



Late Cretaceous crustaceans (Decapoda) from the Brazilian Tethyan domain

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ABSTRACT

This study deals with the distribution analysis of the decapod crustaceans *Callianassa* sp. and *Ophthalmoplax brasiliensis* throughout the Potiguar Basin (late Maastrichtian), Rio Grande do Norte State, Brazil. This occurrence is correlated to the Recife- Natal platform and Gramame Formation (Paraíba Basin), suggesting a Maastrichtian deposition in the Potiguar Basin, in areas previously considered to only contain Cenozoic deposits. The identified specimens expand the current knowledge of the fossiliferous content of Late Cretaceous carbonates from the Northeastern Brazil.

1. Introduction

The Potiguar Basin is located in Northeastern Brazil, between 4° 10' and 5° 50' S and 35° 00' and 38° 20' W, encompassing parts of the Rio Grande do Norte and Ceará states, covering an area of 21,500 km² onshore and 26,500 km² offshore. The sediments of this basin were deposited from Early Cretaceous to present times, and are generally grouped in the Rift (Early Cretaceous), Post-rift (Alagoas Age) and Drift (Albian to the Holocene) Supersequences (Santos Filho et al., 2015).

The uppermost carbonatic succession was deposited during the Drift Supersequence which includes the Jandaíra Formation, the great expansion of the carbonatic domain in this basin. Its basal portion consists of calcarenites, sandstones and calcilutites with bird's-eye structures that distally grades into limestones, mudstones and shales. The fossil content is characteristic of the Tethyan Domain, with a relatively high dominance and low specific diversity of mollusks, green algae, benthic foraminifera, bryozoans and echinoids. They are typical of a tidal flat environment including the supratidal, mesotidal and infratidal zones (Cordoba et al., 1996) as well as lagoons and shallow shelf environments, (Santos et al., 1994a; Cassab, 2003; Monteiro et al., 2007). The upper contact of the Jandaíra Formation is limited by a regional erosive unconformity that crops out in several localities on the onshore section of the basin, which represent the most fossiliferous deposits in the Potiguar Basin. There are paleoinvertebrates, represented by mollusks, echinoids, conchostraceans, bryozoans, corals, polychaetes fishes and chelonians (Cassab, 2003; Santos Filho et al., 2015; Monteiro et al., 2007).

The fossiliferous content found in the Jandaíra Formation corresponds generally to allochthonous concentration, intensely

recrystallized with dolomite (Cassab, 2003). In the tidal flats deposits the fossils of the bivalves, gastropods and echinoids are generally fragmented showing signs of low grade of abrasion. At the lagoonal deposits there are oyster banks (Cassab, 2003). Based on calcareous nanofossils, mollusks and ostracods, the Jandaíra Formation is considered as Turonian-middle Campanian age (Santos et al., 1994a; Cassab, 2003; Souza Lima et al., 2007; Santos Filho et al., 2015).

This research expands the current knowledge of the fossiliferous content of the rocks named informally by Barbosa et al. (2007) as undefined carbonatic deposits, that are generally misinterpreted as the Jandaíra Formation. This succession is also found in the sedimentary sequence of the eastern Brazilian Recife-Natal, which can be partially correlated with the carbonates that contain the fossil Decapoda described herein found in the Potiguar Basin.

2. Geological and paleontological setting

The sedimentary sequence of the eastern Brazilian Recife-Natal coastal zone, appears to be an isolated portion of the Brazilian continental margin. It represents a Late Cretaceous carbonatic section composed of shales, siliciclastic limestones and carbonatic sandstones, deposited in a marine environment directly on to the Precambrian basement (Barbosa et al., 2007). Based on geological and geophysical data, Campanha (1979), Campanha and Saad (1999), Barbosa (2007) and Barbosa et al. (2007) interpreted in the Recife-Natal coastal zone, the occurrence of two carbonate sequences separated by discordances. The basal is associated with the Jandaíra Formation (Turonian-early Campanian, Potiguar Basin) and the upper, the Natal Platform, is correlated with Itamaracá and Gramame formations (middle Campanian-

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Maastrichtian) at Paraíba Basin.

The basement of the Potiguar and Paraíba basins, occurs from Recife to Natal and is controlled by precambrian shear zones that influenced its tectono-sedimentary evolution. The sedimentation in both basins occurred probably during a highstand system tract, following a rapid transgression that affected the region since the upper Campanian times. This area is a structural ramp extending from the coastal zone to the platform divided in two sections: Paraíba Basin-platform, wider and steeper deflected ramp, and Potiguar Basin, thinner sedimentary sequence and low angle ramp (Barbosa and Lima Filho, 2006; Barbosa et al., 2007). The deposits in this context are informally known as un-defined carbonatic deposits.

The correlation between the top of the Natal Platform with Gramame Formation was reported for the first time by Kegel (1957), during geological and paleontological studies in the coastal zone of Rio Grande do Norte State, and then later by Beurlen (1961, 1964, 1967b). These authors observed that the upper lithological sequence of these areas, suggest a Late Cretaceous transgressive episode.

The paleontological investigation in the upper section of the Natal Platform area, was initially performed by Kegel (1957) who analyzed gastropods, cephalopods and echinoids of Maastrichtian age. Data integration of planktonic foraminifera and palynomorphs studies, from seven wells, revealed Upper Cretaceous marine deposits dated as Campanian - early Maastrichtian (Viviers and Regali, 1987). Based on the mollusk fauna, Muniz (1993) suggested a similar age range and correlation with the Gramame Formation. Lana and Roesner (1999), through palynological data concluded that the upper portion was deposited within an marine environment during the Maastrichtian. The fossil data also confirms an expressive record of Maastrichtian at Natal Platform, mainly through the ammonite taxa (Souza-Lima et al., 2007; Souza-Lima et al., 2007), gastropods and bivalves (Hessel and Barbosa, 2005), as well as the *Pholadomya* bivalve (Benaim and Senra, 2008), a very important genus as its greatest distribution occurs during the Maastrichtian.

The fossil taxa are indicative of a mixed platform, especially a restricted shallow ramp with siliciclastic high content, correlated with the West African Maastrichtian. The fossil species suggest environmental stress caused by the restricted-marine conditions. Although the upper section of Natal Platform and Paraíba Basin can be correlated, there are clear differences in the paleoenvironmental and depositional conditions. While in the Paraíba Basin the environments were shallow warm and quite marine waters, the deposits of Natal Platform were typical of tidal-flat, shallow coastal bays, lagoonal system, reef fringes and carbonatic banks with siliciclastic influence (Barbosa, 2007; Monteiro et al., 2007).

The analyzed Decapoda in this study occur in the upper section of Natal Platform area. They were collected in Brasil Química 1000 quarry (5° 8' 35,5" S, 37° 10' 35,6" W), near Mossoró city, Rio Grande do Norte State, Brazil (Figs. 1 and 2). The sedimentary succession in this quarry is characterized by a 10 m sequence of rhythmic cycles of gray calcareous sandstones interbedded with marls. There are trace fossils represented by *Thalassinoides* icno spp. filled with pelitic sediments. The Decapoda specimens are found in limestones associated with isolated spines of echinoids and oysters (see Fig. 3).

3. Material and methods

The analyzed sample comprises 19 well preserved specimens which represent the sternum articulated with ambulatory legs, sternum articulated with ambulatory legs, isolated torax and movable and fixed fingers. The primary calcitic composition of the decapods carapace is preserved and the diagnostic morphological features were described with a Leika S6E binocular stereomicroscope, with a precision caliper for obtaining dimensions.

The following abbreviations were used to indicate the measurements of the Callianassidae, cl: carpus length; cw: carpus width; pl:

palm length and pw: palm width. To Macropipidae, cl: carapace length; cw: carapace width; chl: cheliped length and chw: cheliped width.

The decapods at the Brasil Química 1000 quarry (considered so far as included in the area of Potiguar Basin) are abundant, and the specimens illustrated here are the ones best preserved. Detailed descriptions are provided depending on the degree of preservation of the material, especially in regards to the diagnostic morphological structures. The comparisons (measurements and features) amongst species discussed in this study were made from the original description (Maury, 1930) and other descriptions available from literature such as Vega et al. (2013).

4. Results

4.1. Systematic Paleontology

The analyzed material is housed at Rio de Janeiro Federal University under the Paleontological Collection of the Geology Department (UFRJ – DG). The description, systematic classification, essential terminology and nomenclature was mainly based on Glaessner (1969), Biffar (1971), Williams (1984), Manning and Felder (1991) and Melo (1996). In addition, other complementary works such as Stephenson and Campbell (1960) and Vega et al. (2013) were considered.

Order Decapoda Latreille, 1802

Infraorder Thalassinidea Latreille, 1831

Superfamily Callianassoidea Dana, 1852

Family Callianassidae Dana, 1852

Subfamily Callianassinae Dana, 1852

Genus *Callianassa* Leach, 1814

Callianassa sp.

Description: Incomplete robust cheliped with carpus, palm, fixed and movable fingers. Carpus subquadrate, probably shorter than palm; dorsal margin straight, ventral margin straight with acute prominence; proximoventral margin rounded and proximal margin not visible; surface ornamented with ciliate striae, lacking spines, two rows of small granules near the ventral margin. Palm rectangular compressed, more longer than wide and narrowing distally, with straight dorsal margin and a short, rounded proximal prominence, slightly undulated ventral margin. Proximodorsal margin extending proximally beyond the level of dorsal articulation with carpus. Outer surface ornamented with random small granules and ciliate striae, lacking spines as well as two rows of smaller granules near the ventral margin. Dactylus strong, lacking strong dentition; fixed finger subtriangular, robust with pointed terminations, straight dorsal and ventral margins, elements of cutting edge not visible; movable finger preserves only the large and robust proximal extremity.

Material: one cheliped fragment (UFRJ-DG 244Cr), from the Brasil Química 1000 quarry, near Mossoró city, Rio Grande do Norte State, Brazil.

Dimensions: cl: 3 mm; cw: 4 mm; pl: 6 mm; pw: 4 mm.

Discussion: Preservation of this specimen suggests that it belongs to the *Callianassa* genus. Others diagnostic morphological elements for species classification are not preserved, therefore a species cannot be determined until better preserved material is obtained.

Infraorder Brachyura Latreille, 1802

Superfamily Portunoidea Rafinesque, 1815

Family Macropipidae Stephenson and Campbell, 1960

Genus *Ophthalmoplax* Rathbun, 1935

Ophthalmoplax brasiliiana (Maury, 1930)

Description: Carapace large, subquadrate, wider at anterior third. Dorsal view marked by deep grooves visible between the metagastric and cardiac regions. Cardiac region subtrapezoidal; posterior edge metabranchial region with a deeply and recurved branchiocardiac groove. Anterior and posterior margins as well as dorsal and ventral regions of carapace not completely preserved. Front, orbits and eye-stalk, cervical, protogastric, hepatic, epibranchial, metagastric,

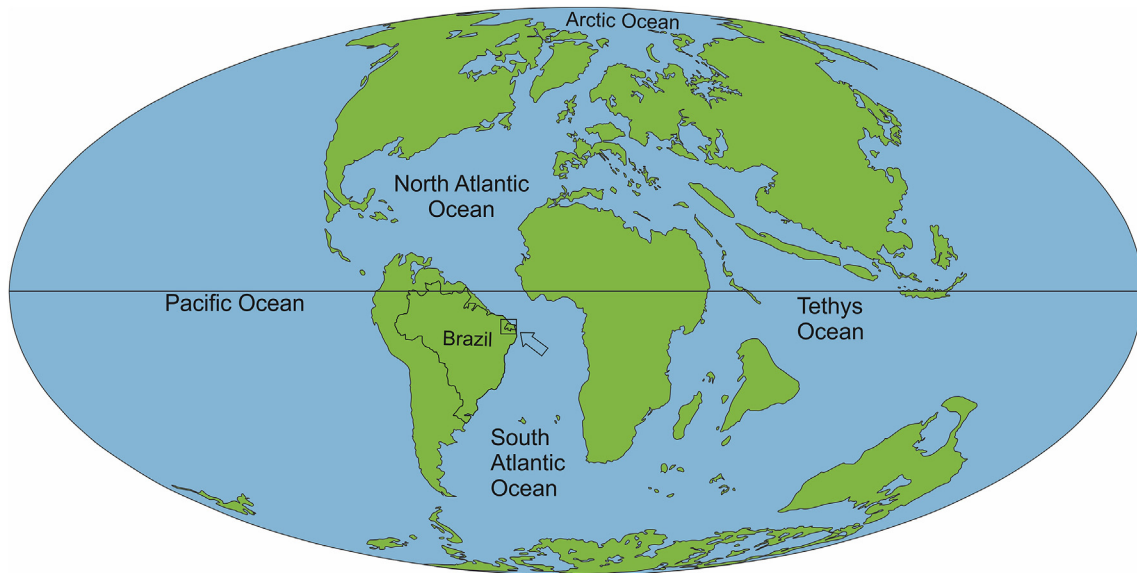


Fig. 1. Paleogeographic map of Latest Maastrichtian with location of Rio Grande do Norte state during this time (modified by Scotese, 2014).

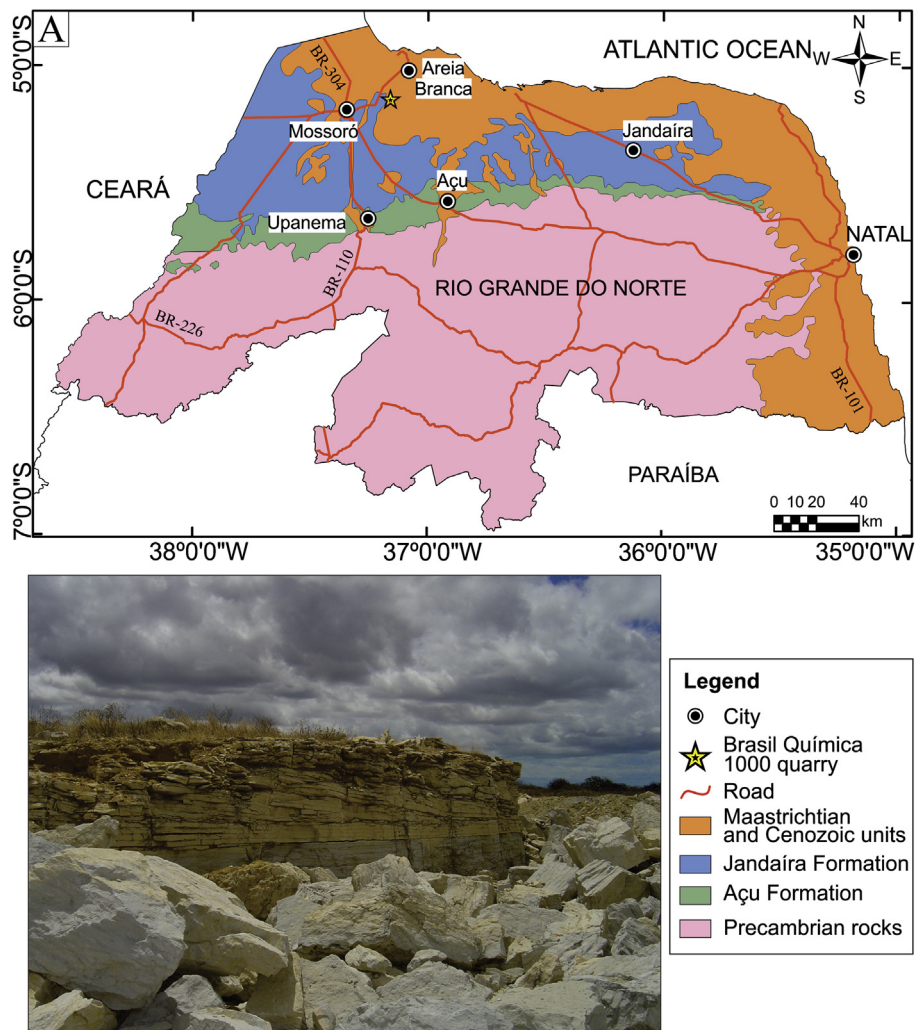


Fig. 2. Geologic map of the Potiguar basin and geographic location of Brasil Química 1000 quarry where the fossil crabs were collected (based of Angelim et al., 2006 and Medeiros et al., 2010).

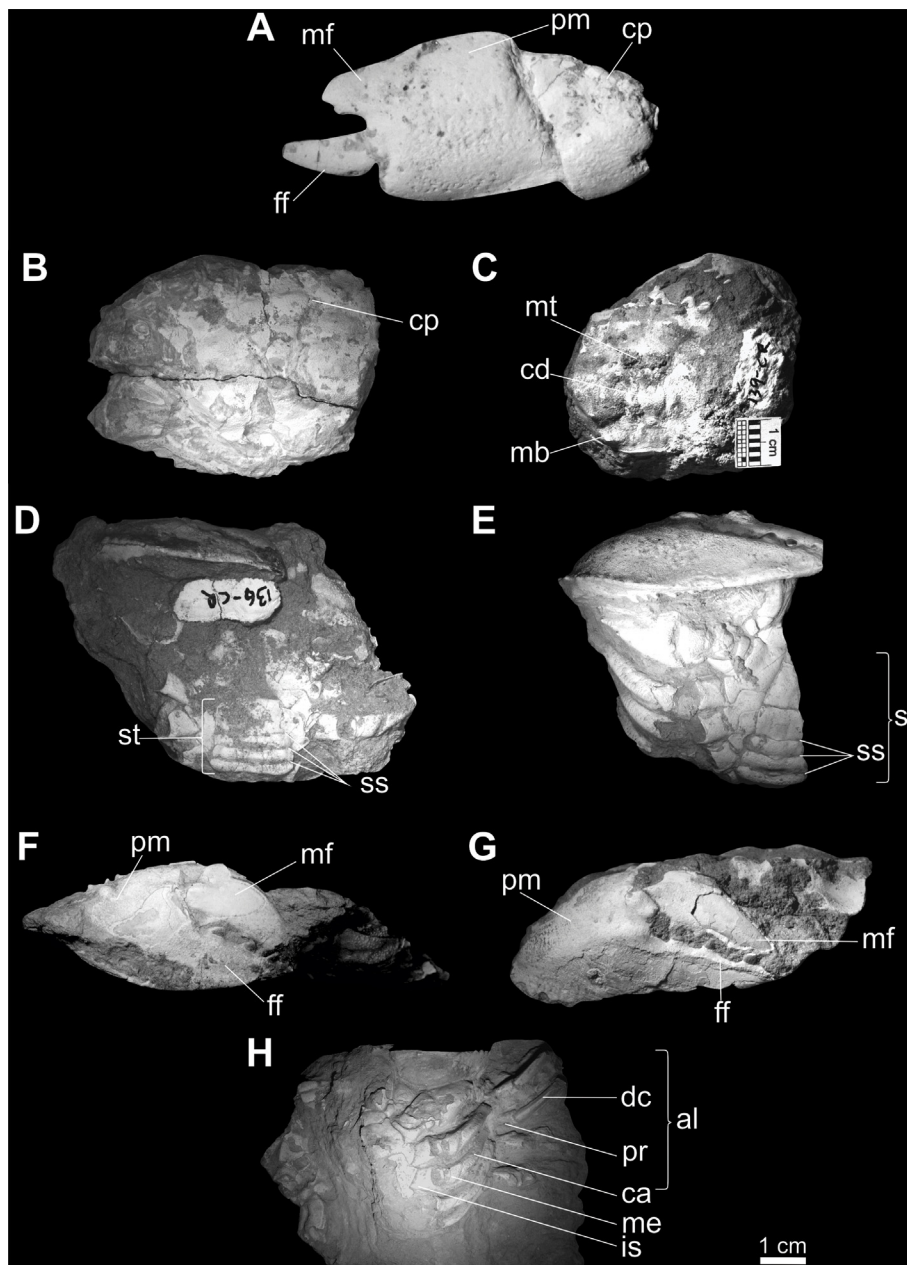


Fig. 3. A. Chepiled fragment of *Calianassa* sp. (244Cr); *Ophthalmoplax brasiliiana* (Maurý, 1930) B (184Cr) and C (139Cr) carapaces; D female sternum (136Cr); E male sternum (148Cr); F (139Cr) and G (139Cr) cheliped; and H (131Cr) ambulatory legs.

urogastric, mesogastric, mesobranchial and intestinal carapace areas are not preserved. Chelipeds large, robust, massive and convex, right chela larger than left; merus and carpus not visible; palm subtriangular elongate, with spiny margins, outer surface with longitudinal row of eight to ten small, delicate spines, upper margin has thick and strong spine pointing out from posterior edge and a longitudinal row of five to seven spines, lower margin with narrow and sharp spines; fixed finger robust with outer keel, lower margin with spines and occlusal surface with four to six thick, subtriangular, equidistant and about same size teeth, with broad base and pointed ends; movable finger with one row of delicate and curved sharp spines on upper surface, occlusal surface with prominent and rounded teeth. Outer surface is ornamented with small granules and striae. Third maxilliped not preserved. Right ambulatory legs elongate, strongly calcified and rounded in cross-section; first and second cylindrical, third and fourth compressed toward the extremities; ischium subquadrate to rhombic, merus inflated, carpus subrectangular, propodus smaller and narrower with lower edge

slightly arcuate, dactylus long with pointed ends. Sternum wide in male, narrow and elongate in female, with subparallel margins, widest anteriorly and narrowing posteriorly; sternal sutures entire, equidistant, parallel, deep and slightly undulated; sternites not preserved.

Occurrence: United States of America: Escondido, Ripley, Prairie Bluff, Owl Creek and Peedee formations, Maastrichtian; Mexico: Cerro Grande, Las Imágenes and Potrerillos formations, Maastrichtian; Venezuela: Mito Juan Formation, Maastrichtian; Colombia: Puerto Romero Formation, Maastrichtian; Brazil: Gramame Formation, Maastrichtian (Vega et al., 2013).

Material: eighteen shell fragments including only cheliped (UFRJ-DG 129Cr, UFRJ-DG 130Cr, UFRJ-DG 132Cr, UFRJ-DG 133Cr, UFRJ-DG 134Cr, UFRJ-DG 135Cr, UFRJ-DG 136Cr, UFRJ-DG 137Cr, UFRJ-DG 138Cr, UFRJ-DG 140Cr, UFRJ-DG 141Cr, UFRJ-DG 145Cr, UFRJ-DG 147Cr, UFRJ-DG 148Cr, UFRJ-DG 151Cr), torax an cheliped articulated (139Cr, 184Cr), abdomen and ambulatory legs articulated (UFRJ-DG 131Cr) from the Brasil Quimica 1000 quarry, near Mossoró

city, Rio Grande do Norte State, Brazil.

Dimensions: The specimens have on average cl: 60 mm; cw: 50 mm; chl: 80 mm; chw: 30 mm.

Discussion: The good preservation of these specimens and the diagnostic morphological elements confirm the presence *Ophthalmoplax brasiliiana* (Maury, 1930) in the studied rocks. The portunoid crab *Ophthalmoplax Rathbun, 1935* is recognized from Late Cretaceous marine deposits of Africa and Americas, represented by one species in each of these continents (Vega et al., 2013). In Brazil it was described by Maury (1930) at the Gramame Formation as the genus *Zanthopsis* genus and considered by Rathbun (1935), Beurlen (1958) and Santos et al. (1994b) as *Ophthalmoplax*.

4.2. Decapods at Brasil Química 1000 quarry

The Callianassidae fossils are absent in the Potiguar Basin but they are very common in the Paraíba Basin, distributed continuously as isolated cheliped fragments in the uppermost layers at Gramame Formation and all strata of the Maria Farinha Formation (Beurlen, 1962, 1967a; Távora et al., 2005).

The record of *Ophthalmoplax minimus* by Ossó-Morales et al. (2010) at Taghit Formation (Coniacian- Campanian) in Morocco, west Tethyan realm, may represent the oldest record for the genus, suggesting a possible African origin, with a westward migration across the proto Atlantic, to rapidly spread along the northeast coast of South America and southeast coast of North America. Its absence in southern Mexico and Caribbean region may be due by environmental preferences including temperature, substrate and depth.

Ophthalmoplax brasiliiana (Maury, 1930) was distributed along the Atlantic and Gulf coasts of the Americas throughout the Maastrichtian from Brazil to North Carolina, and became extinct just below the K/T boundary (Vega et al., 2013). The large-sized specimens of late Maastrichtian in these areas may be due to a decrease in ocean water temperatures.

Thus the geological context and decapod association found at Brasil Química 1000 quarry are typical of Late Maastrichtian, correlated with the previous researches in the Paraíba Basin and Natal Platform (i.e. Maury, 1930; Muniz, 1993; Santos et al., 1994b; Lima and Koutsoukos, 2006; Nascimento-Silva et al., 2011).

4.3. Discussion

The general geology of the Rio Grande do Norte State consists of exposed Precambrian rocks, distributed in westernmost, central and eastern portions of the Rio Grande do Norte, overlaid by a belt of Cretaceous sedimentary rocks in the northern region including the Potiguar, Gangorra, Rafael Fernandes and Coronel João Pessoa basins, which are associated with volcanic sequences. Unconformably overlying the Cretaceous records are Cenozoic deposits, best exposed as sea-cliffs (Jenkins et al., 1913; Angelim et al., 2006; Medeiros et al., 2010).

The geological and paleoenvironmental interpretations (Kegel, 1957; Oliveira, 1957; Beurlen, 1961, 1964; 1967b; Campanha, 1979; Mabesoone and Alheiros, 1993; Muniz, 1993; Araripe and Feijó, 1994; Santos et al., 1994b; Cremonini et al., 1996; Campanha and Saad, 1999; Hessel and Barbosa, 2005; Barbosa and Lima Filho, 2006; Souza, 2006; Barbosa, 2007; Barbosa et al., 2007; Monteiro et al., 2007) of the upper carbonate sequence in the Potiguar Basin support a Maastrichtian age correlated to the Gramame Formation. Barbosa et al. (2007) considered this sequence as undivided carbonate deposits. Cassab (2003) and Pralon et al. (2017) interpreted the Jandaíra Formation as a shallow and rough sea platform in some areas.

The fossiliferous content (Viviers and Regali, 1987; Lana and Roesner, 1999; Kegel, 1957; Oliveira, 1957; Beurlen, 1961, 1964, 1967b; Souza-Lima et al., 2007; Souza-Lima et al., 2007; Hessel and Barbosa, 2005; Benaim and Senra, 2008) also supports a deposition of this sequence during the Maastrichtian. The presence of the decapod

Ophthalmoplax brasiliiana (Maury, 1930) was recorded until now from two localities of the Paraíba Basin (Maury, 1930) and in Potiguar Basin (Pralon et al., 2017). Its geological, paleoenvironmental, biochronological and taphonomic settings are not compatible with the Jandaíra Formation context.

Therefore the decapods studied in this research allow recognition of the Brasil Química 1000 quarry as Maastrichtian, where they were collected and to correlate them with the Gramame Formation. The data reported here suggest that the sedimentary sequence of the Recife-Natal coastal zone is not an isolated portion of the Brazilian continental margin, instead it appears to have reached others continental areas of Rio Grande do Norte State, which was previously considered as Cenozoic sedimentary rocks (Santos et al., 1994b; Cassab, 2003; Angelim et al., 2006; Medeiros et al., 2010; Pralon et al., 2017).

5. Conclusions

The main Cretaceous record in Rio Grande do Norte state covers the fluvial-estuarines sandstones and mudstones of the Açú (Albian-Cenomanian), rocks typical of tidal flat system of the Jandaíra formations (Turonian-middle Campanian), and a marine sedimentary sequence of the eastern Brazilian Recife- Natal coastal zone, informally known as undivided carbonatic deposits (Maastrichtian), correlated to the Gramame Formation by many authors.

The Decapoda association at Brasil Química 1000 quarry, composed of *Callianassa* sp. and *Ophthalmoplax brasiliiana*, is typical of Late Maastrichtian. The geological, paleontological, paleoenvironmental, biochronological and taphonomic settings allow correlation of these deposits with the Gramame Formation of Paraíba Basin and the undivided carbonatic deposits of the Recife-Natal Platform. The data obtained suggest that the Late Maastrichtian sedimentary sequence of the Recife-Natal Platform reached others areas, which was previously considered Cenozoic sedimentary rocks by many authors.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jsames.2019.102307>.

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