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NEW OSTRACODE SPECIES FROM THE UPPER CRETACEOUS OF THE SANTOS BASIN, BRAZIL

ENELISE KATIA PIOVESAN, CRISTIANINI TRESCASTRO BERGUE & GERSON FAUTH
Laboratório de Micropaleontologia, UNISINOS, Av. Unisinos, 950, 93022-000, São Leopoldo, RS.
kpiovesan@unisinos.br, ctbergue@gmail.com, gersonf@unisinos.br

ABSTRACT – Two new species of Cretaceous ostracodes from the Santos Basin are proposed here: *Afrocytheridea*? *cretacea* sp. nov. and *Pelecocythere dinglei* sp. nov. The first one possibly constitutes the youngest record of *Afrocytheridea*, a typical Jurassic genus, while the latter the eldest of *Pelecocythere*. Both genera are typical elements of Gondwanide ostracode faunas and are recorded for the first time in Brazil. The paleoecologic and paleogeographic aspects of these two new species are discussed based on other published occurrences of *Pelecocythere* and *Afrocytheridea.*

Key words: *Afrocytheridea*, *Pelecocythere*, ostracodes, taxonomy, Santos Basin, Brazil.

RESUMO – Duas novas espécies de ostracodes do Cretáceo da bacia de Santos são propostas: *Afrocytheridea*? *cretacea* sp. nov. e *Pelecocythere dinglei* sp. nov. A primeira é possivelmente o registro mais recente de *Afrocytheridea*, um gênero típico do Jurássico, enquanto a última constitui o registro mais antigo de *Pelecocythere*. Estes gêneros são elementos típicos da fauna de ostracodes do Gondwana, e são registrados pela primeira vez no Brasil. O significado paleoecológico e paleogeográfico destas espécies é discutido com base em outros registros de *Pelecocythere* e *Afrocytheridea* previamente publicados.

Palavras-chave: *Afrocytheridea*, *Pelecocythere*, ostracodes, taxonomia, bacia de Santos, Brasil.

INTRODUCTION

The Upper Cretaceous deposits from Brazilian marginal basins are very rich in both marine and coastal (= inner shelf, with variable influence of freshwater discharge) ostracode faunas. Despite being relatively well studied in the northeastern region (*e.g.* Delicio *et al*., 2000; Viviers *et al*., 2000; Fauth *et al*., 2005; Piovesan *et al*., 2009), studies in the south/southeastern basins are still very scarce. In the Senonian of the Santos Basin, the marine ostracode faunas are dominated by the *Brachycythere-Bairdoppilata-Cytherella-Majungaella* association, while in the coastal environment the faunas are composed mainly of *Fossocytheridea* and *Afrocytheridea*.

The main purpose of this article is to describe two new species typical from those environments: *Afrocytheridea*? *cretacea* sp. nov. (coastal) and *Pelecocythere dinglei* sp. nov. (marine). Although these genera are fairly well known in other Gondwanide faunas, there is no published record of them in Brazilian basins. *Afrocytheridea* is a shallow marine inhabitant whose type species has been described in the Middle Callovian of Tanzania as a cytherideid and later assigned to the family Progonocytheridae by Whatley & Ballent (2004). The cytherurid *Pelecocythere*, on the other hand, has been recorded in both bathyal and abyssal depths, in the Cenozoic with occasional occurrences in the Cretaceous.

STUDY AREA

The Santos Basin is located in the southeast part of the Brazilian continental margin, between latitudes 23°S and 28°S (Figure 1). The evolution of the basin is related to the break-up of Gondwana. The first marine formations were deposited during the early Albian as a result of South Atlantic opening. The sedimentary record of this basin ranges from the Lower Cretaceous (Hauterivian) to the Quaternary. The Cretaceous marine section is composed of the Ariri, Florianópolis, Guarujá, Itanhaém, Santos, Juréia and Itajaí-Açu Formations which are the record of global and local sea-level changes and tectonic events (Moreira *et al*., 2007). During the Senonian, the sedimentation processes were strongly influenced by the Serra do Mar uplift (at 90-80 Ma) which prompted a coarse siliciclastic progradational trend (Modica & Brush, 2004). The interval studied in the present work corresponds to the sandstones and shales of the Juréia Formation, deposited in continental to shallow shelf paleoenvironments (Moreira *et al.*, 2007).

MATERIAL AND METHODS

The 234 cutting samples studied are from the well SAN-04, cored by Petróleo Brasileiro S.A. (Petrobras). This well is 4,905 m in length and was sampled every nine meters. The samples were prepared according to the usual techniques for calcareous microfossils, involving disaggregation in hydrogen peroxide under heating, fractionating using three

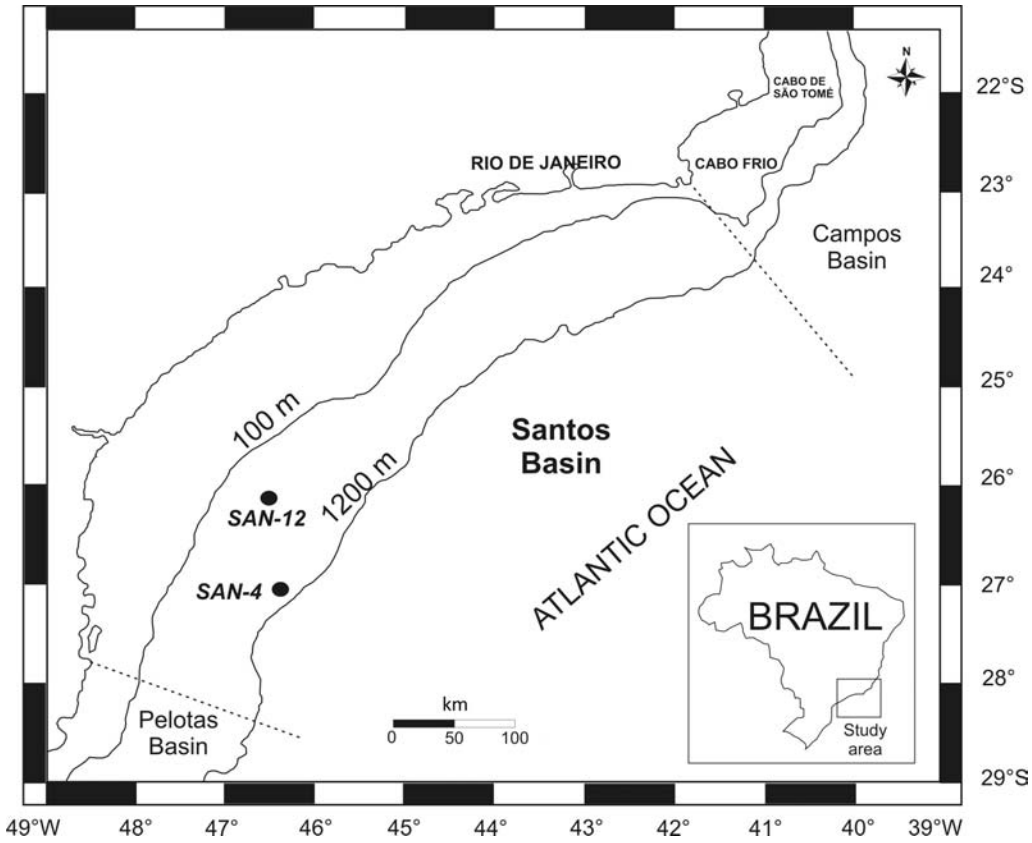

Figure 1. Location map of the Santos Basin, with the position of the wells studied (modified from Bergue & Coimbra, 2008).

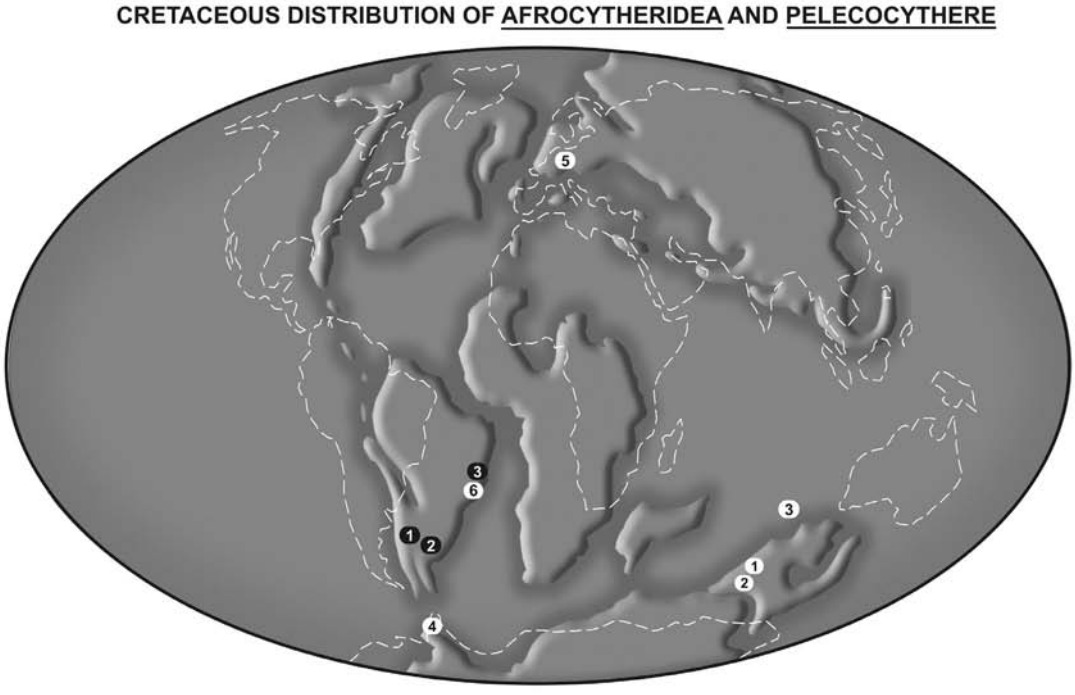

Figure 2. Cretaceous occurrences of the genera *Afrocytheridea* and *Pelecocythere.* Paleogeographic reconstruction from the Upper Cretaceous. Dashed lines indicate the actual position of the continents (modified from Scotese, 2009).

meshes (0.250, 0.180 and 0.062 mm) and drying at 60°C. All the specimens from the three fractions were picked. Three specimens from another well situated nearby (SAN-12, sample 3,110 m) were used as complementary material for the description of the species *Afrocytheridea*? *cretacea* sp. nov. The type specimens were cleaned in ultrasound baths for a few minutes before being imaged by SEM.

The type material is hold at the Museu de Paleontologia da Universidade do Vale do Rio dos Sinos under the curator numbers ULVG-7342 to ULVG-7351. The suprageneric taxonomy adopted in this work follows Liebau (2005). **Morphological abbreviations. C**, carapace; **RV**, right valve; **LV**, left valve; **l**, length; **h**, height; **w**, width.

SYSTEMATIC DESCRIPTIONS

Order PODOCOPIDA Müller, 1894
Suborder CYTHEROCOPINA Gründel 1967
Superfamily CYTHERIDEOIDEA Liebau, 2005
Family PROGONOCYTHERIDAE Sylvester-Bradley, 1948
Genus *Afrocytheridea* Bate, 1975

Type species. *Afrocytheridea laevigata* Bate, 1975.

Afrocytheridea? *cretacea* sp. nov.
(Figures 3A-G; Table 1)

Etymology. In reference to the age of the species.
Stage. Santonian-Campanian.
Material. 1,055 carapaces.
Diagnosis. Carapace subrectangular, slightly depressed at anterior and posterior margins, rounded and posteriorly inflated, reticulated and with ribs in the ventro-lateral area. Antero-dorsal sulcus oblique and short.
Description. Carapace subrectangular in lateral view. LV overlapping the RV except in the ventral region. Maximum height at the anterior cardinal angle; greatest width immediately after the median region. Dorsal margin almost straight in the RV and slightly projected upward in the posterior cardinal angle of LV; ventral margin not seen due to the ventro-lateral inflation of the carapace. Anterior margin asymmetrically rounded, depressed, with a narrow sulcus and a rib along its length. This depressed area forms a projected rim easily noticeable in dorsal view. Posterior margin symmetrically rounded, projected upward, slightly acuminate at mid-height in the RV, and more angulate in the LV valve due to the swollen posterior cardinal angle. In dorsal view, the posterior margin has the same pattern as the anterior one. Ventral surface of carapace depressed in the middle and with longitudinal ribs. Surface reticulated, with conspicuous ventro-lateral ribs running from the antero-ventral to postero-dorsal area. Close to the posterior cardinal angle a feeble rib originates and runs along the dorsal margin becoming thicker and bifurcating at the anterior cardinal angle, forming an antero-dorsal sulcus. Sexual dimorphism pronounced: males longer and lower than females.
Stratigraphic distribution. Southeast Brazil: Santonian-Campanian.
Occurrence. Well SAN-04: 2,879 m-4,473 m. Well SAN-12: 3,110 m.
Remarks. *Afrocytheridea*? *cretacea* sp. nov. is shorter and has the antero-dorsal furrow shallower than *A. laevigata* Bate, 1975. It is, moreover, smaller than *A. faveolata*, differing from both Bate's species by the strong reticulation and ventrolateral ribs concentrically distributed. Compared to *A. reticulata* Dingle (*in*: Dingle & Klinger, 1972), the length/width ratio of the species described here is smaller, the posterior region more rounded and the dorsal margin less oblique. The precise generic position of this species is questionable. In spite of being morphologically and ecologically similar to *Perissocytheridea* Stephenson, 1938, it lacks the two well-developed antero-dorsal sulci and the inflation at the posterior third of the carapace, found in typical representatives of the genus (see Pinto & Ornellas, 1970; Uliana & Musacchio, 1978; Andreau & Ettachfini, 1994; Nicolaidis & Coimbra, 2008). Although the internal features were not taken into account in the present description, the genus *Afrocytheridea* seems to be the most appropriate option to accommodate this species.

Family CYTHERURIDAE Müller, 1894
Genus *Pelecocythere* Athersuch, 1979

Type species. *Pelecocythere sylvesterbradleyi* Athersuch, 1979.

Pelecocythere dinglei sp. nov.
(Figures 3H-O; Table 2)

Etymology. In honor of Richard Dingle for his contribution to Gondwanide ostracode research.
Stage. Santonian-Campanian.
Material. 13 carapaces.
Diagnosis. Carapace robust, strongly ornamented, with pronounced antero-dorsal sulcus. Alae poorly developed.
Description. Carapace large. Dorsal margin straight; ventral margin hidden by the outline. Ventral surface flattened, bordered by both a carinate alae and a ventro-lateral ridge.

Table 1. Type material of *Afrocytheridea*? *cretacea* sp. nov.

			Dimensions (mm)		
Type material	Collection number	Sample	lenght	height	width
Female C (holotypus)	ULVG-7342	SAN-04 3897 m	0.46	0.26	0.35
Female C	ULVG-7343	SAN-04 3924 m	0.46	0.28	0.33
Female C	ULVG-7344	SAN-04 3888 m	0.50	0.29	0.33
Female C	ULVG-7345	SAN-12 3110 m	0.43	0.25	0.26
Male C	ULVG- 7346	SAN-12 3110 m	0.60	0.29	0.34
Male C	ULVG- 7347	SAN-12 3110 m	0.55	0.25	0.29

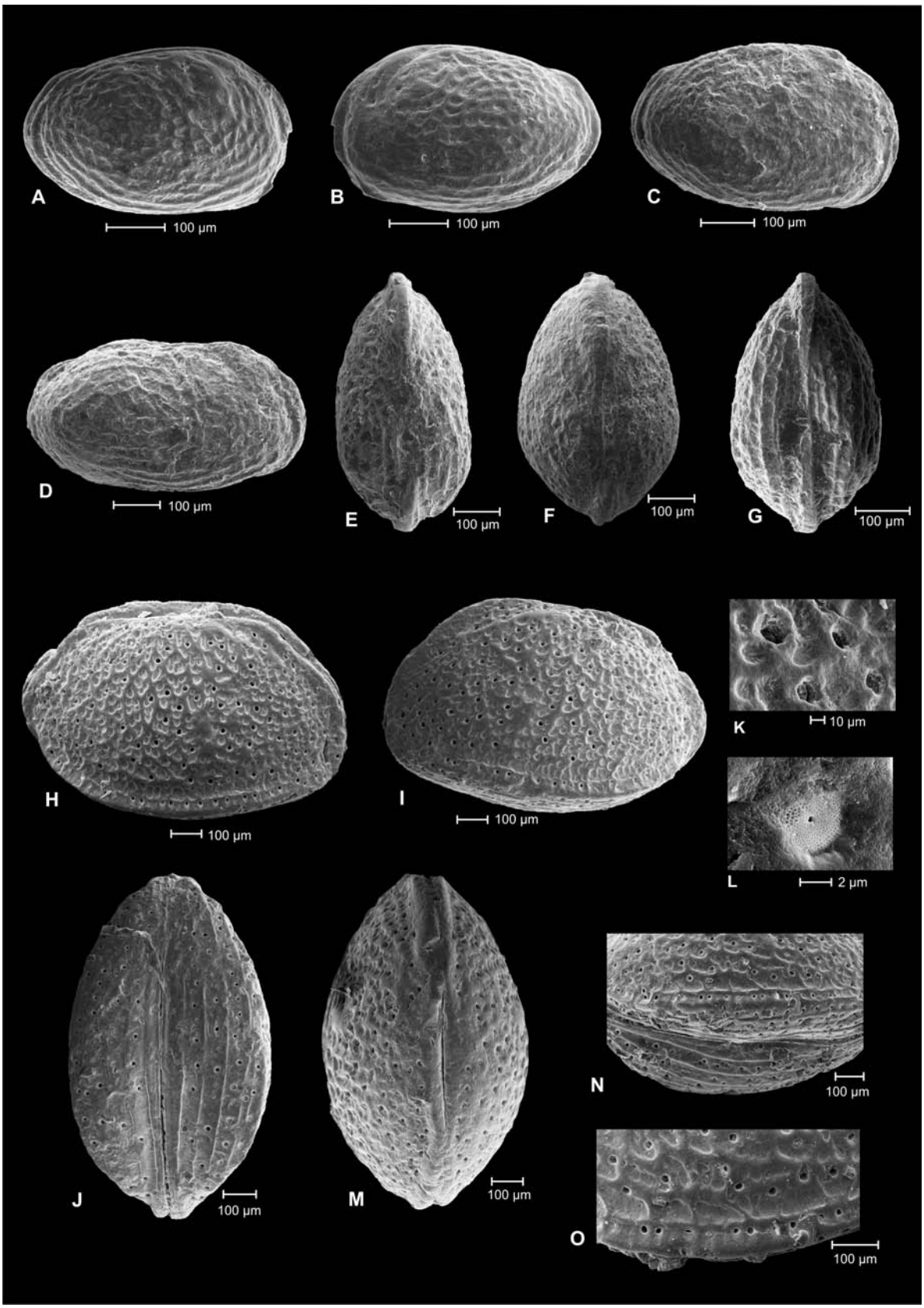

Figure 3. A-G, *Afrocytheridea*? *cretacea* sp. nov.: **A**,**B**, holotype, ULVG-7342, female C, lateral view, 3,897 m; A= RV; B= LV; **C**, paratype, ULVG-7343, female C, RV, 3,924 m; **D**, paratype, ULVG-7346, male C, RV, 3,110 m; **E**, paratype, ULVG-7347, male C, dorsal view, 3,110 m; **F**, paratype, ULVG-7344, female C, dorsal view, 3,888 m; **G**, paratype, ULVG-7345, female C, ventral view, 3,110 m. **H-O**, *Pelecocythere dinglei* sp. nov.: **H-L**, holotype, ULVG-7348, C, 3339 m, H= RV; I= LV; **J**, ventral view; **K**, normal pore canals; **L**, detail of the sieve pore canals; **M-O**, paratype, ULVG-7349, 3303 m; **M**= C, dorsal view; **N**= carinate alae, with pore canals; **O**= detail of ornamentation.

Table 2. Type material of *Pelecocythere dinglei* sp. nov.

			Dimensions (mm)		
Type material	Collection number	Sample	lenght	height	width
C (holotypus)	ULVG-7348	SAN-04 3339 m	1.05	0.62	0.67
C	ULVG-7349	SAN-04 3303 m	1.04	0.59	0.64
C	ULVG-7350	SAN-04 4140 m	1	0.58	0.59
C	ULVG-7351	SAN-04 3357 m	1.05	0.54	0.58

Maximum height and maximum width in the middle of the carapace. Anterior margin depressed, rounded and oblique in the upper part; posterior end oblique at the upper part, with a small caudal process. Outline ellipsoidal in dorsal view. Ventral surface of carapace ornamented with eight longitudinal ribs, four in each valve. Lateral surface reticulated, forming irregular fossae. Antero-dorsal region with pronounced sulcus running up to the antero-median portion of carapace. Left valve overlapping the right one in the postero- and antero-dorsal margins. Normal sieve-type pore canals, large and widely distributed over the lateral surface, but aligned along the carinate alae and the ventral surface.

Occurrence. Well SAN-04: 2,862 m - 4,140 m.

Remarks. *Pelecocythere dinglei* sp. nov. differs from *P. carinoalatum* (Bate, 1972) from the Santonian-Campanian from Australia, by the strong reticulation and the absence of the three parallel ridges in the alae. It differs from *P. collisarboris* (Neale, 1975) from Santonian from Australia, by the absence of the antero-ventral spination in the right valve. Furthermore, *Pelecocythere dinglei* sp. nov. is larger and more robust than the above mentioned species.

DISCUSSION AND CONCLUSIONS

The distribution of ostracode species during the Upper Cretaceous in the Santos Basin was strongly influenced by sea level changes, which probably caused the faunal change observed in the well SAN-04. Based on the analysis of the ostracode fauna along the well, it is possible to propose the transition from a coastal (bottom) to a marine (top) environment.

In the samples from the lower part, predominate *Fossocytheridea* spp. and *Afrocytheridea*? *cretacea* sp. nov., which are the most abundant species in the well and which compose an association characteristic of mixohaline waters. Towards the top, the fauna indicates the establishment of fairly marine conditions, as indicated by the occurrence of *Bairdoppilata*, *Brachycythere*, *Cytherella*, *Majungaella* and *Paracypris*.

Afrocytheridea is an extinct genus typical of the Jurassic/Neocomian strata, and its presence in the Senonian of the Santos Basin represents the enlargement of its temporal distribution. Such pattern of evolution is, in some aspects, similar to that of *Majungaella* Grékoff, another Jurassic progonocytherid, which became more disperse and less diverse along the Cretaceous and Paleogene (Whatley *et al*. 2005). Besides the species described here, only *Afrocytheridea* cf. *reticulata* (Dingle, 1972) has been recorded in the American continent (Musacchio, 1979, 1981; Musacchio & Simeoni, 2008). This species was originally described in the genus *Progonocythere* and tentatively accommodated in *Afrocytheridea* by Whatley & Ballent (1996, 2004). This Argentinian species occurs associated with platycopids and cytheroids, with a very high ostracode/foraminiferal ratio (only one species of *Lagenina*). The environment of deposition corresponds to restricted marginal marine conditions with warm waters and changing salinity (Sara Ballent, pers. comm., 2010). Similarly, its high abundance and association with *Fossocytheridea* in the Santos Basin indicate a coastal environment. It is possible that *Afrocytheridea* might have had an ecological behavior similar to the Cenozoic species of *Perisssocytheridea* which can live in both transitional and internal platform environments.

The genus *Pelecocythere* was described in abyssal depths of the North Atlantic and later recorded in many deep sea localities elsewhere. Despite the similarity to other cytherurids, such as *Cytheropteron* and *Eocytheropteron*, it differs from them by the presence of subdivided adductor muscle scars, sieve-type pore canals in the alae and longitudinal ribs along the ventral surface.

The more the study of deep sea ostracodes developed, the older the records of *Pelecocythere* became. Whatley & Coles (1987) recorded *P. foramena* for the Miocene of the North Atlantic, and Guernet & Fourcade (1988) referred to *Pelecocythere trinidadensis* (Bold, 1960) in the Oligocene of Blake Plateau (ODP site 628A, Southeast Atlantic). Guernet & Danelian (2006) reported an older record of *Pelecocythere* cf. *trinidadensis* Bold, 1960 in the Demerara rise (off Surinam) in the Eocene and, possibly, Maastrichtian. Although the poor preservation of the latter does not allow a conclusive statement about their generic position, there are other records which support more convincingly the Cretaceous occurrence of *Pelecocythere*. *Pelecocythere*? *sinecaudata* Herrig, 1992, described in the Maastrichtian of Germany, shows morphologic characteristics consistent with the generic diagnosis, such as the outline and the existence of pore canals along the alae. Dingle (2009) sustains that besides the species recorded in Waipara (New Zealand), the Australian species *Pelecocythere carinoalatum* and *P. collisarboris* are possibly other Cretaceous representatives.

Dingle (2009) suggests that during the Cretaceous, *Pelecocythere* was a shallow water genus, migrating during the Cenozoic to deeper or cold shallow water environments in a retrothermal adaptation. Some taxa that originally lived in shallow water colonized deeper environments becoming widespread in both, such as *Argilloecia* Sars, *Bythocypris* Brady, *Bairdoppilata* Coryell, Samples & Jennings and *Cytherella* Jones. Others, following the same pattern of adaptation, originated psychrospheric taxa living predominantly (*e.g. Bradleya* Hornibrook) or exclusively (*e.g. Agrenocythere* Benson, *Oblitacythereis* Benson) there (Benson & Sylvester-Bradley, 1971). This process explains the ecologic separation of marine ostracodes, which began

in the Upper Cretaceous and resulted in the distinct Cenozoic thermospheric and psychrospheric ostracode faunas.

Based on the published occurrences of *Afrocytheridea* and *Pelecocythere* in the Cretaceous (Figure 2), it can be assumed that, except for the record of *Pelecocythere*? *sinecaudata* (Maastrichtian, Germany), these genera were typical elements of the Gondwanide fauna.

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