REASSESSMENT OF THE LIMNIC OSTRACODS FROM THE ITAPARICA FORMATION, BERRIANSIAN (LOWER CRETACEOUS), RECÔNCAVO BASIN, BAHIA, BRAZIL: A TAXONOMIC AND PALEOENVIRONMENTAL UPDATE

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ABSTRACT

Based on the study of a great quantity of ostracods carapaces from 10 cores of the Recôncavo Basin (Bahia, Brazil), this work presents the detailed and revised taxonomy of limnic ostracoda from the Itaparica Formation (Lower Cretaceous). (7) Seven species belonging to (4) four genera have been recovered: *Kegelina kegeli*, *Kegelina depressa*, *Kegelina bisculpturata*, *Kegelina armata*, *Praecypridea acuta*, *Cypridea brevicornis*, *Theriosynoecum fittoni*. What was once defined as *Theriosynoecum varietuberatum proximum* and *Theriosynoecum varietuberatum varietuberatum* is understood here as a difference in ornamental of the *Theriosynoecum fittoni* due to overall morphological compatibility. This observation is supported by most recent works, as it brings ornamentation itself as an insufficient aspect to distinct and define species for the *Theriosynoecum* genus. Based on the ostracoda associated with the litologic aspects, the Itaparica Fm represent a lacustrine depositional environment in a freshwater lake with depositions of shales, sandstones, siltstones, carbonatite and limestones in an arid climate.

Key words: Depositional Environment; Palaeoecology; Taxonomy.

RESUMO.

O presente trabalho apresenta a taxonomia detalhada e revisão dos ostracodes límnicos na Formação Itaparica (Cretáceo Inferior) da Bacia do Recôncavo (Bahia, Brasil), realizado no estudo de 10 perfurações. Foram identificadas 7 (sete) espécies pertencentes a 4 (quatro) gêneros: *Kegelina kegeli, Kegelina depressa, Kegelina bisculpturata, Kegelina armata, Praecypridea acuta, Cypridea brevicornis, Theriosynoecum fittoni*. O que anteriormente era definido como *Theriosynoecum varietuberatum proximum* e *Theriosynoecum varietuberatum varietuberatum* e aqui entendido como uma diferença ornamental de *Theriosynoecum fittoni* devido à compatibilidade morfológica geral. Esta observação é apoiada pelos trabalhos mais recentes, pois traz a própria ornamentação como um aspecto insuficiente para distinguir e definir espécies de *Theriosynoecum*. Com base nos ostracodes associados aos aspetos litológicos, a Formação Itaparica representa um ambiente deposicional lacustre, em um grande lago de água doce com deposições de xistos, arenitos, siltitos, carbonatos e calcários de clima árido.

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Palavras-chave: Ambiente Deposicional; Paleoecologia, Revisão Taxonômica.

1 – Introduction

Ostracods are small bivalved micro-crustaceans with a calcium carbonate carapace that represent the most abundant arthropods fossils, with a register extended back to the Ordovician (*e.g*. Williams et al. 2015). Mesozoic to Recent non-marine ostracod faunas incorporate taxa of the superfamilies Cypridoidea, Cytheroidea, and Darwinuloidea. Due to their tiny size, good fossil record and preservation, ecologic dispersal strategies, ostracods have considerable potential as index fossils. For these aspects, the ostracod assemblages are highly applicable to marine, marginal marine and non-marine environment interpretation (see Boomer et al., 2003; Horne, 2003; Sames, 2011b for an overview).

The Mesozoic ostracod fauna from the Recôncavo Basin of Bahia state was first studied and registered by Jones (1860), with the earliest findings of Cretaceous ostracods in Brazil. However, research and economic interest for ostracods increased when Petróleo Brasileiro (Petrobrás) commenced petroleum exploration in the 1950s through the published works of Krömmelbein (*e.g*. Poropat & Colin, 2012).

Despite recent revisions of various species and genus, the published works on ostracods from the Itaparica Formation are scattered regarding a paleoenvironmental approach. The first ostracod species of the formation was described by Peck (1941), the *Cypridea brevicornis*, as a nonmarine microfossil of the Rocky Mountain region of the United States of America. Wicher (and Moos), in 1959 described new species and subspecies of three ostracods from the Itaparica Formation of the Recôncavo Basin: *Cypridea acuta*, later assigned as *Praecypridea acuta* in Sames et al. (2010), *C. bisculpturata* and *C. kegeli* Krömmelbein (1962) and Grekoff & Krömmelbein (1967) described two other species from the formation, respectively: *Cypridea armata* and *Theryosinoecum varietuberatum* Moura (1972) revised and reassessed the ostracod faunas of the Recôncavo basin describing several new ostracod taxa including the Itaparica species *C. depressa* and *Theryosinoecum varietuberatum proximum* Recently, Neto et al. (2014) assigned the species C. *acuta, C. kegeli, C armata* and *C. bisculpturata* to the new genus *Kegelina* as *K. acuta, K. kegeli, K. armata* and *K. bisculpturata*.

Here, we suggest the reclassification of the *Theriosynoecum varietuberatum* and original denomination (first classified by Grekoff & Komelbein (1967) later modified to *Theriosynoecum varietuberatum varietuberatum* after Moura (1972) and *Theriosynoecum varietuberatum proximum* as the same species of *Theriosynoecum fittoni* Mantell (1844). The criteria applied by Grekoff & Krömmelbein (1967) and Moura (1972) to differentiate both species from other *Theriosynoecum* should not be used as a taxonomic diagnose as long as the presence of local ornamentation elements alone are considered to be of low, or no, taxonomic relevance. Although, local ornamentation elements can be used for paleoenvironmental, as salinity changes, as well as for the identification of sexual dimorphism in certain cases, as brought by Sames (2011b; 2011d).

In this work, we restudy the ostracod faunas from the Itaparica Formation of the Recôncavo Basin based on the reassessment and description of samples provided by PETROBRAS. In pursuance of an updated approach of the ostracod biostratigraphy for the formation, this paper reassigns the ostracod species and groups according to recent publications (Sames; 2010; Netto et al., 2014) and redescribe the unrevised species. Additionally, the ostracod fauna of the Itaparica Formation is analyzed with respect to their palaeoenvironmental interpretation.

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II - **Geological setting**

The Recôncavo Basin is located in the Bahia state, northeastern Brazil at the Atlantic coast of South America, with a total area of 11,500 km² (Fig. 1). The basin is the southern part of an aborted rift, formed by the Gondwana rupture (Wiedekher, 2010). The geological limits of the basin are represented by Alto do Aporá - north and northeast; by the fault system of Barra – south; by the Maragogipe fault – west; and by the fault system of Salvador – east (Silva et al 2007). The sedimentation of the basin started in Jurassic times as a fluvio-aeolian-lacustrine sequence of the Brotas Group. This group is overlain by the Itaparica Formation, from early Cretaceous (Wiedekher, 2010). The Berriasian (Early Cretaceous) strata of the Recôncavo Basin consist of four formations: Itaparica, Água Grande, Candeias and part of the Salvador Formation.

Among them, the Itaparica Formation represents the tectonic accommodation phase of the rift. The formation represents a deep lacustrine environment, associated with alluvial fans in the east border of the basin. Therefore, the Itaparica Formation consists of shales, sandstones, siltite and limestones deposited under the control of a half-graben geometry of the Recôncavo Basin (Wiedekher, 2010). Although, the tectonic phase of the Itaparica Formation is not agreed upon. According to Silva et al. (2007) the syn-rift phase starts at the base of the Candeias Formation, considering the Itaparica Formation as a pre-rift phase. Mattos (1999) affirms that the limit between those phases is placed on the top of the Candeias Formation. Oppositely, Cupertino (2000) placed the limit between pre-rift phase and syn-rift phase at the base of the Itaparica Formation. In her work, Wiedekher (2010) classified the Itaparica Formation as belonging to the Early Rift Climax Tectonic System Tract of Prosser (1993), or to the Trough-going Fault Stage of Gawthorpe & Leeder (2000), or to the Half-graben Stage of Morley (2002).

The Itaparica Formation is located in the Rio da Serra stage of The Recôncavo Series, biozone RT – 002.1, zone *Theriosynoecum varietuberatum* (Grekoff & Krömmelbein, 1967) suggested herein to be reassigned as *Theriosynoecum fittoni* (Mantel 1844), subzone *Cypridea Kegeli* (reassigned to *Kegelina kegeli* by the work of Neto et al., 2014) (Fig. 2). The paleofauna of the Recôncavo Basin had an important role in the development of the studies that associate the paleoenvironments of the southern Atlantic coasts of Brazil and Africa. As a result of the Gondwana supercontinent rupture, the Recôncavo Basin shares evidence of a rift process with the Atlantic coast of the African continent (Grekoff & Krömmelbein, 1967; Viana, 1996 b; Poropat & Colin, 2012). Viana (1966 b) applied the zonation of the Bahia Series to the African Cocobeach Succession of the Gabon Basin, confirming that the Itaparica Formation was correlated with the Gabonese Transitional Series.

III - Materials and methods

Ostracods samples were provided by PETROBRAS, previously collected by the company from 10 cores placed all over the extension of the Recôncavo Basin. The ostracods carapaces were sorted and grouped from each 30 meters of the cores' depth. The core's locations were separated by the three regions of the basin: Northeast (2 cores) from Central (4 cores) and South (4 cores).

Ostracods carapaces and valves were analyzed in microscope using fine needles and blades under a binocular microscope.

As long as the whole data used in this work was classified due to the PETROBRAS regulation of internal privacy of data, no photos of the cores and ostracods samples were allowed to be published.

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The figures of the ostracods presented in this work were digitally grouped from the original works that have been published about the species identified in this study with permission granted by all the publisher.

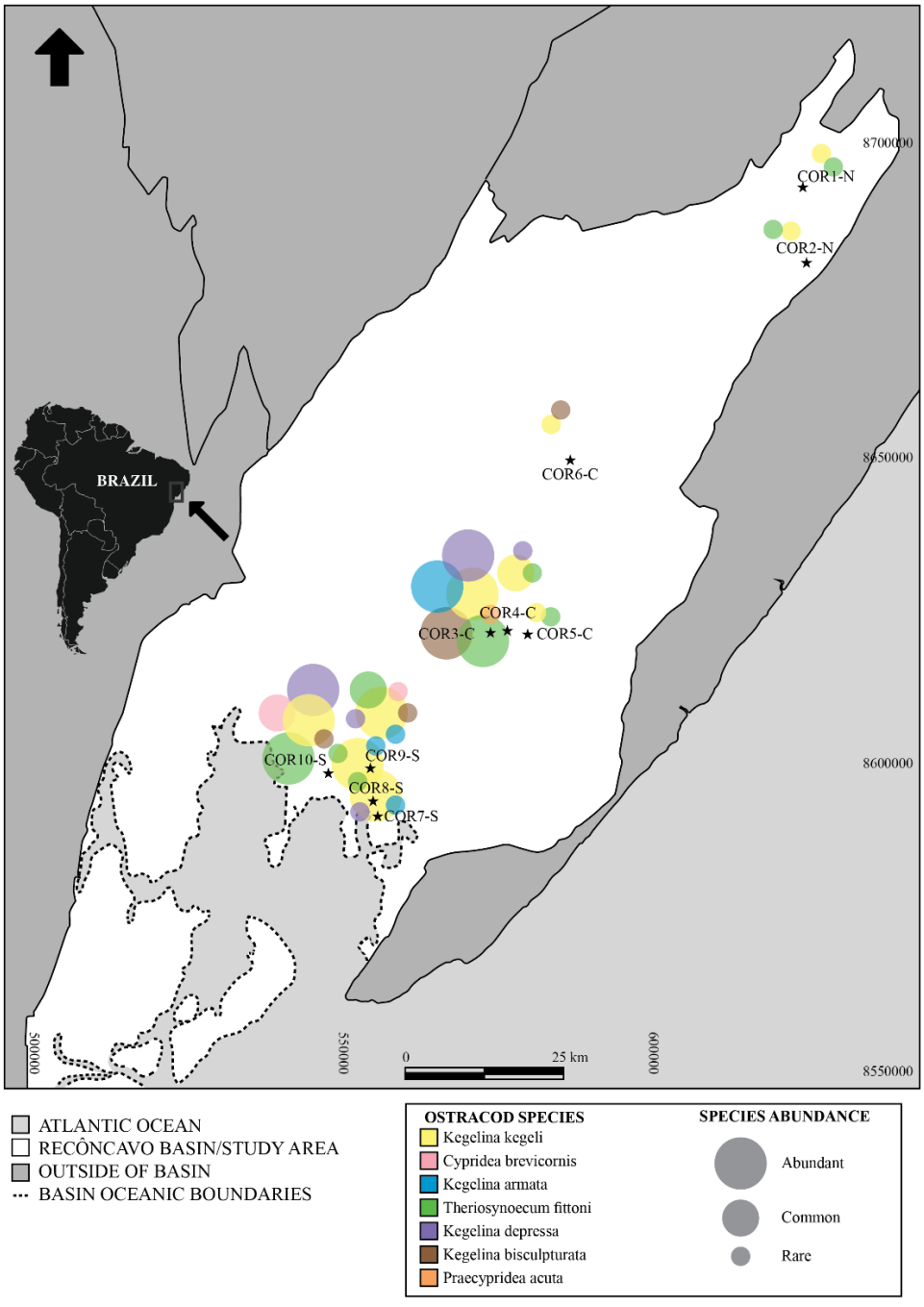

Figure 1: Location map of the Recôncavo basin and distribution of the analyzed cores.

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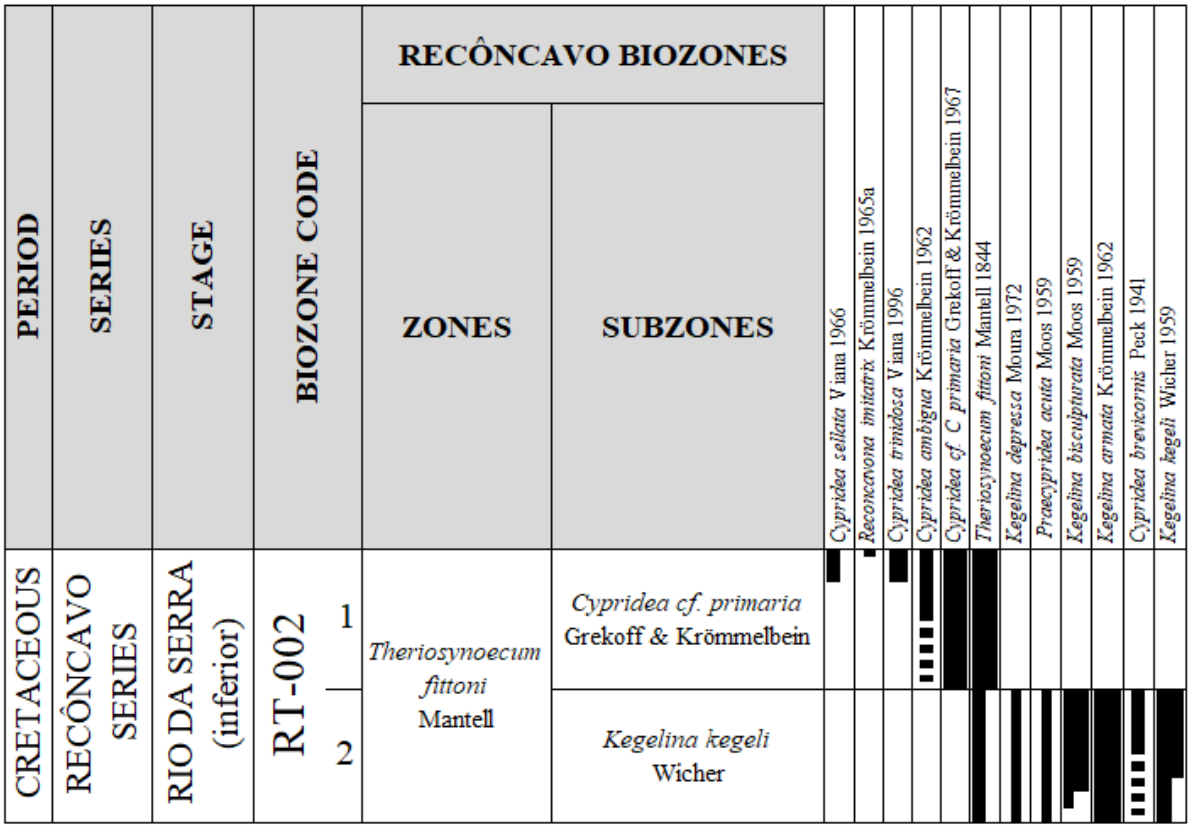

Figure 2: Chart of the Inferior Rio da Serra Stage, biozone RT 002 illustrating the ranges Itaparica Formation ostracod species at the Recôncavo Basin (redrawn from Poropat and Colin, 2012 and Moura, 1972), modified and renamed based on the results of the study pr presented at this work. Upper bars indicate the stratigraphic range; lower bars represent the abundance of the ostracods at the sections.

IV - Systematic paleontology

The following abbreviations and conventions are described as: L: length, H: height, W: width; very small (<0.400 mm), small (0.400-0.500mm), medium (0.510-0.700 mm), large (0.710-0.900 mm), very large (>0.900 mm); C: carapace, RV: right view, LV: left view, DV: dorsal view. All measurements are in millimeters (mm) and are registered as the smaller size and the larger sizes of all the carapaces analyzed.

Class Ostracoda Latreille, 1802
Order Podocopida G.W. Müller, 1894
Suborder Cypridocopina Jones, 1901
Superfamily Cypridoidea Baird, 1845
Family Cyprideidae Martin, 1940

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Genus *Kegelina* Neto, Sames and Colin, 2014

Type species: *Kegelina kegeli* Wicher, 1959.
Remarks. The description of the new Early Cretaceous *Kegelina* species is based on the proposition made by Neto et al. (2014). The authors suggest a new genus for the following four species, which kept the representatives from the Cypridea relatives that presents a rostrum and alveolus in the now-extinct Cyprideidae Family. This suggestion is based on a presumed Praecypridea–Cypridea–*Bisulcocypridea lineage* (Sames et al., 2010a).

Kegelina kegeli (Wicher, 1959)
Figure 5: A-C

1959 *Cypridea kegeli* Wicher, p. 42, pl. 8, fig. 11.
1962 *Cypridea kegeli*, Krömmelbein, p. 454, pl. 56, fig. 25.
1965 *Cypridea kegeli*, Krömmelbein, p. 116, chart 1, fig. 8.
1966 *Cypridea kegeli*, Viana, pl. 1, fig. 22.
1999 *Cypridea kegeli*, Bate, fig. 3.
2014 *Kegelina kegeli*, Neto, Sames and Colin, p. 804, fig. 4.

Material. Approximately 50 carapaces and valves of ostracods and several fragments from the 10 cores drilled all over the Recôncavo Basin, Bahia, Brazil (Fig. 1).
Size. length: 0.81–0.94mm, height 0.50–0.57mm, width 0.41–0.46mm
Diagnosis. Large-size species with both LV and RV exhibiting slight rostrum and alveolar notch (or ‘‘beak’’) in all samples. Lateral-centered coarse punctatiton on the obese part of the carapace with smooth edges. The dorsal views reveal an obese form in the central area of the valves. LV larger than RV.
Description. Large sized carapace with a trapezoidal form in lateral view and LV larger than RV. Maximum length at lower-central height and maximum height closer to the anterior first third portion of the valve. LV accented overlap at ventral margins and becomes slighter through the margin. Anterior margin infracurvature with a plain shape in dorsal portion that ends in a weak rostrum and alveolar notch (‘’beak’’) with a less prominent incisure in the RV. Posterior margin infracurvature to equicurvate with a plain dorsal shape. Sexual dimorphism not observed. Left valve with dorsal margin slightly convex through a weak dorsal ridge with posterior cardinal angle about 30º. Anterior cardinal angle rounded, about 150° with a more angular RV. Posterior cardinal angle well-defined, about 150°, well-rounded in LV, with an angular RV as well. In dorsal view is obese, elongated-elipticaly. Lateral-centered coarse punctatiton in the carapace surface. The size of the puncta becomes smaller towards the margins of the valve with variation in size and form of the puncta. The valves margins are smooth.
Remarks. *Kegelina kegeli* (Krömmelbein, 1962) is the index fossil of the biostratigraphic subzone with which the Itaparica Formation is included. *Kegelina kegeli* is, in several characteristics very similar to the *K. depressa*. The *K. depressa* differs from *K. kegeli* in its larger size, presents a thinner lateral outline similar to a depression in the center of the valves where the punctation is concentrated, the dorsal margin is is more inclined and the lateral outline is thinner, no rostrum and alveolar notch in the LV and the absence of na anteroventral incisure in the RV.

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Kegelina depressa (Moura, 1972)
Figure 5: D-E

non1941 *Cypridea nitidula*, Peck, p. 301, pl. 43, figs. 1–5.
?1959 *Cypridea nitidula*, Moos in Wicher, p. 45, pl. 9, fig. 4a, 4b.
1972 *Cypridea depressa*, Moura, p. 245, fig. 1.
2014 *Kegelina depressa*, Neto, Sames and Colin, p.804, fig. 4.

Material. Approximately 60 carapaces and valves of ostracods and several fragments from of the 10 wells drilled all over the Recôncavo Basin, Bahia, Brazil (Fig. 1).
Size. length 0.61–0.89, height 0.33–0.50, width 0.30–0.45
Diagnosis. Medium sized valves, oblique trapezoidal in lateral view. Anterior margin moderately infracurvate-equicurvate. LV with an anteroventral weak rostrum and very weak incisure. Curved and thin true cyathus. Very rounded cardinal angles. Lateral-centered coarse punctatiton in the valves.
Description. Medium sized carapace, slightly oblique trapezoidal in lateral view. Maximum length below mid-height, maximum width at mid length LV larger than RV, slightly reaching lateral margin at posteroventral and anteroventral portions. Moderate valve overlap decreasing along margin with a convex ventral overlap. Posterior margin infracurvature curve with a true cyathus, slightly angular and round in the margin. Anterior margin wide and equi-infracurvate, ventrally with a weak rostrum and alveolar notch or sharp anteroventral angularity. RV with very slight incisure. LV overreach RV in posterior margin region. Dorsal margin is straight in RV and weakly convex in LV. Anterior cardinal angle rounded and well-marked (120°-130°), posterior cardinal angle rounded and obtuse (155°-160°). Incision in hinge margin in the first third of valve length. Ventral margin slightly concave. Lateral-centered coarse punctation in the valve surface. The size of the puncta becomes smaller towards the margins of the carapace with variation in size and form of the puncta. The valves margins are smooth.
Remarks. *Kegelina depressa* is generally smaller than the other *Kegelina* species. *K. depressa* coarse punctation in the carapace central area, lateral outline, weak indications of a LV rostrum and alveolar notch are the main similarities with *K. kegeli* except for the thinner aspect in dorsal view. According to Neto et al. (2014) this might point to the possibility of *K. depressa* being a juvenile of *K. kegeli*. *Kegelina depressa* has about the same size as *K. bisculpturata* but the posterior margin of *K. depressa* tends to be more equicurvate and the posterior margin is more rectangular.

Kegelina armata (Krömmelbein, 1962)
Figure 5: G-I

1962 *Cypridea armata* Krömmelbein, p. 455, pl. 56, fig. 27.
1966 *Cypridea armata*, Krömmelbein, p. 116, chart 1, fig. 7.
1999 *Cypridea armata*, Bate, fig. 3.
2014 *Kegelina armata*, Neto, Sames and Colin, p.804, fig 4.

Material. Approximately carapaces of 36 ostracods and several fragments from the 10 wells drilled all over the Recôncavo Basin, Bahia, Brazil (Fig. 1).
Size. length: 0.90–1.02mm, height 0.60–0.64mm, width 0.37–0.41mm

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Diagnosis. Large sized carapace, oblique-trapezoidal elongate in lateral view. Both cardinal angles are distinct. Weak incisure in RV and weak rostrum and alveolar notch in LV. Straight and elongated dorsal and prominent posterocentral spine on both valves. Surface with punctation covering the valves fading towards the margins.
Description. Large sized carapace, oblique-trapezoidal elongate in lateral view. Maximum height at the anterior one-third of the length. Maximum width at the last third height of the valves. LV larger than RV, LV weekly overlapping RV along all free margins but not the cyathus area. Anterior margin infracurvate with plain dorsal section, LV with weak rostrum and alveolar notch, RV with weak incisure. Posterior margin also infracurvate with true cyathus. Anterior cardinal angles are distinct, about 125°-130°. Posterior cardinal angles are also distinct, about 140°-150°. Dorsal margin mostly straight and declines towards anterior end, hinge margin incised, about 20-25°.Ventral margin nearly straight, somewhat slightly concave. Most part of the valves surface is covered with punctation fading towards antero and posterolateral areas. In dorsal view the carapace is elongated and elliptic with a weak dorsal furrow. One small anterolateral tubercle in each valve.
Remarks. The main differences from *Kegelina armata* of all the other species from Genus *Kegelina* are the elongate carapace in lateral view, its anterolateral tubercle in each valve, its true cyathus and the valves surface covered with punctation fading towards antero and posterolateral areas. *Kegelina depressa*, compared to *Kegelina armata*, differentiate itself by its smaller size, a less inclined ventral margin, puctation limited to the central area of the valves and rounded cardinal angles. *Cypridea brevicornis* differentiate itself from *K. armata* by its more rectangular shape with a rounded hinge margin.

Kegelina bisculpturata (Wicher, 1959)
Figure 5: J – L

1959 *Cypridea kegeli bisculpturata* Moos in Wicher, p. 44, pl. 9, fig. 2a, 2b.
1962 *Cypridea bisculpturata*, Krömmelbein, p. 455, pl. 56, fig. 26.
1966 *Cypridea bisculpturata*, Krömmelbein, p. 116, chart 1, fig. 9.
2014 *Kegelina bisculpturata*, Neto, Sames and Colin, p. 804, fig. 4.

Material. Approximately, carapaces of 17 ostracods and several fragments from the 10 wells drilled all over the Recôncavo Basin, Bahia, Brazil (Fig. 1).
Size. length 0.67–0.75mm, height 0.39–0.45mm, width 0.20–0.34mm.
Diagnosis. Medium sized carapace with trapezoidal-oblique shape in lateral view. LV larger than RV. LV with weak rostrum, RV with weak anteroventral incisure. ‘true’ cyathus curvate and posterior cardinal angle almost nonexistent. Carapace with coarse punctation and nodes.
Description. Medium-sized carapace with trapezoidal-oblique shape in lateral view and elliptical in dorsal view with maximum width in mid-length. Maximum length at mid-height. maximum height posterior of 2/3 length. LV larger than RV; LV moderately overlapping along all margins stronger in ventral margin, except for the hinge margin. Anterior margin broad and equi-infracurvate; anterior cardinal angle rounded and inconspicuous in both valves, ca. 150°-160°. Rostrum and alveolar notch weak and alveolar furrow narrow and rounded. Posterior margin equicurvate mostly with a rounded true cyathus. Dorsal margin straight and inclined towards the posterior end (10°-20°). Length of the hinge margin ca. 1/3 of the carapace length, incised and inclined towards the posterior portion, ac. 10-20°. Ventral margin with a straight to curvate shape. Both valves with depressions below the

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anterior cardinal angle, with both surfaces covered with coarse punctation and multiple nodes with different sizes. Anterior valve smoother.
Remarks. K. bisculpturata differs from the other *Kegelina* species by its smaller size carapace and its nodelike tubercles (Sames, 2011). *K. kegeli* differs from *K. bisculpturata* in its triangular shape in lateral view, its infracurvate posterior margin and an inclined dorsal margin. *K. depressa* differentiate itself from *K. bisculpturata* in the absence of the nodes besides the size and cardinal angle depression on both valves. *K. armata* is larger in overall size and has a more triangular shape in lateral view compared to *K. bisculpturata* (Sames *et al*., 2014), with two posterocentral spines.

Genus *Cypridea* Bosquet 1852

pars*Cypridea* nom. nov. pro *Cypris* Müller 1776 – Bosquet 1852, p. 47.
Pseudocypridina gen. nov. – Roth 1933, p. 404 [syn. *Langtonia* Anderson 1939].
pars *Cypridea* –Anderson 1939, p. 294 [diagnosis therein not including all forms, e.g. "*Ulwellia*"].
Cyamocypris gen. nov. – Anderson 1939, p. 305.
Langtonia gen. nov. –Anderson 1939, p. 304 [syn. *Pseudocypridina* Roth 1933].
Morinina gen. nov. – Anderson 1939, p. 302.
Ulwellia gen. nov. – Anderson 1939, p. 300.
Cypridea – Sylvester-Bradley 1949, p. 130 [Cypridea s.l.].
Cypridea (Cypridea) – Sylvester-Bradley 1949, p. 135 [*Cypridea* s.s.].
non*Cypridea (Yumenia*) subgen. nov. – Hou 1958, p. 93.
Cypridea (Morininoides) subgen. nov. – Krömmelbein 1962, p. 471.
?*Cypridea (Sebastianites)* subgen. nov. – Krömmelbein 1962, p. 460
?pars*Hourcqia* gen. nov. – Krömmelbein 1965b, p. 68-69 [including *H. africana* Krömmelbein 1965b, *H. africana africana* Krömmelbein and Weber 1971, *H. africana* confluens Krömmelbein and Weber 1971].
non*Cypridea (Guangdongia)* – GUAN 1978 [probably *Bisulcocypridea*]
Longispinella gen. nov. – Sohn 1979, p. 18.
?*Cypridea africana* (Krömmelbein) comb. nov. – Do Carmo et al. 2008, p. 793 [non *Hourcqia angulata angulata, H. angulata salitrensis, H. angulata sinuata, H. angulata symmetrica* Krömmelbein und Weber 1971].

Type species. Cypridea granulosa (Sowerby 1836), designated by Sylvester-Bradley (1949).
Remarks. Based on the hypothesis of the existence of a *Praecypridea-Cypridea-Bysulcocypride*a lineage (Sames *et al*., 2010) in this work is followed the view of keeping *Cypridea* and its relatives with a rostrum and alveolus in a separate family of the superfamily Cypridoidea Baird, 1945, the *Cyprideidae* Martin, 1940.
Occurrence. Europe, North America, Africa and South America. Middle Jurassic to Lower Cretaceous.

Cypridea Brevicornis (Peck, 1941)
Figure 5: O-Q

*1941 *Cypridea brevicornis sp. nov*.: Peck, p. 299, pl. 44, fig. 22-24.

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Material. Approximately, carapaces, valves of 10 ostracods and several fragments from the 10 wells drilled all over the Recôncavo Basin, Bahia, Brazil (Fig. 1).
Size. Length 0.80–1.00mm; height 0.46–0.60mm; width 0.38–0.46mm.
Diagnosis. Large sized carapace with a rounded oblong shape in lateral view with a moderately developed rostrum reaching the entire ventral margin. Alveolar furrow strongly incised and crescent in LV but broad and very short in RV. Surface covered with coarse puncta except for the extreme margins and a single round and short spine in each valve about slightly above mid-length and about the division between 1/3 and 2/3 of the carapace height.
Description. Large sized carapace, rounded and suboblong in lateral view. Maximum length at mid-height, maximum height at 1/3 of the length, and maximum width at mid-length; LV larger than RV and overlapping the margins except for the dorsal margin where it is weaker. Anterior margin equicurvate; anterior cardinal angle round and conspicuous, ca. 130-140º. Strong rostrum and weak but well defined broad alveolar notch, alveolar furrow well incised and crescent, strongly distinct in LV than in in RV. Posterior margin infracurvate to equicurvate; posterior cardinal angle round and weak, ca. 120-130°. Dorsal margin straight slightly inclined towards posterior margin; hinge margin incised inclined towards posterior margin. Ventral margin with a straight shape. Valve surface is entirely covered with puncta and a tubercle.
Remarks. Based on the hypothesis of the existence of a *Praecypridea-Cypridea-Bysulcocypridea* lineage (Sames *et al*., 2010), here the species is interpreted as a *Cypridea* species for the presence of a well-developed rostrum, alveolus and the alveolar notch. The cyathus is mostly obtuse and rounded developed in the larger valve. The hinge margin is incised, forming a marked dorsal furrow. According to Sames (2011a), the reassessment to the type material used at Peck's work is missing from his collection, which makes it difficult to review the comparison between the Itaparica ostracods and the Rocky Mountain Region samples. Through more detailed observation we suggest a further comparison between them as long as the following differences have been perceived for both descriptions: Peck's samples carapace are described as sublong in lateral view, anterior and posterior margins round with strong alveolar notch and beak, surface of both valves covered with very small pits, except for anterior part, or nearly smooth. The figure presented in Peck's work seems to represent a LV overlapping the entire anterior margin and RV with a wide rostrum, posterior and anterior margin equicurvate . However, Itaparica ostracods associated with that species differentiates itself with a large size and subovate shape in lateral view, posterior margin infracurvate and almost straight to subround with a weak but marked rostrum and alveolar notch present in both valves, surface entirely covered with well-defined but small puncta, LV slightly overlapped by RV only in ventral margin.

Genus *Praecypridea* Sames, Whatley and Schudack, 2010.

Type species. *Cypridea acuticyatha* Schudack, 1998.
Remarks. Based on the hypothesis of the existence of a *Praecypridea-Cypridea-Bysulcocypridea* lineage (Sames *et al*., 2010) in this work is followed the view of keeping *Cypridea* and its relatives with a rostrum and alveolus in a separate family of the superfamily *Cypridoidea* Baird, 1945, the *Cyprideidae* Martin, 1940.
Occurrence. Europe, North America, Africa and South America. Middle Jurassic to Lower Cretaceous.

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Praecypridea Acuta (Wicher, 1959)
Figure 5: M-N

*1959 *Cypridea acuta sp. nov.*: Moos in Wicher, p. 46, pl. 9, figs 3 a, b.
non 1971 *Cypridea acuta sp. nov.*: Anderson, p. 50, pl. 16, fig. 5
non 1985 *Cypridea aemulans nom. nov. pro C. acuta* Anderson, 1971: Anderson, p. 25, pl.4, fig. 2.
2011 *Praecypridea acuta comb. nov.*: Sames, Whatley and Schudack, p. 167, pl. 1, fig 14, 15.

Material. Valve of an ostracod from one of the 10 wells drilled all over the Recôncavo Basin, Bahia, Brazil (Fig. 1).
Size. Length 1.2-1.5mm, height 0.7–0.8mm, width 0.3–0.5mm
Diagnosis. Very large sized carapace with an acute cyathus-like protrusion. Almost straight dorsal margin short and inclined towards posterior margin with about 50°- 60°. Anterior margin infracurvate with a weak but wide rostrum, weak alveolar notch and furrow. Ventral margin curved with dorsal edge ending behind rostrum. Smooth valves surfaces.
Description. Very large sized carapace ovate to subtrapezoidal in lateral view. With an acute cyathus-like protrusion. Elliptical shape and slender in dorsal view. Maximum length at ventral margin, maximum height more anterior than mid-length, maximum width at mid-length. LV larger than RV; LV overlapping RV in entire margins except for hinge margin. Anterior margin rounded and infracurvate; anterior cardinal angle rounded and indistinct about 160°-170°. Posterior margin diving straight with a 50°-60° angle towards a cyathus-like protrusion. Posterior cardinal angle rounded and well-marked, ca 130°-140°. Ventral margin straight. Dorsal margin short inclined towards posterior margin in a 20°-25° angle. Alveolar furrow well developed only in RV. Valve texture smooth.
Remarks. P. acuta has restricted limits of spatial and chronological distribution, present in the atlantic margins of Brazil (Reconcavo Basin) and West coast of Africa (Gabon Basin). Its presence in the Itaparica Formation samples were rare, limited to one carapace. As mentioned by Sames et al. (2010) the specimen needs further revision and analysis.

Infraorder Cytherocopina Gründel 1967
Superfamily Cytheroidea Baird 1850
Family Limnocytheridae Klie 1938

Genus *Theriosynoecum* Branson 1936

Morrisonia Branson 1935, p. 521
non *Morrisonia* Grote, 1874.
Theriosynoecum nom. nov., nom. subst. pro *Morrisonia* Branson 1935 – BRANSON 1936, p. 323.
Theriosynecum Mandelstam 1955 in Galeeva
Bisulcocypris gen. nov. – Pinto and Sanguinetti 1958, p. 77.
Dryelba gen. nov. – Sohn 1982, p. 313.

Type species: *Morrisonia wyomingensis* Branson 1935
Remarks. According to Sames (2011b), *Morrisonia* was the first name in Branson's establishment for this genus, in 1935. The author replaced the genus name with *Theriosynoecum*, in 1936, since the first was already associated with another living species of Lepidoptera.

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Theriosynoecum fittoni (Mantell, 1844)
Figure 4: R

1953 *Metacypris persulcata*: Grekoff, p.371
1962 *Metacypris sp. 1*: Krömmelbein, p. 490, pl. 62, fig. 64.
1967 *Theriosynoecum varietuberatum n. sp*.: Grekoff and Krömmelbein, p. 1353, pl. 9, fig. 55.
1972 *Theriosynoecum varietuberatum proximum ssp. n*.: Moura, p. 262, pl. 4, fig. 23.

Material. Approximately 100 valves and carapaces of ostracods and several fragments from 10 cores drilled through the whole extension of the Recôncavo Basin (Fig. 1).
Size. length 0.68-0.95mm, height 0.45–0.53mm, width 0.30–0.56mm
Diagnosis (emend.). Elongated, with a slightly prominent posterior margin. Two dorsomedial sulci compressed extending ¾ of the valve height, separated by an intermediate lobe. Carapace surface covered with puncta, some specimens present tubercles in variable number, varying from 5 to seven in each valve, more or less aligned in the ventral regions.
Description. Medium sized carapace, rounded subrectangular in lateral view. LV and RV with the same size. Maximum length at mid-height, maximum height at 4/5 of length. Anterior margin broad and slightly infracurvate with a curvate dorsal part, anterior cardinal angle broad, rounded and elevated, about 150-155°. Posterior margin broad and moderately rounded, almost straight, posterior cardinal angle about 105-110°, slightly elevated. Dorsal margin concave and broad. Two dorsomedial sulci compressed extending ¾ of the valve height, separated by an intermediate lobe. S1-sulcus, the one closer to anterior margin, shorter than the S2 one, extending from approximately below dorsal margin downwards between 3/4 and 2/3 of maximum carapace height. Ventral lateral outline convex. Carapace regularly punctate, tuberculation is common. Main tuberculation for each valve pattern consisting of four posterolateral tubercles and two anterolateral.
Remarks. This species was identified by Krömmelbein (1962) as *Metacypris sp. 1*, for the Recôncavo basin representatives of the Lower Cretaceous formations. Later being reassigned by Grekoff and Krömmelbein (1967) as *Theriosynoecum varietuberatum* after observing different patterns of distribution for the ornamentation of the species of the Gabon Basin with similar overall characteristics. Grekoff and Krömmelbein (1967) affirm that the only difference between the *Theriosynoecum varietuberatum* species and the *Th. alleni*, *Bisculcocypris martini* (Pinto and Sanguinetti, 1962, both) and *Th. fittoni* Mantell (1844) is only based in the arrangement of the tubercles. Later, Moura (1972) reassessed the Recôncavo Basin ostracods and descripted what would be a similar specimen to the *Theryosinoecum varietuberatum*, reassigning them to another species: *Theriosynoecum varietuberatum proximum.* The latin term *proximum*, as brought by the author, refers to its proximity to the *T. varietuberatum* species based on all the features except for the assumed *T. var. proximum* absence of tubercles. Moura (1972) then suggested the change of *T. varietuberatum* to *T. varietuberatum varietuberatum*.

According to Sames (2011d), the presence of local ornamentation elements, as well as their degree of expression and distribution, are considered to be of low, or no, taxonomic relevance if all other carapace characters are very similar or identical. The author attest that, especially for *Theriosynoecum* genus, local ornamentation elements can be used for paleoenvironmental interpretation, as salinity realms and changes as well as for the identification of sexual dimorphism in certain cases. Sames also present various species that might have been assumed, individually, as

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representatives of high endemicity all over the world based on ornamentation elements alone (Sames, 2011c). According to these observations, the species *B. martini* (used by Grekoff and Krömmelbein as a comparison to differentiate them from *Th. varietuberatum*) is understood as a variation of the *Th. fittoni*, as long as it was described based only on ornamentation. The same way, the *Metacypris sp. 1* Krömmelbein (1962) (previous classification of the *Th. varietuberatum*) is one of the representatives of the *Theryosinoecum fittoni* Mantell 1844 as well, based on the morphologic similarities of the outline, the strong posterior overreach, the well-defined anterior marginal zone and the 45° inclined dorsal part of the anterior marginal zone (Sames, 2011b).

In agreement to Sames (2011b; 2011d) observations, studies and also based on a detailed taxonomic study of the features for specimens that present these variations, we understand the *Theriosynoecum varietuberatum* and *Theriosynoecum varietuberatum proximum* as representatives of the same species. Due to overall outline comparisons and similarities (Fig. 3) the ostracods species are understood here as representatives of the *Theriosynoecum fittoni* (Mantell 1844). The work of Sames (2011b) is strongly reliable about the *Theriosynoecum* observation and study, but, even so, as it is suggested, future access to other *Theriosynoecum* species for the Lower Cretaceous and the use of geometric morphometrics and statistical analysis should be applied to support these affirmations.

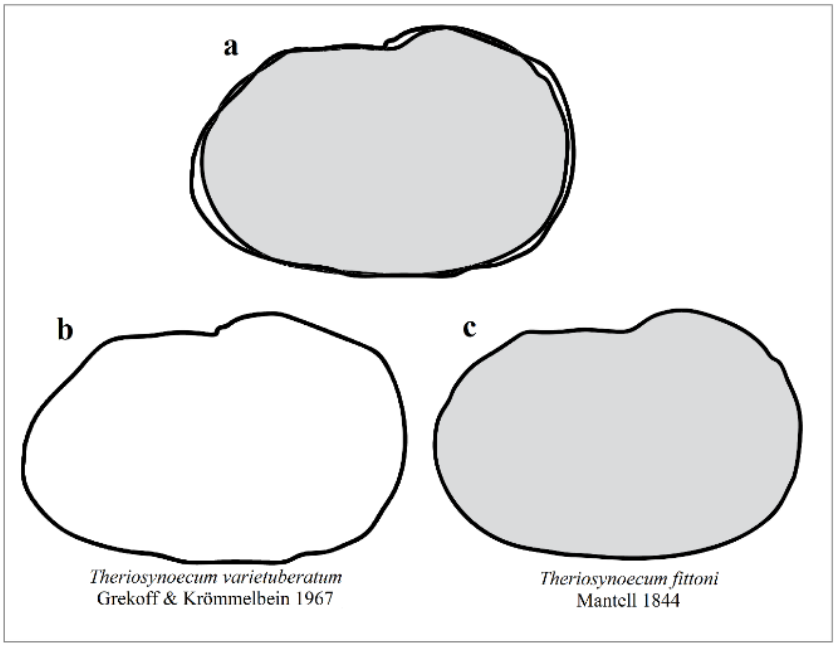

Figure 3: (a) Comparison of the lateral outline for female representatives of *Metacypris* sp. 1 (Krömmelbein 1962) later reassigned as *Theriosynoecum varietuberatum* (Grekoff and Krömmelbein 1967) and *Theriosynoecum fittoni* (Mantell 1884). **(b)** *'Metacypris'* sp. 1 Krömmelbein 1962, SMFXe 4244, lateral view with tubercles, pl. 62, fig. 64a; **(c)** *Theriosynoecum fittoni* Mantell 1884 outline from Kilenyi and Neale (1978), right lateral view, SJCC 68/28.6, pl. 5, fig. 9.

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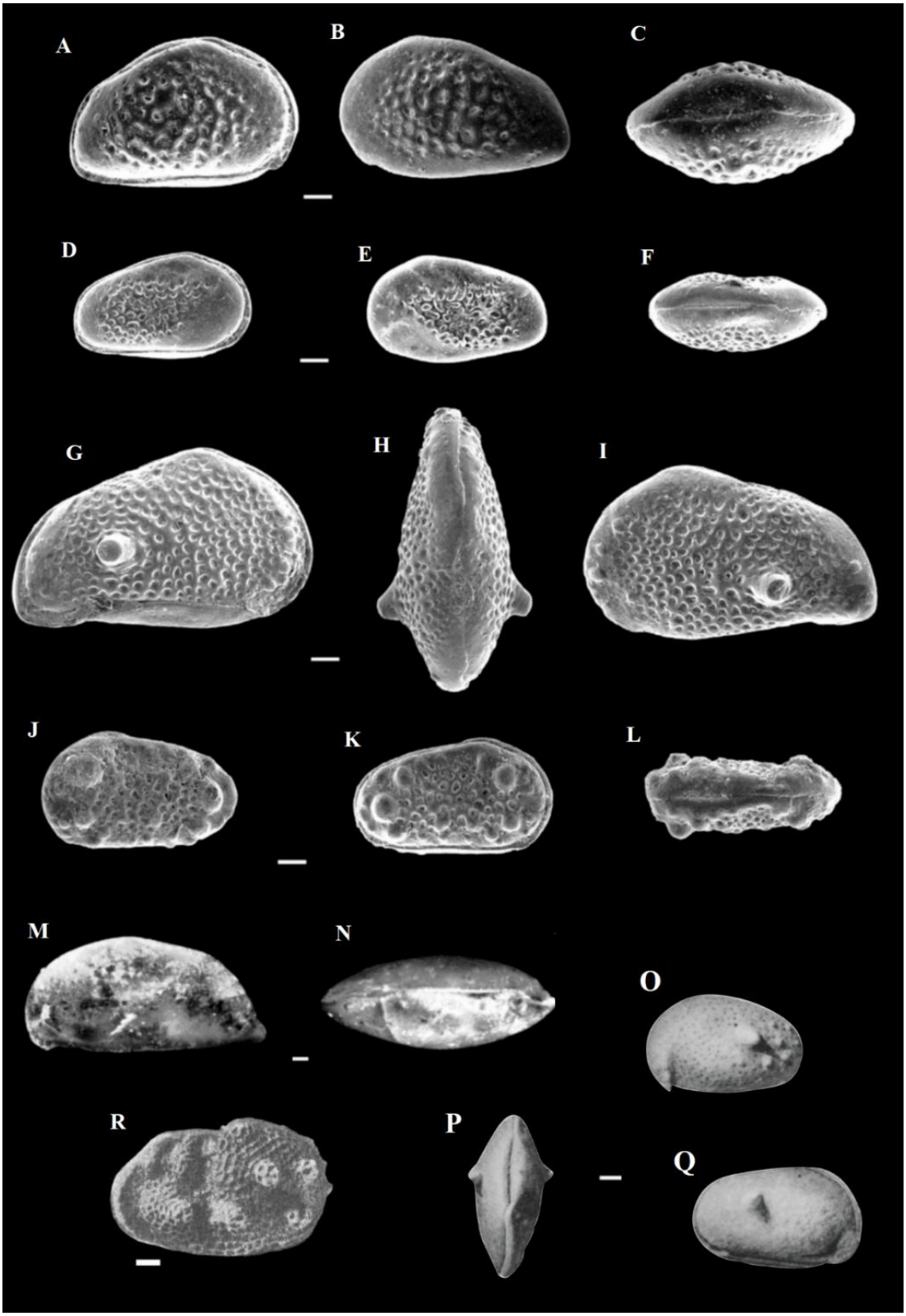

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Figure 4. A-C. *Kegelina kegeli* (Wicher, 1959), LBP 1, Itaparica Formation, Bahia, Brazil refigured from Neto et al. (2014); A, right lateral view of carapace; B, left lateral view of carapace, LBP 1, Itaparica Formation, Bahia, Brazil; C, dorsal view of carapace. **D-F**. *Kegelina depressa* (Moura, 1972), topotype, LBP 2, Itaparica Formation, Bahia, Brazil refigured from Neto et al. (2014); D, right lateral view of carapace; E, left lateral view of carapace; F, dorsal view of carapace. *G-I. Kegelina armata* (Krömmelbein, 1962), LBP 3, Itaparica Formation, Bahia, Brazil refigured from Neto et al. (2014); G, right lateral view of carapace; H, dorsal view of carapace; I, left lateral view of carapace. **J-L.** *Kegelina bisculpturata* (Moos in Wicher, 1959), LBP 4, Itaparica Formation, Bahia, Brazil refigured from Neto et al. (2014); J, left lateral view of carapace; K, right lateral view of carapace; L, dorsal view of carapace. **M-N.** *Praecypridea acuta* (Moos in Wicher, 1959) M, left lateral view of carapace, holotype T.-K.-Nr. 3179, refigured from Sames (2010) as in Wicher (1959, pl. 9, fig. 3a); N, dorsal view, anterior end to the right, holotype T.-K.-Nr. 3179, refigured from Sames (2010) as in Wicher (1959, pl. 9, fig. 3b). **O-Q.** *Cypridea brevicornis* (Peck, 1941) refigured from Peck (1941) O, left lateral view of holotype, U.M. 0-977-5. P, dorsal view; Q, right lateral view of paratypes, U.M. 0-976-1. **R.** *Theriosynoecum fittoni* (Mantell, 1844) – refigured after first classification presented as *Metacypris* sp. 1 in Krömmelbein (1962, pl. 62, fig. 64a), SMFXe 4244, lateral view of carapace.

V Biostratigraphy and Paleoecology

The earliest findings of Cretaceous ostracods in Brazil were made in the Recôncavo Basin (Poropat & Colin, 2012). The first description of the ostracod species from the Itaparica Formation were made by Wicher (and Moos) in 1959, who described several new species and subspecies as *Cypridea acuta, Cypridea bisculpturata* and *Cypridea kegeli* reassigned later, respectively, to the genus *Praecypridea* as *P. acuta* (Sames et al., 2010) and to the genus *Kegelina* as *K. biscupturata* and *K. kegeli* (Neto et al., 2014). In 1962 Krömmelbein described several species of ostracods including *Cypridea armata*, later reassigned to the genus *Kegelina* as *K. armata* (Neto et al., 2014), the species *Metacypris* sp 1 from the Itaparica formation and a biozonation for the Bahia series. Grekoff and Krömmelbein (1967), published a report on the Early Cretaceous ostracods from the offshore Gabon Basin describing the ostracod species that he associated to *Metacypris* sp 1, the *Theriosynoecum varietuberatum*. In 1972, Moura reassessed the ostracod faunas of the Recôncavo Basin and described additional species like *Cypridea depressa* later reassigned to the genus *Kegelina* as *K. depressa*, registering the occurrences of most taxa. In his work Moura (1972) differentiate the species *Theriosynoecum varietuberatum* from the *Theriosynoecum varietuberatum proximum* based only in the "*varietuberatum proximum*" absence of ornamentation, what is discussed and supported by previous works (Sames, 2011b) and herein as nonsufficient evidence to distinguish species if the overall outline of the carapace and valves are similar.

Here, 7 (seven) species from 4 (four) genera are identified from the ostracod fauna of the Itaparica Formation. Among them four of these species are found in the Gabonese Basin, Africa: *Kegelina kegeli, Kegelina armata, Kegelina bisculpturata and Theriosynoecum fittoni.* The three *Kegelina* species are present in the Basal Sandstones Formation of the South Gabon Basin. The presence of species previously identified and associated to the Biozone NRT-002 of the Recôncavo Basin (Vianna, 1971; Moura, 1972; Poropat & Colin, 2012) and species found in the Lower Cretaceous paleoenvironments, confirm the Berriasian age associated to the Itaparica Formation.

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Horne (2002) also affirms that, compared to modern faunas, representatives of the families *Limnocytheridae* and *Cyprididae*, as the genera identified from the Itaparica Formation, are identified as non-marine ostracodes, being found in a diverse range of continental environments, including saline and freshwater lakes, temporary waters, permanent water bodies, rivers and groundwater. The Theriosynoecum genera is believed to require permanent freshwater bodies (Sames, 2011b). The presence of the *Theriosynoecum fittoni* and *Kegelina kegeli* are more abundant towards the south of the basin, still these are the two species that are present in all regions of the basin. In general, the abundance in the number of species and number of carapaces increase towards the south of the basin. This increase is probably due to the deepening of the lake towards the depocenter, where the decrease of the fluvial siliciclastic deposition and the increase of the presence of mud allows the preservation of the carapaces.

The depositional environment of the Itaparica formation has been a subject of different theories and definitions for the rift phase of the Recôncavo Basin. Based on the sedimentological and stratigraphic analysis, a prodelta/lacustrine paleoenvironment was suggested for the Itaparica Formation (Wiedekher, 2012) as an early stage of the rift tectonic. The lithology of the cores analyzed allows the interpretation of the formation as a lacustrine water body with deposition of grey/green laminated mudstones and shales.

The intercalation with fine sandstones observed in the cores closer to the flexural margin indicates an environment with distal river contribution, as long as mudstones are mostly preserved with river discharge (Bhatttacharya, 2006; Wiedekher, 2012).

The observed increase of thickness of the Itaparica Formation (Figs. 2 and 3) towards the south of the basin corroborate that the half-graben structure of the basin was already formed when the Itaparica lake deposition started (Wiedekher, 2012). The posterior deposition of the Água Grande Formation as a Deltaic-Fluvial-Eolian system (Wiedekher, 2012), as an evidence of accommodation space decrease and increase of siliciclastic deposition in an arid climate, corroborates the presence of the Cyprideidae ostracods (Fig. 7).

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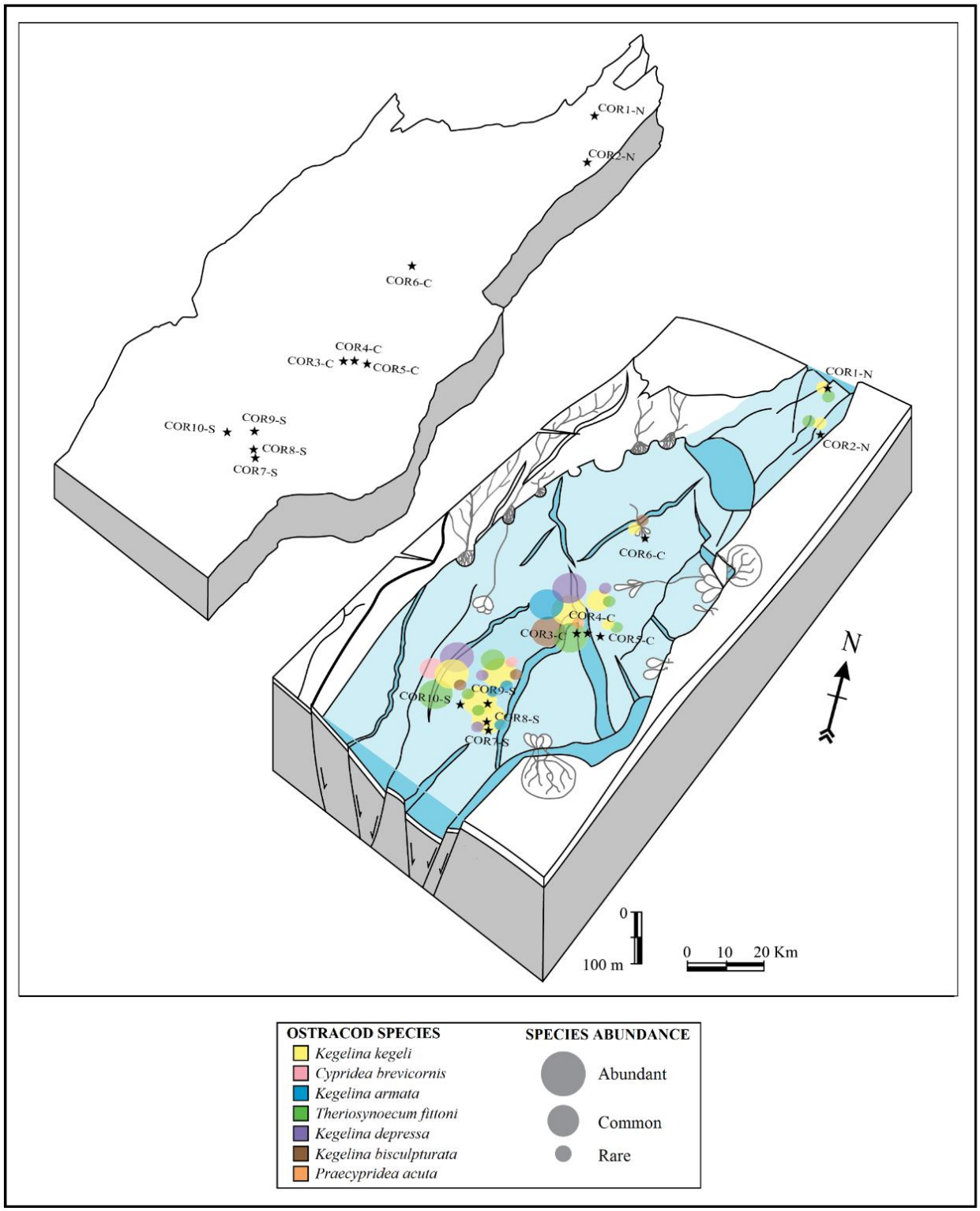

Figure 7. 3D outcrop of the Recôncavo basin with the distribution and placement of the ostracod species for each core. Modified from Destro et al. (2003).

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VI - Conclusions

The ostracod faunas from the Itaparica Formation (Recôncavo Basin) have provided an important biostratigraphic, palaeoecological and paleogeographic data for the Early Cretaceous fauna for both Brazilian and African basins.

This ostracod fauna is represented by the *Cypridеidae* family by the species *Kegeli*na kegeli, *Kegelina armata, Kegelina depressa, Kegelina Bisculpturata*, *Praecypridea acuta* and *Cypridea brevicornis* and from the *Limnocytheridae* family by *Theriosynoecum fittoni.*

The material analyzed and discussed in this work allows an understanding of why species previously associated to the genera *Cypridea* and a (assumed) highly endemic *Theriosynoecum* species, referred to the Biozone RT-002.2 by previous works, must be reclassified to another *Theriosynoecum* species and to *Kegelina* and *Praecypridea* genera.

After a taxonomic update (Sames 2010, Sames. 2011b, Neto et al., 2014) *Theriosynoecum varietuberatum, Theriosynoecum varietuberatum proximum, Cypridea kegeli, Cypridea armata, Cypridea bisculpturata* and *Cypridea acuta* can be understood as outdated and/or invalid taxon.

The identification of limnic species of ostracods corroborates the lacustrine environmental interpretation (e.g. Wiedekher, 2010) for the Itaparica formation, as well as the Lower Cretaceous age due to the biostratigraphic distribution of the species identified here.

It is suggested in addition to the observations brought in this work, a further analysis of the *Theriosynoecum fittoni* presence and more detailed comparison through geometric morphometrics with an outline analysis or landmarks pore position as suggested by Sames (2011b). Also, new and more detailed SEM images of the *Theriosynoecum* species as well as the *Cypridea brevicornis* species are required too.

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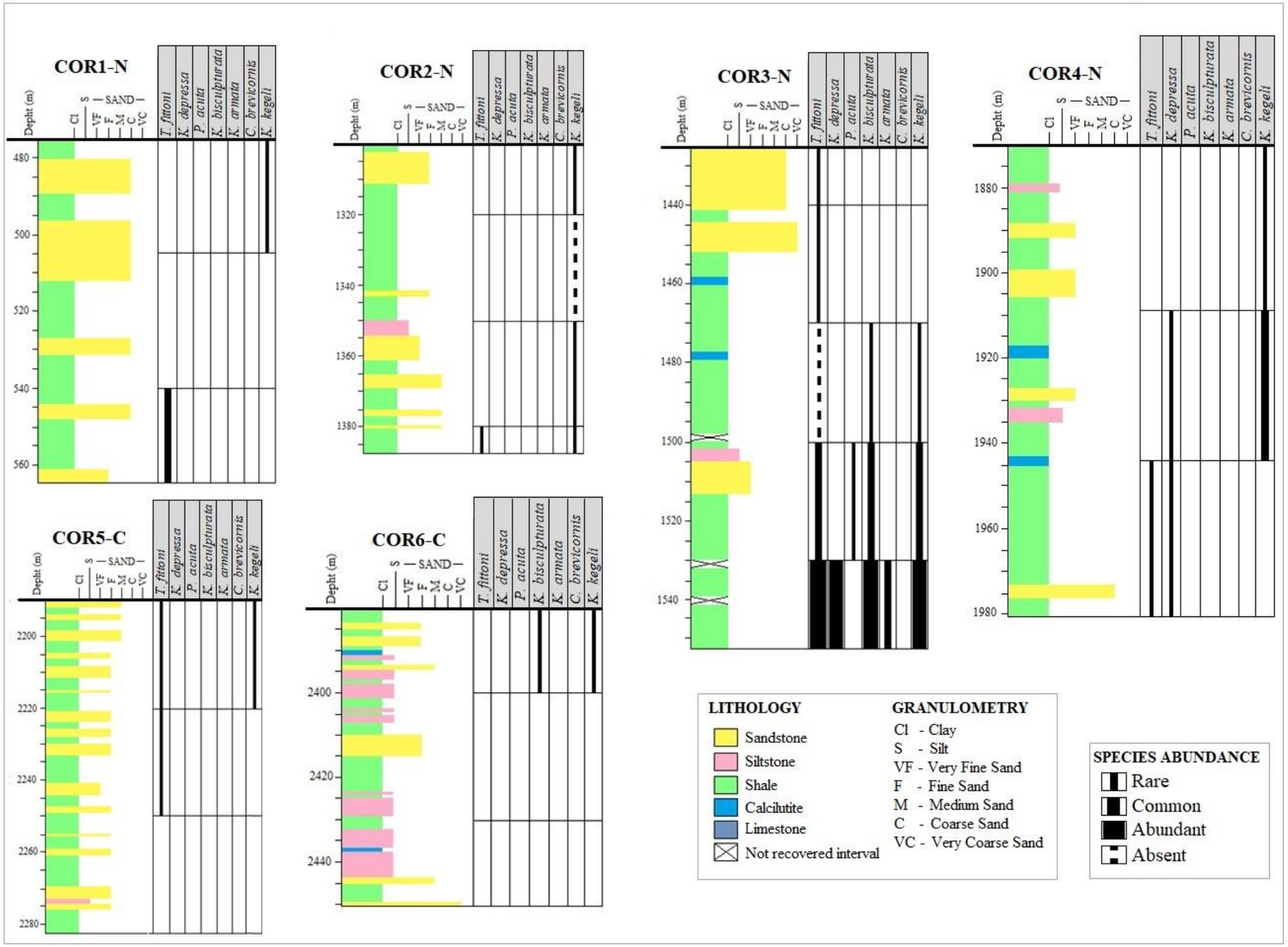

Figure 5. Lithologic sections of the northeastern and central cores of the Recôncavo basin with indications for the presence of ostracods for each 30m analyzed according to its abundance.

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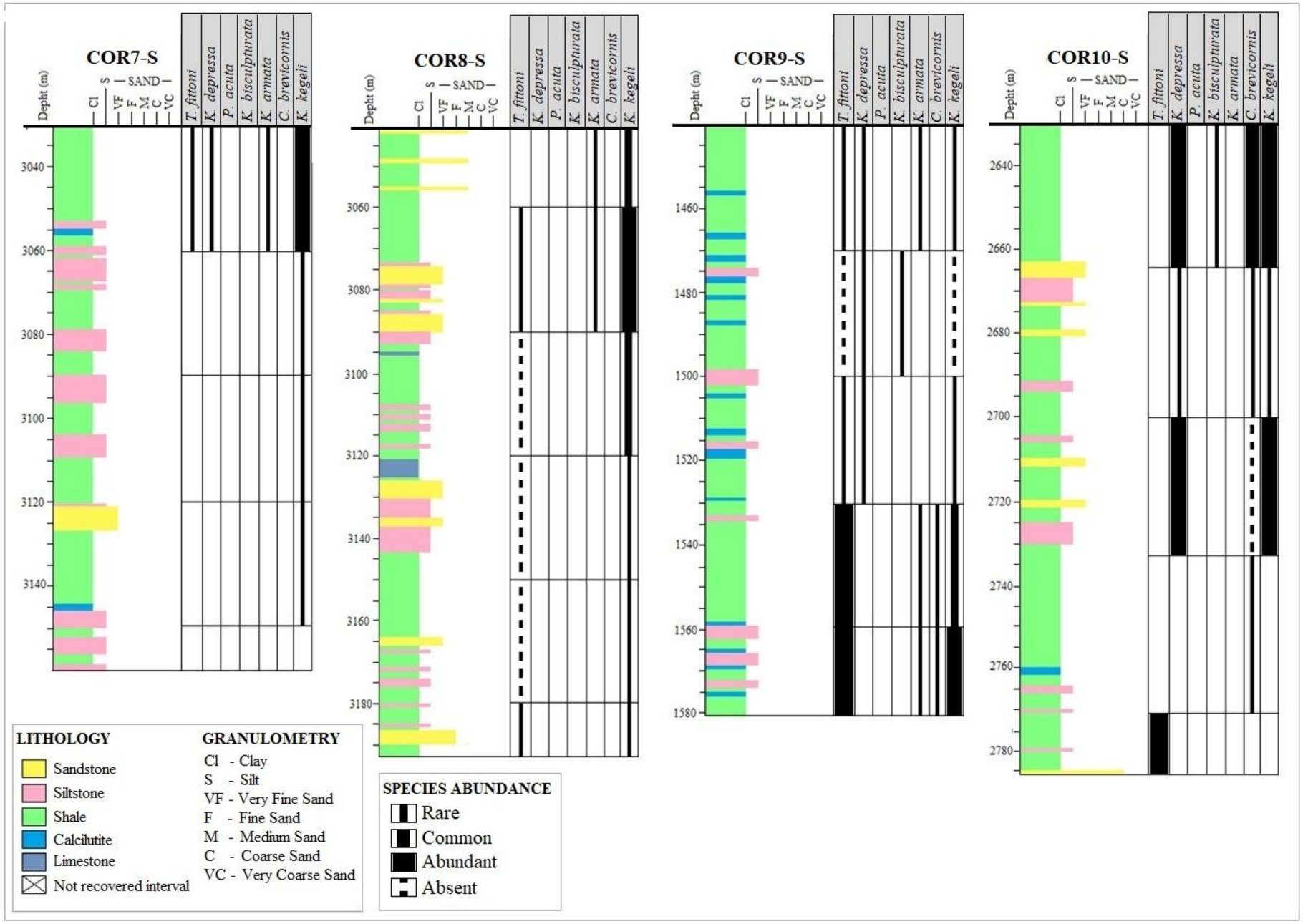

Figure 6: Lithologic sections of the northeastern and central cores of the Recôncavo basin with indications for the presence of ostracods for each 30m analyzed according to its abundance.

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