

# Ostracoda (Crustacea) from the Pozo D-129 Formation (upper Barremian?–Aptian), Golfo San Jorge basin, Patagonia, Argentina: Taxonomic descriptions, palaeoenvironments and palaeogeographical implications

Ana P. Carignano<sup>a,\*</sup>, José M. Paredes<sup>b</sup>, Sabrina X. Olazábal<sup>b</sup>, Mauro N. Valle<sup>b</sup>

<sup>a</sup> División Paleozoología Invertebrados, Facultad de Ciencias Naturales y Museo de La Plata, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900, La Plata, Buenos Aires, Argentina

<sup>b</sup> Departamento de Geología, FCN, Universidad Nacional de la Patagonia San Juan Bosco, Ruta N° 1 S/N, Km 4 (9005), Com. Riv., Chubut, Argentina

## ARTICLE INFO

### Article history:

Received 20 February 2017

Received in revised form

14 June 2017

Accepted in revised form 18 June 2017

Available online 20 June 2017

### Keywords:

Freshwater

Ostracods

Palaeobiogeography

Lower Cretaceous

Patagonia

South America

## ABSTRACT

In this study, we present complete descriptions and illustrations of nine ostracod species recovered from the Pozo D-129 Formation (Golfo San Jorge basin), Patagonia Argentina, discussing their depositional palaeoenvironment and palaeobiogeography. The species described in this study are *Musacchiocythere sarugnata* (Musacchio and Palamarczuk) and *Metacypris herreriensis* (Musacchio) (Family Limnocytheridae), *Alicenula* cf. *leguminella* (Forbes) (Family Darwinulidae), *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simenoni, and *Rhinocypris diadema* Musacchio and Simenoni (Family Ilyocyprididae), *Pattersonocypris* cf. *angulata* (Krömmelbein and Weber) and *Zonocypris* sp. (Family Cyprididae), *Damonella ultima* (Krömmelbein and Weber) and *Candona* sp. (Family Candonidae). The Pozo D-129 Formation is the main source rock of hydrocarbons of the Golfo San Jorge basin, and its deposits represent an extensive lacustrine system. The samples studied come from the Cerro Chenques in the Sierra Silva anticline of the San Bernardo fold belt, Chubut Province, and from the well AAB.x-1002 (Anticlinal Aguada Bandera), Santa Cruz Province. The outcrop succession consists of several shallow and coarsening upward sedimentary cycles 5–8 m thick, evolving from deep lacustrine, sublittoral and shallow lacustrine environments. The micropalaeontological association represents a moderate energy thanatocoenosis, and thus is a good indicator of the depositional palaeoenvironment. Taphonomic attributes and taxonomic composition of the association indicate deep and sublittoral environments, consistent with previous facies models for the outcrop succession, and suggest stressed water bodies. Previous studies of palynomorphs suggested a latest Barremian? to early Aptian Age for the study section, whilst the ostracod species *Damonella ultima*, and the charophytes *Clavator harrisi* Peck and *Porochara ultima* (Peck) are part of the *Flabellochara* [= *Clavator*] *harrisi* zone of Aptian Age. The ostracod fauna shows affinities to contemporaneous faunas of Brazil and West Africa, providing evidence of potential faunistic interchange between distant regions.

© 2017 Elsevier Ltd. All rights reserved.

## 1. Introduction

Numerous studies were carried out on non-marine Cretaceous ostracods of Argentina, but special attention was given to the Neuquén basin (e.g., Musacchio, 1970, 1971, 1973, 1978, 1989; Bertels, 1972; Musacchio and Chebli, 1975; Musacchio and Palamarczuk, 1975; Musacchio and Simeoni, 1991; Carignano and

Cusminsky, 2015). A different situation occurs in the Golfo San Jorge basin, and particularly in the Pozo D-129 Formation, where few studies about non-marine ostracods were accomplished, and many of them correspond to unpublished reports. Hechem et al. (1987) mentioned the presence of abundant and well preserved calcareous microfossils recovered from the Pozo D-129 Formation at Cerro Chenques. These were represented by the charophytes *Flabellochara* aff. *harrisi* (Peck) and *Porochara* aff. *Mundula* Peck 1941, and the ostracods *Pattersonocypris* cf. *angulata* (Krömmelbein and Weber), *Reconavona?* *ultima* Krömmelbein and Weber, 1971,

\* Corresponding author.

E-mail address: [anapcarignano@gmail.com](mailto:anapcarignano@gmail.com) (A.P. Carignano).

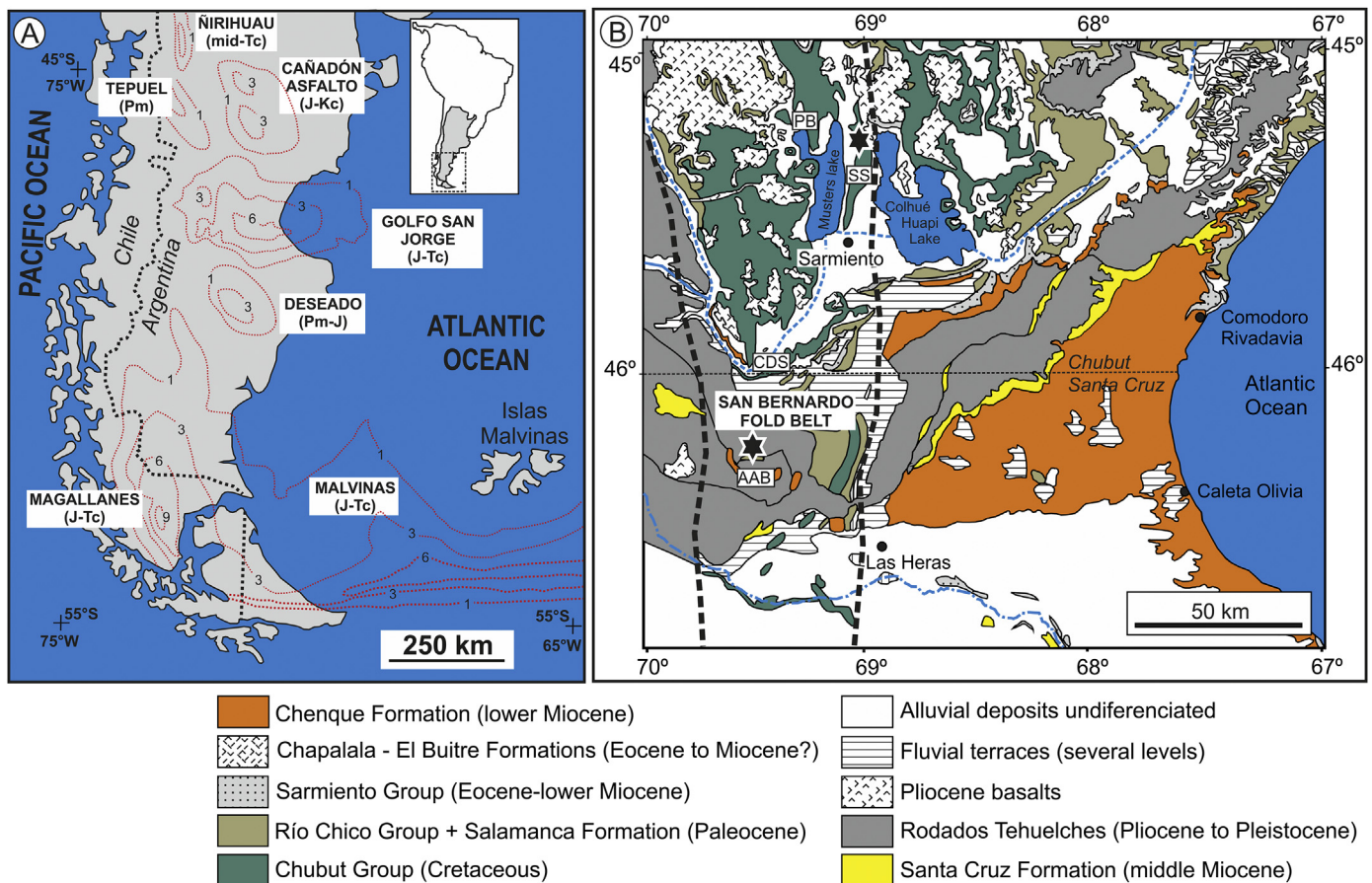
and *Neuquenocypris* sp. Musacchio, 1987, among others. Unfortunately, few of those taxa were illustrated, and lack detailed descriptions. Another study corresponds to Van Nieuwenhuise and Ormiston (1989), who analyzed ostracods recorded in four boreholes of the oil company Yacimientos Petrolíferos Fiscales (YPF). Musacchio (1989) briefly described some of the ostracods recorded in the Pozo D-129 Formation at Cerro Chenques, and proposed the zone of *Flabellochara harrisi* [= *Clavator harrisi*] of Aptian Age. Other studies were performed by Masiuk and Viña (1988a,b,c), who recovered and described at least 34 new species of Lower Cretaceous non-marine ostracods from several boreholes in the Golfo San Jorge basin. Later, Masiuk and Viña (1989) defined 4 formal biozones (ages between early Berriasian to Aptian) combining information of non-marine ostracods and palaeomicroplankton, and correlated 22 wells from the Golfo San Jorge basin.

Therefore, the aim of this research is to provide updated and complete descriptions of the non-marine ostracods collected from outcrops of the Pozo D-129 Formation at Cerro Chenques, (Sierra Silva), and to contribute with palaeoecological and palaeobiogeographical inferences about the association. The results of this study could be of interest to researchers working in non-marine basins, and provide insights about potential microfaunal interchange between distant non-marine settings around the world. On the other hand, the comparison and integration of data obtained from the sedimentology and micropalaeontology allowed the final palaeoenvironmental interpretation to be refined, highlighting the usefulness of integrating different sources of information.

## 2. Geological setting

The Golfo San Jorge basin (Fig. 1A) is a dominantly extensional basin formed as a response to the break-up of the Gondwana supercontinent during the Jurassic and Early Cretaceous, and superimposed on Palaeozoic continental crust (Barcat et al., 1989). The infilling of the basin starts with volcanic-volcaniclastic rocks of the Bahía Laura Volcanic Complex (Sruoga et al., 2008) or Bahía Laura Group (Lesta and Ferello, 1972), referred as the “economic basement” of the Golfo San Jorge basin. Upward, in the subsurface of the Golfo San Jorge basin, uppermost Jurassic and Lower Cretaceous units are represented by the lacustrine Las Heras Group (Fig. 2), integrated by black shales and wedge-shaped, sandstone bodies (Figari et al., 1999).

The overlying Chubut Group reaches a thickness up to 6000 m of fluvial and lacustrine successions (Hechem et al., 1990; Hechem and Strelkov, 2002). Initial sedimentation of the Chubut Group occurred in a widely distributed lacustrine unit (Pozo D-129 Formation – Barremian? to Aptian) which was sourced from the north by fluvial systems within the Matasiete Formation (Paredes et al., 2007). Both units are overlain by the Castillo Formation (Albian), equivalent to the Mina del Carmen Formation in the subsurface (Lesta, 1968), which contains a large proportion of reworked ash-particles (Paredes et al., 2015). The fluvial Bajo Barreal Formation, and subsurface equivalents, constitute the main oil-reservoirs of the basin (Paredes et al., 2016, and references herein). Toward the basin margins, the Bajo Barreal Formation is covered by the fluvial Laguna Palacios Formation (Sciutto, 1981; Genise et al., 2007) and



**Fig. 1.** A, Location map of the Golfo San Jorge basin and nearby basins in central Patagonia, Argentina. B, Geological map of the Golfo San Jorge basin, with boundaries of the San Bernardo fold belt. CDS = Codo del Senguerr anticline, PB = Península Baya, SS = Sierra Silva anticline, AAB = Anticlinal Aguada Bandera. The black stars mark the location of the Cerro Chenques in the northern part of the Sierra Silva anticline, and approximate location of AAB.x-1002 well in the Anticlinal Aguada Bandera oilfield.

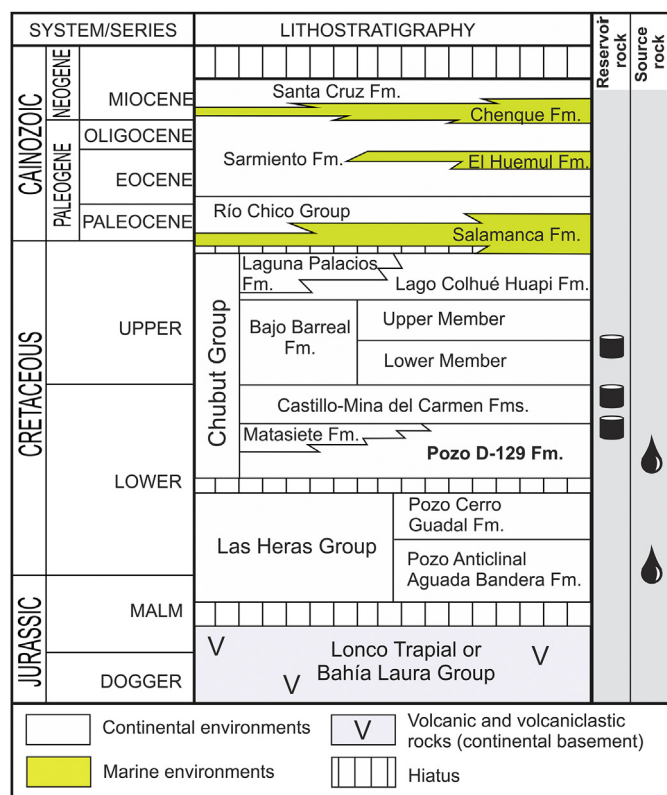


Fig. 2. Stratigraphy of the Golfo San Jorge basin, with indication of main source and reservoir rocks (after Paredes et al., 2016).

by Campanian to Maastrichtian deposits of the Lago Colhué Huapi Formation (Casal et al., 2015; Vallati et al., 2016).

The Chubut Group contains the main source rock (Pozo D-129 Formation) and oil reservoirs of the basin (Castillo and Bajo Barreal Formations), and it mainly crops out in the San Bernardo fold belt, which was formed as a result of the tectonic inversion of extensional depocentres during the Cenozoic (Peroni et al., 1995; Homocv et al., 1995).

The Paleocene sedimentation (Fig. 2) is formed by the marine Salamanca Formation and the continental Río Chico Group. The remaining of the Cenozoic succession is completed with the Sarmiento Formation, El Huemul Formation, Chenque Formation, Santa Cruz Formation and glaciofluvial gravel strata of Plio-Pleistocene Age known as “Rodados Tehuelches”.

### 2.1. Outcrops of the Pozo D-129 Formation

The Pozo D-129 Formation represents the deposition of an extensive lacustrine system distributed over an area up to 150,000 km<sup>2</sup>, which in the deepest part of the basin is up to 1500 m of thickness. The physical stratigraphy of the unit is based in subsurface data (Clavijo, 1986) and it consists of four informal sections of regional distribution; the uppermost section is composed of white tuffs containing sandstones, minor oolitic grainstones and green tuffaceous sandstones, inferred to have been deposited in a marginal to fluvio-deltaic environment (Clavijo, 1986). Anoxic conditions have been inferred for different sections of the Pozo D-129 Formation, based on the presence of laminated shales containing pyrite, dark colors and absence of burrows (Van Nieuwenhuise and Ormiston, 1989). The dominance of *Classopollis* pollen and the abundance of oolitic grainstones, as well as the presence of *Botryococcus*-like algal forms, led these authors to

suggest that deposition occurred in a stratified saline-alkaline lacustrine system in a semiarid climate.

Although widely distributed in the subsurface of the basin, only the uppermost part of the Pozo D-129 Formation is exposed in three areas (see Fig. 1B) of the San Bernardo fold belt: Codo del Senguerr (140 m of thickness), Sierra Silva (43 m of thickness) and Península Baya (~100 m thick).

Previous sedimentological studies carried out in those exposures of the lacustrine succession (Paredes et al., 2007, 2014) have identified deep lacustrine, sublittoral lacustrine and shallow lacustrine facies associations, with shallowing-upward cycles evidencing sedimentary progradation. The 43 m thick section preserved in the core of the Cerro Chenques (Sierra Silva anticline) record several incomplete shallowing upward cycles, being overlain by red-dominated fluvial facies of the Matasiete Formation (Fig. 3). The lower half of the exposed sedimentological section is dominated by pale grey to green mudstones and tuffaceous siltstones preserved in deep and sublittoral environments showing several incomplete shallowing upward cycles, that gradually evolves toward sandstone-dominated successions deposited by distributary mouth-bars, and interdistributary embayments containing coal remains. The upper half of the lacustrine section contains interbedded sandstones and grey siltstones mainly preserved in a low-energy shallow lake, that upward are interbedded with coarse-grained channels up to 7 m of thickness encased into red-dominated floodplain facies containing evidences of subaerial exposure, representing the final progradation of the fluvial system.

Previous palynological studies of this sedimentological section indicated the dominance of the typical palynomorph *Classopollis*, together with *Tucanopollis* and *Stellatopollis*, from equatorial provinces, suggesting warm, seasonally arid to semiarid palaeo-environmental conditions in the area (Volkheimer et al., 2008; Vallati, 2013), assigning to the section a Barremian? to early Aptian Age (Vallati, 2013). Seasonal, semiarid climatic conditions were interpreted in the coeval Matasiete Formation (Paredes et al., 2007) based in the occurrence of vertisols and abundance of carbonate concretions in floodplain facies.

### 3. Materials and methods

Processing followed the standard methodology; the samples were treated for 24 hs with water and hydrogen peroxide (10%), washed through a 63 µm sieve with tap water and finally oven dried (30 °C). The microfossils were picked under a Nikon SMZ645 stereomicroscope. The selected specimens were mounted on stubs using carbon conductive adhesive tape, gold coated and scanned with a JEOL JSM-6360LV Scanning Electron Microscope at the Servicio de Microscopía Electrónica del Museo de La Plata. The classification for suprageneric categories follows Martin and Davis (2001), and Karanovic (2012). Terminology for carapaces descriptions follows Kesling (1951) and Sylvester-Bradley and Benson (1971). Measurements are indicated in mm as follow: very small (<0,400); small (0,401–0,500); medium (0,501–0,700), large (0,701–0,900); very large (>0,900). The common abbreviations used are RV (right valve), LV (left valve), H (height), W (width), and L (length). The figured specimens are housed in the Universidad de la Patagonia San Juan Bosco, under the acronym UNPSJB-MFC.

### 4. Results

From the 18 samples studied only six were productive (Fig. 3). The recovered associations are moderately diverse and very abundant, with three groups of freshwater Ostracoda represented (i.e., Cytherocopina-Limnocytheridae, Darwinulocopina and Cypriidocopina). Charophytes are scarce, poorly preserved and



represented only by *Clavator harrisi* Peck 1941 (Fig. 4O) and *Porochara mundula* (Peck, 1941) Shaikin 1976 (Fig. 4M–N). Additional material from the Anticlinal Aguada Bandera borehole (AAB.x-1002, depths between 1333 and 1345 m), Santa Cruz Province, provided several carapaces of the ostracod *Damonella ultima* (Krömmelbein and Weber).

#### 4.1. Systematic palaeontology

Class Ostracoda Latreille, 1802

Subclass Podocopa Sars, 1866

Order Podocopida Sars, 1866

Suborder Cytherocopina Baird, 1850

Superfamily Cytheroidea Baird, 1850

Family Limnocytheridae Klie, 1938

Subfamily Limnocytherinae Sars, 1925

Genus *Musacchiocythere* Ayress and Whatley, 2014

Type species: “*Wolburgia*” *sarunata* Musacchio, 1978 (recte pro “*Wolburgia*” *sarunata* Musacchio and Palamarczuk, 1975)

***Musacchiocythere sarunata*** (Musacchio and Palamarczuk, 1975)  
Fig. 4A–C

1975 “*Wolburgia*” *sarunata* Musacchio and Palamarczuk, p. 310–312, pl. 1 figs. 13–17

2011b *Wolburgiopsis sarunata*; Ballent et al., p. 521

pars 2014 *Musacchiocythere sarunata*; Ayress and Whatley, p. 1160, (type material only), non? fig. 5K.

**Material.** 21 carapaces from samples 4 and 20. Figured specimens UNPSJB-MFC 131–132.

**Description.** Carapace small, sub-rectangular elongated in lateral view. Anterior border rounded, posterior border ending in a mid-dorsal tip; dorsal border straight to gently winding, somewhat inclined backwards; ventral border concave in the middle; greater height in the anterior third. In dorsal view the carapace is lanceolate, very acuminate anteriorly, with the greater width in the middle third. LV and RV almost equal, LV only slightly larger. Two anterodorsal sulci are visible in both lateral and dorsal view, an anterior one, shorter and shallower, and a middle one, which is wider, strongly marked and exceeds the mid length of the carapace. Surface smooth, with a sub-peripheral crest. Sexual dimorphism evident, males being more elongated than females.

**Dimensions.** UNPSJB-MFC 131: L = 0.441, H = 0.208, W = 0.17; UNPSJB-MFC 132: L = 0.501, H = 0.234, W = 0.240.

**Remarks.** This species was originally described by Musacchio and Palamarczuk (1975) as a member of “*Wolburgia*”. However, in the revision of these forms Musacchio (in Uliana and Musacchio, 1978) did not include “*W.*” *sarunata* within the *Wolburgiopsis* genus, a group of small subtrapezoidal ostracods from the Cretaceous of Argentina. Recently, Ayress and Whatley (2014) stated that the species “*W.*” *sarunata* “... is well beyond being an extreme end-member of the genus *Wolburgiopsis* ...” (p. 1160), a view that is shared in this work. They erected the genus *Musacchiocythere* and included in it the species “*W.*” *sarunata* and *W. plastica* (Musacchio, 1970). Some details are worth mentioning: first, the original spelling of the species name, as stated by Musacchio and Palamarczuk (1975), is incorrect according to Article 27 of the International Code of Zoological Nomenclature (1999), which states that no diacritic mark is to be used in a scientific name. In order to rectify such misspelling, Ballent et al. (2011b) followed recommendation C.13 in the Appendix to ICZN (1985) and spelled the species name as *sarunata*. However, usage as in Ayress and Whatley (2014) is the correct justified emendation to be adopted (see, section 32.5.2.1 of the current code (ICZN, 1999)). Second, the

RV illustrated by Ayress and Whatley (2014, fig. 5K) has a convex dorsal margin, not straight as in *M. sarunata* sensu stricto, while the ventral margin is straight (concave in *M. sarunata* s.s.). Moreover, it has a larger size and neither the peripheral crest nor the two anterodorsal sulci are observable. In the opinion of the present author, this RV is a collapsed cast of another ostracod species.

**Geographical and stratigraphical distribution.** Quili-Malal section, Neuquén Province, Aptian deposits of the Rayoso Formation, Quili-Malal Member (sensu Leanza, 2003), Neuquén basin (Musacchio and Palamarczuk, 1975). Upper section of Pozo D-129 Formation, Golfo San Jorge basin, at Sierra Silva, Chubut.

Subfamily Timiriaseviinae Mandelstam, 1960

Genus *Metacypris* Brady and Robertson, 1870

Type species: *Metacypris cordata* Brady and Robertson, 1870

***Metacypris herreriensis*** (Musacchio in Musacchio and Chebli, 1975)  
Fig. 4D–J

1975 “*Gomphocythere*” *herreriensis* Musacchio nov. sp.; Musacchio and Chebli, p. 84, pl. 2, figs. 15–19.

1987 “*Gomphocythere*” cf. *herreriensis*; Hechem et al., p. 15  
non 1988b *Theriosynoecum riomayensis* (Masiuk and Viña), p. 108, pl. 3, fig. 4

?1989 *Metacypris* aff. *M. herreriensis* (Musacchio, 1975); Van Nieuwenhuise and Ormiston, fig. 8.5

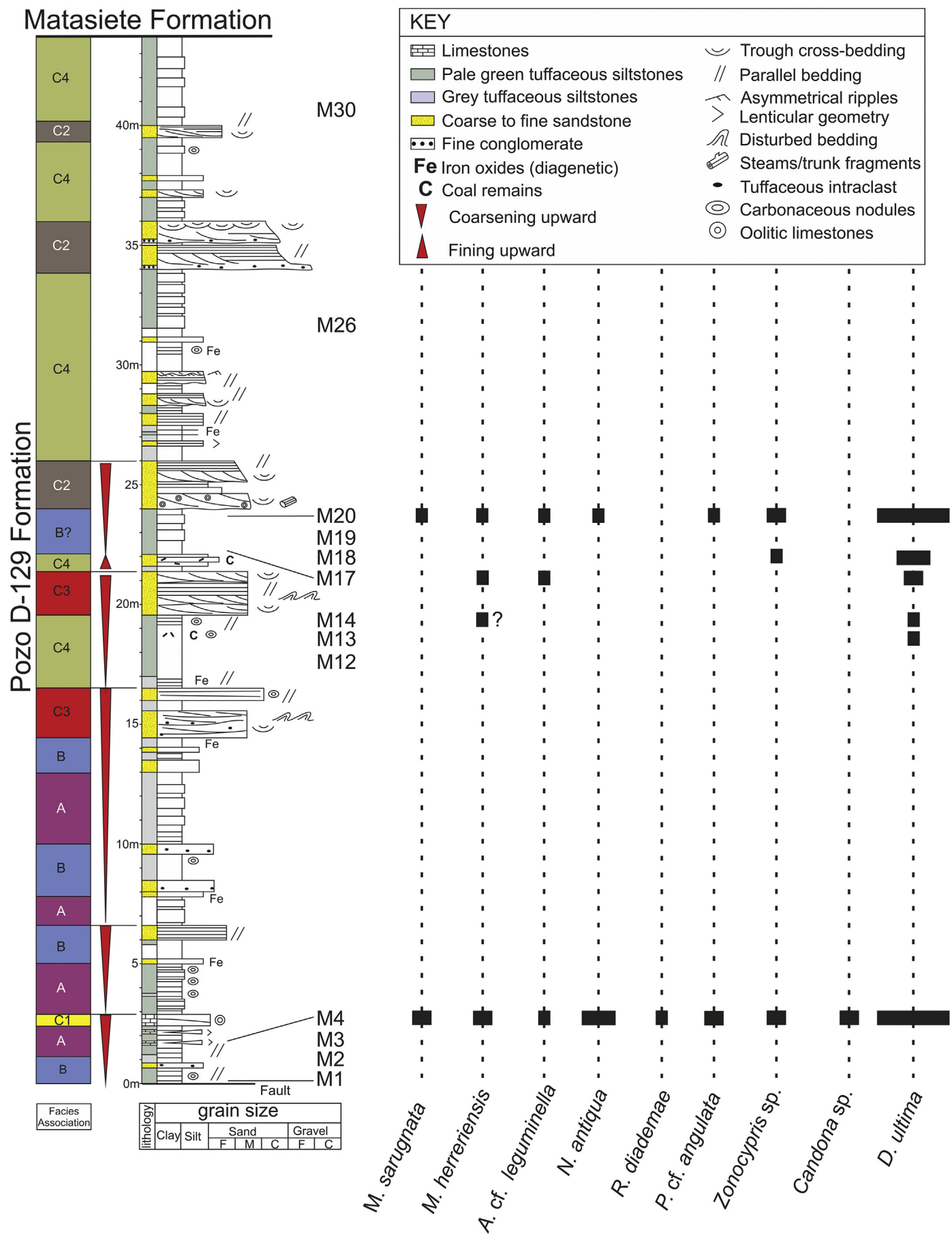
2011a *Theriosynoecum herreriensis*; Ballent et al., p. 548, figs. 3.10–3.18

**Material.** 19 carapaces, from samples 4, 14, 17 and 20. Figured specimens UNPSJB-MFC 133–138.

**Description.** Medium-sized carapace, strongly dimorphic, with a very shallow anterodorsal sulcus. Females rounded subtrapezoidal in lateral view, with obliquely rounded anterior margin and posterior margin truncated dorsally and rounded ventrally; dorsal margin short and straight, ventral margin concave in the middle, visible in ventral view but obscured in lateral view due to the swelling of the carapace. Heart-shaped in dorsal view. Male carapaces rounded subrectangular in lateral view, with obliquely rounded anterior margin and rounded posterior margin, dorsal margin short and straight, ventral margin convex in the middle due to a ventral expansion of the carapace, outline in dorsal view sub-elliptic, greatest width at the middle of the carapace, in the juveniles the greatest width is on the anterior third. In both female and male carapaces the greatest height is towards the posterior half, the RV is larger than the LV, and overlaps at the anterior and posterior margins. Dimorphism of the carapaces can be seen at least up to the A-1 juveniles. The ornamentation consists of a well-defined punctuation that becomes parallel to the margins in ventral view, giving the aspect of a fine striation.

**Dimensions.** UNPSJB-MFC 133: L = 0.585, H = 0.341, W = 0.480; UNPSJB-MFC 134: L = 0.717, H = 0.425, W = 0.366; UNPSJB-MFC 135: L = 0.622, H = 0.480, W = 0.489; UNPSJB-MFC 136: L = 0.589, H = 0.400, W = 0.431; UNPSJB-MFC 137: L = 0.642, H = 0.440, W = 0.310; UNPSJB-MFC 138: L = 0.673, H = 0.381, W = 0.640.

**Remarks.** Originally described as “*Gomphocythere*” *herreriensis* in Musacchio and Chebli (1975), this species was later reassigned to *Theriosynoecum* by Ballent et al. (2011a) who followed the proposal of Carbonel et al. (1988) and Colin and Dépêche (1997), among others. More recently, Sames (2011) restricted the genus *Metacypris* to Aptian–Recent species of the Timiriaseviinae with compact, smaller than 0.6 mm, and weakly monosulcate or non-sulcate carapaces, and, although slightly larger, the present specimens fit better in this genus. *Theriosynoecum riomayensis* (Masiuk and Viña), recovered from the upper Berriasian subsurface of the Golfo



San Jorge basin (Masiuk and Viña, 1988b), was synonymized with *Metacypris herrerensis* by Ballent et al. (2011a), but the anterodorsal sulcus in this species is more conspicuous and the punctuation seems less dense; they are probably two different species. *Geographical and stratigraphical distribution.* Paso de Indios, Chubut Province, Aptian deposits of the Cerro Barcino Formation (Musacchio and Chebli, 1975); Quebrada Don Nielsen, Santa Cruz Province, Albian deposits of the Piedra Clavada Formation, Austral basin (Ballent et al., 2011). YPF Codo del Senguerr x-1 core, Golfo San Jorge basin (Van Nieuwenhuise and Ormiston, 1989). Upper section of Pozo D-129 Formation, Golfo San Jorge basin, at Sierra Silva, Chubut.

Suborder Darwinulocopina Sohn, 1988

Superfamily Darwinuloidea Brady and Norman, 1889

Family Darwinulidae Brady and Robertson, 1885

Genus *Alicenula* Rossetti and Martens, 1998

Type species: *Darwinula serricaudata* Klie, 1935

***Alicenula* cf. *leguminella*** (Forbes in Lyell, 1855)

Fig. 4K–L

cf. 1855 *Cypris leguminella* Forbes; Lyell, p. 294, fig. 334c.

cf. 1885 *Darwinula leguminella*; Jones, p. 8, figs. 30–32.

cf. 2003 *Alicenula leguminella*; Martens et al., fig. 3a–u

2011a *Alicenula* sp. Ballent et al., p. 547–548, fig. 3.9

cf. 2014 *Alicenula leguminella*; Tomé et al., p. 171, fig. 14T–V.

cf. 2016 *Alicenula leguminella*; Wang et al., p. 419–420, fig. 5M–P, R. (With further synonymy).

*Material.* 15 carapaces from samples 4, 17 and 20. Figured specimen UNPSJB-MFC 139.

*Description.* Medium-sized carapace of elongated subrectangular outline in lateral view, dorsal margin evenly sloping, anterior margin gently truncated anterodorsally, posterior margin obliquely rounded, ventral margin slightly concave anteriorly to almost straight, greatest height towards the rear. In dorsal view the carapace is compressed and elongated, narrowing towards the anterior margin, greatest width behind the mid-length. LV larger than the RV, overlap at the posterior and ventral margins. Surface smooth.

*Remarks.* The specimens studied here are similar to those described in several publications of Lower Cretaceous non marine deposits. They share a similar outline with those illustrated by Martens et al. (2003) from the Purbeck Limestone Group, England, in both lateral and dorsal views, although the European species seems to be more tumid. The specimens illustrated by Trabelsi et al. (2015), from the Aptian of North Africa, have a more compact carapace in dorsal view. *Alicenula leguminella* from the Lower Cretaceous of China (Wang et al., 2016) differs from the present in its more acute anterior margin. They are similar also to those recovered from the Crato Formation (Jatobá basin, Brazil, Tomé et al., 2014), particularly in the aspect of the anterior margin (anterodorsally truncated), the posterior obliquely rounded margin and similar L/H ratio. Although the Argentinean specimens seems to narrow more markedly towards the anterior region, this is probably due to the poor preservation of the specimens. *Alicenula* sp. from the Albian of Austral basin, Argentina (Ballent et al., 2011a) is similar in outline to the carapaces studied here, and both taxa are probably conspecific.

*Dimensions.* UNPSJB-MFC 139: L = 0.594, H = 0.246, W = 0.217.

*Geographical and stratigraphical distribution.* To date, *Alicenula* cf. *leguminella* is recognized only in the upper section of Pozo D-129

Formation, Golfo San Jorge basin, at Sierra Silva, Chubut. Should its assignment to the species *leguminella* be confirmed, then its distribution would be wider (Colin and Dépêche, 1997; Martens et al., 2003; Tomé et al., 2014; Trabelsi et al., 2015; Wang et al., 2016)

Suborder Cypridocopina Jones, 1901

Superfamily Cypridoidea Baird, 1845

Family Ilyocyprididae Kaufmann, 1900

Genus *Neuquenocypris* Musacchio, 1973

Type species: *Ilyocypris (Neuquenocypris) calfucurensis* Musacchio, 1973

Subgenus *Protoneuquenocypris* Musacchio and Simeoni, 1991

Type species: *Neuquenocypris (Protoneuquenocypris) antiqua* Musacchio and Simeoni, 1991

***Neuquenocypris (Protoneuquenocypris) antiqua*** Musacchio and Simeoni, 1991

Fig. 5A–B

1991 *Neuquenocypris (Protoneuquenocypris) antiqua* Musacchio and Simeoni, p. 368, fig. 9. 11, 14–17.

2011a *Neuquenocypris (Protoneuquenocypris) antiqua*; Ballent et al., p. 545, fig. 3.1, 3.6

*Material.* 43 carapaces, from samples 4 and 20. Figured specimens UNPSJB-MFC 143–144.

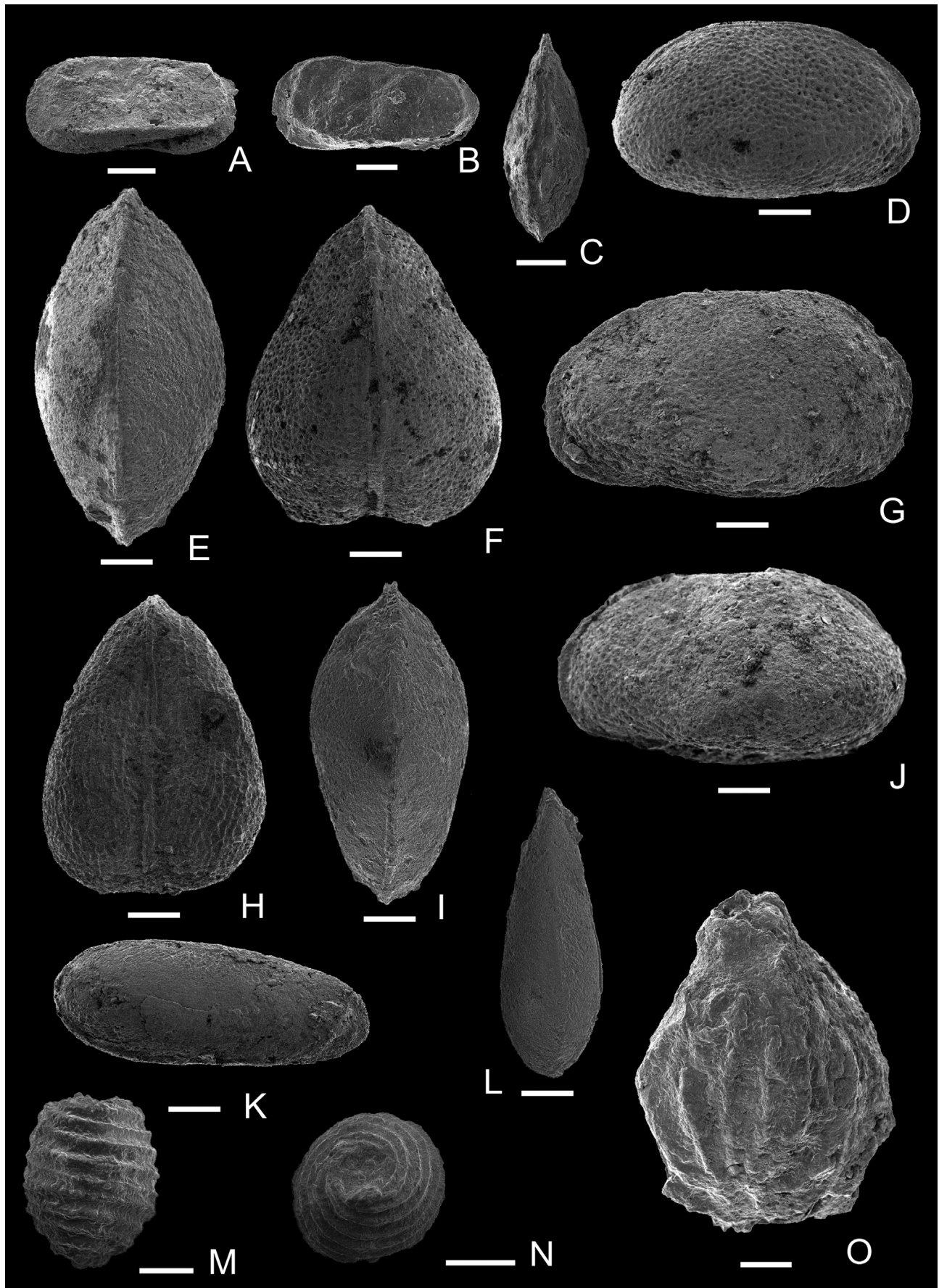
*Description.* Very large carapace with subtrapezoidal outline in lateral view, anterior margin broadly rounded, dorsal margin straight and strongly inclined backwards, posterior margin rounded dorsally and obliquely rounded ventrally, ventral margin slightly concave in the middle. Well-marked cardinal angles, greatest height at the anterior one. In dorsal view the carapace is subelliptic with truncated anterior and posterior margins, greatest width in the middle third. LV larger than de RV. A shallow anterodorsal depression is clearly seen in both lateral and dorsal views, where two sulci can be distinguished towards the center of the valves, as typical for the genus. The carapace is heavily ornamented with cone-shaped tubercles, blunt spines and marginal denticles, and the surface is covered by a coarse punctuation.

*Dimensions.* UNPSJB-MFC 143: L = 0.916, H = 0.505, W = 0.460; UNPSJB-MFC 144: L = 0.970, H = 0.557, W = 0.462.

*Remarks.* The genus *Neuquenocypris* encompasses a group of *Ilyocypris*-like species of large size, dorsal margin clearly sloping backwards, heavily ornamented and with reverse overlap (with the exception of *N. (P.) antiqua* and two other species). To date, *N. (P.) antiqua* represents the oldest member of the group. *Neuquenocypris* is a well-known genus of Argentina, with one species in the Lower Cretaceous of Patagonia, and a close related one of same age in Brazil and Africa (Berthou et al., 1994; Colin y Dépêche, 1997; Tomé et al., 2014). *Neuquenocypris* experienced an explosive radiation during the Campanian–Maastrichtian, which has been recorded in the Neuquén basin (with approximately eight species; Musacchio and Simeoni, 1991); outside Argentina, the genus persisted only in the Campanian–Maastrichtian of France and Brazil (Babinot et al., 1996; Dias-Brito et al., 2001).

*Geographical and stratigraphical distribution.* Sierra Cara Cura, Mendoza Province, Aptian deposits of the Huitrín Formation (Musacchio and Siemoni, 1991; Leanza, 2003); Quebrada Don Nielsen, Santa Cruz Province, Albian deposits of the Piedra Clavada Formation, Austral basin (Ballent et al., 2011). Upper section of Pozo D-129 Formation, Golfo San Jorge basin, at Sierra Silva, Chubut.

**Fig. 3.** Sedimentological section from the Pozo D-129 Formation at Cerro Chenques (modified from Paredes et al., 2014) and abundance of ostracods per sample: ■ = less than 10 specimens; ■ = 10–30 specimens; ■ = 30–60 specimens; ■ = more than 100 specimens. Key of the sedimentological section: A = deep lacustrine, B = Sublittoral lacustrine, C = shallow lacustrine. The latter association consists of four sub-associations: C1 (carbonatic lake), C2 (distributary channels), C3 (distributary mouth bar) and C4 (interdistributary bay). M1–M30 = samples 1 to 30.





Genus *Rhinocypris* Anderson, 1940

Type species: *Rhinocypris scabra* Anderson, 1940

***Rhinocypris diadema* Musacchio and Simeoni, 1991**

Fig. 5C–D

1991 *Rhinocypris diadema* Musacchio and Simeoni, p. 361–362, fig. 8.1–3.

**Material.** Only three carapaces from sample 4. Figured specimens UNPSJB-MFC 145.

**Description.** Medium-sized carapace of subtrapezoidal outline in lateral view, rounded anterior margin, dorsal margin inclined backwards, posterodorsal margin obliquely truncated, posteroventral margin rounded, and ventral margin slightly concave in the posterior half. Greatest height at the anterior cardinal angle. Ellipsoidal outline in dorsal view, in the posterior half an excavated triangular area can be seen. Greatest width immediately behind the mid-length of the carapace. LV larger than RV, overlap on the entire outline except posterodorsally. Two well-marked anterodorsal sulci that limit three nodules and a subcentral depression coincident with the position of the muscle scars are present. Surface covered by small, regularly distributed pustules and small marginal denticles.

**Dimensions.** Figs. C and D, UNPSJB-MFC 145: L = 0.599, H = 0.325, W = 0.308.

**Remarks.** *R. diadema* differs from the type species *R. scabra* Anderson mainly in its ornamentation, the latter having scattered sharper spines on the surface. Another similar species is *R. aff. R. diadema*, from the upper Aptian of Brazil (see Tomé et al., 2014), but differs also in the ornamentation and in details of the outline. Van Itterbeek et al. (2004) stated that “The extent and significance of both inter- and intra-specific variation in ornament in the Ilyocyprididae is poorly understood, and the genus *Rhinocypris* is certainly in need of revision.” (p. 400–401), and the present author is in agreement with this opinion. Unfortunately, the scarcity of materials recovered in this study is not enough to make further comparisons.

**Geographical and stratigraphical distribution.** To date, this species is only known from the upper section of Pozo D-129 Formation, Golfo San Jorge basin, at Sierra Silva, Chubut.

Family Cyprididae Baird, 1845

Subfamily Cypridinae Baird, 1845

Genus *Pattersonocypris* Bate, 1972

Type species: *Pattersonocypris micropapillosa* Bate, 1972

***Pattersonocypris cf. angulata* (Krömmelbein and Weber, 1971)**

Fig. 5E–H

cf. 1971 *Hourcya angulata angulata* Krömmelbein and Weber, p. 20, pl. 6, fig. 23a–c.

1987 *Pattersonocypris cf. angulata angulata*; Musacchio in Hechem et al., p.15, fig. 2 d.

cf. 1998 *Harbinia angulata*; Do Carmo, p. 32, pl. 4, figs. 2–5.

cf. 2012 *Kroemmelbeincypris angulata*; Poropat and Colin, p. 708, fig. 4. 4–5.

cf. 2014 *Pattersonocypris angulata*; Tomé et al., p. 166, fig. 10 G–I. (With further synonymy).

**Material.** 14 carapaces, from samples 4 and 20. Figured specimens UNPSJB-MFC 146–147.

**Description.** Large carapace of subtrapezoidal outline in lateral view, dorsal margin convex anteriorly and straight, inclined backwards posteriorly, where it forms a distinct cardinal angle; anterior margin broadly rounded, posterior margin obliquely rounded to almost truncated, ventral margin slightly convex; greatest height at the anterior cardinal angle, LV larger than the RV. In dorsal view the carapace is subelliptic, with acute ends and greatest width at mid-length. Surface smooth or with thick irregular striations that run lengthwise.

**Dimensions.** UNPSJB-MFC 146: L = 0.781, H = 0.499, W = 0.327; UNPSJB-MFC 147: L = 0.798, H = 0.531, W = 0.308.

**Remarks.** The identity of the genus *Pattersonocypris* has been subject of debate over the last decade (Ayres and Whatley, 2014; Trabelsi et al., 2015). An extensive taxonomic study was carried out by Poropat and Colin (2012), who erected the genus *Kroemmelbeincypris* to include the species *P. symmetrica* and *P. angulata*, and rejected the assignment to *Harbinia* proposed by Do Carmo (1998) and Do Carmo et al. (2008). Tomé and Lima Filho (2013) and Tomé et al. (2014) considered the intraspecific variations seen in some of the species of *Pattersonocypris* as ecologically induced, thus rejecting the validity of *Kroemmelbeincypris*, a proposal that is followed in this work. The specimens studied here are very similar to those found in several sites of Brazil, particularly the smooth carapaces; however, differences can be seen in the ornamentation pattern of some of the specimens. Taking into account that these variations were suggested to be ecologically induced, the lack of agreement in the genus identity, plus the scarcity and poor preservation of the fossil material studied here, all specimens are included under *P. cf. angulata*, in order to avoid adding “noise” to the already problematic taxonomy of this genus.

**Geographical and stratigraphical distribution.** *P. angulata* is widely distributed in Brazil, e.g., upper Aptian of the São Sebastião Formation, Recôncavo basin (Krömmelbein and Weber, 1971); Riachuelo? Formation, Sergipe/Alagoas basin (Do Carmo et al., 2008), upper Aptian–lower Albian of the Rio da Batateira and Santana formations (Coimbra et al., 2002; Poropat and Colin, 2012); upper Aptian of the Crato Formation, Jatobá and Cedro basins (Tomé et al., 2014), Alagamar Formation, Potiguar basin (Do Carmo et al., 2013). Aptian–lower Albian Bongor basin, Tchad, Africa (Colin and Dépêche, 1997). To date, *P. cf. angulata* is recognized only in the upper section of Pozo D-129 Formation, Golfo San Jorge basin, at Sierra Silva, Chubut.

Subfamily Cypridopsinae Kaufmann, 1900

Genus *Zonocypris* G.W. Müller, 1898

Type species: *Zonocypris madagascarensis* G.W. Müller, 1898

***Zonocypris* sp.**

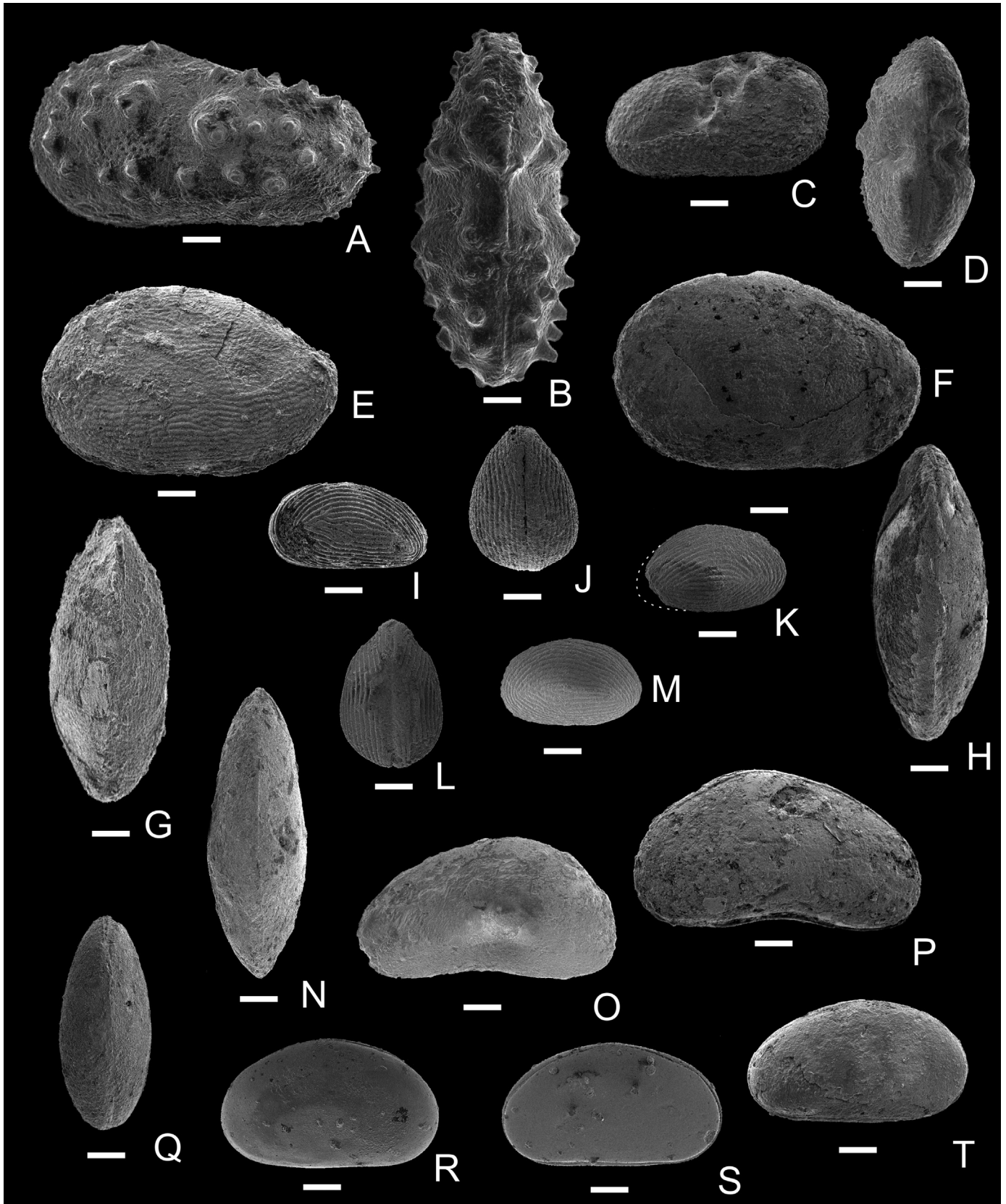
Fig. 5I–M, Fig. 6

**Material.** 32 carapaces from samples 4, 18 and 20. Figured specimens UNPSJB-MFC 148–150.

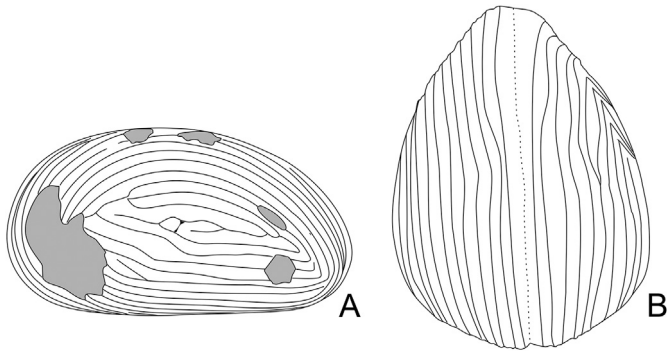
**Description.** Very small to small carapace, rounded subtrapezoidal in lateral view, with convex dorsal margin evenly inclined towards the anterior margin, rounded posterior and anterior margins, but the latter is narrower, ventral margin straight. Greatest height in the posterior half. In dorsal view the carapace is rounded triangular, with acute anterior margin, posterior margin truncated, and greatest width in the posterior half. LV slightly larger than RV as typical for

**Fig. 4.** Limnocytheridae, Darwinulidae, and Charophyta. A–C, carapaces of *Musacchiocythere sarunata* (Musacchio and Palamarczuk), A, female? left lateral view, C, dorsal view, UNPSJB-MFC 131; B, male? left lateral view, UNPSJB-MFC 132. D–J, carapaces of *Metacypris herreriensis* (Musacchio), D, female juvenile (A-1), right lateral view, UNPSJB-MFC 133; E and G, adult male, in dorsal and left lateral views, UNPSJB-MFC 134; F, adult female, dorsal view, UNPSJB-MFC 135; H, female juvenile (A-1), ventral view, UNPSJB-MFC 136; I, male juvenile (A-1), dorsal view, UNPSJB-MFC 137; J, adult female, left lateral view, UNPSJB-MFC 138. K–L, carapace of *Alicenula cf. leguminella* (Forbes), in right lateral and dorsal views, UNPSJB-MFC 139. M–N, *Porochara mundula* (Peck), lateral view, UNPSJB-MFC 140 apical view, UNPSJB-MFC 141. O, *Clavator harrisi* Peck, lateral view, UNPSJB-MFC 142. Scale bar = 0.1 mm.





**Fig. 5.** Cypridocopina. A–B Carapaces of *Neuquenocypris* (*P.*) *antiqua* Musacchio and Simeoni, A, left lateral view, UNPSJB-MFC 143; B, dorsal view, UNPSJB-MFC 144. C–D, *Rhinocypris diadema* Musacchio and Simeoni, carapace in right lateral view and dorsal view, UNPSJB-MFC 145. E–H, Carapaces of *Pattersonocypris angulata* (Krömmelbein and Weber), E–G, same specimen in left lateral and dorsal views, UNPSJB-MFC 146; F–H, same specimen in left lateral and dorsal views, UNPSJB-MFC 147. I–M, Carapaces of *Zonocypris* sp. I, L, same specimen in left lateral and dorsal views, UNPSJB-MFC 148; J, M same specimen in dorsal and right lateral views, UNPSJB-MFC 149; K, left lateral view, UNPSJB-MFC 150. N–P, Carapaces of *Candona* sp. N, P, same specimen in dorsal and right lateral views, UNPSJB-MFC 151; O, left lateral view UNPSJB-MFC 152. Q–T Carapaces of *Damonella ultima* (Krömmelbein and Weber), Q, dorsal view, UNPSJB-MFC 153; R–S, same specimen in R, left lateral view and S, right lateral view, UNPSJB-MFC 154; T, right lateral view; UNPSJB-MFC 155. Scale bar = 0.1 mm.



**Fig. 6.** Schematic drawing of *Zonocypris* sp. A, right lateral and B, dorsal view, showing the ornamentation pattern.

the genus, valves ornamented by concentrically arranged well marked ribs, which at least in the right valve form intricate designs, i.e., they became bi or trifurcate at the center of the valves (Fig. 6). **Dimensions.** UNPSJB-MFC 148: L = 0.410, H = 0.274, W = 0.231; UNPSJB-MFC 149: L = 0.381, H = 0.225, W = 0.293; UNPSJB-MFC 150: L = 0.358, H = 0.236, W = 0.320.

**Remarks.** The present species is left in open nomenclature because no open carapaces were available, and thus the internal features could not be observed. The specimens studied here are very similar to *Zonocypris* sp. from the Crato Formation (upper Aptian–lower Albian, Araripe basin), Brazil (Berthou et al., 1994), particularly in the disposition of the concentric ribs at the center of left valve; although the latter has a more compact (shorter) and less compressed carapace in lateral view. In the Upper Cretaceous of Argentina, *Zonocypris* sp. (as *Timiriasevia*? sp. in Uliana and Musacchio, 1978, pl. 2, fig. 30–31) from the Neuquén basin, differs from the present material in ornamentation details (punctuation among the concentric ribs). *Zonocypris* sp. 1 from the lower Aptian of Portugal (Lusitanian basin; Cabral, 1995) shares with the species described here a similar outline in lateral view and a ornamentation pattern; although in dorsal view it seems less tumid. *Zonocypris digitalis* Babinot, 2003, from the Upper Cretaceous of France, has a different outline in lateral view, with almost truncated anterior and posterior margins, and is less swollen in dorsal view.

**Geographical and stratigraphical distribution.** Upper section of Pozo D-129 Formation, Golfo San Jorge basin, at Sierra Silva, Chubut.

Family Candonidae Kaufmann, 1900  
Subfamily Candoninae Kaufmann, 1900

Genus *Candona* Baird, 1845

Type species: *Cypris candida* O.F. Müller, 1776

*Candona* sp.

Fig. 5N–P

**Material.** 13 carapaces from sample 4. Figured specimens UNPSJB-MFC 151–152.

**Description.** Large carapace of subreniform-subtrapezoidal elongated outline, dorsal margin strongly arched, sloping anteriorly, and posteriorly shorter and more steeply inclined. Anterior and posterior margins rounded, but the anterior margin is narrower. Ventral margin distinctly concave at mid-length. Greatest height at the posterior half. In dorsal view the carapace is compressed, subelliptical in shape, with narrow ends and greatest width approximately at the mid length. LV larger than RV, overlap at the dorsal and ventral margins. Surface smooth.

**Dimensions.** UNPSJB-MFC 151: L = 0.766, H = 0.411, W = 0.269; UNPSJB-MFC 152: L = 0.690, H = 0.373, W = 0.263.

**Remarks.** *Candona* sp. strongly resembles in lateral view the male carapaces of several recent species of the genus *Candona* (e.g., *Candona neglecta* Sars, 1887 and *Candona candida* (O.F. Müller, 1776)). *Candona* sp. B, from the Lagarcito Formation (upper Albian, San Juan Province, Argentina) is similar to the present species in lateral view. However, the ventral concavity is barely noticeable, the posterior margin is less rounded and the surface of the valves are faintly punctated (Prámparo et al., 2005). Another similar species is *Candona altanulaensis* Szczechura and Błaszyk, 1969 from the Upper Cretaceous of the Nemegt basin, Gobi desert. However, this species is wider in dorsal view, and the greatest height of the carapace is more withdrawn towards the posterior region (Szczechura and Błaszyk, 1969).

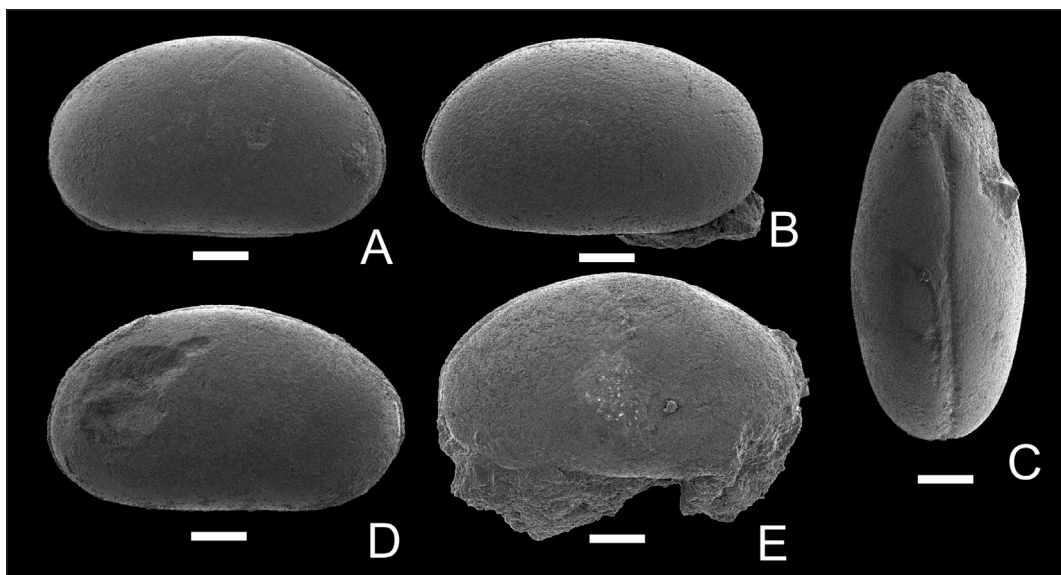
**Geographical and stratigraphical distribution.** To date, this species is only known from the upper section of Pozo D-129 Formation, Golfo San Jorge basin, at Sierra Silva, Chubut.

Subfamily Cyclopyridinae Kaufmann, 1900

Genus *Damonella* Anderson, 1966

Type species: *Cypris pygmaea* Anderson, 1940

*Damonella ultima* (Krömmelbein and Weber, 1971)



**Fig. 7.** *Damonella ultima* (Krömmelbein and Weber), carapaces from Anticlinal Aguada Bandera well. A, right lateral view, UNPSJB-MFC 156; B, left lateral view, UNPSJB-MFC 157; C, dorsal view, UNPSJB-MFC 158; D, left lateral view, UNPSJB-MFC 159; E, right lateral view, UNPSJB-MFC 160. Scale bar = 0.1 mm.

## Fig. 5Q–T, Fig. 7

- 1971 *Reconcavona? ultima* n. sp. Krömmelbein and Weber, p. 27, 57, pl. 9, fig. 39a–c.  
 1987 *Reconcavona? cf. ultima*; Musacchio in Hechem et al., p. 15, fig. 2C  
 1989 *Reconcavona? ultima*; Musacchio, p. 843, pl. 2, figs. 10–11  
 2014 *Damonella ultima* (Krömmelbein and Weber); Tomé et al., p. 161, fig. 7 T–X.

**Material.** More than 700 carapaces and a few valves, from samples 4, 13, 14, 17, 18 and 20. Additional material from the Anticlinal Aguada Bandera borehole, depths 1333–34; 1336, 1342 and 1346 m. SEM photographs of the paratypes assigned by Krömmelbein and Weber (1971) were also available for comparisons. Figured specimens UNPSJB-MFC 153–160.

**Description.** Carapace of medium size, outline irregularly oval in lateral view, dorsal margin convex, anterior margin broadly rounded in both valves, posterior margin rounded, in the RV the posterodorsal margin is gently inclined towards the posterior region and the ventral is only slightly concave in the posterior third. Ventral border in LV gently convex. Greatest height at the mid-length of the carapace. Outline in dorsal view subelliptic with blunt posterior margin, greatest width behind the mid-length of the carapace. LV larger than the RV, overlapping it at the entire margin, except posteroventrally. Surface smooth.

**Dimensions.** UNPSJB-MFC 153: L = 0.505, H = 0.400, W = 0.246; UNPSJB-MFC 154: L = 0.601, H = 0.346, W = 0.320; UNPSJB-MFC 155: L = 0.607, H = 0.340, W = 0.320; UNPSJB-MFC 156 L = 0.615, H = 0.367, W = 0.360; UNPSJB-MFC 157: L = 0.619, H = 0.356, W = 0.360; UNPSJB-MFC 158: L = 0.674, H = 0.440, W = 0.325; UNPSJB-MFC 159: L = 0.636, H = 0.440, W = 0.287; UNPSJB-MFC 160: L = 0.655, H = 0.376, W = 0.400.

**Remarks.** Specimens recovered from the AAB.x-1002 borehole (Pozo D-129 Formation, Santa Cruz Province), slightly larger and with similar outline, are assigned to *D. ultima* (Fig. 7). The present species shares with the one described by Krömmelbein and Weber (1971) as *Reconcavona? ultima*, a carapace with ovoid outline in lateral view, normal overlap continuous over the entire outline except in the posteroventral region, and the RV with a posterodorsal margin obliquely truncated.

The reassignment of this species to the genus *Damonella* Anderson was made by Tomé et al. (2014). They include the genus in the Family Cypridae due to their muscle scar pattern and a narrow internal lamella with an internal margin subparallel to the external one. However, the muscle scar pattern (as seen in Tomé et al., 2014, fig. 7 U, X, p. 162) is similar to the one present in the Family Cyclopyridinae, i.e., an anterior row of three scars and a posterior one next to the lowest-anterior, and two smaller ones beneath each. The inclusion of *Damonella* within this family is further supported by the general outline in both lateral (dorsal margin strongly convex and ventral almost straight) and dorsal views (rather compressed), the greatest height behind the mid-length, the presence of a narrow inner lamella, the lack of an anterior beak. A similar approach was suggested by Horne (2002), and followed by Nye et al. (2008), and Trabelsi et al. (2015). As already noted by Krömmelbein and Weber (1971), *D.ultima* is extremely similar to *Damonella? tinkoussouensis* Grosdidier, 1967, from Wealden facies of West Africa.

**Geographical and stratigraphical distribution.** Lower Aptian of the São Sebastião Formation, Recôncavo basin (Krömmelbein and Weber, 1971); upper Aptian of the Crato Formation, Jatobá basin, Serra Negra, Brazil (Tomé et al., 2014). Upper section of the Pozo D-129 Formation, Golfo San Jorge basin, at Sierra Silva, Chubut. YPF Codo del Senguerr x-1 well, Pozo D-129 Formation, Golfo San Jorge basin (Van Nieuwenhuise and Ormiston, 1989). Anticlinal Aguada Bandera x-1 well, Pozo D-129 Formation, Golfo San Jorge basin,

Santa Cruz Province (Fig. 7). A close form to *Damonella ultima* occurs in the central High-Atlas, Morocco (Mojon et al., 2009).

## 5. Discussion

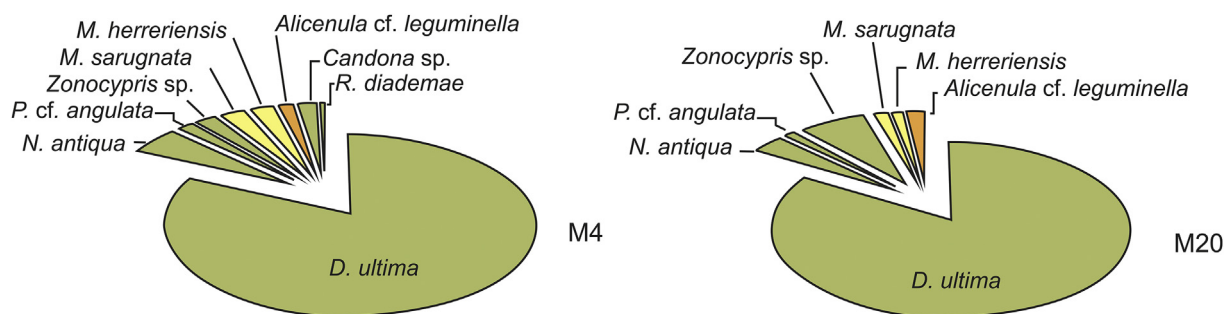
### 5.1. Age and palaeoenvironment

The age of the Pozo D-129 Formation was established by its palynological content. Archangelsky and Seiler (1980) proposed a Hauterivian–early Aptian Age for deposits of the UnOil OS-1 well, near Río Mayo, Chubut Province, by comparison with those found in outcrops of the Baqueró Formation, Santa Cruz Province, and in Neuquén basin within the Agrio, lower Huitrín and Mulichinco formations. Cortiñas and Arbe (1981) proposed a Hauterivian–Aptian Age for the Pozo D-129 Formation on the basis of palynomorphs and ostracods found in the laterally equivalent Puesto Albornoz Formation. Archangelsky et al. (1984) proposed an early Berriasian/Valanginian–early Aptian Age for part of the subsurface deposits (SC Cordón el Pluma x-1 well) of the Pozo D-129 Formation, corresponding to the palynozones *tectifera-corrugatus* and *Antulosporites-Clavatipollenites*. Subsequently, based on the presence of the palynomorph *Tucanopolis crisopolensis* (Regali), Vallati (2013) proposed a late Barremian?–early Aptian Age for the outcrops of the Pozo D-129 Formation at Cerro Chénques (age between the zones of *Foraminisporis* cf. *F. variornatus* and *Afropollis zonatus*). Bate (1999) considered the species *D. ultima*, recorded in the Pre-Salt rift basins of West Africa, as part of the AS10 zone, of late Barremian Age. The association recovered in this study exhibits typical components of Aptian Age, and the presence of gyrogonites of *Porochara mundula* and *Clavator harrisi* place it in the *Flabellochara* [= *Clavator*] *harrisi* Zone (Musacchio, 1989).

In order to derive palaeoenvironmental inferences, a series of analysis should take place first to determine whether the fossils were significantly transported or deposited in situ. In the case of ostracods, the proportion of valves/carapaces, adults/juveniles are good indicators of transport (Whatley, 1983a,b, 1988; Boomer et al., 2003). The ostracods recovered at Pozo D-129 Formation are represented mainly by carapaces of adults and juveniles of the last instars, and there is a wide range of sizes between the species (e.g., *N. (P.) antiqua*, the largest, with average length = 0.915 mm, and *Zonocypris* sp. the smallest, with average length = 0.377 mm). Following the clear steps outlined by Boomer et al. (2003), the association studied here represents a moderate energy thanatocoenosis, i.e., the juvenile instars were probably removed by currents and the association is a good palaeoecological indicator. On the other hand, by uniformitarian palaeobiological approaches, the taxonomical composition (at specific and generic/suprageneric levels) could be also indicative of the depositional environment (Whatley, 1983a,b, 1988; Carbonel et al., 1988; Boomer et al., 2003; Sames and Horne, 2012). Of the nine genera found at the Pozo D-129 Formation, four have living representatives (i.e., *Metacypris*, *Candona*, *Zonocypris* and *Alicenula*), and in the case of *Rhinocypris* and *Neuquenocypris*, their closeness with *Ilyocypris* Brady and Norman, 1889 makes possible the comparison with the living representatives of this genus.

Living species of *Metacypris* inhabit marginal vegetation of meso-eutrophic water bodies (lakes, springs, marshes) (Meisch, 2000; Smith and Hiruta, 2004; Karanovic, 2012). The genus *Alicenula* has three living species found in a variety of habitats, rivers, springs, and lakes, among littoral vegetation and even mosses (Higuti et al., 2009; Karanovic, 2012). The presence of brood pouches in both *Metacypris herreriensis* and *Alicenula* cf. *leguminella* restrict their distribution to permanent water bodies (Carbonel et al., 1988; Horne, 2002; Sames and Horne, 2012; Trabelsi et al., 2015). Extant *Ilyocypris* species inhabit lakes, small and shallow



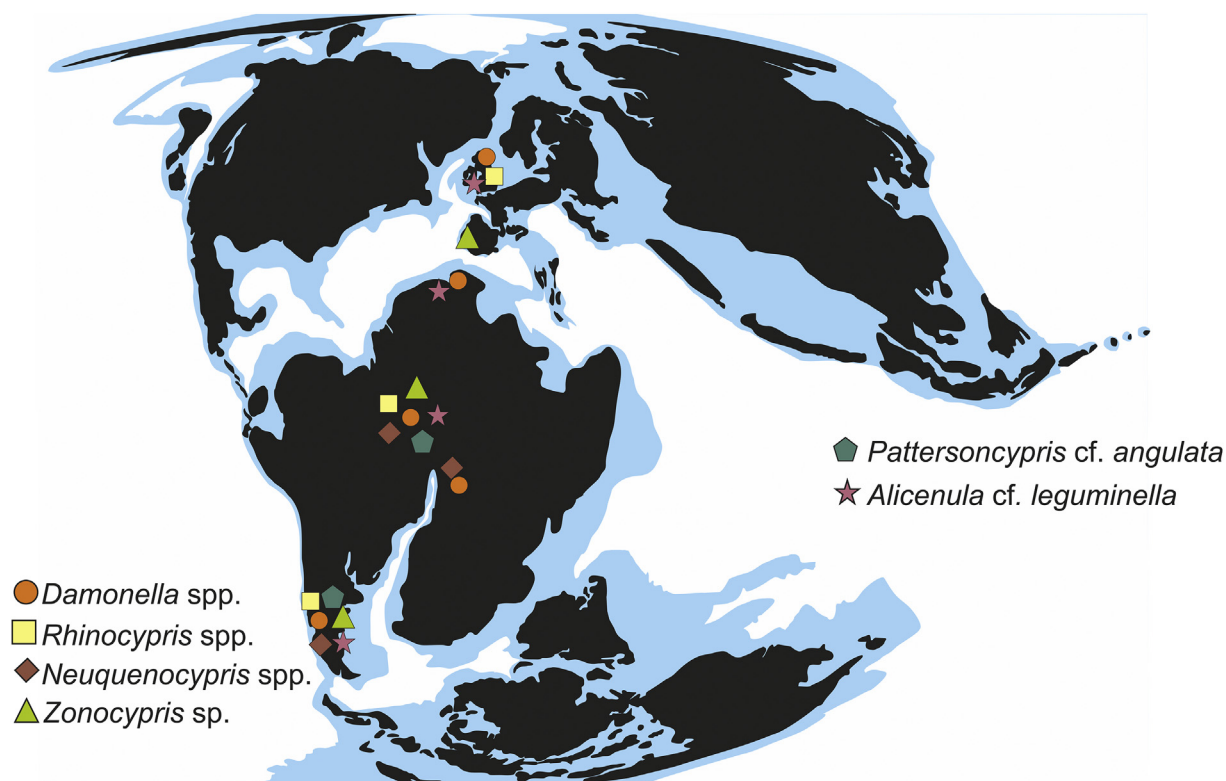


**Fig. 8.** Comparison between the relative abundance of species from the two most diverse samples, deep lacustrine (M4) and sublittoral (M20). Green = Cypridoidea, yellow = Cytheroidea, orange = Darwinuloidea. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

permanent water bodies, and some species are found in springs and streams (Karanovic, 2012). The living species of *Candona* are all adapted to crawling and/or digging, and live on and in the muddy bottom of lakes and springs (Meisch, 2000; Karanovic, 2012). Lastly, *Zonocypris* can be found mostly in permanent lakes, no more than 7 m deep, but seems to have a wide tolerance for water temperature, dissolved oxygen and pH (Babinot, 2003; Karanovic, 2012; Yilmaz et al., 2015).

In the Crato Formation (Jatobá basin), the species *D. ultima*, and congeneric *D. grandiensis* Tomé et al., 2014, were the dominant ostracods and appeared in large numbers, a situation that is matched by *D. ultima* in the Pozo D-129 Formation (83% of the total specimens). It is worth noting that carapaces and valves of *D. ultima* were present in three different lithofacies associations of the Pozo D-129 Formation at Sierra Silva: deep lacustrine, sublittoral and shallow lacustrine, with high abundance in deep lacustrine and sublittoral deposits. The high number of specimens of *D. ultima* in a variety of depositional environments in the Pozo D-129 Formation (Fig. 8) seems to indicate a wide range of tolerance to environmental conditions for this species.

The ostracod associations recovered at different levels were consistent with the lithofacial interpretation of Paredes et al. (2014). Supporting evidence is the presence of charophytes and valves with cup in cup biofabric – considered by Wakefield (1995) as evidence of deposition at, or just below the water's edge –, towards the middle section (samples 18, 20, sublittoral). An increase in the abundance of carapaces of *Zonocypris* sp. in sample 20 provides further evidence for shallow waters (Fig. 8). At the lower section of the Pozo D-129 Formation (sample 4, deep lacustrine) the association recovered is very similar to that from the upper section, but with subtle differences. The carapaces displayed poor preservation, with blurred ornamentation, features that suggest transportation. Although the same species were recorded in both samples (with the exception of *Candona* sp. and *Rhinocypris diademae*), differences in the proportion of specimens could be seen between them. These characteristics seem to be consistent with the interpretation of Paredes et al. (2014) for this section of the outcrops, however, with the data available, it was difficult to clearly validate a deep lacustrine environment for the samples, and transportation from littoral zones cannot be ruled out.



**Fig. 9.** Distribution of non-marine ostracods species found in this study and closely comparable forms on an early Aptian palaeogeographical map (Redrawn from Scotese, 2014).

## 5.2. Palaeobiogeography

The recovered association has conspicuous elements of wide distribution (Fig. 9). Affinities at generic level can be seen between the ostracod association from the Pozo D-129 Formation and those from North Africa (Trabelsi et al., 2015) and Europe (Horne, 2002). The genera *Damonella*, *Rhinocypris* and the species *Alicenula leguminella* have been recognized in the Purbeck-Wealden facies of England, and, since then, subsequently recorded in several similar deposits worldwide (Hechem et al., 1987; Musacchio and Simeoni, 1991; Colin and Dépêche, 1997; Horne, 2002; Arp and Mennerich, 2008; Tomé et al., 2014; Trabelsi et al., 2015, and others). If *D. ultima* is in fact a junior synonym of *Damonella tinkoussouensis*, the distribution of this species would be wider than previously thought, and could be considered for biostratigraphical studies.

The ostracods recovered in the Pozo D-129 Formation show clear biogeographical relations with basins of northeastern Brazil and West Africa. With the Brazilian basins, this faunal exchange that occurred during Aptian times continued up to the latest Cretaceous (Berthou et al., 1994; Musacchio and Simeoni, 1996; Musacchio et al., 1996; Musacchio, 2001; Dias-Brito et al., 2001, among others). The ostracod association studied here is better compared with that recovered from core samples of the Jatobá basin, northeastern Brazil (Aptian–lower Albian), with which it shares the species *D. ultima*, *Rhinocypris* aff. *diadema*, *P. angulata*, *Alicenula leguminella*, and a close relative of *N. antiqua*, the species *Neuquenocypris berthou* Colin and Dépêche, 1997.

Living ostracods have unique capabilities that allow them to be transported over long distances, they are known to be dispersed passively inside the mud attached to the body of large mammals (Vanschoenwinkl et al., 2008), viable eggs have been recovered from the digestive tract and faecal samples of aquatic birds and fishes (Proctor, 1964, 1967; Kornicker and Sohn, 1971; Green et al., 2008), even live adults have been recovered in duck faeces (Frisch et al., 2007). Serramo Lopez et al. (1999) found ostracods attached to amphibians, as a way of active dispersal between neighbouring ponds. Desiccation/freeze resistant eggs are known in members of the superfamilies Cypridoidea and Cytheroidea Limnocytheridae, which allow them to conquer temporary habitats and to be passively transported by other animals and/or abiotic factors, such as the wind (Horne and Martens, 1998; Sames and Horne, 2012). In the case of ostracods with brood pouches, as the Darwinulocopina and some Limnocytheridae, a female with eggs or juveniles enclosed inside the carapace may be also transported by other animals and/or abiotic agents (Sames and Horne, 2012). Finally, the capability to reproduce by parthenogenesis of some non-marine ostracods, implies that a single individual could give rise to a new population, an advantageous feature in terms of dispersal and reproduction (Whatley, 1990, 1992).

This non-marine interchange of ostracods during the Early Cretaceous between distant regions, such as the Golfo San Jorge basin in Argentina, Araripe and Jatobá basins in Brazil and basins from West Africa could be explained by the combination of such capabilities and has been used by several authors to explain similar widespread distributions (Whatley, 1990, 1992; Sames and Horne, 2012; Trabelsi et al., 2015).

## 6. Conclusions

Complete descriptions and figures are presented for the ostracods recovered from the Pozo D-129 Formation, at Cerro Chenques (Sierra Silva anticline), Chubut Province; and from the well AAB.x-1002 (Anticlinal Aguada Bandera), Santa Cruz Province, Golfo San Jorge basin in Central Patagonia. The studied association confirms an Aptian Age for outcrops of the Pozo D-129 Formation at Cerro

Chenques, without ruling out older ages (late Barremian). The ostracod *Damonella ultima* seems to have had a wide tolerance to different palaeoenvironmental factors, and its large numbers suggest an opportunistic behaviour. Although *Zonocypris* sp., *Metacypris herreriensis* and *Alicenula* cf. *leguminella* point out to permanent water bodies, the predominance of *D. ultima* suggests a stressed palaeoenvironment (at least seasonally). This would be in agreement with the facies model proposed by Paredes et al. (2014), who described shallowing upward cycles along the outcrops of the Pozo D-129 Formation. This study corroborates that in the Golfo San Jorge basin occurs the earliest geological record of the genus *Neuquenocypris*, and adds one of the earliest records of *Zonocypris*.

The data presented herein add further evidence to the potential interchange between distant regions, since a number of species are shared with African and Brazilian basins, and brings attention about possible agents and paths of dispersal.

## Acknowledgements

We are grateful to Dr. Jochen Erbacher and Sabine Stäger from the Federal Institute for Geosciences and Natural Resources & State Authority for Mining, Energy and Geology of Lower Saxony (Germany), for providing the SEM photographs of the Paratypes of *Damonella ultima*. We deeply thank Prof. Dr. M.O. Manceñido, from the Museo de La Plata for the critical reading of the manuscript, and his useful comments; and especially to Geologist Martín Cevallos who kindly provided us the samples from the AAB x-1 well. We are grateful to Prof. Dr. María Cristina Cabral and three anonymous reviewers whose comments and suggestions greatly improve our manuscript. This research was supported by the Agencia Nacional de Promoción Científica y Tecnológica (PICT 2012-1369 and PICT 2014-1964).

## References

- Anderson, F.W., 1940. Ostracoda from the Portland and Purbeck beds at Swindon. *Proceedings of the Geologists Association* 51, 373–384.
- Anderson, F.W., 1966. New genera of Purbeck and Wealden Ostracoda. *Bulletin of the British Museum (Natural History) Geology* 11, 435–446.
- Archangelsky, S., Seiler, J., 1980. Algunos resultados palinológicos de la perforación UN Oil OS-1, del SO de la provincia de Chubut, Argentina. 2º Congreso Argentino de Paleontología y Bioestratigrafía y 1º Congreso Latinoamericano de Paleontología, (Buenos Aires) Actas, 5, pp. 215–225.
- Archangelsky, S., Baldoni, A., Gamarro, J.C., Seiler, J., 1984. Palinología estratigráfica del Cretácico de Argentina Austral. III. Distribución de las especies y conclusiones. *Ameghiniana* 21, 15–33.
- Arp, G., Mennerich, C., 2008. Ostracod assemblages, palaeoenvironment and cyclicity of Purbeck-type sediments of the Munder Formation (Lower Cretaceous, Hils Syncline, N-Germany). *Palaeogeography, Palaeoclimatology, Palaeoecology* 264, 230–249.
- Ayress, M.A., Whatley, R.C., 2014. Early Cretaceous non-marine Ostracoda from the north Falkland Basin, South Atlantic. *Palaeontology* 57, 1143–1175.
- Babinot, J.-F., 2003. *Zonocypris digitalis* (Ostracoda, Crustacea), nouvelle espèce du Fuvélien (Campanien continental) de Provence (sud-est France). *Revue de micropaléontologie* 46, 3–9.
- Babinot, J.-F., Colin, J.-P., Tambareau, Y., 1996. Late Cretaceous non-marine ostracods from Europe: biostratigraphy, palaeobiogeography and taxonomy. *Cretaceous Research* 17, 151–167.
- Baird, W., 1845. Arrangement of the British Entomostraca, with a list of species, particularly noticing those which have as yet been discovered within the bounds of the club. *Transactions of the Berwickshire Naturalist's Club* 2, 145–158.
- Baird, W., 1850. *The Natural History of the British Entomostraca*. The Royal Society, London, 355 pp.
- Ballent, S.C., Carignano, A.P., Iglesias, A., Poiré, D.G., 2011a. Microfósiles calcáreos y semillas de la Formación Piedra Clavada (Albiano) en su área tipo, provincia de Santa Cruz, Argentina. *Ameghiniana* 48, 541–555.
- Ballent, S.C., Concheyro, A., Nández, C., Pujana, I., Lescano, M., Carignano, A.P., Caramés, A., Angelozzi, G., Ronchi, D., 2011b. Microfósiles Mesozoicos y Cenozoicos. In: Leanza, H.A., Arregui, C., Carbone, O., Danieli, J.C., Vallés, J.M. (Eds.), *Relatorio del 18º Congreso Geológico Argentino. Asociación Geológica Argentina, Ciudad Autónoma de Buenos Aires*, pp. 489–528.
- Barcat, C., Cortiñas, J.S., Nevistic, V.A., Zucchi, H.E., 1989. Cuenca Golfo San Jorge. In: Chebli, G., Spalletti, L.A. (Eds.), *Cuencas Sedimentarias Argentinas, Serie*

- Correlación Geológica 6. Instituto Superior de Correlación Geológica, Tucumán, pp. 319–345.
- Bate, R.H., 1972. Phosphatised ostracods with appendages from the Lower Cretaceous of Brazil. *Palaeontology* 15, 379–393.
- Bate, R.H., 1999. Non-marine ostracod assemblages of the Pre-Salt rift basins of West Africa and their role in sequence stratigraphy. In: Cameron, N.R., Bate, R.H., Clure, V.S. (Eds.), *The Oil and Gas Habitats of the South Atlantic*, Geological Society of London Special Publications 153. Geological Society Publishing House, Bath, pp. 283–299.
- Bertels, A., 1972. Ostrácodos de agua dulce del miembro inferior de la Formación Huantrai-Co (Maastrichtiano inferior), Provincia del Neuquén, República Argentina. *Ameghiniana* 9, 173–182.
- Berthou, P.Y., Dépêche, F., Colin, J.-P., de Melo Figueira, J.B., Lopes Teles, M.S., 1994. New data on the ostracodes from the Crato lithologic units (lower member of the Santana Formation, latest Aptian-lower Albian) of the Araripe Basin (northeastern Brazil). *Acta Geologica Leopoldensia* 39, 539–554.
- Boomer, I., Horne, D.J., Slipper, I.J., 2003. The use of ostracods in palaeoenvironmental studies, or what can you do with an ostracod shell? *Paleontological Society Papers* 9, 153–180.
- Brady, G.S., Robertson, D., 1870. The Ostracoda and Foraminifera of tidal rivers. Part I. *Annals and Magazine of Natural History* 6, 1–33.
- Brady, G.S., Robertson, D., 1885. Genus Darwinula. In: Jones, T.R. (Ed.), *On the Ostracoda of the Purbeck Formation with notes on the Wealden species*. Journal of the Geological Society of London, 41, pp. 311–353.
- Brady, G.S., Norman, A.M., 1889. A monograph of the marine and freshwater Ostracoda of the North Atlantic and of northwestern Europe. Section I: Podocopa, 2, 4. *Scientific Transactions of the Royal Dublin Society, Series*, pp. 63–270.
- Cabral, M.C., 1995. Ostrácodos do Cretácico inferior do Algarve e da região de Lisboa: sistemática, biostratigrafia, aspectos paleoecológicos e paleobiogeográficos (Unpubl. PhD Thesis). University of Lisbon, 442 pp.
- Casal, G.A., Allard, J.O., Foix, N., 2015. Análisis estratigráfico y paleontológico del Cretácico Superior en la Cuenca del Golfo San Jorge: nueva unidad litoestratigráfica para el Grupo Chubut. *Revista de la Asociación Geológica Argentina* 72, 77–95.
- Carbonel, P., Colin, J.-P., Danielopol, D.L., Löffler, H., Neustrueve, I., 1988. Paleogeology of limnic ostracodes: a review of some major topics. *Palaeogeography, Palaeoclimatology, Palaeoecology* 62, 413–461.
- Carignano, A.P., Cusuminsky, G., 2015. New Upper Cretaceous Limnocytheridae (Ostracoda, Crustacea) from Argentina. *Micropaleontology* 61, 25–36.
- Clavijo, R., 1986. Estratigrafía del Cretácico Inferior en el sector occidental de la Cuenca del Golfo San Jorge. *Boletín de Informaciones Petroleras* 9, 15–32.
- Coimbra, J.C., Arai, M., Carreño, A.L., 2002. Biostratigraphy of Lower Cretaceous microfossils from the Araripe Basin, northeastern Brazil. *Geobios* 35, 687–698.
- Colin, J.-P., Dépêche, F., 1997. Faunes d'ostracodes lacustres des bassins intracratoniques d'âge albio-aptien en Afrique de l'Ouest (Cameroun, Tchad) et au Brésil: considérations d'ordre paléoécologique et paléobiogéographique. *Africa Geoscience Review* 4, 431–450.
- Cortinas, J.S., Arbe, H.A., 1981. El Cretácico continental inferior en el sector occidental de la Cuenca del Golfo San Jorge. *Boletín de Informaciones Petroleras* 9, 15–32.
- Dias-Brito, D., Musacchio, E.A., de Castro, J.C., Maranhão, M.S.A.S., Suárez, J.M., Rodrigues, R., 2001. Grupo Bauru: uma unidade continental do Cretáceo no Brasil – concepções baseadas em dados micropaleontológicos, isotópicos e estratigráficos. *Revue de Paléobiologie Gêneve* 20, 245–304.
- Do Carmo, D.A., 1998. Taxonomia, paleoecologia e distribuição estratigráfica dos ostrácodos da Formação Alagamar (Cretáceo Inferior), bacia Potiguar, Brasil (Unpubl. PhD Thesis). Universidade Federal do Rio Grande do Sul, 156 pp.
- Do Carmo, D.A., Coimbra, J.C., Whatley, R.C., Silveira Antonietto, L., de Paiva Citon, R.T., 2013. Taxonomy of limnic Ostracoda (Crustacea) from the Alagamar Formation, middle–upper Aptian, Potiguar Basin, northeastern Brazil. *Journal of Paleontology* 87, 91–104.
- Do Carmo, D.A., Whatley, R.C., Queiroz Neto, J.V., Coimbra, J.C., 2008. On the validity of two Lower Cretaceous non-marine ostracode genera: biostratigraphic and paleogeographic implications. *Journal of Paleontology* 82, 790–799.
- Figari, E.G., Strelkov, E., Laffitte, G., Cid De La Paz, M.S., Courtade, S.F., Celaya, J., Vottero, A., Lafourcade, P., Martínez, R., Villar, H., 1999. Los Sistemas Petroleros de la Cuenca del Golfo San Jorge: Síntesis estructural, estratigráfica y geoquímica. 4º Congreso de Exploración y Desarrollo de Hidrocarburos (Buenos Aires), *Actas*, pp. 197–237.
- Frisch, D., Green, A.J., Figuerola, J., 2007. High dispersal capacity of a broad spectrum of aquatic invertebrates via waterbirds. *Aquatic Sciences* 69, 568–574.
- Genise, J.F., Melchor, R., Belloso, E.S., Gonzalez, M.G., Krause, M., 2007. New insect pupation chambers (*Pupichnia*) from the Upper Cretaceous of Patagonia, Argentina. *Cretaceous Research* 28, 545–559.
- Grosdidier, E., 1967. Quelques ostracodes nouveaux de la série Anté-salifère (Wealdienne) des Bassins Côtiers du Gabon et du Congo. *Revue de Micropaleontologie* 10, 107–118.
- Green, A.J., Jenkins, K.M., Bell, D., Morris, P.J., Kingsford, R.T., 2008. The potential role of waterbirds in dispersing invertebrates and plants in arid Australia. *Freshwater Biology* 53, 380–392.
- Hechem, J.J., Figari, E.G., Musacchio, E.A., 1987. Hallazgo de la Formación D-129. Información estratigráfica y paleontológica. *Petrotecnica* 28, 13–15.
- Hechem, J.J., Homocv, J.F., Figari, E.G., 1990. Estratigrafía del Chubutiano (Cretácico) en la Sierra de San Bernardo, cuenca del Golfo San Jorge, Argentina. 11º Congreso Geológico Argentino, San Juan, pp. 173–176.
- Hechem, J.J., Strelkov, E.E., 2002. Secuencia sedimentaria mesozoica del Golfo San Jorge. In: Haller, J.M. (Ed.), *Relatorio del 15º Congreso Geológico Argentino, Geología y Recursos Naturales de Santa Cruz 1*. Asociación Geológica Argentina, Ciudad Autónoma de Buenos Aires, pp. 129–147.
- Higuti, J., Lansac-Tôha, F.A., Velho, L.F.M., Pinto, R.L., Vieira, L.C.G., Martens, K., 2009. Composition and distribution of Darwinulidae (Crustacea, Ostracoda) in the alluvial valley of the upper Paraná River, Brazil. *Brazilian Journal of Biology* 69, 253–262.
- Homocv, J.F., Conforto, G.A., Lafourcade, P.A., Chelotti, L.A., 1995. Fold belt in the San Jorge Basin, Argentina: an example of tectonic inversion. In: Buchanan, J.G., Buchanan, P.G. (Eds.), *Basin Inversion*, Geological Society Special Publications 88. Lyell Collection, London, pp. 235–248.
- Horne, D.J., 2002. Ostracod biostratigraphy and palaeoecology of the Purbeck Limestone Group in southern England. *Special Papers in Palaeontology* 68, 53–70.
- Horne, D.J., Martens, K., 1998. An assessment of the importance of resting eggs for the evolutionary success of Mesozoic non-marine cypridoidean Ostracoda (Crustacea). *Archives Hydrobiologie. Special Issues on Advanced Limnology* 52, 549–561.
- International Commission on Zoological Nomenclature, 1985. *International Code of Zoological Nomenclature*, third ed. International Trust for Zoological Nomenclature, London, 338 pp.
- International Commission on Zoological Nomenclature, 1999. *International Code of Zoological Nomenclature*, fourth ed. Online version at: <http://www.iczn.org/iczn/index.jsp>.
- Jones, T.R., 1885. On the ostracods of the Purbeck Formation. *The Quarterly Journal of the Geological Society of London* 41, 311–353.
- Jones, T.R., 1901. On some Carboniferous shale from Siberia. *Geological Magazine* 8, 433–436.
- Karanovic, I., 2012. *Recent freshwater Ostracoda of the world*. Springer-Verlag, Berlin, 620 pp.
- Kaufmann, A., 1900. Cypriden und Darwinuliden der Schweiz. *Revue Suisse De Zoologie* 8, 209–423.
- Kesling, R.V., 1951. Terminology of ostracod carapaces. *Contributions from the Museum of Paleontology* 9. University of Michigan, pp. 93–171.
- Klie, W., 1935. Ostracoda aus dem tropischen Westafrika. *Archiv für Hydrobiologie* 28, 35–68.
- Klie, W., 1938. *Krebstiere oder Crustacea – III: Ostracoda, Muschelkrebse*. Verlag von Gustav Fischer, Jena, 230 pp.
- Kornicker, L.S., Sohn, I.G., 1971. Viability of ostracode eggs egested by fish and effect of digestive fluids on ostracode shells - ecological and paleoecological Implications. In: Oertli, H.J. (Ed.), *Paleoécologie des Ostracodes*, 5. Bulletin Centre Recherche Pau-SNPA, pp. 125–135.
- Krömmelbein, K., Weber, R., 1971. Ostrakoden des “Nordost-Brasilianischen Wealden”. *Geologisches Jahrbuch* 115, 1–93.
- Latreille, P.A., 1802. *Histoire naturelle générale et particulière des Crustacés et des Insectes*. F. Dufart, Paris, 467 pp.
- Leanza, H.A., 2003. Las sedimentitas huitrinianas y rayosianas (Cretácico inferior) en el ámbito central y meridional de la cuenca Neuquina, Argentina, 2. Servicio Geológico Minero Argentino, Serie Contribuciones Técnicas, Geología, pp. 1–31.
- Lesta, P., 1968. Estratigrafía de la Cuenca del Golfo San Jorge. 3º Jornadas Geológicas Argentinas, Buenos Aires, pp. 251–280.
- Lesta, P., Ferello, R., 1972. Región Extra-andina del Chubut y norte de Santa Cruz. In: Leanza, A.F. (Ed.), *Geología Regional Argentina*. Academia Nacional de Ciencias, Córdoba, pp. 601–654.
- Lyell, C., 1855. *A manual of elementary geology: or, the ancient changes of the Earth and its inhabitants as illustrated by geological monuments*, fifth ed. J. Murray, London, p. 294.
- Mandelstam, M.I., 1960. In: Kashevarova, N.P., Mandelstam, M.I., Schneider, G.F. (Eds.), *Osnovy Paleontologii*, 8, pp. 347–365 (in Russian).
- Martens, K., Rossetti, G., Horne, D.J., 2003. How ancient are ancient asexuals? *Proceedings of the Royal Society of London B* 270, 723–729.
- Martin, J.W., Davis, G.E., 2001. An updated classification of the recent Crustacea. *National History Museum of Los Angeles County—Science Series* 39, 1–124.
- Masiuk, V., Viña, F.J., 1988a. Ostrácodos no marinos del Cretácico Inferior en el área occidental del Golfo San Jorge. *Boletín de Informaciones Petroleras, Tercera Época* 13, 2–26.
- Masiuk, V., Viña, F.J., 1988b. Ostrácodos no marinos del Cretácico Inferior en el área occidental del Golfo San Jorge (II Parte). *Boletín de Informaciones Petroleras, Tercera Época* 14, 98–114.
- Masiuk, V., Viña, F.J., 1988c. Ostrácodos no marinos del Cretácico Inferior en el área occidental del Golfo San Jorge (III Parte). *Boletín de Informaciones Petroleras, Tercera Época* 15, 57–82.
- Masiuk, V., Viña, F.J., 1989. Bioestratigrafía del subsuelo en el área sudoccidental de Chubut. *Boletín de Informaciones Petroleras, Tercera Época* 18, 70–95.
- Meisch, C., 2000. *Freshwater Ostracoda of western and central Europe*. Süßwasserfauna von Mitteleuropa 8/3. Spektrum Akademischer Verlag Gustav Fischer, Berlin, 522 pp.
- Mojon, P.-O., Haddoumi, H., Charrière, A., 2009. Nouvelles données sur les Charophytes et Ostracodes du Jurassique moyen-supérieur-Crétacé inférieur de l'Atlas marocain. *Carnets de Géologie, Mémoire* 3, 1–39.
- Müller, O.F., 1776. *Zoologie danicae prodromus, seu animalium Danie et Norvegie indigenarum characteres, nomina, et synonymy imprimis popularium*, 1–32, pp. 198–199.
- Müller, G.W., 1898. Ergebnisse einer zoologischen Forschungsreise in Madagaskar und Ost-Afrika 1889–1895 von Dr A Voeltzkow: Die Ostracoden. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft* 21, 255–296.



- Musacchio, E.A., 1970. Ostrácodos de las Superfamilias Cytheracea y Darwinulacea de la Formación La Amarga (Cretácico inferior) en la Provincia de Neuquén, República Argentina. *Ameghiniana* 7, 301–316.
- Musacchio, E.A., 1971. Hallazgo del género *Cypridea* (Ostracoda) en Argentina y consideraciones estratigráficas sobre la Formación La Amarga (Cretácico Inferior) en la provincia de Neuquén. *Ameghiniana* 8, 105–125.
- Musacchio, E.A., 1973. Charophytas y ostrácodos no marinos del Grupo Neuquén (Cretácico superior) en algunos afloramientos de las provincias de Río Negro y Neuquén, República Argentina. *Revista del Museo de La Plata. Paleontología* 8, 1–37.
- Musacchio, E.A., 1978. Ostrácodos del Cretácico inferior en el Grupo Mendoza, Cuenca del Neuquén, Argentina. 7° Congreso Geológico Argentino, (Neuquén), Actas, 2, pp. 459–473.
- Musacchio, E.A., 1989. Biostratigraphy of the non-marine Cretaceous of Argentina based on calcareous microfossils. In: Wiedmann, J. (Ed.), *Cretaceous of the western Tethys*. Schweizerbart Science Publishers, Stuttgart, pp. 811–851.
- Musacchio, E.A., 2001. Relaciones paleobiogeográficas de los ostrácodos no marinos del Jurásico y el Cretácico de Patagonia. *Acta Geológica Leopoldensia* 24, 293–310.
- Musacchio, E.A., Chebli, G., 1975. Ostrácodos no marinos y carofitas del Cretácico Inferior en las provincias de Chubut y Neuquén, Argentina. *Ameghiniana* 12, 70–96.
- Musacchio, E.A., Palamarczuk, S.C., 1975. Microfósiles calcáreos de la Formación Ranquiles (Cretácico inferior) en la Provincia de Neuquén, Argentina. *Ameghiniana* 12, 306–314.
- Musacchio, E.A., Simeoni, M., 1991. Taxonomy of some Cretaceous non-marine ostracods of palaeobiogeographical interest. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* 180, 349–389.
- Musacchio, E.A., Simeoni, M., 1996. Biogeographic relationships of Lower Cretaceous calcareous microfossils from Patagonia: an approach to causal factors. 29° Congreso Brasileiro Geologia, (Salvador), Anais, 7, pp. 374–376.
- Musacchio, E.A., Vallati, P., Simeoni, M., 1996. Microfósiles no marinos del Cretácico en Patagonia: sus relaciones con asociaciones brasileñas. 4° Simpósio sobre o Cretáceo do Brasil (Rio Claro), Boletim, pp. 189–193.
- Nye, E., Feist-Burkhardt, S., Horne, D.J., Ross, A.J., Whittaker, J.E., 2008. The palaeoenvironment associated with a partial *Iguanodon* skeleton from the Upper Weald Clay (Barremian, Early Cretaceous) at Smokejacks Brickworks (Ockley, Surrey, UK), based on palynomorphs and ostracods. *Cretaceous Research* 29, 417–444.
- Paredes, J.M., Foix, N., Colombo, F., Nillni, A., Marquillas, R., 2007. Volcanic and climatic control on fluvial style in a high energy system: the Lower Cretaceous Matasiete Formation, Golfo San Jorge basin, Argentina. *Sedimentary Geology* 202, 96–123.
- Paredes, J.M., Allard, J.O., Foix, N., Álvarez, B., Olazábal, S.X., 2014. Sedimentología y perfiles Rayos Gamma de la Formación Pozo D-129 (Aptiano) en la Sierra de San Bernardo, Chubut. 9° Congreso de Exploración y Desarrollo de Hidrocarburos (Mendoza), Actas, pp. 455–479.
- Paredes, J.M., Foix, N., Allard, J.O., Colombo, F., Tunik, M.A., 2015. Alluvial architecture of reworked pyroclastic deposits in peri-volcanic basins: Castillo Formation (Albian) of the Golfo San Jorge basin, Argentina. *Revista de la Asociación Geológica Argentina* 72, 38–58.
- Paredes, J.M., Foix, N., Allard, J.O., 2016. Sedimentology and alluvial architecture of the Bajo Barreal Formation (Upper Cretaceous) in the Golfo San Jorge Basin: Outcrop analogues of the richest oil-bearing fluvial succession in Argentina. *Marine and Petroleum Geology* 72, 317–335.
- Peck, R., 1941. Lower Cretaceous Rocky Mountain non marine microfossils. *Journal of Paleontology* 15, 285–304.
- Peroni, G.O., Hegedus, A.G., Cerdán, J., Legarreta, L., Uliana, M.A., Laffitte, G., 1995. Hydrocarbon Accumulation in an Inverted Segment of the Andean Foreland: San Bernardo Belt, Central Patagonia. In: Tankard, A.J., Suárez, S.R., Welsink, H.J. (Eds.), *Petroleum basins of South America*. American Association of Petroleum Geologists, Memoir 62. American Association of Petroleum Geologists, Tulsa, pp. 403–419.
- Poropat, A.F., Colin, J.-P., 2012. Reassessment of the Early Cretaceous non-marine ostracod genera *Hourquia* Krömmelbein, 1965 and *Pattersoncypris* Bate, 1972 with description of a new genus, *Krommelbeincypris*. *Journal of Paleontology* 86, 699–719.
- Prámparo, M.B., Ballent, S.C., Gallego, O.F., Milana, J.P., 2005. Paleontología de la Formación Lagarcito (Cretácico Inferior) en la provincia de San Juan, Argentina. *Ameghiniana* 42, 93–114.
- Proctor, V.W., 1964. Viability of crustacean eggs recovered from ducks. *Ecology* 45, 656–658.
- Proctor, V.W., 1967. Dispersal of aquatic organisms: viability of disseminules recovered from the intestinal tract of captive killdeer. *Ecology* 48, 672–676.
- Rossetti, G., Martens, K., 1998. Taxonomic revision of the Recent and Holocene representatives of the Family Darwinulidae (Crustacea, Ostracoda), with a description of three new genera. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Biologie* 68, 55–110.
- Sames, B., 2011. Early Cretaceous *Theriosynoecum* Branson 1936 in North America and Europe. *Micropaleontology* 57, 291–344.
- Sames, B., Horne, D., 2012. Latest Jurassic to Cretaceous non marine ostracod biostratigraphy: Unde vensi, quo vadis? *Journal of Stratigraphy* 36, 266–288.
- Sars, G.O., 1866. Oversigt af Norges marine ostracoder. *Christiania Videnskabs-Selskabs Forhandling* 1865, 1–130.
- Sars, G.O., 1925. An account of the Crustacea of Norway with short descriptions and figures of all the species. *Ostracoda*. The Bergen Museum, Bergen, pp. 73–208.
- Sciutto, J.C., 1981. Geología del Codo del Río Senguerr, Chubut, Argentina. 8° Congreso Geológico Argentino (San Luis), Actas, 3, pp. 203–219.
- Scotese, C.R., 2014. Atlas of Early Cretaceous Paleogeographic Maps. PALEOMAP Atlas for ArcGIS, volume 2, The Cretaceous, Maps 23–31, Mollweide Projection. PALEOMAP Project, Evanston, IL.
- Serrano Lopez, L.C., Pena Rodrigues, P.J., Iglesias Rios, R., 1999. Frogs and snakes as phoretic dispersal agents of bromeliad ostracods (Limnocytheridae: *Elpidium*) and annelids (Naididae: *Dero*). *Biotropica* 31, 705–708.
- Shaikin, M.L., 1976. New data on biostratigraphy of the Jurassic and Cretaceous of the Fore-Dobrogean Trough. *Geologicheskij Zhurnal* 36, 77–86 (in Russian).
- Smith, R.J., Hiruta, S., 2004. A new species of *Metacypris* (Crustacea: Ostracoda: Cytheroidea: Limnocytheridae) from Hokkaido, Japan. *Species Diversity* 9, 37–46.
- Sohn, I.G., 1988. Darwinulocopina (Crustacea: Podocopa), a new suborder proposed for nonmarine Paleozoic to Holocene Ostracoda. *Proceedings of the Biological Society of Washington* 101, 817–824.
- Sruoga, P., Busteros, A., Giacosa, R., Kleiman, L., Japas, S., Maloberti, A., Martínez, H., 2008. Análisis litofacial y estructural del Complejo Bahía Laura en el área El Dorado-Monserrat, pcia. de Santa Cruz, Argentina. *Revista Asociación Geológica Argentina* 63, 653–664.
- Sylvester-Bradley, P.C., Benson, R.H., 1971. Terminology for surface features in ornate ostracodes. *Lethaia* 4, 249–286.
- Szczeczura, J., Blaszyk, J., 1969. Fresh-water Ostracoda from the Upper Cretaceous of the Nemegt Basin, Gobi Desert. *Palaeontologia Polonica* 21, 107–118.
- Tomé, M.E., Lima Filho, M.F., 2013. Registro de flocks species asociado a ostracofauna encontrada no Andar Alagoas (Aptiano/Eoalbio) das bacias sedimentares do nordeste do Brasil. 23° Congresso Brasileiro de Paleontologia (Gramado), Actas, pp. 160–161.
- Tomé, M.E.T.R., Lima Filho, M.F., Neumann, V.H.M.L., 2014. Taxonomic studies of non-marine ostracods in the Lower Cretaceous (Aptian–lower Albian) of post-rift sequence from Jatobá and Araripe basins (Northeast Brazil): stratigraphic implications. *Cretaceous Research* 48, 153–176.
- Trabelsi, K., Sames, B., Salmouna, A., Piovesan, E.K., Rouina, S.B., Houla, Y., Tuir, J., Soussi, M., 2015. Ostracods from the marginal coastal Lower Cretaceous (Aptian) of the Central Tunisian Atlas (North Africa): paleoenvironment, biostratigraphy and paleobiogeography. *Revue de Micropaléontologie* 58, 309–331.
- Uliana, M.A., Musacchio, E.A., 1978. Microfósiles calcáreos no marinos del Cretácico Superior en El Zampal, Provincia de Mendoza, Argentina. *Ameghiniana* 15, 111–135.
- Vallati, P., 2013. A mid-Cretaceous palynoflora with *Tucanopollis crisopolensis* from D-129 Formation, San Jorge Gulf Basin, Argentina. *Revista brasileira de Paleontologia* 16, 237–244.
- Vallati, P., Casal, G., Foix, N., Allard, J., De Sosa Tomas, A., Calo, M., 2016. First report of a Maastrichtian palynoflora from the Golfo San Jorge Basin, central Patagonia, Argentina. *Ameghiniana* 53, 495–505.
- Van Itterbeek, J., Markevich, V.S., Horne, D.J., 2004. The age of the dinosaur-bearing Cretaceous sediments at Dashuiguu, Inner Mongolia, P.R. China based on charophytes, ostracods and palynomorphs. *Cretaceous Research* 25, 391–409.
- Van Nieuwenhuise, D.S., Ormiston, A.R., 1989. A model for the origin of source-rich lacustrine facies, San Jorge basin, Argentina. 1° Congreso Nacional de Hidrocarburos (Buenos Aires), Actas, 2, pp. 854–883.
- Vanschoenwinkel, B., Waterkeyn, A., Vandecaetsbeek, T., Pineau, O., Grillas, P., Brendonck, L., 2008. Dispersal of freshwater invertebrates by large terrestrial mammals: a case study with wild boar (*Sus scrofa*) in Mediterranean wetlands. *Freshwater Biology* 53, 2264–2273.
- Volkheimer, W., Rauhut, O.W.M., Quattrocchio, M.E., Martinez, M.A., 2008. Jurassic paleoclimates in Argentina, a review. *Revista de la Asociación Geológica Argentina* 63, 549–556.
- Wakefield, M.J., 1995. Ostracod biostratigraphy at lagoonal shorelines: examples from the Great Estuarine Group, Middle Jurassic, Scotland. *Proceedings of the Geologists' Association* 106, 211–218.
- Wang, Y.-Q., Sha, J.-G., Pan, Y.-H., Zuo, Q.-M., 2016. The Early Cretaceous non-Cypriidea Ostracoda from Yixian and Jiufotang formations of western Liaoning (China). *Palaeoworld* 25, 406–424.
- Whatley, R., 1983a. The application of Ostracoda to palaeoenvironmental analysis. In: Maddocks, R.F. (Ed.), *Applications of Ostracoda*. University of Houston, Geosciences, Houston, pp. 51–77.
- Whatley, R., 1983b. Some simple procedures for enhancing the use of Ostracoda palaeoenvironmental analysis. *Norwegian Petroleum Directorate, Bulletin* 2, 129–146.
- Whatley, R., 1988. Population structure of ostracods: some general principles for the recognition of palaeoenvironments. In: De Deckker, P., Colin, J.-P., Peypouquet, J.P. (Eds.), *Ostracoda in the Earth Sciences*. Elsevier Sciences Publishers, Amsterdam, pp. 245–256.
- Whatley, R., 1990. The relationship between extrinsic and intrinsic events in the evolution of Mesozoic non-marine Ostracoda. In: Kauffman, E.G., Walliser, O.H. (Eds.), *Extinction events in Earth History, Lecture Notes in Earth Sciences* 30. Springer-Verlag Berlin Heidelberg, Berlin, pp. 253–263.
- Whatley, R., 1992. The reproductive and dispersal strategies of Cretaceous nonmarine Ostracoda: the key to pandemonium. In: Mateer, N., Chen, P.J. (Eds.), *Aspects of Nonmarine Cretaceous Geology*. China Ocean Press, Beijing, pp. 177–192.
- Yilmaz, O., Külköylüoğlu, O., Tunçoglu, C., Tuncer, A., 2015. Geographical and stratigraphical distribution of the genus *Zonocypris* Müller, 1898 in Turkey and in the World. 8° European Ostracodologist's Meeting (Estonia), Abstracts, pp. 87–88.