-16, 20030.1-27, 20031.1-14, 20032.1-11).

Description. Almost all of the material consists of fragments of body chambers to about 80 mm diameter. The shell is slightly to moderately involute, moderately inflated, whorl height and thickness very similar in inner whorls, thickness slightly greater than height in more advanced growth stages. The whorl section is gently arched, the flanks merging into the rounded venter and rounded umbilical wall. There are 6–8 well-marked, shallow, slightly sinuous constrictions per whorl. Between adjacent constrictions are a variable number of ribs (usually 5–11) of equal strength. These arise singly or in pairs on the umbilical wall and often bifurcate at varying positions in mid-flank. The rib that forms the posterior margin to a constriction is usually swollen slightly, especially in the ventral area, and often truncates immediately adjacent ribs on the higher part of the flank and the venter. A few specimens become more finely ribbed, almost striate, during growth, and this can happen at varying diameters. There is no evidence to suggest whether this is an adult feature.

Dimensions of figured specimens (in mm).

	d	wh	wh%d	wt	wt%d	wu	wu%d
CPBA 18178.7	88.3[a]	34.4	0.39	39.1	0.44	–	–
CPBA 20022.5	65.2	28.1	0.44	27.7	0.42	19.7	0.30
CPBA 20022.9	56.1	22.8	0.41	22.5	0.40	18.5	0.33
CPBA 20022.4	59.2	27.3	0.46	25.9	0.44	14.3	0.24
CPBA 20032.5	51.3	21[a]	0.41	22.2[a]	0.43	14.6	0.28
CPBA 18185.43	50.4	22.3	0.44	21.1	0.42	13.3	0.26
CPBA 20022.7	43.2	20.7	0.48	23.1	0.54	10.8	0.25
CPBA 20028.10	40	17.5	0.44	18.1	0.45	11.9[a]	0.30
CPBA 20022.2	39.7	17.5	0.44	17.6	0.44	9.6	0.24
CPBA 20022.3	38.2	18.1	0.47	17.6	0.46	9.4	0.25
CPBA 20028.17	27.3	14.3	0.52	14.4	0.53	5.8	0.21

[a] Approximate measurement.

Discussion. The material shows some variation, especially in the strength of ribbing which is usually well-defined but tends to fade on some specimens. In inflation and rib pattern, *S. kilapiae* looks quite like the *S. rotula inflatus* Kilian figured by Thieuloy (1972, pl. 2, figs 4, 5), but appears more evolute and the constrictions are narrower and more numerous. *Spitidiscus pavlowi* (Karakasch) from the Speeton Clay of eastern England (Pavlow and Lamplugh, 1892, pl. 17, figs 11, 12) is slightly more evolute, the whorl thickness expands more rapidly and the constrictions are broad and shallow.

4. Age of the *Spitidiscus* fauna

Although *Spitidiscus riccardii* and *S. kilapiae* are known only from Argentina several lines of evidence suggest that they are of mid Hauterivian age, though the exact correlation of the *S. riccardii* Zone with the West Mediterranean “standard” sequence is debatable. Aguirre-Urreta and Rawson (1997) concluded that the sudden appearance of *Spitidiscus* in Argentina, immediately above the non-marine Avilé sandstones, is a local reflection of the main mid-Hauterivian sea level rise. They tentatively correlated the *S. riccardii* Zone with the *Lyticoceras nodosoplicatum* Zone of the West Mediterranean area. Bulot (personal communication in Rawson, 1999) supported the comparison of the Argentine *Spitidiscus* with forms from the *L. nodosoplicatum* Zone.

However, Aguirre-Urreta and Rawson (2001) later described some olcostephanid ammonites from Argentina that indicate an alternative correlation. The occurrence of *Olcostephanus* (*Jeannoticeras*) *agrioensis* Aguirre-Urreta and Rawson in the upper part of the *Olcostephanus* (*O.*) *laticosta* Subzone suggested a correlation with the *O.* (*J.*) *jeannoti* Subzone in the West Mediterranean Province (Fig. 4). This was supported by the discovery in the immediately overlying *Hoplitocrioceras giovinei* Subzone of very rare examples of *Olcostephanus* (*Olcostephanus*) *variegatus* (Paquier), which is the index form for a biohorizon at the base of the *L. nodosoplicatum* Zone in the West Mediterranean Province.

Hence Aguirre-Urreta et al. (2005, 2007) and Rawson (2007) have suggested that the interval between the *H. giovinei* Subzone and the *S. riccardii* Zone (i.e. the *H. gentilii* Subzone and the *W. vacaensis* Zone) represents the remainder of the *L. nodosoplicatum* Zone. They correlated the *S. riccardii* Zone with part of the overlying *Subsaynella sayni* Zone, where *Spitidiscus*, though becoming rare, occurs through the zone and into the base of the overlying *Plesiospitidiscus ligatus* Zone (Bulot, 1995, p. 134).

Further evidence is provided by the crioceratitids of the overlying *C. schlagintweiti* zone in the Neuquén Basin, some of which, especially *Crioceratites apricus* (Giovine), are virtually indistinguishable from forms in the *S. sayni* to *P. ligatus* zones of the West Mediterranean Province.

The nannoplankton biostratigraphy supports this alternative correlation. In the Neuquén Basin the LO of *Cruciellipsis cuvillieri* occurs in the *S. riccardii* Zone at Pampa Tril (Bown and Concheyro, 2004) while elsewhere in the basin (Agua de la Mula and Mina San Eduardo) it coincides with the base of the *C. schlagintweiti* Zone This appears to be consistent with its global extinction level, which in the West Mediterranean Province lies high in the *S. sayni* Zone.

A numerical age of 132.5 ± 1.3 Ma (based on U–Pb SHRIMP zircon analysis) has been obtained from a 1.2 m thick tuff layer occurring in the lower part of the *S. riccardii* Zone (only 7 m above the Avilé Member) at Caepe Malal (Aguirre-Urreta et al., 2008). This provides a close age constraint for the base of the Upper Hauterivian in the southern Hemisphere. The biostratigraphic correlations discussed above also indicate that it can provide firm evidence for the age of the Early-Late Hauterivian boundary (base of the *S. sayni* Zone) in the “standard” West Mediterranean sequences,

	NEUQUEN BASIN Aguirre-Urreta *et al.* 2005		WEST MEDITERRANEAN PROVINCE Reboulet, Klein *et al.* 2009	
AGE	BIOZONE	SUB-BIOZONE	BIOZONE	SUB-BIOZONE (S)/ HORIZON (H)
L H (p)	*Crioceratites schlagintweiti*		*Pleisiospitidiscus ligatus*	
	Spitidiscus riccardii		*Subsaynella sayni*	
EARLY HAUTERIVIAN	*Weavericeras vacaensis*		*Lyticeras nodosoplicatum*	
	Hoplitocrioceras gentilii	*Hoplitocrioceras gentilii*		*Olcostephanus (O.) variegatus* H
		Hoplitocrioceras giovinei		
	Holcoptychites neuquensis	*Olcostephanus (O.) laticosta*	*Crioceratites loryi*	*O. (Jeannoticeras) jeannoti* S
				Crioceratites loryi S
		Holcoptychites agrioensis	*Acanthodiscus radiatus*	
		Holcoptychites neuquensis		

Fig. 4. Biostratigraphical correlation with the "standard" zonation of the West Mediterranean Province.

which awaits accurate dating, though the base of the Hauterivian is currently placed at 133.9 Ma (Ogg et al. 2008).

5. Concluding remarks

It is only 19 years since *Spitidiscus* was first recorded from Argentina, from a single locality in the Neuquén Basin (Leanza and Wiedmann, 1992). We have now been able to show that it is a widespread genus there, stratigraphically limited to the *S. riccardii* Zone and the base of the overlying *C. schlagintweiti* Zone. But nowhere have we found both *S. riccardii* and *S. kilapiae* in one section. While at a few localities the genus first appears at the base of the Spitidiscus shales, within a few centimetres of the boundary with the Avilé member beneath, at others it first appears quite high in the shales. However, there is no evidence so far to indicate a stratigraphical separation of the two species. There is a geographical distinction as all the localities with *S. kilapiae* lie to the north of those with *S. riccardii*. But this does not appear to reflect either distance from presumed shorelines or a dependence on differing lithofacies.

Leanza and Wiedmann's (1992) records of *Plesiospitidiscus* associated with *Spitidiscus* at their original locality of Agrio del Medio appear to be based on a confusion of material from two distinct, closely adjacent horizons. We suggest that the "*Plesiospitidiscus*" are actually the closely similar innermost whorls of *Weavericeras*, a genus which at Agrio del Medio is common immediately beneath the Avilé Member while *Spitidiscus* occurs just above. One of the original collectors of Leanza and Wiedmann's material, Mr. Sergio Cocca, showed MBA-U that the *Weavericeras* level is where he obtained small "*Plesiospitidiscus*" by breaking them out from large pieces of *Weavericeras*, and we too have found "*Plesiospitidiscus*" this way. So it appears that *Spitidiscus* is the only ammonite genus to occur in the *S. riccardii* Zone. It eventually overlaps slightly with earliest *Crioceratites* at the base of the overlying *C. schagintweiti* Zone, after which a varied plexus of heteromorph ammonites characterises the remainder of the Agua de La Mula Member of the Agrio Formation.

Acknowledgements

Our research in the Neuquén Basin was initially supported by grants from the British Council/Fundación Antorchas (1995-2001). MBA-U acknowledges partial support from grants ANPCYT PICT 189 and UBACYT x001. PFR acknowledges the award of a 2003 Leverhulme Emeritus Fellowship from the Leverhulme Trust which supported further field work in Argentina. We are grateful to Marcela Cichowolski, Andrea Concheyro, Dario Lazo, Victor Ramos (University of Buenos Aires) and Sue Rawson for help in the field. This is contribution R-25 of the Instituto de Estudios Andinos Don Pablo Groeber (UBA-CONICET).

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