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DÉBORA SOARES DE ALMEIDA LIMA

OSTRACODES DAS FASES RIFTE E PÓS-RIFTE DAS BACIAS JATOBÁ, TUCANO NORTE E ARARIPE: taxonomia, bioestratigrafia e paleoecologia

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Dissertação apresentada ao Programa de Pós-Graduação em Geociências da Universidade Federal de Pernambuco, Centro de Tecnologia e Geociências, como requisito parcial para obtenção do título de mestre em Geociências. Área de concentração: Geologia Sedimentar e Ambiental.

Orientadora: Profa. Dra. Enelise Katia Piovesan.

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“Ninguém ignora tudo. Ninguém sabe tudo. Todos nós sabemos alguma coisa. Todos nós ignoramos alguma coisa. [...]. Estudar para servir ao Povo não é só um direito, mas também um dever revolucionário” (FREIRE, 1982, p. 44–45).

RESUMO

As bacias do Araripe, Jatobá e Tucano Norte representam bacias interiores localizadas na região Nordeste do Brasil que foram implantadas sobre terrenos cristalinos Pré-Cambrianos que constituem a Província Borborema. O empilhamento sedimentar destas bacias é subdividido nas sequências tectono-estratigráficas Sinéclise, Início de Rifte, Clímax de Rifte e Pós-Rifte. O arcabouço bioestratigráfico das bacias interiores do Nordeste do Brasil foi estabelecido a partir da identificação de sua ostracofauna, tendo, portanto, representantes da Classe Ostracoda como marcadores de seus andares locais. Com o intuito de refinar o conhecimento das fases rifte e pós-rifte a respeito da sistemática taxonômica, o arcabouço bioestratigráfico e realizar inferências a respeito dos paleoambientes em que esses ostracodes se encontravam inseridos, foram estudadas 109 amostras coletadas de 29 afloramentos, provenientes das formações Brejo Santo, Abaiara e Romualdo, na Bacia do Araripe, e formações Aliança, Candeias e Grupo Ilhas, nas bacias do Jatobá e Tucano Norte. Após preparação laboratorial destas amostras para a recuperação dos microfósseis calcários e triagem do material, foram identificadas 30 espécies, pertencentes aos gêneros não-marinhos *Theriosynoecum*, *Cypridea*, *Paracypridea*, *Salvadoriella*, *Reconcavona*, *Rhinocypris*, *Darwinula*, *Alicenula* e *Pattersoncypris*. Uma dessas é uma nova espécie, nomeada como *Pattersoncypris minima* Almeida-Lima & Piovesan sp. nov., recuperada nos depósitos da Formação Romualdo. Foi realizada uma emenda na diagnose e na descrição e de *Theriosynoecum pricei* (Pinto & Sanguinetti, 1958) e a revisão deste táxon, que representa um importante fóssil guia para a datação do Tithoniano (Jurássico Superior) nas bacias sedimentares interiores do nordeste do Brasil e demais bacias cronocorrelatas. A partir da classificação dos ostracodes foi possível identificar as biozonas RT-001 Andar Dom João (=Tithoniano), RT-002, RT-003 e RT-004 Andar Rio da Serra (=Berriasiano–Hauteriviano), RT-005 e RT-006 Andar Aratu (=Hauteriviano–Barremiano), RT-007 Andar Buracica (=Barremiano) e RT-011 Andar Alagoas (=Aptiano).

Palavras-chave: bioestratigrafia; paleoecologia; ostracodes não-marinhos.

ABSTRACT

The Araripe, Jatobá and Tucano Norte basins represent inland basins located in the Northeast region of Brazil that were deployed on Precambrian crystalline terrains that constitute the Borborema Province. The sedimentary stacking of these basins is subdivided into the tectonostratigraphic sequences Syneclise, Early Rift, Rift-Climax and Post-Rift. The biostratigraphic framework of the inland basins of the Northeast of Brazil was established based on the identification of its ostracod fauna, having, therefore, representatives of the Class Ostracoda as markers of their local stages. In order to refine the knowledge of the rift and post-rift phases regarding taxonomic systematics, the biostratigraphic framework, and to make inferences about the paleoenvironments in which these ostracods were inserted, 109 samples collected from 29 outcrops of the Brejo Santo, Abaiara and Romualdo formations, in the Araripe Basin, and Aliança, Candeias and Grupo Ilhas formations, in the Jatobá and Northern Tucano basins, were studied. After laboratory preparation of these samples for the recovery of calcareous microfossils and picking up of the ostracods, 30 species were identified, belonging to the non-marine genera *Theriosynoecum*, *Cypridea*, *Paracypridea*, *Salvadoriella*, *Reconcavona*, *Rhinocypris*, *Darwinula*, *Alicenula* and *Pattersoncypris*. One of these is a new species, named *Pattersoncypris minima* Almeida-Lima & Piovesan sp. nov. recovered in deposits of the Romualdo Formation. An emendation in the diagnosis and description and of *Theriosynoecum pricei* (Pinto & Sanguinetti, 1958) and the revision of this taxon, which represents an important guide fossil for the dating of the Tithonian (Upper Jurassic) in the interior sedimentary basins of Northeast Brazil and other chronocorrelated basins, was carried out. From the ostracods classification it was possible to identify the biozones RT-001 Dom João Local Stage (=Tithonian), RT-002, RT-003 and RT-004 Rio da Serra Local Stage (=Berriasian-Hauterivian), RT-005 and RT-006 Aratu Local Stage (=Hauterivian-Barremian), RT-007 Buracica Local Stage (=Barremian) and RT-011 Alagoas Local Stage (=Aptian).

Keywords: biostratigraphy; paleoecology; non-marine ostracods.

LISTA DE ILUSTRAÇÕES

LISTA DE ABREVIATURAS E SIGLAS

ANP	Agência Nacional de Petróleo
C	Carapaça
CAV	Centro Acadêmico de Vitória
LMA	Laboratório de Micropaleontologia Aplicada
LV	Valva esquerda
MEV	Microscopia Eletrônica de Varredura
RV	Valva direita
URCA	Universidade Regional do Cariri

SUMÁRIO

1 INTRODUÇÃO

O presente trabalho foi desenvolvido de acordo com as normas do Programa de Pós-Graduação em Geociências e do Sistema Integrado de Bibliotecas da UFPE, sob a forma de artigos científicos. Os manuscritos que compõem a dissertação foram submetidos em revistas indexadas, cujo escopo contempla os temas abordados.

Neste primeiro tópico encontra-se uma breve introdução a respeito da Classe Ostracoda e o estudo destes organismos nas bacias sedimentares interiores do Nordeste do Brasil, bem como os objetivos (geral e específicos) desta pesquisa.

É apresentado, no item 2, uma contextualização a respeito da área de estudo, detalhando aspectos geológicos e estratigráficos das bacias sedimentares do Araripe, Jatobá e Tucano Norte.

O item 3 diz respeito ao material utilizado para desenvolver a pesquisa e a metodologia aplicada desde a preparação laboratorial, análise e organização dos espécimes estudados e elaboração das ilustrações e mapas.

Os resultados do trabalho são apresentados e discutidos em três artigos científicos, contidos nos itens 4, 5 e 6. O primeiro artigo apresenta a fauna do Rifte das três bacias abordadas, no que tange à taxonomia e bioestratigrafia dos táxons. O artigo seguinte traz uma abordagem taxonômica e interpretações paleoecologicas a respeito espécie *Theriosynoecum pricei* (Pinto & Sanguinetti, 1958). Por fim, o terceiro artigo contribui com o conhecimento a respeito dos ostracodes do Pós-Rifte, a partir da descrição de uma nova espécie do gênero *Pattersoncypris* Bate, 1972 para a Formação Romualdo, Bacia do Araripe.

As considerações finais da dissertação e perspectivas para trabalhos futuros estão contidas no item 7.

Em ambientes aquáticos continentais, representantes da Classe Ostracoda normalmente são os microfósseis calcários mais frequentes e abundantes. O alto potencial de fossilização, frequência de ocorrência, grande diversidade durante o Jurássico Superior–Cretáceo Inferior e seus mecanismos de distribuição facilitando o transporte passivo a longas distâncias caracteriza o grupo como uma excelente ferramenta para muitas aplicações (SAMES, 2009), como as interpretações paleoecológicas, paleobiogeográficas, bioestratigráficas e quimioestratigráficas.

Devido a sua sensibilidade aos fatores ambientais, a ocorrência dos ostracodes é controlada por parâmetros hidroquímicos como composição da água e salinidade, e pela variabilidade da temperatura da água (LISTER, 1988). Os ostracodes possuem valvas compostas de calcita com baixo teor de magnésio, dessa maneira, estes microfósseis servem como fonte de carbonato biogênico e podem informar a composição elemental e isotópica da água hospedeira, provendo uma variedade de informação dos ambientes aquáticos antigos como temperatura, salinidade, composição da água (DE DECKKER; FORESTER, 1988).

O Nordeste do Brasil constitui a denominada Província Borborema, uma ampla região de dobramentos arranjados em frações do embasamento e, nas suas bacias sedimentares interiores e marginais está contido o registro da evolução da separação dos continentes Africano e Sul Americano, além da instalação do Oceano Atlântico. Ao contrário das bacias da margem continental que evoluíram ao estágio de margem passiva, as bacias mesozoicas interiores do Araripe e do subsistema Tucano Norte-Jatobá representam um ramo do Rifte Sul-Atlântico abortado no Eoaptiano. A geometria e evolução destas bacias são fortemente condicionadas pelas estruturas do embasamento Precambriano/Neopaleozoico, cuja reativação controlou o arranjo dos depocentros ao longo do tempo (ASSINE, 2007).

Estudos relativos aos ostracodes não-marinhos vem sendo desenvolvidos desde a década de 1960, especialmente devido a sua aplicação na exploração de hidrocarbonetos (e.g. KRÖMMELBEIN, 1962, 1966; VIANA 1966a, b; SCHALLER, 1969; VIANA et al., 1971). O arcabouço bioestratigráfico e estabelecimento dos andares locaisdas bacias interiores do Nordeste do Brasil foi estabelecido a partir da identificação da ostracofauna registrada nas Bacias Recôncavo/Tucano e Sergipe/Alagoas. O registro sedimentar da fase tectono-estratigráfica Rifte abrange, na estratigrafia local, os andares Dom João (Neojurássico), Rio da Serra (Berriasiano–Eohauteriviano), Aratu (Hauteriviano–Barremiano), Buracica (Barremiano) e Jiquiá (Barremiano–Aptiano) contendo as biozonas de ostracoda RT-001–RT-009 e da fase Pós-Rifte o Andar Alagoas (Aptiano) correspondente a biozona RT-011 (Figura 1) (VIANA, 1966a; VIANA et al., 1971; MELO et al., 2020; MENDES et al., 2020).

Rochas sedimentares com características flúvio-lacustres foram depositadas durante os intervalos Dom João–Jiquiá, abrangendo as formações Aliança, Sergi e Candeias, Grupo Ilhas e Formação São Sebastião nas bacias de Jatobá e Tucano Norte e as formações Brejo Santo, Missão Velha e Abaiara na Bacia do Araripe (Figura 2). Da tectono-sequência Pós-Rifte correspondente ao Andar Alagoas (Aptiano), a Formação Marizal nas bacias de Jatobá e Tucano Norte e a Formação Barbalha na Bacia do Araripe registram eventos deposicionais, tradicionalmente caracterizados como de paleoambiente flúvio-lacustre (Figura 2). O Grupo Santana, presente nas três bacias estudadas, registra uma fase lacustre bem estabelecida e em alguns locais com registro de ingressão marinha no topo (Formação Romualdo), sendo estas unidades associadas à biozonas RT-011 (Figuras 1 e 2) (ASSINE, 2007; KUCHLE; SCHERER, 2010; KUCHLE et al., 2011; SCHERER et al., 2014; GUZMÁN et al., 2015; MELO et al., 2020; MENDES et al., 2020).

O trato tectônico de início do Rifte, composto pelas formações Aliança e Sergi (bacias de Tucano Norte e Jatobá) e pelas formações Brejo Santo e Missão Velha (Araripe), registra o primeiro ciclo lacustre desenvolvido durante esta fase (Neojurássico, Andar Dom João), denominado Lago Capianga que é caracterizado como uma bacia endorréica de grande extensão, cujo registro nestas bacias corresponde às formações Brejo Santo e Aliança, relacionada a biozona de ostracode RT-001 *Theriosynoecum pricei* (KUCHLE et al. 2011, GUZMÁN et al. 2015). Durante o desenvolvimento tectônico do hemi-gráben e clímax do rifte (Andar Rio da Serra, Berriasiano–Hauteriviano), foram depositadas as formações Abaiara na Bacia do Araripe, Candeias e a base do Grupo Ilhas nas bacias de Jatobá e Tucano Norte. Estas unidades representam a segunda fase flúvio-lacustre e deltaica que se instalou no sistema, com caraterísticas de maior profundidade que evidenciam tectonismo mais intenso, aumento progressivo na taxa da subsidência e maior umidade (KUCHLE; SCHERER, 2010). A fauna de ostracodes representativa corresponde às biozonas *Theriosynoecum varietuberatum* (RT-002), *Cypridea* (*Morininoides*) *candeiensis* (RT-003) e *Paracypridea brasiliensis* (RT-004) (CUNHA; MOURA, 1979).

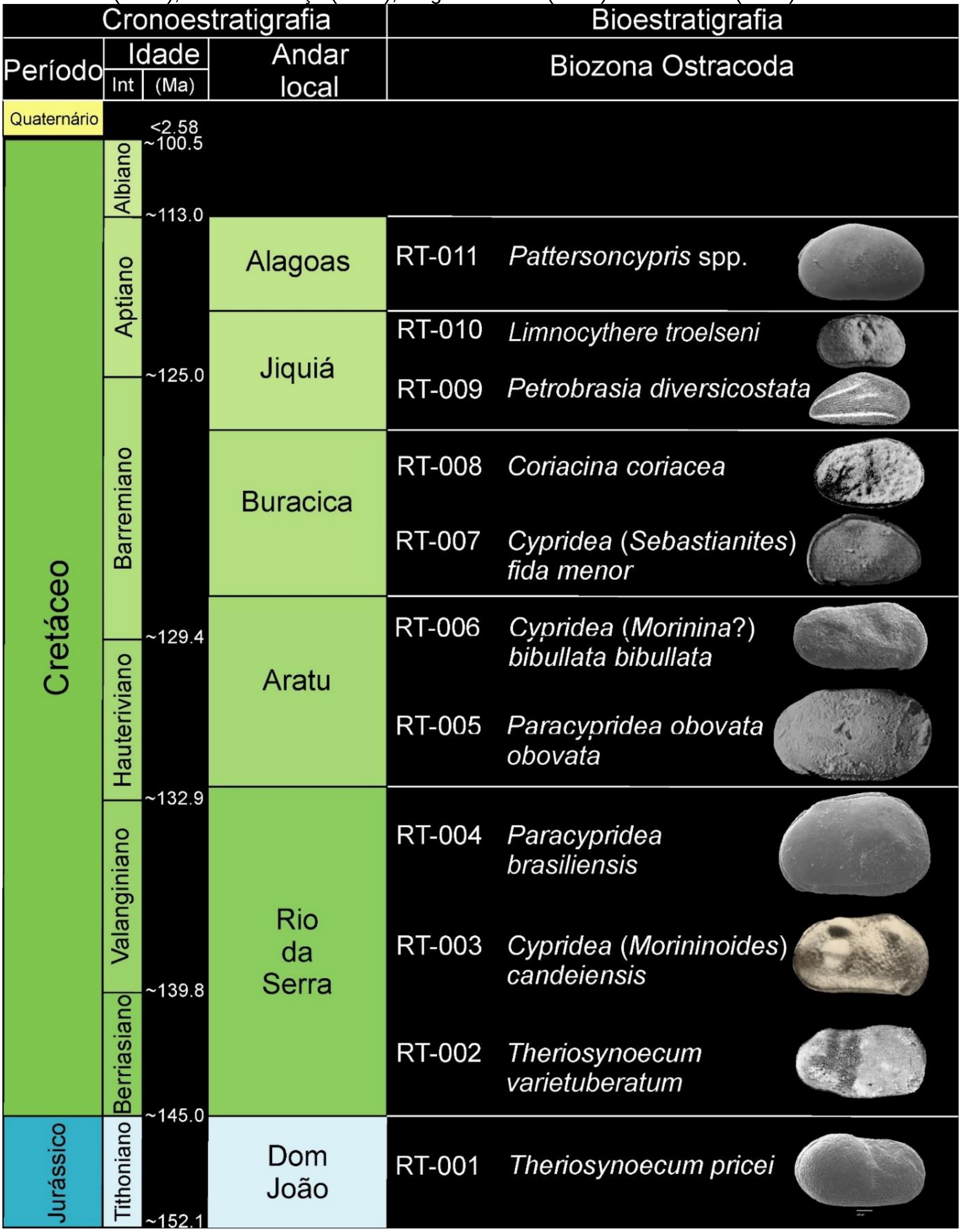
O estágio final do Rifte é marcado por uma diminuição da atividade tectônica e o recuo do sistema lacustre (KUCHLE; SCHERER, 2010). O total preenchimento do rifte com a deposição da porção média e superior do Grupo Ilhas e as formações

Salvador e São Sebastião nas bacias de Tucano Norte e Jatobá representa esta fase final do rifteamento. Na Bacia do Recôncavo, estas unidades registram associações de ostracodes dos andares Aratu, biozonas *Paracypridea obovata obovata* (RT-005), *Cypridea* (*Morinina?*) *bibullata bibullata* (RT-006), Buracica, biozonas *Coriacina coriacea* (RT-007) e *Cypridea* (*Sebastianites*) *fida minor* (RT-008) e Andar Jiquiá, biozona *Petrobrasia diversicostata* (RT-009) (CUNHA; MOURA, 1979). Na Bacia do Araripe, não se tem registro de seções pertencentes aos andares Buracica e Jiquiá, devido provavelmente a estruturação rúptil não criando espaço de acomodação e basculhando as unidades mais antigas (ASSINE, 2007).

A sequência Pós-Rifte ocorre através de todo o sistema rifte Recôncavo-Tucano-Jatobá e na Bacia do Araripe compreendendo as formações Marizal (correlata à Formação Barbalha, na Bacia do Araripe) e Grupo Santana, este último com deposição continental a transicional. A fauna de ostracodes presente na sequência Pós-Rifte tem sido associada à Biozona RT-011 que caracteriza o Andar Alagoas. Esta biozona apresenta duas propostas de denominação: 1. Poropat e Colin (2012a), propõem os táxons *Pattersoncypris* e *Kroemmelbeincypris* como espécies-guia deste intervalo; 2. Tomé et al. (2014), na qual descrevem a espécie *Damonella grandiensis* e consideraram este táxon como o guia da biozona. Uma revisão taxonômica detalhada dos ostracodes deste intervalo poderá com maior critério definir qual é a espécie mais apropriada para formalmente nomear a biozona.

Esforços para revisão das espécies de ostracodes, refinamento da bioestratigrafia local e paleoecologia das bacias interiores do NE vem sendo realizados ao longo das últimas décadas. Uma revisão sobre a bioestratigrafia do nordeste brasileiro e noroeste africano foi realizada por Poropat e Colin (2012b), assim como os trabalhos de Sousa et al. (2018, 2019) na Bacia de Sousa, Paraíba e Santos Filho et al. (2020) na Bacia de Iguatu, no Ceará, são exemplos desses estudos. Na Bacia do Araripe, pode-se destacar trabalhos como o de Coimbra et al. (2002), Melo et al. (2020) e Coimbra e Freire (2021) que apresentam a integração de dados da ostracofauna com outros grupos de microfósseis, em especial os foraminíferos e palinomorfos. Para a Bacia do Jatobá, o trabalho recente de Mendes et al. (2020) traz atualizações estratigráficas na seção Rifte desta bacia com base nos ostracodes estudados. Entretanto, para a Bacia de Tucano Norte não se encontram trabalhos atuais sobre a fauna de ostracodes.

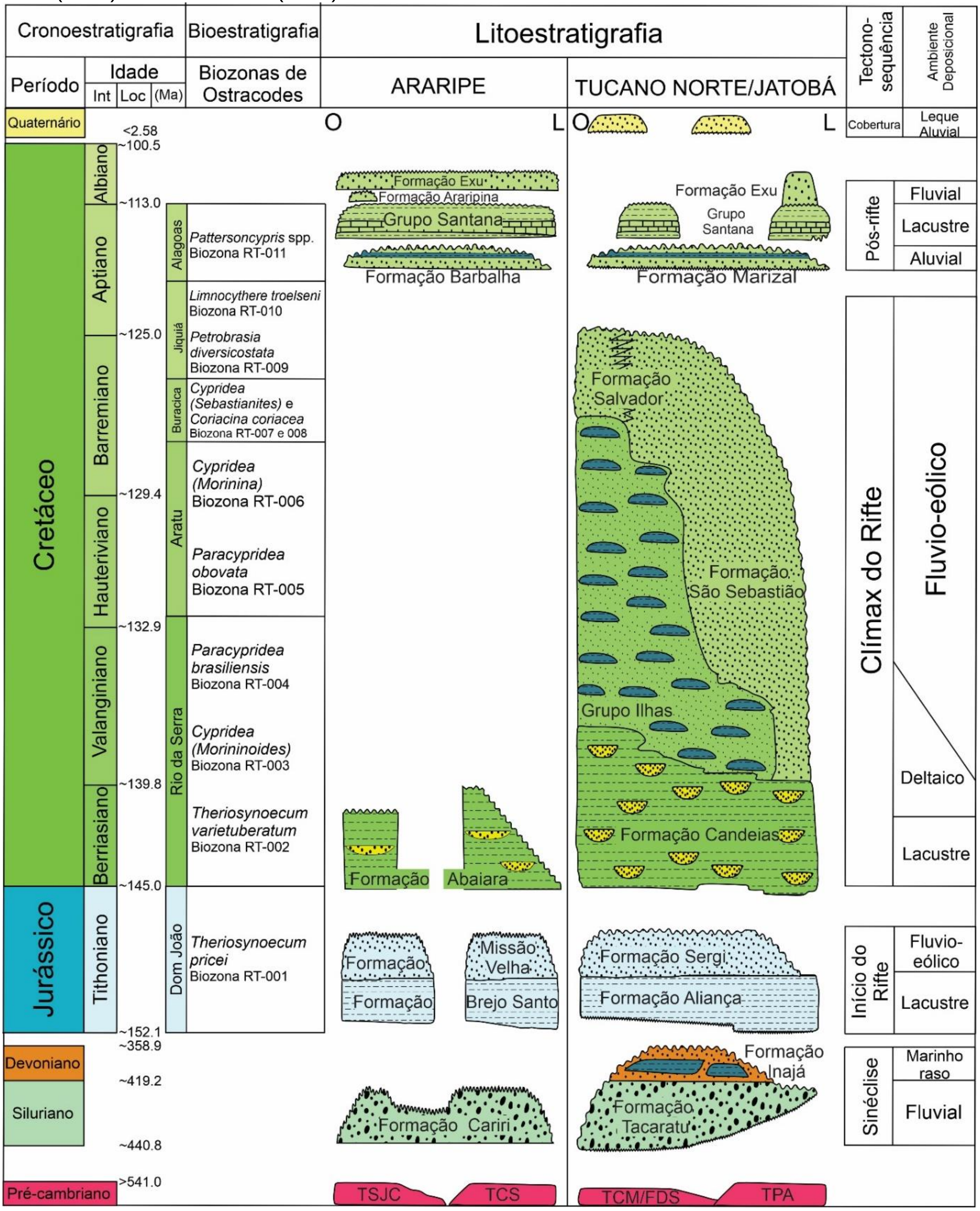
Figura 1 – Andares locais e biozoneamento de Ostracoda das bacias mesozoicas brasileiras associados à cronoestratigrafia internacional. Dados bioestratigráficos conforme Schaller (1969), Viana et al. (1971), Moura e Praça (1985), Regali e Viana (1989) e Melo et al. (2020)



Cronoestratigrafia				Bioestratigrafia
Período	Idade Int	Idade (Ma)	Andar local	Biozona Ostracoda
Quaternário		<2.58		
Cretáceo	Albiano	~100.5		
	Aptiano	~113.0	Alagoas	RT-011 *Pattersoncypris* spp.
			Jiquiá	RT-010 *Limnocythere troelseni*
	Barremiano	~125.0		RT-009 *Petrobrasia diversicostata*
			Buracica	RT-008 *Coriacina coriacea*
				RT-007 *Cypridea* (*Sebastianites*) *fida menor*
	Hauteriviano	~129.4	Aratu	RT-006 *Cypridea* (*Morinina*?) *bibullata bibullata*
				RT-005 *Paracypridea obovata obovata*
	Valanginiano	~132.9	Rio da Serra	RT-004 *Paracypridea brasiliensis*
				RT-003 *Cypridea* (*Morininoides*) *candeiensis*
	Berriasiano	~139.8		RT-002 *Theriosynoecum varietuberatum*
Jurássico	Tithoniano	~145.0	Dom João	RT-001 *Theriosynoecum pricei*
		~152.1		

Fonte: Projeto ARTUNJA (2020).

Figura 2 – Carta estratigráfica atualizada da Bacia do Araripe e do sistema de bacias Tucano Norte-Jatobá ilustrando andares locais, biozonas de ostracodes e tectono-sequências estratigráficas. Baseada em Schaller (1969), Moura e Praça (1985), Moura (1988), Regali e Viana (1989), Caixeta et al. (1994), Assine (2007), Costa et al. (2007), Neumann e Rocha (2013), Guzmán et al. (2015), Melo et al. (2020) e Mendes et al. (2020)



Fonte: Projeto ARTUNJA (2020).

1.1 OBJETIVOS

Ampliar o conhecimento sobre os ostracodes das bacias do Araripe, Jatobá e Tucano Norte e integrar os dados para interpretação de uma possível correlação entre os sistemas lacustres das tectonosequências Rifte e Pós-Rifte das mesmas, visando contribuir com o conhecimento taxonômico, paleoecológico e cronoestratigráfico das bacias interiores do nordeste brasileiro.

1.1.1 Objetivos Específicos

- Identificar e classificar os ostracodes encontrados no intervalo Tithoniano–Aptiano recuperados das amostras de afloramentos da fase Rifte e Pós-Rifte, atualizando suas proposições taxonômicas quando pertinente e descrevendo possíveis novos táxons.
- Estabelecer correlações bioestratigráficas entre as bacias estudadas com base nas espécies guias das biozonas de ostracodes.
- Propor inferências paleoambientais para as seções analisadas, com base nos aspectos paleoecológicos das associações identificadas.

2 ÁREA DE ESTUDO

As áreas alvo deste estudo são as bacias interiores do Araripe, Jatobá e Tucano Norte (Figura 3), que representam bacias interiores tipo rifte abortado localizadas na região Nordeste do Brasil que foram implantadas sobre terrenos cristalinos Pré-Cambrianos que constituem a Província Borborema. A Província Borborema (PB) engloba o conjunto de unidades geológicas estabilizadas ao final da Orogênese Brasiliana/Pan-Africana (600 ± 50 Ma) e representa um segmento crustal de uma extensa faixa fortemente afetada pela deformação, resultante da colisão entre os crátons do Oeste Africano/São Luís e Congo-Kasai/São Francisco, que constituíam massas continentais consolidadas em tempos anteriores à articulação de Gondwana (BRITO NEVES et al. 2000).

O registro estratigráfico do Mesozoico das bacias da margem continental brasileira, foi consolidado por Asmus e Ponte (1973) que estabeleceram quatro grandes estágios tectono-estratigráficos: pré-rifte, sin-rifte, transicional (pós-rifte I) e pós-rifte (pós-rifte II). Estes estágios, amplamente utilizados na estratigrafia mesozoica brasileira, estão bem representados nas bacias rifte da margem leste, porém nas bacias interiores, o rifteamento foi abortado durante o estágio transicional.

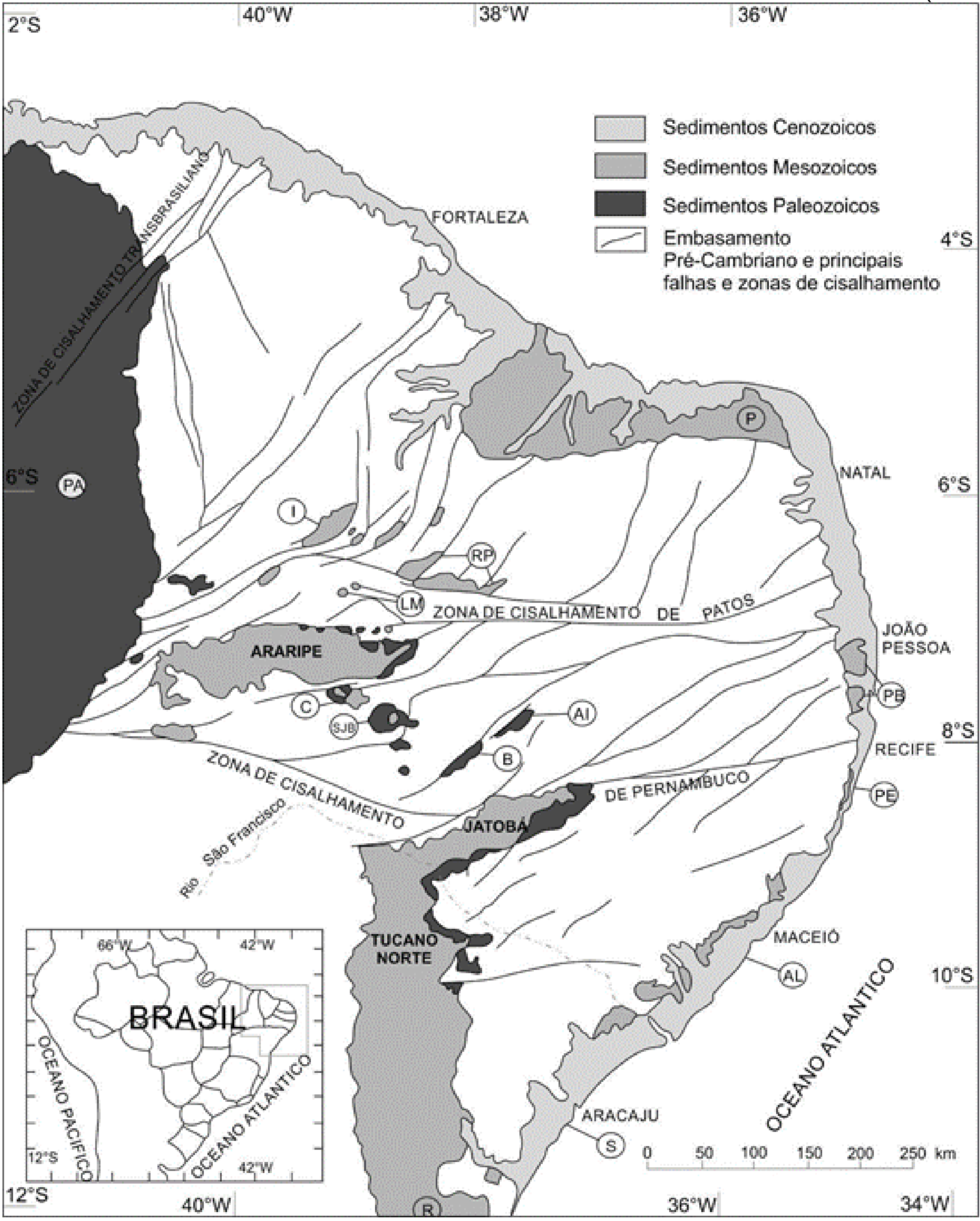
Segundo Mohriak (2003) o estágio Pré-Rifte é constituído pelas supersequências Paleozoica e Jurássica e representa a fase intracratônica do Supercontinente Gondwana, precedendo o rifte do Atlântico Sul e formando amplas e suaves depressões que foram preenchidas por sedimentos de águas rasas. Embora, no nordeste do Brasil a supersequência do Jurássico, separada da sequência do Paleozoico por um hiato que envolve todo o Triássico, resultou de um novo pulso de subsidência no desenvolvimento de depressões regionais relacionadas ao estiramento litosférico inicial que precedeu a fase principal de rifteamento e formou uma grande bacia que é designada como “Depressão Afrobrasileira” (GARCIA, 1991); na margem sudeste brasileira esta fase é associada ao derrame de lavas da Formação Serra Geral. Seguindo a abordagem de Scherer et al. (2014), o termo “pré-rifte” é inadequado para englobar os sedimentos jurássicos já que o termo é usado para designar rochas que não são em absoluto relacionadas ao processo de ruptura continental e normalmente são centenas a milhões de anos mais antigos do que os depósitos acumulados durante o evento rifte. Assim, o termo mais apropriado para esta fase inicial de acumulação numa grande bacia de geometria sinclinal endorréica, conectada e denominada depressão Afro-Brasileira, deveria ser fase de Início de Rifte (KUCHLE et al. 2011, SCHERER et al. 2014).

A estratigrafia das bacias de Araripe, Tucano Norte e Jatobá, alvo deste estudo, tem sido dividida adotando a nomenclatura proposta por Kuchle e Scherer (2010) e Kuchle (2010) em base ao modelo de Prosser (1993), que organizaram as unidades em quatro sequências tectono-estratigráficas: sinéclise, início do rifte, desenvolvimento do hemi-gráben e clímax do rifte, e pós-rifte.

A Bacia do Araripe, implantada nos terrenos pré-cambrianos São José do Caiano da Zona Transversal da Província Borborema (BRITO NEVES et al., 2000) ao norte da Zona de Cisalhamento de Pernambuco e sul da Zona de Cisalhamento de Patos, abarcando territórios dos estados de Pernambuco, Piauí e principalmente, do Estado do Ceará. A bacia apresenta duas fisionomias distintas, o Vale do Cariri e a Chapada do Araripe. O Vale do Cariri estende-se para leste onde afloram a Formação Cariri (Paleozoico) da sequência sinéclise, as formações Brejo Santo e Missão Velha (Neojurássico) da sequência início do rifte e a Formação Abaiara (Berriasiano–Eohauteriviano) da sequência clímax do rifte. A Chapada do Araripe, de maior extensão para o oeste, é formada principalmente por afloramentos das unidades da sequência pós-rifte, as formações Barbalha, Crato, Ibupi, Romualdo, Araripina e Exu. Segundo Assine (2007), essas sequências foram formadas em contextos paleogeográficos diferentes, e estavam integradas a outras bacias próximas. A distribuição geográfica original de cada uma das diferentes sequências era mais extensa, o que é testemunhado por remanescentes isolados em várias pequenas bacias situadas entre as zonas de cisalhamento de Pernambuco e Paraíba, e nas bacias de Jatobá (Serra Negra e Serra do Periquito) e Tucano Norte (Serra de Tonã) ao sul da Zona de Cisalhamento de Pernambuco.

A Bacia de Tucano Norte e de Jatobá representam a extremidade setentrional do Sistema Rifte Recôncavo-Tucano-Jatobá. Estas bacias situadas principalmente nos estados da Bahia, Sergipe e Pernambuco, são formadas por um sistema de grábens de direção S–N (Recôncavo–Tucano), que muda abruptamente de direção para W–E constituindo a Bacia de Jatobá. O sistema compreende essas três bacias, separadas por altos/arcos do embasamento: a Bacia do Recôncavo é limitada a norte pelo Alto de Aporá e seguida pela de Tucano, que é separada da de Jatobá pelo Alto do São Francisco (COSTA et al., 2007). O embasamento da Sub-bacia de Tucano Norte é representado pelos terrenos Canindé-Marancó e Pernambuco-Alagoas a noroeste e leste-nordeste, pelos metassedimentos da Faixa de Dobramentos Sergipana a oeste-sudoeste e sudeste, e pelas rochas sedimentares da Bacia Juá, a sudeste. A Bacia do Jatobá instalou-se integralmente sobre o terreno Pernambuco-Alagoas. A configuração estrutural destas bacias reflete a atuação dos esforços extensionais em um embasamento heterogêneo e tanto a Sub-bacia de Tucano Norte, como a Bacia de Jatobá, apresenta uma geometria típica de meio-gráben, com falhas de borda a oeste e noroeste, respectivamente (SANTOS et al. 1990; MAGNAVITA, 1996). A área abrangida pela Sub-bacia de Tucano Norte e pela Bacia de Jatobá representa a porção distal dos sistemas aluviais do Neojurássico (Andar Dom João) e rochas das formações Aliança e Sergi foram depositadas no início do rifte sob paleoclima árido. As sequências clímax e fase final do rifte (Berriasiano–Eoaptiano), compreendem depósitos relacionáveis à Formação Candeias, ao Grupo Ilhas e à Formação São Sebastião.

Figura 3 – Esquema das bacias fanerozoicas da região nordeste do Brasil: Destacam-se em negrita as bacias de Araripe, Jatobá e Tucano Norte. Legenda: AI = Afogados da Ingazeira; AL = Alagoas; B = Betânia; C = Cedro; I = Iguatu; LM = Lavras da Mangabeira; P = Potiguar; PA = Parnaíba; PB = Paraíba; PE = Pernambuco; RP = Rio do Peixe; S = Sergipe; SJB = São José do Belmonte; R = Recôncavo. Modificada de Assine (1992)



Fonte: Projeto ARTUNJA (2020).

3 MATERIAL E MÉTODOS

Para o desenvolvimento deste trabalho foram analisadas 109 amostras coletadas de 29 afloramentos provenientes das formações Brejo Santo e Abaiara, na Bacia do Araripe, e formações Aliança, Candeias e Grupo Ilhas, nas bacias do Jatobá e Tucano Norte, correspondendo a tectonosequência Rifte, e da Formação Romualdo, na Bacia do Araripe, para a seção Pós-Rifte. As excursões de campo para amostragem do Rifte e apoio para processamento do material em laboratório foram realizadas no âmbito do Projeto ARTUNJA: Correlações bioestratigráficas dos sistemas flúvio-lacustres das fases Rifte e Pós-Rifte das bacias do Araripe, Jatobá e Tucano Norte, NE do Brasil, financiado pela ANP/PETROBRAS. A amostra estudada do Pós-Rifte foi cedida para análise por meio de parceria com pesquisadoras da URCA e UFPE-CAV.

As amostras foram encaminhadas ao Laboratório de Micropaleontologia Aplicada (LMA) para preparação e recuperação dos microfósseis calcários (Figura 4). A preparação seguiu os procedimentos padrões, com algumas adaptações que são descritas abaixo:

1) Identificação e pesagem de 50 a 100 g de sedimento para cada amostra em balança de precisão, separados em recipientes adequados para as próximas etapas.

2) Quando necessário, a amostra passa por trituração mecânica com auxílio de pistilo e almofariz para fragmentação da rocha em frações menores, com o intuito de facilitar o ataque químico/lavagem em água e separação dos microfósseis da matriz.

3) Na etapa de ataque químico foram utilizados recipientes do tipo béquer para acomodar as amostras e recobri-las com peróxido de hidrogênio como reagente químico por 24 h, seguindo a metodologia convencional. Entretanto, em algumas amostras mais friáveis, não foi necessário o ataque químico e o material ficou imerso em água pelo mesmo período de tempo para, assim, ocorrer a separação dos microfósseis da matriz rochosa.

4) Lavagem das amostras em pia adequada utilizando água corrente e peneiras de malha com aberturas de > 500 µm, > 250 µm, > 180 µm e > 63 µm. O resíduo retido nas peneiras foi colocado em recipientes, e em seguida foram levados à estufa a 60 ºC, para secagem.

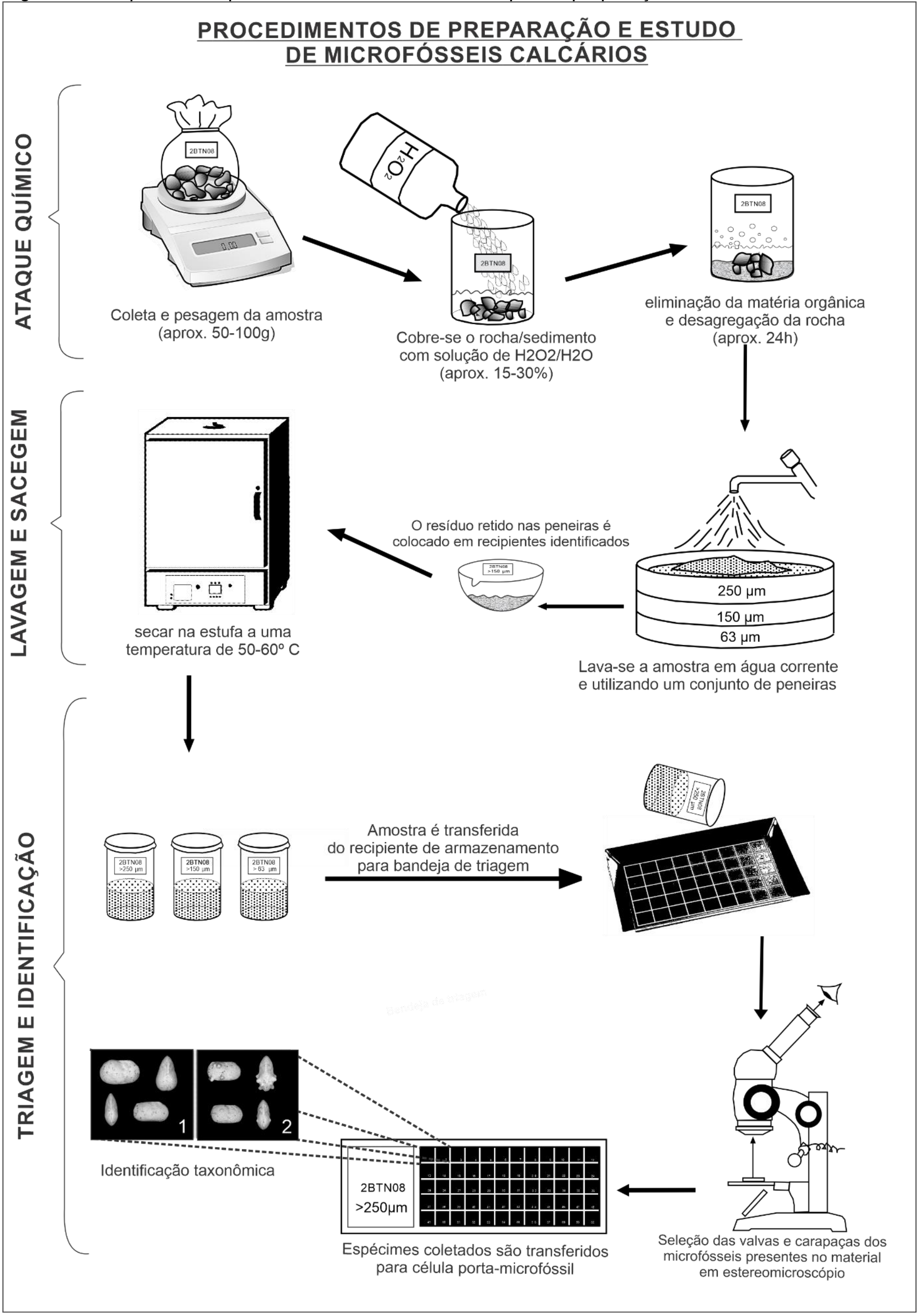
5) Acondicionamento do material seco e identificado em potes de acrílico.

6) Visando evitar a contaminação cruzada entre amostras, o conjunto de peneiras utilizado é lavado cuidadosamente e as peneiras são imersas em solução de azul de metileno, dessa forma os espécimes que, acaso tenham ficado retidos na malha, são tingidos de azul e facilmente detectados em outras amostras.

7) Triagem das frações acima de 180 µm para seleção dos ostracodes e dos fragmentos de rocha residuais. Transferência dos espécimes em células micropaleontológicas com o auxílio do estereomicroscópio Zeiss Stemi-305. Os espécimes de cada morfotipo que apresentaram melhor preservação foram selecionados para MEV (PHENOM XL).

Após as etapas descritas, foi possível analisar os aspectos morfológicos e realizar a identificação taxonômica, bem como inferências paleoambientais e bioestratigráficas a partir a ostracofauna presente. Os espécimes ilustrados na elaboração dos artigos científicos que compõem a presente dissertação encontram-se depositados na coleção micropaleontológica do LMA, na Universidade Federal de Pernambuco (UFPE). O processamento das imagens e elaboração das figuras foram realizadas no programa CorelDRAW X7 e a confecção dos mapas em ESRI ArcMap v.10.3.

Figura 4 – Esquema das práticas laboratoriais utilizadas para a preparação das amostras



Fonte: A autora (2021).

4 ARTIGO 1 – NON-MARINE OSTRACODS FROM THE LATE JURASSIC–EARLY CRETACEOUS OF ARARIPE, JATOBÁ AND TUCANO NORTE BASINS, NORTHEAST OF BRAZIL

Este artigo apresenta o estudo taxonômico dos ostracodes do Jurássico Superior–Cretáceo Inferior das bacias do Araripe, Jatobá e Tucano Norte. Foram identificados 29 morfotipos pertencentes aos gêneros *Theriosynoecum*, *Cypridea*, *Paracypridea*, *Salvadoriella*, *Reconcavona*, *Rhinocypris*, *Darwinula* e *Alicenula*. A partir da classificação taxonômica foi possível posicionar as amostras entre as biozonas RT-001–RT-007, que correspondem aos andares locais Dom João–Buracica. Considerando a fauna recuperada, a biozona RT-001 (Andar Dom João, fase de Início do Rifte) foi a única possível de correlacionar nas três bacias estudadas. Em relação ao Clímax do Rifte, a Bacia do Jatobá foi a mais diversificada, com 22 morfotipos identificados, possibilitando o posicionamento das amostras nas biozonas RT-003–RT-007. Para a Bacia do Tucano Norte foi identificada a biozona RT-002 e na Bacia do Araripe não houve recuperação de fósseis na sequência rifte.

Este manuscrito será submetido à revista *Revue de Micropaléontologie* e sua formatação segue seus padrões.

NON-MARINE OSTRACODS FROM THE LATE JURASSIC–EARLY CRETACEOUS OF ARARIPE, JATOBÁ AND TUCANO NORTE BASINS, NORTHEAST BRAZIL

OSTRACODES NON MARINS JURASSIQUE SUPERIEUR–CRETACE INFERIEUR DES BASSINS D'ARARIPE, JATOBÁ ET TUCANO NORTE, NORD-EST BRESIL

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ABSTRACT

The Araripe, Jatobá and Tucano Norte basins, northeast Brazil, have an extensive fossil record. Among the groups found, are the ostracods, which have great relevance for this region due to their significant occurrence and wide diversity during the Upper Jurassic–Lower Cretaceous. These basins contain the rift process record of the Gondwana breakup for the posterior installation of the South Atlantic Ocean, data reinforced by the correlated ostracod non-marine fauna with some African basins. This paper presents a detailed study of the taxonomy and biostratigraphic inferences of the ostracod species recovered from outcrops from these three basins. A total of 29 species were identified, distributed in eight genera: *Theriosynoecum pricei*, *Theriosynoecum* sp. cf. *T.* sp. 6, *Cypridea acicularis*, *Cypridea ambígua*, *Cypridea indiennensis densipunctata*, *Cypridea sellata*, *Cypridea semilunaris*, *Cypridea vianai*, *Cypridea paraibensis, Cypridea* (*Morinina*?) *bibullata bibullata, Cypridea* (*Morinina*?) *bibullata tribullata, Cypridea* sp. cf. *C.* (*Morinina*?) *langei, Cypridea* sp. cf. *Cypridea miritiensis*, *Cypridea* sp. 1, *Paracypridea brasiliensis*, *Paracypridea quadrirugosa quadrirugosa*, *Paracypridea* ex. gr. *elegans*, *Salvadoriella redunca posterior*, *Reconcavona*? *jatobaensis*, *Reconcavona striata*, *Reconcavona striatula*, *Reconcavona swaini*, *Reconcavona* aff. *R.*? *polita*, *Reconcavona* sp. cf. *R. triebeli*, *Reconcavona* sp.1, *Reconcavona* sp.2, *Rhinocypris* sp.1, *Darwinula*? sp. cf. *D*. *oblonga*, *Alicenula* sp. cf. *Alicenula leguminella*. From the identification of these species, it was possible to infer a stratigraphic interval from the Tithonian to the Barremian, which corresponds to the local RT-001 to RT-007 biozones.

Keywords: Biostratigraphy; taxonomy; rift basins.

RESUME

Les bassins de l'Araripe, du Jatobá et du Tucano Norte, au nord-est du Brésil, possèdent une grande variété de fossiles. Parmi les groupes trouvés, les ostracodes ont une place de choix due à leur grande importance pour la région d’une part, et de leur grande diversité au cours du Jurassique supérieur et du Crétacé inférieur d’autre part. Ces bassins contiennent l'enregistrement du processus de rift de la rupture du Gondwana pour l'installation postérieure de l'océan Atlantique Sud, données renforcées par la corrélation de la faune ostracode non marine avec certains bassins africains. Cet article présente une étude détaillée de la taxonomie et des inférences biostratigraphiques des espèces d'ostracodes rencontrées dans les affleurements de ces trois bassins. Un total de 29 espèces a été identifié, réparties dans huit genres: *Theriosynoecum pricei*, *Theriosynoecum* sp. cf. *T*. sp. 6, *Cypridea acicularis*, *Cypridea ambigua*, *Cypridea indiennensis densipunctata*, *Cypridea sellata*, *Cypridea semilunaris*, *Cypridea vianai*, *Cypridea paraibensis*, *Cypridea* (*Morinina*?) *bibullata bibullata*, *Cypridea* (*Morinina*?) *bibullata tribullata*, *Cypridea* sp. cf. *C*. (*Morinina*?) *langei*, *Cypridea* sp. cf. *Cypridea miritiensis*, *Cypridea* sp. 1, *Paracypridea brasiliensis*, *Paracypridea quadrirugosa quadrirugosa*, *Paracypridea* ex. gr. *elegans*, *Salvadoriella redunca posterior*, *Reconcavona*? *jatobaensis*, *Reconcavona striata*, *Reconcavona striatula*, *Reconcavona swaini*, *Reconcavona* aff. *R*.? *polita*, *Reconcavona* sp. cf. *R*. *triebeli*, *Reconcavona* sp.1, *Reconcavona* sp.2, *Rhinocypris* sp.1, *Darwinula*? sp. cf. *D*. *oblonga*, *Alicenula* sp. cf. *Alicenula leguminella*. L'identification de ces espèces, a permis de déduire un intervalle stratigraphique allant du Tithonien au Barrémien, correspondant aux biozones locales RT-001 à RT-007.

Mots clés: Biostratigraphiques; taxinomie; bassins rift.

1. Introduction

The sedimentary deposits from the Upper Jurassic–Lower Cretaceous in the basins of Northeast Brazil encompass studies of fossil ostracods since the 1960s, when the biostratigraphic framework was established based on this calcareous microfossil group and biozones from the Tithonian (RT-001) to Aptian (RT-011) were proposed (Viana, 1966; Schaller, 1969; Viana et al., 1971; Cunha and Moura, 1979).

The Syn-rift tectono-stratigraphic sequence in the Araripe, Jatobá and Tucano Norte basins records the breakup of Gondwana and the subsequent installation of the South Atlantic Ocean, following crustal separation of the South America and Africa continents (Chang et al., 1992). Krömmelbein (1966) and Grekoff and Krömmelbein (1967) demonstrate the correspondence between the ostracod fauna present in the African and Brazilian basins, pointing out the occurrence of same species on both sides of the South Atlantic Ocean, allowing to infer that during the Late Jurassic–Early Cretaceous these basins belong to one single basin and the ostracods lived in with completely free interchange. Although ostracods are significant to understand the paleoecology, paleobiogeography and biostratigraphy of this interval, most of their studies were restricted to the 1960s and 1970s, with rare updates thereafter (Krömmelbein, 1961, 1962, 1964, 1966; Viana, 1966; Krömmelbein and Weber, 1971; Viana et al., 1971; Cunha and Moura, 1979).

Recently the ostracods from the basins of northeast Brazil have been again the target of new researches, which have been important for the resumption of taxonomic, paleoenvironmental and biostratigraphical knowledge of this group (Sousa et al., 2018, 2019; Santos Filho et al., 2020). Taxonomy emerges in this context as a basis for more assertive interpretations after the identification of these microfossils. The present work carries a taxonomic contribution concerning of the ostracods recovered from three sedimentary basins in northeast Brazil, the Araripe, Jatobá and Tucano Norte basins.

2. Geological and stratigraphical background

The Araripe, Jatobá and Tucano Norte basins are rift-type inland basins located in the northeast region of Brazil that were implanted on Precambrian crystalline terrains which constitute the Borborema Province. The Araripe Basin, implanted in the Precambrian São José do Caiano Terrain of the Transversal Zone Domain of the Borborema Province, between the Patos Shear Zones to the north and the Pernambuco Sher Zone to the south (Brito Neves et al., 2000), is the most extensive of the inland basins of Northeast Brazil, comprising territory in the states of Pernambuco, Piauí and mainly Ceará (Assine, 2007). The Tucano Norte and Jatobá basins represent the northern end of the Recôncavo-Tucano-Jatobá Rift System, these basins are located mainly in the states of Bahia, Sergipe and Pernambuco and are formed by a system of S-N direction grabens (Recôncavo-Tucano), that abruptly changes direction to W-E constituting the Jatobá Basin. The rift system comprises these three basins separated by embasement highs/arcs: The Recôncavo Basin is limited to the north by the Aporá High and followed by the Tucano Basin, which is separated from the Jatobá Basin by the São Francisco High (Costa et al., 2007). The basement of the Tucano North sub-basin is represented by the Canindé-Marancó and Pernambuco-Alagoas terrains to the northwest and east-northeast, by the metasediments of the Sergipano Fold Belt to the west-southwest and southeast, and by the sedimentary rocks of the Juá Basin to the southeast. The Jatobá Basin was entirely installed on the Pernambuco-Alagoas terrain (Costa et al., 2007).

Kuchle and Scherer (2010) and Kuchle (2010) proposed a stratigraphic model for dividing the rift-associated deposits of these basins into four tectonostratigraphic sequences, Syneclise, Early Rift, the developing of the half-graben and Rift-Climax, and Post-Rift. The Early Rift Sequence, which in the Tucano Norte and Jatobá basins is composed of the Aliança and Sergi formations (Brotas Group) and in the Araripe Basin by the Brejo Santo and Missão Velha formations, records fluvial, eolian and lacustrine sedimentation (Assine, 2007; Kuchle and Scherer, 2010). The first lacustrine cycle during this phase (Neojurassic, Dom João Local Stage) was developed in an endorheic basin of great extension, the Afro-Brazilian Depression (Cesero and Ponte, 1972), wherein the “Capianga Lake” was established (Kuchle et al., 2011). The Capianga Lake record in these basins corresponds to the Brejo Santo and Aliança formations, related to the ostracode biozone RT-001 *Theriosynoecum pricei* (Kuchle et al., 2011; Guzmán et al., 2015). These formations are mainly composed by massive or laminated, red mudstones, with some greenish gray strata, interspersed by sandstones and cross-laminated ostracod grainstones (Guzmán et al., 2015).

During the tectonic development of the half-graben, the Rift-Climax Sequence (Rio da Serra Local Stage, Berriasian–Hauterivian), the Abaiara Formation in the Araripe Basin, and the Candeias Formation and the base of the Ilhas Group in the Jatobá and Tucano Norte basins, were deposited. These units represent the second fluvio-lacustrine and deltaic phase settled in the system, with features of greater depth which display more intense tectonism, progressive increase in subsidence rate and higher humidity (Assine, 2007; Kuchle and Scherer, 2010). The Rio da Serra Local Stage in these basins is recorded by silty shales and red siltstones, with laterally discontinuous intercalations of deltaic sandstones (Assine, 2007; Costa et al., 2007; Scherer et al., 2014). The representative ostracod fauna corresponds to the *Theriosynoecum varietuberatum* (RT-002), *Cypridea* (*Morininoides*) *candeiensis* (RT-003) and *Paracypridea brasiliensis* (RT-004) biozones (Cunha and Moura, 1979).

The final stage of the rift is marked by a decrease in tectonic activity and the retreat of the lake system (Kuchle and Scherer, 2010). The full filling of the rift system valleys with the deposition of the middle and upper portion of the Ilhas Group and the Salvador and São Sebastião formations in the Tucano Norte and Jatobá basins, represents this final stage of the rifting process. In the Recôncavo Basin, these units record associations of ostracods of the Aratu Local Stage *Paracypridea obovata obovata* (RT-005) and *Cypridea* (*Morinina*?) *bibullata bibullata* (RT-006) biozones, the Buracica Local Stage, *Coriacina coriacea* (RT-007) and *Cypridea* (*Sebastianites*) *fida minor* (RT-008) biozones and the Jiquiá Local Stage, *Petrobrasia diversicostata* (RT-009) biozone (Cunha and Moura, 1979). In the Araripe Basin, no sections belonging to the Buracica and Jiquiá local stages have been recorded, probably due to the ruptile structure not creating space for accommodation (Assine, 2007).

3. Material and Methods

For this study 28 outcrops of the rift phase were analyzed, of which 3 are located in the Araripe Basin (Bar), 16 in the Jatobá Basin (BJ) and 9 in the Tucano Norte Basin (BT) (Fig. 1). A total of 108 samples were collected and analyzed from these 60 showed fossiliferous material and 48 were barren (Table 1).

After collection, the samples were taken for laboratory preparation adapted from Sohn (1961), which consisted of: (1) weighing approximately 60 g of rock per sample; (2) fragmentation of the rocks in smaller fragments; (3) submersion of the sedimentary fragments in water or hydrogen peroxide solution (depending on the friability) for 24 hours; (4) wash with water in a set of sieves with pore sizes of 500 μm, 250 μm, 180 μm and 62 μm; (5) separate the content of each sieve and let it dry in the oven at 50º C for 24 hours.

The fractions of 500 μm and 250 μm were analyzed using a stereomicroscope Zeiss Stemi-305 and the ostracod specimens picked out and transferred to micropaleontological slides. After previous recognition of the morphotypes, the specimens with the best preservation were selected for image acquisition in the SEM (Scanning Electron Microscope) Phenom XL, in the *Laboratório de Micropaleontologia Aplicada* [Laboratory of Applied Micropaleontology] (LMA–UFPE) and are deposited under the numbers LMA-0106, LMA-0107 and LMA-0146 to LMA-0174. The taxonomic identification was performed based on data available in specialized literature, following Liebau (2005) up to family nomenclature.

Abbreviations: **C=** carapace; **RV=** right valve; **LV**= left valve; **H**= height; **W**= width; **L**= length.

4. Systematic Paleontology

Subclass OSTRACODA Latreille, 1802
Superorder PODOCOPOMORPHA Kozur, 1972
Order PODOCOPIDA Müller, 1894
Suborder CYTHEROCOPINA Gründel, 1967
Infraorder ARCHAEOCYTHERININA Liebau, 1991
Superfamily LIMNOCYTHERIDAE Klie, 1938
Family LIMNOCYTHERIDAE Klie, 1938
Subfamily TIMIRIASEVIINAE Mandelstam, 1960
Genus *Theriosynoecum* Branson, 1936 emend. Sames, 2011
Theriosynoecum pricei (Pinto and Sanguinetti, 1958)
(Figure 2: A–D)

1958 *Bisulcocypris pricei* Pinto and Sanguinetti, p. 78, pl. 1, figs. 19–24; pl. 2, figs. 1–7; pl. 3, figs. 1–5.

1958 *Bisulcocypris uninodosa* Pinto and Sanguinetti, p. 80, pl. 2, figs. 8–13; pl. 3, figs. 6–8.

1971 *Theriosynoecum quadrinodosum* Krömmelbein and Weber, p. 62, pl. 12, figs. 54–56.

2011 *Bisulcocypris pricei* Pinto and Sanguinetti - Barros et al., p. 112, pl. I, fig. 1.

2016 *Theriosynoecum pricei* (Pinto and Sanguinetti) - Guzmán et al., p. 18, pl. 4, figs. A–D.

2016 *Theriosynoecum uninodosa* (Pinto and Sanguinetti) - Guzmán et al., p. 18, pl. 4, figs. E–G.

2016 *Theriosynoecum quadrinodosum* Krömmelbein and Weber - Guzmán et al., p. 19, pl. 4, figs. H–I.

2017 *Theriosynoecum pricei* (Pinto and Sanguinetti) - Melo and Carvalho, p. 71, pl. 11, figs. D–F.

2017 *Theriosynoecum uninodosa* (Pinto and Sanguinetti) - Melo and Carvalho, p. 71, pl. 11, figs. J–L.

2017 *Theriosynoecum quadrinodosum* Krömmelbein and Weber - Melo and Carvalho, p. 71, pl. 11, figs. G–I.

Figured specimen: LMA-00106, L: 863 µm, H: 530.29 µm, W: 552 µm (Fig. 2: A-B); LMA-00107, L: 761 µm, H: 424 µm, W: 330 µm (Fig. 2: C-D).

Material: About ten thousand specimens including carapaces and valves of adults and juvenile specimens.

Occurrence: Brejo Santo Formation, Araripe Basin, outcrop 2BAr01; Aliança Formation, Jatobá and Tucano Norte basins, outcrops BJ-MG-10, BJ-01, BJ-06, BJ-08, 2BTN07 and 2BTN08.

Stratigraphic and geographic distribution: Tithonian, Upper Jurassic. Aliança Formation, Recôncavo and Tucano basins, Bahia, Brazil (Krömmelbein and Weber, 1971; Viana, 1966; Viana et al., 1971 and this study) and Jatobá Basin, Pernambuco, Brazil (Pinto and Sanguinetti, 1958; Guzmán et al., 2016 and this study); Brejo Santo Formation, Araripe Basin, Ceará, Brazil (Barros et al., 2011; Melo and Carvalho, 2017 and this study).

Remarks: *Theriosynoecum pricei* is the index species of the ostracod biozone RT-001, Dom João local Stage (=Tithonian) in the interior sedimentary basins of Northeast Brazil. Recently, Almeida-Lima et. al (2021, preprint) presents a taxonomical review where they identify different morphological patterns among individuals of this species, synonymizing two morphotypes that were previously identified as distinct species. The differentiation of the five morphotypes presented was carried out based on the nodes that can be developed on the carapace in response to environmental variations (Van Harten, 1996, 2000; Keyser and Aladin, 2004; Keyser, 2005).

Theriosynoecum sp. cf. *T.* sp. 6 (Krömmelbein, 1962)

(Figure 2: E-F)

cf. 1962 "*Metacypris*" sp. 6 Krömmelbein - Krömmelbein, p. 491, pl. 62, fig. 70.

Figured specimen: LMA-00146, L: 814 µm, H: 433 µm, W: 283 µm.

Material: twenty-seven carapaces.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.

Stratigraphic and geographic distribution: Hauterivian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1962); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study).

Remarks: Morphologically, it is similar in lateral and dorsal outline, anterodorsal position of the grooves, and ornamentation of the carapace to the species *Theriosynoecum* sp. 6 reported by Krömmelbein, 1962. However, it was not possible to refine the identification or describe as a new species due to the poor preservation of the specimens.

Suborder CYPRIDOCOPINA Jones, 1901
Superfamily CYPRIDOIDEA Baird, 1845
Family CYPRIDEIDAE Martin, 1940
Genus *Cypridea* Bosquet, 1852 emend. Sames, 2011
Cypridea acicularis Krömmelbein and Weber, 1971
(Figure 2: G-H)

1971 *Cypridea acicularis* Krömmelbein and Weber, p. 19, pl. 2, fig. 8.

2020 *Cypridea acicularis* Krömmelbein and Weber - Mendes et al., p. 40, pl. 10, fig. F.

Figured specimen: LMA-00147, L: 852 µm, H: 503 µm, W: 315 µm.

Material: One adult carapace.

Occurrence: Candeias Formation, Jatobá Basin, outcrop BJ-DM-29.

Stratigraphic and geographic distribution: Berriasian–Valanginian, Lower Cretaceous. Candeias Formation, Recôncavo Basin, Bahia, Brazil (Krömmelbein and Weber, 1971); Candeias Formation, Jatobá Basin, Pernambuco, Brazil (Mendes et al., 2020 and this study).

Remarks: Although the recovered specimen is partially broken, its identification was possible due to the analysis of its characteristic spines near the carapace margins, presence of concavity in the posteroventral portion followed by protrusion of the LV over the RV, its rostrum wide and slightly acuminated, deep rostral groove exceeding the mid-height and the typical anterior cardinal angle.

Cypridea ambigua Krömmelbein, 1962
(Figure 2: I–K)

1962 *Cypridea ambigua* Krömmelbein, p. 456, pl. 57, fig. 28.

2018 *Cypridea ambigua* Krömmelbein - Sousa et al., p. 26, pl. 3, figs. 1–9.

Figured specimen: LMA-00148, L: 797 µm, H: 458 µm, W: 344 µm.
Material: Forty-one carapaces.
Occurrence: Candeias Formation, Tucano Norte Basin, outcrop 1BTN02 and 1BTN05.
Stratigraphic and geographic distribution: Berriasian, Lower Cretaceous. Candeias Formation, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1962); Sousa Formation, Sousa Basin, Paraíba, Brazil (Sousa et al., 2018); Candeias Formation, Tucano Norte Basin, Bahia, Brazil (this work).
Remarks: *Cypridea ambigua* is a typical species of the faunal association of the Rio da Serra Local Stage (= Berriasian) and its stratigraphic range is limited to the RT-002.2 biozone, making it an important pointer for local biostratigraphy (Moura, 1972; Sousa et al., 2019).

Cypridea indiennensis densipunctata Krömmelbein and Weber, 1971
(Figure 2: L–N)

1971 *Cypridea indiennensis densipunctata* Krömmelbein and Weber, p. 11, pl. 1, fig. 1.

Figured specimen: LMA-00149, L: 907 µm, H: 572 µm, W: 372 µm.
Material: Four carapaces.

Occurrence: Candeias Formation, Tucano Norte Basin, outcrop 1BTN02 and 1BTN05.

Stratigraphic and geographic distribution: Berriasian–Valanginian, Lower Cretaceous. Candeias Formation, Jatobá Basin, Pernambuco, Brazil (Krömmelbein and Weber, 1971) Candeias Formation, Tucano Norte Basin, Bahia, Brazil (this work).

Remarks: The specimen here illustrated do not display a well-developed nodulation as described in the type material of *Cypridea indiennensis densipunctata*, but as has been discussed by several authors (Van Harten, 2000; Keyser and Aladin, 2004; Keyser, 2005; Frenzel et al., 2012), the nodes can be varying among individuals of the same species, so it was not considered a distinctive feature.

Cypridea sellata Viana, 1966

(Figure 3: G)

1966 *Cypridea sellata* Viana, p. 244, pl. 1 and 2, figs. 1.

1971 *Cypridea sellata* Viana - Krömmelbein and Weber, p. 23, pl. 3, fig. 13.

2002 *Cypridea sellata* Viana - Coimbra et al., p. 691, pl. 4, figs. 17–18.

2020 *Cypridea sellata* Viana - Mendes et al., p. 40, pl. 10, fig. D–E.

Figured specimen: LMA-00150, L: 901 µm, H: 468 µm.

Material: Four valves of adult specimens.

Occurrence: Candeias Formation, Jatobá Basin, outcrop BJ-DM-30.

Stratigraphic and geographic distribution: Valanginian, Lower Cretaceous. Candeias Formation, Recôncavo/Tucano Basin, Bahia, Brazil (Viana, 1966; Krömmelbein and Weber, 1971); Abaiara Formation, Araripe Basin, Ceará, Brazil (Coimbra et al., 2002); Candeias Formation, Jatobá Basin, Pernambuco, Brazil (Mendes et al., 2020 and this study).

Cypridea semilunaris Cunha and Moura, 1979

(Figure 3: D–F)

1979 *Cypridea semilunaris* Cunha and Moura, p. 92, pl. 1, figs. 8–9.

2020 *Cypridea semilunaris* Cunha and Moura - Mendes et al., p. 40, pl. 10, fig. O.

Figured specimen: LMA-00151, L: 645 µm, H: 356 µm, W: 240 µm.
Material: One carapace of juvenile.
Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.
Stratigraphic and geographic distribution: Barremian, Lower Cretaceous. São Sebastião Formation, Recôncavo Basin, Bahia, Brazil (Cunha and Moura, 1979); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (Mendes et al., 2020 and this study).
Remarks: The species *Cypridea semilunaris* is one of the typical faunal association of the subzones RT-007.1 and RT-007.2, and was the taxon that made it possible to mark the basal part of the Buracica Local Stage (=Barremian).

Cypridea vianai Sousa et al., 2018
(Figure 3: H–J)

2018 *Cypridea vianai* Sousa et al., p. 27, pl. 4, figs. 1–12.

Figured specimen: LMA-00152, L: 848 µm, H: 556 µm, W: 393 µm.
Material: Twelve carapaces of juvenile specimens.
Occurrence: Candeias Formation, Tucano Norte Basin, outcrop 1BTN02.
Stratigraphic and geographic distribution: Berriasian–Hauterivian Lower Cretaceous. Sousa Formation, Sousa Basin, Paraíba, Brazil (Sousa et al., 2018); Candeias Formation, Tucano Norte Basin, Bahia, Brazil (this work).

Cypridea paraibensis Sousa et al., 2018

(Figure 3: M–O)

2018 *Cypridea paraibensis* Sousa et al., p. 27, pl. 3, figs. 10–21.

2020 *Cypridea paraibensis* Sousa et al. - Santos Filho et al., p. 5, pl. 4, fig. 2.

Figured specimen: LMA-00153 (juvenile), L: 756 µm, H: 449 µm, W: 291 µm.

Material: Fifty-two carapaces of juvenile specimens.

Occurrence: Candeias Formation, Tucano Norte Basin, outcrop 1BTN05.

Stratigraphic and geographic distribution: Berriasian–Hauterivian, Lower Cretaceous. Sousa Formation, Sousa Basin, Paraíba, Brazil (Sousa et al., 2018); Orós Formation, Iguatu Basin, Ceará, Brazil (Santos Filho et al., 2020); Candeias Formation, Tucano Norte Basin, Bahia, Brazil (this work).

Remarks: The species *Cypridea paraibensis* was identified, however, the measurements of length, width, and height are smaller than those described for adults of this species, as well as the sexual dimorphism presented by the authors of *C. paraibensis* was not observed in the specimens analyzed here, which leads us to infer that they are juvenile specimens.

Subgenus *Cypridea* (*Morinina*) Anderson, 1939

Cypridea (*Morinina*?) *bibullata bibullata* Wicher, 1959

(Figure 4: A–C)

1959 *Cypridea quadrilateralis bibullata* Wicher, p. 40, pl. 6, figs. 4.

1962 *Cypridea* (*Morinina*?) *bibullata bibullata* Wicher - Krömmelbein, p. 467, pl. 59, fig. 41–42.

1966 *Cypridea* (*Morinina*?) *bibullata* Wicher - Viana, p. 256, pl. 1, fig. 18.

2020 *Cypridea* (*Morinina*?) *bibullata* Wicher - Mendes et al., p. 40, pl. 10, fig. K.

Figured specimen: LMA-00154, L: 1,020 µm, H: 523 µm, W: 382 µm.

Material: Seven carapaces of adult specimens.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.

Stratigraphic and geographic distribution: Valanginian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo/Tucano Basin, Bahia, Brazil (Wicher, 1959; Krömmelbein, 1962; Viana, 1966); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (Mendes et al., 2020 and this study).

Remarks: This subspecies is considered the index fossil of the RT-006 biozone, which corresponds to the Aratu Local Stage (=Hauterivian–Barremian). Our specimens show the RV larger than the LV, differing of the previous records. However, valves reversion is one of the morphological features that can be caused by environmental stress (e.g. Bergue et al., 2011), so it was not considered.

Cypridea (*Morinina*?) *bibullata tribullata* Krömmelbein, 1962
(Figure 4: D–F)

1962 *Cypridea* (*Morinina*?) *bibullata tribullata* Krömmelbein, p. 468, pl. 59, fig. 43–45.
Figured specimen: LMA-00155, L: 969 µm, H: 486 µm, W: 467 µm.
Material: Seven carapaces of adult specimens.
Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.
Stratigraphic and geographic distribution: Valanginian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1962); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study).
Remarks: *Cypridea* (*Morinina*?) *bibullata tribullata* is important for the positioning in the local chronostratigraphy because this subspecies is index for subzone RT-006.2, end of the Aratu local stage (=Hauterivian–Barremian). The lateral and dorsal outline, rostrum position, dimensions and ornamentation are like the *Cypridea* (*Morinina*?) *bibullata bibullata* subspecies, distinguished from it by the number of nodes on the valves surface. However, the presence and number of these nodes may be linked to environmental stress, an aspect that has already been analyzed in extant ostracod species such as *Cyprideis torosa* (Jones, 1850) (Van Harten, 1996, 2000; Keyser and Aladin, 2004; Keyser, 2005), stress that can also influence the reversal overlapping (RV covering LV), feature also displayed by the specimens here studied. A review of the subspecies *Cypridea* (*Morinina*?) *bibullata bibullata* and *Cypridea* (*Morinina*?) *bibullata tribullata* was not feasible due to the rarity of the material and the poor preservation of the individuals, but we do not rule out the possibility that they may belong to the same species.

Cypridea sp. cf. *C.* (*Morinina*?) *langei* Krömmelbein, 1962
(Figure 4: G-H)

cf. 1962 *Cypridea* (*Morinina*?) *langei* Krömmelbein, p. 469, pl. 60, fig. 46.

cf. 2020 *Cypridea* (*Morinina*?) *langei* Krömmelbein - Mendes et al., p. 40, pl. 10, fig. L.

Figured specimen: LMA-00156, L: 1,010 µm, H: 493 µm, W: 357 µm.
Material: One adult carapace.
Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.
Stratigraphic and geographic distribution: Valanginian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1962); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (Mendes et al., 2020 and this study).
Remarks: The specimen recorded in our study is like *Cypridea* (*Morinina*?) *langei* in the carapace outline, anterior cardinal angle and inclination of the rostrum facing the ventral portion of the carapace, nonetheless its poor preservation did not allow identifying the typical features of the species, such as overlapping valves that is very pronounced in *C*. (*Morinina*?) *langei* and visualization of the entire rostrum.

Cypridea sp. cf. *C. miritiensis* Krömmelbein and Weber, 1971

(Figure 3: A–C)

cf. 1971 *Cypridea miritiensis* Krömmelbein and Weber, p. 12, pl. 1, fig. 2.

Figured specimen: LMA-00157, L: 835 µm, H: 521 µm, W: 309 µm.
Material: Three carapaces.
Occurrence: Candeias Formation, Tucano Norte Basin, outcrop 1BTN02.
Stratigraphic and geographic distribution: Berriasian–Valanginian, Lower Cretaceous. Candeias Formation, Tucano Central Basin, Bahia, Brazil (Krömmelbein and Weber, 1971); Candeias Formation, Tucano Norte Basin, Bahia, Brazil (this work).
Remarks: Although the lateral and dorsal outline, cardinal angles, and dorsal margin, as well as ornamentation displaying nodes are features similar to those of *Cypridea miritiensis*, the recovered specimens of this morphotype did not show well-preserved features that would support the classification of this species.

Cypridea sp. 1

(Figure 3: K–L)

Figured specimen: LMA-00158, L: 1,040 µm, H: 586 µm, W: 326 µm.

Material: One adult carapace.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.

Stratigraphic and geographic distribution: Valanginian–Barremian, Lower Cretaceous. Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study).

Remarks: The specimen identified as *Cypridea* sp. 1 has the outline, nodes position, and rostrum similar to *Cypridea quadrilateralis bibullata* described by Wicher (1959). This subspecies was invalidated by Krömmelbein (1962), nevertheless, in lateral view the outline of the specimen illustrated by Wicher (1952) is more sub-rectangular than that of *Cypridea bibullata bibullata*, subspecies that Krömmelbein (1962) included in *C. quadrilateralis bibullata* as a junior synonym. The morphotype also can not be assigned to the species *Cypridea quadrilateralis* Swain, 1946 because they differ in the rostrum' morphology which is an important feature for classification of species within the genus *Cypridea*. Due to the rarity of the material and its preservation it was not possible to carry out the revision for the taxon, not allowing to identify our specimen as another species or even to describe as a new species.

Family CYPRIDIDAE Baird, 1845

Genus *Paracypridea* Swain, 1946

Paracypridea brasiliensis Krömmelbein, 1961

(Figure 4: I)

1961 *Paracypridea brasiliensis* Krömmelbein, p. 362, pl. 5, fig. 38–40.

1962 *Paracypridea brasiliensis* Krömmelbein - Krömmelbein, p. 476, pl. 53, fig. 4.

1966 *Paracypridea brasiliensis* Krömmelbein - Viana, p. 252, pl. 1, fig. 17.
1967 *Paracypridea brasiliensis* Krömmelbein - Grekoff and Krömmelbein, p. 1321, pl. 5, fig. 29.

1971 *Paracypridea brasiliensis* Krömmelbein - Krömmelbein and Weber, p. 18, pl. 5, fig. 18.

2020 *Paracypridea brasiliensis* Krömmelbein - Mendes et al., p. 40, pl. 10, fig. G.

Figured specimen: Lost, L: 1,214 µm, H: 829 µm.
Material: One carapace
Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-63.
Stratigraphic and geographic distribution: Valanginian–Hauterivian, Lower Cretaceous: Ilhas Group, Tucano Sul Basin, Bahia, Brazil (Krömmelbein, 1962, 1961; Krömmelbein and Weber, 1971); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (Mendes et al. 2020 and this study); Fourou Plage Formation, Cocobeach Group, Gabon Basin, Africa (Grekoff and Krömmelbein, 1967).
Remarks: The species *P. brasiliensis* is the index of the RT-004 biozone, which corresponds to the Rio da Serra Local Stage (=Valanginian–lower Hauterivian). This species is an important marker for the correlation between the Brazilian and African basins (Grekoff and Krömmelbein, 1967).

Paracypridea quadrirugosa quadrirugosa (Wicher, 1959)

(Figure 6: A-B)

1959 *Cypridea obovata quadrirugosa* Wicher, p. 40, pl. 6, fig. 3.

1961 *Paracypridea quadrirugosa quadrirugosa* Wicher - Krömmelbein, p. 356, pl. 6, fig. 3.

2020 *Paracypridea quadrirugosa quadrirugosa* Wicher - Mendes et al., p. 40, pl. 10, fig. M.

Figured specimen: LMA-00159, L: 1,620 µm, H: 931 µm, W: 663 µm.

Material: Eight carapaces and one valve of the adult specimens.
Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.
Stratigraphic and geographic distribution: Hauterivian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1961;

Wicher, 1959); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (Mendes et al.,2020 and this work).

Remarks: *P. quadrirugosa quadrirugosa* has a stratigraphic range that comprises the local stages Aratu (=Hauterivian–lower Barremian) and Buracica (=middle Barremian). Biostratigraphically they correspond to the subzones RT-006.1 – RT-007.3.

Paracypridea ex. gr. *elegans* Krömmelbein, 1962

(Figure 5: A–I)

1962 *Paracypridea elegans* Krömmelbein, p. 478, pl. 53, fig. 7a.

1964 *Paracypridea elegans elegans* Krömmelbein - Krömmelbein, p. 147, pl. 3 and 4, fig. 6 and 8.

1964 *Paracypridea elegans santantoensis* Krömmelbein - Krömmelbein, p. 149, pl. 3, fig. 5.

1964 *Paracypridea elegans inflata* Krömmelbein - Krömmelbein, p. 151, pl. 4, fig. 7.

2020 *Paracypridea elegans santantoensis* Krömmelbein - Mendes et al., p. 40, pl. 10, fig. I.

Figured specimen: LMA-00160, L: 929 µm, H: 567 µm, W: 401 µm (Fig. 5: A–C); LMA-00161, L: 891 µm, H: 536 µm, W: 352 µm (Fig. 5: D–F); LMA-00162, L: 967 µm, H: 541 µm, W: 373 µm (Fig. 5: G–I).

Material: Three carapaces of adult specimens.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-63.

Stratigraphic and geographic distribution: Valanginian–Hauterivian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1962; Krömmelbein, 1964); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (Mendes et al., 2020 and this study); Schistes Bruns, Cocobeach Group, Gabon Basin, Africa (Grekoff and Krömmelbein, 1967).

Remarks: The species *Paracypridea elegans* was refined to three subspecies by Krömmelbein (1964), *Paracypridea elegans elegans*, *Paracypridea elegans santantoniensis* and *Paracypridea elegans inflata* due to the some differences in the general outline and width of the posteroventral region of the individuals. However, a revision of this group of subspecies is necessary, considering that important morphological features such as the outline of the carapace in lateral and dorsal views and dimensions vary discretely within these three subspecies and attributed to sexual dimorphism. We considered parsimonious to maintaining our material in open nomenclature, since the small number of specimens did not allow a review of this taxon in the present work. This taxonomic group has a stratigraphic range from subzone RT-004.4 to subzone RT-005.2, belonging to the local stages Rio da Serra (=Valanginian) and Aratu (=Hauterivian).

Genus *Salvadoriella* Krömmelbein, 1963
Salvadoriella redunca posterior Krömmelbein, 1963
(Figure 5: J–L)

1963 *Salvadoriella redunca posterior* Krömmelbein, p. 388, pl. 2, fig. 7.

Figured specimen: LMA-00163, L: 1,020 µm, H: 475 µm, W: 361 µm.

Material: Eleven carapaces of adult specimens.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.

Stratigraphic and geographic distribution: Hauterivian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1963); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study).

Remarks: The anteroventral region not very pronounced, posterior region infracurved and acute, fusiform outline in dorsal view and position of the greatest width, characterized the subspecies and led to differentiated it from *Salvadoriella redunca redunca* (Krömmelbein, 1962) and *Salvadoriella redunca comitans* Krömmelbein, 1963. Due to the preservation of the specimens, it was not possible to clearly visualize the rib in the lateral portion of the valves pointed in the original diagnosis of *Salvadoriella redunca posterior*. This subspecies is associated to the RT-006 biozone, local stage Aratu (=Hauterivian–Barremian).

Subfamily CANDONINAE Kaufmann, 1900

Genus *Reconcavona* Krömmelbein, 1962

Reconcavona? *jatobaensis* Krömmelbein and Weber, 1971

(Figure 6: C-D)

1971 *Reconcavona*? *jatobaensis* Krömmelbein and Weber, p. 48, pl. 9, fig. 40.

2016 *Reconcavona*? *jatobaensis* Krömmelbein and Weber - Guzmán et al., p. 19, pl. 4, fig. 4J–K.

2017 *Reconcavona*? *incerta* Krömmelbein and Weber - Melo and Carvalho, p. 70, pl. 10, fig. 10J–L.

Figured specimen: LMA-00164, L: 884 µm, H: 502 µm, W: 335 µm.

Material: Eleven carapaces of adult specimens.

Occurrence: Aliança Formation, Jatobá and Tucano Norte basins, outcrops BJ-MG-10, BJ-01, BJ-06, BJ-08 and 2BTN08.

Stratigraphic and geographic distribution: Tithonian–Valanginian, Upper Jurassic–Lower Cretaceous. Candeias Formation, Jatobá Basin, Bahia, Brazil (Krömmelbein and Weber, 1971); Brejo Santo Formation, Araripe Basin, Ceará, Brazil (Melo and Carvalho, 2017); Aliança Formation, Jatobá Basin, Pernambuco, Brazil (Guzmán et al., 2016 and this study); Aliança Formation, Tucano Norte Basin, Bahia, Brazil (this study).

Remarks: *Reconcavona*? *jatobaensis* was firstly recorded in strata from the Candeias Formation, Jatobá Basin, by Krömmelbein and Weber (1971). After, Guzmán et al. (2016) reported the occurrence of this species in the Aliança Formation in the Jatobá Basin, and Melo and Carvalho (2017) for the Brejo Santo Formation, Araripe Basin, extending its stratigraphic range from Tithonian. This work demonstrates the occurrence for the Aliança Formation, Tucano Norte Basin, improving the knowledge about the geographical distribution of this species.

Reconcavona striata Cunha and Moura, 1979

(Figure 4: J–L)

1979 *Reconcavona striata* Cunha and Moura, p. 94, pl. 2, figs. 7–8.

Non 2005 *Reconcavona striata* - Mojon et al., p. 9, pl. 7, fig. C.

2020 *Reconcavona striata* - Mendes et al., p. 40, pl. 10, fig. N.

Figured specimen: LMA-00165, L: 717 µm, H: 386 µm, W: 201µm.
Material: Seventeen carapaces of adult and juvenile specimens.
Occurrence: Ilhas Group, Jatobá Basin, outcrops BJ-DM-68.
Stratigraphic and geographic distribution: Hauterivian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Cunha and Moura, 1979); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (Mendes et al., 2020 and this study).
Remarks: Mojon et al. (2005) reported this species in deposits of Hauterivian–lower Barremian in central High Atlas Mountains (Morocco). However, the illustrated material by Mojon et al. (2005) has a suboval lateral outline and an equicurved posterior margin, which differs of the description of Cunha and Moura (1979)

Reconcavona striatula (Swain, 1946)

(Figure 6: E-F)

1946 *Candona*? *striatula* Swain, p. 546, pl. 83, figs. 4–6.
1962 *Reconcavona striatula* Swain - Krömmelbein, p. 483, pl. 61, figs. 54–58.
1967 *Reconcavona striatula* Swain - Grekoff and Krömmelbein, p. 1322, pl. 6, fig. 30.
2020 *Reconcavona striatula* Swain - Mendes et al., p. 40, pl. 10, fig. H.
Figured specimen: LMA-00166, L: 714 µm, H: 377 µm, W: 189 µm.
Material: One juvenile carapace.
Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-63.
Stratigraphic and geographic distribution: Valanginian–Hauterivian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Swain, 1946; Krömmelbein, 1962); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (Mendes et al., 2020 and this study); Schistes Bruns, Cocobeach Group, Gabon Basin, Africa (Grekoff and Krömmelbein, 1967).

Reconcavona swaini Krömmelbein, 1962

(Figure 6: G–I)

1962 *Reconcavona swaini* Krömmelbein, p. 485, pl. 61, fig. 60.
1967 *Reconcavona swaini* Krömmelbein - Grekoff and Krömmelbein, p. 1323, pl. 6, fig. 35.
1984 *Reconcavona swaini* Krömmelbein - Grosdidier and Bignoumba, p.95, pl. 1, fig. 10.
2018 *Reconcavona swaini* Krömmelbein - Sousa et al., p. 31, pl. 6, figs. 1–6.

Figured specimen: LMA-00167, L: 670 µm, H: 361 µm, W: 262 µm.

Material: Two carapaces of juvenile specimens.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.

Stratigraphic and geographic distribution: Hauterivian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1962); Sousa Formation, Sousa Basin, Paraíba, Brazil (Sousa et al., 2018); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study); Schistes Noirs (Melania Formation), Cocobeach Group, Gabon Basin, Africa (Grekoff and Krömmelbein, 1967; Grosdidier and Bignoumba, 1984).

Remarks: The holotype of this species illustrated by Krömmelbein (1962) is wider and higher when compared to the specimens recovered from our material. This difference in dimensions can be related to intraspecific variations, such an ontogenetic stage or sexual dimorphism. Thus, our specimens can be considered a juvenile specimen.

Reconcavona sp. aff. *R.*? *polita* Viana, 1966

(Figure 7: A–C)

aff. 1966 *Reconcavona*? *polita* Viana, p. 249, pl. 4, fig. 14.

Figured specimen: LMA-00168, L: 935 µm, H: 501 µm, W: 365 µm.

Material: Eleven carapaces of adult specimens.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.

Stratigraphic and geographic distribution: Hauterivian–Barremian, Lower Cretaceous. Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study).

Remarks: The specimens presented here is similar in anterior and anteroventral outline to the species *Reconcavona*? *polita*, but the posterior margin of *R.*? *polita* is infracurved, whereas our specimen presents an equicurved posterior margin. The dorsal margin of the illustrated specimen could not be evaluated because is partially broken. In dorsal view, both show a biconvex outline, the width is greater in the median region of the carapace, and the normal overlap. The association of the species *Paracypridea quadrirugosa quadrirugosa*, *Salvadoriella redunca posterior*, *Reconcavona striata*, *Reconcavona swaini* and *Cypridea* (*Morinina*?) *bibullata bibullata* allowed the inference of their stratigraphic range to the Hauterivian–Barremian.

Reconcavona sp. cf. *R. triebeli* Krömmelbein, 1964

(Figure 7: D–F)

cf. 1964 *Reconcavona triebeli* Krömmelbein, p. 32, pl. 4, fig. 3–4.

cf. 1966 *Reconcavona triebeli* Krömmelbein - Viana, p. 253, pl. 4, fig. 11.

cf. 1967 *Reconcavona triebeli* Krömmelbein - Grekoff and Krömmelbein, p. 1323, pl. 6, fig. 32.

cf. 1984 *Reconcavona triebeli* Krömmelbein - Grosdidier and Bignoumba, p.95, pl. 1, fig. 11.

Figured specimen: LMA-00169, L: 659 µm, H: 354 µm, W: 265 µm.

Material: Ten carapaces.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-68.

Stratigraphic and geographic distribution: Hauterivian–Barremian, Lower Cretaceous. Ilhas Group, Recôncavo Basin, Bahia, Brazil (Krömmelbein, 1964; Viana, 1966); Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study); Schistes Noirs (Melania Formation), Cocobeach Group, Gabon Basin, Africa (Grekoff and Krömmelbein, 1967; Grosdidier and Bignoumba, 1984).

Remarks: The specimens are similar to *Reconcavona triebeli*, in subtrapezoidal lateral outline and biconvex dorsal outline, position of the greater height and greater width and in the position of obtuse cardinal angles. In the original diagnosis *R. triebeli* has a node (described as a thorn by the species author) on posterior margin, it is known that environmental factors can influence this type of carapace ornamentation, and that can be present or absent depending on the variations of the environment in which the individuals inhabit (Van Harten, 2000; Keyser and Aladin, 2004; Keyser, 2005).

Reconcavona sp.1

(Figure 7: G–I)

Figured specimen: LMA-00170, L: 521 µm, H: 299 µm, W: 119 µm.

Material: Two carapaces and one valve.

Occurrence: Ilhas Group, Jatobá Basin, outcrop BJ-DM-63.

Stratigraphic and geographic distribution: Valanginian–Hauterivian, Lower Cretaceous. Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study).

Remarks: *Reconcavona* sp. 1 resembles the lateral outline of species *Reconcavona gastracantha* Krömmelbein, 1964, but on the dorsal margin *Reconcavona* sp. 1 has a slight convexity, whereas *R. gastracantha* is straighter. The dorsal view differs significantly in outline, *Reconcavona gastracantha* is biconvex and has a greater width just after the midlength whereas *Reconcavona* sp. 1 in dorsal view is narrow and symmetric. The stratigraphic positioning of this species was possible because it was associated with *Paracypridea brasiliensis*, *Reconcavona striatula* and *Paracypridea* ex. gr. *elegans* typical association of the assigned interval.

Reconcavona sp. 2

(Figure 7: J–L)

Figured specimen: LMA-00171, L: 546 µm, H: 308 µm, W: 134 µm.

Material: Two carapaces.

Occurrence: Ilhas Group, Jatobá Basin, outcrops BJ-DM-63 and BJ-DM-68.

Stratigraphic and geographic distribution: Valanginian–Barremian, Lower Cretaceous. Ilhas Group, Jatobá Basin, Pernambuco, Brazil (this study).

Remarks: *Reconcavona* sp. 2 is similar to *Reconcavona*? *jatobaensis* in rounded anterodorsal outline, straight ventral margin and infracurved posterior margin, however, the dorsal margin of *Reconcavona* sp. 2 has a more rounded oultine, whereas *R.*? *jatobaensis* is more angular in the anterodorsal portion. The greatest width and greatest height are also discrepant with *R.*? *jatobaensis* and in dorsal view *Reconcavona* sp. 2 is narrower. The stratigraphic positioning of *Reconcavona* sp. 2 was inferred from its association with other species, such as *Paracypridea brasiliensis*, *Reconcavona striatula*, *Paracypridea quadrirugosa quadrirugosa* and *Salvadoriella redunca posterior*.

Family ILYOCYPRIDIDAE Kaufmann, 1900

Subfamily ILYOCYPRIDINAE Kaufmann, 1900

Genus *Rhinocypris* Anderson, 1941

Rhinocypris sp. 1

(Figure 7: M–O)

Figured specimen: LMA-00172, L: 622 µm, H: 336 µm, W: 254 µm.

Material: Twenty-two carapaces and three valves.

Occurrence: Candeias Formation, Tucano Norte Basin, outcrop 1BTN02.

Stratigraphic and geographic distribution: Berriasian–Valanginian, Lower Cretaceous. Candeias Formation, Tucano Norte Basin, Bahia, Brazil (this work).

Remarks: The genera *Rhinocypris* and *Ilyocypris* are similar in lateral outline, ornamentation and overlapping, their original descriptions are very similar. Some differences can be pointed out to distinguish species from these genera, such as the ornamentation composed of small tubercles covering the entire carapace surface and absence of well-developed nodes in dorsal region in *Rhinocypris*, inasmuch as *Ilyocypris* displays three well-developed nodes on each valve and ornamentation with punctuations, reticules, and small tubercles. We prefer maintain our species in open nomenclature because these genera needs a wide revision as discussed by Santos Filho et al. (2020).

Suborder DARWINULOCOPINA Sohn, 1988
Superfamily DARWINULOIDEA Brady and Norman, 1889
Family DARWINULIDAE Brady and Norman, 1889
Genus *Darwinula* Brady and Robertson, 1885
Darwinula? sp. cf. *D*. *oblonga* (Roemer, 1839)

(Figure 7: S–U)

cf. 2002 *Darwinula* gr. *oblonga* (Roemer) - Coimbra et al., p. 692, pl. 4, figs. 1–2.

cf. 2011 *Darwinula oblonga* (Roemer, 1839) - Barros et al., p. 114, pl. 1, figs. 2.

cf. 2017 *Darwinula* cf. *oblonga* (Roemer, 1839) - Melo and Carvalho, p. 70, pl. 10, figs. D–F.

Figured specimen: LMA-00173, L: 1,010 µm, H: 460 µm, W: 369 µm.
Material: About nine thousand specimens including carapaces and valves of adults and juveniles.
Occurrence: Brejo Santo Formation, Araripe Basin, outcrop 2BAr01; Aliança Formation, Jatobá and Tucano Norte basins, outcrops BJ-MG-10, BJ-01, BJ-06, BJ-08, 2BTN07 and 2BTN08.
Stratigraphic and geographic distribution: Tithonian, Upper Jurassic: Aliança Formation, Tucano Norte and Jatobá basins, Brazil (this study); Brejo Santo Formation, Araripe Basin, Brazil (Coimbra et al., 2002; Barros et al., 2011; Melo and Carvalho, 2017).
Remarks: The fossil representatives of the Family Darwinulidae have been constantly revised because they are groups that have a similar external carapace morphology. Problems in taxonomy of the fossil darwinuliids are common, since the genera descriptions are based on extant organisms, including the soft parts data. In most of fossils, only external features of carapaces are available to taxonomic identification, and what would distinguish the genera *Darwinula*, *Alicenula*, *Vestalenula* and *Penthensilenula* are presence or absence of keel and/or internal

teeth, overlapping pattern and size of the valves (Rossetti and Martens, 1998). Thus, only in well-preserved adult carapaces and clean valves it would be possible to visualize the diagnostic characteristics. The specimens we recovers had their carapaces articulated, or when disarticulated fully filled, making it impossible to observe the internal morphology of the valves and the type of preservation and taphonomic signatures such as cup-in-cup preservation, factors that make the genus designation uncertain. In view of these points, it was decided to keep it in *Darwinula* requiring further investigation in the future. Due to the taxonomic problematics commented above we have chosen to remain as *Darwinula*? cf. *D. oblonga* since it is an already known and well documented taxon for the Tithonian interval.

Genus *Alicenula* (Rossetti and Martens, 1998)

Alicenula? sp. cf. *Alicenula leguminella* (Forbes, 1855)

(Figure 7: P–R)

cf. 2018 *Alicenula* ex gr. *leguminella* - Sousa et al., p. 34, pl. 6, figs. 24–26.

cf. 2020 *Alicenula leguminella* (Forbes, 1855 in Lyell, 1855) Martens, Rossetti and Horne, 2003 – Santos Filho et al., p. 18, pl. 6, figs. 6.

Figured specimen: LMA-00174, L: 714 µm, H: 317 µm, W: 269 µm.

Material: Eight carapaces and nineteen valves.

Occurrence: Candeias Formation, Tucano Norte Basin, outcrop 1BTN02.

Stratigraphic and geographic distribution: Berriasian–Valanginian, Lower Cretaceous. Candeias Formation, Tucano Norte Basin, Bahia, Brazil (this work).

Remarks: The taxonomic issues surrounding the genus *Alicenula* are common to that already discussed for *Darwinula*, we chose to follow the generic classification revised by Martens et al. (2003). The recovered specimens resemble the morphotype of what has been classified as belonging or related groups to the species *A. leguminella* for the stratigraphic range studied (Sousa et al., 2018; Santos Filho et al., 2020). It was decided to maintain in open nomenclature due to the poor preservation of the recovered individuals, and by the need for a revision of the species, a better description of the diagnosis in order to elucidate what has been classified within this taxon.

5. Final Considerations

The identification of the rift phase ostracod fauna allowed the positioning of the sedimentary deposits in the RT-001 to RT-007 biozones and determine the correlation between the three basins during the Tithonian (=Dom João Local Stage) by identifying the index taxon of the RT-001 biozone, the *Theriosynoecum pricei*. In the Tucano Norte Basin, RT-002 biozone was recognized through the occurrence of the species *Cypridea ambigua*, which corresponds to the Berriasian (=Rio da Serra Local Stage), whilst in the Jatobá Basin the register was from RT-003 to RT-007 biozones, marked by the presence of the species *Cypridea sellata*, *Paracypridea brasiliensis*, *Cypridea* (*Morinina*?) *bibullata bibullata* and *Cypridea semilunaris*, comprising the Valanginian to the Barremian (=Rio da Serra to Buracica local stages). From Araripe Basin, there were not recovered ostracods typical of the Berriasian–Barremian interval (RT-002 to RT-007 biozones) corresponding to the Rio da Serra, Aratu and Buracica local stages. There may have been no recovery of correlated biozones due to a sedimentation gap, deposits erosion or because rocks from the same periods are not outcropping in all studied basins.

The species and subspecies already identified in older studies have been appropriately updated and illustrated, and our contribution brings additions to these taxa that will provide support for future applied studies of the Tithonian–Barremian rift deposits in the basins of Northeast Brazil.

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Subtitles

Table 1 – Location data, geographic coordinates, and samples collected for the outcrops studied.

Figure 1 – Geological setting of the Araripe, Jatobá and Tucano Norte basins in Transverse and South tectonic domains of Borborema Province, northeast Brazil. The red stars correspond to the fossiliferous rift outcrop sampling areas. Metadata at scale 1:1,000,000 provided by Geological Survey of Brazil-CPRM.

Figure 2 – Ostracoda species. A-B (dorsal and RV): *Theriosynoecum pricei* ♀; C-D (dorsal and RV): *Theriosynoecum pricei* ♂; E-F (RV and dorsal): *Theriosynoecum* sp. cf. *Theriosynoecum* sp. 6; G-H (LV and dorsal): *Cypridea acicularis*; I–K (RV, LV and dorsal): *Cypridea ambigua*; L–N (LV, RV and dorsal): *Cypridea indiennensis densipunctata*.

Figure 3 – Ostracoda species. A–C (RV, LV and dorsal): *Cypridea* sp. cf. *Cypridea miritiensis*; D–F (RV, LV and dorsal): *Cypridea semilunaris*; G (RV): *Cypridea sellata*; H–J (RV, LV and dorsal): *Cypridea vianai*; K-L (dorsal and LV): *Cypridea* sp. 1; M–O (LV, RV and dorsal): *Cypridea paraibensis*.

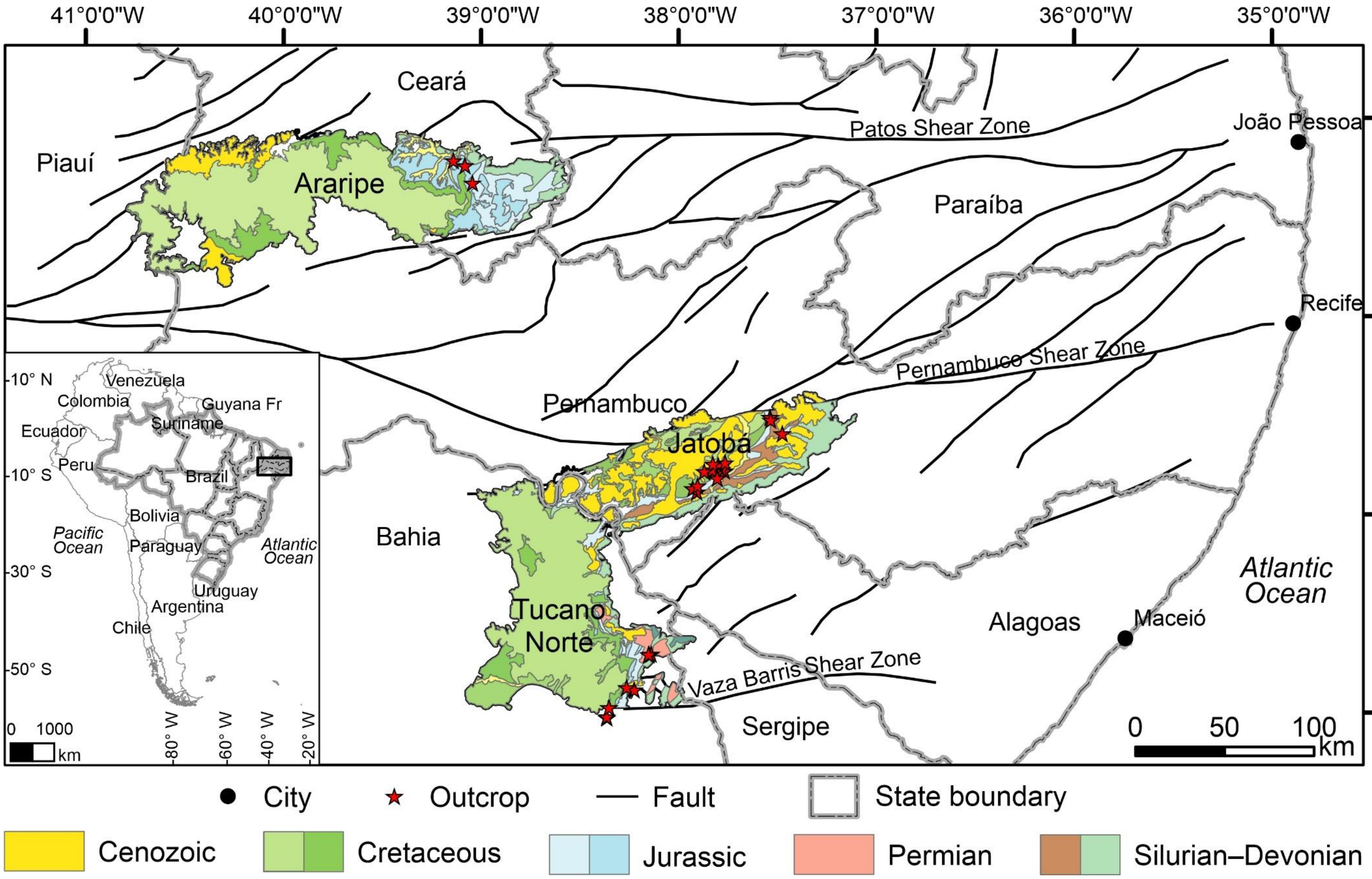
Figure 4 – Ostracoda species. A–C (RV, LV and dorsal): *Cypridea* (*Morinina*?) *bibullata bibullata*; D–F (RV, LV and dorsal): *Cypridea* (*Morinina*?) *bibullata tribullata*; G-H (LV and dorsal): *Cypridea* sp. cf. *Cypridea* (*Morinina*?) *langei*; I (LV): *Paracypridea brasiliensis*; J–L (LV, RV and dorsal): *Reconcavona striata*.

Figure 5 – Ostracoda species. A–I (RV, LV and dorsal): *Paracypridea* ex. gr. *elegans*; J–L (dorsal, RV and LV): *Salvadoriella redunca posterior*.

Figure 6 – Ostracoda species. A-B (RV and dorsal): *Paracypridea quadrirugosa quadrirugosa*; C-D (RV and dorsal): *Reconcavona*? *jatobaensis*; E-F (LV and dorsal): *Reconcavona striatula*; G–I (LV, RV and dorsal): *Reconcavona swaini*.

Figure 7 – Ostracoda species. A–C (RV, LV and dorsal): *Reconcavona* aff. *Reconcavona*? *polita*; D–F (RV, LV and dorsal): *Reconcavona* sp. cf. *R*. *triebeli*; G–I (RV, LV and dorsal): *Reconcavona* sp.1; J–L (LV, RV and dorsal): *Reconcavona* sp.2; M–O (RV, LV and dorsal): *Rhinocypris* sp.1; P–R (RV, LV and dorsal): *Alicenula* sp. cf. *Alicenula leguminella*; S–U (RV, LV and dorsal): *Darwinula*? sp. cf. *D*. *oblonga*.

Outcrop	Coordinates		Basin	Samples	Result
	S	W			
2BAr01	7º14’18.93”	39º8’23.58”	Araripe	9	fossiliferous
2BAr02	7º11’23.32”	39º5’35.64”	Araripe	2	barren
2BAr03	7º21’11.08”	39º2’37.18”	Araripe	3	barren
BJ-01	8°37'6.16”	37°28'4.26”	Jatobá	5	fossiliferous
BJ-06	8°32'10.82”	37°31'50.34„	Jatobá	12	fossiliferous
BJ-08	8°32'56.28”	37°31'41.19„	Jatobá	4	fossiliferous
BJ-MG-10	8º54’35.02"	37º53’38.49„	Jatobá	1	fossiliferous
BJ-MG-29	8º53’47.57”	37º55’22.44„	Jatobá	1	barren
BJ-MG-37	8º52’58.28”	37º53’54.95„	Jatobá	7	barren
BJ-DM-05	8º48’28.12”	37º45’42.15„	Jatobá	1	barren
BJ-DM-09	8º48’28.12”	37º45’42.15„	Jatobá	1	barren
BJ-DM-19	8º46’44.22”	37º47’47.08„	Jatobá	1	barren
BJ-DM-29	8º48’31.08”	37º48’40.93„	Jatobá	3	fossiliferous
BJ-DM-30	8º48’29.9”	37º48”37.6”	Jatobá	4	fossiliferous
BJ-DM-38	8º45’55.51”	37º45’33.01„	Jatobá	4	barren
BJ-DM-63	8º48’9.52”	37º49’29.5”	Jatobá	1	fossiliferous
BJ-DM-68	8º46”22.69”	37º49’16.42„	Jatobá	2	fossiliferous
BJ-DM-76	8º46’22.69”	37º49’16.42„	Jatobá	3	barren
BJ-PB-33	8º48’41.18”	37º51’54.16„	Jatobá	4	barren
1BTN02	10º3’27.17”	38º21’25.84„	Tucano Norte	2	fossiliferous
1BTN03	10º3’0.03”	38º21’30.43„	Tucano Norte	2	barren
1BTN04	10º0’21.1”	38º20’47.22„	Tucano Norte	1	barren
1BTN05	10º0’19.73”	38º20’46.17„	Tucano Norte	5	fossiliferous
2BTN02	9º54’59.57”	38º13’6.19”	Tucano Norte	3	barren
2BTN03	9º54’15.09”	38º15’26.5”	Tucano Norte	1	barren
2BTN06	9º44’3.31”	38º7’55.01”	Tucano Norte	4	barren
2BTN07	9º44’9.92”	38º8’33.23”	Tucano Norte	2	fossiliferous
2BTN08	9º44’11.44”	38º8’43.20”	Tucano Norte	20	fossiliferous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Piauí
Araripe
Patos Shear Zone
João Pessoa
Paraíba
Recife
Pernambuco Shear Zone
Pernambuco
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Tucano Norte
Vaza Barris Shear Zone
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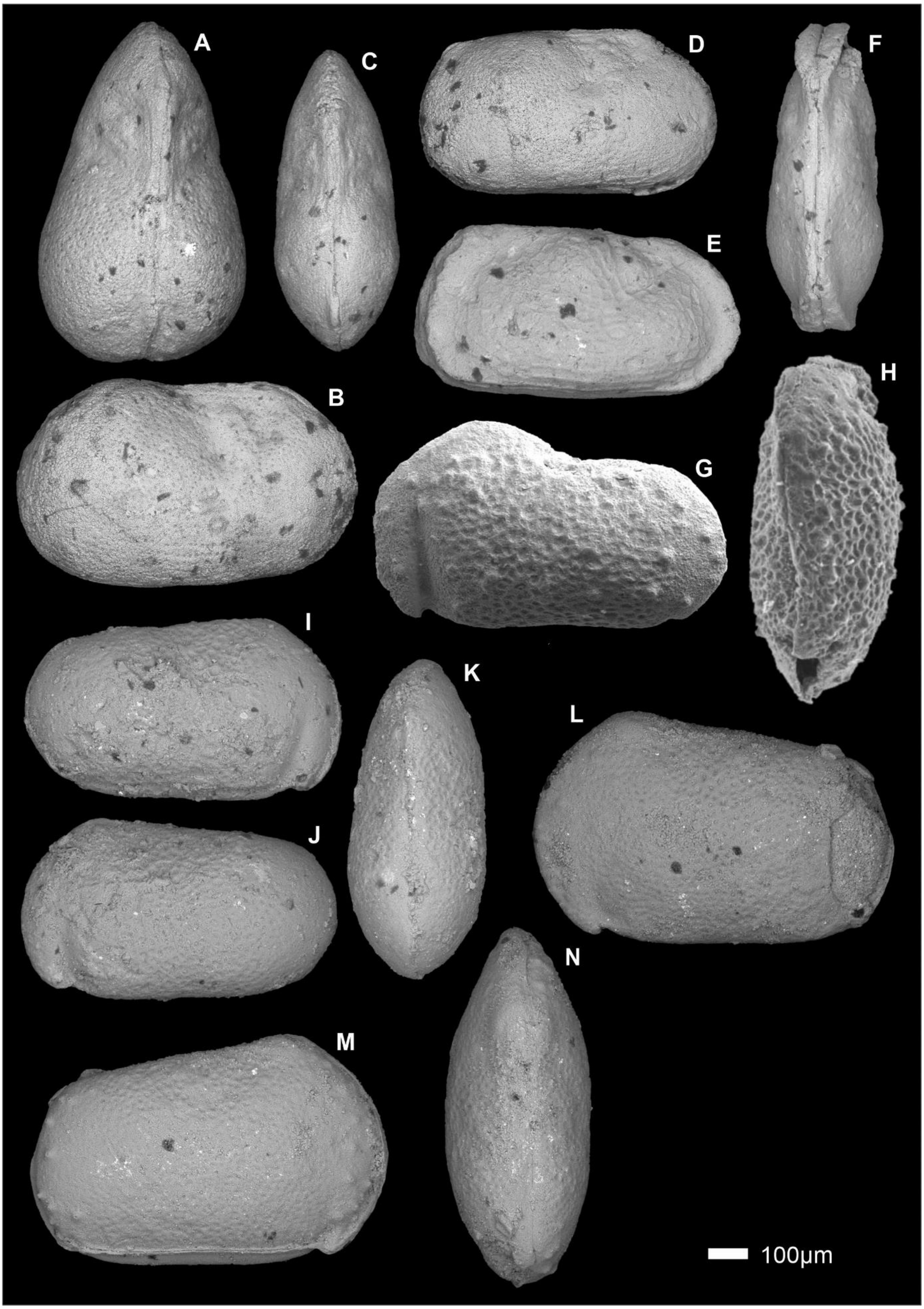
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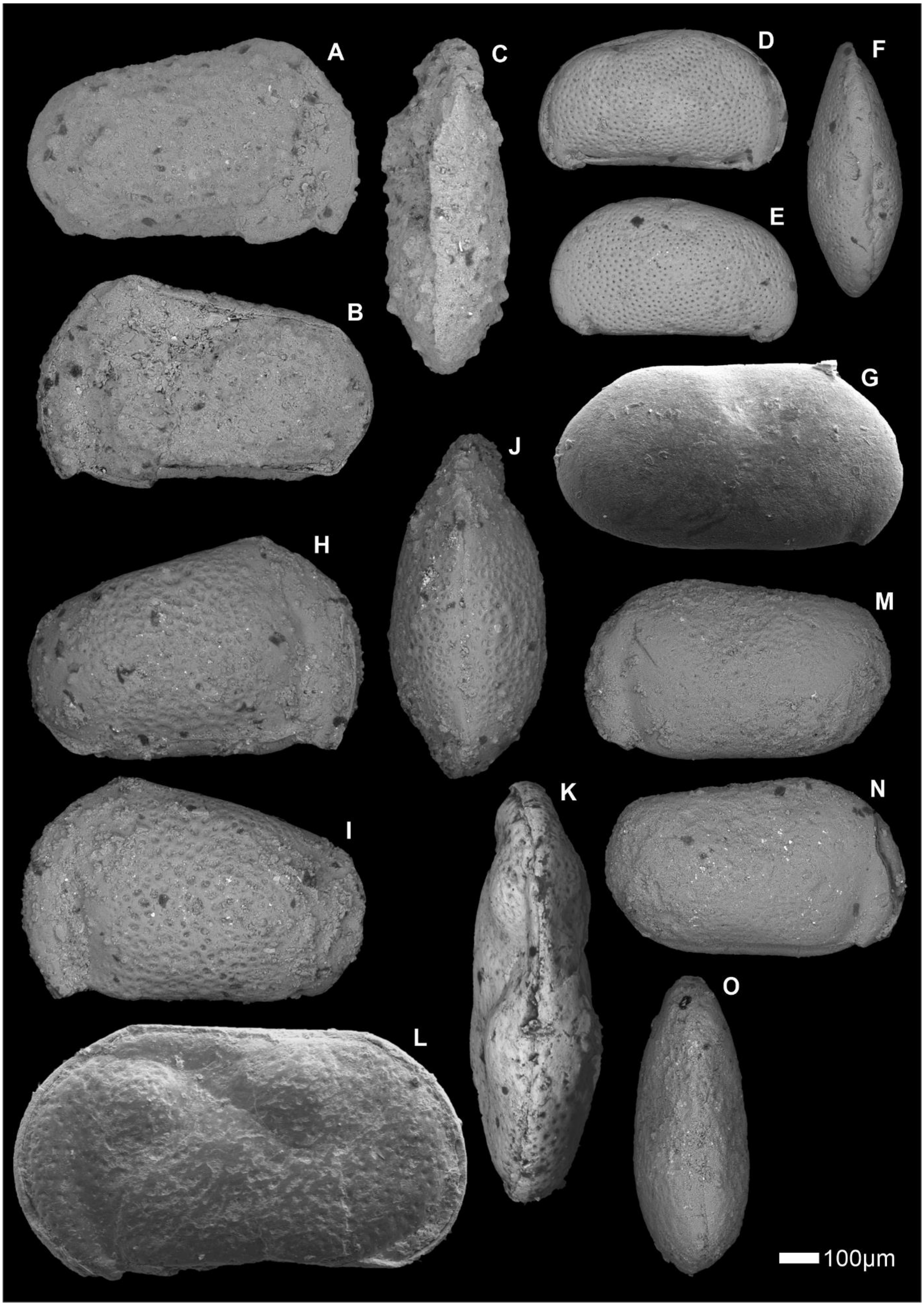
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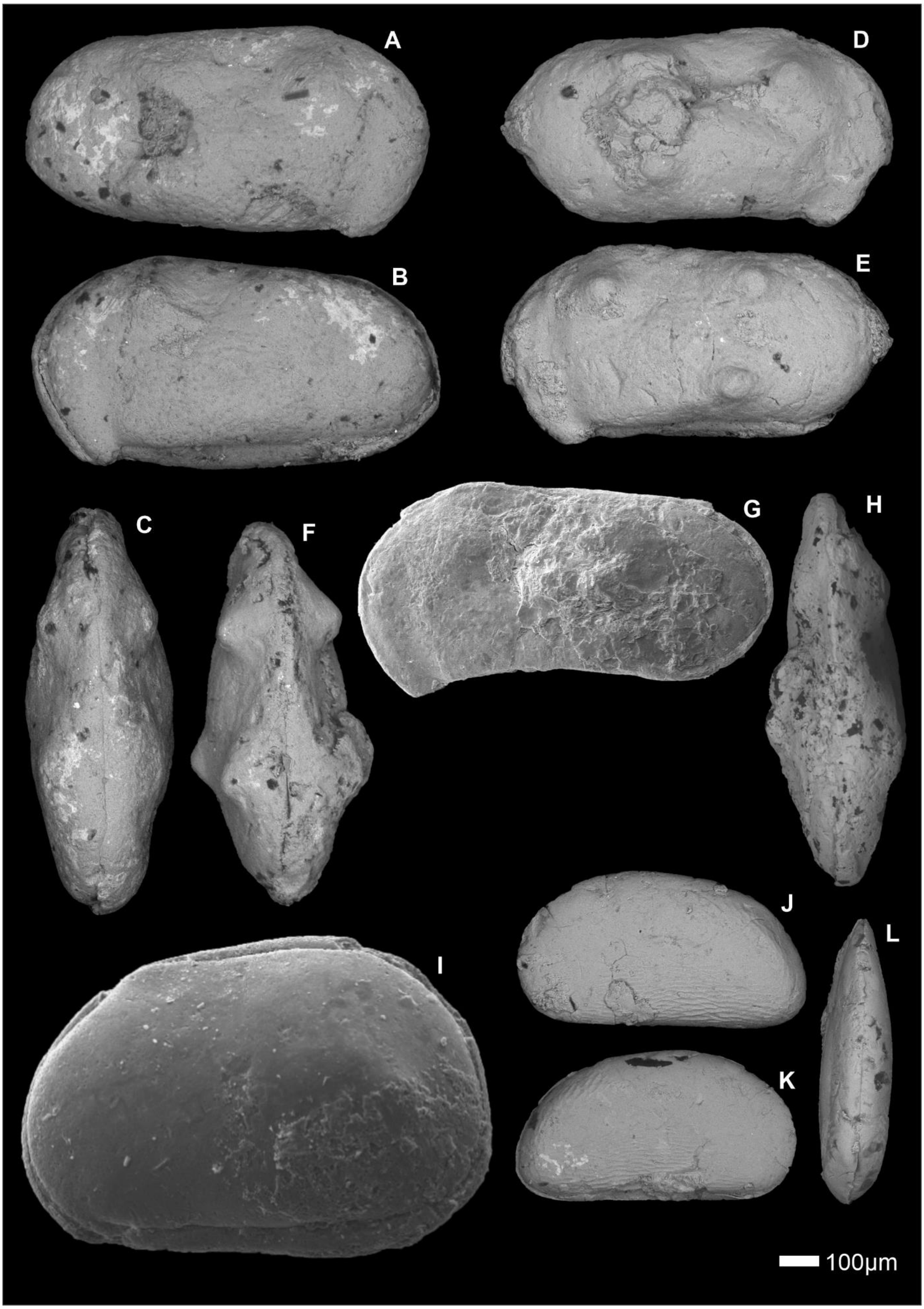
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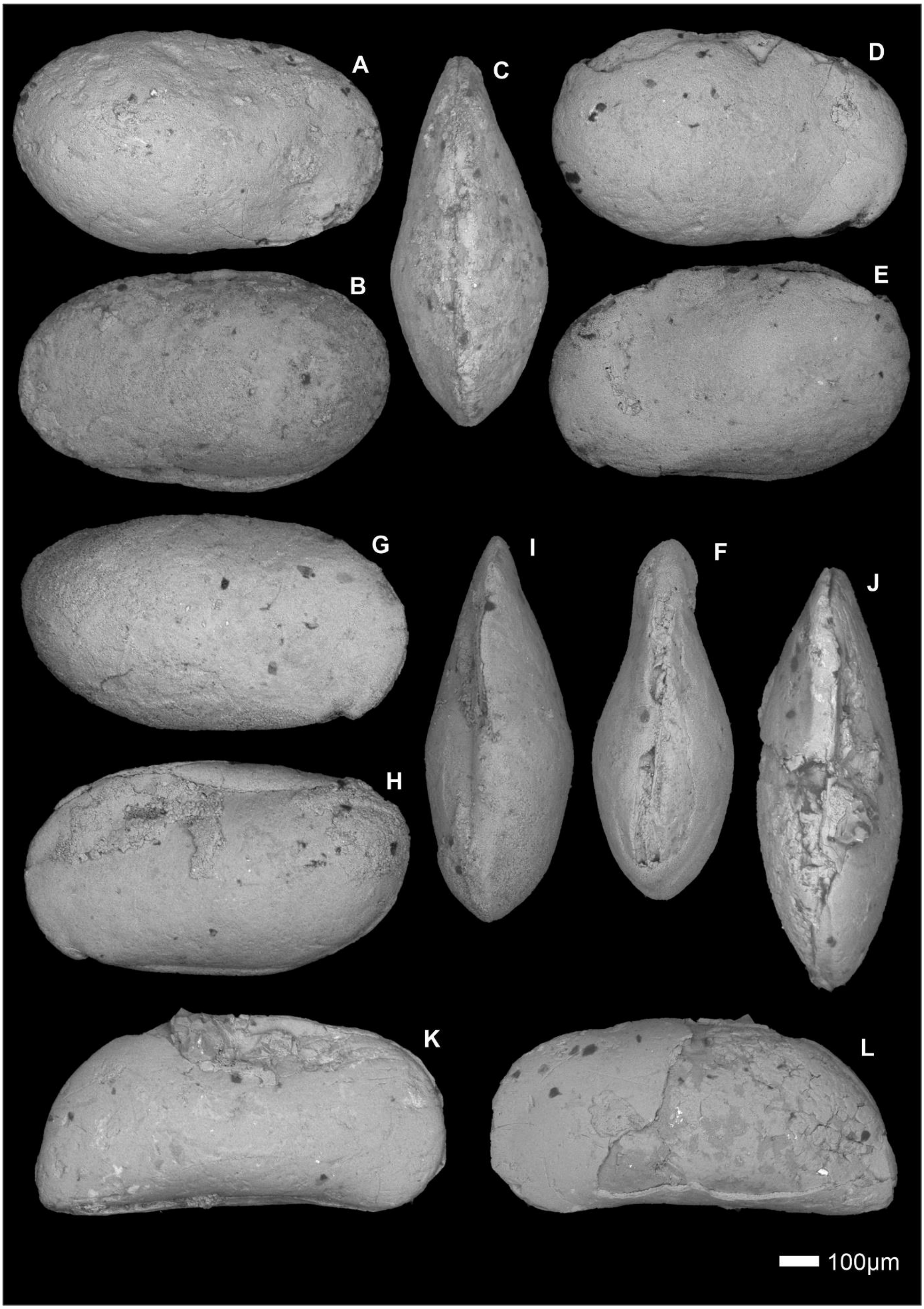
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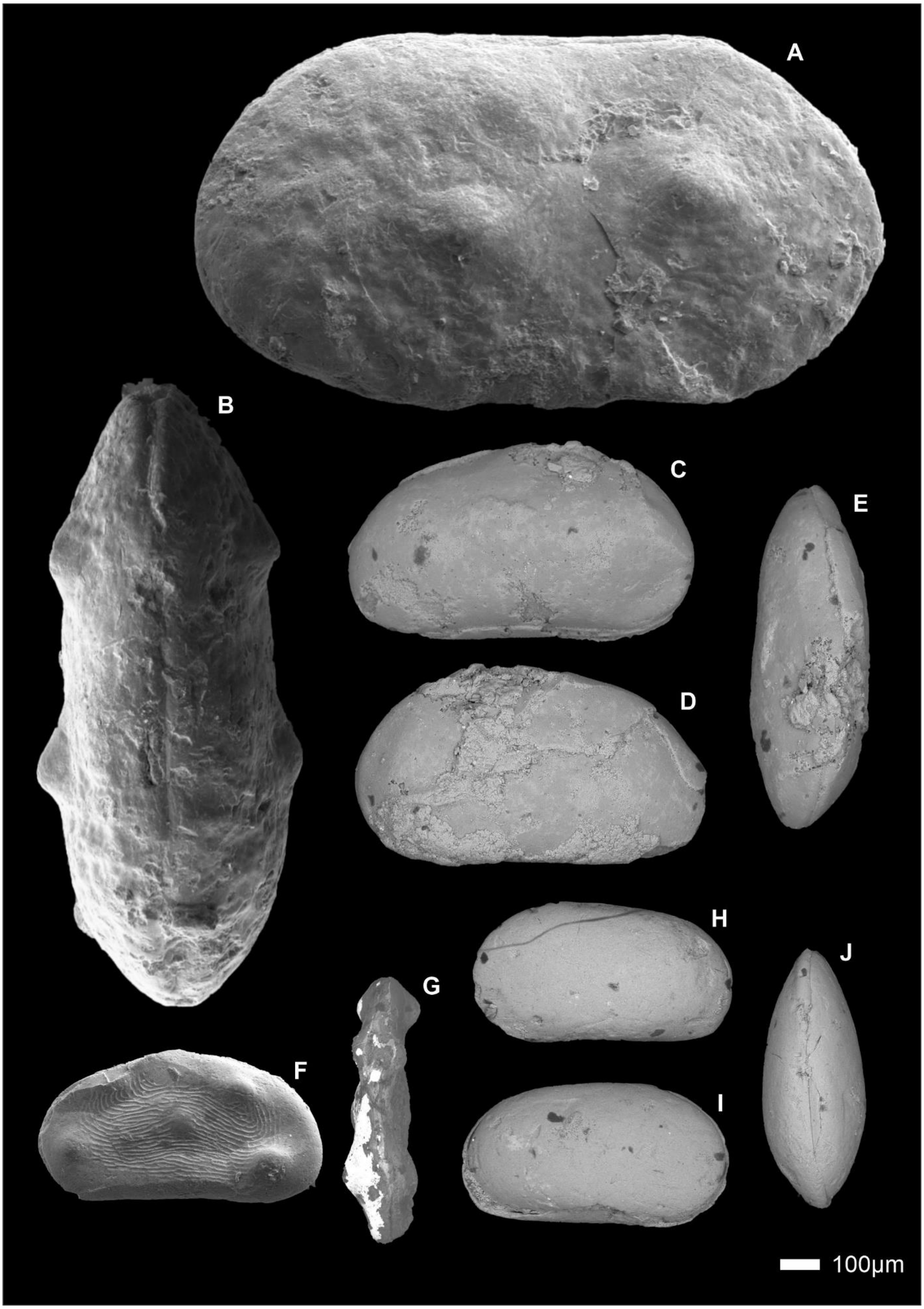
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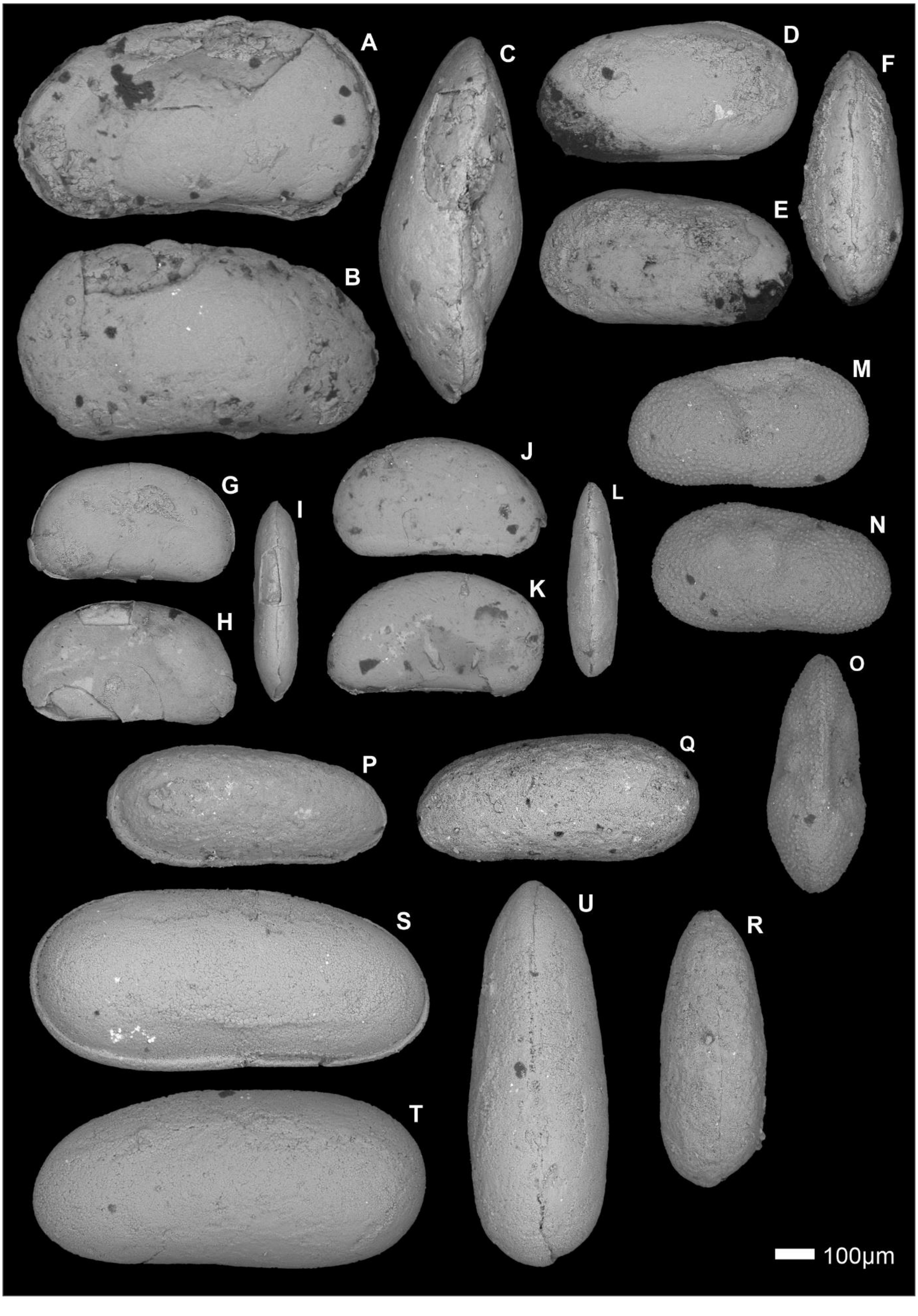
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5 ARTIGO 2 – FRESHWATER OSTRACOD *Theriosynoecum pricei* (PINTO AND SANGUINETTI, 1958): ECOPHYSIOLOGICAL VARIATIONS, TAXONOMIC REVIEW AND PALEOENVIRONMENTAL IMPLICATIONS

Este segundo manuscrito aborda uma revisão da espécie *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958) e a proposta de uma emenda em sua descrição e inclusão de *Theriosynoecum uninodosa* (Pinto and Sanguinetti, 1958) e *Theriosynoecum quadrinodosum* Krömmelbein and Weber, 1971 como seus sinônimos junior.

Este manuscrito foi submetido à revista *Palaeobiodiversity and Palaeoenvironments* e segue seu padrão de formatação.

Freshwater ostracod *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958): ecophysiological variations, taxonomic review and paleoenvironmental implications

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Abstract

The origin of the nodes on ostracod carapaces has been widely discussed in recent decades, and studies have shown that these characters can be produced as an individual response to changes in the environment which the specimens inhabit. Previous experiments with living ostracod species have shown that the variation in water salinity during the ecdysis phase, added to a deficiency in the regulation of internal osmotic pressure may result in the formation of nodes on the new carapace. Based on this knowledge, a reassessment of fossil species may be necessary, especially in those in which the nodes were considered a diagnostic feature. The present work addresses a taxonomic review of the species *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958), which is a marker for the Tithonian in the sedimentary basins of Northeast Brazil, adding an emendation to its description and bringing new information about the development of its nodes as ecophysiological and ecophenotypic response. Geochemical and lithological aspects are discussed, corroborating the paleoenvironmental inferences presented here.

Keywords: Ornamentation; Paleolimnological changes; Nodes; Ostracoda

Introduction

In the last few decades, there have been efforts by researchers to understand the importance and origin of the ornamentation of ostracod carapaces (e.g. Fitz-Gerald 1983; De Deckker and Martens 2013). According to these studies, ornamentation development is based on genetic premises, and environmental and intraspecific variations are becoming increasingly elucidated (Eagar 1999; Neil 2000; Tanaka et al. 2011).

A good example of ornamentation of ostracod carapaces in response to environmental changes are the nodes, hollow protruding structures of intermediate size (larger than tubercles) (Moore 1961; Sames 2011a). The nodes occur outside the isthmus region and internally are observed as cavities in the carapaces, covered by outer epidermal layer that becomes thicker than normal and can completely fill the node cavity, and this thickening sometimes also occurs in the layer of inner epidermis near the region of inner lamella of the carapace (Keyser and Aladin 2004; Keyser 2005). One of the best-known examples regarding the mechanism of formation of this type of ornamentation is the extant species *Cyprideis torosa* (Jones, 1850). Several experimental works using this species corroborate the idea that the nodes result from changes in the chemical composition of water (Van Harten 2000; Keyser and Aladin 2004; Keyser 2005). With increasing knowledge of ecophysiological responses in nodes development, this character became less expressive in ostracod taxonomy (Sames 2011a).

The biostratigraphy of the interior basins of Northeast Brazil was based on the ostracod fauna, with ostracod indicator species defining the local stages (Schaller 1969; Viana et al. 1971; Moura and Praça 1985). In the present study, we investigate the typical Ostracoda association of Tithonian age (Late Jurassic, Dom João local stage) in the Araripe, Jatobá and Tucano Norte basins. A taxonomic review of the species *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958), marker of this stage, was carried out evaluating morphological variations in response to paleoenvironmental changes, leading to the synonymization of *Theriosynoecum uninodosa* (Pinto and Sanguinetti, 1958) and *Theriosynoecum quadrinodosum* Krömmelbein and Weber, 1971.

Geological setting

The studied areas are located in the Araripe, Jatobá and Tucano Norte basins, which represent aborted rift-type interior basins in Northeast Brazil. The sedimentary units of these basins were deposited over the Precambrian Borborema Province, recording expressive geological and paleontological evidences of the Gondwana supercontinent break-up (Asmus and Ponte 1973; Assine 2007; Kuchle and Scherer 2010; Kuchle et al. 2011; Assine et al. 2014). The lithostratigraphic units sampled were the Aliança Formation, from the Tucano Norte and Jatobá basins (Capianga Member), and the correlated Brejo Santo Formation, from the Araripe Basin. These units consist mainly of red and green laminated or massive mudstones, interspersed with sandstones and cross-laminated ostracod grainstones (Caixeta et al. 1994; Assine 2007; Scherer et al. 2014; Guzmán et al. 2015; Fambrini et al. 2019).

The tectono-stratigraphic context of the Araripe, Jatobá and Tucano Norte basins are divided into four sequences: Syneclise, Early Rift, Rift-Climax, and Post-Rift (Kuchle et al. 2011). The Early Rift tectonic stage, composed by Aliança and Sergi formations (Brotas Group, Tucano Norte and Jatobá basins) and the Brejo Santo and Missão Velha formations (Araripe Basin), records sedimentation of fluvial, eolian and lacustrine systems (Kuchle et al. 2011). The first lacustrine cycle, named "Capianga Lake" developed during this phase (Upper Jurassic, Tithonian age), was accommodated in a large endorheic basin, the "Afro-Brazilian Depression" formed from subsidence related to the initial lithospheric stretching. The record of the Afro-Brazilian Depression in the Araripe, Jatobá and Tucano Norte basins corresponds to the Brejo Santo and Aliança formations, subject of the present study (Garcia 1991; Kuchle et al. 2011; Scherer et al. 2014; Guzmán et al. 2015; Souto and Fernandes 2017).

Biostratigraphically, these basins have their frameworks based on the ostracod fauna recovered, the biozones range from RT-001 to RT-011 (Viana et al. 1971; Coimbra et al. 2002; Mendes et al. 2020). The Aliança and Brejo Santo formations are positioned in the RT-001 biozone, determined by the presence of the ostracod index species *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958) (Viana et al. 1971) and assigned to the Dom João local stage (=Tithonian, Upper Jurassic) (Caixeta et al. 1994; Costa et al. 2007; Silva et al. 2007).

Material and methods

Material was collected from to the Araripe Basin near the Missão Velha municipality, Ceará State, to the Jatobá Basin near the Inajá and Ibimirim municipalities, Pernambuco State, and to the Tucano Norte Basin near the Santa Brígida municipality, Bahia State. In total, 74 outcrop samples were analyzed, nine from the Brejo Santo Formation, Araripe Basin, and 65 from the Aliança Formation, Tucano Norte and Jatobá basins (Fig. 2).

The samples were prepared according to the following protocol for calcareous microfossil recovery: (1) weighing approximately 60 g for each sample; (2) mechanical disaggregation of the rock in small fragments; (3) immersion in water and/or H_2O_2 for a period of 24 hours; (4) washing each sample with water in a sieve set of 500, 250, 180 and 62 µm mesh and drying at 50°C. The specimens from fractions 250 and 180 µm were picked out for analysis under stereomicroscope, and some individuals were selected for imaging in a scanning electron microscope (SEM) Phenom XL, at the Applied Micropaleontology Laboratory, Federal University of Pernambuco (*Laboratório de Micropaleontologia Aplicada*, LMA–UFPE).

The taxonomic classification was performed based on the available literature and on morphological comparisons with paratypes from *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958) [MP-O-1B, MP-O-2A, MP-O-2B and MP-O-2C] and *Theriosynoecum uninodosa* (Pinto and Sanguinetti, 1958) [MP-O-4A and MP-O-4B], provided by the Calcareous Microfossils Laboratory, Federal University of Rio Grande do Sul (*Laboratório de Microfósseis Calcários,* LMC–UFRGS). The illustrated specimens were deposited in the micropaleontological collection of the LMA-UFPE under the number LMA-0106 to LMA-0111.

Throughout the text, the following abbreviations were used: RV= right valve; LV= left valve; C= carapace.

Paleontological Systematics

Order Podocopida Müller, 1894

Suborder Podocopina Sars, 1866

Superfamily Cytheroidea Baird, 1850

Family Limnocytheridae Klie, 1938

Subfamily Timiriaseviinae Mandelstam, 1960

Genus *Theriosynoecum* Branson, 1936 emend. Sames, 2011

1935 *Morrisonia* Branson, p. 521

1955 *Theriosynecum* Mandelstam, p. 56 [spelling error]

1958 *Bisulcocypris* Pinto and Sanguinetti, p. 77

1982 *Dryelba* Sohn, p. 313

Type-species: *Morrisonia wyomingensis* Branson, 1935

Remarks: The genus *Theriosynoecum* was first described as *Morrisonia* in Branson (1935). The author subsequently noticed that the genus name was preoccupied by *Morrisonia* Grote, 1874 (Lepidoptera, Hexapoda) and published a short communication with the replacement name *Theriosynoecum* (Branson 1936). According to the original description (Branson 1935), nodes would be characters frequently present in the composition of *Theriosynoecum* carapace ornamentation. However, this morphological feature has been discussed by different authors who point out the presence of these nodes as phenotypic responses induced by environmental changes (Vesper 1975; Van Harten 1996; Do Carmo et al. 1999; Yin et al. 1999; Van Harten 2000; Keyser and Aladin 2004; Keyser 2005; Zhai et al. 2010; De Deckker and Martens 2013). We follow the view of the authors who bring the arguments that for the genus *Theriosynoecum*, the ornamentation pattern, the bipartite hinge element and the accommodation groove of the hinge do not represent taxonomically relevant characters on the genus level and thus do not justify the erection of the genus *Bisulcocypris* Pinto and Sanguinetti, 1958 and *Dryelba* Sohn, 1982 classifying them as junior synonyms of *Theriosynoecum* (Colin and Danielopol 1978; Colin and Danielopol 1980; Colin and Dépêche 1997; Do Carmo et al. 2004).

Theriosynoecum pricei (Pinto and Sanguinetti, 1958) emend.

(Fig. 3)

1958 *Bisulcocypris pricei* Pinto and Sanguinetti, p. 78, pl. I, figs. 19–24; pl. II, figs. 1–7; pl. III, figs. 1–5

1958 *Bisulcocypris uninodosa* Pinto and Sanguinetti, p. 80, pl. II, figs. 8–13; pl. III, figs. 6–8

1971 *Theriosynoecum quadrinodosum* Krömmelbein and Weber, p. 62, pl. 12, figs. 54–56

2011 *Bisulcocypris pricei* Pinto and Sanguinetti - Barros et al., p. 112, pl. I, fig. 1.

2016 *Theriosynoecum pricei* (Pinto and Sanguinetti) - Guzmán et al., p. 18, pl. 4, figs. A–D.

2016 *Theriosynoecum uninodosa* (Pinto and Sanguinetti) - Guzmán et al., p. 18, pl. 4, figs. E–G.

2016 *Theriosynoecum quadrinodosum* Krömmelbein and Weber - Guzmán et al., p. 19, pl. 4, figs. H–I.

2017 *Theriosynoecum pricei* (Pinto and Sanguinetti) - Melo and Carvalho, p. 71, pl. 11, figs. D–F.

2017 *Theriosynoecum uninodosa* (Pinto and Sanguinetti) - Melo and Carvalho, p. 71, pl. 11, figs. J–L.

2017 *Theriosynoecum quadrinodosum* Krömmelbein and Weber - Melo and Carvalho, p. 71, pl. 11, figs. G–I.

Material: More than ten thousand specimens were recovered including adults and juveniles, comprising complete carapaces and disarticulated valves, many with cup-in-cup preservation.

Repository: Collection of *Laboratório de Micropaleontologia Aplicada* (LMA) [Applied Micropaleontology Laboratory], Federal University of Pernambuco (UFPE).

Material and measurements: LMA-0106, L: 863 µm, H: 530 µm, W: 552 µm (Fig. 3: A, D); LMA-0107, L: 761 µm, H: 424 µm, W: 330 µm (Fig. 3: B–C); LMA-0108, L: 727 µm, H: 424 µm, W: 361 µm (Fig. 3: G–H); LMA-0109, L: 727 µm, H:413 µm, W: 344 µm (Fig. 3: E–F); LMA-0110, L: 729 µm, H: 402 µm, W: 321 µm (Fig. 3: I–J); LMA-0111, L: 735 µm, H: 405 µm, W: 432 µm (Fig. 3: K–M).

Original diagnosis: Carapace rhomboid in lateral outline, it is slightly higher in the posterior part. Dorsal and ventral margin straight and almost parallel. Laterally showing a strong development of some ventral ridges of the reticulum, forming a process like an ala in the posterior ventral part. Right valve larger than the left.

Emended diagnosis: Dorsal margin almost straight, sometimes showing slight depressions in the sulci region, commonly in ♀, on which the posterior third shows a convex dorsal outline associated with the development of the inflated morphology of the brood pouches; ventral margin almost straight to slightly convex, ♀ shows a convex posteroventral outline due to the brood pouches prominent; anterior margin asymmetrically rounded, somewhat oblique in its upper portion; LV slightly overlaps RV in anterior and posterior regions; noded or unnoded, when present the nodes can vary from one to four in the posterior region of valves.

Emended description: Marked sexual dimorphism; in dorsal view ♂ ellipsoid and ♀ piriform. Greater width in the posterior third, more conspicuous in ♀; greater length at mid-height; greater height at the middle in ♂ and at the posteromedian region in ♀. Dorsal margin almost straight, sometimes showing slight depressions in the sulci region, commonly in ♀, on which the posterior third shows a convex dorsal outline associated with the development of the inflated morphology of the brood pouches; ventral margin almost straight to slightly convex, ♀ shows a convex posteroventral outline due to the prominent brood pouches; the anterior margin asymmetrically rounded, somewhat oblique in its upper portion, the posterior margin is rounded and in ♀ more convex than ♂ (brood pouches). Obtuse cardinal angles, the posterior is more rounded than the anterior. Presence of two sulci: one in the anterodorsal region and the second being larger and located near the mid-length, both pointing to the anterior region of the carapace. LV slightly overlaps RV in the anterior and posterior regions, the overlap is mainly visualized in the posterodorsal and anterodorsal position where the cardinal angles are situated, ventrally no valve overlap is observed. Surface almost completely covered by punctuated ornamentation which might present deep and wide puncta that resemble reticulations, however, in the ventrolateral and ventral regions the puncta are more elongated forming subparallel rows. The carapace may have ecophysiologically induced nodes as additional ornamentation; when present, they are found in the posterior region of the carapace and can vary from 1 to 4, respectively, with the first appearing in the upper portion of the posterocentral region, the second in the posteroventral, the third in the ventromedian position, the fourth in the posterodorsal near the cardinal angle, and the order of occurrence for these nodes seems to be invariable, following the one presented here.

Remarks: *Theriosynoecum uninodosa* (Pinto and Sanguinetti, 1958) and *Theriosynoecum quadrinodosum* Krömmelbein and Weber, 1971 are here considered junior synonyms of *Theriosynoecum pricei*. These species were described from the correlated strata and are associated to *T. pricei*, not occurring in any other stratigraphical position. In the original diagnosis of *T. uninodosa* and *T. quadrinodosum*, the character that significantly distinguishes these two species is the number of nodes. This character is not appropriate to distinguish species because the formation process of the nodes is associated to environmental parameters.

Pinto and Sanguinetti (1958) described in the original diagnosis a reversion of the valves' symmetry (RV overlapping LV) in *T. pricei*, but when observing the images of the holotype and paratype material of this species, the preservation of specimens does not allow a clear identification of this character. The type and quality of preservation of microfossils directly influences the parsimonious identification and description of taxa and this is what may have caused a doubtful interpretation of valve overlapping of this species. All other characters (e.g., lateral outline, dimensions, sexual dimorphism) have similar descriptions among the three species, and the morphological variations are often a matter of interpretation or too small and too individual to be species-specific (Fig. 4).

In the original descriptions of the material studied here the authors compared and discussed their taxa with other species of *Theriosynoecum*. Pinto and Sanguinetti (1958) compared their new species *T. pricei* with *Theriosynoecum striata* (Martin, 1940) and argued in favor of rejecting the possibility that they are the same species because *T. striata* has thin lateral ridges that form a prominent appendage like an ala and the males of *T. pricei* are narrower when observed in dorsal view (see Pinto and Sanguinetti 1962, p. 116 and 148). Krömmelbein and Weber (1971), when describing *T. quadrinodosum*, have compared it with *Theriosynoecum roberti* (Marlière, 1948) and argued that it was not the same species since *T. roberti* has thorns on the anterior and posterior regions.

Results and Discussion

Theriosynoecum Branson, 1936 is a very abundant taxon in the samples of the three studied basins, Araripe, Tucano Norte and Jatobá. Associated to *Theriosynoecum*, the genera *Alicenula* Rossetti and Martens, 1998 and *Reconcavona* Krömmelbein, 1962 occurred, the latter only recovered from Tucano Norte and Jatobá basins material. This faunal association is typical of the local Dom João Stage, that allows the recognition of Tithonian age units in both the interior and the marginal sedimentary basins of Brazil (Barros et al. 2011; Guzmán et al. 2016; Melo and Carvalho 2017).

All specimens of the genus *Theriosynoecum* obtained from our studied samples were identified as *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958), according to our emended diagnoses of this species, previously detailed. The most common morphotype, found in all locations, was as described by Pinto and Sanguinetti (1958). However, individuals with variation in carapace ornamentation, like the presence of different quantities of nodes and in different positions, were recovered, except for three localities in the Jatobá Basin near the Municipality of Inajá (sample BJ-MG-10) and near the village of Campos in the Municipality of Ibimirim (section BJ-01 and BJ-08) where just specimens without nodes were found (Fig. 1). In the Araripe Basin, five morphotypes were abundantly registered in the assemblage. In this basin, the morphotypes of *T. pricei* varied between total absence and presence of up to four nodes in the posterior portion of the valves surface. The occurrence of specimens with nodes was also abundant for one locality near Ibimirim municipality (section BJ-06), in the Jatobá Basin, where we recovered individuals with one, three and four nodes. The presence of this ornamentation was extremely rare for the Tucano Norte Basin, with only two specimens showing three nodes and one specimen with four nodes in our samples.

The formation of nodes on the carapace was studied in *Cyprideis torosa* (Jones, 1850) by many authors (e.g. Van Harten 1996, 2000; Keyser and Aladin 2004; Keyser 2005), where the presence of these structures was evaluated and discussed as related to changes in salinity in the aqueous environment which the individuals of this species inhabited. The salinity fluctuation acted as an alteration factor in the osmoregulation of *C. torosa* individuals, causing the cell-to-cell connections that stabilize the inner and outer epidermis layers to break, causing a thickening of the outer epidermis during the ecdysis process, where strong internal forces would be acting in order to inflate the newly formed carapace, which is flexible and enables the development of these nodes after the rupture of these stabilizing connection structures (Keyser and Aladin 2004; Keyser 2005). From this knowledge, it is inferred in this study that the polymorphism present among *T. pricei* populations would be associated with ecophysiological changes triggered by environmental factors.

Studies concerning the appearance of nodes in fossil ostracods linked to some kind of paleoenvironmental issue have been done before. Guzzo and Coimbra (1989) presented a polymorphism in individuals of the subspecies *Paracypridea elegans elegans* Krömmelbein, 1962 recovered in the Potiguar Basin, Northeast Brazil, where they contained morphotypes with smooth carapace (like those described in the type series by Krömmelbein), and morphotypes with presence of one, two, or three nodes. In their conclusions, Guzzo and Coimbra (1989) found similarity between the nodes in *Paracypridea elegans elegans* and those present in living species developed from environmental induction. In the same way, in the material under study of the species *T*. *pricei*, the nodes are never present only on the left valve, there is an order in the appearance of the nodes and the location and maximum number of nodes is constant, but their development and expression are variable inside populations. For the species *Theriosynoecum kirtlingtonense* Bate, 1965 assessments of pore canals present in nodes were conducted, concluding that these structures would form at higher paleoenvironmental salinities (Do Carmo et al. 1999). The relationship between pore canal morphology and salinity variation has been frequently investigated (Bodergat et al. 2014), however, this estimation cannot be applied to our populations due to the poor preservation of this character.

The pattern of populations between noded and unnoded specimens was described for *C. torosa* by Van Harten (2000), who observed the possibility that in natural environment populations can occur formed only by unnoded specimens or populations composed of ostracods with and without nodes, however, it would not be possible to find assemblages presenting only noded specimens. This author describes that even in environments that induce nodulation, which for the species *C*. *torosa* is low salinity, this structure would not necessarily be produced by all individuals, and some individuals with smooth carapaces could still be found. Van

Harten (2000) explained from his previous proposed hypothesis (Van Harten 1996), that in order to develop nodes it would require energy, so probably a lack of energy would be restricting the production of nodes in organisms of *C*. *torosa* in low salinity environments. The pattern of the populations studied here follows the pattern described by Van Harten (2000), with assemblages composed exclusively by *T*. *pricei* with unnoded carapaces or formed by noded and unnoded individuals of this species. From the comparison of the aforementioned works, we infer that this morphological variation for the nodes in *T. pricei* is intraspecific and the inducer for the formation of this character would be external (linked to the mechanism of osmoregulation).

In addition to osmotic pressure regulation being a factor in node formation for *C. torosa* as described above, a low Ca concentration would also facilitate this process (a so called control factor "X" in Van Harten 2000) according to Keyser (2005). Ca ions are important for muscle activities, acting in the configuration of the bonding molecule between actin and myosin filaments. Similarly, Ca works in the configuration of other molecules that perform functions integrated to the desmosomes in cell membranes such as desmocolin, essential for the good performance of these cell-to-cell connections present between the inner and outer epidermal layers (Keyser, 2005). Thus, with a low concentration of calcium in the environment and, consequently, in the body fluid during the ecdysis process, the cell-to-cell connections become less flexible and break up more easily (Keyser 2005). Subsequently, De Deckker and Lord (2017) argued that this issue needs to be further studied, including analyses of hemolymph composition, to determine whether calcium would indeed be involved as a controlling factor.

Based on previous knowledge and applying the data obtained in *C. torosa*, we support the inference that the formation of nodes in ostracods of the species *T*. *pricei* would be formed as ecophysiological responses to paleoenvironmental changes in the Araripe, Tucano Norte, and Jatobá basins. The Aliança Formation of the Recôncavo, Tucano and Jatobá basins, and the Brejo Santo Formation of the Araripe Basin and correlated strata in other basins, are lacustrine deposits which belong to the system “Capianga Lake”, formed during the early Gondwana rift process (Kuchle et al. 2011). This palaeolake would have a decrease or increase in its water surface related to climatic and tectonic factors, which would result in the expansion/contraction of this water body (Cabaleri et al. 2005; Barros et al. 2011; Fambrini et al. 2013; Souto and Fernandes 2017).

Recently, Guzmán et al. (2020) published an isotope geochemical study carried out including unnoded *T. pricei* carapaces in outcrop sections near the municipality of Ibimirim, in the same locations included in this work. Data from the Puiú (BJ-01 with occurrence of a 2 cm-thick gypsum layer) and Macambira (BJ-08) sections show positive covariance between oxygen and carbon isotopes (r = 0.94 and 0.98) and $\delta^{18}O_{T.\ pricei}$ varies between -6.23 and +3.03 %. In the Modubim section (BJ-06) data display less significant covariance (r = 0.70) and a broader $\delta^{18}O_{T.\ pricei}$ variation, with values ranging between -10.1 and +4.09 %. According to Talbot (1990), co-variation between $\delta^{18}O_{carbonate}$ and $\delta^{13}C_{carbonate}$ with r ≥ 0.7, is probably a consequence of changes in closed-hydrologic basins that result from shifts in climate and environmental conditions, which in turn, lead to dilution/concentration of solutes and changes in the stable isotope values of the lake water. Negative $\delta^{18}O$ values indicate more humid conditions during the rainy season, whereas slightly positive $\delta^{18}O$ values indicate lower freshwater recharge during the dry season (Leng et al. 2005). The moderate to strong covariation between $\delta^{18}O$ and $\delta^{13}C$ of *T. pricei* carapaces accompanied by large shifts in $\delta^{18}O$ (> 10 %) from the localities near the Ibimirim municipality in the Jatobá Basin, can be attributed to changing precipitation/evaporation ratios in a closed-basin hydrology (Guzmán et al. 2020). Thus, the local salinity conditions of the Capianga Lake water in the area of Jatobá Basin, should had been very variable. The Modubim section displays a stratigraphic distribution of different *T. pricei* morphotypes, where the most negative $\delta^{18}O_{T.\ pricei}$ values, interpreted as freshwater inputs (Guzmán et al. 2020), occur in the unique stratus containing four nodes-bearing *T. pricei* (previously identified as *T. quadrinodosum* in Guzmán et al. (2020)).The formation of nodes for this species would be linked to environments with greater freshwater supply, following the detailed model described for *Cyprideis torosa* (Van Harten 1996, 2000; Keyser and Aladin 2004; Keyser 2005).

Current representatives of the ostracods of the family Limnocytheridae have been analyzed in more recent works and authors have pointed to parameters such as sedimentation rate and depth of the water body as nodulation inducers, in addition to water salinity and alkalinity (Zhai et al. 2010; McCormack et al. 2019), further expanding knowledge regarding these complex mechanisms of node development and contributing to future paleoenvironmental interpretations.

Conclusions

From the present work, the species previously described as *Theriosynoecum uninodosa* and *Theriosynoecum quadrinodosum* were synonymized with *Theriosynoecum pricei*, which now has five morphotypes:

Morphotype 1 – Carapace without apparent nodes.

Morphotype 2 – With a node present in the upper portion of the posterocentral region.

Morphotype 3 – Two nodes, the first described for morphotype 2 plus one developed in the posteroventral region.

Morphotype 4 – Three nodes, two that are present in the previous morphotypes and the third in the ventromedian region.

Morphotype 5 – Combines the nodes of the three previous morphotypes plus the fourth node appearing in the posterodorsal position.

This taxonomic revision was possible from inferences regarding different factors that may indicate that nodes are induced by ecological factors, demonstrated by experiments performed on living species.

Regarding the lithological record of the studied locations, like the presence or absence of evaporitc rocks, and the isotopic geochemistry data obtained from some outcrops of the Jatobá Basin, it suggests that the origin of the nodes in the *T. pricei* carapaces could be attributed to a decrease in salinity in the aquatic environment. Further studies about fossil ostracod nodulation could improve the knowledge of this feature and will provide more detailed taxonomy and paleoecological interpretations for this important group.

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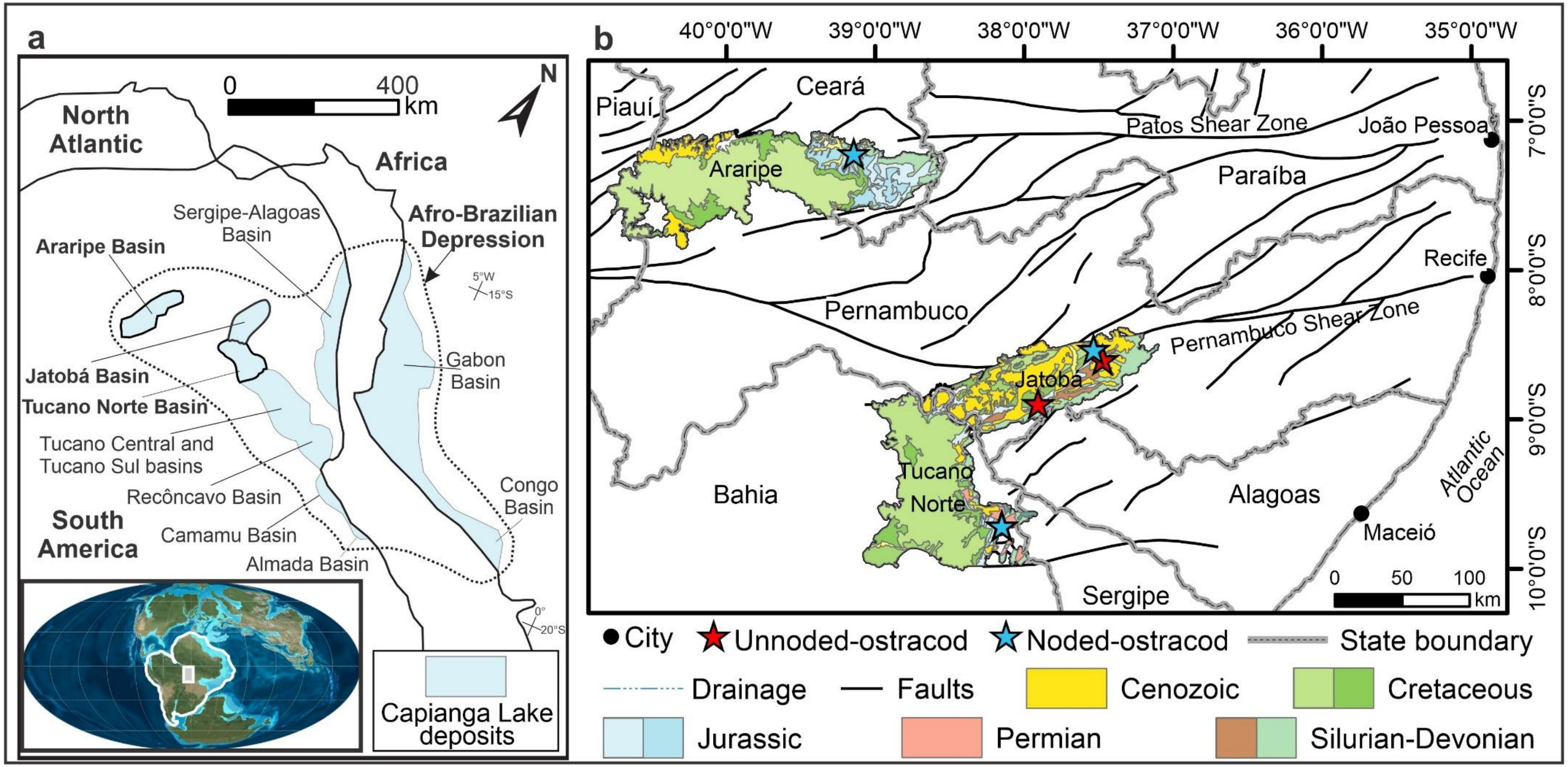
Figure captions

Figure 1 – a- Paleogeographic map of the Afro-Brazilian Depression highlighting the Araripe, Jatobá and Tucano Norte basins, modified from Silva et al. (2012). b- Geological map of the studied basins and geographical position of the collected samples, indicating in blue the outcrops that presented polymorphism for *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958) and in red the outcrops composed by unnoded individuals.

Figure 2 – Photographs of the studied outcrops. a–c Photomosaic and views of the outcrops collected in the Tucano Norte Basin (a: 2BTN07 S9°44’9.92”/W38°8’33.23”; b–c: 2BTN08 S9°44’11.44”/W38°8’43.20”). d- View of the outcrop collected in the Araripe Basin (2BAr01 S7°14’18.94”/W39°8’23.58”). e–g Views and photomosaic of the outcrops collected in the Jatobá Basin (e: MG-10 S8°54’35.03”/W37°53’38.49”; f: BJ-06 Modubim S8°32’10.82”/W37°31’50,35”; g: BJ-08 Macambira S8°32’56.28”/W37°31’41,19”; h: BJ-01 Puiú S8°37’6.16”/W37°28’4.27”).

Figure 3 – *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958) specimens recovered in the present study. LMA-0106: a- Dorsal view, d- Right view; Unnoded female. LMA-0107: b- Dorsal view, c- Right view; Unnoded male. LMA-0109: e- Dorsal view, f- Right view; Male with two nodes. LMA-0108: g- Dorsal view, h- Right view; Male with one node. LMA-0110: i- Dorsal view, j- Right view; Male with three nodes. LMA-0111: k- Dorsal view, l- Right view, m- Ventral view; Male with four nodes.

Figure 4 – Comparative chart with the morphological characters based on the original descriptions of (a) *Theriosynoecum pricei* (Pinto and Sanguinetti, 1958), (b) *Theriosynoecum uninodosa* (Pinto and Sanguinetti, 1958) and (c) *Theriosynoecum quadrinodosum* (Krömmelbein and Weber, 1971).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km
N
North Atlantic
Africa
Sergipe-Alagoas Basin
Afro-Brazilian Depression
Araripe Basin
5°W
15°S
Gabon Basin
Jatobá Basin
Tucano Norte Basin
Tucano Central and Tucano Sul basins
Recôncavo Basin
South America
Camamu Basin
Almada Basin
Congo Basin
0°
20°S
Capianga Lake deposits
b
40°0'0"W
39°0'0"W
38°0'0"W
37°0'0"W
36°0'0"W
35°0'0"W
7°0'0"S
8°0'0"S
9°0'0"S
10°0'0"S
Piauí
Ceará
Patos Shear Zone
João Pessoa
Araripe
Paraíba
Recife
Pernambuco
Pernambuco Shear Zone
Jatoba
Tucano Norte
Bahia
Alagoas
Atlantic Ocean
Maceió
Sergipe
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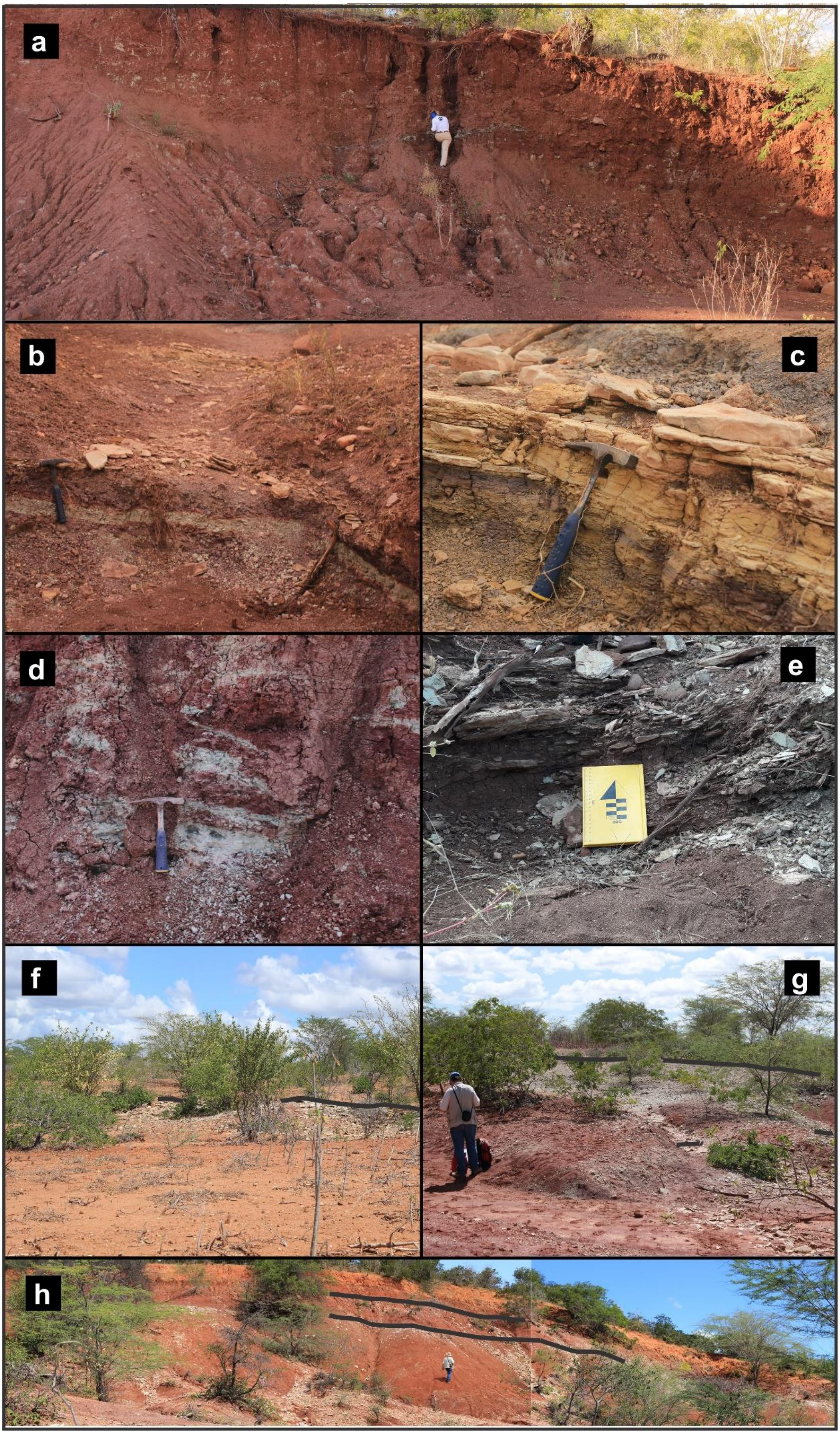
50
100
km
● City
Unnoded-ostracod
Noded-ostracod
State boundary
Drainage
Faults
Cenozoic
Cretaceous
Jurassic
Permian
Silurian-Devonian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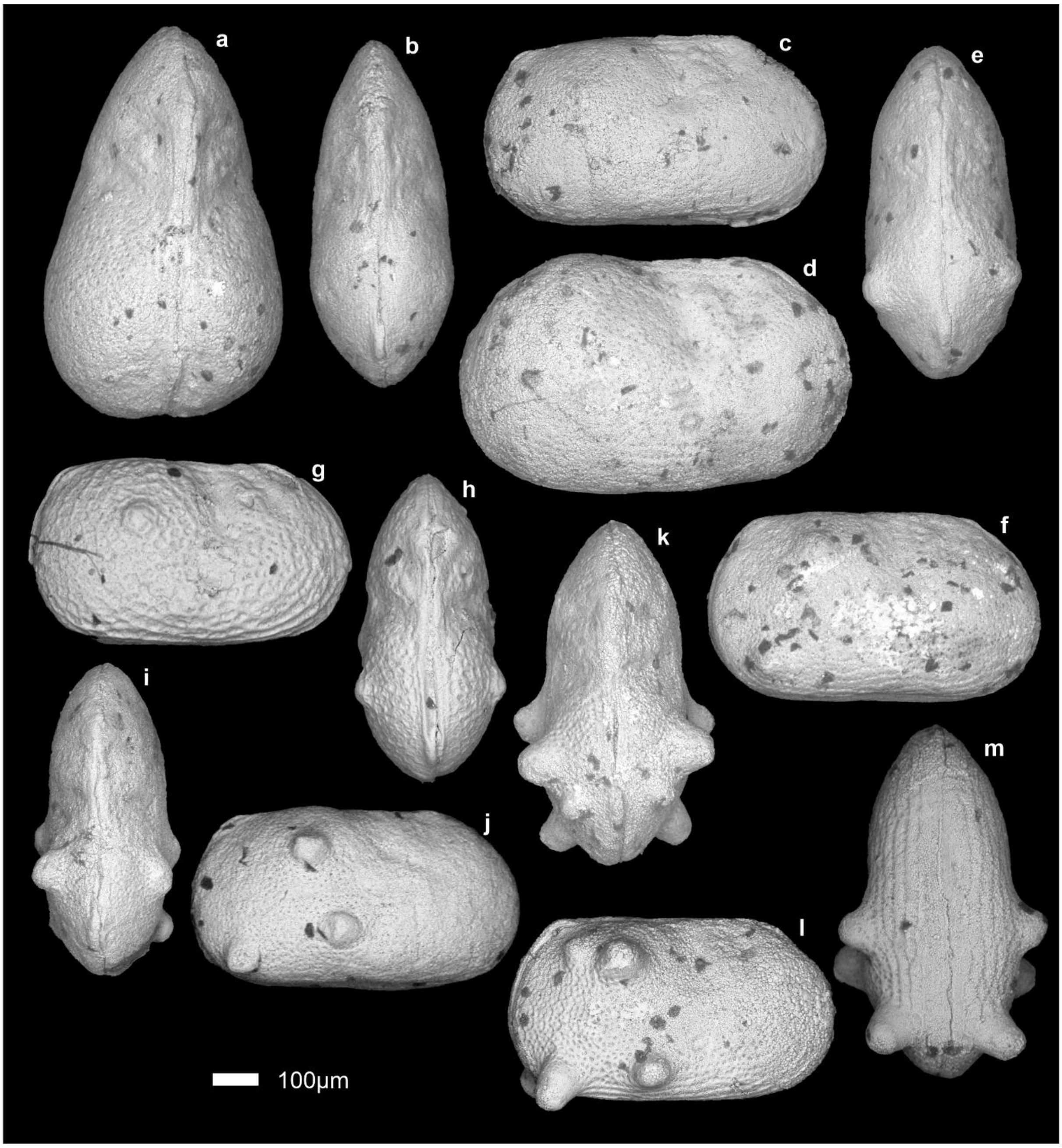
a
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100μm

	(a) *Theriosynoecum pricei*	**(b)** *Theriosynoecum uninodosa*	**(c)** *Theriosynoecum quadrinodosum*
Material preservation	Valves and carapace molds	Valves and carapace molds	Carapaces
Lateral outline	Rhomboid	Subquadrangular	Rounded-rhomboid
Dorsal and ventral margins	Dorsal and ventral margin straight and almost parallel. In the male, showing a little elevation in the anterior cardinal angle.	Dorsal margin almost straight, showing some slight depressions in the place of sulci. Ventral margin slightly convex and parallel to the dorsal margin.	Dorsal margin is almost straight with an elevation in the higher part of the carapace at the posterior third. Ventral margin nearly straight to slightly convex.
Anterior and posterior margins	Anterior margin is straight going downward and forward until almost the midlength where it becomes unequally rounded and grades into the ventral margin. The posterior margin is rounded grading into the ventral surface and meeting the dorsal margin with an obtuse angle at the posterior end of the hinge	Similar to the posterior margin, the anterior margin is also rounded but it is slightly flattened and forms a broad angle with the dorsal margin.	Anterior margin rounded to flattened from ventral margin to anterior cardinal angle, posterior margin broadly curved.
Cardinal angles	The anterior cardinal angle is very obtuse; the posterior cardinal angle is prominent but much less obtuse than the anterior	The antero cardinal angle it forms with the anterior margin an obtuse and sharp angle; at the postero-cardinal angle the carapace is subrounded.	Anterior cardinal angle is obtuse but less than the posterior one.
Ornamentation	Just anterior to midlength two prominent sulci indent deeply each valve. The posterior one extends downward until the midlength or slightly lower, the anterior is not so long. Surface of valves covered with very small and inconspicuous pits, which form a reticulate network that in the ventral portion has the longitudinal ridges more prominent forming a process like a keel.	Two shallow sulci occur in the anterior portion, the posterior is slightly larger than the anterior. The surface ornamentation consists of a meshwork of strong polygonal pits, which become elongated into parallel riblets along the ventral margin.	Two sulci indent just in front of midlength in each valve, the posterior sulcus is slightly larger and deeper than the anterior one. Surface reticulated with irregular fine to médium pits, following ventral margin the reticule is more elongated and forms three routes.
Overlapping valve	Right valve larger than the left and overlaps the left strongly in the anterior and posterior cardinal angles.	The left valve is slightly larger than the right.	No information in description
Sexual dimorphism	Female carapace differs from the male in lateral view to have a more rounded anterior end. The posterior end is more flattened: posterior part is higher. Dorsal margin strongly concave in the anterior portion at the sulci.	Female seen from dorsal the outline is triangular rounded, it is flattened posterior and acuminate in anterior and having just anteriorly to the midlength a concavity at each side, corresponding to the posterior sulcus. Maximum width is in the third posterior quarter. The left valve is slightly larger than the right. The sulci are not deeply impressed.	Females are higher and wider than males.
Dimensions	**Adult female** length: 0,77 mm height: 0,45 mm width: 0,40 mm **Adult male** length: 0,78 mm height: 0,41 mm width: 0,32 mm	**Adult female** length: 0,77 mm height: 0,45 mm width: 0,40 mm **Adult male** length: 0,78 mm height: 0,41 mm width: 0,32 mm	**Adult female** length: 0,70 mm height: 0,40 mm width: 0,37 mm **Adult male** length: 0,71 mm height: 0,41 mm width: 0,31 mm
Nodules	No nodules	It presents typically one node (like a spur) in the posterocentral portion.	In posterior region, four elongated and rounded nodes are present in each valve. One node located in posteroventral position, two in posterodorsal position at midlength and below the posterior cardinal angle, and the fourth is in midventral position.

6 ARTIGO 3 – DESCRIPTION AND ONTOGENY OF *Pattersoncypris minima* sp. nov. (CRUSTACEA: OSTRACODA), ARARIPE BASIN, NORTHEAST BRAZIL

Este artigo apresenta a descrição da espécie *Pattersoncypris minima* Almeida-Lima & Piovesan sp. nov., bem como de sua série ontogenética completa. O trabalho contribui no conhecimento a respeito da riqueza taxonômica deste gênero, que é extremamente abundante nas seções Pós-Rifte das bacias interiores do nordeste brasileiro, e aborda questões tafonômicas a respeito da assembleia recuperada, proveniente de amostras da Formação Romualdo, Bacia do Araripe, Ceará.

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DESCRIPTION AND ONTOGENY OF *Pattersoncypris minima* sp. nov. (CRUSTACEA: OSTRACODA), ARARIPE BASIN, NORTHEAST BRAZIL

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Abstract

Representatives of the Class Ostracoda are widely applied in paleoecological and biostratigraphical studies in all continents. In the Araripe Basin, located in the northeastern of Brazil, the Romualdo Formation is one of the most studied, not only for the preservation but also for the abundance of its fossils. The genus *Pattersoncypris* Bate, 1972 is well-represented in this formation and it is the most abundant, which reinforces the importance of its taxonomic study. In this work, *Pattersoncypris minima* **sp. nov.** is described for the Romualdo Formation as a contribution to the knowledge on Brazilian Cretaceous non-marine ostracods. Taphonomic aspects are also presented, considering the complete ontogenetic stages of the material.

Keywords: Taxonomy, ostracod, taphonomy, Cretaceous, ontogenetic development

Introduction

Important aspects such as the fossilization potential, expressive occurrence and high diversity characterize ostracods as an excellent tool for paleoenvironmental studies and chronostratigraphic calibration (Sames & Horne, 2012; Rodriguez-Lázaro & Ruiz-Muñoz, 2012). In Brazil, research on Cretaceous non-marine ostracods has been carried out since the nineteenth century (Jones, 1860), especially due to its application in biostratigraphic frameworks of the interior basins of the Northeast region (e.g. Pinto & Sanguinetti, 1958; Wicher, 1959; Krömmelbein, 1962, 1966; Schaller, 1969; Krömmelbein & Weber, 1971; Moura, 1972; Bate, 1972, 1973; Coimbra et al., 2002; Poropat & Colin, 2012a). Among these basins, the Araripe Basin, especially Crato and Romualdo formations, stand out due to the abundance and quality of their fossils, and are therefore considered as a Konservat Lagerstätte Fossil (Maisey, 1991).

For Romualdo Formation, the genera of ostracods commonly reported in the literature are *Cypridea* Bosquet, 1852, *Darwinula* Brady & Robertson, 1885, *Ilyocypris* Brady & Norman, 1889, *Paracypria* Sars, 1910, *Theriosynoecum* Branson, 1936, *Damonella* Anderson, 1966 and *Pattersoncypris* Bate, 1972 (Coimbra et al., 2002; Tomé et al., 2014). *Pattersoncypris* is one of the most frequent genera in the Araripe Basin post-rift sequence (Antonietto et al., 2012; Souza et al., 2017). The genus is also recorded in several northeastern and eastern basins, including Tucano Norte Basin (Almeida-Filho et al., 2002), Sanfranciscana Basin (Do Carmo et al., 2004), Grajaú Basin (Ramos et al., 2006), Cedro Basin (Tomé & Lima-Filho, 2010), Santos and Espírito Santo basins (Piovesan et al., 2013), Sergipe-Alagoas Basin

(Antonietto et al., 2016), Jatobá Basin (Nascimento et al., 2017) and Potiguar Basin (Do Carmo et al., 2018).

Ontogenetic studies in *Pattersoncypris* species have shown that the initial instars can be very similar in morphology, which hinders their specific differentiation when there are no studies showing the ontogenetic development (Bate, 1972; Antonietto et al., 2012; Do Carmo et al., 2013). Its abundance in the samples demonstrate the importance of this genus in the Cretaceous, especially in the Aptian–Albian interval. In the present work, a new species of *Pattersoncypris* from the Romualdo Formation is proposed with its complete ontogenetic stages, and taphonomic inferences are discussed.

Material and Methods

The analyzed sample was collected from *Geossítio Parque dos Pterossauros* [Geosite Pterossauros Park], located in the Araripe Basin, Santana do Cariri Municipality, Ceará State, Northeast Brazil (Fig. 1). The Araripe Basin covers more than 9000 km^2 in the states of Ceará, Pernambuco and Piauí and is one of the most important intracratonic basins in northeastern Brazil. The origin of this basin is related to the Gondwana break-up and the opening of the South Atlantic Ocean, during the Late Jurassic and Early Cretaceous (Assine, 2007; Scherer et al., 2015).

The material here studied is part of the post-rift mega-sequence of the Araripe Basin, which corresponds stratigraphically to the Santana Group, represented, from bottom to top, by the Barbalha, Crato, Ipubi and Romualdo formations, dated as Aptian by the occurrence of the palynological zone P-270 (Regali & Santos, 1999; Rios-Netto et al., 2012; Teixeira et al., 2017). The recovered ostracods are from deposits of the Romualdo Formation. Although renowned for its fossiliferous concretions (Maisey, 2000; Saraiva et al., 2007), the lithological framework of the Romualdo Formation is also composed of conglomerate, sandstone, shale and marl and shell-rich limestones (Assine et al., 2014; Fürsich et al., 2018).

The limestone sample studied was processed following the usual protocol for calcareous microfossil recovery, involving the following steps: (1) mechanical fragmentation of the rock with the aid of pistil and mortar; (2) chemical attack, using hydrogen peroxide (H_2O_2) to react in a becker with 20 g of the sample for approximately 24 h; (3) wash with running water in a sieve set of 500, 250, 180 and 62 µm mesh followed by oven drying at 60 ºC. All specimens from the fractions 250, 180 and 62 µm were picked out for analysis under a stereomicroscope.

A structural histogram of the assemblage was made to analyze the abundance of each instar (Fig. 2). Height and length measurements were performed on 11 randomly selected individuals from each instar, and a scatter plot was used to visualize ontogenetic growth (Fig. 3). Representative specimens from each ontogenetic stage were selected for images in a scanning electron microscope (SEM), at *Laboratório de Nanoestruturas* [Nanostructures Laboratory] (LDN-UFPE) and at *Instituto Tecnológico de Micropaleontologia* [Technological Institute of Micropaleontology] (Itt Fossil - Unisinos). The suprageneric classification followed the proposal of Horne et al. (2002). The new taxon is registered in Zoobank (the Official Registry of Zoological Nomenclature of the International Commission on Zoological Nomenclature).

Abbreviations: L = length; H = height; W = width; C = carapace; LV = left valve; RV = right valve.

Paleontological Systematic

Order PODOCOPIDA Sars, 1866

Suborder CYPRIDOCOPINA Jones, 1901

Superfamily CYPRIDOIDEA Baird, 1845

Family CYPRIDIDAE Baird, 1845

Subfamily CYPRIDEINAE Martin, 1940

Genus *Pattersoncypris* Bate, 1972

Type-species: *Pattersoncypris micropapillosa* Bate, 1972

Remarks: The relationship between Cyprididae representatives of the genera *Harbinia* Tsao, 1959 and *Pattersoncypris* Bate, 1972 has been debated since Do Carmo (1998). Do Carmo et al. (2008) discusses the taxonomic aspects involving *Harbinia*, formalizing *Pattersoncypris* as its junior synonym and reallocating four subspecies of *Hourcqia angulata* Krömmelbein & Weber, 1971 in the genus *Harbinia*. Both proposals were refused subsequently by Poropat & Colin (2012b) who reviewed these taxa and suggested the revalidation of *Pattersoncypris* and *Hourcqia* Krömmelbein, 1965, describing also the new genus *Kroemmelbeincypris* Poropat & Colin, 2012. This proposal has also received criticism, Do Carmo et al. (2013) argues that features considered by Poropat & Colin (2012b) are shared with the *Harbinia* genus, further pointing out that one of the distinctive characters for the description of the *Kroemmelbeincypris* causes dichotomy within the clade itself, since the anteroventral inclined posterior end, which separates them from *Harbinia*, is not present in *K. symmetrica* Poropat & Colin, 2012. In view of the actual knowledge concerning the taxonomy of the genera discussed above, the authors have chosen to allocate the new species in *Pattersoncypris* for now.

***Pattersoncypris minima* Almeida-Lima & Piovesan sp. nov.**

(Fig. 4A-R)

ZooBank-link: urn:lsid:zoobank.org:pub:D609D813-B9CB-4284-ADBC-98246162332E

Etymology: In reference to the small size.

Type-locality: Santana do Cariri Municipality, Ceará State, Northeast Brazil.

Type-horizon: Outcrop sample, coordinates 07º11'32"S - 39º42'52"W. Aptian. Romualdo Formation, Araripe Basin.

Material: 722 carapaces (92 adults; 630 juveniles).

Holotype: LMA-00020, Adult L: 0.49 mm, H: 0.29 mm, W: 0.24 mm (Fig. 2: A–B).

Paratypes: LMA-00021, A-1 L: 0.41 mm, H: 0.6 mm. W: 0.17 mm; LMA-00022, A-2 L: 0.34 mm, H: 0.20 mm, W: 0.16 mm; LMA-00023, A-3 L: 0.29 mm, H: 0.18 mm, W: 0.14 mm; LMA-00024, A-4 L: 0.26 mm, H: 0.16 mm, W: 0.13 mm; LMA-00025, A-5 L: 0.23 mm, H: 0.14 mm, W: 0.12 mm; LMA-00026, A-6 L: 0.21 mm, H: 0.14 mm, W:

0.10 mm; LMA-00027, A-7 L: 0.18 mm, H: 0.12 mm, W: 0.09 mm; LMA-00028, A-8 L: 0.15 mm, H: 0,11 mm, W: 0.07 mm (Fig. 2: C-R).

Repository: Collection from *Laboratório de Micropaleontologia Aplicada* [Applied Micropaleontology Laboratory] (LMA) from UFPE, Recife, Brazil.

Diagnosis: A small-shelled species of *Pattersoncypris*, suboval in lateral view, hump barely pronounced. LV overlapping the RV along the anterodorsal and ventral margins, except in the oral region.

Description: Carapace small, suboval in lateral view; ellipsoid in dorsal view. Ventral margin straight; dorsal margin slightly concave, steep posteriorly. Anterior margin broadly rounded; posterior margin infracurvate (sensu Lüttig, 1962). Greater length at mid-height, greater height and greater width in the median region. LV larger than RV, overlapping along anterodorsal, anterior and almost all the ventral margins, except for the anteroventral portion. Carapace smooth. Sexual dimorphism and internal characters not observed. The instars A-2 to A-7 have a more triangular lateral outline and from A-1 to A-8 a symmetrical dorsal view.

Remarks: *Pattersoncypris minima* **sp. nov.** differs from other species of the genus mainly in the size, which is significantly smaller. This new species was proposed based on the occurrence of complete ontogenetic series, which reinforce the hypothesis that it is a new taxon instead of an instar of a previously described species. Moreover, morphological differences are noticed when *P. minima* **sp. nov.** is compared to other species of the genus. Compared to *P. crepata* (Do Carmo et al., 2013) from the Aptian-Albian of Araripe and Potiguar basins, Brazil, the new species is distinguished by the absence of the prominent hump, the posterior margin less rounded and the positions of the greater height and width. *P. alta* (Antonietto et al., 2012) from the Aptian-Albian of Araripe, Pará-Maranhão and Potiguar basins, Brazil, is highest in the anteromedian region, its posterior portion is slightly supracurvate, and it is ornamented. With respect to *P. salitrensis* (Krömmelbein & Weber, 1971), from the Aptian-Albian of Araripe and São Luís-Grajaú basins, Brazil, *P*. *minima* **sp. nov.** is distinguished by the dorsal region without the pronounced hump, the carapace subtriangular in lateral view and the greatest width at the postero-median region on *P*. *salitrensis*. Comparing with *P*. *sinuata* (Krömmelbein & Weber, 1971) from the Aptian-Albian of Araripe, Potiguar and Sergipe-Alagoas basins, Brazil, it differs from *P*. *minima* **sp. nov.** by the developed hump and the bigger size. In relation to *P. micropapillosa* Bate, 1972, from the Aptian-Albian of Araripe, Potiguar, Cedro and Jatobá basins, Brazil, in addition to the pronounced hump, the equicurvate posterior margin and ornamentation present in the carapace of *P. micropapillosa*, allow to distinguish it from *P*. *minima* **sp. nov.**

Stratigraphic distribution: Brazil, Araripe Basin, Romualdo Formation, Aptian.

Taphonomic considerations

The specimens recovered in the present study are poorly preserved, containing signs of dissolution. First instar specimens usually present fragile carapaces due to poor calcification, as occurs in living cypridids (Smith & Martens, 2000). For this reason, Smith (2000) rejected the possibility of fossilization of a A-8 instar. More complete works dealing with the ontogeny of other species of *Pattersoncypris* (e.g. Antonietto et al. 2012, Do Carmo et al., 2013) report up to the A-7 instar. The recovered material studied here consists of different ontogenetic stages of a single species, in a ratio of eight juveniles to one adult (8:1). Carbonel (1988) demonstrates that these types of monospecific and abundant assemblages are characteristic of brackish water (in fig. 1, p. 159). This is coherent to the literature data, that indicates a marine influence in the Romualdo Formation (Assine, 2007; Assine et al. 2014; Fürsich et al., 2018) and corroborates the interpretation of a transitional paleoenvironment in the deposits where this species was recorded. This is the most complete ontogenetic record for *Pattersoncypris* ever registered and shows that biostratinomic events, fossil diagenesis, abundance and diversity of a sample can be strongly influenced by environmental conditions.

Comparing the distribution of *P*. *minima* **sp. nov.** instars in the assemblage (Fig. 2) to models by Whatley (1988), the frequency distribution is similar to type A (in fig. 1, p. 248) which represents a complete life assemblage with all the moult stages, rarely found preserved in sedimentary. The preservation of the extremely small and delicate carapaces of the first ontogenetic stages found, associated with fine grained rocks, such as the limestone in which we recovered our fossil assemblage, indicate that they were produced by low energy environments (Whatley, 1983; Whatley, 1988). Bate (1972) sustains that the abundance of individuals varies according to the environmental dynamics and nutritional availability. Therefore, calm water conditions are necessary to preserve the actual population structure, which reinforces the suitability of the model by Whatley (1988) to the assemblage of *P*. *minima* **sp. nov.** discussed previously.

The ontogenetic development model observed for *P*. *minima* **sp. nov.** (Fig. 3) is similar to that found by Smith (2000) in *P. micropapillosa*, and Antonietto et al. (2012) for both *P. alta* and *P. salitrensis*, inferring that species of this genus have the same growth pattern*.* The ontogenetic pattern of this genus follows the one currently known in other representatives of the family Cyprididae (Aguilar-Alberola & Mesquita-Joanes, 2013). The graph obtained permits to discern the growth trend along the ontogeny, where individuals – represented by dots on the graph 3 – are arranged in sequence according to progressive increase in size.

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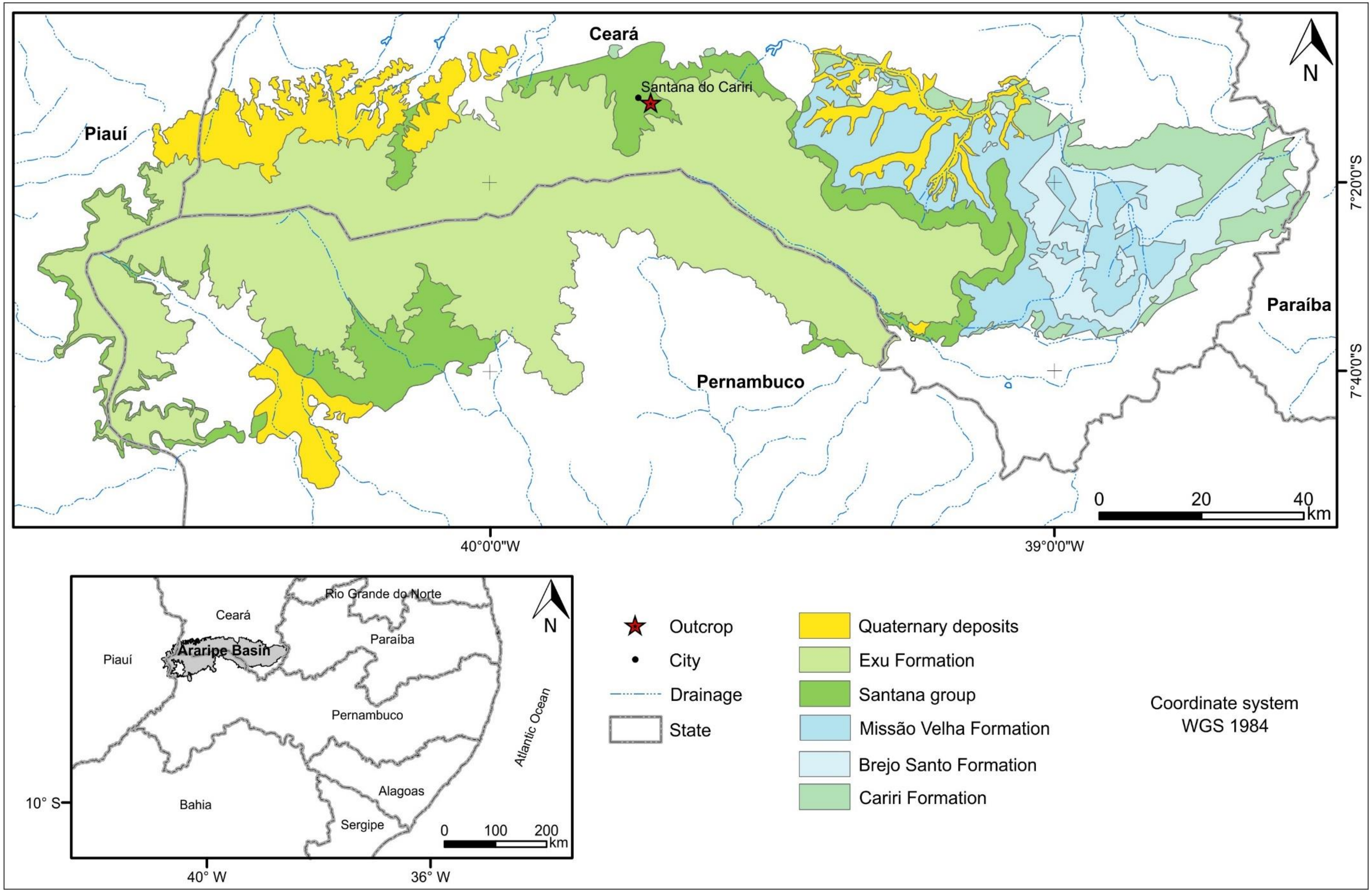
Figure captions

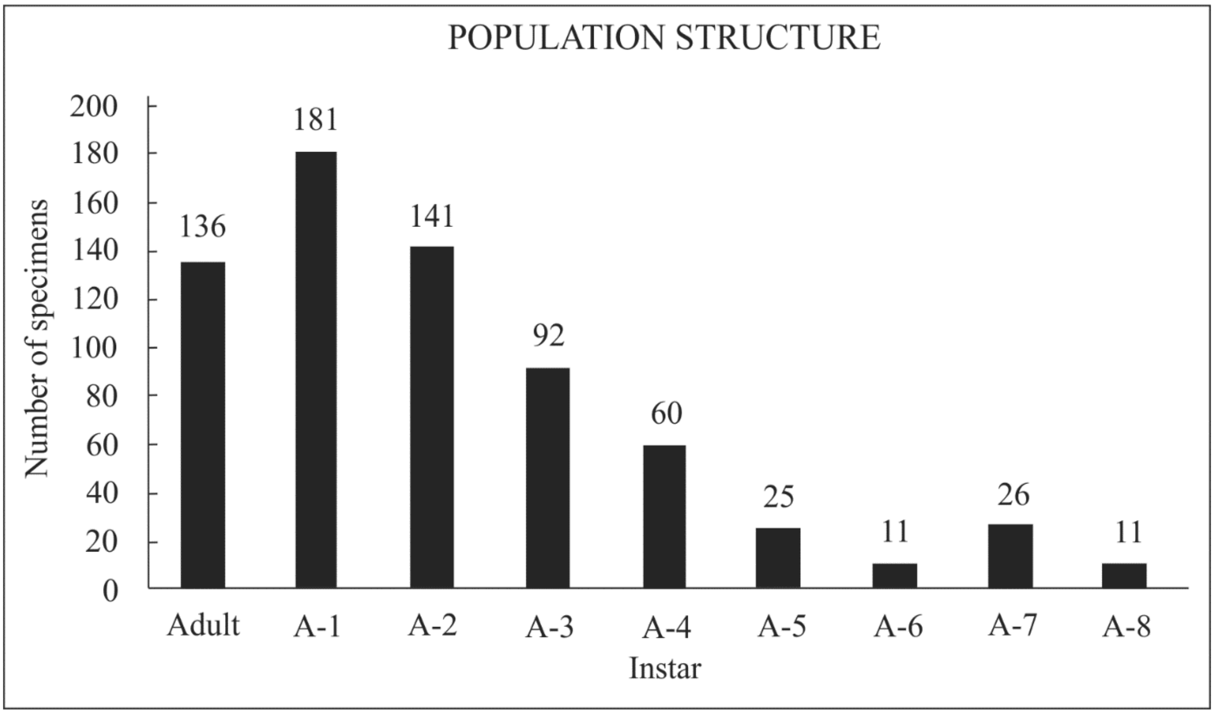
Figure 1 – Map of the study area showing the collection location in the Araripe Basin, NE of Brazil. (Produced from metadata provided by CPRM).

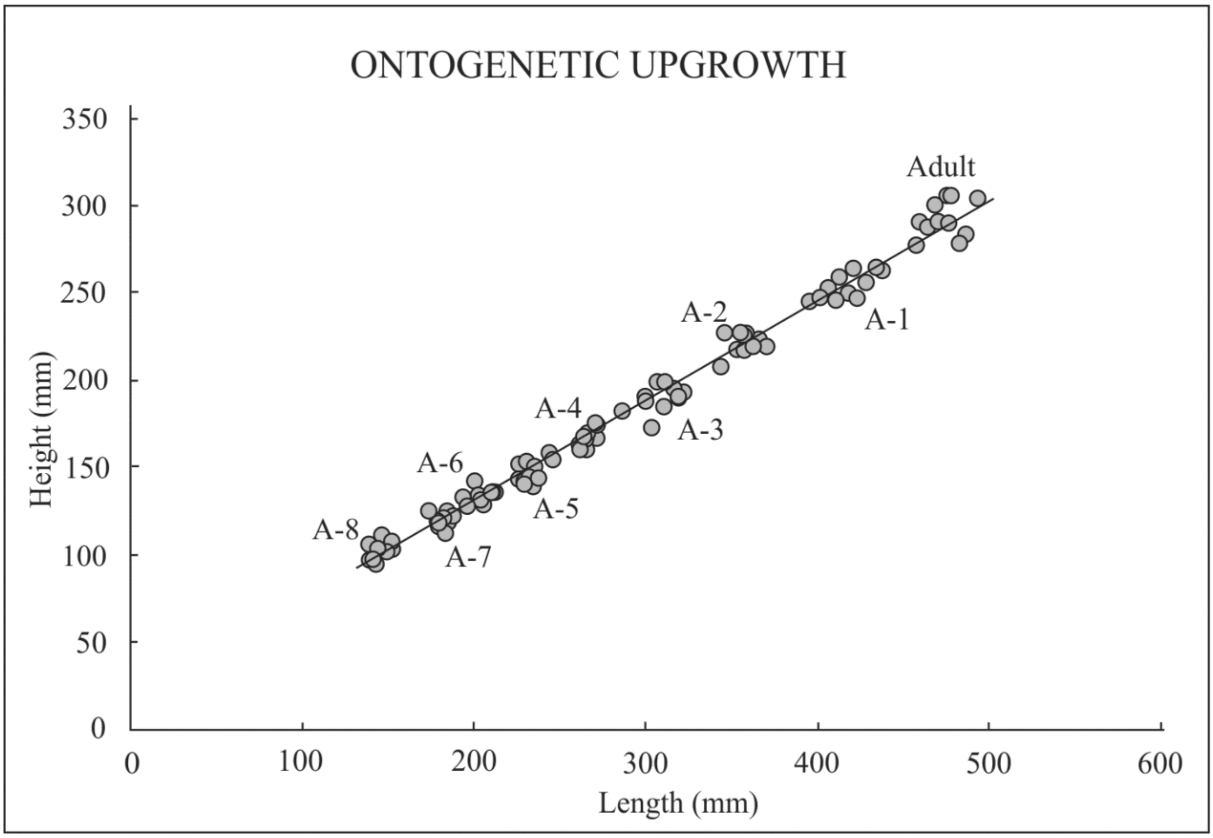
Figure 2 – Population histogram according to ontogenetic stages present in the studied assemblage of *Pattersoncypris minima* sp. nov.

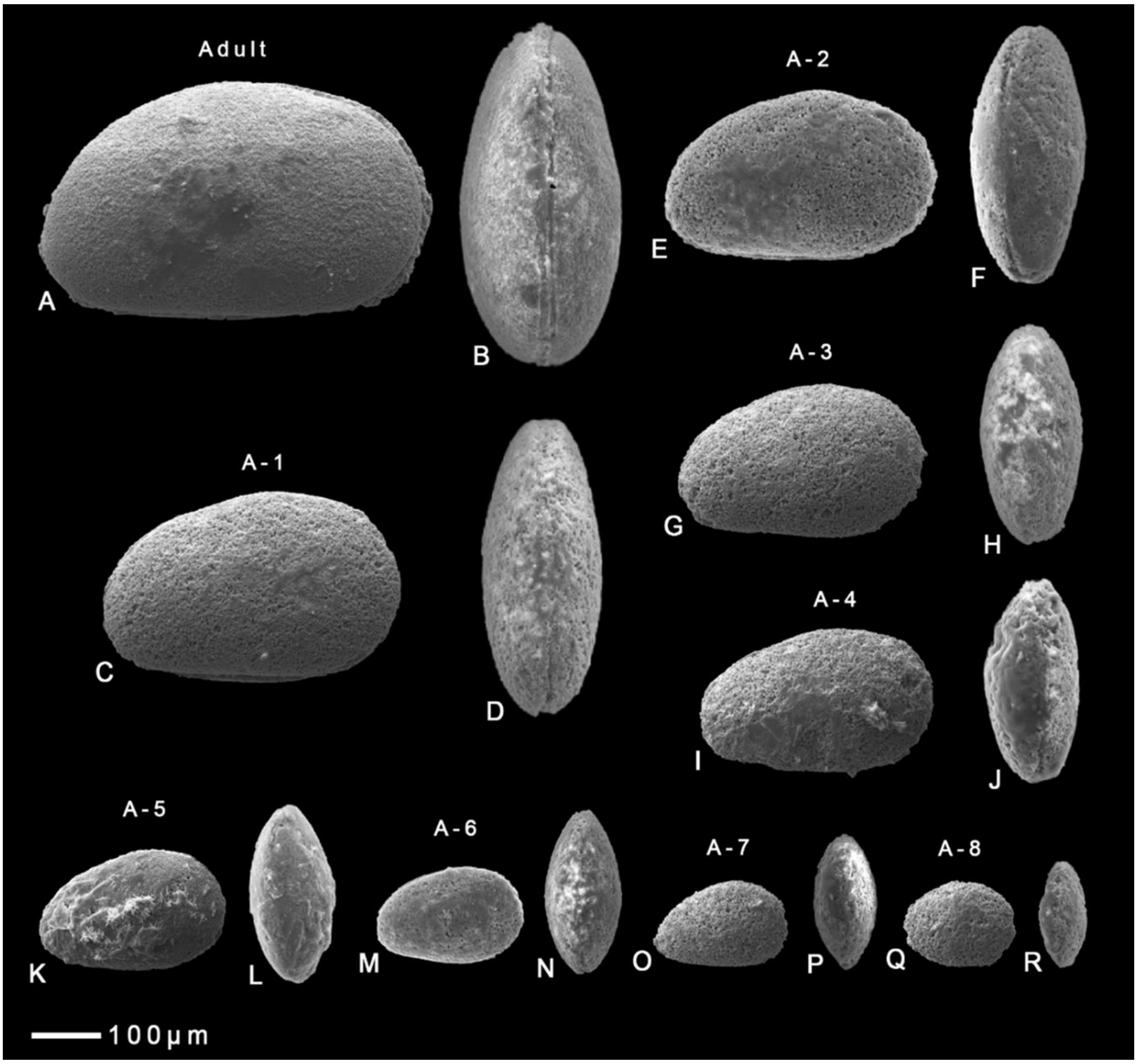
Figure 3 – Length versus height plots for *Pattersoncypris minima* sp. nov. showing its different growth stages.

Figure 4 – (A–R) *Pattersoncypris minima* sp. nov. (A–B) LMA-00020, holotype, C, right and dorsal views; (C–D) LMA-00021, paratype A-1, C, right and dorsal views; (E–F) LMA-00022, paratype A-2, C, right and dorsal views; (G–H) LMA-00023, paratype A-3, C, right and dorsal views; (I–J) LMA-00024, paratype A-4, C, right and dorsal views; (K–L) LMA-00025, paratype A-5, C, right and dorsal views; (M–N) LMA-00026, paratype A-6, C, right and dorsal views; (O–P) LMA-00027, paratype A-7, C, right and dorsal views; (Q–R) LMA-00028, paratype A-8, C, right and dorsal views.


Ceará
Santana do Cariri
Piauí
Paraíba
Pernambuco
N
7°20'0"S
7°40'0"S
40°0'0"W
39°0'0"W
0
20
40
km
Rio Grande do Norte
Ceará
Paraíba
Piauí
Araripe Basin
Pernambuco
Atlantic Ocean
Alagoas
Bahia
Sergipe
10° S
40° W
36° W
0
100
200
km
N
Outcrop
City
Drainage
State
Quaternary deposits
Exu Formation
Santana group
Missão Velha Formation
Brejo Santo Formation
Cariri Formation
Coordinate system
WGS 1984


POPULATION STRUCTURE
Number of specimens
200
180
160
140
120
100
80
60
40
20
0
136
181
141
92
60
25
11
26
11
Adult
A-1
A-2
A-3
A-4
A-5
A-6
A-7
A-8
Instar


ONTOGENETIC UPGROWTH
Height (mm)
350
300
250
200
150
100
50
0
Adult
A-2
A-1
A-4
A-3
A-6
A-5
A-8
A-7
0
100
200
300
400
500
600
Length (mm)


Adult
A
B
A - 2
E
F
A - 3
G
H
A - 1
C
D
A - 4
I
J
A - 5
K
L
A - 6
M
N
A - 7
O
P
A - 8
Q
R
100μm

7 CONSIDERAÇÕES FINAIS

A presente dissertação representou mais uma contribuição no que diz respeito ao estudo dos ostracodes não-marinhos do Jurássico Superior–Cretáceo Inferior das bacias sedimentares interiores do NE.

A ostracofauna presente no estágio final do Período Jurássico das bacias do Araripe, Tucano Norte e Jatobá se mostrou extremamente abundante, tendo sido recuperados mais de 10.000 espécimes, entretanto, sua diversidade foi baixa, identificando-se apenas três espécies. Nas amostras que correspondem ao Cretáceo Inferior dessas bacias, o padrão inverso foi observado. Neste intervalo, a abundância de ostracodes foi baixa, enquanto a riqueza de espécies foi de 27 taxons, incluindo a descrição de uma nova espécie, nomeada como *Pattersoncypris minima*.

Com relação a sistemática e taxonomia do grupo, muitos táxons carecem de atualizações, visto que foram descritos majoritariamente nas décadas de 60 e 70 e pouco abordadas em trabalhos subsequentes. Revisões dessa fauna foram propostas parcimoniosamente neste estudo, uma vez que a preservação de alguns espécimes impossibilitou uma abordagem mais detalhada. Este fato evidencia a necessidade de esforços para o aprimoramento dos estudos ostracodológicos, uma vez que esse é um grupo chave para a compreensão da evolução destas bacias.

Nesta pesquisa realizou-se a emenda à descrição de *Theriosynoecum pricei*, importante espécie marcadora do Andar Dom João, a partir de dados taxonômicos, inferências paleoambientais e noções a respeito da fisiologia de ostracodes atuais, tornando possível uma maior compreensão a respeito da paleoecologia desses organismos com relação ao meio em que viviam durante o Tithoniano nessas bacias. A descrição de *Pattersoncypris minima*, espécie registrada para o Andar Alagoas, também incrementou o conhecimento paleoambiental e tafonômico, uma vez que sua assembleia fóssil era contituida por todos os estágios ontogenéticos da espécie em questão.

Bioestratigraficamente, foram reconhecidos os andares locais Dom João, Rio da Serra, Aratu, Buracica e Alagoas, proporcionando base para o refinamento deste arcabouço em trabalhos futuros.

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