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# PALAEOENVIRONMENTAL SIGNIFICANCE OF ALLOCHTHONOUS *VS.* AUTOCHTHONOUS LATE QUATERNARY OSTRACODES FROM IMARUÍ LAGOON AND D'UNA RIVER, SOUTHERN BRAZIL

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ABSTRACT – Late Quaternary ostracodes collected from 15 cores in two adjacent localities, Imaruí and D'Una River, both in Santa Catarina State, southern Brazil, were analyzed. Among the 12 identified species, only three are left in open nomenclature. The population age-structure was studied in order to distinguish between allochthonous *vs.* autochthonous ostracodes in each sample. Two typically mixohaline species, *Cyprideis multidentata* Hartmann and *C. salebrosa* Bold, are the most abundant autochthonous fossils in the cores. The taphonomic analysis and the sedimentological evidences allow the inference of a permanent lagoonal palaeoenvironment in the 15 cores. Micropalaeontological and geological data suggest that the marine species were transported into the lagoonal palaeoenvironment, reworked with the autochthonous mixohaline fauna and deposited along the lagoonal border.

**Key words:** Late Quaternary, ostracodes, palaeoenvironments, taphonomy, southern Brazil.

RESUMO – Foram analisados os ostracodes recuperados de 15 perfurações realizadas em duas áreas adjacentes, o município de Imaruí e a região do Rio D'uma, ambas no Estado de Santa Catarina, sul do Brasil. Dentre as 12 espécies identificadas apenas três foram deixadas em nomenclatura aberta. O estudo da estrutura populacional, realizado em cada amostra, permitiu a diferenciação entre fauna alóctone *vs.* autóctone. As espécies mixohalinas *Cyprideis multidentata* Hartmann e *C. salebrosa* Bold são os fósseis autóctones mais abundantes nos testemunhos investigados. A análise tafonômica e as evidências sedimentológicas indicaram um paleoambiente tipicamente lagunar ao longo das 15 perfurações. Tanto a microfauna quanto os dados advindos da geologia sugerem que as espécies marinhas foram transportadas para o ambiente lagunar, retrabalhadas juntamente com a fauna mixohalina e depositadas ao longo da borda da laguna.

**Palavras-chave:** Neoquaternário, ostracodes, paleoambientes, tafonomia, sul do Brasil.

## INTRODUCTION

The coast of Santa Catarina State, southern of Brazil, is characterized by extensive sedimentary coastal plains with mineral deposits. The region has a large deposit of calcareous shells with economic relevance and great significance in an evolutionary perspective of the coastal plain. The southern coast of this State has some lagoons and coastal lakes being the Mirim, Imaruí and Santo Antônio lagoons complex the main regional aquatic body, which has been object of geological, sedimentological and morphological studies (Caruso Jr., 1995a). The shell deposits have been studied from a palaeontological point of view, especially concerning micromolluscs (Pitoni, 1993; Mendes, 1993) and foraminifers (Thiesen *et al*., 1993). The previous palaeontological studies were mainly taxonomic ones included some data about palaeoecology. Using sedimentological analysis Caruso Jr. (1995a, 1995b) dated the shell deposits in the Imaruí region to the Holocene.

## STUDY AREA

Studies carried out on the coast of the State of Santa Catarina have revealed large oscillations of the sea level during the Quaternary (Suguio *et al*., 1985, 2005; Martin & Suguio, 1986; Martin *et al*., 1988; Gré *et al*., 1993). During that interval, the evolution of the southern Brazilian continental margin was driven by global changes affecting climate and sea level oscillations, due to the geode response to the variations of the ice masses and surface water distribution. In particular, the sea level changes exerted the strongest influence on the construction of the coastal plains, and marine sediments deposited on the continental deposits were repeatedly reworked by transgressions/regressions (Caruso Jr., 1995a, 1995b, 1999; Villwock & Tomazelli, 1995; Carreño *et al*., 1999; Caruso Jr. *et al*., 1999). This allowed the accumulation of coastal marine and eolic deposits which, in some cases, originated bars that isolated coastal lagoons. The shell deposits have an irregular distribution along the coastal plain probably associated to a palaeolagoonal environment occurring at 5100 B.P. during the maximum of the Holocene transgression. As a result, an extensive lagoonal zone was created with a much larger distribution of sand than found at the present day (Caruso Jr., 1992).

## MATERIAL AND METHODS

The material analyzed originates from drilling cores carried out in the southeastern region of the coastal zone of the State of Santa Catarina and designated by prefix LI-01, IM and D. The core LI-01 is located in the central part of the Imaruí Lagoon, 4.5 km from the coast margin, while IM cores are situated in the district of the municipality of Imaruí, 12 km from the coast. The core D are located in the D'Una River between Imaruí and Imbituba, about 8 km from the coast (Figure 1). This study concerns the analysis of 73 samples: 29 samples from the Imaruí area were collected from six sediment-cores (IM-03, IM-06, IM-09, IM-34, IM-40, and IM-102) drilled between the SC-437 highway and the edge of the north of the Imaruí Lagoon; 44 samples from the D'Una River came from eight sediment-cores (D-133, D-200, D-236, D-315, D-323, D-412, and D-434) drilled along the flood plains of the D'Una River; finally nine samples came from the core LI-01 (Figure 1).

The sediment-cores were obtained through the courtesy of the company Inducal, with the aim of defining the calcareous shell reserves and spatial distribution of the beds in the studied localities. Sondeq equipment was used for probing to recover 15 m of sediments, and the samples were taken at intervals of 60 cm. The core LI-01 was sampled at intervals of 1 m, except for the two superficial samples, which were 5 m spaced. The material was sieved and dried into three different size fractions: 0.250, 0.177 and 0.074 mm.

The Shannon-Wiener diversity index, equitability and dominance were calculated in level of genera by means of the Paleontological Statistics (PAST) program (Table 1). It is important to record that only the genus *Cyprideis* is represented by more than one species, *C. salebrosa* and *C. multidentata*, and both have the same ecological requirements. All the figured specimens (Figure 2, Appendix 1) were illustrated using SEM and they are housed at the Ostracoda section (MP-O) in the collection of the Departamento de Paleontologia e Estratigrafia of the Universidade Federal do Rio Grande do Sul (UFRGS).

## FAUNAL DISTRIBUTION

The ostracode assemblages studied in both areas are represented by mixohaline species (*Cyprideis multidentata, Cyprideis salebrosa, Perissocytheridea kroemmelbeini*), eurihaline species (*Loxoconcha bullata*, *Callistocythere litoralensis*) and marine species (*Orionina similis*, *Ruggiericythere dimorphica*, *Argenticytheretta laevipunctata*, *Neocaudites triplistriatus*, *Paracypris* sp., *Cytherella* sp. and *Bairdopillata* sp.). The most abundant mixohaline, euryhaline and marine species are *C. multidentata, L. bullata* and *R. dimorphica*, respectively (Table 1, Figure 2).

Except by one sample, all the analyzed material from D'Una River and Imaruí show the dominance of *C. multidentata* and *C. salebrosa*. A low occurrence of *L. bullata*, *C. litoralensis*, *R. dimorphica* and *P. kroemmelbeini* it is also recorded, but always more abundant in D'Una River. In both areas instars of *C. multidentata* and *C. salebrosa* were found even if with a very high A:J ratio. On the contrary, a large number of instars of these two mixohaline species is present in the samples of the LI-01 core (Table 1).

## TAPHONOMY AND PALAEOENVIRONMENTS

Ostracodes are an important tool for making palaeoecological interpretations, inclusive from ancient marginal marine environments. Slack *et al*. (2000), studying samples from Lake Manzala, considered the most abundant and mixohaline species *Cyprideis torosa* (Jones) as noise which had masked the signal of rare species. However, our analyses on both D'Una River and Imaruí reveal that the marine species should be considered as noise and the abundant mixohaline *Cyprideis* as a strong environmental signal. Additional taphonomical and palaeoecological analyses based only on marine taxa, demonstrate that these taxa have an allochthonous population structure and should be considered as environmental noise.

Studies using Recent and Quaternary ostracodes demonstrated that the population age structure analysis of each species included in the ostracod assemblages is useful to discriminate between biocenoses and thanatocenoses (Wagner, 1957; Whatley & Wall, 1969). This technique has also been used for fossil faunas and leads to recognize the energy levels which characterised the palaeoenvironment (Whatley, 1983, 1988; van Harten 1986; Brouwers, 1988; Whatley & Boomer, 1995). During their life cycle the ostracodes moults eight times until reaching the adult stage. Thus, in a low energy environment, one individual could leave 18 valves in the sediment. The ideal preservation of the real populational age structure will produce an average of adult:juvenile valves (A:J ratio) of 1:8, where the ninth and last stage is counted as adult. As many early ontogenetic stages are destroyed, mainly by taphocoenotic factors, the A:J ratio will be modified from the ideal 1:8 to an interval near 1:5 or 1:6, but even intervals from 1:3 to 1:6 are considered enough good to characterise authochtonous fossil species (Brouwers, 1988).

The population age structure of *Cyprideis multidentata* and *C. salebrosa* have been analyzed in this paper using all juveniles and adults collected in the studied cores. In the samples that came from Imaruí and D'Una River the number of adult valves is much higher than the young ones (Table 1). According to Brouwers (1988) these high A:J ratios point to an allochthonous concentration deposited in a high energy environment. In the Imaruí and D'Una River cores these species, it is suggested, have suffered *post mortem* transport processes in high energy environments.

At the LI-O1 core, it was observed that the *C. multidentata* and *C. salebrosa* population age structure is opposite to that shown in Imaruí and D'Una River. In this core, young instars were approximately 80% of the total population, except for the two first samples, in which the A:J ratio is 1:1 (Table 1). These relatively low ratios could still indicate an allochthonous fauna deposited in high energy environments, but it should be pointed out that the energy level recorded in the LI-01 core should has been lower than that reported in Imaruí and D'Una River because here the A:J ratios are lower. The samples depth 1-2 m, 2-3 m and 6-7 m present ratios of 1:2, showing an asymmetrical proportion of young valves in relation to adult ones. According to Brouwers (1988), this ratio characterizes those faunas that are deposited in low energy environments. The samples depth 3-4 m, 4-5 m, 5-6 m and 7-8 m present ratios comprised between 1:3 and 1:6, thus recorded authochtonous fauna, which did not suffer transport *post-mortem* (Table 1).

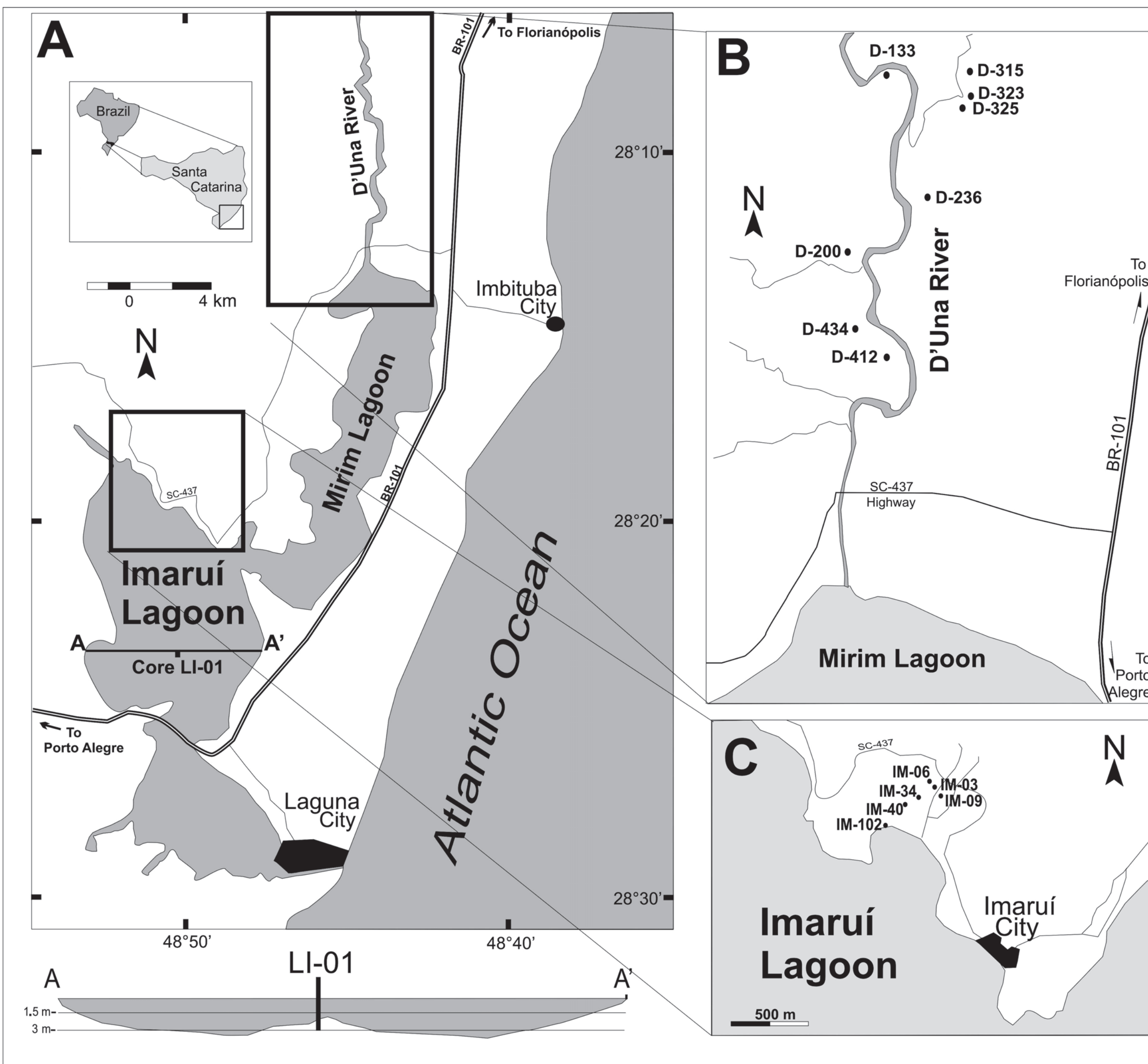


**Figure 1.** Location map of the study area: **A**, A-A' transversal section with the core LI-01; **B**, location of D'Una River area and cores studied; **C**, location of Imaruí Lagoon and studied cores.

**Table 1.** Ecological and sedimentological data and the A:J ratio of *Cyprideis* in each fossiliferous sample. For the methodology used to calculate the Shannon-Wiener diversity index, equitability and dominance see the text. Total of specimens = 8284; OM = organic matter.

| Core | Depth (m) | Sediment | Shannon-Wiener | Dominance | Equitability | *P. kroemmelbeini* | *L. bullata* | *R. dimorphica* | *O. similis* | *Bairdoppilata* sp. | *Paracypris* sp. | *Cytherella* sp. | *N. triplistriatus* | *A. laevipunctata* | *C. litoralensis* | *C. salebrosa* | *C. multidentata* | *Cyprideis* (juveniles) | A:J ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LI-01** | **0,0-0,5** | clay | - | 1 | - | | | | | | | | | | | 2 | | 3 | 01:01 |
| **LI-01** | **0,5-1** | clay | 0.31 | 0.83 | 0.44 | 5 | | | | | | | | | | 49 | | 52 | 01:01 |
| **LI-01** | **1-2** | clay | 0.26 | 0.86 | 0.38 | 4 | | | | | | | | | | 44 | 6 | 111 | 01:02 |
| **LI-01** | **2-3** | clay | - | 1 | - | | | | | | | | | | | 67 | 26 | 232 | 01:02 |
| **LI-01** | **3-4** | clay | 0.04 | 0.98 | 0.06 | 1 | | | | | | | | | | 108 | 32 | 862 | 01:06 |
| **LI-01** | **4-5** | clay | 0.05 | 0.98 | 0.04 | 2 | 2 | | | | | | | | | 402 | 152 | 2508 | 01:05 |
| **LI-01** | **5-6** | clay | 0.08 | 0.97 | 0.12 | 1 | | | | | | | | | | 46 | 14 | 225 | 01:03 |
| **LI-01** | **6-7** | clay | 0.65 | 0.63 | 0.6 | | 1 | | | | | | | | 4 | 16 | 1 | 37 | 01:02 |
| **LI-01** | **7-8** | clay | 0.03 | 0.99 | 0.05 | 1 | | | | | | | | | | 135 | 49 | 621 | 01:03 |
| **IM-03** | **1,2-1,8** | clay + OM | - | 1 | - | | | | | | | | | | | 5 | | 5 | 01:01 |
| **IM-03** | **4,2-4,8** | clay | - | 1 | - | | | | | | | | | | | 29 | 17 | 43 | 01:01 |
| **IM-03** | **4,8-5,4** | clay | 0.29 | 0.88 | 0.21 | | | | | | 1 | 2 | | | 6 | 44 | 89 | 27 | 05:01 |
| **IM-03** | **6,6-7,2** | clay + OM | 0.69 | 0.5 | 1 | | | | | | | | | | 2 | | 2 | | |
| **IM-03** | **9,6-10,2** | clay + OM | - | 1 | - | 2 | | | | | | | | | | | | | |
| **IM-06** | **4,8-5,4** | clay + sand | - | 1 | - | | | | | | | | | | | 12 | 24 | 5 | 07:01 |
| **IM-06** | **5,4-6,0** | clay + sand | 0.44 | 0.79 | 0.32 | | 7 | | | | 1 | | 2 | | | 27 | 53 | 38 | 02:01 |
| **IM-06** | **7,2-7,6** | clay + sand | 0.64 | 0.55 | 0.92 | | | | | | | | | | | | 1 | | |
| **IM-06** | **8,4-9,6** | clay + sand | - | 1 | - | | | | | | | | | | | | 3 | | |
| **IM-06** | **9,6-10,8** | clay + sand | - | 1 | - | | | | | | | | | | | | 3 | | |
| **IM-09** | **3,6-4,2** | clay + sand | - | 1 | - | | | | | | | | | | | 12 | 11 | 7 | 03:01 |
| **IM-09** | **4,2-4,8** | clay + sand | - | 1 | - | | | | | | | | | | | 1 | 3 | | |
| **IM-09** | **4,8-5,4** | clay + sand | 0.16 | 0.93 | 0.23 | | | | | | | | | | 2 | 4 | 46 | 14 | 03:01 |
| **IM-09** | **6,0-6,6** | clay + sand | 0.16 | 0.93 | 0.23 | | | | | | | | | | 2 | 2 | 49 | 10 | 05:01 |
| **IM-34** | **1,2-1,8** | clay + sand | - | 1 | - | | | | | | | | | | | 63 | 1 | 18 | 04:01 |
| **IM-34** | **1,8-2,4** | clay + sand | - | 1 | - | | | | | | | | | | | 13 | | 5 | 02:01 |
| **IM-34** | **2,4-3,0** | clay + sand | - | 1 | - | | | | | | | | | | | 59 | 2 | 18 | 03:01 |
| **IM-34** | **3,0-3,6** | clay + sand | 0.51 | 0.68 | 0.72 | | 1 | | | | | | | | | 2 | 2 | | |
| **IM-34** | **3,6-4,2** | clay + sand | - | 1 | - | | | | | | | | | | | 1 | 3 | | |
| **IM-34** | **4,2-4,8** | clay + sand | - | 1 | - | | | | | | | | | | | 2 | | | |
| **IM-34** | **4,8-5,4** | clay + sand | - | 1 | - | | 1 | | | | | | | | | | | | |
| **IM-40** | **6,0-6,6** | clay | - | 1 | - | | | | | | | | | | | 1 | 1 | | |
| **IM-40** | **6,6-7,2** | clay | - | 1 | - | | | | | | | | | | | 8 | 5 | 6 | 02:01 |
| **IM-40** | **7,2-7,8** | clay | 0.45 | 0.72 | 0.65 | | | | | | | | | | 2 | 2 | 8 | | |
| **IM-40** | **7,8-8,4** | clay | 0.13 | 0.95 | 0.19 | | | | | | | | | | 1 | 37 | 44 | 6 | 13:01 |
| **IM-40** | **8,4-9,0** | clay | - | 1 | - | | | | | | | | | | | 15 | 131 | 4 | 36:01 |
| **IM-102** | **1,8-2,4** | clay + OM | - | 1 | - | | | | | | | | | | | 22 | | | |
| **IM-102** | **2,4-3,0** | clay + OM | - | 1 | - | | | | | | | | | | | 22 | 6 | 15 | 02:01 |
| **IM-102** | **3,6-4,2** | clay | - | 1 | - | | | | | | | | | | | | 3 | | |
| **IM-102** | **4,2-4,8** | clay | - | 1 | - | | | | | | | | | | | 1 | | | |
| **IM-102** | **4,8-5,4** | clay + OM | 0.69 | 0.5 | 1 | | 1 | | | | | | | | | | 1 | | |
| **D-133** | **0,6-1,2** | clay | - | 1 | - | | | | | | | | | | 2 | | | | |
| **D-133** | **1,2-1,8** | clay + sand | 1.06 | 0.36 | 0.96 | | 6 | 4 | | | | | | | | 4 | 4 | | |
| **D-133** | **1,8-2,4** | clay | 1.12 | 0.40 | 0.80 | | 2 | 1 | | | | | | | 2 | 4 | 3 | | |
| **D-133** | **2,4-3,0** | clay | - | 1 | - | | | | | | | | | | | | 1 | 3 | 01:03 |
| **D-133** | **3,0-3,6** | clay | - | 1 | - | | | 2 | | | | | | | | | | | |
| **D-133** | **3,6-4,2** | clay | - | 1 | - | | | 2 | | | | | | | | | | | |
| **D-200** | **1,8-2,4** | clay | 0.51 | 0.73 | 0.46 | | 2 | 10 | | | | | | | | 13 | 51 | 2 | 32:01 |
| **D-200** | **2,4-3,0** | clay | 0.44 | 0.79 | 0.40 | | 4 | | | | | | | | 2 | 12 | 33 | 5 | 09:01 |
| **D-200** | **3,0-3,6** | clay | 0.99 | 0.44 | 0.71 | | 8 | 33 | 4 | | | | | | | 22 | 41 | 9 | 07:01 |
| **D-200** | **3,6-4,2** | sand | 0.45 | 0.72 | 0.65 | | | 5 | | | | | | | | | 1 | | |
| **D-200** | **4,2-4,8** | sand | 0.94 | 0.43 | 0.85 | | 1 | 5 | | | | | | | | | 3 | | |
| **D-200** | **4,8-5,4** | sand | - | 1 | - | | | | | | | | | | | | 2 | | |
| **D-200** | **5,4-6,0** | clay | 1.4 | 0.3 | 0.81 | | 7 | 2 | | | 1 | | 2 | 2 | | | 11 | | |
| **D-236** | **2,4-3,0** | clay | 0.19 | 0.91 | 0.27 | | 2 | | | | | | | | | 11 | 30 | 3 | 14:01 |
| **D-236** | **3,6-4,2** | clay | - | 1 | - | | | | | | | | | | | 2 | 9 | 4 | 03:01 |
| **D-236** | **4,2-4,8** | clay | 0.50 | 0.68 | 0.72 | | | 1 | | | | | | | | 2 | 2 | | |
| **D-236** | **4,8-5,4** | clay | 0.50 | 0.68 | 0.72 | | 1 | 4 | | | | | | | | | | | |
| **D-236** | **6,0-6,6** | clay | 0.64 | 0.55 | 0.99 | | | 1 | | | | | 2 | | | | | | |
| **D-236** | **6,6-7,2** | clay | - | 1 | - | | | | | | | | | | | | 1 | | |
| **D-315** | **2,4-3,0** | clay | - | 1 | - | | | | | | | | | | | 49 | | 2 | 25:01 |
| **D-315** | **3,0-3,6** | clay | 0.49 | 0.72 | 0.45 | 1 | | 9 | | | | | | | | 52 | | 3 | 18:01 |
| **D-315** | **3,6-4,2** | clay | 0.60 | 0.60 | 0.86 | | | 5 | | | | | | | | 2 | | | |
| **D-315** | **4,2-4,8** | clay | - | 1 | - | | | | | | | | | | | 14 | | | |
| **D-315** | **4,8-5,4** | clay | - | 1 | - | | | | | | | | | | | 2 | | | |
| **D-315** | **5,4-6,0** | clay | - | 1 | - | 3 | | | | | | | | | | | | | |
| **D-323** | **3,6-4,2** | clay | 0.64 | 0.69 | 0.46 | | 5 | 6 | | | | | | | 2 | 5 | 56 | 6 | 10:01 |
| **D-323** | **4,2-4,8** | clay | 0.69 | 0.50 | 0.99 | | | 11 | | | | | | | | | 9 | 1 | 09:01 |
| **D-323** | **5,4-6,0** | clay | 1.02 | 0.44 | 0.73 | | 9 | 20 | | | | | | 4 | | 2 | 50 | 3 | 17:01 |
| **D-323** | **7,2-7,8** | clay | - | 1 | - | | 2 | | | | | | | | | | | | |
| **D-325** | **4,2-4,8** | clay | 0.86 | 0.50 | 0.79 | | 10 | 12 | | | 1 | | | | | 4 | 40 | 9 | 05:01 |
| **D-325** | **4,8-5,4** | clay | 1.23 | 0.35 | 0.69 | | 8 | 36 | 2 | 2 | | | | | 2 | | 30 | | |
| **D-325** | **5,4-6,0** | clay | 0.62 | 0.63 | 0.56 | | 1 | 8 | | | | | | | | | 30 | 2 | 15:01 |
| **D-325** | **7,8-8,4** | clay | - | 1 | - | | | | | | | | | | | | 3 | | |
| **D-412** | **1,2-1,8** | clay | - | 1 | - | | | | | | | | | | | 49 | 1 | | |
| **D-412** | **1,8-2,4** | clay | - | 1 | - | | | | | | | | | | | 4 | 5 | 2 | 04:01 |
| **D-412** | **2,4-3,0** | clay | 0.29 | 0.84 | 0.42 | | | 4 | | | | | | | | 12 | 30 | | |
| **D-412** | **3,0-3,6** | clay | 1.02 | 0.44 | 0.73 | | 2 | 8 | | 2 | | | | | | 5 | 13 | 5 | 04:01 |
| **D-412** | **3,6-4,2** | clay | 0.5 | 0.68 | 0.72 | | | 2 | | | | | | | | | 8 | | |
| **D-412** | **4,8-5,4** | clay | - | 1 | - | | | | | | | | | | | 1 | 4 | | |
| **D-434** | **2,4-3,0** | clay | - | 1 | - | | | | | | | | | | | 34 | 27 | 7 | 09:01 |
| **D-434** | **3,0-3,6** | clay | - | 1 | - | | | | | | | | | | | 4 | 12 | 3 | 05:01 |
| **D-434** | **3,6-4,2** | clay | - | 1 | - | | | | | | | | | | | | 6 | | |
| **D-434** | **4,2-4,8** | clay | - | 1 | - | | | | | | | | | | | 5 | 9 | 6 | 02:01 |
| **D-434** | **4,8-5,4** | clay | - | 1 | - | | | | | | | | | | | 5 | 25 | 3 | 10:01 |
| **D-434** | **5,4-6,0** | clay | - | 1 | - | | | | | | | | | | | 28 | 49 | 4 | 19:01 |
| | | **Total** | | | | 20 | 83 | 191 | 6 | 4 | 4 | 2 | 6 | 6 | 29 | 1600 | 1386 | 4947 | |

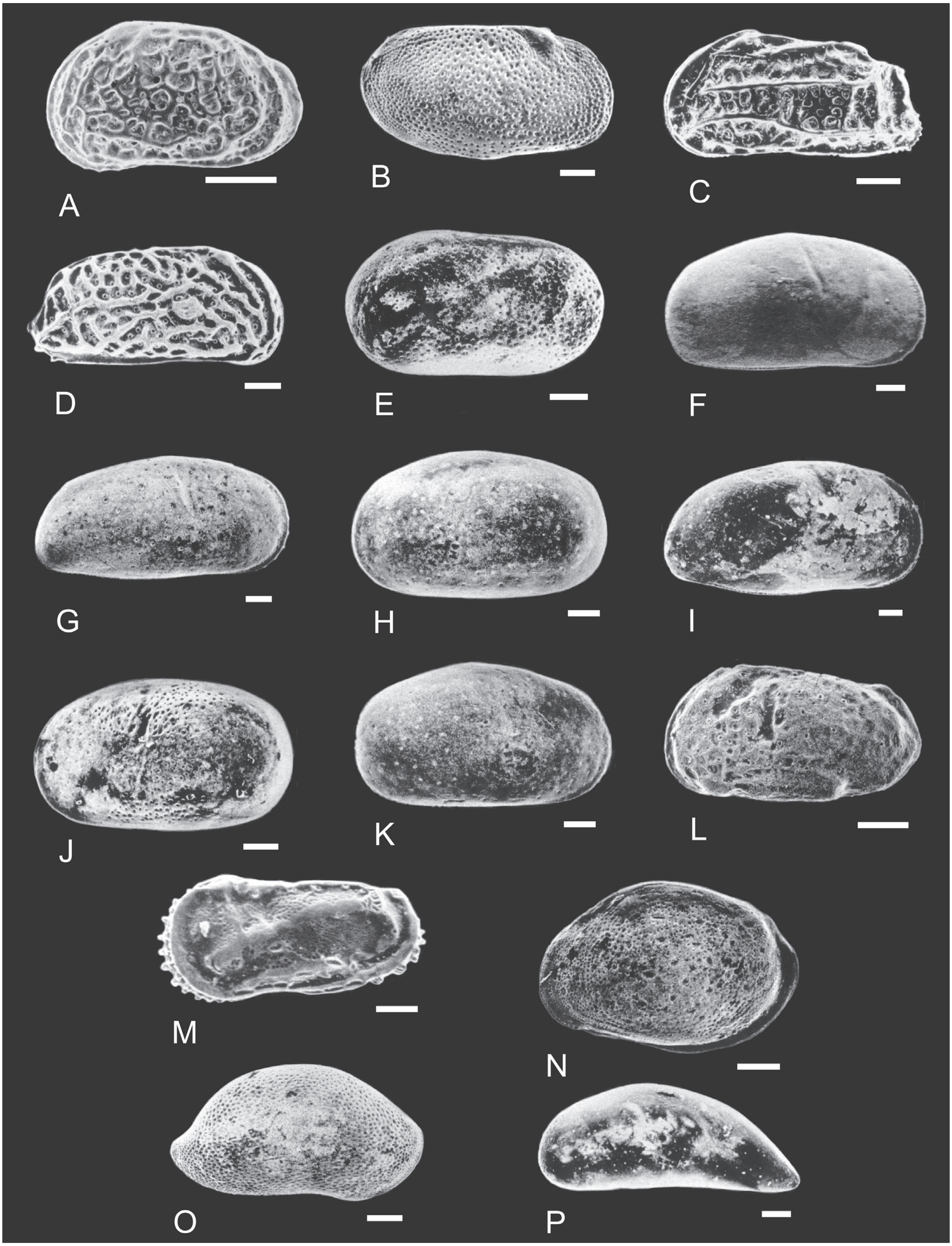


**Figure 2. A,** *Callistocythere litoralensis*, MP-O-1976, female carapace left valve; **B,** *Argenticytheretta laevipunctata*, MP-O-1977, female right valve; **C,** *Orionina similis*, MP-O-1978, left valve; **D,** *Ruggiericythere dimorphica*, MP-O-1979, male right valve; **E,** *Cytherella* sp., MP-O-1980, right valve; **F-G,** *Cyprideis multidentata*: **F,** MP-O-1981, female right valve; **G,** MP-O-1982, male right valve; **H-K,** *Cyprideis salebrosa*: **H,** MP-O-1983, female left valve; **I,** MP-O-1984, male right valve; **J,** MP-O-1985, female left valve; **K,** MP-O-1986, female right valve; **L,** *Perissocytheridea kroemmelbeini*, MP-O-1987, male left valve; **M,** *Neocaudites triplistriatus*, MP-0-1988, male left valve; **N,** *Loxoconcha bullata*, MP-O-1989, female left valve; **O,** *Bairdoppilata* sp., MP-O-1990, right valve; **P,** *Paracypris* sp., MP-O-1991, left valve. Scale bar = 100 μm.

Studying the micromolluscs in the same region, Mendes (1993) and Pitoni (1993) suggested that the large majority of the studied species were autochthonous. Pitoni (1993) reported that Imaruí's micromolluscs were characteristics of shallow bay or inlet marine environments, with high and low energy areas more influenced by the sea than by the continental processes. On the other hand, based on a detailed geological study, Caruso Jr. (1995b) proposed another origin of the calcareous shells found in this region, to which the ostracodes and micromolluscs are associated, suggesting that the region was characterized by a large lagoonal body formed during the maximum Holocene transgression. It is pointed out that the micromollusc shells are accumulated and concentrated by high energy processes due to the presence of levels with gradational layering and a mixing of lagoonal mixohaline and marine fauna. According to Caruso Jr. (1995b, 1999), the intensity of the winds over the lagoons was able to produce waves that generate coastal currents eroding and depositing sediments along their margins, reworking old deposits, generating beaches, and building sandy areas.

## DISCUSSION AND CONCLUSIONS

Mendes (1993) and Pitoni (1993), recorded specimens that inhabit modern shallow marine, high and low energy environments, associated with species typical of estuaries and lagoons. According to those authors, the majority of these species present a balanced population age structure typical of an authochtonous fauna. According to Mendes (1993), the dominant species of marine gastropods and bivalves are constituted mainly by fragmented, rolled and young shells (*e.g. Finella dubia* (d'Orbigny, 1842); Mytilidae). Notwithstanding these data, Mendes (1993) and Pitoni (1993), consider that marine and lagoonal micromollusc faunas did not suffer *post-mortem* transport, suggesting that they were deposited in a shallow marine environment under some estuarine or lagoonal influence.

Taking into account the ecological and palaeoecological preferences of *C. multidentata* and *C. salebrosa*, typically found in mixohaline environments, it is possible to assume that the environment where these species lived was probably a marginal marine lagoon with some mixohaline characteristics, because living specimens of *C. multidentata* and *C. salebrosa* have a low tolerance to normal marine salinity. Whatley (1988) records that mixohaline ostracode faunas possess low diversities and high dominances. These characteristics are observed in the Imaruí, D'Una River and LI-01 samples by the majority of the assemblages (Table 1). The shallow marine (*A. laevipunctata*, *Bairdoppilata* sp., *Cytherella* sp., *N. triplistriatus*, *O. similis*, *Paracypris* sp. and *R. dimorphica*) and eurihaline (*C. litoralensis* and *L. bullata*) species are represented only by very few adult specimens. Anyway, high energy environments are suggested for the Imaruí and D'Una River palaeolagoons (mainly ostracode adult valves) and, partially, also for the central portion of the Imaruí Lagoon (LI-01 core) in which only few samples (core depths: 3-4 m, 4-5 m, 5-6 m and 7-8 m) recorded autochthonous ostracode assemblages. These conclusions are in agreement with Caruso Jr. (1995b, 1999) statement that the regional calcareous shell deposits were formed by high energy environmental processes.

Thus, the ostracode data have provided a very different palaeoenvironmental interpretation from those drawn from micromolluscs. In fact, the present study suggests that the marine ostracodes were moved, after death, into the lagoonal system, as no juvenile ontogenetic stages of these species were found and the adults are represented by few specimens (Table 1). Morover, the mixohaline ostracode fauna which lived in a lagoonal environment, underwent *post-mortem* transport into the lagoon itself, being reworked together with the marine ostracodes, and then redeposited.

Based on the above data and the sedimentary structures observed by Caruso Jr. (1995a, 1999), it is assumed that the ostracodes and micromolluscs, typical of shallow marine environments, were transported inside the lagoons through the action of storms and tides more than by the relative sea level oscillations. Inside the lagoons lived an autochthonous fauna of mixohaline micromolluscs and ostracodes. The wind action generated waves and currents inside the lagoons, that were able to rework the pre-existent deposits allowing the fragmentation of the shells, thus mixing faunas from different environments, and redepositing this material on the lagoon banks.

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**Appendix 1.** Ostracoda species examined in this study. We follow Moore & Pritat (1961) in considering the traditional classification of Ostracoda to be a suitable option for the present, but note that some authors follow the supra-generic categories modified by Horne *et al.* (2002). However, since Hartmann & Puri (1974) the genus *Paracypris* Sars, 1866 has been included within the family Candonidae Kaufmann, 1900 as adopted below.

Suborder Platycopina Sars, 1866
Family Cytherellidae Sars, 1866
Genus *Cytherella* Jones, 1849
*Cytherella* sp.
Suborder Podocopina Sars, 1866
Superfamily Cytheracea Bair, 1850
Family Leptocytheridae Hanai, 1957
Genus *Callistocythere* Ruggieri, 1953
*Callistocythere litoralensis* (Rossi de García, 1966) emend. Sanguinetti, Ornellas & Coimbra, 1991
Family Cytherettidae Triebel, 1952
Genus *Argenticytheretta* Rossi de García, 1969 emend. Sanguinetti, Ornellas & Coimbra, 1991
*Argenticytheretta laevipunctata* Sanguinetti, Ornellas & Coimbra, 1991
Family Hemicytheridae Puri, 1953
Genus *Orionina* Puri, 1954 emend. Coimbra & Ornellas, 1986
*Orionina similis* Bold, 1963 emend. Coimbra & Ornellas, 1986
Genus *Ruggiericythere* Aiello, Coimbra & Barra, 2004
*Ruggiericythere dimorphica* (Whatley *et al.*, 1998) emend. Aiello, Coimbra & Barra, 2004
Family Cytherideidae Sars, 1925
Genus *Cyprideis* Jones, 1857
*Cyprideis multidentata* Hartmann, 1955
*Cyprideis salebrosa* Bold, 1963
Genus *Perissocytheridea* Stephenson, 1938 emend. Pinto & Ornellas, 1970
*Perissocytheridea kroemmelbeini* Pinto & Ornellas, 1970

Family Trachyleberididae Sylvester-Bradley, 1948
Genus *Neocaudites* Puri, 1960
*Neocaudites triplistriatus* (Edwards, 1944) emend. Bold, 1963
Family Loxoconchidae Sars,1925
Genus *Loxoconcha* Sars, 1866
*Loxoconcha bullata* Hartmann, 1956
Superfamily Bairdiacea Sars, 1888
Family Bairdiidae Sars, 1888
Genus *Bairdoppilata* Coryell, Sample & Jennings, 1935
*Bairdoppilata* sp.
Superfamily Cypridacea Baird, 1845
Family Candonidae Kaufmann, 1900
Subfamily Paracyprididae Sars, 1923
Genus *Paracypris* Sars, 1866
*Paracypris* sp.