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Climatically induced changes in late Quaternary bathyal ostracod assemblages of the Camamu Basin, Brazil

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Abstract
Bathybic ostracods (i.e., bathyal and abyssal assemblages) are important indicators of temperature and productivity changes of Cenozoic marine ecosystems. The present work presents the first study on Quaternary ostracods of the Camamu Basin, off the state of Bahia, northeastern Brazilian continental margin. The analysis of 59 samples from the piston-core CMU 14 (14°24'S, 38°49'W; 965 m water depth), revealed rich and abundant assemblages. The ^{14}C accelerator mass spectrometry (AMS) dating indicates that the studied interval covers the last 108 kyr, corresponding to the oxygen stable isotope stages (MIS) 5 to 1. Comparison with data from previous publications allowed discernment of three groups of ostracod species in CMU 14: Pandemic Group of species registered in more than one oceanic basin; Atlantic/Mediterranean Group of species restricted to the Atlantic Ocean and Mediterranean; and Brazilian Group of species restricted to the Brazilian continental margin). Four new species are herein proposed: *Cytherella pindoramensis* sp. nov., *Ambocythere amadoi* sp. nov., *Pseudobosquetina pucketti* sp. nov., and *Bythoceratina bonaterrae* sp. nov. Ostracod occurrences reveal the influence of glacial/interglacial cycles on assemblages composition. Interglacial stages 5 and 1 in the Camamu Basin are characterized by the association *Bythocypris affinis–Cytherella pindoramensis* sp. nov.–*Cytheropteron perlaria–Bradleya dictyon*; glacial stages (i.e., 2 to 4) register decreased diversity, possibly due to lower oceanic productivity.

KEYWORDS: paleoceanography; bathybic faunas; Atlantic Ocean; paleoproductivity; ostracod taxonomy.

INTRODUCTION

Research over the past 50 years has supplied invaluable data for the understanding of ostracod assemblages from deep oceanic regions (Benson 1975, Cronin 1983, Benson *et al.* 1984, Whatley and Coles (1991), Majoran and Dingle 2002, Cronin and Dwyer 2003, Yasuhara and Cronin 2008, Yasuhara *et al.* 2014, *inter alia*). Those studies revealed not only the bathymetric distributional pattern, but also changes in assemblage composition along glacial, deglacial and interglacial stages, especially in response to variations of the oxygen minimum zone (OMZ) depth, and oceanic productivity.

In spite of its potentiality, the research on bathybic ostracods in Brazil is mostly limited to a few bathyal regions of the Brazilian Continental Margin (BCM), more precisely the Pelotas, Santos and Campos basins (*i.e.* ~21–35°S) (Carreño *et al.* 1999, Drozinski *et al.* 2003, Bergue *et al.* 2006, 2007, 2017, Bergue and Coimbra 2008, Sousa *et al.* 2013, Maia *et al.* 2021). A northward expansion of this research is imperative to broaden our understanding on the parameters influencing species occurrence in different basins scenarios. The main purpose of this paper was to extend the research into the northeastern Brazilian margin. To accomplish this goal, we studied a site in the Camamu Basin (off Bahia State) and discussed the geographic and stratigraphic occurrences of some species registered therein.

The Camamu Basin lies in the northeastern sector of the BCM (Martins and Coutinho 1981) between 13° and 14°S, and it registers deposits ranging from the Jurassic to the Quaternary in age (Fig. 1). It is limited to the north by the Recôncavo and Jacuípe

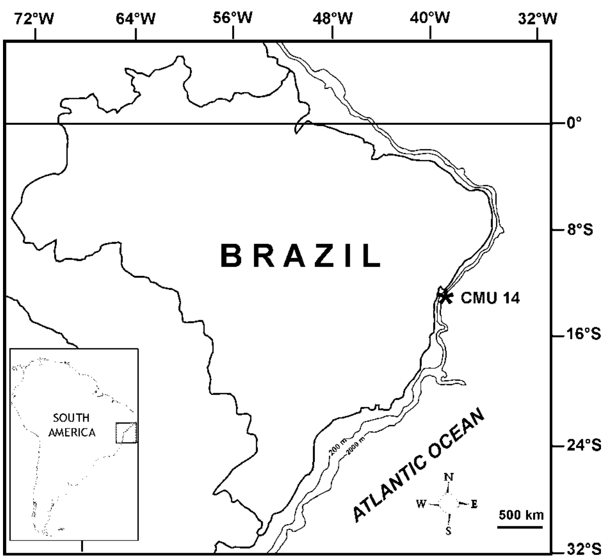

Figure 1. Study area with location of the core CMU 14 in the in the BCM.

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basins, and to the south by the Almada Basin. The Quaternary sediments studied herein correspond to the sequence N60, which is predominantly composed of clay (Caixeta *et al.* 2007). The Camamu Basin is in the narrowest sector of the BCM, whose bathyal portion is bathed by the Antarctic Intermediate Water (AAIW) (Stramma and England 1999).

MATERIAL AND METHODS

The piston-core CMU 14 (4.56 m length), obtained in the continental slope of the Camamu Basin (14°24'S; 38°49'W) at 965 m water depth, was sampled approximately each six centimeters, yielding 59 samples. Preparation involved washing through a 0.062 mm sieve, followed by oven-drying at 60°C. All specimens from the samples were picked out and stored in micropaleontological slides for taxonomic analysis. Representative specimens (either valves or carapaces) of each species were selected for SEM at *Centro de Microscopia e Microanálise, Universidade Federal do Rio Grande do Sul.*

The sedimentation rate at this site was approximately 6.5 cm/kyr during the Last Glacial Maximum (LGM) and deglacial, and ~3 cm/kyr during the Holocene (Toledo *et al.* 2007). The ^{14}C accelerator mass spectrometry (AMS) dating — carried out at NOS AMS–WHOI laboratory, and corrected for a reservoir effect of 400 yr (Bard 1988) — indicates that the studied interval covers the last 108 kyr (*i.e.*, marine isotope stages – MIS, 5 to 1).

The Shannon index was calculated for diversity assessment along the core. This metric is an entropy estimate that includes the relative abundance of taxa (Shannon 1948). In this paper, the term "fauna" refers to taxa that lived during a certain interval of time, either in the local or global sense; "assemblage" refers to a group of fossil specimens present in a sample (both autochthonous [within-habitat time-averaged] and allochthonous [out-of-habitat]), and "association" is a group of taxa that lived together and characterize an ecological scenario (also called census). The material herein studied is held at the *Museu de Paleontologia Irajá Damiani Pinto*, *Universidade Federal do Rio Grande do Sul*, Porto Alegre, Brazil.

RESULTS

Assemblage composition

Taxonomic analysis of the assemblages recovered from the core CMU 14 allowed the identification of 40 taxa, four of which proposed as new species (Figs. 2 and 3). In zoogeographic terms, these species are divided into three groups, as follows:

- Pandemic Group, composed of species registered in several deep-sea regions worldwide;
- Atlantic/Mediterranean Group, composed of species restricted to the Atlantic Ocean and Mediterranean;
- Brazilian Group, whose species are restricted to the BCM.

Examples of the Pandemic Group are *Jonesia cuneata* Schornikhov 1981, *Bythoceratina scaberrima* (Brady 1886), and *Cytheropteron perlaria* Hao 1988 all registered in the Atlantic, Indian, and Pacific oceans. The Atlantic/Mediterranean Group includes *Bythopussella brandtae* Brandão 2008, *Bythocypris affinis* Brady 1880, and *Saida ionia* Ciampo 1988. Lastly, the Brazilian Group is represented by *Cytherella santosensis* Bergue *et al.* 2007, *Microcythere dubia* (Bergue and Coimbra 2008) and *Microcythere acuminata* Bergue *et al.* 2019, for instance. The four new species herein described probably belong to this group, but only additional studies will allow this hypothesis to be tested.

Taxonomic descriptions (by C.T. Bergue & J.C. Coimbra)

The suprageneric taxonomy used herein mainly follows Liebau (2005). Morphological abbreviations: H, height; L, length; W, width; C, carapace; RV, right valve; LV, left valve; AMS, adductor muscle scars; MIS, marine isotope stage.

Subclass OSTRACODA Latreille 1802
Superorder PODOCOPOMORPHA Kozur 1972
Order PLATYCOPIDA Sars 1866
Superfamily CYTHERELLOIDEA Sars 1866
Family CYTHERELLIDAE Sars 1866
Cytherella Jones 1849
Cytherella pindoramensis sp. nov.
(Figs. 2B–2F)

Etymology. From the Tupy language *pindorama* (= the land of palm trees), a designation formerly given to Brazil by native people.

Zoobank register.
act:65791522-F7EF-4A3C-9AFF-1CE913C13D45.

Holotype. MP-O-2950, LV, L = 1.35 mm, H = 0.83 mm (Sample 377 cm, Pleistocene).

Paratypes. MP-O-2951, RV, L = 1.4 mm, H = 0.92 mm (Sample 199 cm, Pleistocene); MP-O-2952, RV, L = 1.4 mm, H = 0.90 mm (Sample 456 cm, Pleistocene); MP-O-2953, LV, L = 1.35 mm, H = 0.93 mm (Sample 178 cm, Pleistocene); MP-O-2954, juvenile RV, L = 0.76 mm, H = 0.55 mm (Sample 43 cm, Holocene); MP-O-2955, juvenile LV, L = 0.73 mm, H = 0.50 mm (Sample 43 cm, Holocene).

Type-locality and horizon. Camamu Basin (Brazil), piston-core CMU 14 (14°24'S; 38°49'12"W). Pleistocene.

Occurrence and abundance. MIS 5, 3, and 1. Samples: 0 cm (1v), 12 cm (1v), 43 cm (1c), 54 cm (1v), 167 cm (1v), 190 cm (1v), 199 cm (2v), 260 cm (1v), 278 cm (1v), 377 cm (1v), and 456 cm (1v).

Stratigraphical and geographical distribution. Known only in the type-locality.

Diagnosis. A giant and smooth species of *Cytherella*. RV much more ovate than LV, overlapping it mainly dorsally and ventrally. A narrow and delicately corrugated rim adorns the LV free margin. A group of two rows with 25 AMS stands out close to the center, just above mid-height.

Description. Very large C. RV overlapping LV along all margins, more conspicuously in the dorsal and ventral ones. Greatest length at mid-height; greatest width in the middle; greatest height median in LV, immediately before the middle in RV. LV subovate to subrectangular in lateral view. Anterior

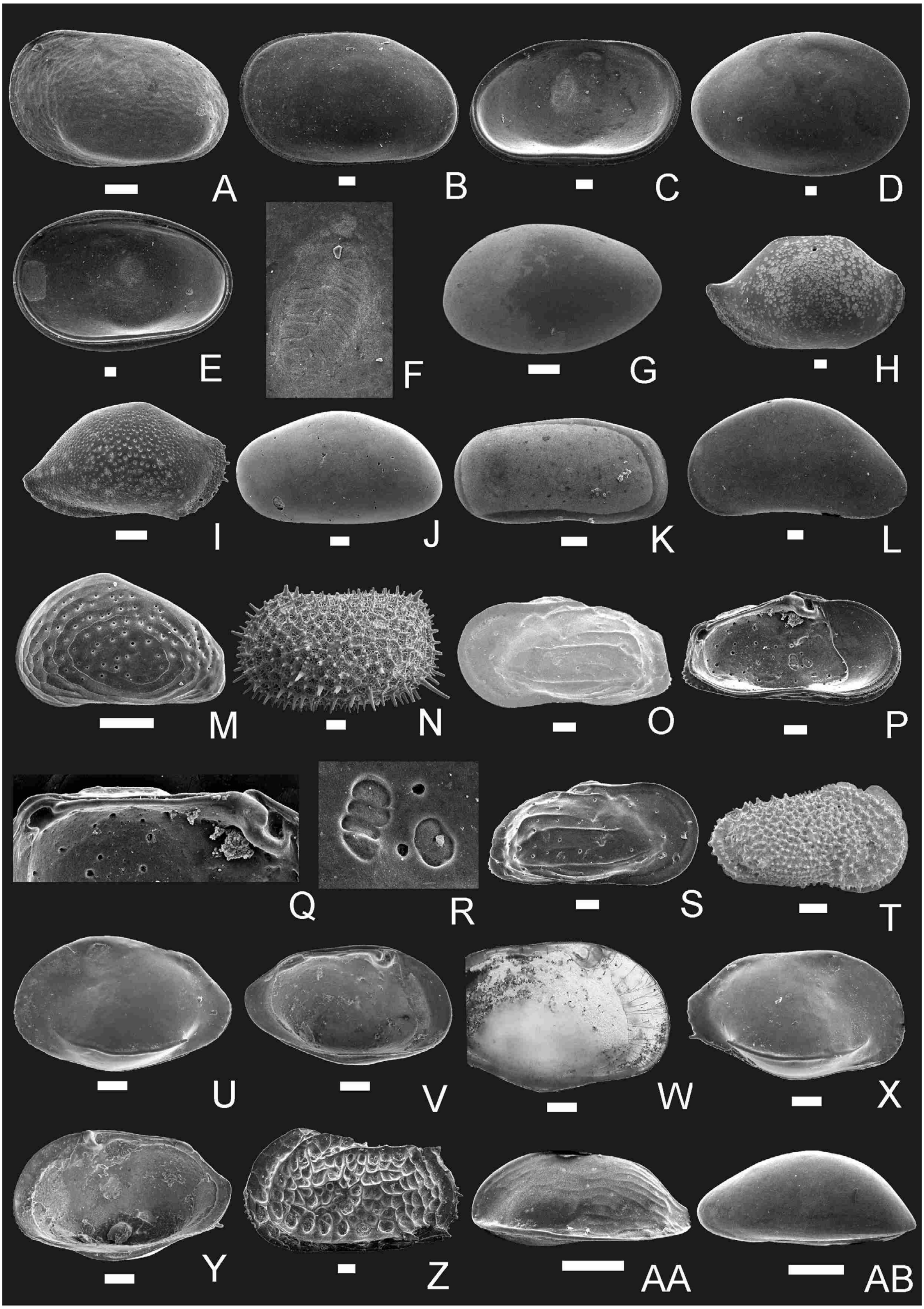

Figure 2. (A) *Cytherella santosensis* Bergue *et al.* 2007, juvenile LV, MP-O-2949; (B–F), *Cytherella pindoramensis* sp. nov. B, LV, holotype, MP-O-2950; (C), holotype internal view; (D), RV, paratype, MP-O-2951; (E) paratype internal view, MP-O-2951; (F) detail of the AMS of the holotype; (G) *Cardobairdia bensoni* (Maddocks 1972), LV, MP-O-2956; (H) *Bairdia* sp. aff. *B. hirsuta* Brady (1880), RV, MP-O-2957; (I) *Bythopussella brandtae* Brandão 2008, RV, MP-O-2958; (J) *Bythocypris affinis* (Brady 1886), male LV, MP-O-2959; (K) *Bythocypris* sp., RV, MP-O-2960; (L) *Zabythocypris* sp., LV, MP-O-2961; (M) *Eucythere circumcostata* Whatley and Coles 1987, LV, MP-O-2962; (N) *Marwickcythereis ericea* (Brady 1880), LV, MP-O-2963; (O–S) *Ambocythere amadoi* sp. nov.; (O) LV, holotype, MP-O-2964; (P) holotype internal view; (Q) detail of the holotype hinge; (R) detail of the holotype central muscle scars; (S) RV, paratype, MP-O-2965; (T) *Rugocythereis horrida* Whatley and Coles 1987, male RV, MP-O-2968; (U–Y) *Pseudobosquetina pucketti* sp. nov.; (U) LV, MP-O-2969, holotype; (V) holotype internal view; (W) details of the holotype CMS and RPC (optical microscopy); (X) RV, paratype, MP-O-2970; (Y) paratype internal view, MP-O-2970; (Z) *Bradleya dictyon* (Brady 1880), RV, MP-O-2974; (AA) *Microcythere dubia* (Bergue and Coimbra 2008), LV, MP-O-2975; (AB) *Microcythere acuminata* Bergue *et al.* 2019, LV, MP-O-2976.

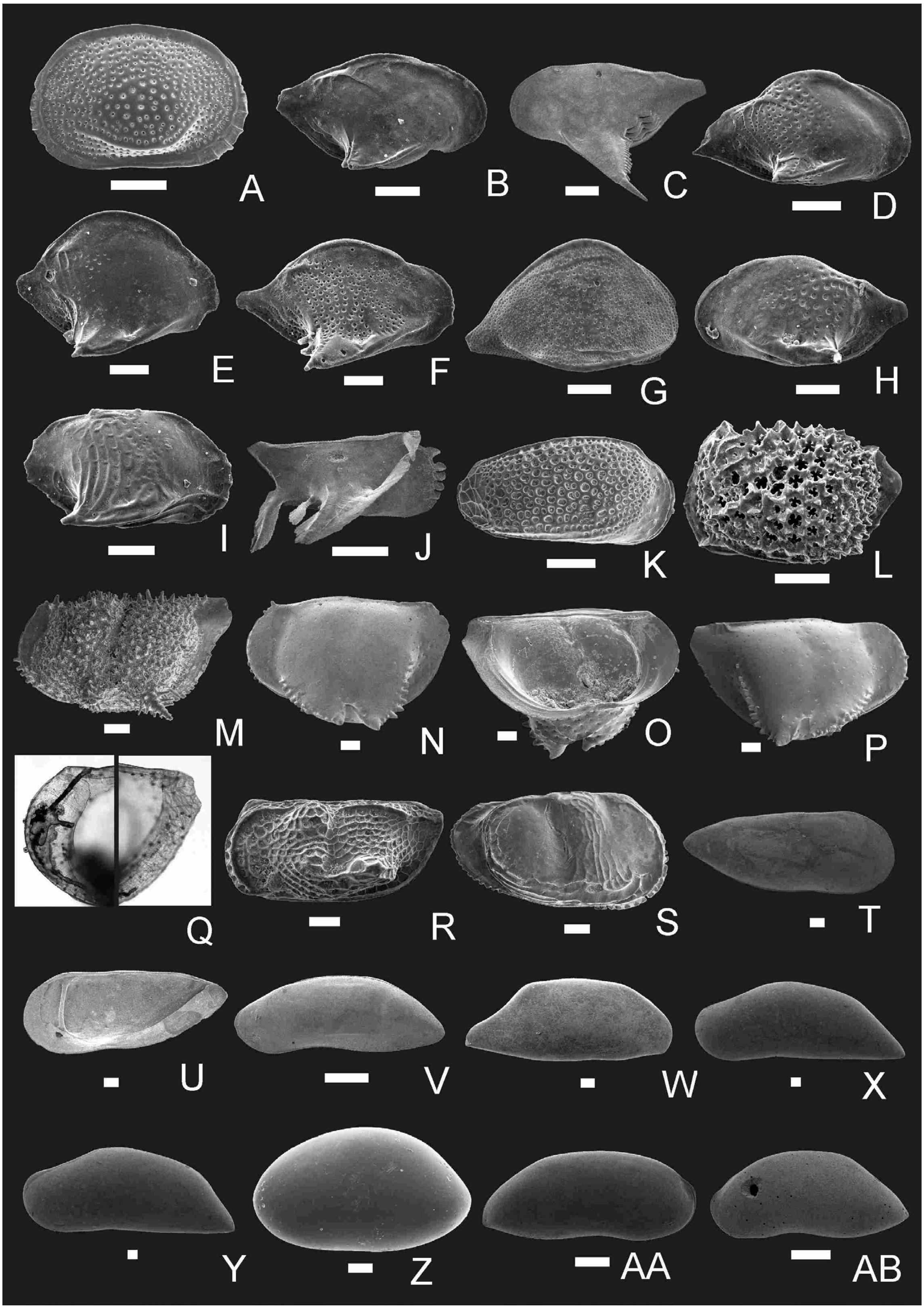

Figure 3. (A) *Saida ionia* Ciampo 1988, LV, MP-O-2977; (B) *Cytheropteron inornatum* Brady and Robertson 1872, RV, MP-O-2976; (C) *Cytheropteron pherozigzag* Whatley *et al.* 1986, LV, MP-O-2979; (D) *Cytheropteron massoni* Whatley and Coles 1987, RV, MP-O-2980; (E) *Cytheropteron lineoporosa* Whatley and Coles 1987, RV, MP-O-2981; (F) *Cytheropteron carolinae* Whatley and Coles 1987, RV, MP-O-2982; (G) *Cytheropteron perlaria* Hao 1988, RV, MP-O-2983; (H) *Cytheropteron demenocali* Yasuhara *et al.* 2009c, LV, MP-O-2984; (I) *Aversovalva hydrodynamica* Whatley and Coles 1987 RV, MP-O-2985; (J) *Pedicythere lachesisopetasi* Yasuhara *et al.* 2009c, RV, MP-O-2986; (K) *Xylocythere turnerae* Maddocks and Steineck 1987 RV, MP-O-2987; (L) *Eucytherura* sp. cf. *E. calabra* Colalongo and Pasini 1980 LV, MP-O-2988; (M) *Bythoceratina scaberrima* (Brady 1866), LV, MP-O-2989; (N–Q) *Bythoceratina bonaterrae* sp. nov.; (N) broken LV, holotype, MP-O-2990; (O) holotype internal view; (P) RV, paratype, MP-O-2992; (Q) detail of the anterior and posterior margins showing the radial porecanals (in optical microscopy); (R) *Bythoceratina* sp., RV, MP-O-2994; (S) *Bythocythere eugenischornikovi*, RV, MP-O-2995; (T–U) *Jonesia cuneata* Schornikhov 1981; (T) RV, MP-O-2996; (U) same specimen internal view; (V) *Paracytherois antarctica* Hartmann 1992, LV, MP-O-2997; (W) *Macrosarissa bensoni* Maddocks 1990, RV, MP-O-2998; (X) *Macropyxis cronini* Brandão 2010 LV, MP-O-2999; (Y) *Macropyxis alanlordi* Brandão 2010, LV, MP-O-3000; (Z) *Australoecia* sp. cf. *A. tipica* van den Bold 1974, LV, MP-O-3001; (AA) *Argilloecia acuminata* Müller 1894, RV, MP-O-3002; (AB) *Argilloecia labri* Yasuhara and Okahashi 2015, LV, MP-O-3003.

margin asymmetrically rounded, more protruded in the upper half. Posterior margin narrowly and asymmetrically rounded, more protruded in the lower half. Dorsal margin slightly convex, sloping posteriorly. Ventral margin with a gentle oral concavity hidden by somewhat convex outline. RV subovate in lateral view. Anterior margin more broadly rounded than in LV, but also asymmetric and more protruded dorsally. Posterior margin similar to the LV. Dorsal and ventral margins hidden by the strongly convex outline. Smooth valve surface. LV with a narrow and delicately corrugated rim along the free margin. Internally, a well-developed selvage-like structure runs along all margins, fitting into a groove in the complementary valve. AMS placed near the center, immediately above middle height, on a subtle internal elevation, being composed of about 25 individual marks grouped into two rows. Above these, a small group of scars lies near the dorsal margin. Sexual dimorphism not observed.

Remarks. Swanson *et al.* (2005) proposed the genus *Inversacytherella* to accommodate cytherellids with a reverse overlap pattern (*i.e.*, LV > RV) and unusual AMS composed of over 20 individual scars. Fossil *Inversacytherella* species were registered in Brazil by Bergue *et al.* (2007, 2019) and Manica *et al.* (2015). Although AMS of *Cytherella pindoramensis* sp. nov. are composed of over 20 scars, the RV is larger than the LV, *i.e.,* the species herein proposed have diagnostic characters of both *Cytherella* and *Inversacytherella*. Following a more conservative approach, we opted to describe this species in the genus *Cytherella*. *Cytherella pindoramensis* sp. nov. differs from most species of the genus recorded in the BCM in having the surface totally smooth. It is somewhat similar to *Inversacytherella pleistocenica* (Bergue *et al.* 2007, Manica *et al.* 2015), but the latter has more subelliptical LV outline and LV larger than RV. *Cytherella pindoramensis* sp. nov. occurs only in interglacial stages in the piston-core CMU 14.

Order PODOCOPIDA Sars 1866

Family TRACHYLEBERIDIDAE Sylvester-Bradley 1948

Ambocythere van den Bold 1957

Ambocythere amadoi sp. nov.

(Figs. 2O–2S)

Etymology. In honor of the Brazilian writer Jorge Amado (1912–2001), born in Bahia State, on whose coast lies the Camamu Basin.

Zoobank register.
act:08771EE1-081B-458D-B841-C62B64748D35.

Holotype. MP-O-2964, LV, L = 0.65 mm, H = 0.30 mm (sample 359 cm).

Paratypes. MP-O-2965, LV, L = 0.63 mm, H = 0.30 mm (sample 238 cm); MP-O-2966, C, L = 0.55 mm, H = 0.35 mm, W = 0.27 mm (sample 260 cm); MP-O-2967, LV, L = 0.56 mm, H = 0.33 mm (sample 260 cm).

Type-locality and horizon. Camamu Basin (Brazil), core CMU 14 (14°24'S; 38°49'W). Pleistocene.

Occurrence and abundance. MIS 5–2. Samples: 144 cm (1v), 238 cm (1v), 260 cm (3v), 283 cm (2v), 289 cm (2v), 359 (1v), and 438 cm (1v).

Stratigraphical and geographical distribution. Known only in the type-locality. Pleistocene.

Diagnosis. A medium and thick-shelled species of *Ambocythere* without a typical caudal process. Dorsal margin with a conspicuous dome-like anterior cardinal angle. Few longitudinal ribs whose length decreases from the ventral to the dorsal region, ornate the last two thirds of each valve. Three delicate rounded spines developed posteroventrally.

Description. Medium carapace, thick shelled, subrectangular in lateral view. Greatest length at mid-height; greatest height in the first third; greatest width posteriorly. Dorsal margin well marked by the anterior cardinal angle, situated roughly at mid-length of each valve. Ventral margin sinuous, slightly obscured by a ventral carina mainly in RV, and with oral concavity at mid-length. Anterior margin supracurvate bordered by a carina running from the base of the dome formed at the anterior cardinal angle, up to the mid-ventral. Posterior margin obliquely truncate, ventrally ornamented by three delicate rounded spines. Surface predominantly smooth at the anterior third; median and posterior parts marked by few longitudinal ribs whose length decreases from the ventral toward the dorsal ones. A gentle dorsal rib runs sinuously along the posterior half. Large normal pore-canals scattered along the surface, more numerous in the posterior half. Internally, very wide anterior duplicature with a sinuous inner margin; posterior one relatively narrow. Central muscle scars typical for the genus, placed at the lower half and marked by two normal porecanals between the AMS and frontal scar. Hinge holamphidont quite robust compared to other species of the genus. LV anterior element, a deep subtriangular socket completely closed. Anterior tooth elongated and projected forward, followed by a thick smooth bar slightly enlarged posteriorly. Posterior socket deep, subelliptical, and open. Marginal porecanals numerous, some branched near the anterior margin. Sexual dimorphism not seen.

Remarks. *Ambocythere amadoi* sp. nov. belongs to a group of species of the genus with a non-projected posterior margin. It differs from *A. hyakunome* Yasuhara *et al.* 2015, described in the northwestern Atlantic, mainly in the outline of the posterior margin, surface features, and robustness of hinge elements. From *A. circumporus* Bergue *et al.* 2017 differs mostly in having a more subrectangular outline, a less ornate surface, and absence of a typical caudal process.

Pseudobosquetina Guernet and Moulade 1994

Remarks. The authors are aware of the debate about the validity of the genus *Pseudobosquetina*, mainly about its synonymization (or not) with the oldest genus *Pterygocythere* Hill 1954. Ayress *et al.* (2004) and Yasuhara *et al.* (2015), although they did not elaborate on this subject, considered *Pseudobosquetina* as a junior synonym of *Pterygocythere*. Conversely, Jellinek *et al.* (2006, and bibliography therein) not only thoroughly discussed the similarities and differences of *Pseudobosquetina* with several other genera, but also ratified *P. mucronulata* (Brady 1880) as its type species. In addition, they described in detail two new species for this genus, which is still poorly diversified.

Pseudobosquetina pucketti sp. nov.

(Figs. 2U–2Y)

Etymology. In honor of Terry Markham Puckett for his contribution to the taxonomy and paleozoogeography of Brachycytherinae.

Zoobank register.
act:2E388EA5-B88D-4701-92D6-14124A90FDA5.

Holotype. MP-O-2969, LV, L = 0.70 mm, H = 0.45 mm (sample 167 cm).

Paratypes. MP-O-2970, LV, L = 0.80 mm, H = 0.50 mm (sample 377 cm); MP-O-2971, LV, L = 0.70 mm, H = 0.47 mm (sample 199 cm), MP-O-2972, RV, L = 0.68 mm, H = 0.40 mm (sample 167 cm); MP-O-2973, LV, L = 0.70 mm, H = 0.45 mm (sample 278 cm).

Type-locality and horizon. Camamu Basin (Brazil), core CMU 14 (14°24'S; 38°49'W). Pleistocene.

Occurrence and abundance. MIS 5 and 3. Samples: 167 cm (2v), 199 cm (2v), 278 cm (2v), 371 cm (1v), and 377 cm (1v).

Stratigraphical and geographical distribution. Known only in the type-locality.

Diagnosis. Carapace small, very inflated in the middle, and depressed in the anterior and posterior regions. Surface predominantly smooth, except for a feeble but conspicuous ventrolateral rib with short backwardly projected spine. LV without a dorsal plicated area. Anterior duplicature with mostly branched radial porecanals.

Description. Carapace small, strongly calcified, laterally depressed, and quite inflated medianly. Greatest length at mid-height; greatest height and greatest width near the middle. LV suboval in lateral view; RV more subrectangular. LV dorsal margin almost straight, short and slightly oblique; ventral margin slightly convex, but masked by the outline due to the median inflation of carapace. Anterior margin infracurvate in LV, more equicurvate in RV; posterior margin oblique in the upper part and forming median but short caudal process more truncate and with a spine in RV. Surface predominantly smooth. Ventrolateral region marked with feeble rib, almost invisible in its anterior part and becoming gradually thicker toward the posterior region, which holds a short and backwardly projected spine. Subparallel and below this rib, two or three few visible ribs. Regions adjacent to the cardinal angles marked with pits, the anterior one deeper than the posterior one. Normal porecanals few and sparse, more concentrated at the dorsal and posterodorsal margins. Internally, hinge amphidont, with anterior, median, and posterior elements well-defined. Anterior element composed of oblong small socket followed by bilobate tooth; median element composed of bar marked at the middle by short and shallow longitudinal sulcus; posterior socket long and faintly crenulated. Accommodation groove conspicuous along the middle element. Anterior duplicature fairly wide with line of concrescence and inner margin coincident, and with about 15 true (mostly branched) and three false radial porecanals. Posterior duplicature narrow with sparse radial porecanals, not properly observed in the specimens analyzed. AMS discrete but typical of the genus, composed of a row of four small adductor scars and a U-shaped frontal one placed slightly above the mid height. Ventral region marked with deep and well-developed sulcus analogous to the accommodation groove, where the ventral portion of the RV probably fits. Sexual dimorphism not observed.

Remarks. The LV of *Pseudobosquetina pucketti* sp. nov. is similar to the LV of the Cretaceous species *Brachycythere sphenoides* (Reuss 1854), illustrated by Jellinek *et al.* (2006, Figs. 1G and 1H), but differs externally mainly in the obliquity of the dorsal margin and position and robustness of the ventrolateral rib. *Pseudobosquetina pucketti* sp. nov. resembles brachycytherine ostracods, mainly *Brachycythere* in several aspects, however, the adductor muscle scars are clearly different. Puckett (2002) argues that the median adductor scars of brachycytherine are subdivided, while in *P. pucketti* sp. nov. they are not. The hinge of *P. pucketti* sp. nov. is more robust than the specimens illustrated by Jellinek *et al.* (2006), and the radial pore canals are predominantly branched. Moreover, those species are larger and present feeble reticulation in some parts of carapace, contrasting with *P. pucketti* sp. nov, which is totally smooth. Finally, it is noteworthy the absence of a plication dorsal area in the LV of *P. pucketti* sp. nov.

Family BYTHOCYTHERIDAE Sars 1866

Bythoceratina Hornibrook 1953

Bythoceratina bonaterrae sp. nov.

(Figs. 3N–3Q)

2008 *Bythocythere* sp. Bergue and Coimbra, p. 117, pl. 2, figs. 10, 11.

Etymology. *L.* In allusion to *Boa Terra* (=good land), an informal designation for the Bahia State, where the Camamu Basin lies.

Zoobank register.
act:BA4727B3-5A20-4599-AA6B-375609705EAA.

Holotype. MP-O-2990, LV, L = 1.10 mm; H = 0.65 mm (Sample 432 cm, Pleistocene).

Paratypes. MP-O-2991, RV, L = 1.12 mm; H = 0.60 mm (Sample 36 cm, Holocene); MP-O-2992, LV, L = 1.08 mm; H = 0.70 mm (Sample 456 cm, Pleistocene); MP-O-2993, RV, L = 1.03 mm; H = 0.55 mm (Sample 450 cm, Pleistocene).

Type-locality and horizon. Camamu Basin, core CMU 14 (14°24'S; 38°49'12''W). Holocene.

Occurrence and abundance. MIS 5, 3, and 1. Samples: 12 cm (2v), 43 cm (2v), 199 cm (1v), 260 cm (1v), 322 cm (1v), 335 cm (1v), 341 cm (3v), 395 cm (1v), 414 cm (3v), 432 cm (1v), 450 cm (1v), and 456 cm (1v).

Stratigraphical and geographical distribution. Pleistocene: Santos Basin (Brazil); Pleistocene–Holocene: Camamu Basin (Brazil); Recent: South Atlantic (*Albatross* Station 2760, 12°11'S; 37°28'W).

Diagnosis. A quite large species of *Bythoceratina*. Carapace predominantly smooth, but with numerous small normal porecanals. Anterior and posterior extremities of the bifurcated alae ornate with obtuse spines, some forked, and others simple, short, and robust.

Description. Carapace very large, subrectangular with outline strongly modified due to the well-developed alae. Anterior and posterior parts of the carapace flattened; the middle one inflated and with subtle and curved sulcus. Greatest length dorsally; greatest height and greatest width posteriorly. Dorsal margin almost straight but masked externally by longitudinal ridge resulting in false sinuosity in the anterior third. Ventral margin strongly sinuous, with conspicuous concavity in the oral region. Anterior margin slightly supracurvate with few delicate marginal spines whose number and position vary between the RV and the LV. Posterior margin supracurvate, marked by a short caudal process in line with hinge. Surface smooth, with numerous and small normal porecanals scattered throughout the carapace. A well-developed alae backwardly projected, subdivided and with a terminal spine at each extremity. Alae margin with many obtuse spines, some bifurcated, others simple, short, and robust. Internally, large duplicature as for the genus. Hinge merodont; anterior and posterior elements of LV composed by elongate sockets; median element a narrow crenulate grove. Central muscle scars and marginal porecanals not seen. Sexual dimorphism not observed.

Remarks. This quite large and smooth species of *Bythoceratina* shows many small and regularly scattered normal pore canals, and peculiar spines bordering the margin of the bifurcated alae, making it easy to distinguish it from the other species of the genus.

DISCUSSION

Paleoclimatic and paleobathymetric analyses in this paper are based on previously described ostracod species and in new species proposed herein, totaling 40 taxa (Figs. 2 and 3, Tab. 1). Only 19 of these species have been previously registered in the BCM or in the Rio Grande Rise. Data from the core CMU 14, therefore, indicate that bathyal ostracod assemblages from the northeast region of the BCM differ to some degree from the southeastern and southern ones. Additional studies, however, are necessary to test this hypothesis.

Occurrences along the CMU 14 reveal patterns at species and family level, not only of bathymetric preferences, but also their MIS occurrence. Considering that some of these species have been registered elsewhere along BCM, they constitute potential paleoclimatic indexes. An analogous pattern has been observed in other oceanic regions as, for instance, in the Arctic Ocean, where major climatic transitions in the mid-to-late Quaternary are correlated to foraminifera and ostracods turnovers (Cronin *et al.* 2014). Bergue *et al.* (2017) discussed a possible correlation between the MIS and the occurrences of some ostracod species in bathyal regions off Brazil and southeast of the USA, based on the finding that *Aversovalva tomcronini* Bergue *et al.* 2016, *Bythocypris kyamos* Whatley *et al.* 1998 and *Saida ionia* are restricted to MIS 1. Occurrences of other species in the Campos Basin (Southeastern Brazilian Margin) also demonstrated paleoclimatic influence, particularly decreased diversity during MIS 2 (LGM) (Bergue *et al.* 2017).

In the core CMU 14 the most conspicuous pattern in terms of assemblage composition is also the decrease in abundance and diversity in MIS 2 (Fig. 4). Moreover, the occurrence of Bythocyprididae and Bythocytheridae is limited — with rare exceptions — to interglacial stages. Regarding Bythocyprididae (Fig. 5), *Bythocypris affinis* and *Bythocypris* sp. occur only in MIS 1, while *Zabythocypris* sp. occurs in MIS 5, 3 (rare), and 1. The Bythocytheridae species (Fig. 6) show pattern similar to Bythocyprididae except for the single occurrence of

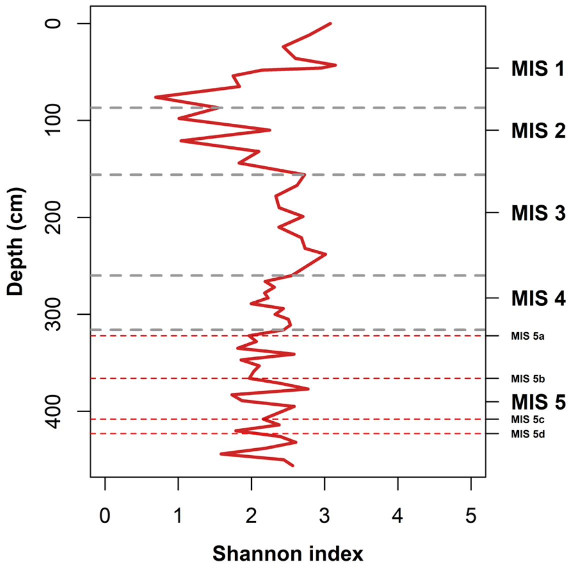

Figure 4. Shannon-Wiener diversity in CMU 14.

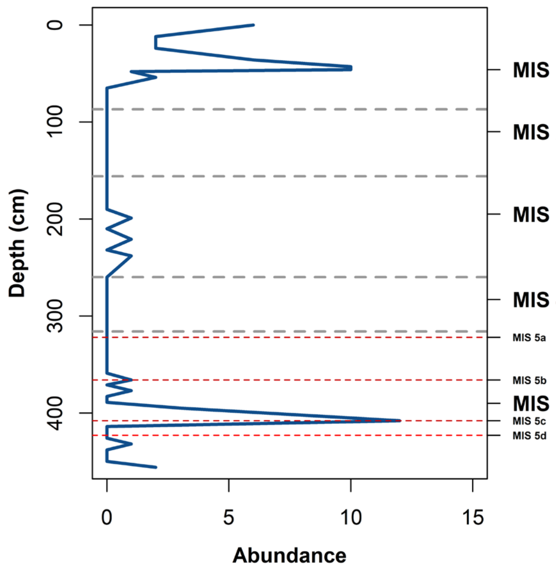

Figure 5. Total abundance of Bythocyprididae along the core CMU 14.

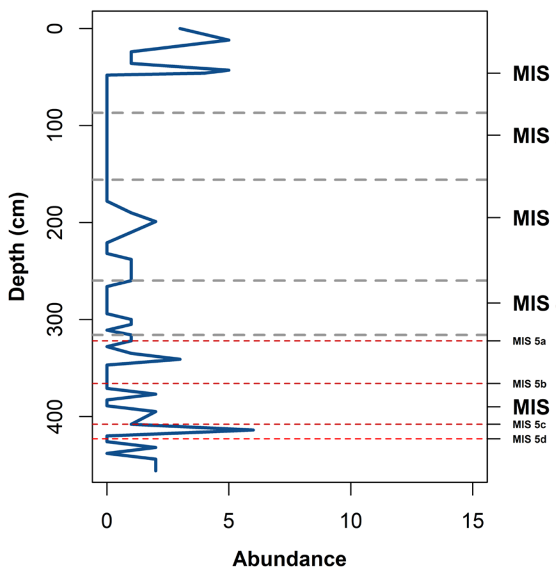

Figure 6. Total abundance of Bythocytheridae along the core CMU 14.

Bythoceratina sp. in MIS 4 (300 cm). Other species are also restricted to interglacial stages along the core CMU 14, such as *Ambocythere circumporus*, *Bradleya dictyon* (Brady 1880), *Cytherella pindoramensis* sp. nov., *Cytheropteron perlaria* and *Cytheropteron inornatum* Brady and Robertson 1872.

On the other hand, a few taxa (*e.g.* *Rugocythereis horrida* (Whatley and Coles 1987) and *Macrosarisa bensoni* Maddocks 1990 occur continuously throughout the core. Ostracods species with continual occurrence are not uncommon in the fossil record as demonstrated by *Bradleya majorani* Bergue *et al.* 2019, in the Rio Grande Rise and *Paracypris polita* Sars 1866 in the Mediterranean (Pirkenseer *et al.* 2018). Probably, taxa with continual occurrence are physiologically less influenced by the OMZ and thermocline depth changes, that triggers upslope/downslope migrations (Rodriguez-Lazaro and Cronin 1999). In the core CMU 14, however, the changes

Table 1. Species registered in the core CMU 14 and in other bathyal regions in the BCM and respective marine isotope stage.

Species	(a,b)Pelotas	(c)Santos	(d, e)Campos	(f)Camamu
Ambocythere amadoi sp. nov.				5-2
Ambocythere circumporus		1	3, 1	5, 3
Argilloecia acuminata			2, 1	5-1
Argilloecia labri			3	5, 3
Aversovalva hydrodynamica		2, 1	2,1	5, 2, 1
Bairdia sp. aff. *B. hirsuta*		1		5-1
Bradleya dictyon				5, 1
Bythoceratina bonaterrae sp. nov.		Ple		5, 3, 1
Bythoceratina scaberrima				5, 4, 1
Bythoceratina sp.	1	1	2,1	1
Bythocypris sp.	1	1	1	
Bythocypris affinis			1	1
Bythocythere eugeneschornikovi				5, 1
Bythopussela brandtae				3
Cardobardia bensoni				5-1
Cytherella santosensis		Ple		5, 4
Cytherella pindoramensis				5, 3, 1
Cytheropteron carolinae				1
Cytheropteron demenocali				3, 1
Cytheropteron inornatum				5, 3, 1
Cytheropteron lineoporosa				3, 1
Cytheropteron massoni				3
Cytheropteron perlaria	1	Ple/1	1	5-1
Cytheropteron pherozigzag				5, 3
Eucythere circumcostata				1
Eucytherura sp. cf. *E. calabra*		2,1		3-1
Jonesia cuneata		Ple		3, 1
Macropyxis alanlordi				5
Macropyxis cronini				5, 2, 1
Macrosarisa bensoni				5-1
Marwickcythereis ericea			2	5-1
Microcythere dubia		2,1		3
Microcythere acuminata				2
Paracytherois antarctica				5, 3-1
Pedicythere lachesisopetasi		2,1		5-3, 1
Pseudobosquetina pucketti				5,3
Rugocythereis horrida				5-1
Saida ionia	1	1	1	3, 1
Xylocythere turnerae				5-3, 1
Zabythocypris sp.				5,3,1

(A) Bergue *et al.* (2016); (B) Maia et al. (2021); (C) Bergue and Coimbra (2008); (D) Sousa *et al.* (2013); (E) Bergue *et al.* (2017); (F) this study; Ple: Pleistocene.

observed in assemblages composition are probably related to productivity instead because the core site is below the thermocline. Therefore, the appearance/disappearance of species along the core CMU 14 are neither attributed to hydrological changes nor to speciation/extinction, but to productivity variations climatically induced as observed by Cronin *et al.* (1999) and Yasuhara *et al.* (2009b).

Comparison of CMU 14 data to previous studies in the BCM (Tab. 1) also reveals three bathymetric intervals of occurrence: an outer neritic/upper bathyal (~400 m water depth); a middle bathyal (400–1,000 m water depth); and a lower bathyal (below 1,000 m water depth). The taxonomic composition of the assemblages in these intervals might vary from basin to basin, but in general they share some characteristics as described below.

Outer neritic/upper bathyal assemblages

Composed of species which inhabit both the outer shelf and the upper part of the slope. These asemblages are particularly prone to be influenced by changes in the thermocline depth, and most of their species have limited geographic occurrence. Examples: *Aversovalva tomcronini*, *Bradleya gaucha* Bergue *et al.* 2016, *Cytherella pleistocenica* Bergue *et al.* 2007, *Eucythere macerata* Bergue and Coimbra 2008, *Krithe coimbrai* Do Carmo and Sanguinetti 1999, and *Krithe gnoma* Do Carmo and Sanguinetti 1999.

Middle bathyal assemblages

These assemblages have a high incidence of psychrospheric taxa such as bythocytherids, bythocypridids, and some krithids. Some species present broad geographic occurrence. Examples: *Apatihowella acelos* Bergue *et al.* 2016, *Apatihowella besnardi* Bergue *et al.* 2016, *Bythoceratina scaberrima, Cytheropteron perlaria*, *Legitimocythere aorata* Bergue and Coimbra 2008, and *Saida ionia*.

Lower bathyal assemblages

Species registered in the BCM exclusively below the 1,000 m isobath. Many have pandemic distribution. The most characteristic component of this fauna is *Poseidonamicus* Benson 1972 (Bergue and Coimbra 2008, Bergue *et al.* 2017, Maia *et al.* 2021, and other unplublished data), which constitutes a reliable hydrological marker. Examples: *Cytherella santosensis*, *Krithe trinidadensis* van den Bold 1958, *Krithe morkhoveni* van den Bold 1960, *Jonesia cuneata*, *Poseidonamicus hisayoae* Yasuhara *et al.* 2009a, and *Poseidonamicus pintoi* Benson 1972.

CONCLUSIONS

- Assemblages of the core CMU 14 (northeastern margin) show some differences in composition when compared to the southern Brazilian margin ones (*i.e.* Pelotas, Santos, and Campos), possibly due to ecological particularities linked to the slope morphology, which influenced locally ostracod faunas during the last 108 kyr;
- Bythocytheridae and Bythocyprididae of the present study have a climatically induced pattern of occurrence, as evidenced by their remarkable records during the interglacial MIS, and are possibly paleoceanographical markers;
- Podocopid richness diminished during the LGM (MIS 2) but no faunal turnover is observed, because all species occurring after the LGM are also present before it, except *Bythocypris affinis* and *Bythocypris* sp.;
- The association *Bythocypris affinis–Cytherella pindoramensis* sp. nov.– *Cytheropteron perlaria–Bradleya dictyon* characterize MIS 5 and 1 (interglacials). Glacial stages do not present typical associations, but as a rule they show lower diversity;
- The data from the CMU 14 reinforce the possibility of an ostracod-based climatic zoning for the BCM as preliminarily proposed by Bergue *et al.* (2017).

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