

NEW SPECIES OF *FOSSOCYTHERIDEA* SWAIN & BROWN, 1964 (OSTRACODA, CRUSTACEA) IN THE UPPER CRETACEOUS OF SANTOS BASIN, BRAZIL

CRISTIANINI TRESCASTRO BERGUE, GERSON FAUTH, CARLOS EDUARDO LUCAS VIEIRA, ALESSANDRA DA SILVA DOS SANTOS

Laboratório de Micropaleontologia, UNISINOS, Av. Unisinos, 950, 93022-000, São Leopoldo, RS, Brasil.
ctbergue@gmail.com, gersonf@unisinos.br, carlosev@unisinos, alessandrass@unisinos.br

MARTA CLÁUDIA VIVIERS

PETROBRAS/CENPES/PDEXP/BPA, Cidade Universitária, Ilha do Fundão, 21941-915, Rio de Janeiro, RJ, Brasil.
mcriviers@petrobras.com.br

ABSTRACT – Eleven wells (1,765 cutting samples) from the Senonian of Santos Basin were examined, with the record of both marine and mixohaline ostracode faunas. The latter are composed mainly by *Fossocytheridea* and characterized by medium specific richness and high abundance. Four new species are here described: *F. posterodentata*, *F. ventrotuberculata*, *F. santosensis* and *F. anfulcata* and another one is left in open nomenclature. Besides the conspicuous variability, *F. ventrotuberculata* sp. nov. is the first species described for the genus with valve reversal. The significance of these new species described and their potential for applied approaches are discussed.

Key words: *Fossocytheridea*, Ostracoda, taxonomy, Brazil, Santos Basin.

RESUMO – Onze poços (1.765 amostras de calha) do Senoniano da bacia de Santos foram estudados, registrando faunas de ostracodes marinhas e mixoalinas. Estas são compostas basicamente por *Fossocytheridea* e caracterizadas pela riqueza específica baixa e alta abundância. Quatro novas espécies são aqui descritas: *F. posterodentata*, *F. ventrotuberculata*, *F. santosensis* e *F. anfulcata*, e outra é deixada em nomenclatura aberta. Além da notável variabilidade, *F. ventrotuberculata* sp. nov. é a primeira espécie descrita para o gênero com reversão de valvas. A importância destas novas espécies descritas e seu potencial para estudos aplicados são discutidos.

Palavras-chave: *Fossocytheridea*, Ostracoda, taxonomia, Brasil, bacia de Santos.

INTRODUCTION

The first researches on Cretaceous ostracodes from Santos Basin were done by Benson (1977) and Miller *et al.* (2002). More detailed taxonomic work began with the description and ecological characterization of the species *Afrocytheridea? cretacea* and *Pelecocythere dinglei* by Piovesan *et al.* (2010).

One of the most remarkable consequences of the scarcity of taxonomic knowledge is the limitation it imposes on paleoceanographical and biostratigraphical uses. Ostracodes are the most abundant calcareous microfossil in the Upper Cretaceous paralic deposits of Santos Basin. Considering that this basin was strongly affected by sea-level changes, ostracode populations were influenced accordingly, under conditions favorable for speciation. These faunas are dominated by cytherideids, *Fossocytheridea* Swain & Brown being the most common genus.

The first record of *Fossocytheridea* in Brazil was by Viviers *et al.* (2000) in the Campanian of Potiguar Basin, as *Sarlatina Babinot* & Colin, which is now considered its junior synonym (Tibert *et al.*, 2003). In the latter article, some species of *Fabanella* Martin, *Ovocytheridea* Grekoff, *Dolocytheridea* Triebel, *Antibithocypris* Jennings and *Cytheridea* Bosquet, were also

reassigned to *Fossocytheridea*. In other Cretaceous deposits (*e.g.* Western Interior Basin, USA: Swain & Brown, 1964, Tibert *et al.*, 2003, 2009; West Africa, Mali: Colin *et al.*, 1996) assemblages with *Fossocytheridea* are interpreted as indicators for marginal-marine environments. The ecological classification of brackish-water environments into oligohaline, mesohaline and polyhaline used herein follows Belt *et al.* (2005).

The main objective of this study is to describe four new species of *Fossocytheridea*, their ecologic relationships and intraspecific variability. These data are potentially important for biostratigraphical and paleoecological use not only in Brazilian basins but also in other similar deposits along the south and equatorial Atlantic margins.

STUDY AREA

The wells studied in the present article were drilled in the central area of the Santos Basin, located in the southeast part of Brazilian continental margin, between 23°S and 28°S (Figure 1). The sedimentary record of this basin ranges from the Lower Cretaceous to Quaternary and is related to the opening of the Atlantic Ocean. The Cretaceous marine section is composed by the Ariri, Florianópolis, Guarujá, Itanhaém, San-

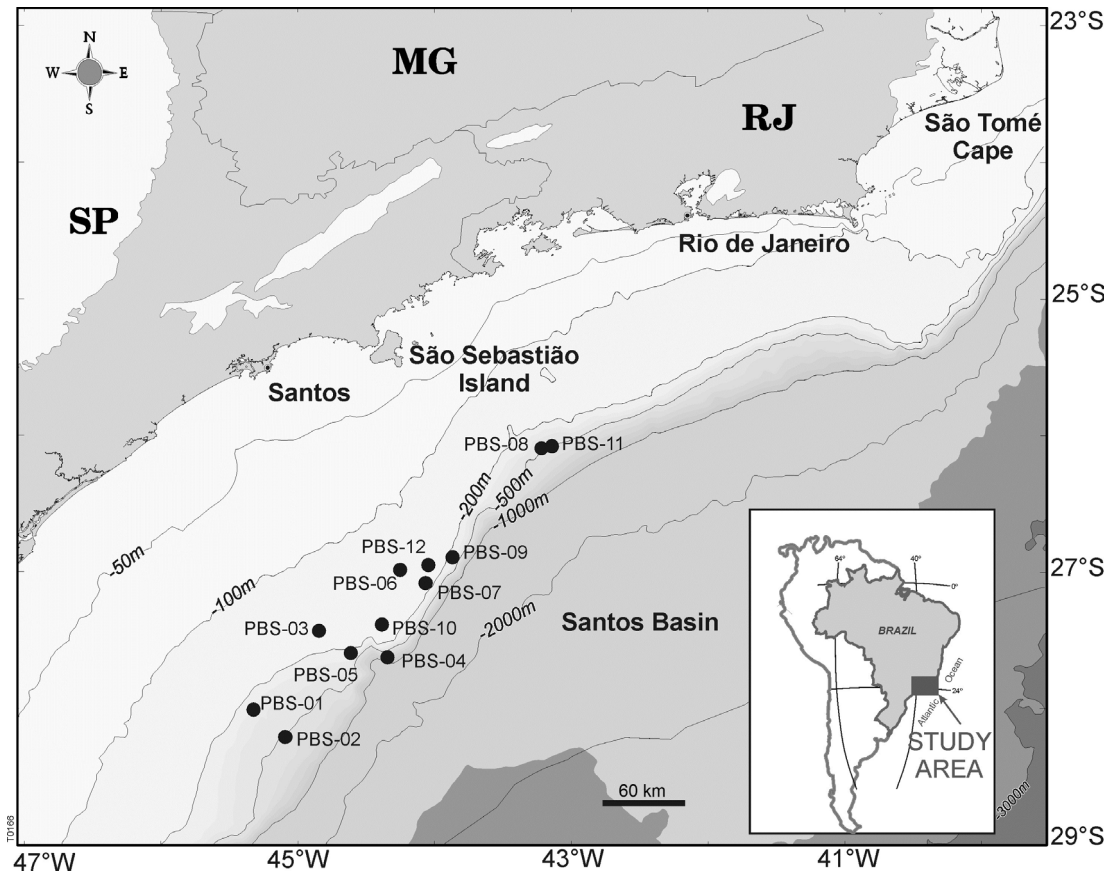


Figure 1. Map of study area showing the location of the studied wells. **Abbreviations:** MG, Minas Gerais State; RJ, Rio de Janeiro State; SP, São Paulo State.

tos, Juréia and Itajaí-Açu formations that record 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 that prompted a coarse siliciclastic progradational trend into the basin, developing coastal environments (Modica & Brush, 2004). Therefore, the lithological interval here studied corresponds to sandstones and shales deposited in continental to shallow shelf paleoenvironments (Moreira *et al.*, 2007) (Figure 2).

MATERIAL AND METHODS

The 1,765 cutting samples studied were obtained from 11 wells (SAN-01 to SAN-11) drilled by Petróleo Brasileiro S.A. (Petrobras). The wells have different lengths and number of samples, as demonstrated in the Table 1. The age proposed for the studied interval is based on palynological data and follows Arai *et al.* (2006).

The samples were prepared according to traditional techniques for calcareous microfossils, involving disaggregation in hydrogen peroxide under heating, fractionation into three meshes (0.250, 0.180 and 0.062 mm) and drying at 60°C. All the specimens from the two coarser fractions were picked. Whenever necessary, the specimens chosen for SEM were cleaned with histological needles and ultrasonic baths for a few minutes before being coated with an Au-Pd alloy. The internal molds selected for the study of the internal morphological features were simply cleaned with a dry brush before the coating (Figure 3).

The type material of this study is deposited at Museu de História Geológica do Rio Grande do Sul, Universidade do Vale do Rio dos Sinos (UNISINOS), under the curatorial numbers 7235 to 7256 and 7846 to 7850. **Morphological abbreviations.** A, adult; V, valve; C, carapace; RV, right valve; LV, left valve; l, length; h, height; w, width. The suprageneric classification proposed by Liebau (2005) is adopted in the present study.

Table 1. Length and number of samples per well.

Well	Length (m)	Number of samples
SAN-01	1230	105
SAN-02	720	18
SAN-03	1500	150
SAN-04	2106	234
SAN-05	2450	242
SAN-06	1130	104
SAN-07	1050	110
SAN-08	2097	233
SAN-09	2052	228
SAN-10	1566	174
SAN-11	1503	167

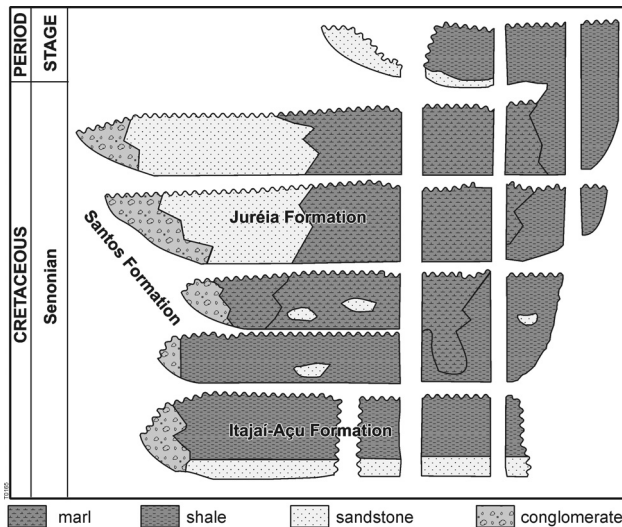


Figure 2. Stratigraphic position of Juréia formation in the Santos Basin (modified from Pereira & Feijó, 1994).

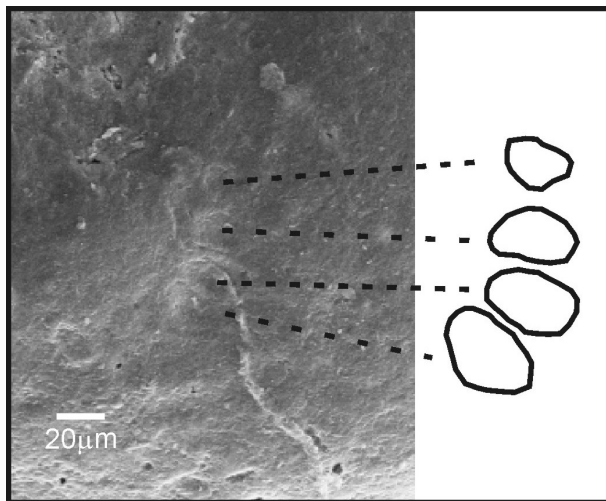


Figure 3. Internal mold of an unknown *Fossocytheridea* species (ULVG-7849) showing the line tracing of the adductor muscle scars impressions.

SYSTEMATIC PALEONTOLOGY

Order PODOCPIIDA Sars, 1866

Suborder CYTHEROCOPINA Gründel, 1967

Superfamily CYTHERIDEOIDEA Sars, 1925

Family CYTHERIDEIDAE Sars, 1925

Genus *Fossocytheridea* Swain & Brown, 1964, *emend.*

Tibert *et al.*, 2003

Sarlatina Babinot & Colin, 1976.

Type species. *Fossocytheridea lenoirensis* Swain & Brown, 1964.

Fossocytheridea posterodentata sp. nov.
(Figures 4A-E)

Etymology. In reference to the posteroventral part of the RV, outwardly projected and serrated.

Holotype. Female C (ULVG 7235).

Paratype. Female C (ULVG 7236), A-1 female C (ULVG 7237), female RV (ULVG 7238).

Type locality and age. Santos Basin, well SAN-09, sample 2,919 m. Santonian.

Material. 847 specimens.

Diagnosis. Carapace subrectangular with shallow sulcus along the anterior margin and posteroventral region of RV outwardly projected.

Description. Carapace subrectangular in lateral view, highest at the middle. LV overlapping both the hinge and free margins of the RV except in the posteroventral region. Greatest width and height at the middle of the carapace. Anterior margin rounded; posterior margin oblique. Dorsal margin slightly convex; ventral margin straight in the LV, concave in RV. Anterodorsal sulcus subtle. Surface with sparsely and finely punctuated. Posteroventral portion of the RV with conspicuous depression, seen both in lateral and dorsal views. Angle between the posterior and ventral margins outwardly projected and faintly serrated. Sexual dimorphism not seen.

Dimensions. ULVG 7235, SAN-09 2,919 m, l: 1.00 mm, h: 0.52 mm, w: 0.39 mm; ULVG 7236, SAN-09 2,319 m, l: 0.98 mm, h: 0.50 mm, w: 0.41 mm; ULVG 7237, SAN-07 3,090 m, l: 0.81 mm, h: 0.45 mm, w: 0.39 mm; ULVG 7238, SAN-01 2,770 m, l: 1.00 mm, h: 0.45 mm.

Occurrence. SAN-07: 2,922 m; 2,940 m; 2,949-3,030 m; 3,069 m; 3,090 m; 3,099 m; 3,123 m; 3,180 m; 3,189 m; 3,219 m; 3,249 m; 3,261 m; 3,330-3,363 m; 3,390 m; 3,399 m; 3,435 m; 3,444 m; 3,534 m; 3,600 m; 3,690 m. SAN-09: samples 2,541 m; 2,784 m; 2,793 m; 2,802 m; 2,811-2,901 m; 2,919-2,982 m; 3,045 m; 3,198 m; 3,207 m; 3,225 m; 3,234 m; 3,648 m; 3,810 m.

Remarks. *Fossocytheridea posterodentata* sp. nov. differs from the other species here described mainly for the depressed and outwardly projected posteroventral area of the RV.

Fossocytheridea ventrotuberculata sp. nov.
(Figures 4F-L; 5A-I)

Etymology. With reference to the tubercle seen in the ventrolateral part of LV.

Holotype. Male C (ULVG 7239).

Paratypes. Female C (ULVG 7240), male C (ULVG 7241), female C (ULVG 7242), male C (ULVG 7243), male C (ULVG 7244), female C (ULVG 7245), male C (ULVG 7846).

Type locality and age. Santos Basin, well SAN-05, sample 3,770 m. Santonian.

Material. 589 specimens.

Diagnosis. Carapace subrectangular, with valve reversion and well developed tubercle in the posteroventral region of LV.

Description. Carapace subrectangular in lateral view with unequal valves and deep and wide anterodorsal sulcus. Greatest width at the middle; greatest height at the anterior cardinal angle. Anterior margin almost symmetrically rounded and bordered by shallow sulcus up to the middle; posterior margin asymmetrically rounded, slightly oblique at upper part and projected outward in the LV, forming a rib clearly seen in ventral view. Dorsal margin straight; ventral margin slightly concave. LV smaller, overlapped along all the margins by RV. Posterior part of carapace depressed and marked in the

ventrolateral region with a tubercle. Surface predominantly smooth. Sexual dimorphism conspicuous: males longer and lower than females.

Dimensions. ULVG 7239 (SAN-05 3,770 m), l: 0.87 mm, h: 0.43 mm, w: 0.31 mm; ULVG 7240 (SAN-05 3,790 m), l: 0.83 mm, h: 0.48 mm, w: 0.31 mm; ULVG 7241 (SAN-05 3,810 m), l: 0.83 mm, h: 0.43 mm, w: 0.35 mm; ULVG 7242 (SAN-10 3,686 m), l: 0.73 mm, h: 0.45 mm, w: 0.33 mm; ULVG 7243 (SAN-05 3,790 m), l: 0.85 mm, h: 0.44 mm, w: 0.31 mm; ULVG 7244 (SAN-05 3,880 m), l: 0.79 mm, h: 0.41 mm, w: 0.33 mm; ULVG 7245 (SAN-10 3,812 m), l: 0.81 mm, h: 0.41 mm, w: 0.29 mm; ULVG 7846 (SAN-10 3,866 m), l: 0.83 mm, h: 0.39 mm, w: 0.29 mm.

Occurrence. SAN-05: 3,710 m; 3,740 m; 3,770-3,920 m; 3,940-3,960 m; 3,980 m; 4,090 m; 4,110 m; 4,140 m; 4,190 m; 4,240 m;

4,260 m; 4,280 m; 4,290 m; 4,330 m; 4,360 m; 4,480 m; 4,580 m; 4,600 m; 4,640-4,670 m; 4,720 m; 4,750 m; 4,800 m; 4,840 m; 4,900 m. SAN-06: 4,250 m; 4,280 m; 4,350 m; 4,520 m. SAN-10 3,389 m; 3,407 m; 3,470 m; 3,497 m; 3,533-3,632 m; 3,650-3,686 m; 3,704-3,866 m.

Remarks. *Fossocytheridea ventrotuberculata* sp. nov. is a species with intraspecific variation, readily identified by a posteroventral tubercle which *per se* is a variable feature (compare Figures 4G and 5G,I). It is also the first species of the genus known with valve reversion. The two morphotypes identified, morphotype A (which the species' description refers to) and morphotype B, differ mainly in outline. The first one is bigger, has the tubercle more developed and in one specimen (ULVG 7245), even a faint reticulation was observed.

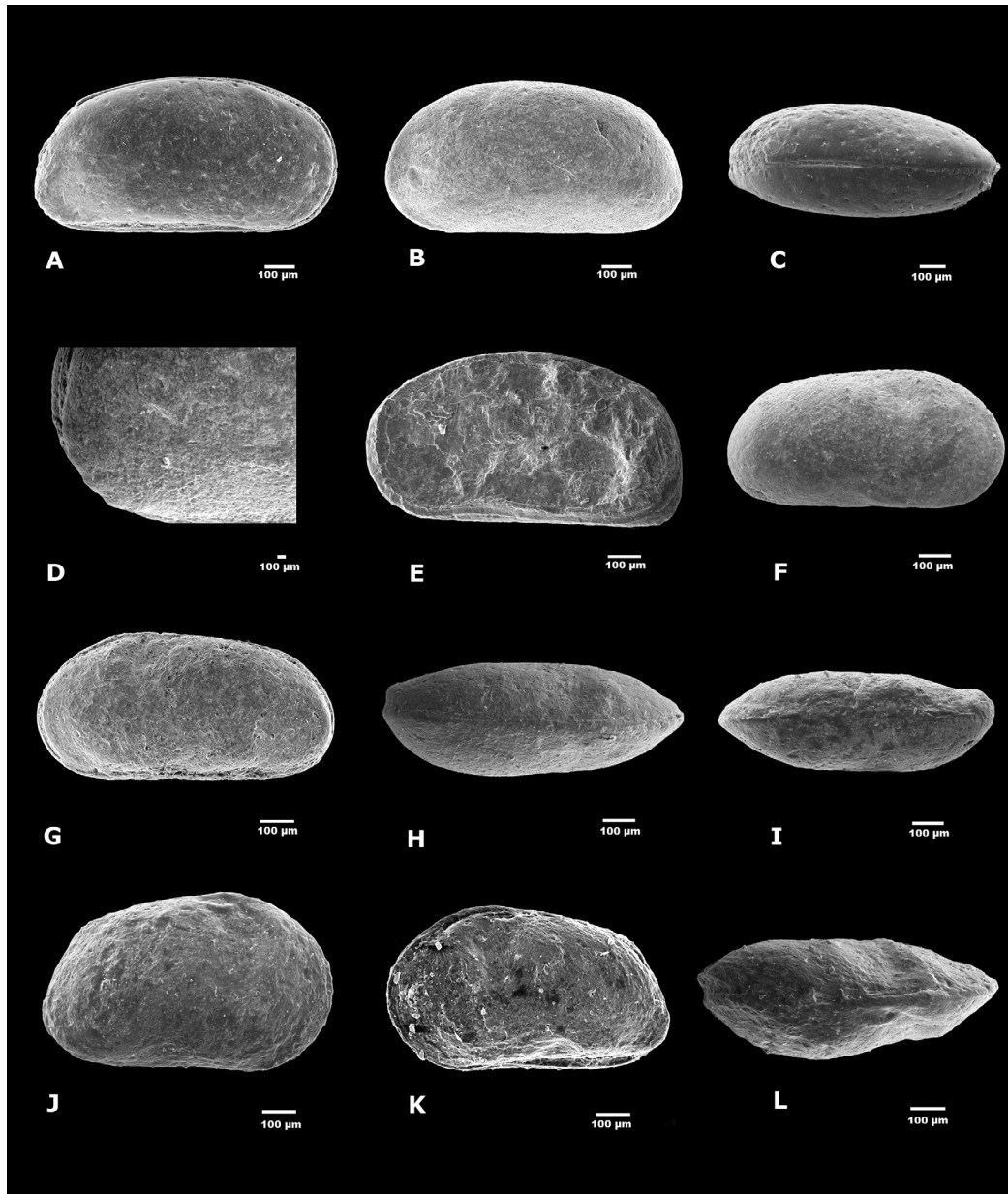


Figure 4. A-E, *Fossocytheridea posterodentata* sp. nov.: A-C, holotype, ULVG-7235, C, lateral view; A, RV; B, LV; C, dorsal view; D, paratype, ULVG-7236, detail of the posteroventral region; E, paratype, ULVG-7238, RV in internal view showing the posteroventral projection. F-L, *Fossocytheridea ventrotuberculata* sp. nov. - morphotype A: F-H, holotype, ULVG-7239, male C, lateral view; F, RV; G, LV; H, dorsal view; I, paratype, ULVG-7241, male C in ventral view; J-L, paratype, ULVG-7240, female C, lateral view; J, RV; K, LV; L, dorsal view.

All the specimens of the morphotype B were smooth, more robust and with the carapace overlap more pronounced.

Fossocytheridea santosensis sp. nov.
(Figures 5J-L; 6A)

Etymology. In reference to the name of the sedimentary basin here studied.

Holotype. Male C (ULVG 7246).

Paratypes. Female C (ULVG 7247), male A-1 C (ULVG 7248), female A-1 C (ULVG 7249), female A-1 C (ULVG 7250).

Type locality and age. Santos Basin, well SAN-04, sample 4,221 m. Santonian.

Material. 469 specimens.

Diagnosis. Carapace elongated, subrectangular and smooth. Antero and posteroventral regions marked by faint shallow sulci.

Description. Carapace elongated, subrectangular in lateral view. LV larger than the right one, showing clear overlap at posterodorsal, anterodorsal and dorsal areas. Greatest width at the middle; greatest height at the anterior cardinal angle. Anterior margin broad and asymmetrically rounded; posterior margin symmetrically rounded, slightly projected at middle. Dorsal margin straight; ventral margin slightly concave. Both antero and posteroventral regions marked by shallow sulci. Carapace with sparse puncta, more conspicuous in the juvenile specimens. Shape ellipsoid in dorsal view. Sexual dimorphism pronounced: males longer and lower than females.

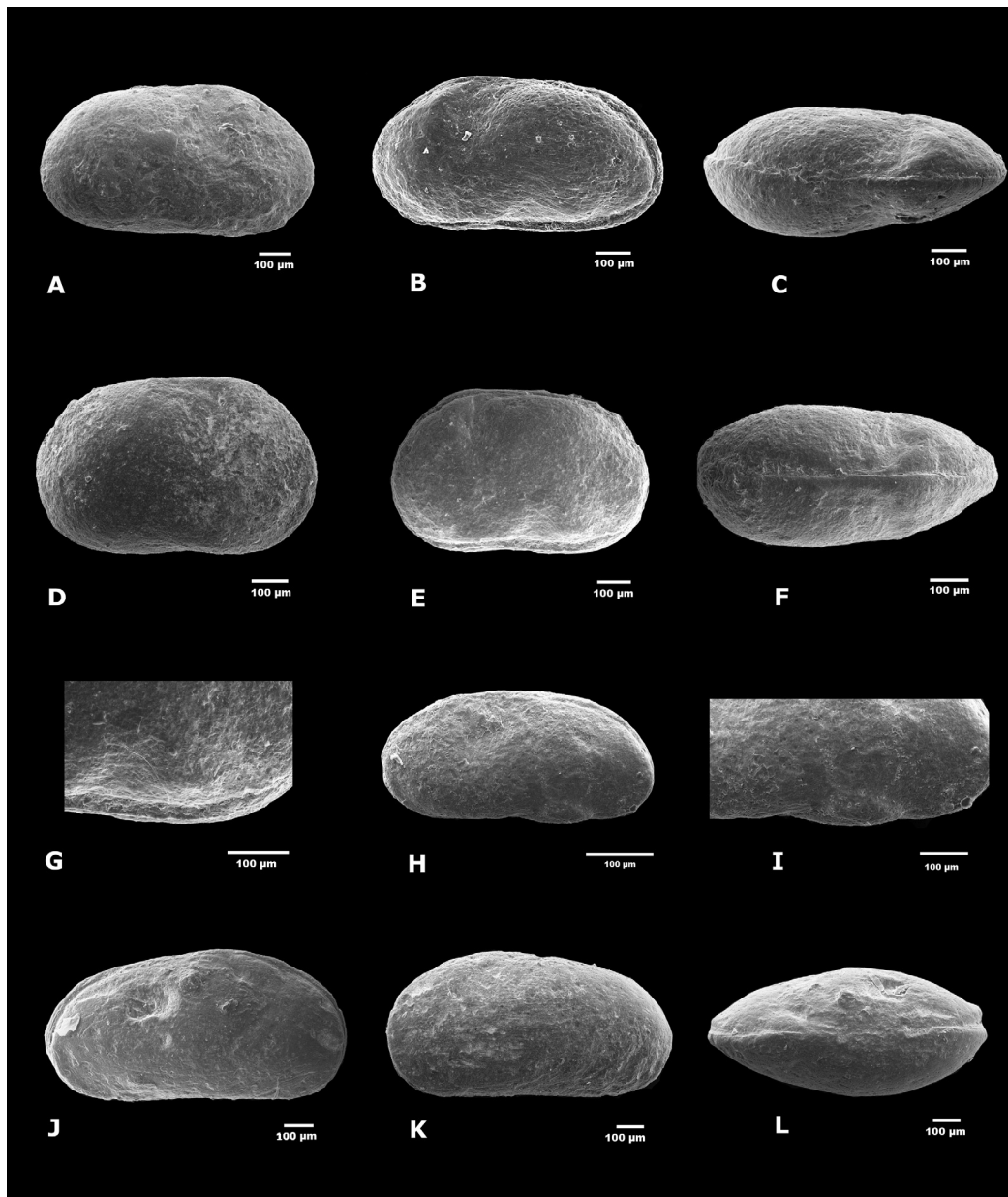


Figure 5. A-E, *Fossocytheridea ventrotuberculata* sp. nov. - morphotype B: A-C, paratype, ULVG-7243, male C, lateral view; A, RV; B, LV; C, dorsal view; D, paratype, ULVG-7242, female C, right lateral view. E-I, *Fossocytheridea ventrotuberculata* sp. nov. - morphotype B: E-G, paratype, ULVG-7245, female C; E, LV lateral view; F, dorsal view; G, detail of the posteroventral tubercle of the same specimen; H-I, paratype, ULVG-7846, male C; H, LV lateral view; I, detail of the posteroventral tubercle. J-L, *Fossocytheridea santosensis* sp. nov.: J, holotype, ULVG-7246, male C, RV lateral view; K, LV lateral view; L, dorsal view.

Dimensions. ULVG 7246 (SAN-04 4,221 m), l: 1.00 mm, h: 0.50 mm, w: 0.44 mm; ULVG 7247 (SAN-04 3,879 m); l: 1.00 mm, h: 0.54 mm, w: 0.43 mm; ULVG 7248 (SAN-10 3,173 m), l: 0.97 mm, h: 0.47 mm, w: 0.39 mm; ULVG 7249 (SAN-04 3,897 m), l: 0.98 mm, h: 0.52 mm, w: 0.39 mm; ULVG 7250 (SAN-04 3,879 m), l: 0.95 mm, h: 0.50 mm, w: 0.42 mm.

Occurrence. SAN-04: 3,861 m; 3,870 m; 3,888-3,987 m; 4,014 m; 4,023 m; 4,032 m; 4,059 m; 4,068 m; 4,176 m; 4,221 m. SAN-05: 3,270 m; 3,280 m; 3,310 m. SAN-06: 3,650 m; 3,680 m; 3,740 m; 3,850 m; 3,890-3,910 m. SAN-07: 2,940 m; 2,937 m; 3,000 m; 3,039 m; 3,123 m; 3,180 m; 3,699 m; 3,744-3,819 m; 3,909 m; 3,918 m; 3,945 m. SAN-10: 2,615 m; 3,074 m; 3,164 m; 3,146 m; 3,182 m; 3,281 m; 3,290 m; 3,299 m; 3,389 m.

Remarks. *Fossocytheridea santosensis* sp. nov. has the dorsal margin more slopped than *F. posterodentata* sp. nov. The presence of a posteroventral sulcus and the absence of the posteroventral downwardly projected region constitute additional differences between those species.

Fossocytheridea amphisulcata sp. nov.
(Figures 6B-E)

Etymology. In reference to the anterodorsal and medioventral sulci in the carapace.

Holotype. Female C (ULVG 7251).

Paratypes. Female C (ULVG 7252), female C (ULVG 7253), female A-1 C (ULVG 7254), male C (ULVG 7255), male A-1 (ULVG 7256).

Type locality and age. Santos Basin, well SAN-10, sample 3,866 m. Campanian.

Material. 245 specimens.

Diagnosis. Carapace subelliptical in lateral view with conspicuous posterodorsal overlap and a sulcus at the midventral part of carapace.

Description. Carapace subelliptical in lateral view, inflated. Greatest width at the posterior region; greatest height at the anterior cardinal angle. Anterior margin broadly and asymmetrically rounded, oblique at upper part and bordered by a shallow sulcus; posterior margin symmetrically rounded. Dorsal margin convex in RV, slightly concave in the LV; ventral margin of both valves with wide and shallow median sulcus, more developed in the males. Surface inflated and smooth. LV larger than the right one with conspicuous overlap at posterodorsal region, making this part of the carapace slightly angular. Sexual dimorphism present: males longer than females.

Dimensions. ULVG 7251 (SAN-10 3,866 m), l: 0.85 mm, h: 0.43 mm, w: 0.35 mm; ULVG 7252 (SAN-10 3,866 m), l: 0.79 mm, h: 0.43 mm, w: 0.33 mm; ULVG 7253 (SAN-10 3,866 m), l: 0.79 mm, h: 0.41 mm, w: 0.35 mm; ULVG 7254 (SAN-10 3,866 m), l: 0.77 mm, h: 0.43 mm, w: 0.33 mm; ULVG 7255 (SAN-05 3,840 m), l: 0.91 mm, h: 0.41 mm, w: 0.37 mm; ULVG 7256 (SAN-10 3,173 m), l: 0.85 mm, h: 0.37 mm, w: 0.37 mm.

Occurrence. SAN-02: 3,500 m. SAN-05: 3,710 m; 3,810 m; 3,900 m; 3,920 m; 3,940 m; 3,980 m; 4,660 m; 4,840 m. SAN-10: 3,119 m; 3,317 m; 3,389 m; 3,398 m; 3,407 m; 3,425 m; 3,434 m; 3,470 m; 3,461 m; 3,479 m; 3,488 m; 3,497 m; 3,506 m; 3,545 m; 3,551 m; 3,578 m; 3,560 m; 3,569 m; 3,623 m; 3,650 m; 3,686 m; 3,713 m; 3,722 m; 3,866 m.

Remarks. *Fossocytheridea anfisulcata* sp. nov. is similar to

Fossocytheridea maliensis (Colin *et al.*, 1996), but this species has an outline more ellipsoid and a more pronounced overlap along the dorsal margin. It is also similar to *Fossocytheridea kirklandi* Tibert *et al.*, 2003 due to the well developed anterodorsal and anteromarginal sulci, but differs in the overall outline both in lateral and dorsal views.

Fossocytheridea? sp.
(Figures 6F-I)

Figured specimens. Male C (ULVG 7255), female C (ULVG 7256).

Locality and age. Santos Basin well SAN-10, samples 3,398 m and 3,866 m, respectively. Santonian.

Material. Eight specimens.

Dimensions. ULVG 7255 (SAN-10 3,398 m), l: 0.85 mm, h: 0.41 mm, w: 0.31 mm; ULVG 7256 (SAN-10 3,866 m), l: 0.87 mm, h: 0.43 mm, w: 0.33 mm.

Occurrence. SAN-10 3,299 m; 3,389 m; 3,398 m; 3,434 m; 3,866 m.

Remarks. This species is tentatively identified in the genus *Fossocytheridea*, but its outline is somewhat different from the others here described. It is characterized by a long median sulcus, a conspicuous ventrolateral inflation, a wide sulcus bordering the anterior margin and sexual dimorphism. The study of more and better preserved specimens is necessary to elucidate the precise generic position of this species.

SPECIES DISTRIBUTION AND ASSEMBLAGE COMPOSITION

The ostracode assemblages are very rich in some levels being the abundance peaks composed mainly by *Fossocytheridea* species. The stratigraphical distribution and paleoecological characteristics of the ostracodes in the 11 studied wells show both brackish and marine characteristics. This is in accordance to Piovesan *et al.* (2010) who identified marine faunas composed predominantly by the *Bairdoppilata-Cytherella-Brachycythere-Majungaella* association, and brackish ones composed mainly by the *Fossocytheridea* spp. and *Afrocytheridea? cretacea* Piovesan *et al.*, 2010.

Three out the five species here studied are restricted to the Santonian (*F. ventrotuberculata* sp. nov., *F. posterodentata* sp. nov. and *Fossocytheridea?* sp.) while *F. amphisulcata* sp. nov. and *F. santosensis* sp. nov., occur up to the Campanian. The Santonian-Campanian boundary is based on the last occurrence of the pollen *Anacolosidites* sp. (Arai *et al.*, 2006) (Figure 7).

The *Fossocytheridea* species here described have different patterns of abundance and preservation. They are completely absent in the well SAN-03 and represented predominantly by juveniles and mostly broken specimens in SAN-01. Despite the high abundance in some levels, only one adult valve was recovered in the samples studied (Figure 4E). Internal molds are rather common in many samples, and occasionally preserve muscle scars impressions (Figures 3, 6J). *Fossocytheridea ventrotuberculata* sp. nov., *F. amphisulcata* sp. nov. and *F. posterodentata* sp. nov., are restricted to a few wells. Intervals with monospecific faunas or the predominance of juvenile specimens also occur. The

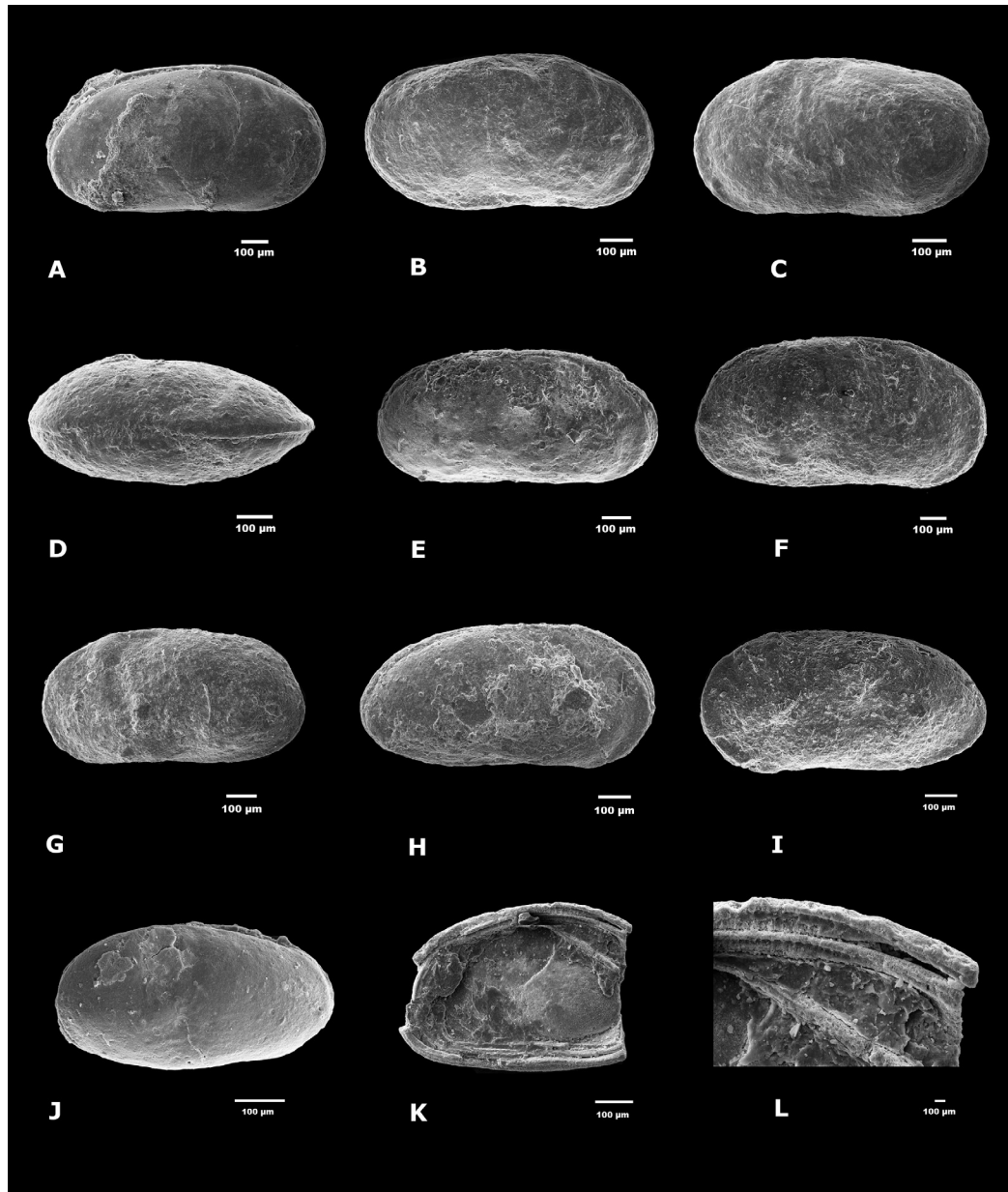


Figure 6. A, *Fossocytheridea santosensis* sp. nov.: paratype, ULVG-7247, female C, RV lateral view. B-C, *Fossocytheridea amphisulcata* sp. nov.: holotype, ULVG-7251, female C, lateral view; B, RV; C, LV; D, paratype, ULVG-7252, female C, dorsal view; E, paratype, ULVG-7255, male C, RV lateral view. F-L, *Fossocytheridea?* sp. 1: F-G, ULVG-7847, female C, lateral view; F, RV; G, LV; H-I, ULVG-7848, male C, lateral view; H, RV; I, LV; J, ULVG-7849, internal mold of an unknown *Fossocytheridea* species; K-L, ULVG-7850, juvenile valves of *Fossocytheridea* with cup-in-cup accommodation; L, detail of the same specimen showing the anterior and median hinge elements.

latter characteristic and taphonomic restraints such as crushing, abrasion and cup-in-cup preservation (Figure 6K) hampered more precise figures of species abundance and occurrence.

FINAL CONSIDERATIONS

Compared to other ostracode studies on Upper Cretaceous marginal-marine deposits (e.g. Swain & Brown, 1964; Swain, 1982; Tibert *et al.*, 2009), the richness of *Fossocytheridea* in Santos Basin is higher. This might be explained by successive establishments of environments ranging from oligo- to polyhaline characteristics during shelf progradation processes, as proposed by Modica & Brush (2004). The sporadic

occurrences of *Ilyocypris* sp. and charophytes, for instance, demonstrates the proximity of freshwater environments (oligohaline environment) which is in accordance with the depositional model proposed for the Senonian of the Santos Basin by Moreira *et al.* (2007). The connection between speciation and environmental changing has already been discussed by Neale (1988) and Tibert *et al.* (2003), implying that the species here recorded could represent elements from successive paralic paleoenvironments.

Fossocytheridea ventrotuberculata sp. nov. has characteristics which deserve more detailed comments. Firstly, it is the only *Fossocytheridea* species known with valve reversal, although it is not possible to state if it is environmentally induced or an intrinsic characteristic of the species. The same pattern of

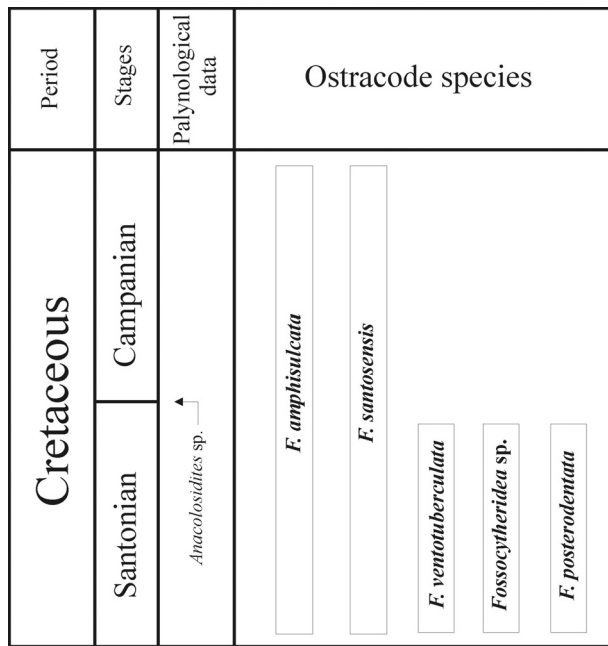


Figure 7. Schematic representation of the temporal distribution of the ostracode species here studied. Palynological data: according to Arai *et al.* (2006) the Santonian-Campanian boundary is based on the last occurrence of the pollen *Anacolosidites* sp.

valve accommodation, however, has already been recorded in other cytherideid species, *Haplocytheridea insolita* (Alexander & Alexander, 1933), from the US Gulf Coastal Plain. Secondly, its morphologic variability, here described as morphotypes A and B, reveals it as a potential paleoenvironmental indicator.

Another relevant data is that the higher abundances of *F. ventrotuberculata* sp. nov., *F. amphisulcata* sp. nov. and *Afrocytheridea? cretacea* Piovesan *et al.* usually take place simultaneously. This association, possibly, indicates mesohaline characteristics, *i.e.*, higher than in intervals with only *Fossocytheridea* species (oligohaline), but lower than in intervals where the typical polyhaline/marine association previously mentioned occurs (see previous section). Those results are a small demonstration of the ostracode faunal richness of the marginal-marine deposits of Santos Basin and its paleoecological potential.

ACKNOWLEDGEMENTS

The authors would like to thank Petróleo Brasileiro S.A. (Petrobras) for providing the samples used in this study. R. Martins and A.T. Dias are thanked for the SEM work and the elaboration of the figures, respectively. Thanks to G. Klaser for the assistance on the preparation of the plates. N.E. Tibert and T.M. Puckett are thanked for the useful comments and suggestion which improved considerably this article.

REFERENCES

- Alexander, C.I. & Alexander, C.W. 1933. Reversal of valve size and hinge structure in a species of the genus *Cytheridea*. *American Midland Naturalist*, **14**(3):280-283.
Arai, M.; Lana, C.C.; Araújo, C.V. & Menezes, T.R. 2006. O grande

- incêndio do Santoniano: considerações geológicas e exploratórias. *Boletim de Geociências da Petrobrás*, **14**(1):125-135.
Babinot, J.F. & Colin, J.P. 1976. *Sarlatina*, n. gen. (ostracode): sa position dans l'évolution des Cyprideidini Kollmann, 1960. *Abhandlungen und Verhandlungen des Naturwissenschaftlichen Vereins in Hamburg*, **18/19**:161-174.
Belt, E.S.; Tibert, N.E.; Curran, H.A.; Diemer, J.A.; Hartman, J.H.; Kroeger, T.J. & Harwood, D.M. 2005. Evidence for marine influence on a low gradient coastal plain: ichnology and invertebrate paleontology of the lower Tongue River Member (Fort Union Formation, middle Paleocene), western Williston Basin, USA. *Rocky Mountain Geology*, **40**(1):1-24.
Benson, R.H. 1977. The Cenozoic ostracode faunas of the São Paulo Plateau and Rio Grande Rise (DSDP LEG 39, sites 356 and 357). In: P.R. Supko; K. Perch-Nielsen; P. Neprochnov; H.B. Zimmerman; F. McCoy; N. Kumar; J. Thiede; E. Bonatti; R. Fodor; A. Boersma; M.G. Dinkelman & R.L. Carlson (eds.) *Initial Reports of the Deep Sea Drilling Project*, vol. 39, U.S. Government Printing Office, p. 856-883.
Colin, J.P.; Tambareau, Y. & Krashnnikov, V.A. 1996. Ostracodes limniques et lagunaires dans le Crétacé supérieur du Mali (Afrique de l'Ouest): systematique, paléoécologie et affinités paléobiogéographiques. *Revue de Micropaléontologie*, **39**:211-222.
Liebau, A. 2005. A revised classification of the higher taxa of the Ostracoda (Crustacea). *Hydrobiologia*, **538**:115-137. doi:10.1007/s10750-004-4943-7
Miller, C.G.; Richter, M. & Carmo, D.A. 2002. Fish and ostracod remains from the Santos Basin (Cretaceous to Recent), Brazil. *Geological Journal*, **37**:297-316. doi:10.1002/gj.917
Modica, C.J. & Brush, E. 2004. Postrift sequence stratigraphy, paleogeography and fill history of the deep-water Santos Basin, offshore southeast Brazil. *Bulletin of the American Association of Petroleum Geology*, **88**:923-945. doi:10.1306/01220403043
Moreira, J.L.P.; Madeira, C.V.; Gil, J.A. & Machado, M.A.P. 2007. Bacia de Santos. *Boletim de Geociências da Petrobras*, **15**:531-549.
Neale, J.W. 1988. Ostracods and paleosalinity reconstruction. In: P. De Deckker, J.P. Colin & J.P. Peypouquet (eds.) *Ostracoda in the Earth Sciences*, Elsevier, p. 125-155.
Pereira, M.J. & Feijó F.J. 1994. Bacia de Santos. *Boletim de Geociências da Petrobras*, **8**:219-234.
Piovesan, E.K.; Bergue C.T. & Fauth, G. 2010. Two new ostracode species from the Upper Cretaceous of Santos Basin, Brasil. *Revista Brasileira de Paleontologia*, **13**(3):175-180. doi:10.4072/rbp.2010.3.02
Swain, F.M. 1982. Marine and brackish water Cretaceous Ostracoda from wells in central and southern Florida. *Journal of Micropalaeontology*, **1**:115-128.
Swain, F.M. & Brown, P.M. 1964. Cretaceous Ostracoda from wells in the southeastern United States. *Bulletin of North Carolina Department of Conservation and Development*, **78**:1-55.
Tibert, N.E.; Colin J.P. & Leckie, R.M. 2009. Taxonomy, biostratigraphy and paleoecology of Cenomanian and Turonian ostracodes from the Western Interior Basin, Southeast Utah, USA. *Revue de Micropaléontologie*, **52**:85-105. doi:10.1016/j.revmic.2007.02.006
Tibert, N.E.; Colin, J.P.; Leckie, R.M. & Babinot, J.P. 2003. Revision of the ostracode genus *Fossocytheridea* Swain & Brown, 1964: Mesozoic ancestral root for the modern eurytopic *Cyprideis* Jones. *Micropaleontology*, **49**:205-230.
Viviers, M.C.; Koutsoukos, E.A.M.; Silva-Telles A. & Bengston, P. 2000. Stratigraphy and biogeographic affinities of the late Aptian-Campanian ostracods of the Potiguar and Sergipe basins in northeastern Brazil. *Cretaceous Research*, **21**:407-455. doi:10.1006/cres.2000.0205

Received in December, 2010; accepted in April, 2011.