FIRST RECORD OF OSTRACODS IN THE ESTIVA FORMATION (PERNAMBUCO BASIN, UPPER CRETACEOUS), NORTHEAST OF BRAZIL

Cecília de Lima Barros¹;
Enelise Katia Piovesan²;
Mário Ferreira de Lima Filho³
Sonia Maria Oliveira Agostinho⁴.

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¹ Pesquisadora e Pós-Doutoranda, Instituto de Geociências/Departamento de Geologia, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro/RJ, Brasil.

ORCID: <https://orcid.org/0000-0001-6760-6988>

Email: ceciliabarros@geologia.ufrj.br

² Professora, Doutora, Centro de Tecnologia e Geociências/Departamento de Geologia, Universidade Federal de Pernambuco (UFPE), Recife/PE, Brasil.

ORCID: <https://orcid.org/0000-0002-0433-0395>

Email: enelise.katia@ufpe.br

³ Professor, Doutor, Centro de Tecnologia e Geociências/Departamento de Geologia, Universidade Federal de Pernambuco (UFPE), Recife/PE, Brasil.

ORCID: <https://orcid.org/0000-0002-8523-3457>

Email: mario.limafo@ufpe.br

⁴ Doutora, Centro de Tecnologia e Geociências/Departamento de Geologia, Universidade Federal de Pernambuco (UFPE), Recife/PE, Brasil.

ORCID: <https://orcid.org/0000-0003-3900-5741>

Email: sonia@ufpe.br

RESUMO

O presente trabalho trata do primeiro registro de ostracodes na Formação Estiva, Bacia Pernambuco (Poço Cupe, 1 LABIO-PE1). A Bacia Pernambuco estende-se por todo o litoral sul do Estado de Pernambuco e está delimitada pela Zona de Cisalhamento de Pernambuco, a norte, e pelo Alto de Maragogi, a sul. A Formação Estiva é composta por carbonatos plataformais, datados como Cretáceo Superior. A análise e interpretação dos dados foram realizadas através de revisão bibliográfica, levantamentos de dados estratigráficos e coleta de amostras. A metodologia adotada para o tratamento das amostras estudadas consistiu na coleta, pesagem e desagregação de amostras; lavagem e secagem do material desagregado e triagem dos microfósseis carbonáticos. Foram registrados raros ostracodes, tentativamente atribuídos ao gênero mixohalino *Fossocytheridea* Swain & Brown, 1964. O reconhecimento da fauna de ostracodes e sua paleoecologia tem como objetivo contribuir na compreensão da evolução da Bacia Pernambuco.

Palavras chave: *Fossocytheridea*; Paleoambiente; Cretáceo Superior.

ABSTRACT

The present work deals with the first record of ostracods in the Estiva Formation, Pernambuco Basin (Cupe, 1 LABIO-PE1 borehole). The Pernambuco Basin extends throughout the southern coast of the state of Pernambuco and is limited by the Pernambuco Shear Zone, in the north and by the Maragogi High, in the south. The Estiva Formation consists of continental shelf carbonates dated as Upper Cretaceous. The analysis and interpretation of the data were performed through literature review,

stratigraphic data surveys, and sampling. The methodology used for the treatment of the samples consisted of the following steps: collection, weighing and fragmentation of the samples; washing and drying of the calcined materials; and screening and picking of the carbonatic microfossils. Rare ostracods were found, probably belonging to the brackish genus *Fossocytheridea* Swain & Brown, 1964. The recognition of the ostracod fauna and its paleoecology aims to contribute to the understanding of the Pernambuco Basin evolution.

Keywords: *Fossocytheridea*; Paleoenvironment; Upper Cretaceous.

INTRODUCTION

Paleontological studies in the Pernambuco Basin are scarce, including microfossils (Lima & Pedrão, 1987, 1989, 1994; Lima Filho & Santos, 2001) and macrofossils. Among the last ones, fish bones occurrences belonging to the *Diplomystus* genus stand out, which were tentatively correlated with Aptian deposits of the Cabo Formation (Costa *et al.*, 1979). Gastropods and bivalves were recorded in limestones of the Estiva Formation by Maury (1930), Beurlen (1964), Beurlen & Cobra (1960) and Muniz & Almeida (1988). Regarding to the biostratigraphy of the Pernambuco Basin, palynological studies developed by Lima & Pedrão (1987, 1989) attributed a Cenomanian–Turonian age for the Estiva Formation deposits. Based on the presence of the bivalve *Neithea sergipensis*, Beurlen & Cobra (1960) suggested that the Estiva Formation is correlated to the Albian of the Riachuelo Formation, from the Sergipe-Alagoas Basin.

With respect to the paleoecology, Lima & Pedrão (1987) suggested that the Estiva Formation was deposited in a coastal environment, with evident marine influence, under low oxygen conditions and during a warm and dry climate. According to Lima Filho & Silva Santos (2001) through palynological information in the SR-06 well (depth of 39 m) in the Pernambuco Basin, the sampling at this point showed an association of species considered restricted to Cenomanian

(*Psilatricolpites papilioniformis*, *Hexaporotricolpites coranatus*) and Turonian (*Tricolpites microstriatus*, *Tricolpites synstriatus*).

Ferreira (2009) studied the organo-faciological variation of the Cenomanian-Turonian interval of the Pernambuco Basin, observing that in the four sedimentary sections, organic components from the phytoclasts group are predominant particulate organic components, followed by the palynomorphs group and, subordinately, by the amorphous organic matter group. These data indicated a typically coastal environment, with the influence of fluvial-deltaic environments.

The Pernambuco Basin extends all over the south coast of the Pernambuco state and is limited by the Pernambuco Shear Zone (PESZ), in the north, and by the Maragogi High, in the south (Barbosa & Lima Filho, 2006; Barbosa *et al.*, 2008). Lima Filho (1998), Lima Filho & Szatmari (2002), and Lima Filho *et al.* (2005) pointed out differences between the basins to the south and north of the Pernambuco Lineament (Fig. 1). These works individualized and formalized the Paraíba Basin, which is located between the Pernambuco Lineament and the Touros High, subdivided into sub-basins according to Mabesoone & Alheiros (1988), and Pernambuco Basin the one of rift-type (formerly called Cabo Basin), located between the Pernambuco Lineament and the Maragogi-Barreiros High.

Later, based on stratigraphic data, Barbosa (2004) limited the Paraíba Basin to the area between the Pernambuco Lineament and the Mamanguape High. The Pernambuco Basin may be subdivided into two sectors. The first one occupies a narrow area along the Northeast coast, the Cupe Rift, while the second one is located in deep and ultradeep water. The separation between these two sectors is the Maracatu High, according Almeida *et al.* (2005). The stratigraphy is well known in the emerged portion along the coast, although it is totally unknown in the offshore portion due to the scarce sampling (absence of drilling).

Oliveira & Leonardos (1943) first named the Estiva Formation, which was widely used to designate carbonate deposits that crop out in the several localities of the Pernambuco Basin (Beurlen & Cobra, 1960; Cobra, 1960; Maciel, 1968). The age for the Estiva Formation was firstly proposed by Maury (1930). Based on invertebrate macrofossils occurrences, the author suggested that the Turonian age for the formation (see data in Barbosa *et al.*, 2008). The presence of carbonatic deposits in the Pernambuco Basin was already long known, being considered at the time to be correlated to levels of

the same nature and Paleocene age occurring in the Paraíba Basin shore according to Branner (1902). In the Pernambuco Basin, the Estiva Formation comprises platformal carbonates of either Cenomanian–Turonian age or Albian–Cenomanian age according to Lima Filho *et al.* (2006).

The outcropping limestones from the Pernambuco Basin have been commonly treated as correlated and grouped into the Estiva Formation in recent works. The lithotype is a dolomitic limestone of grey color and massive aspect, frequently with clay and fossiliferous intercalations, comprising poorly preserved marine macrofossils and microfossils. Later, works kept this interpretation that groups the deposits in a big unit divided into three main lithofacies groups: basal or lower (alluvial proximal), medium (fluvial-alluvial), and distal (fluvial-lacustrine) (Cruz, 2002; Nascimento, 2003; Nóbrega & Lima Filho, 2003; Campello, 2004; Almeida *et al.*, 2005).

The fossils scarcity in the Estiva Formation results in a poorly detailed biostratigraphic framework for the Pernambuco Basin. Until now, there was no record of ostracods in the basin, which shows the importance of developing such studies in it.

Figure 1 – A Map showing the location of the Pernambuco Basin and the Cupe, 1 LABIO-PE1 borehole. Source: Modified from Lima Filho (1998).

METHODOLOGY

The studied samples were collected from the Cupe 1-LABIO-PE1 core, drilled in the Pernambuco Basin (Estiva Formation). The drilling was executed in the scope of the research project "Micropaleontological and biostratigraphic analysis of the rift and post-rift sequences of the Pernambuco Basin, based on the main microfossiliferous groups", with the financial support of PETROBRAS, process nº 401812/2010-3. The core is located in front of the Condomínio Privê Baía do Cupe, on the Cupe beach, Porto de Galinhas, Ipojuca Municipality (near 60 km from Recife). One hundred samples were analyzed from the CUPE (1-LABIO-PE) core, collected at depth intervals of 5 to 10 cm (when possible).

The samples were processed on CENPES-PETROBRAS laboratory, in

the Rio de Janeiro state, following classical technics for recovery of carbonate microfossils, as it is detailed below:

Sampling - The samples were collected from the CUPE (1 LABIO-PE) core;

Sample weighting - The amount established was 60 g;

Sample disaggregation - The fragmented samples were placed into a Becker recipient and submitted to attack using hydrogen peroxide (130 vol), aiming the disaggregation and oxidation of the organic matter. After intense chemical reaction, alcohol 70% was added at variable amounts. These procedures were carried out in CENPES-PETROBRAS laboratory, with constant monitoring until the reaction was ceased. The volume of hydrogen peroxide added was from 100 to 300 ml and the reaction time established was about 24 hours;

Sample washing and drying - Under running water, the samples were separated using mesh sieves (75, 180, and 250 µm). Each sieve content was transferred to glass beakers labeled with the core name, sample number, and granulometric fraction, and put to dry at 60 °C in a drying oven. To avoid contamination between different samples, the sieves were carefully washed, first using a brush and neutral detergent. Following, the sieves were rinsed off and immersed in a methylene blue solution;

Picking - The granulometric fractions were weighed and placed in properly labeled repositories to be used for the separation of microfossils. Screening is a meticulous part of the research that requires the use of a stereomicroscope and a specific plate. The microfossils found were glued on associative slides;

Systematic classification of fossils - This step included recognition of the ostracods, identifying the genus and species, consulting specialized literature (for example Liebau, 2005; Tibert *et al.*, 2002, 2003 and 2009; Bergue *et al.*, 2011; Piovesan *et al.*, 2013, 2015). The specimens were photographed using the stereomicroscope Leica Model EZ4D and the Scanning Electron Microscope (SEM) from the *Laboratório de Dispositivos e Nanoestruturas (LDN)* – of the Department of Geology of the

Federal University of Pernambuco (DGEO-UFPE).

All fossil specimens are deposited in the *Laboratório de Micropaleontologia Aplicada (LMA)* of the Department of Geology of the Federal University of Pernambuco UFPE, identified as “Sample 48”.

RESULTS AND DISCUSSION

Class OSTRACODA Latreille, 1802
Subclass PODOCOPA Sars, 1866
Order PODOCOPIDA Sars, 1866
Family CYTHERIDEIDAE Sars, 1925

Genus *Fossocytheridea* Swain & Brown, 1964
(Figure 2)

Material: Five ostracod specimens preserved mainly as internal molds. Sample 48 (56.74 m depth)

Comments: Out of one hundred samples analyzed, only five registered ostracods, from the limestone sample 48 (56.74 m depth) poorly preserved. Three ostracod taxa were identified, tentatively attributed to the mixohaline genus *Fossocytheridea* Swain & Brown, 1964 (Fig. 2), kept in open nomenclature: *Fossocytheridea* sp. 1; *Fossocytheridea* sp. 2; and *Fossocytheridea?* sp. 3.

Figure 2- Ostracode specimens SEM images. A. *Fossocytheridea* sp. 1; B. *Fossocytheridea* sp. 2; C. and D. *Fossocytheridea?* sp. 3.

The recorded taxa, *Fossocytheridea* sp. 1, *Fossocytheridea* sp. 2, and *Fossocytheridea?* sp. 3, were not formally described due to poor preservation of the carapaces. However, it was possible to separate them into different taxa based on the morphological features described as follows. *Fossocytheridea* sp. 1 presents a subrectangular carapace in the lateral view, with the bigger width positioned in the posterior third of its length and the bigger height positioned in the anterior cardinal angle. The right valve strongly overlaps the left valve all through the outline of the carapace. The posterior margin is asymmetrically round, the dorsal margin is slightly convex, and the ventral margin is substraight.

Fossocytheridea sp. 2 differs from *Fossocytheridea* sp. 1 by presenting a subrectangular and elongated carapace in the lateral view, with a pronounced sulcus in the anterodorsal region.

Besides, it presents valve reversal, with a less pronounced dorsal overlap. The anterior and posterior valves are subrounded. The dorsal margin is slightly convex, and the ventral margin is almost straight, with a concavity in the medium region of the left valve.

Fossocytheridea? sp. 3 is different from the other two by presenting a sub-rectangular to sub-triangular carapace in lateral view. The right valve overlaps the left one, which is less pronounced in the posterior region. The anterior and posterior margins are asymmetrically rounded, with a narrower posterior region. The dorsal margin is convex, the ventral margin of the right valve is slightly convex, and the left valve is almost straight. Anteromarginal and posteroventral regions are compressed into both valves. This last taxon is possibly a juvenile specimen.

Fossocytheridea Swain & Brown, 1964 is a genus that inhabits marginal

marine environments of the Late Cretaceous, widely distributed from the Aptian to the Maastrichtian of America, Europe, China, Africa and Middle East (Swain & Brown, 1964; Babinot & Colin, 1976; Tibert *et al.*, 2003; Bergue *et al.*, 2011). Previous works such as Colin *et al.* (1990) and Tibert *et al.* (2002, 2003 and 2009) already highlighted the importance of *Fossocytheridea* to characterize coastal marine environments.

The first record of *Fossocytheridea* in Brazil was pointed out by Viviers *et al.* (2000) for the Campanian of the Potiguar Basin. In that work, the recorded specimens were identified in the genus *Sarlatina* Babinot & Colin, 1976, which is currently considered a junior synonym of *Fossocytheridea*, according Tibert *et al.* (2003). An extensive study of Tibert *et al.* (2003) revised the representants of the Cytherideidae family and some species of *Fabanella* Martin, *Ovocytheridea* Grekoff, *Dolococytheridea* Triebel, *Antibythyocypris* Jennings and *Cytheridea* Bosquet, also relocated into the *Fossocytheridea* genus.

The *Fossocytheridea* record became frequent in the Cretaceous of Brazil, mainly in the marginal basins. Bergue *et al.* (2011) described four new species of *Fossocytheridea*, analyzing their ecological relationships and intraspecific variability. Piovesan *et al.* (2013) registered and described *Fossocytheridea* species for the Late Cretaceous of Santos Basin. Subsequently, Piovesan *et al.* (2014) proposed the species *Fossocytheridea potiguarensis* Piovesan, Cabral & Colin, 2014 and *Fossocytheridea* POT 1 for the Santonian–Campanian interval of the Potiguar Basin. These authors pointed that *Fossocytheridea* was the most abundant mixohaline genus of the Potiguar Basin in that time interval.

Piovesan *et al.* (2015) analyzed the paleoecological response of

Fossocytheridea and *Perissocytheridea* in deposits from the Upper Cretaceous of Brazil and Portugal, observing that the two genera present different salinity tolerances. Comparatively, the two genera studied showed different behaviors in Brazil and Portugal: *Perissocytheridea jandairensis* seems to tolerate greater salinity conditions than *Perissocytheridea estribeirensis*. On the other hand, *Fossocytheridea merlensis* resists to considerable salinity variations, which does not seem to occur with the *Fossocytheridea* from the Potiguar Basin. The results suggest that, in the Late Cretaceous, both *Fossocytheridea* and *Perissocytheridea* were euryhaline and their tolerance to salinity gradients in the mixohaline context is related to the ecology of each species. The euryhaline character of *Fossocytheridea* is supported by its record in the Sanfranciscana Basin (Bittencourt *et al.*, 2019), associated with species of *Ilyocypris* Brady & Norman, 1889, a genus typically registered in non-marine environments.

In terms of depositional environment, Tomé *et al.* (2006) suggested a shallow carbonate shelf, with terrigenous intervals due to the influence of tidal plains, on the Estiva formation. The great amount of organic matter and palynomorphs indicate sedimentation with terrigenous influence and warm and dry climate conditions. However, the presence of some dinoflagellates and foraminifera indicate a marine influence for the Estiva Formation of the Pernambuco Basin. Analysis performed by Barbosa *et al.* (2008) in outcrops and core samples, as well as petrographic analyzes, indicate that the deposition of carbonates, although still in the context of a shallow platform, should have occurred in coastal lagoon environment and reef banks, as suggested previously by Lima & Pedrão (1989, 1994). The recovery of *Fossocytheridea*

in the Estiva Formation corroborates the paleoecological data previously obtained in the Pernambuco Basin, from a transitional to a shallow marine environment in the Late Cretaceous.

FINAL CONSIDERATIONS

Here, it is presented the first record of ostracods in the Cretaceous of the Estiva Formation, Pernambuco Basin, northeastern Brazil. Most of the specimens are preserved as molds, which limited a precise taxonomical identification. The ostracod specimens probably represent the mixohaline genus *Fossocytheridea*. Based on the previous studies, the recovered ostracod fauna allows to infer a transitional to a shallow marine paleoenvironment to the studied interval.

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