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The distribution of the gondwanine ostracod *Rostrocytheridea* Dingle: palaeozoogeographical implications

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The genus *Rostrocytheridea* is strictly gondwanine in its distribution and, in Argentina, is shown to be restricted to Patagonia. Of the six recorded Argentinian species, five are restricted to the southern part of South America: *Rostrocytheridea opisthorhynchus* nov. sp. (late Tithonian-Berriasian), *Rostrocytheridea* sp. (Valanginian), *Rostrocytheridea cerasmoderma* nov. sp., *Rostrocytheridea covuncoensis* Musacchio (Hauterivian) and *Rostrocytheridea*? sp. (Campanian). One species, *Rostrocytheridea ornata* Brenner and Oertli, is of much wider distribution, occurring in the Neocomian of South Africa and the Hauterivian of central-west Argentina. In Australia, the genus first appears in the Albian-Cenomanian and ranges up to the Santonian with two species: *Rostrocytheridea canaliculata* Bate and *Rostrocytheridea westraliensis* (Chapman). The youngest record of the genus is *R. hamiltonensis* Fauth and Seeling from the Middle to Upper Campanian of the James Ross Basin, Antarctic Peninsula. The implications for intercontinental correlation and the reconstruction of palaeo-migration routes are considered.

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1. INTRODUCTION

The genus *Rostrocytheridea* was first described by Dingle (1969), with the type species *R. chapmani*, occurring very commonly in the Upper Valanginian to Hauterivian of the Algoa Basin (South Africa). The genus was shown to belong to the Cytherideidae, Cytherideinae, because of its subtriangular outline in lateral view, rounded anterior and subventrally pointed posterior. It was diagnosed as being smooth or with fine ribs on the lateral surface, with abundant normal pore canals and antimerodont hinge with dorsal accommodation groove in the left valve. *Rostrocytheridea* is strictly gondwanine in its distribution, ranging from the Upper Jurassic (Tithonian) in South Africa and west-central Argentina to the Upper Cretaceous (Campanian) of the Antarctic Peninsula.

The purpose of this paper is to review the current state of knowledge of *Rostrocytheridea* in Argentina and to describe two new species. Given the geographical distribution of the species, we discuss their value in correlation both within southern Argentina and other localities along the southern margins of Gondwana. This study complements others of the authors concerning the distribution of Mesozoic gondwanine ostracods (Ballent *et al*. 1998; Ballent and Whatley 2000, 2006; Whatley *et al*. 2005).

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2. ARGENTINIAN SPECIES OF *ROSTROCYTHERIDEA*

Five species have been recovered from the Neuquén Basin, located in west-central Argentina and eastern Chile, between latitudes 34°S and 41°S. One species is from the Austral or Magallanes Basin, which extends in a NWW-SSE direction, over most of southern Patagonia (Argentina and Chile) south of 47°S (Figure 1).

Two groups of species are recognized within *Rostrocytheridea*:

Jurassic species: only one species: *Rostrocytheridea opisthorhynchus* nov. sp. from the late Tithonian-Berriasian.

Cretaceous species: *Rostrocytheridea* sp. from the Valanginian; *Rostrocytheridea ornata* Brenner and Oertli, *Rostrocytheridea covuncoensis* Musacchio and *Rostrocytheridea cerasmoderma* nov. sp., all from the Hauterivian of different localities in the Neuquén Basin and *Rostrocytheridea*? sp. from the Campanian of the Austral Basin.

3. SYSTEMATICS

The suprageneric classification adopted is that proposed in Moore and Pitrat (1961). In the systematic descriptions, the following conventions are employed: L = length, H = height, W = width; very small (less than 0.4 mm), small (0.4–0.5 mm), medium (0.51–0.7 mm), large (0.71–0.9 mm), very large (more than 0.9 mm). Type and figured

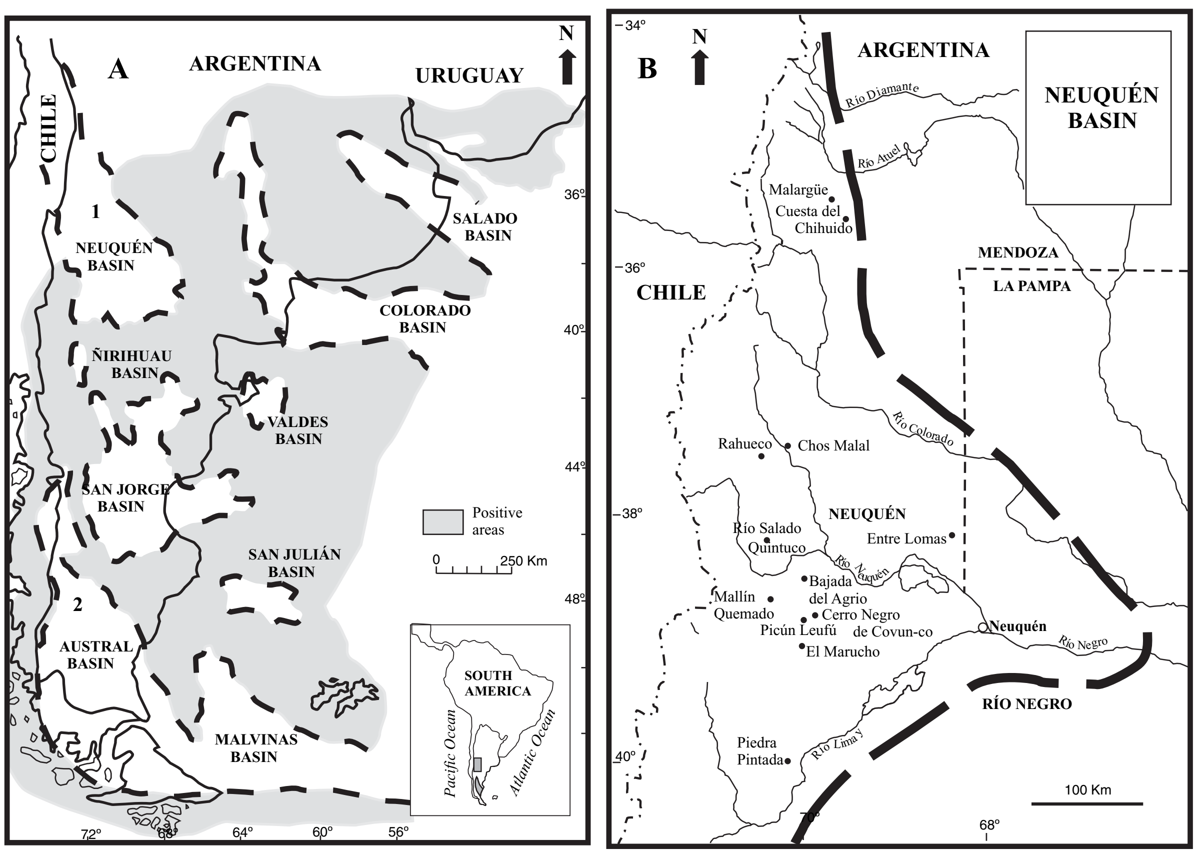

Figure 1. (A) Main sedimentary basins of southern South America (after Malumián and Ramos 1984). 1, Neuquén Basin; 2, Austral Basin; (B) Neuquén Basin and studied localities.

specimens are deposited in the collections of the Museo de Ciencias Naturales de La Plata, Argentina-Sección Micropaleontología (MLP-Mi) under their respective catalogue numbers.

Class OSTRACODA Latreille, 1806
Order Podocopida Müller, 1894
Suborder Podocopina Sars, 1866
Superfamily Cytheroidea Baird, 1850
Family Cytherideidae Sars, 1925
Subfamily Cytherideinae Sars, 1925
Genus *Rostrocytheridea* Dingle, 1969

Type species. *Rostrocytheridea chapmani* Dingle (1969, pp. 154–156, figs. 12, 14 c–g, pl. IX d, e, f, i).

Rostrocytheridea opisthorhynchus nov. sp.
Figure 2C–G, V

Etymology. Gr. *Oπιισθεν ophisten* behind, plus *ρυψχoς rhynchos* snout = *opisthorhynchus*. With reference to the snout-like posterior of this species.

Type collection. Holotype. MLP-Mi 1576, female carapace, figured in Figure 2C, from well YPF.PC.Nq.EC.24 (El Caracol), Neuquén Basin, Argentina, 1950–1960 m below surface. *Paratypes*. MLP-Mi 1577–1582. MLP-Mi 1577, male carapace, YPF.PC.EL. a-9 (Entre Lomas), 1860 m below surface; MLP-Mi 1578, male carapace, YPF.PC.EL.10 (Entre Lomas), 1880 m below surface; MLP-Mi 1579, female carapace, YPF.PC.EL.10 (Entre Lomas), 1880 m below surface; MLP-Mi 1580, juvenile carapace, YPF.PC.Nq.EC.26 (El Caracol), 1925 m below surface; MLP-Mi 1581, juvenile carapace, YPF.PC.EC.26 (El Caracol), 1925 m below surface; MLP-Mi 1582, right valve, YPF.PC.Nq.EC.24 (El Caracol), 1950–1960 m below surface, all from the Entre Lomas area, Neuquén Basin, Argentina.

Type locality and type level. Well YPF.PC.Nq.EC.24 (El Caracol), Entre Lomas area (between 37°50′–38°15′S and 68°–68°30′W) Neuquén Basin, west-central Argentina, 1950–1960 m below surface, Loma Montosa Formation, late Tithonian-Berriasian.

Other material. Carapaces of adults and a wide range of instars, 20 of which are housed as MLP-Mi 1583 YPF.PC.Nq. EC 26 (El Caracol) 1925 m below surface.

Diagnosis. A medium-sized and very strongly dimorphic species of *Rostrocytheridea*, female subtriangularly rounded and male more elongate, subcylindrical in lateral view with the entire surface covered with fine punctations.

Description. Medium. Sexual dimorphism very strongly developed. Females subtriangularly rounded in lateral view with the posterior 'beak' blunt and pointing backwards, they are also rather tumid laterally, with the greatest height antero-medially. Males are subtriangular elongate in lateral view with the blunt posterior 'beak' at mid-height and pointing backwards. Greatest length below mid-height in female; at mid-height in males. In dorsal view, both sexes are subovate with maximum width at mid-length. Anterior margin, obliquely rounded in females, with apex below mid-height but more perfectly rounded in males with apex at mid-height. Dorsal margin broadly convex in female left valve, straight between cardinal angles and inclined towards the posterior margin in female right valve; straighter in males. Ventral margin evenly concave in both valves and sexes. The ornamentation consists of fine punctations, arranged in delicate concentric lines, parallel to margins. Normal pores spaced. Hinge antimerodont. Other internal features unknown.

Dimensions (mm). Figured specimens
MLP-Mi 1576 holotype, $L = 0.603$, $H = 0.314$, $W = 0.300$ (Figure 2C)
MLP-Mi 1577 paratype, $L = 0.630$, $H = 0.292$, $W = 0.226$ (Figure 2D)
MLP-Mi 1578 paratype, $L = 0.712$, $H = 0.331$, $W = 0.228$ (Figure 2E)
MLP-Mi 1579 paratype, $L = 0.633$, $H = 0.333$, $W = 0.22$ (Figure 2F)

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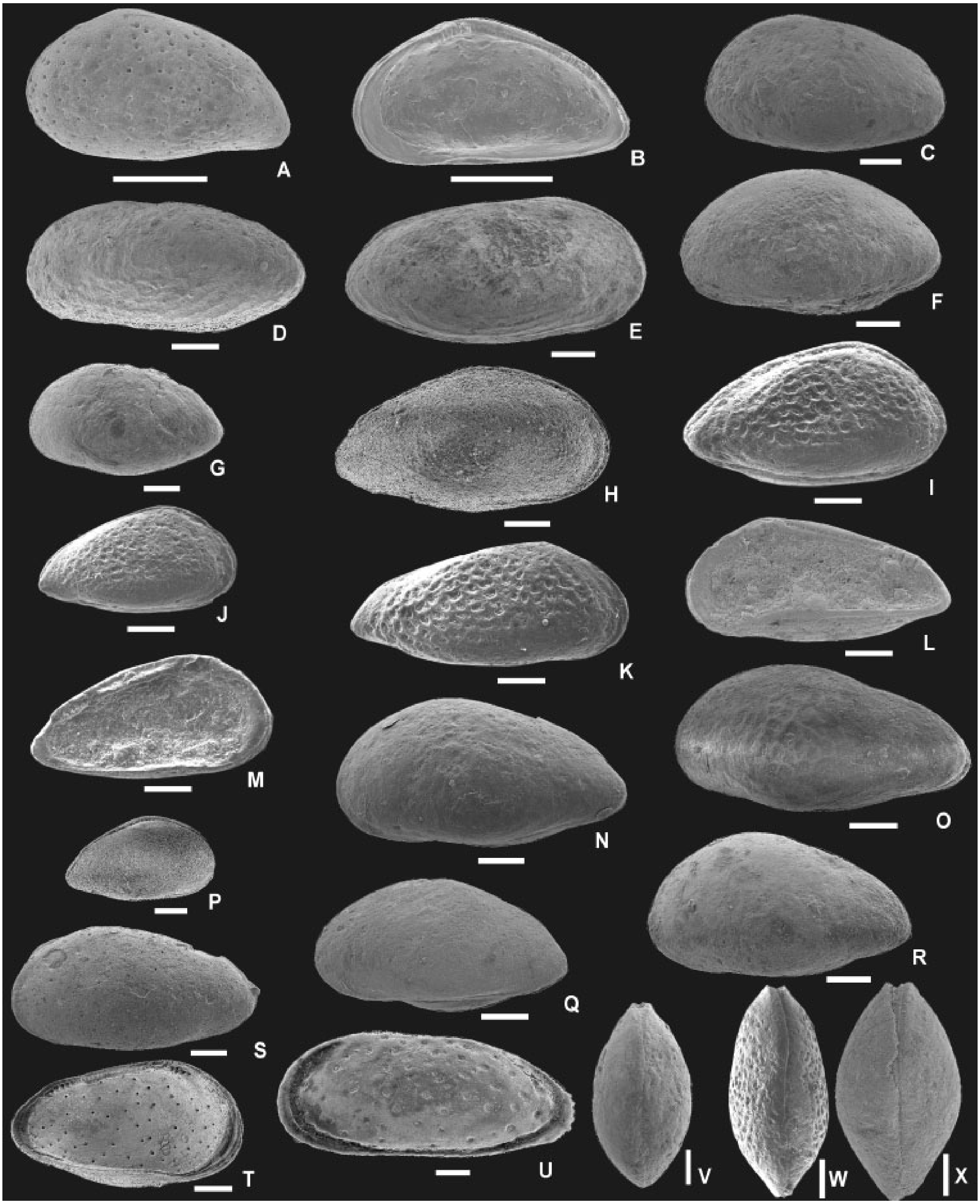
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MLP-Mi 1580 paratype, $L = 0.561$, $H = 0.319$, $W = 0.180$ (Figure 2G)

MLP-Mi 1581 paratype, $L = 0.530$, $H = 0.270$, $W = 0.290$ (Figure 2V)

Age and distribution. The species occurs in the late Tithonian-Berriasian (Loma Montosa Formation) from wells of the Entre Lomas area, Neuquén Basin, Argentina.

Remarks. The rounded subtriangular outline in lateral view and the posterior 'beak' mainly pointing backwards serve to distinguish this new species from others of the genus.

Rostrocytheridea cerasmoderma nov. sp.
Figure 2I–M, W

2006. *Rostrocytheridea* sp. nov.? Ballent *et al*., p. 65, fig. 4F.

Etymology. Gr. *κερασματος kerasmatos* a mixture, plus *δερμα derma* skin. With reference to the mixed ornament of reticulation and punctation that characterizes this species.

Type collection. *Holotype*. female carapace, MLP-Mi 1424 figured in Figure 2I.

Paratypes. MLP-Mi 1425-1432. MLP-Mi 1425 female carapace; MLP-Mi 1426 male right valve; MLP-Mi 1427 female left valve; MLP-Mi 1428 juvenile carapace; MLP-Mi 1429, left valve; MLP-Mi 1430 female carapace; MLP-Mi 1431 female carapace; MLP-Mi 1432 female left valve, all from Cuesta del Chihuido section, level CH 147, Neuquén Basin, west-central Argentina.

Type locality and type level. Cuesta del Chihuido section (35°45′S, 69°34′W), Neuquén Basin, west-central Argentina, level CH 147, Agrio Formation, late Hauterivian.

Other material. One carapace and eight valves housed as MLP-Mi 1584.

Diagnosis. A medium-sized species of *Rostrocytheridea* with a coarse reticulate-punctate network subparallel to margins.

Description. Medium. Subtriangular in lateral view with the greatest length below mid-height and the greatest height coincident with the anterior cardinal angle. Left valve larger than right and overlapping along the periphery except along the posterior margin. Moderate postero-ventral incision and blunt beak-shaped posterior end pointing downwards. Anterior margin broadly but obliquely rounded. The dorsal margin is straight and declines towards the posterior margin from the anterior cardinal angle. Ventral margin broadly concave with a posterior incision poorly marked. Valve surface with a coarse reticulate-punctate network subparallel to margins. In dorsal view the carapace is biconvex, with the greatest width at mid-length. Strongly dimorphic; males are larger and with cardinal angles and beak-shaped posterior more prominent than in females. Hinge antimerodont; long anterior and posterior five dentate terminal elements in right valve, separated by straight, depressed crenulate groove. Complementary

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Figure 2. Type species (*R. chapmani* Dingle) and Argentinian species of *Rostrocytheridea*. (A, B) *Rostrocytheridea chapmani* Dingle, Neocomian South Africa; (A) Io753, female left valve, external view; (B) Io752 female right valve, internal view; (C–G) *Rostrocytheridea opisthorhynchus* nov. sp., late Tithonian-Berriasian; (C) MLP-Mi 1576, holotype, female carapace, left lateral view; (D) MLP-Mi 1577, paratype, male carapace, left lateral view; (E) MLP-Mi 1578, paratype, male carapace, right lateral view; (F) MLP-Mi 1579, paratype, female carapace, left lateral view; (G) MLP-Mi 1580, paratype, juvenile carapace, left lateral view; (H) *Rostrocytheridea* sp., Valanginian, MLP-Mi 1591, female carapace, right lateral view; (I–M) *Rostrocytheridea cerasmoderma* nov. sp., late Hauterivian; (I) MLP-Mi 1424, holotype, female carapace, right lateral view; (J) MLP-Mi 1428, paratype, juvenile carapace, right lateral view; (K) MLP-Mi 1426, paratype, male right valve, external view; (L) same specimen, internal view; (M) MLP-Mi 1427, paratype, female left valve, internal view; (N–R) *Rostrocytheridea ornata* Brenner and Oertli, late Hauterivian; (N) MLP-Mi 339, female carapace, left lateral view; (O) MLP-Mi 338, male carapace, left lateral view; (P) MLP-Mi 1588, juvenile carapace, right lateral view; (Q) MLP-Mi 1587, female carapace, left lateral view; (R) MLP-Mi 340, female carapace, left lateral view; (S) *Rostrocytheridea covuncoensis* Musacchio, Hauterivian, MLP-Mi 331, female left valve, external view; (T) same specimen, internal view; (U) *Rostrocytheridea*? sp., Campanian, MLP-Mi 1592, male? carapace, left lateral view; (V) *Rostrocytheridea opisthorhynchus* nov. sp., MLP-Mi 1581, paratype, juvenile carapace, dorsal view; (W) *Rostrocytheridea cerasmoderma* nov. sp., MLP-Mi 1425, paratype, female carapace, dorsal view; (X) *Rostrocytheridea ornata* Brenner and Oertli, MLP-Mi 1586, female carapace, dorsal view. Repository: Io = British Museum (Natural History), London; MLP-Mi = Museo de Ciencias Naturales de La Plata, Argentina-Sección Micropaleontología. Scale bar: (A) = 0.200 mm, (B) = 0.250 mm, (C–X) = 0.100 mm.

elements and accommodation groove above median bar in left valve. Inner lamella moderately wide with narrow anterior vestibulum. Other internal features not observed.

Dimensions (mm). Figured specimens:

MLP-Mi 1424 holotype, $L = 0.575$, $H = 0.305$, $W = 0.250$ (Figure 2I)

MLP-Mi 1425 paratype, $L = 0.550$, $H = 0.290$, $W = 0.250$ (Figure 2W)

MLP-Mi 1426 paratype, $L = 0.600$, $H = 0.255$ (Figure 2K, L)

MLP-Mi 1427 paratype, $L = 0.550$, $H = 0.230$ (Figure 2M)

MLP-Mi 1428 paratype, $L = 0.420$, $H = 0.250$, $W = 0.220$ (Figure 2J)

Age and distribution. Late Hauterivian, Agrio Formation, Cuesta del Chihuido section, Neuquén Basin, west-central Argentina.

Remarks. The outline of the carapace and the reticulate ornamentation distinguish this species from others of the Neocomian of South Africa. The type species, *R. chapmani* Dingle is higher and punctate with six faint ridges on the ventral surface; *R. ornata* Brenner and Oertli has a convex ventral outline, the blunt beak-shaped posterior end is pointed markedly downwards and an ornament consisting of small riblets and puncta, extending parallel to the margins. *R. covuncoensis* Musacchio from the Hauterivian of the Covun-Co section (Neuquén Basin, Argentina) is large and more robust, externally smooth or very feebly ribbed ventrally and with a more delicate antimerodont hinge.

Rostrocytheridea ornata Brenner and Oertli, 1976
Figure 2N–R, X

1976. *Rostrocytheridea ornata* Brenner and Oertli, p. 500, pl. 5, figs. 8–10; pl. 8, fig. 3.
1979a. *Rostrocytheridea* sp. 1 Musacchio, p. 464, pl. 1, figs. 17–19.
1979b. *Rostrocytheridea* cf. *ornata* Brenner and Oertli, Musacchio, pl. 6, figs. 9, 11.
1998. *Rostrocytheridea ornata* Brenner and Oertli, Simeoni and Musacchio, pl. 2, p. 1412.

Material studied. 50 carapaces housed as MLP-Mi 338, 339, 340 (Picún Leufú section), 1585, 1586, 1587 (Cerro Birrete section), 1588 (El Marucho section), 1589, 1590 (Puesto Jara section).

Complementary description. Medium, strongly dimorphic. Females with a tumid carapace, subtriangular in lateral view with the greatest length in the lower third coincident with the posterior 'beak' and the greatest height in the anterior third of the carapace. Left valve larger than right and overlapping dorsally. H/L ratio nearly 0.5. Anterior margin regularly rounded and posterior margin bluntly pointed downwards. Dorsal margin convex, declining towards the posterior end from the point of the greatest height. Ventral margin convex medially, obscured by a well-developed tumidity. In dorsal view, the carapace is an inflated ovoid with maximum width at mid-length. Males are elongate, longer and thinner in dorsal view than females, with the dorsal margin strongly declining towards the posterior end and the posterior margin with the blunt apex markedly pointing downwards. Both sexes have the surface of the valves with fine and delicate, variably visible punctations which, along the ventral area, are disposed subparallel to the margin, with a fine ornamentation of ribs which are concentrically disposed parallel to the margins (as diagnosed by Brenner and Oertli 1976). Internal features: anterior inner lamella moderately broad; anterior vestibulum very narrow. Hinge antimerodont, with accommodation groove above median bar in left valve. Juveniles are subtriangular in outline with the greatest height anterior mid-length.

Dimensions (mm). Figured specimens:

MLP-Mi 338, $L = 0.675$, $H = 0.320$, $W = 0.345$ (Figure 2O)

MLP-Mi 339, $L = 0.680$, $H = 0.340$, $W = 0.355$ (Figure 2N)

MLP-Mi 340, $L = 0.630$, $H = 0.335$, $W = 0.345$ (Figure 2R)

MLP-Mi 1586, $L = 0.580$, $H = 0.360$, $W = 0.345$ (Figure 2X)

MLP-Mi 1587, $L = 0.589$, $H = 0.283$, $W = 0.280$ (Figure 2Q)

MLP-Mi 1588, $L = 0.460$, $H = 0.245$, $W = 0.260$ (Figure 2P)

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Age and distribution. Late Hauterivian, Agrio Formation, Cerro Birrete, El Marucho, Puesto Jara, Picún Leufú (area approx. 39°S/70°W) and other sections in the southern of the Neuquén Basin, west-central Argentina. Upper Valanginian and Hauterivian of the Algoa Basin wells in South Africa (Brenner and Oertli 1976; Dingle 1996).

Remarks. A complementary description of this species is provided in order to enlarge that from Brenner and Oertli (1976). These authors refer to it as a small species of *Rostrocytheridea* with a convex ventral outline with the posterior end markedly inclined downwards and an ornamentation on the surface consisting of small riblets and punctations; sexual dimorphism is not mentioned. However, since the scattergram showing dimensions of this species (Brenner and Oertli 1976, p. 501, figure 20) has mainly specimens between 0.6–0.7 mm in length, we consider these species as medium in size. Also, the figured specimens by these authors (pl. 5, figs. 8–10 and pl. 8, fig. 3) seem to be males.

R. ornata differs from *Rostrocytheridea cerasmoderma* nov. sp. from the late Hauterivian of sections of northern Neuquén Basin in its punctate to ribbed ornamentation rather than reticulate-punctate as in the latter.

Rostrocytheridea covuncoensis Musacchio, 1979a
Figure 2S, T

1979a. *Rostrocytheridea*? *covuncoensis* Musacchio, p. 463, pl. 1, figs. 24–26.

Material studied. Three carapaces. MLP-Mi 331, 332, 333.

Description. Carapace robust, medium size, smooth to weakly ribbed ventrally. Sexual dimorphism very marked. Females subtriangular in lateral view with the greatest height in the anterior third coincident with the anterior cardinal angle; anterior margin obliquely rounded. Males are longer than females, subtriangular, elongate in lateral view with the anterior margin broadly and regularly rounded; dorsal margin straight between the cardinal angles, and markedly inclined to posterior margin. In both sexes the anterior margin is compressed and the posterior 'beak' typical of the genus is posteroventral and pointing backwards. Normal pores large and well spaced. Five posteroventral denticles are present. Internal morphology: hinge antimerodont; anterior and posterior elements in left valve consist of sockets subdivided into five locules, separated by a median denticulate bar; an accommodation groove is also present. Narrow anterior and posterior vestibula. Anterior marginal zone with *ca*. 30 pore canals. Vertical row of four adductors muscle scars situated just coincident with the position of greatest height. Frontal scar V-shaped.

Age and distribution. Hauterivian (Agrio Formation), Cerro Negro de Covun-co section (38°46′S, 69°59′W), Neuquén Basin.

Dimensions (mm). MLP-Mi 331, specimen figured, left valve female, $L = 0.727$, $H = 0.363$.

Remarks. *R. covuncoensis* is close to *R. hamiltonensis* Fauth and Seeling (in Fauth *et al*. 2003) from the Middle-Upper Campanian of the James Ross Basin, Antarctica. However, this is larger (holotype $L = 0.913$ mm), with a strongly inflated ventrolateral area and a denticulate posterior margin.

Rostrocytheridea sp.
Figure 2H

Material studied. Six carapaces, MLP-Mi 1591.

Dimensions (mm). Specimen figured: MLP-Mi 1591, female carapace, $L = 0.642$, $H = 0.390$.

Age and distribution. Valanginian (Mulichinco Formation), Río Salado and Quintuco sections (area between 38°10′–38°20′S and 70°10′–70°25′W) and Rahueco section (approx. 37°30′S/70°25′W; see Schwarz 2003) Neuquén Basin, west-central Argentina.

Remarks. Other than the figured carapace, the material consists of a few specimens (juveniles?), precluding further determination. Carapace dimorphic, medium in size, with left valve larger than right overlapping along entire periphery except posteriorly.

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Rostrocytheridea? sp.
Figure 2U

Material. Two carapaces. MLP-Mi 1592.

Dimensions (mm). Specimen figured, MLP-Mi 1592, male? carapace, $L = 0.950$, $H = 0.370$, $W = 0.320$.

Age and distribution. Campanian, from wells in the Austral Basin.

Remarks. The two specimens are quite well preserved. Carapace large and elongate subrectangular with the posterior end centrally obtuse in lateral view. The ornamentation consists of a number of coarse, shallow pits, containing large sieve-type normal pore canals, and a well-developed marginal furrow paralleling the free margins. The posterior margin bears six to seven rounded marginal denticles. This species shares some characters with two Santonian-Campanian western Australian species, *R. westraliensis* (Chapman) and *R. canaliculata* Bate, which are very closely related (Neale 1975, p. 40). These characteristics are the marginal furrow and the denticulate posterior end. The Argentinian species particularly resembles males of *Rostrocytheridea westraliensis*, although the latter species is comparatively higher, with concentric foveolate ornamentation, has three well-developed spines posteriorly and seven marginal denticles along the anterior margin in well-preserved specimens.

4. OTHER SPECIES OF *ROSTROCYTHERIDEA*

Dingle (1969) described the type species, *Rostrocytheridea chapmani*, from the Upper Valanginian to Hauterivian of the Algoa Basin, South Africa (see Figure 2A, B). It is a species with well-rounded subtriangular carapace, strongly arched dorsal margin and smooth surface, with abundant marginal pore canals (25–30 anteriorly, and up to 6 posteriorly). It is very common in the Algoa Basin and is widely distributed over the Agulhas Bank, in South Africa (Brenner and Oertli 1976; McLachlan *et al*. 1976). Three other species have been recognized in South Africa. The oldest is *Rostrocytheridea* sp. from the ?Portlandian of the Brenton Formation (Dingle 1982, table 2, p. 373). Brenner and Oertli (1976, p. 500, plate 5, figs. 8–10; pl. 8, fig. 3) described *Rostrocytheridea ornata*, a species with an ornament of riblets and punctations, from the Upper Valanginian-Hauterivian of the Algoa Basin wells. McLachlan *et al*. (1976, p. 364, figs. 15, 10–13) assigned a left and a right valve from the Upper Valanginian of the Brenton Formation to *Rostrocytheridea* sp. This species is fully arched dorsally with an atypical (?) posterior margin, but with internal morphology consistent with the genus.

In Australia, the genus first appears in the Albian-Cenomanian with *Rostrocytheridea*? *allaruensis* Krömmelbein (1975, p. 457, pl. 4, figs. 14–15) from the Great Artesian Basin, Queensland. This is a smooth species with a shallow median sulcus and denticles around the anterior and posterior margins. Because of the presence of only nine anterior marginal pore canals, Krömmelbein at one stage even considered whether a new genus should be established for the Australian species.

There are two very closely related species recognized from the Upper Cretaceous of western Australia. In 1972 Bate (p. 38, pl. 12, fig. 9; pl. 13, figs. 4, 6–8) described *Rostrocytheridea canaliculata* from the Santonian-Campanian Toolonga calcilutite of the Carnarvon Basin. This is a smooth species with a deep furrow parallel to anterior margin and a downturned and denticulate posterior end. The other Australian species is *Rostrocytheridea westraliensis* (Chapman) described by Neale (1975, p. 39, pl. 2, figs. 1, 2; pl. 6, fig. 4; pl. 7, figs. 1–3), very common in the Santonian of Gingin. This species is ornamented with large pits and has a well-developed marginal sulcus anterior and posteriorly. The anterior margin bears seven denticles and three well-developed spines occur on the posterior margin of well-preserved specimens.

The last record of the genus seems to be *Rostrocytheridea hamiltonensis* Fauth and Seeling (in Fauth *et al*. 2003, p. 102, pl. 2, figs. 8–12) from the Middle to Upper Campanian of the James Ross Island, Antarctic Peninsula. The species is smooth with a strongly inflated ventrolateral area and a denticulate posterior margin.

Bassiouni (2002) described two species tentatively assigned to *Rostrocytheridea*; they are, ? *R. anterocompressa* (p. 29, pl. 5, figs. 11–14) and ? *R. quadricostata* (p. 30, pl. 6, figs. 11–15) from the Aptian-Albian of Sinai, Egypt. These Egyptian species differ from others of the genus in being much smaller size (0.4 mm length = small size), are posteroventrally compressed, lack the anterior vestibulum, have few marginal pore canals (about seven to eight anteriorly and four posteriorly) and an antimerodont hinge in which the median element is smooth to faintly loculate rather than denticulate.

Rostrocytheridea? of Ahmad *et al*. (1991, pl. 10, figs. 3–4) from the Upper Eocene of Tanzania is subovate to egg-shaped in outline, with the dorsal margin convex, sloping both anteriorly and posteriorly from the greatest height. It is certainly not *Rostrocytheridea* and Ahmad *et al*. (1991) considered it an evolutionary intermediate stage between this genus and the Miocene-Recent *Cyprideis*, with almost equally rounded posterior and anterior margins. This relationship is rejected by the present authors.

5. ABUNDANCE AND ENVIRONMENT OF DEPOSITION

Rostrocytheridea opisthorhynchus nov. sp. from the late Tithonian-Berriasian, eastern Neuquén Basin, central-west Argentina represents almost 50% of all ostracods, and together with *Cytherella montosaensis* Ballent and Ronchi dominates the microfauna. This seems to typify a marginal marine environment, with warm-temperate waters, normal salinity levels and low energy regime (Ballent and Ronchi 1999).

Rostrocytheridea ornata from the Late Hauterivian of the El Marucho, Cerro Birrete and Puesto Jara sections and *Rostrocytheridea covuncoensis* from the Cerro Negro de Covun-co section, all close to the southern border of the Neuquén Basin, occur associated with several species of Platycopina, with a relatively high ostracod/foraminiferal ratio with the latter dominated by polymorphinids and spirillinids among the foraminifers (Concheyro *et al*. 2005). The environment of deposition corresponds to restricted marginal marine conditions with warm waters. Changing salinity seems to have had an influence on the high inter- and intra-population variability of some species of *Cytherelloidea* (Musacchio and Abrahamovich 1984). In both cases the abundant presence of *Cytherelloidea*, a well-known warm-water indicator (Sohn 1962), militates in favour of inner, rather than outer, shelf in a subtropical or warmer environment. In the case of the Cuesta del Chihuido section, northeastern Neuquén Basin, *Rostrocytheridea cerasmoderma* nov. sp. comes from mudstones and silty-sandstone intercalations containing allochthonous adherent foraminifers and adult carapaces of cytherids, mainly *Sondagella colchesterensis* Valicenti and Stephens. The facies represents distal storm deposits (Ballent *et al*. 2006). In this case, the specimens of *Rostrocytheridea* seem to have been transported from a shallow-marine environment to distal facies.

Brenner and Oertli (1976) regarded the early Cretaceous of the Sundays River Formation (Algoa Basin, South Africa), where ostracods (including species of *Rostrocytheridea*) are abundant, to have accumulated in a warm-water, shallow-marine environment with an abundant food supply. Associated diverse lagenid foraminifers corroborate that environment (McMillan 2003).

At Gingin, in the northern part of the Perth Basin (Western Australia), the Santonian species *Rostrocytheridea westraliensis* usually makes up between 3% and 6% of the specimens recovered. It is suggested that the Gingin Chalk may be regarded as a warm-water deposit laid down in a shallow-shelf sea, whose depth was around 100 m and the minimum temperature not less than 10°C. This agrees with the associated well-developed trachyleberid species, which suggests a relatively shallow-shelf sea area; in addition the Platycopina confirm warm, clear, shallow seas (Neale 1975).

Rostrocytheridea hamiltonensis from the Middle-Upper Campanian of southern James Ross Island, Antarctica represents 22% of the total individuals, only outnumbered by *Mandestamia antarctica* Fauth and Seeling (nearly 48%). The environment of deposition corresponds to a shallow platform of normal marine salinity and relatively warm-water temperatures (Fauth *et al*. 2002, 2003). The occurrence of *Cytherelloidea* and of *Majungaella* (the latter with nearly 14% with two species), *M. pseudonymos* Rossi de García and Proserpio and *Majungaella* sp. (of Ballent *et al*. 1998), which had a typically tropical distribution in the Cretaceous (Whatley *et al*. 2005) corroborates that environment.

6. DISCUSSION

Rostrocytheridea was a medium–large marine Mesozoic podocopid ostracod, which, in common with all contemporary (and modern) cytherids, was unable to swim and also lacked pelagic larvae. They could, therefore,

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Table 1. Specific diversity and geographical and stratigraphical occurrences of all records of the genus *Rostrocytheridea*

	? Portlandian	Late Tithonian-Berriasian	Valanginian	Valanginian-Hauterivian	Hauterivian	Albian-Cenomanian	Santonian	Campanian
South Africa	*R*. sp. of Dingle 1982		*R*. sp. of McLachlan *et al*. 1976	*R. chapmani*; *R. ornata*				
Argentina		*R. opistorhynchus* nov. sp	*R*. sp.		*R. cerasmoderma* nov. sp; *R. ornata*; *R. covuncoensis*			*R*.? sp.
Australia						*R*.? *allaruensis*	*R. canaliculata*; *R. westraliensis*	
Antarctica								*R. hamiltonensis*

only migrate as far as they could 'walk' or be transported by marine agencies. The dispersion of ostracods in shallow-water marine environments is much more constrained by physical factors than it is for deep-water forms. Only where continuity of continental shelf occurs latitudinally are conditions likely to be ideal for the successful migration of such shallow-water faunas (Whatley 1986, 1988). Ostracods can migrate latitudinally when temperature and other ecological parameters, such as the bathymetry, remain stable within certain limits and continental margins can function as migration pathways (Babinot and Colin 1992).

The oldest records of *Rostrocytheridea* seem to be *Rostrocytheridea* sp. mentioned by Dingle (1982, table 2) from the ?Portlandian Brenton Formation in South Africa and *Rostrocytheridea opisthorhynchus* nov. sp. from the late Tithonian-Berriasian of the Neuquén Basin in Argentina. These constitute the only Jurassic records of the genus, and their almost simultaneous appearances clearly confirm the short distances of the marine migration routes along the southern margins of Gondwana at that time. Table 1 shows the specific diversity and stratigraphical and geographical occurrences of all records of *Rostrocytheridea*.

During the latest Jurassic-Berriasian the opening of a shallow intermittent epicontinental seaway between southern South Africa and southern Argentinian Patagonia favoured faunal interchange. This seaway corresponds to the commencement of the continental separation between Africa and South America (124 Ma), which created the South Atlantic and a small ocean basin off south-east Africa (Natal Valley, see Dingle 1988) producing a Valanginian-Hauterivian influx of new species and an increase in population diversity. Several progonocytherid and cytherurid species have coeval records in South Africa and western Argentina (Whatley and Ballent 1996; Ballent *et al*. 1998; Simeoni and Musacchio 1998; Ballent and Whatley 2000) at that time. *Rostrocytheridea* was represented by three species in South Africa (*Rostrocytheridea* sp. of McLachlan *et al*. 1976, the type species *R. chapmani* Dingle and *R. ornata* Brenner and Oertli) and four in Argentina (*Rostrocytheridea* sp., *R. cerasmoderma* nov. sp., *R. covuncoensis* Musacchio and *R. ornata*), being the latter species with coeval record in western Argentina and the Algoa Basin.

The migration of species, as shown by Dingle (1999), occurred along the southern flanks of the Walvis Ridge, an east-west orientated barrier separating in the newly opening South Atlantic, marine (and temperate) conditions in the south from non-marine environments to the north. No pre-Albian marine ostracods have been reported from the South Atlantic. The scarcity and relatively restricted occurrence of Albian-Cenomanian-Turonian ostracods in the Potiguar Basin (northeastern Brazil) studied by Delicio *et al*. (2000) and Viviers *et al*. (2000) corroborate that interpretation. The ubiquitous oxygen depletion presence in the South Atlantic during mid-Cretaceous time has also probably acted as a barrier which may have contributed to isolate benthonic faunas (Delicio *et al*. 2000).

Some palaeoceanographical and palaeogeographical changes, such as the opening pole change at 105 Ma (early Albian, see Dingle 1988, table 3), probably led to the deep-water passages forming along the line of the Falkland Plateau-southern Africa fracture zone, allowing the dysaerobic temperate South Atlantic to be flushed by oxygenated waters, which favoured the appearance of new taxa and the rapid distribution in the Albian of *Arculicythere tumida* Dingle along the southern margins of Gondwana (Ballent and Whatley 2006). At the same time, some 'old' or original elements of the South Gondwana Fauna (SGF of Dingle 1988) such as *Majungaella* Grékoff (see Whatley *et al*. 2005) and *Rostrocytheridea* made their way to Australia. *Rostrocytheridea* arrived there in the Albian-Cenomanian (*R*.? *allaruensis* Krömmelbein) and continued up into the Upper Cretaceous with *R. westraliensis* (Chapman) (Gingin Basin, Santonian) and *R. canaliculata* Bate (Carnarvon Basin, Santonian-Campanian). The record of *Rostrocytheridea* in Antarctica (*R. hamiltonensis* Fauth and Seeling) from the Middle-Upper Campanian of southeastern James Ross Island shows that the Ross Sea area was connected faunally to southeastern Australia, presumably via the Tasman shelf/rise (Lawver *et al*. 1992; Lawver and Gahagan 2003). This Antarctic fauna, together with the record of *Rostrocytheridea*? from the Campanian of the Austral Basin in Argentina, provides clear evidence of links between western Australia, Argentinian Patagonia and the Antarctic Peninsula during the Late Cretaceous. The presence of *Rostrocytheridea hamiltonensis* Fauth and Seeling (close to *R. canaliculata* Bate) in western Australia and Antarctica and of *Rostrocytheridea*? sp. (which is close to males of *R. westraliensis* (Chapman) from the Santonian of western Australia) in the Campanian of the Austral Basin reinforce such links. Also, the occurrences of *Eocytheropteron carinoalatum* (Bate 1972) in western Australia and Antarctica and of a species very close (*E*. aff. *carinoalatum* of Rossi de García and Proserpio 1978) in the Upper Campanian-Lower Maastrichtian of the Austral Basin in Argentina, as well as of *Majungaella pseudonymos* Rossi de García and Proserpio and of *Majungaella* sp. of Ballent *et al*. (1998) in the Late Cretaceous of Argentinian Patagonia reinforce links between southern South America and Antarctica (Whatley *et al*. 2005). This is in agreement with the assumption that the Drake Passage (now *ca*. 1000 km wide) started to open at about 36 Ma (Lawver *et al*. 1992; Lawver and Gahagan 2003), so that, prior to that time, the distance between Antarctica and Patagonia would have been less.

With respect to palaeoenvironmental preferences (in Section 5), all records of *Rostrocytheridea* are from similarly warm and normal salinity, shallow-water environments.

Several important events influenced parts of Gondwanaland during the Late Cretaceous-Early Tertiary time and had the following effects: (a) final continental separation across the Equatorial Fracture Zones (80 Ma), (b) the breakdown of the Walvis-Ridge barrier to ostracod migration (Dingle 1988), (c) environments became gradually deeper and cooler. Cool temperatures have been indicated for late Maastrichtian-earliest Paleocene period in high latitudes (Dingle and Lavelle 1998) and ostracod assemblages were dominated by deep-sea species (Majoran and Widmark 1998; Majoran *et al*. 1998).

7. CONCLUSIONS

The genus *Rostrocytheridea* is strictly gondwanine in its distribution and in Argentina is shown to be restricted to Patagonia. Five species have been recorded from the Neuquén Basin: *Rostrocytheridea opisthorhynchus* nov. sp. (late Tithonian-Berriasian); *Rostrocytheridea* sp. (Valanginian); *Rostrocytheridea covuncoensis* Musacchio and *Rostrocytheridea cerasmoderma* nov. sp. (Hauterivian) which are restricted to southern South America; one species, *R. ornata* Brenner and Oertli, is of much wider distribution, since it also occurs in the Neocomian of South Africa and in the Hauterivian of central-west Argentina. *Rostrocytheridea*? sp. is recorded from the Campanian of the Austral Basin. In Australia, the genus first appears in the Albian-Cenomanian and ranges up to the Santonian. Its last record seems to be *R. hamiltonensis* Fauth and Seeling from the Middle to Upper Campanian of James Ross Basin, Antarctic Peninsula.

The almost simultaneous records of the genus from the Upper Jurassic-Berriasian in South Africa and central-west Argentina clearly confirm the short distance of the marine migration routes and the consequent relative ease by which faunal exchanges took place along the southern margins of Gondwana at that time. During the Valanginian the genus seems to have migrated from South Africa to southern South America, as demonstrated by the coeval occurrence of *R. ornata* in western Argentina and the Algoa Basin. The continuing southward migration resulted in its arrival in Australia in the Albian-Cenomanian where it ranges up to the Santonian. The record of

Rostrocytheridea in the late Cretaceous of Antarctica shows that the Ross Sea area was faunally connected to southeastern Australia presumably via the Tasman shelf/rise. This Antarctic record, together with that of *Majungaella* Grékoff, which has a typically tropical distribution in the Cretaceous as well as the co-occurrence of the thermophile *Cytherelloidea* Alexander, supports once again the idea of warm climates in high-latitude regions in the Late Cretaceous (*cf.* Seeling *et al*. 2004). Also, the records of *Rostrocytheridea* and other ostracod taxa provide clear evidence of links between western Australia, Argentinian Patagonia and the Antarctic Peninsula during the late Cretaceous.

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