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TAXONOMIA, PALEOECOLOGIA E BIOESTRATIGRAFIA (OSTRACODA) DO OLIGO-MIOCENO DA FORMAÇÃO PIRABAS (ESTADO DO PARÁ, BRASIL)

Tese apresentada por:

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Orientador: Prof.ª Maria Inês Feijó Ramos (MPEG)

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TESE APRESENTADA POR

ANNA ANDRESSA EVANGELISTA NOGUEIRA

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“*Se queremos progredir, não devemos repetir*
a história, mas fazer uma história nova”.

Mahatma Gandhi

RESUMO

O limite Oligo-Mioceno é marcado por uma das maiores transgressões marinhas do planeta registrados na Formação Pirabas, uma unidade predominantemente carbonática exposta no litoral Norte do Brasil. A identificação dos ostracodes provenientes de 35 amostras de afloramentos e 22 do testemunho de sondagem FPR-160 Primavera, desta unidade, por meio do estudo comparativo do material tipo das coleções de Bold e Howe, bem como da literatura consultada, permitiu o registro de 36 novas espécies, 12 espécies deixadas em "aff." e três em "cf."; 27 espécies comuns ao Neógeno do Caribe; duas espécies reconhecidas para outras áreas e uma já descrita para a unidade em estudo previamente, além de 38 deixadas em nomenclatura aberta, completando um total de 119 espécies. Este extensivo estudo taxonômico proveu de um banco de dados robusto para o refinamento dos estudos paleoambientais, bioestratigráficos e paleogeográficos, além de contribuir com o incremento do registro da paleobiodiversidade dos ostracodes do Neógeno do Norte do Atlântico Sudoeste. A classificação taxonômica dos ostracodes rendeu aproximadamente 23 famílias, 64 gêneros e 119 espécies. A associação de fácies indicam ambientes desde marinho raso plataformal a lagunar, e a variação de salinidade inerente destes ambientes foi indicado por ostracodes dos gêneros *Haplocytheridea*, *Cytheridea*, e, principalmente, *Perissocytheridea* e *Cyprideis* associados à foraminíferos bentônicos dos gêneros *Ammonia* e *Elphidium*. As 27 espécies comuns às unidades do Caribe, mostraram estreita similaridade em comparação com o significativo número de espécies novas registrados para a Formação Pirabas. A irradiação, restrição e extinção da ostracofauna, devido à processos tectônicos e eustáticos nestas regiões, durante o Oligo-Mioceno, proporcionaram um novo arranjo na sua distribuição e, consequentemente das províncias paleobiogeográficas. Desta forma, a ostracofauna da Formação Pirabas insere-se em uma nova subprovíncia que correlaciona-se com as subprovíncias Caribeanas. Ainda, o registro de cinco espécies-guias *Glyptobairdia crumena*, (N5/N6) e *Neocaudites macertus* (N4 e N5) inseridos na Zona *Globigerinatella insueta* e, *Porkonyella deformis* (N6 a N16), *Cytherella stainforthi* (N2 a N5) e *Quadracythere brachypygaia* (N3 a N6) nas Zonas *Globigerinoides trilobus*, *Catapsydrax dissimilis* e *Catapsydrax stainforthi* permitiram estabelecer o intervalo Neooligoceno – Eomioceno para a unidade em apreço. As mais de 100 espécies registradas dentro deste intervalo proporcionaram o reconhecimento de uma Zona *Cytherella stainforthi*, qual é subdividida em quatro subzonas: *Jugosocythereis pannosa*, *Quadracythere brachypygaia*, *Glyptobairdia crumena* e *Pokornyella* *deformis* com limites marcados pela primeira e última ocorrência ao longo das sequências estudadas. Este novo biozoneamento, preliminarmente calibrado com as zonas de foraminíferos planctônicos, correspondentes às zonas N3 à N7 de Blow, permitiu estabelecer as idades Chatiano ao Burdigaliano para a Formação Pirabas, e estender as biozonas propostas para a região caribeana através da bioestratigrafia dos ostracodes do Neógeno da região norte do Brasil. Assim, a aplicação do zoneamento com ostracodes deste intervalo é de grande importância para a correlação local, intrabacinal e regional, particularmente onde o controle de foraminíferos, nanofósseis ou palinomorfos é pobre, principalmente devido à característica litorânea dos depósitos da Formação Pirabas.

Palavras-Chave: Ostracodes; Formação Pirabas; Oligo-Mioceno; Brasil.

ABSTRACT

The limit Oligo-Miocene is marked by one of the largest marine transgressions in the world recorded in the Pirabas Formation, a predominantly carbonate sequence exposed in the littoral northern Brazil. The identification of ostracods from 35 outcrops samples and 22 from the drill core FPR-160 Primavera, collected in the Pirabas Formation, trough an extensive survey of the literature as well as the comparative study with type material from Bold´s and Howe´s collections allowed the identification of 36 new species, 12 species left in “aff.” and three in “cf.”; and 27 species common to the Caribbean Neogene; two species recognized for other areas and more one species already described for the studied unit herein, as well as 38 in open nomenclature completing a record of a total of 119 species. This broad taxonomic study provided a robust database for the accuracy of paleoenvironmental, biostratigraphic and paleogeographic studies from this unit, and also to increase the record of the paleobiodiversity of Neogene Ostracods from North of Southwestern Atlantic. The taxonomic study of ostracods yielded approximately 23 families, 64 genera and 119 species. The facies association indicate from shallow marine plataformal to lagoonal environments, and the ostracods genera as *Haplocytheridea*, *Cytheridea*, and mainly, *Perissocytheridea* and *Cyprideis* genus, as well as benthic foraminifera of *Ammonia* and *Elphidium* genera indicated the salinity variation in the environments. The 27 common species to Caribbean units showed a tiny similarity compared to the large number of new species recorded to Pirabas unit. The irradiation, restriction and extinction of the ostracofauna in these regions, due to the tectonic and eustatic process in these regions, provided a new arrangement in the distribution and consequently the paleobiogeographics provinces. However, it is considered that the ostracofauna recorded to Pirabas unit is inserted in a new subprovince correlated to the Caribbean subprovinces. In Pirabas Formation, the record of the five species indexes *Glyptobairdia crumena*, (N5 / N6) and *Neocaudites macertus* (N4 and N5) inserted in *Globigerinatella insueta* Zone; and *Pokornyella deformis* (N6 to N16), *Cytherella stainforthi* (N2 to N5), *Quadracythere brachypygaia* (N3 to N6) in *Globigerinoides trilobus* Zones, *Catapsydrax dissimilis* and *Catapsydrax stainforthi* allowed to determinate the Late Oligocene to Early Miocene to Pirabas sequence. The more than 100 species recorded into this interval allowed the recognition of a *Cytherella stainforthi* zone which is subdivided in four subzones: *Jugosocythereis pannosa*, *Quadracythere brachypygaia*, *Glyptobairdia crumena* and *Porkonyella deformis* with limits marked by first and last occurrence along the succession. This new zonation is preliminarly calibrated with the zonal planktonic foraminifers, corresponding to N3 to N7 zones of Blow, included in the Chatian to Burdigalian ages, corroborating with Neogene ostracod biostratigraphy to the Caribbean region. Thus, this ostracod zonation is of great significance for local, intrabasinal and regional correlation, particularly where foraminiferal, nannofossil or palinomorfs control is poor due to the litoral caracteristc of the Pirabas sequence.

Key-words: Ostracods; Pirabas Formations; Oligo-Miocene; Brazil.

LISTA DE ABREVIAÇÕES E SIGLAS

UFPA: Universidade Federal do Pará
MPEG: Museu Paraense Emílio Goeldi
SIGEP: Sítio Geológicos e Paleontológicos
CIBRASA: Cimentos do Brasil S. A.
VOTORANTIM ou VC: Grupo Votorantim de Cimentos
MEV: Miscroscópio Eletrônico de Varredura
LSU: Louisiana State University
SNMNH: Smithsonian National Museum of Natural History
SEM e ESEM: Scanning Electron Microscope
USNM: United States National Museum
HVH: Henry V. Howe Collection
UH: University of Houston
FPR: Furo de Primavera
USA: United State of America
IG: Instituto de Geociências
UNB:Universidade Nacional de Brasília
CNPq: Conselho Nacional de Pesquisa
CAPES: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
PDSE: Programa de Doutorado Sanduíche no Exterior

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CAPÍTULO 1

1. INTRODUÇÃO

1.1. APRESENTAÇÃO

O Mioceno foi caracterizado por oscilações glacio e tectono-eustáticas responsáveis pela expressiva subida relativa do nível do mar em diversas partes do mundo, principalmente afetando as margens do continente sul-americano (Szatmari *et al.* 1987, Rossetti *et al.* 2013, Aguilera *et al.* 2014). Na porção Norte da América do Sul, nordeste do Estado do Pará, Brasil, estudos prévios têm contribuído na caracterização fossilífera e paleoambiental dos depósitos carbonáticos da Formação Pirabas, bem como dos siliciclásticos das Formações Barreiras e Pós-Barreiras, as quais estão sobrepostas à esta unidade. Neste contexto, as exposições da Formação Pirabas ao longo das margens nesta porção do continente, refletem uma parte destes eventos de variação relativa do nível do mar (e.g. Góes & Truckembrodt 1980, Arai *et al.* 1988, Rossetti *et al.* 1990, Rossetti 2001, Costa 2011).

Tentativas de datar a Formação Pirabas, definida originalmente como rochas calcárias fossilíferas exposta na foz do rio Pirabas, nordeste do Estado do Pará (Maury 1925), foram realizadas embora haja divergências entre os autores quais consideraram a unidade do Oligoceno Superior ao Mioceno Inferior (Ferreira *et al.* 1981, Ferreira *et al.* 1983, Ferreira *et al.* 1984, Rossetti 2001) e por outros que a consideram do Mioceno Inferior (Petri 1957, Fernandes 1984, Fernandes & Távora 1990, Távora & Fernandes 1999, Leite *et al.* 1997a, b, Távora *et al.* 2007, 2010, Aguilera & Paes 2012). A maioria dos estudos paleontológicos desta unidade abordaram principalmente aspectos taxonômicos da fauna (Petri 1954, 1957, Beurlen 1958, Brito 1971, 1972, 1977, Toledo e Domning 1989, Martins-Neto 2001, Távora *et al.* 2010), embora muitos grupos ainda necessitam ser revisados e estudados detalhadamente, como os ostracodes. Os fósseis são diversificados e incluem desde invertebrados (gastrópodes, pelecípodes, foraminíferos, ostracodes, celenterados, equinodermos, briozoários, cefalópodes, crustáceos, poríferos), vertebrados (sirênios, répteis e peixes) e fragmentos vegetais (Toledo 1989, Arai 1997, Leite *et al.* 1997a, b, Fernandes 1984, Távora *et al.* 2010, Duarte 2004). Em geral, os estudos paleoecológicos e faciológicos desta unidade permitiram interpretar os depósitos como de plataforma interna, lagunar e de manguezal (Rossetti 2006, Rossetti & Santos Jr. 2004, Rossetti & Góes 2004).

A estreita similaridade entre a fauna da Formação Pirabas com a de unidades sincrônicas na América Central, principalmente com a região do Caribe e golfo do México, por meio do estudo de diferentes grupos de fósseis de paleovertebrados e paleoinvertebrados, incluindo microfósseis, tem sido mencionada na literatura (Maury 1925, Macedo 1970). Recentemente, uma compilação dos estudos de invertebrados proveniente dos principais afloramentos estudados da Formação Pirabas, refuta a possibilidade desta similaridade e adotam para esta região uma nova subprovíncia paleobiogeográfica denominada de "*Neogene Tropical Western Central Atlantic*", embora com limites indefinidos (Aguilera & Paes 2012).

O estudo detalhado e extensivo da taxonomia dos ostracoda da Formação Pirabas como proposto neste trabalho, é de fundamental importância para o entendimento do padrão da distribuição paleobiogeográfica da microfauna, principalmente da relação entre a região do Caribe e a costa norte do Brasil (Ramos *et al.* 2004a, Sanchez-Villagra *et al.* 2010). Este grupo por serem organismos bentônicos, são de fundamental importância para o refinamento das interpretações paleoambientais e na definição de províncias paleobiogeográficas. Além disto o presente estudo irá contribuir para o entendimento da origem e evolução da ostracofauna das Américas e complementar o estudo de Wood *et al.*(1999).

A alta diversidade e radiação da ostracofauna da Formação Pirabas por conta da ciclicidade das oscilações do nível relativo do mar e da complexidade dos paleoambientes faz dela de grande aplicação para estudos bioestratigráfico e de correlação de bacias sedimentares.

Desta forma, a análise paleontológica e sedimentológica da Formação Pirabas realizada em exposições de rochas calcárias descontínuas, em frente de lavra de minas e também em testemunho de sondagem no nordeste do Estado do Pará, norte do Brasil, possibilitou a análise de uma sequência estratigráfica mais completa da unidade e permitiu o posicionamento estratigráfico das seções aflorantes através da correlação entre as mesmas, o que veio a contribuir na elucidação da evolução paleoambiental da unidade. O estudo do testemunho de sondagem alcançou quase a metade da espessura da sucessão Pirabas, estimada em torno de 130 m (Freimann 2014) na região da Praia do Atalaia, Salinópolis. A combinação de dados de afloramento e de subsuperfície permitiu estabelecer biozonas e, consequentemente, datar a Formação Pirabas, propondo um modelo evolutivo para as plataformas carbonáticas do Mioceno do norte do Brasil, baseado principalmente na ostracofauna.

1.2. OBJETIVOS

Este trabalho tem como objetivo geral contribuir com o levantamento da paleobiodiversidade da ostracofauna do Neógeno do norte da América do Sul, mais especificamente da Fm. Pirabas, por meio do estudo taxonômico detalhado, auxiliando nas análises paleoambientais, bioestratigráficas e paleobiogeográficas. Ao se considerar esse propósito geral pretende-se: i) revisar a identificação taxonômica de espécies já registradas na Formação Pirabas; ii) visitar as coleções tipo de Bold e Howe para estudos comparativos das espécies da Formação Pirabas; iii) verificar o grau de similaridade com a ostracofauna do Neógeno do Caribe; iv) refinar os limites das províncias paleobiogeográficas de ostracodes do Norte do Brasil; v) refinar o intervalo estratigráfico da unidade por meio da bioestratigrafia da ostracodes; vi) refinar as interpretações paleoambientais da Formação Pirabas em uma sequência evolutiva; vii) refinar os limites das províncias paleobiogeográficas de ostracodes do Norte do Brasil.

1.3. ORGANIZAÇÃO DA TESE E RESUMO DOS PRINCIPAIS RESULTADOS

A tese está organizada em oito capítulos onde são apresentados três artigos. Os textos fornecem os principais tópicos da pesquisa de doutorado. Na parte introdutória da tese consta a apresentação da problemática e contextualização do assunto principal, os objetivos, a geologia regional e os métodos utilizados, os quais são mencionados e descritos de forma um pouco diferenciada em cada artigo, para assim evitar repetições.

Os aspectos sedimentológicos das localidades estudadas do capítulo 5 inicia os capítulos de resultados do trabalho, com destaque para os artigos científicos mostrados nos capítulos 6 a 8. O primeiro artigo refere-se à ocorrência inédita do gênero *Perissocytheridea* nos depósitos da Formação Pirabas, representado por 4 novas espécies, considerado um importante indicador de ambientes transicionais e águas salobras, o que confere intervalos de ambientes mais restritos e de menor salinidade que a marinho normal para a Fm. Pirabas. O segundo artigo trata da taxonomia dos ostracodes da Formação Pirabas, onde mais de 100 espécies foram identificadas com a descrição de diversas espécies novas. No terceiro artigo foi feito um estudo paleoecológico e bioestratigráfico da ostracofauna da Formação Pirabas correlacionando-a com as biozonas do Neógeno descritas para o Caribe, propondo novas biozonas para a Plataforma Bragantina e confirmando o intervalo Oligo-Mioceno para a unidade.

CAPÍTULO 2

2. A FORMAÇÃO PIRABAS NO NORTE DO BRASIL

2.1. CONTEXTO TECTÔNICO

A América do Sul tem sido influenciada por intensos eventos tectônicos que afetaram as configurações dos oceanos desde o Mesozóico. Após os eventos de desagregação do Pangea, iniciado aproximadamente há 100 milhões de anos (Jurássico e Cretáceo), e com a separação do Brasil da África culminou na abertura do Oceano Atlântico. A região norte da América do Sul e América Central são assoladas por intenso magmatismo e tectonismo, decorrentes da interação de diversas placas tectônicas (Fig. 2.1).

O Oceano Atlântico Equatorial evoluiu a partir de três episódios distensivos (Soares Júnior *et al*. 2008; Fig. 2.2): 1) formação do Oceano Atlântico Central no Triássico que formou o Gráben Calçoene da Bacia da Foz do Amazonas; 2) geração do Oceano Atlântico Equatorial, com sentido de rifteamento de NW para SE, que formou o Gráben Cassiporé da Bacia da Foz do Amazonas e as bacias de Marajó, Bragança-Viseu, São Luís e Ilha Nova; e 3) extensão no extremo leste da placa Sul-Americana do Neocretáceo ao Neógeno, com sentido de movimentação de SE para NW, formando as bacias Potiguar, Ceará, Barreirinhas e Pará-Maranhão (Soares Junior *et al.* 2008).

A sequência de margem passiva, que foi depositada na porção continental do norte do Brasil, é dividida em dois intervalos: Pré-Amazonas (Cenomaniano ao Mioceno, 96 a 11 Ma) e Leque do Amazonas (Mioceno ao Recente). O Proto-Amazonas representa a deposição anterior ao estabelecimento do rio Amazonas como um sistema de drenagem bem desenvolvido e é formado por duas sequências sedimentares geradas em ambientes variando de flúvio deltaico, marinho raso a marinho profundo, que compreendem as formações Limoeiro, Marajó, Amapá e Travosas (Brandão 1990, Brandão & Feijó 1994, Pasley *et al.* 2004, Schaller *et al.* 1971). O Leque do Amazonas é o resultado do desenvolvimento do rio Amazonas após o soerguimento da cordilheira dos Andes e é formado pelo Grupo Pará (Schaller *et al.* 1971, Brandão & Feijó 1994).

A região norte do Brasil tornou-se tectonicamente estável a partir do Cenozóico. Esta estabilidade foi perturbada por reativações de falhas normais e transcorrentes que reconfiguraram a região da desembocadura do rio Amazonas, bacia da Foz do Amazonas e Gráben do Marajó e regiões adjacentes como as plataformas Bragantina e do Pará (Costa *et al*. 2002; Fig. 2.2). A subsidência de blocos tectônicos concomitante com os eventos transgressivos do Mioceno levou a deposição de carbonatos marinhos da Formação Pirabas até 150 km ao sul do continente (Costa *et al*. 2002).

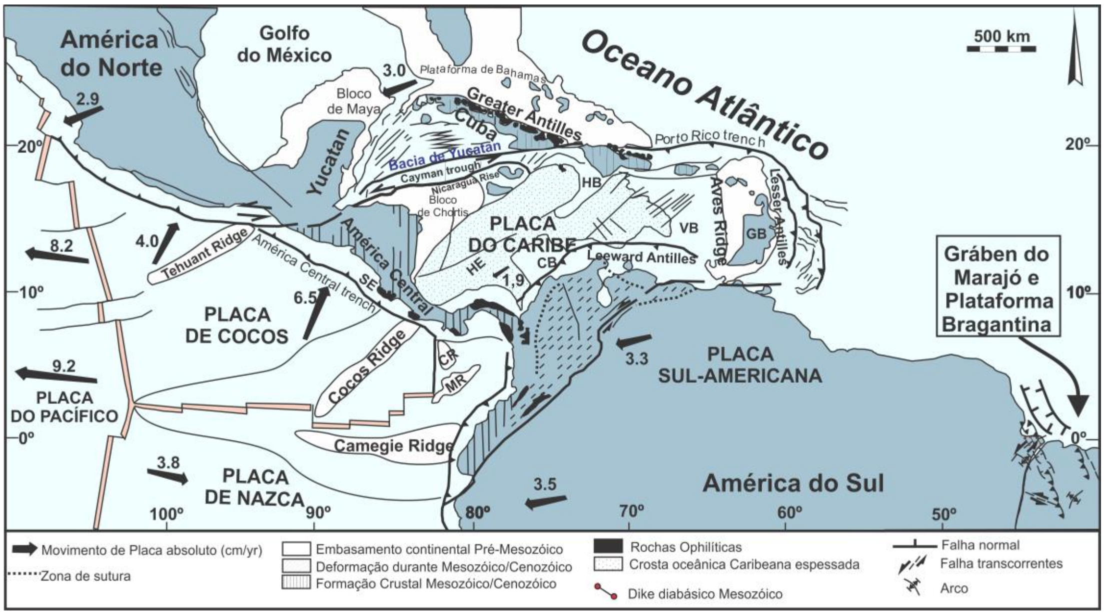

Figura. 2.1. Mapa da tectônica de placas do Caribe e do norte da América do Sul (Modificado de Mabesoone *et al.* 1981, Bachmann 2001 e Costa *et al.* 2002).

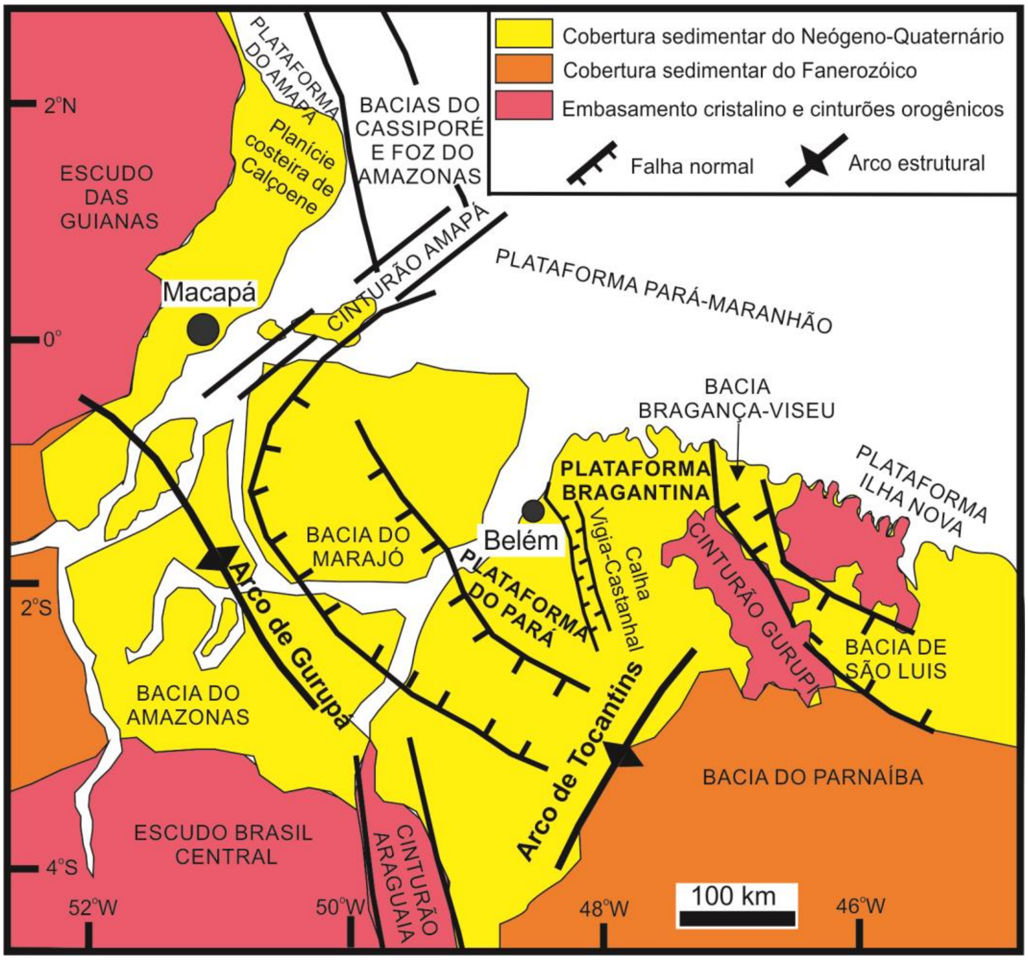

Figura 2.2. Contexto tectônico simplificado da região norte do Brasil com a localização da Plataforma Bragantina, Embasamento pré-cambriano, cinturões de cisalhamento e coberturas sedimentares fanerozóicas (Modificado de Soares Junior *et al.* 2008 e Costa *et al*. 2002).

A Formação Pirabas foi depositada em plataformas e grábens ao longo da costa norte do Brasil, influenciada por expressivas transgressões durante o Mioceno que modificaram profundamente as áreas continentais marginais (Fig. 2.2). Em grande parte, os segmentos tectônicos subsidentes e os paleovales encaixados ao longo de zonas de falhas normais e falhas transcorrentes, funcionaram como zonas de transferências ligadas ao evento de separação da América do Sul-África (Costa *et al.* 1993). O desenvolvimento deste cenário foi crucial para a preservação de grande parte do registro sedimentar, utilizado na reconstrução da história geológica do Mioceno (Rossetti & Góes 2004, Rossetti 2006).

2.2. ASPECTOS ESTRATIGRÁFICOS

A Formação Pirabas juntamente com a Formação Barreiras e Unidade Pós-Barreiras consistem nas unidades sedimentares das plataformas do Pará e Bragantina (Fig. 2.2, 2.3); está inserida na sequência A, exposta em afloramentos descontínuos de rochas carbonáticas depositadas durante o Oligo-Mioceno (Maury 1925, Petri 1957, Ferreira 1966, Ferreira *et al.* 1978, Ferreira 1982, Ferreira *et al.* 1984). Os afloramentos encontram-se expostos ao longo de falésias costeiras na região litorânea do norte do Brasil, bem como em cortes de estradas e minas a céu aberto, principalmente nos estados do Pará e Maranhão, sendo que ao norte do Estado do Piauí são menos frequentes (Rossetti & Góes 2004). Aguilera & Paes (2012) sugerem que esta heterogeneidade na sedimentologia e paleontolologia, e consequentemente, nos paleoambientes associados, poderiam suportar uma divisão formal ou informal em diferentes membros e/ou indicar diferentes idades ao longo da sequência da Formação Pirabas.

Os primeiros trabalhos faciológicos e estratigráficos realizados na Formação Pirabas foram baseados essencialmente em dados paleontológicos. Três diferentes biofácies foram estabelecidas por Petri (1957) para a Formação Pirabas com base no estudo exclusivo de foraminíferos: biofácies Castelo, representando depósitos de ambiente marinho raso, a biofácies Canecos, de ambiente marinho costeiro a transicional e a biofácies Baunilha Grande, representando os mangues abrangendo, respectivamente, afloramentos do atual litoral paraense, Zona Bragantina e Furo de Baunilha Grande. Posteriormente, Ferreira (1977) adotou as subdivisões de Petri (1957), porém fez algumas modificações no posicionamento das biofácies Castelo (ou Fortaleza), Capanema (biofácies Canecos) e Baunilha Grande, devido a problemas conotativos surgidos ao se comparar os dados bibliográficos no que se concerne a distribuição vertical destas fácies.

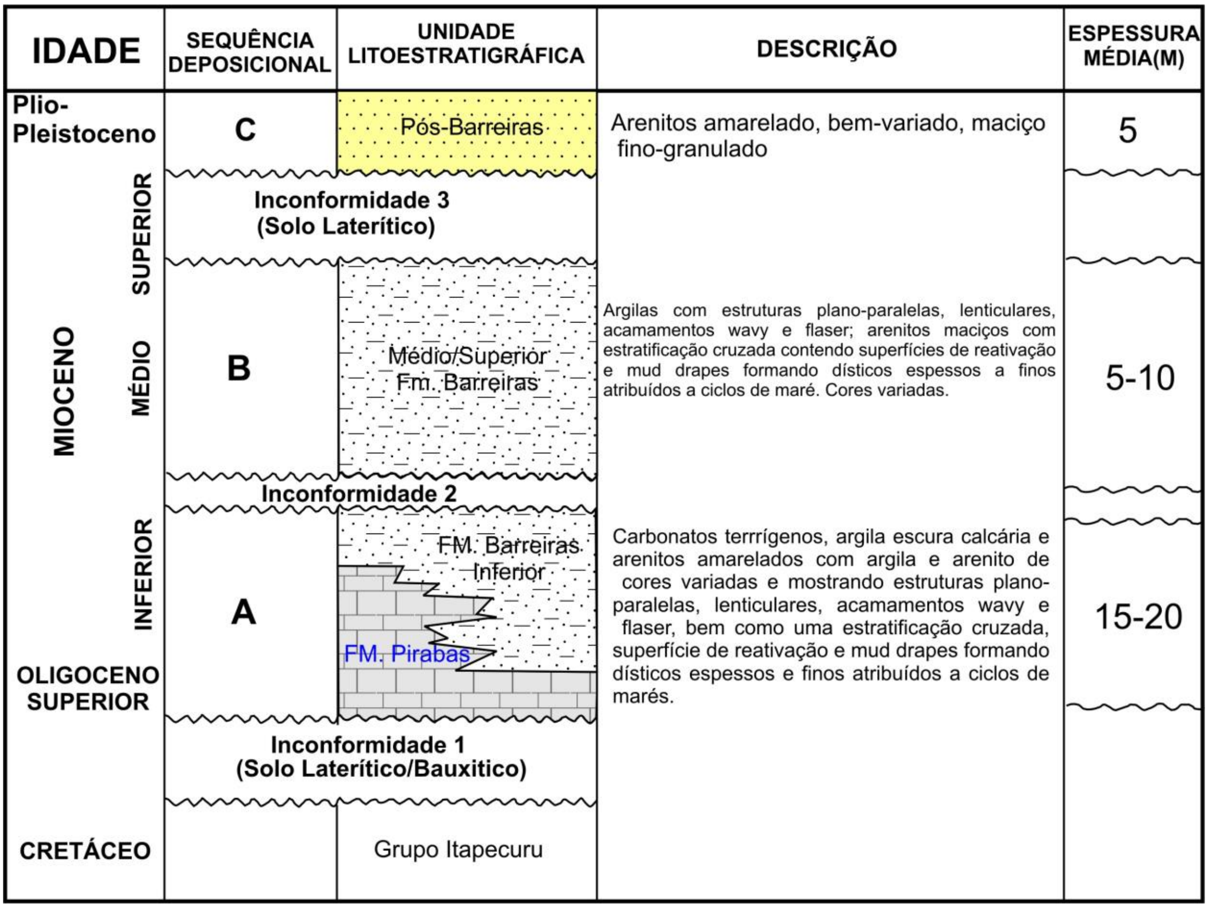

Figura. 2.3. Cronolitoestratigrafia dos depósitos miocenos das plataformas Bragantina e Pará no nordeste do Estado do Pará, Brasil (Rossetti 2001).

Estudos sedimentológicos mais detalhados, levando em consideração a análise de fácies, em afloramentos da Zona Bragantina, Estado do Pará, especificamente, nos Municípios de Salinópolis e Capanema, permitiu estabelecer um novo modelo deposicional para esta unidade subdividindo-a em sete fácies (Góes *et al.* 1990, Rossetti 2001): 1) biocalciruditos, 2) biocalcarenitos não estratificado, 3) biocalcarenitos estratificado, 4) marga, 5) folhelho, 6) biohermito e 7) calcilutito. Com base nessas 7 descrições faciológicas, os depósitos foram caracterizados como sendo: a) plataforma externa em parte influenciada por tempestades (*grainstone/packstone* maciços, *wackstone-packstone* estratificados com estratificação cruzada *hummocky* e argilitos laminados); b) plataforma restrita/lagunar (margas, calcilutitos, argilitos cinza e verde oliva, e biocalcarenitos não estratificados); c) litorânea (*Shoreface/foreshore*); e d) mangue (argilitos negros, maciços ou laminados, pirita local, argilitos laminados esverdeados contendo lentes ou camadas de arenito). Estas litofácies são aproximadamente correlatas às biofácies de Petri (1957) que representam seus ambientes respectivos: plataforma aberta, plataforma restrita/lagunar e mangue (Ackermann 1964, 1969 e 1976, Ferreira 1966).

Os ambientes de condições redutoras desenvolvidos durante a deposição da Formação Pirabas tais como marinho restrito e lagunar suportam, respectivamente, baixa diversidade de macrofósseis inteiros sustentados por micrito (*floatstone, wackestone)* e rara ou ausência destes fósseis em depósitos de margas e calcilutitos, além da presença de restos vegetais carbonizados ou piritizados. Os ambientes costeiros lagunares apresentam um arcabouço com grãos flutuantes que sugerem a ausência de compactação. A presença de terrígenos em todas as microfácies aponta para um ambiente deposicional costeiro (Rossetti & Góes 2004).

A sucessão sedimentar da Formação Pirabas apesar de apresentar fácies exclusivamente marinhas exibe um padrão geral progradacional, caracterizado por uma superposição de fácies de plataforma aberta a mais costeira associada a ilhas-barreiras, passando para depósitos flúvio-estuarinos da Formação Barreiras. Estruturas sedimentares indicativas da atuação de correntes de maré, icnofósseis costeiros e palinomorfos do Mioceno na Formação Barreiras, indica uma continuidade da sedimentação com os depósitos da Formação Pirabas (Arai *et al.* 1988, Góes *et al.* 1990, Arai 1997).

CAPÍTULO 3

3. A RADIAÇÃO DA OSTRACOFAUNA E A EVOLUÇÃO DO ATLÂNTICO EQUATORIAL

No Atlântico Equatorial e norte da América do Sul, os movimentos de compressão e transcorrentes entre as placas do Caribe, Norte-Americana, Sul Americana, de Nazca e de Cocos, resultaram na formação de bacias sedimentares e compartimentos estruturais subsidentes, fundamentais à preservação das sucessões sedimentares cretáceas e inclusive aquelas do Neógeno. A paleoceanografia foi fortemente alterada causando variações nos padrões da circulação oceânica, formação e deslocamento de ilhas (Antilhas Maiores e Menores e “Leeward Antilhas”), mudança na batimetria e na temperatura das massas d´água, bem como a formação do mar do Caribe, influenciando na radiação e evolução da biota (Iturralde-Vinet & McPhee 1999, Bachmann 2001, Iturralde-Vinet 2004-2005, Pindell *et al.* 2005; Fig. 3.1).

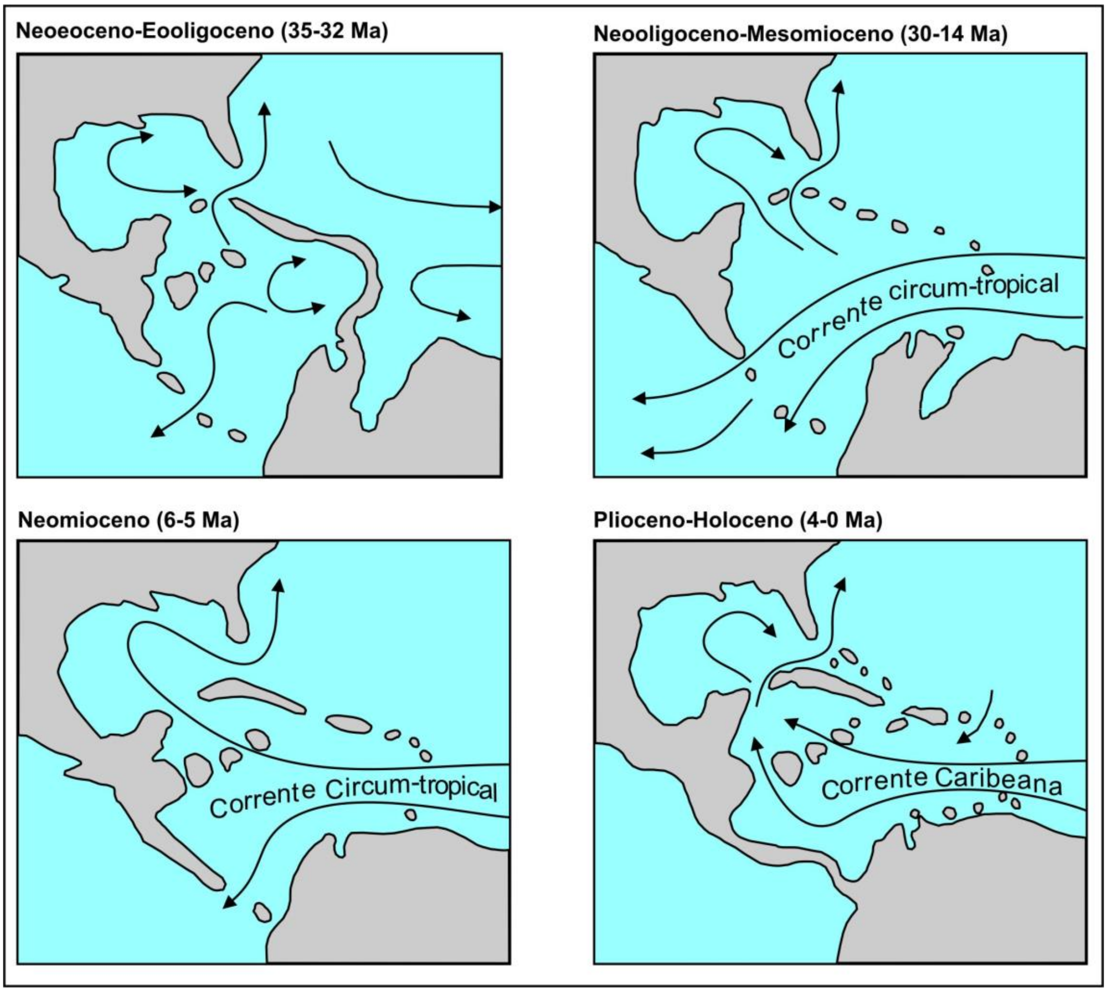

Figura 3.1. Circulação das correntes oceânicas e comunicação entre o Atlântico equatorial e o oceano Pacífico, desde o Neoeoceno (Modificado de Iturralde-Vinet & MacPhee 1999 e Potter & Szatmari 2009).

No Paleoceno, os oceanos apresentavam restrição à circulação das massas de água. As intensas colisões arco-continentais cessaram, ao mesmo tempo, nos limites norte e sul da placa do Caribe. No Neógeno, os eventos de compressão entre as placas do Caribe e Sul-Americana permitiram o desenvolvimento do cinturão de borda acrecionária da placa Sul-Americana, porém, ainda assim, não havia uma conexão de fato entre as Américas (Pindell & Barrett 1990). Segundo Vince (2011), o aparecimento e desaparecimento de ilhas vulcânicas, em associação com a contínua elevação dos Andes, ocorrido a cerca de 20 Ma atrás, ocasionou o fechamento e posterior reabertura efêmera do Canal do Panamá. Segundo este autor, o período da conexão entre as Américas por meio da elevação do istmo do Panamá ainda permanece em discussão. O soerguimento de ilhas naquela região promoveu rotas migratórias e corredores-filtros de migração para a biota (Fig. 3.1).

Neste cenário de intenso soerguimento de áreas continentais, a tendência ao raseamento das massas d´água do Atlântico Equatorial facilitou a rápida dispersão dos ostracodes bentônicos, levando a redução do nível de endemismo, principalmente no Eomioceno, diretamente relacionado à fatores extrínsecos (condições climáticas e oceanográficas) e intrínsecos (fisiologia), selecionando-os neste processo migratório e definindo assim as províncias paleobiogeográficas (Wood *et al.* 1999). A radiação, restrição e extinção ao longo do tempo da ostracofauna por meio do processo de formação de áreas emersas, proporcionou um novo arranjo na sua distribuição e no desenvolvimento das províncias paleobiogeográficas (Valentine 1976, Wood *et al.* 1999).

No Oligo-Mioceno, a dispersão e a interação da ostracofauna da margem continental norte do Brasil com a região do Caribe foi facilitada pelos fatores de reconfiguração paleoceanográfica, principalmente durante o estabelecimento de extensas plataformas carbonáticas. Este cenário começou a se modificar durante o Eomioceno a Neomioceno, com o soerguimento máximo da cordilheira dos Andes que culminou na intensificação do fluxo do rio Amazonas para leste e o estabelecimento da drenagem transcontinental (Nogueira 2008, Figueiredo *et al.* 2009, Gorini *et al.* 2013, Nogueira *et al.* 2013). A bacia da Foz do Amazonas e o Gráben do Marajó, fortemente subsidentes, permitiram, respectivamente, o acúmulo de 6 a 10 km de espessura de sedimentos (Costa *et al.* 1996 e 2002, Rossetti 2006, Soares Júnior *et al.* 2008). Esta descarga fluvial para dentro da Plataforma Continental Norte durante o Neomioceno-Plioceno, afetou a configuração e as condições físico-químicas das massas d’água, inibindo a deposição carbonática. As plataformas predominantemente carbonáticas foram paulatinamente substituídas pela atual plataforma continental siliciclástica que margeia a desembocadura do rio Amazonas, formando barreiras na dispersão da ostracofauna.

O estabelecimento da drenagem continental do Amazonas pouco influenciou a plataforma que se desenvolvia na Plataforma Bragantina no nordeste do Estado do Pará durante o Oligo-Mioceno. O influxo siliciclástico para a plataforma Pirabas, durante o Mioceno foi devido ao soerguimento da porção sul desta plataforma que propiciou a progradação de leques aluviais e sistemas fluviais meandrantes da Formação Barreiras (Soares Júnior *et al.* 2008, Rossetti *et al.* 2013).

A distribuição da ostracofauna e os modelos atuais auxiliaram na definição das províncias e subprovíncias paleozoogeográficas, possibilitando a compreensão de eventos paleobiológicos e paleobiogeográficos, importantes na reconstrução de antigos padrões de circulação oceânica (Whatley *et al.* 1998; Coimbra *et al.* 1995, 1999a,b,). Além disso, permitiu a definição de possíveis conexões da ostracofauna da região caribeana com a do Sudoeste Atlântico, ao longo da margem continental brasileira durante o Cenozóico. contribuindo na correlação das sucessões sedimentares e na compreensão dos padrões paleoceanográficos (Wood *et al.* 1999).

CAPÍTULO 4

4. MATERIAL E MÉTODOS

4.1. MATERIAL

O material de estudo é proveniente de afloramentos e testemunho estudados da Formação Pirabas que localizam-se no litoral da região nordeste do Estado do Pará, mais especificamente ao que se denomina de zona fisiográfica do Salgado (Fig. 4.1). Com exceção da frente de lavras da Mina da CIBRASA, próximo à cidade de Capanema, as localidades de Aricuru, Praia do Atalaia, Ilha de Fortaleza e São João de Pirabas situam-se na região costeira. O testemunho de sondagem foi realizado às proximidades da cidade de Primavera também na região do salgado.

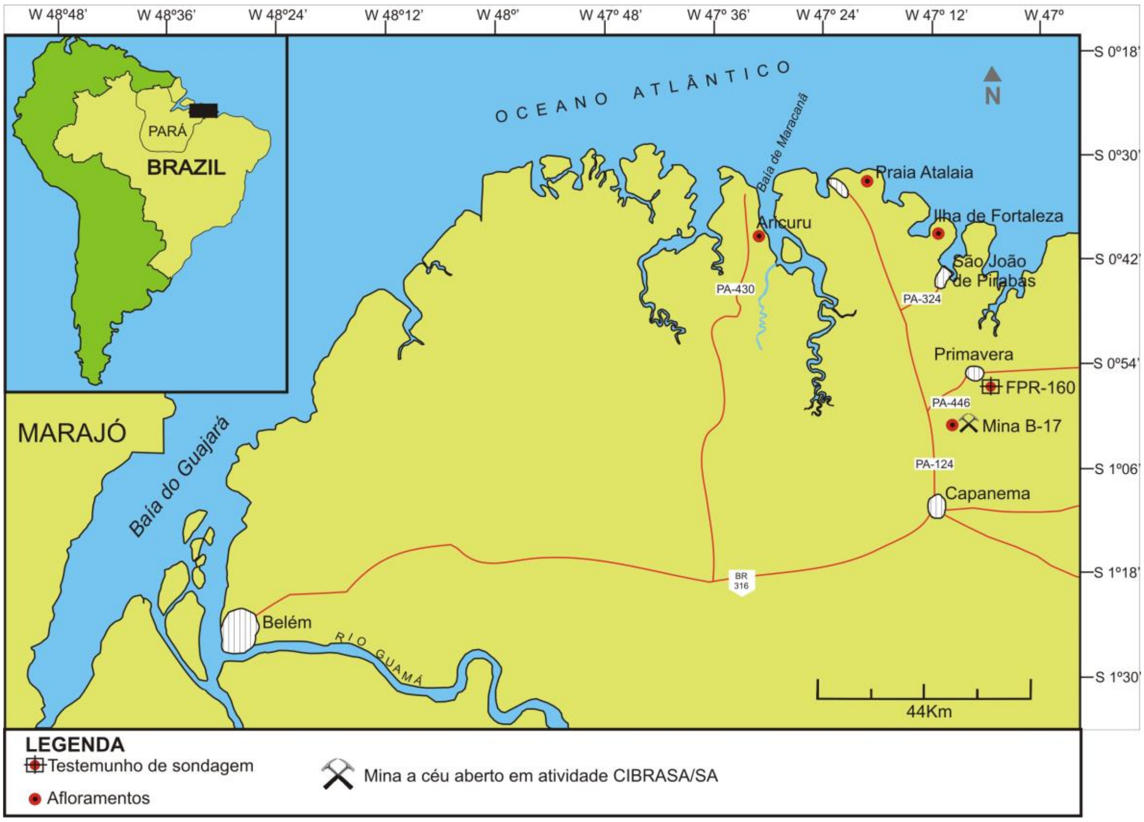

Figura 4.1. Localização da área de estudo da Formação Pirabas com indicação das principais localidades estudadas (Modificado de *Google Earth* 2015).

4.2. ANÁLISE FACIOLÓGICA E ESTRATIGRÁFICA

Essas análises consistiram nas observações dos pacotes sedimentares no campo utilizando-se os parâmetros usuais para descrição de fácies segundo Walker (1992), tais como estrutura, textura, conteúdo fossilífero e geometria dos corpos sedimentares. Foram utilizadas para embasar a análise de fácies as informações faciológicas e paleoambientais disponíveis na literatura para as localidades estudadas (Góes *et al.*1990, Rossetti 2001, Góes & Rossetti 2004, Costa 2011). Este procedimento permitiu um melhor entendimento dos processos de sedimentação e da interpretação paleoambiental da sucessão carbonática aflorante. A observação das fácies nos testemunhos de sondagem, apesar de limitada foi perfeitamente correlacionável com as descrições de campo.

4.3. COLETA E AMOSTRAGEM

O material das unidades em estudo é proveniente de campanhas realizadas entre 2009 e 2012. Amostras foram coletadas sistematicamente ao longo dos perfis geológicos de acordo com a fácies e paleontologia (Fig.4.2). As coletas na Formação Pirabas seguiram a mesma metodologia entre as localidades da Mina B17(19 amostras, B0 a B13B), Ponta do Castelo (4 amostras; PC-00 a PC-04), Aricuru (6 amostras; AR-01 a AR-06) e Salinópolis (2 amostras: AT-01 e AT-02). Além das amostras de superfície foram também analisadas 22 amostras do furo de sondagem FPR-160, de 45 metros de profundidade, cedido pela empresa VOTORANTIM.

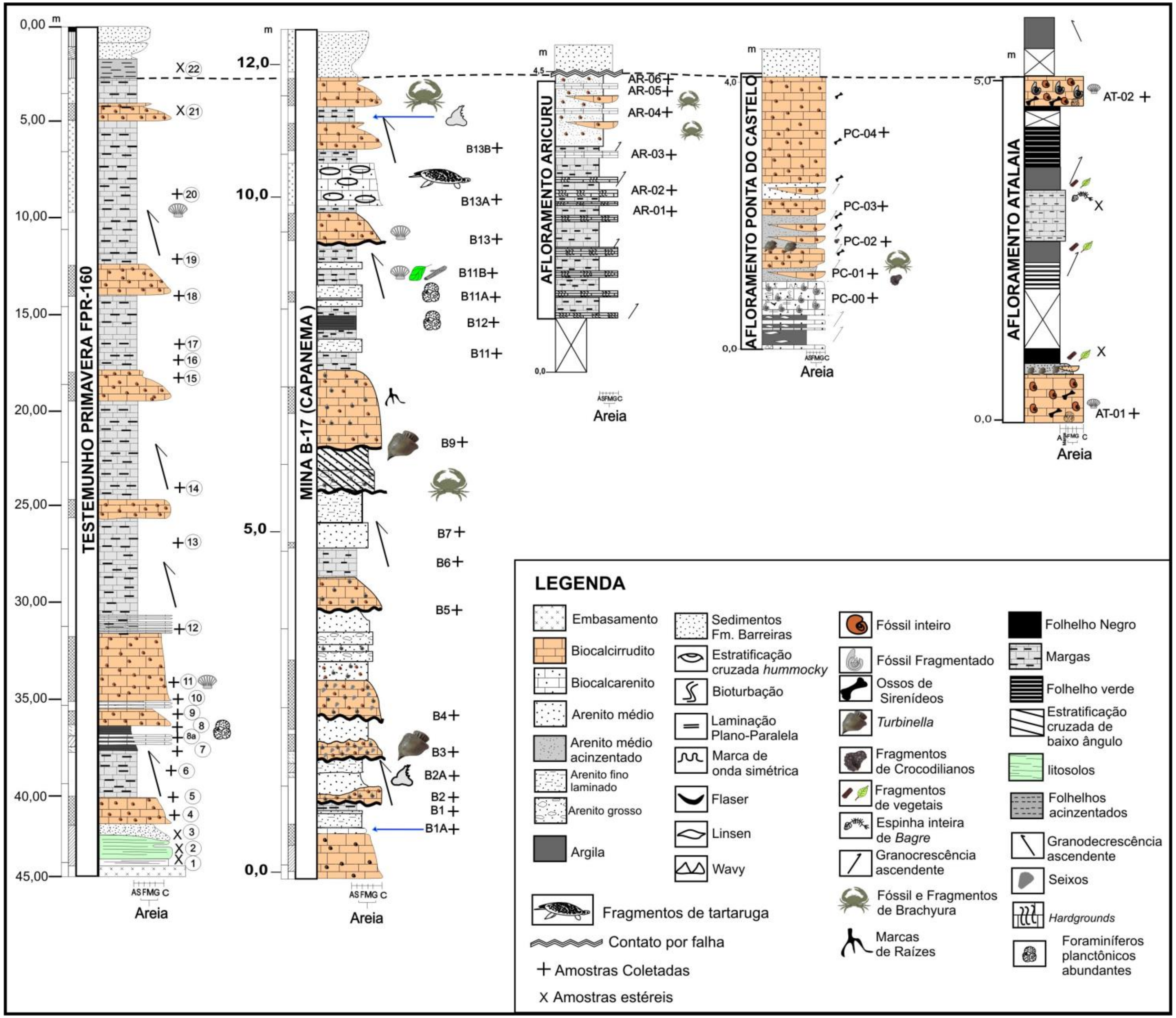

Figura. 4.2. Perfis estratigráficos das localidades estudadas com destaque para os depósitos da Formação Pirabas.

4.4. ANÁLISE MICROPALEONTOLÓGICA: OSTRACODES

As amostras foram tratadas por métodos usuais para os estudos de microfósseis calcários no Laboratório de Sedimentologia da UFPA e do MPEG envolvendo as seguintes etapas:

1) desagregação das amostras, na qual para calcários compactos foram utilizados o método de Acetólise o qual envolve a inserção de 30 g de sedimento em 100 ml de ácido acético 10% por 12 horas; posteriormente as amostras foram lavadas com água corrente e peneiradas (Rodrigues *et al.* 2011);

2) lavagem e peneiramento das amostras em água corrente utilizando-se as frações de malhas 500, 250 e 180 µm; e secagem em estufa a 60ºC;

3) pesagem do material seco padronizando em 6g para a análise quantitativa;

4) triagem das amostras das peneiras de malha 250 e 180 µm com auxílio de pincel 00 e estereomicroscópio da marca Zeiss;

5) colagem dos microfósseis (ostracodes) em Células Franke para ordenadamento em nível genérico;

6) contagem dos espécimens;

7) seleção dos melhores espécimens para serem fotografados: limpos com álcool e água deionizada, ou colocados no ultrassom;

8) preparação dos “stubs” com ostracodes colados com fita dupla-face para posterior metalização;

9) aquisição de microfotografias foram realizadas no (MEV) modelo LEO 1450VP do Laboratório do MPEG e no MEV do Smithsonian Institution;

10) Os espécimes tipo e figurados foram posteriormente tombados e armazenados na Coleção de Micropaleontologia do Acervo Paleontológico do MPEG.

4.5. IDENTIFICAÇÃO TAXONÔMICA

Para o levantamento bibliográfico dos ostracodes utilizou-se a coleção “Index of Non-Marine and Marine Ostracoda de Kempf” e o Catálogo de Ostracoda “Ellis Messina”. Para a classificação taxonômica seguiu-se o “Treatise” (Moore 1961), Morkhoven (1963) e as atualizações de Liebau (2005). O estudo taxonômico foi também auxiliado por amplo levantamento de publicações científicas especializadas. As coleções tipo de Bold e Howe (LSU, Baton Rouge) e o material tipo depositado em Smithsonian Inst. (NMNH) também foram consultados e utilizados para a comparação.

CAPÍTULO 5

5. ASPECTOS SEDIMENTOLÓGICOS DAS LOCALIDADES ESTUDADAS

As características gerais, e informações do tipo de exposição bem como as coordenadas das localidades são apresentadas na figura 5.1. A descrição detalhada de cada localidade estudada segue abaixo nos itens 5.1 a 5.5.

Município	**Ocorrência, tipo de afloramento/denominação**	**Informações gerais**	**Coordenadas**
Capanema	Frente de lavra/Mina B-17	Sucessão carbonática de até 12m passando no topo para os siliciclásticos da Formação Barreiras.	1º2’53.77’’S// 47º9’9.21’’O
São João de Pirabas	Falésia e lajedos/Ponta do Castelo na Ilha de Fortaleza	Sucessão carbonática de até 4m de espessura. Maior exposição durante a maré baixa.	0º40’59.19’’S// 47º10’14.47’’O
Maracanã	Falésia e lajedos/Aricuru	Sucessão carbonática de até 4m de espessura. Maior exposição durante a maré baixa. Os carbonatos estão em contato tectônico (falha normal com rejeito métrico) com a Formação Barreiras	0º42’46, 08”S// 47º30’7,2”O
Salinópolis	Lajedos/Praia do Atalaia	Sucessão carbonática de até 4m de espessura. Maior exposição durante a maré baixa e quando os níveis de erosão costeira são máximos.	0°35'37,01"S// 47°18'57,44” O
Primavera	Testemunho de sondagem/ FPR – 160.	Os testemunhos estão armazenados na litoteca do Grupo de Sedimentologia da UFPA.	(0°56'52.76"S// 47° 5'48.58”O)

Figura 5.1. Quadro com as principais informações das localidades estudadas.

5.1. LOCALIDADE DA MINA B-17, MUNICÍPIO DE CAPANEMA

A Mina B-17 está situada no Município de Capanema com aproximadamente 20 m de espessura exposta, sendo considerada um dos maiores depósitos do Brasil de rochas para produção de cimento e registrada no SIGEP (Távora *et al.* 2007) como sítio geológico e paleontológico. Para se ter acesso a Mina B-17 segue-se a rodovia BR-316 até Capanema tornando-se a direita pela PA-124 e deslocando-se até próximo ao km 11; virando à direita segue mais 5 km até a mina (Figs. 4.1).

A primeira interpretação paleoambiental para a Mina B-17 foi proposto por Góes *et al.* (1990), integrado ao modelo paleoambiental geral para a Formação Pirabas. A seção da mina é constituída por intercalações de areias, siltes e argilas caracterizadas pela presença de argilitos, camadas heterolíticas (*wavy* e lenticular) biocalcarenitos estratificados e não estratificados, margas, folhelhos, biocalcirruditos, e calcilutitos, sendo que as amostras mais basais (B0 a B2) apresentam biocalcirruditos com presença de fósseis inteiros dispersos, seguidos de arenitos calcíferos com presença de fósseis mais fragmentados e de vegetais. Os níveis B3 a B7 são arenitos com calcário e presença de muitos fragmentos fósseis dispersos seguidos de margas e folhelhos com presença de fragmentos de vegetais. Já, os níveis B8 a B11 são biocalcarenitos com estratificação cruzada (ação de onda) e laminação cruzada com presença de fragmentos de vegetais, seguidos por biocalcirruditos e argilitos silticos com concreções. Por fim, os níveis do topo (B12 a B13B) são depósitos com camadas heterolíticas do tipo *wavy* e lenticular com intercalações de arenitos e argilitos e presença de fósseis invertebrados dispersos e fragmentados mais ao topo (Fig. 5.2).

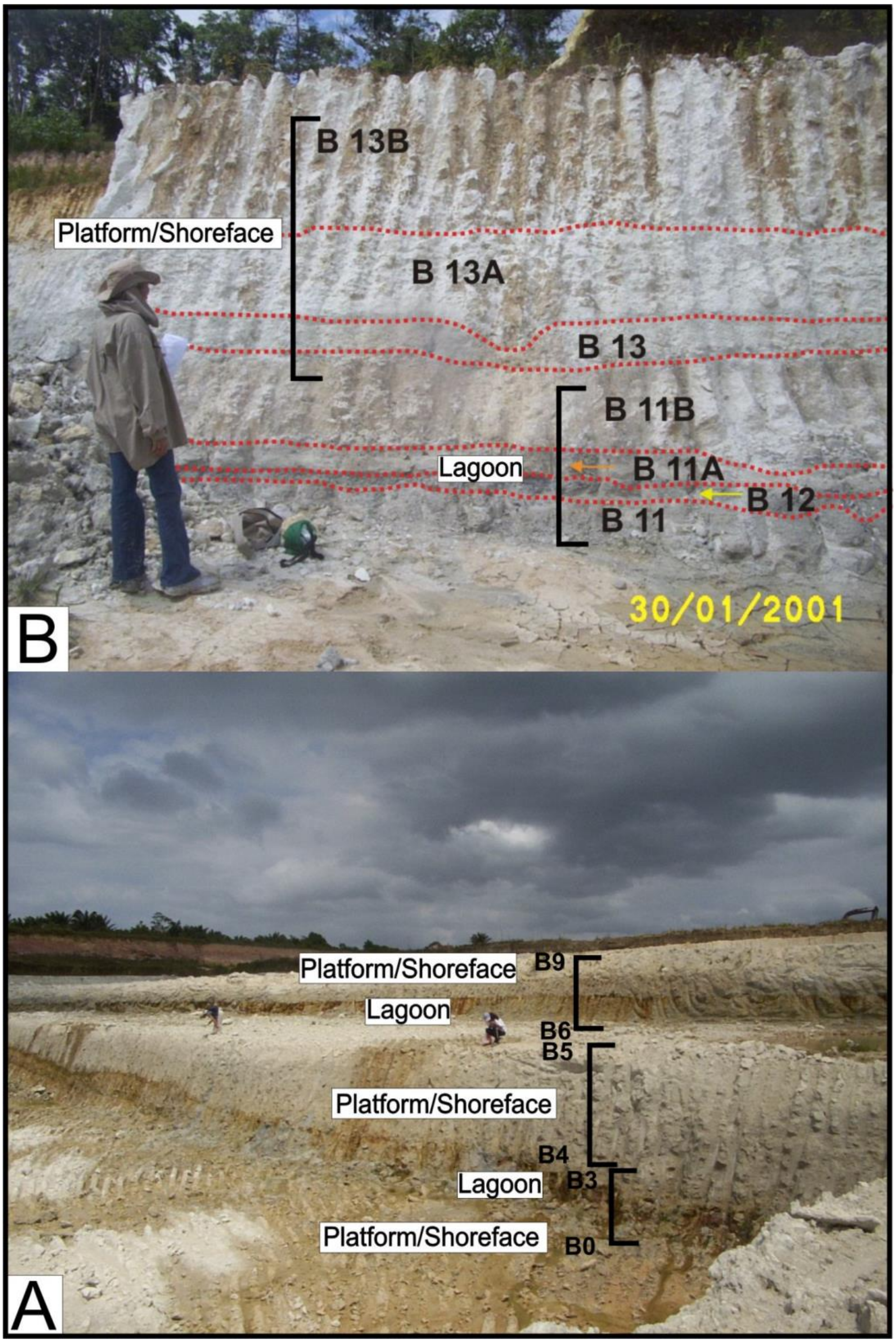

Figura 5.2 Depósitos carbonáticos expostos na Mina B-17, Município de Capanema. A) Camadas de margas intercaladas com biocalcirruditos e indicação dos níveis B0 a B9; e (B) Sucessão de margas e biocalcarenitos e níveis B11 a B13B.

5.2. LOCALIDADE DA PONTA DO CASTELO, ILHA DE FORTALEZA, MUNICÍPIO SÃO JOÃO DE PIRABAS

A seção tipo da Formação Pirabas está situada no litoral norte do Brasil, no Município São João de Pirabas, na localidade Ponta da Fazenda e está representada por uma exposição de 1,5 m de espessura (Távora *et al.* 2002) representando como uma extensão do afloramento Ponta do Castelo, onde as camadas apresentam estruturas sedimentares com biocalcarenitos estratificados na base com presença de marcas onduladas e laminações plano-paralelas (Fig. 5.3 B e C); o conteúdo fossilífero é fragmentado. A camada sobrejacente são biocalcirruditos maciços com conteúdo fossilífero rico e pouco bioturbados em que foi possível observar traços de icnofósseis em espiral (Fig. 5.3 D) e presença de gastrópodes e bivalves (*péctens*) inalterados (Fig. 5.3E). Segundo Costa *et al.* (1993) esse afloramente é o que apresenta mais calcarenitos estratificados.

A localidade Ponta do Castelo na Ilha de Fortaleza, foi alvo de coleta de amostras para o presente estudo (Fig.5.3A). Este afloramento é caracterizado por apresentar um pacote sedimentar, em geral, com aspecto erosivo e bastante intemperizado de camadas litológicas mais arenosas a calcário maciço, de tonalidade acinzentada a amarelada. A porção mais basal (PC-00 e PC-01) apresenta um biocalcarenito maciço bioturbado com presença de fósseis fragmentados dispersos, estrutura de laminação plano-paralela, marcas de ondas e *flaser*, um calcário médio amarelado e arenoso com presença de fósseis inteiros dispersos e fragmentos de crocodilianos. A porção média (PC-02) é caracterizada por uma camada de calcário médio acinzentado com intercalações de calcirruditos e presença de fósseis inteiros dispersos. Ao topo uma camada de biocalcirruditos (PC-03 e PC-4) apresenta-se com um arcabouço densamente fossilífero, presença de moldes internos bem preservados a exemplos gastrópodes como a *Turbinella tuberculata* (Ferreira 1970), pelecípodas, equinodermos, celenterados (*Flabellum*), briozoários, crustáceos, peixes, répteis (crocodilos) e mamíferos (sirenídeos). Esta camada está sujeita a ação erosiva das ondas e pela variação da maré (Fig. 5.3A).

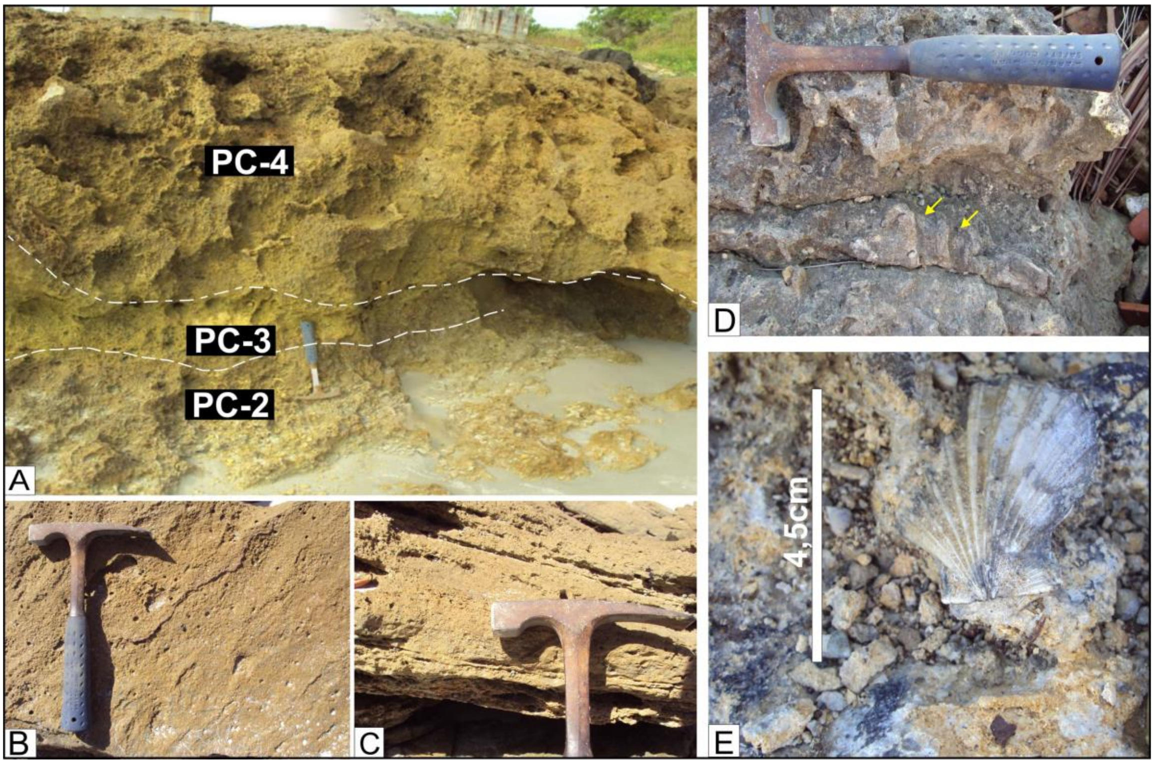

Figura 5.3. Afloramentos da Ilha de Fortaleza; (A) Localidade Ponta do Castelo (PC) com detalhe dos níveis PC-2 a PC-4 amostrados; (B-E) Localidade Ponta da Fazenda; (B) biocalcarenitos com marcas onduladas em planta; (C) laminação plano-paralela; (D) bioermito com traços de Icnofóssil em espiral, e (E) Presença de pectenídeos.

5.3. LOCALIDADE DE ARICURU, MUNICÍPIO DE MARACANÃ

O afloramento está situado a 2 km NNW do Município de Maracanã, e está representado por uma exposição de 50 m de extensão e 3,5 m de espessura (Távora 1992). Os pacotes mais am topo (AR-1 a AR-3) iniciam com um biocalcarenito mais friável amarelado, um *hardground* mais compactado e bioturbado de cor amarelada, gradando para uma marga amarelada rica em fósseis inteiros e ainda em posição de vida (ver Fig. 5.4B), e finalmente um *hardground* calcário compactado, bioturbado e amarelado (Fig. 5.4A). A porção mais basal e média do afloramento (AR-4 a AR-6) consiste de um calcário acinzentado, argila amarelada e acinzentada contendo fragmentos de vegetais carbonizados; biocalcarenito *hardground* acinzentado bastante fossilífero com presença de icnofósseis (principalmente de *Thalassinoides*, ver Fig. 5.4D) e invertebrados dispersos e incrustados (ex. caranguejo, ver Fig. 5.4C), bioturbado de coloração cinza escura. Além de pelitos mais arenosos acinzentados com abundantes fragmentos de vegetais carbonizados.

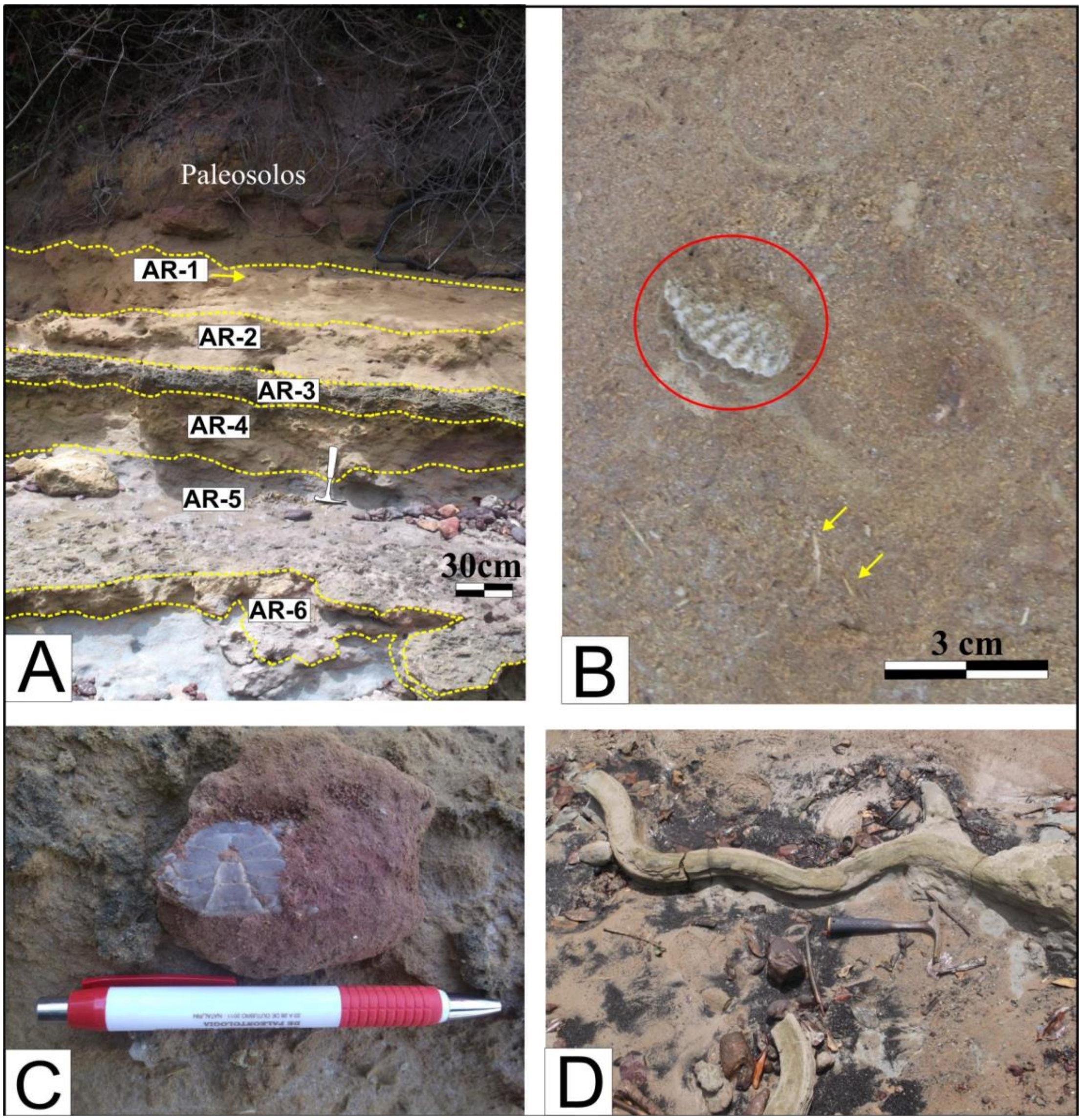

Figura 5.4. Aspectos faciológicos da localidade de Aricuru, Município de Maracanã (AR): (A) níveis estratigráficos diferenciados por margas e calcarenitos (AR-1, 2 e 4) e biocalciruditos formando *hardgrounds* (AR-6, 3); (B) bivalves inteiros (pécten) em posição de vida e conchas fragmentadas em calcarenito (nível AR-1); (C) crustáceo decapoda (Brachyura); e (D) icnofóssil horizontal endicnial produzido por artrópode.

5.4. LOCALIDADE DA PRAIA DO ATALAIA, MUNICÍPIO SALINÓPOLIS

A porção mais basal é constituída pela fácies biocalcirrudito (Bm), com abundantes equinodermas; bivalves e sirenídeos (Figs. 5.5 A, B e D). No entanto, esta porção basal está em contato brusco com a porção média a qual apresenta as fácies de argilito com siltito (ArS). Ao topo, esta porção está também em contato brusco com o bloco de biocalcirrudito e acima deste com a fácies de folhelho negro na porção superior. A porção interna da plataforma, possivelmente foi limitada por ilhas barreiras ao longo da costa, proporcionando a formação de lagunas e mangues, sendo estes depósitos representados por margas (Ma) e folhelhos (Flh), além de calcilulitos, e biocalcarenito não estratificados (Fig. 5.5). Os depósitos de mangue podem ter se formado atrás das ilhas barreiras ou adjacentes à costa, provavelmente acumulando-se em depressões suaves e descontínuas, inerentes à própria topografia (Góes *et al.* 1990). Paleossolos lateríticos colunares desenvolveram-se localmente sobre exposições do nível de biocalcirrudito maciço. Também ocorrem calcários interestratificados com argilas ricas em restos de vegetais (Fig. 5.5 C), muitas vezes piritizados.

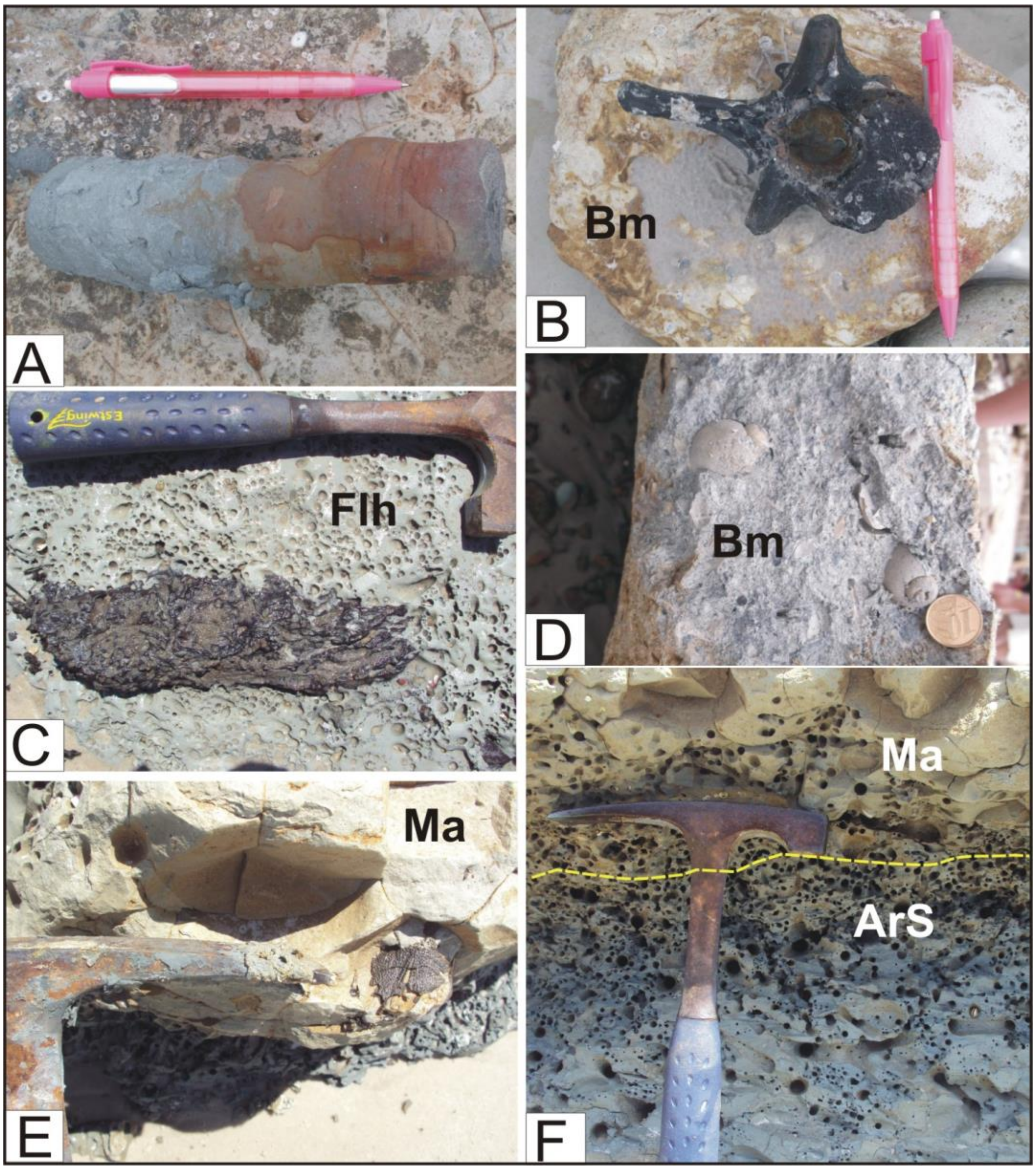

Figura 5.5 – Detalhes do Afloramento de Atalaia: (A) Fragmento de *Thalassinoides*; (B) Vertebra de sirênios; (C) Restos de vegetais piritizados em argilitos (ArS); (D) Gastrópodes presentes no nível AT -02 de biocalcirrudito maciço (Bm); (E) Crânio de *Bagre* nas margas (Ma), e (F) Contato entre o argilito e a marga (Ma).

5.5. FURO DE SONDAGEM (FPR – 160), MUNICÍPIO DE PRIMAVERA

O Município de Primavera situa-se nas proximidades do Município de Capanema. O testemunho de sondagem FPR – 160 está aproximadamente à 2 km de distância desse Município de Primavera (Fig. 4.1). As porções mais basais do testemunho de sondagem são constituídas por um embasamento de litosolos alterados com coloração verde e presença de mica (muscovita) além de uma brecha de matriz carbonática; calcário fino, de coloração cinza com intercalações de marga de coloração verde, com aspecto laminado. Os pacotes sedimentares na porção média do testemunho são um calcário fino de coloração cinza com pequenas intercalações de margas e um calcário médio de coloração cinza, fossilífero, friável. Ao topo, tem-se um pacote sedimentar consistindo de um calcário fino a médio, de coloração cinza esbranquiçada e amarelada, intercalado com marga, pouco a muito fossilífera e friável; uma porção de argilito de coloração marrom e esverdeada pouco arenosa; e uma areia fina moderadamente selecionada de coloração escura, pouco argilosa (Fig.5.6).

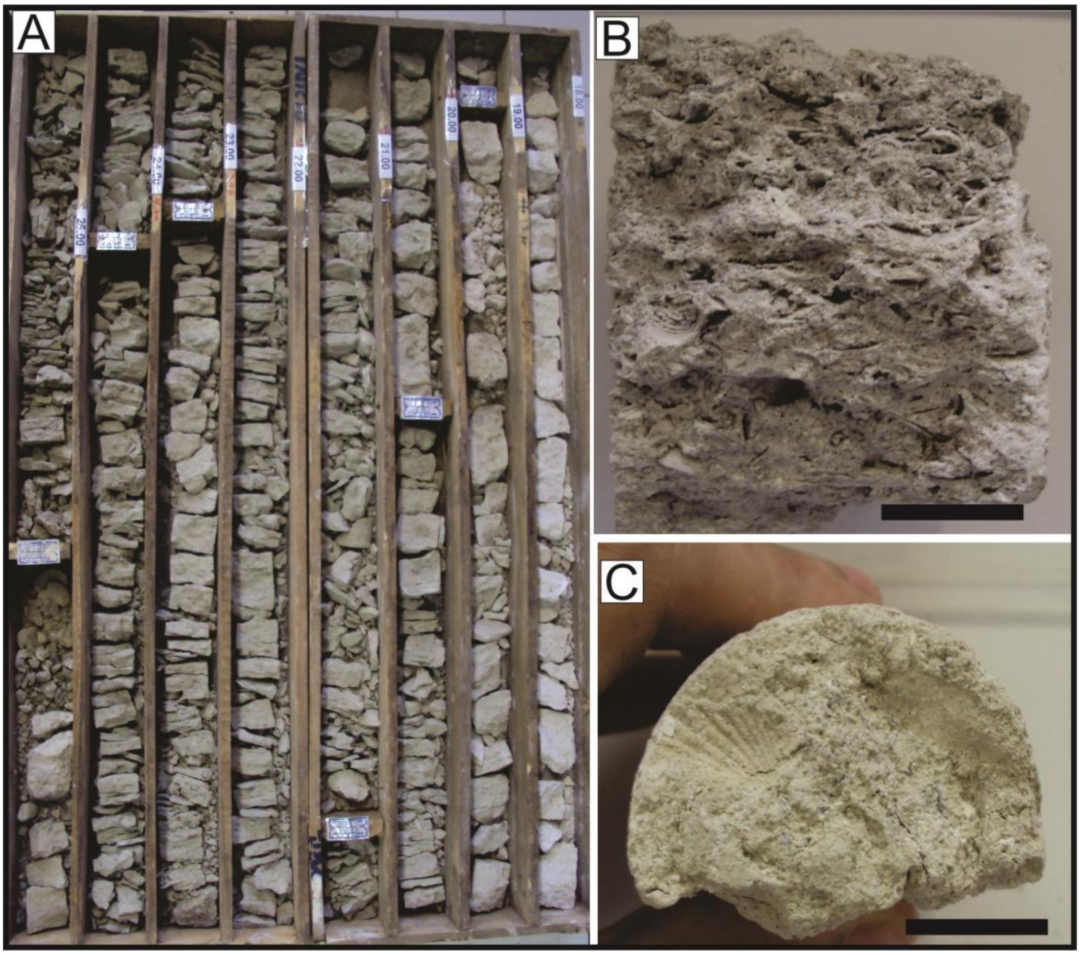

Figura 5.6. Aspectos faciológicos do testemunho de sondagem FPR – 160. A) Intervalos dominados por marga laminada; B) e C) Amostras de biocalcirudito em seção longitudinal e transversal exibindo conchas fragmentadas. Barra= 3 cm.

CAPÍTULO 6

6. THE GENUS *PERISSOCYTHERIDEA* STEPHENSON, 1938 (CRUSTACEA-OSTRACODA) AND EVIDENCE OF BRACKISH WATER FACIES ALONG THE OLIGO-MIOCENE, PIRABAS FORMATION, EASTERN AMAZONIA, BRAZIL.

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ABSTRACT

The genus *Perissocytheridea* is characteristic of brackish water facies and has a wide paleobiogeographical occurrence and stratigraphic distribution ranging from the Cretaceous to Recent. It has already been recorded in the northern of South America, especially in the Neogene of Solimões Basin, but this is the first report to the Oligo-Miocene deposits of Pirabas Formation, Northern Brazilian coast, Pará State. The layers with frequencies and abundances of *Perissocytheridea* coincide with the occurrence of foraminifera *Elphidium* and *Ammonia* in the studied sections supporting the presence of the brackish water facies to the respective layers. Their quantitative variation through the studied sections indicate more than one phase of salinity reduction and/or the decrease of the sea level, forming lagoon along the Pirabas Formation. Among the eleven *Perissocytheridea* species identified, four are new: *P. punctoreticulata* n. sp., *P. largulateralis* n. sp., *P. colini* n. sp. and *P. pirabensis* n. sp.; five species in open nomenclature: *Perissocytheridea* sp. 1, *P.* sp. 2, *P.* sp. 3, *P.* sp. 4, and *P.* sp. 5 and two species left in "aff." abbreviation: *Perissocytheridea* aff. *P. pumila* and *Perissocytheridea* aff. *P. brachyforma* subsp. *excavata*.

Key words: Ostracods; *Perissocytheridea*; Pirabas Formation; Oligo-Miocene; Brazil.

6.1. INTRODUCTION

The Oligo-Miocene Pirabas Formation represents a densely fossiliferous carbonate succession, discontinuously exposed along of the Northern Coast of Brazil. This unit was discovered by Ferreira Penna (1876) and designated of “Pirabas” by Maury (1925) in the Fortaleza Island, considered the type locality. Based on paleontological and sedimentological data, the Pirabas Formation was interpreted as lagoon, mangrove, swamps and outer to restricted platform deposits (Ferreira 1977; Ferreira and Fernandes 1987; Góes *et al.* (1990), Rossetti and Góes (2004) and Rossetti 2006, Rossetti and Góes 2004).

Paleontological data is concentrated in the invertebrate macrofauna and subordinately in vertebrates and microfossil. Foraminifera and ostracod were described locally in outcrops and some core focusing mainly taxonomic studies (Petri 1952; 1954; 1957; Macedo 1971; Ferreira *et al.* 1981, 1984; Távora 1994a, 1994b, 1994c, Ramos *et al.* 2004a), some authors focused in dating the Pirabas unit spite of the most these studies not presents a stratigraphic control more confident due to use of boreholes rather than drill cores (Petri 1957, Fernandes 1984; 1988; Fernandes and Távora 1990). Moreover, all these also contributed for paleoenvironmental interpretations as shallow, clean and hot waters. In a more recent study of ostracods from the Pirabas Formation, Nogueira *et al.* (2011) showed the stratigraphical distribution of *Haplocytheridea* and *Cytheridea* genera in the upper part of Pirabas Formation correlated these levels with progradational cycles linked to the Miocene transgressive-regressive events of the Northeastern South America, in agreement with Fernandes (1984) and Távora *et al.* (2007).

Although there are advances in the stratigraphic and biostratigraphic studies providing a general knowledge of paloenvironment and age, a refined taxonomic study still is necessary to expand these informations in the Pirabas Formation. Among the ostracods genera recorded to this unit, *Perissocytheridea* is one of the most representative of transicional environments (lagoons, bays and estuaries). The number of *Perissocytheridea*’s species recorded to Neogene in both South and Central America is relatively large (see the following papers and references therein: an extensive list of species related by Bold (1946, 1975a and b, 1981); Ornellas and Pinto 1970; Zabert 1978; Purper 1979; Sheppard and Bate 1980; Muñoz-Torres *et al.* 1998 and Nicolaides and Coimbra (2008). Its occurrence has been very important to indicate transitional environments and brackish water facies with salinity fluctuations. This article describes new species of the genus *Perissocytheridea*, and presents the paleoenvironmental significance to the Pirabas Formation sections (outcrops and core) located at about 35 km from the town of Belém, Pará State, in the Bragantina plataform, northeastern coast of Brazil (Fig. 6.1).

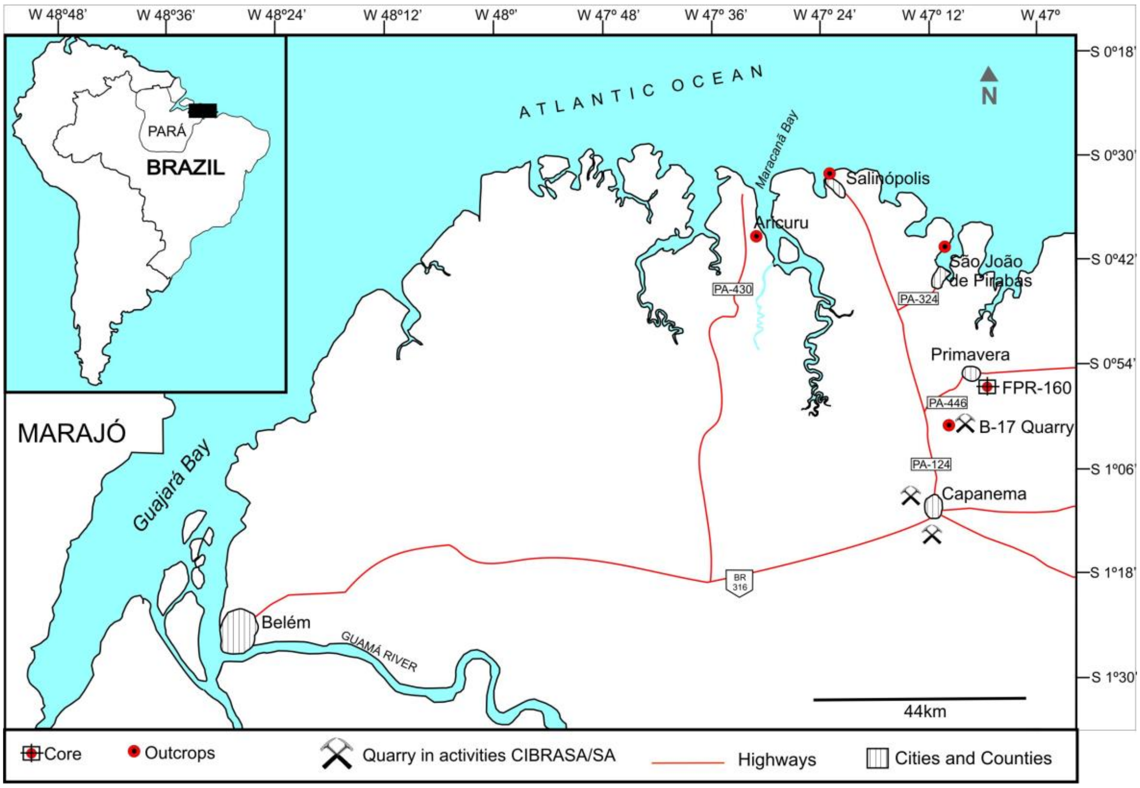


Figure 6.1 – Location of the studied areas from Northern Equatorial margin of Brazil (Google Earth 2014).

6.2. GEOLOGIC SETTING AND AGE

The northeastern region of Brazil, especially in Pará and Maranhão States, a set of different deposits ranging from Cretaceous until the Holocene occur (Fig.6.2A). More specifically in northeastern Pará approximately five sedimentary basins are recognized: Cametá basin, Mexiana basin, Pará-Maranhão basin, Limoeiro basin, and graben Vigia-Castanhal (Fig.6.2A). The Bragantina and Pará platforms correspond to areas of the basement that remain tectonically stable between sedimentary basins. The Pará platform corresponds to a broad area that is little explored, encompassing the eastern portion of the Marajó Island, extending *offshore*, where it is intercepted by Vigía-Castanhal trough. Its boundaries correspond to Mexiana sub-basin northeast, southeast Limoeiro trough, Pará-Maranhão basin to the southeast. However, the Bragantina platform is well defined, corresponding to two flattened areas located on both sides of the Vigía-Castanhal trough. Farther west sector is limited by Cametá south sub-basin, Pará platform west and by extension to north of Vigia-Castanhal trench. The basement this platform is recorded by igneous and metamorphic rocks and Paleozoic sandstones in the São Miguel do Guamá. Deposition on Bragantina platform consists exclusively of Tertiary deposits formed from the Oligo-Miocene, reaching thicknesses generally less than 60 m (Rosseti and Góes 2004).

The studied area is situated in the Bragantina platform, Pará State, north of Brazil where the crystalline basement occurs near the surface (Fig. 6.2A). Natural exposures are rare in this area, but there are open mines and boreholes that offer access. The area is represented mainly by the carbonate rocks of the Pirabas Formation that are exposed discontinuously superposed, at the top of the succession, by around 3 m of siliciclastic rocks from the Barreiras Formation (Rossetti and Góes 2004). The Pirabas Formation is exposed along the coastal cliffs of northern Brazil and along roads and open-cast mines of the State of Pará, as well as of the States of Maranhão and Piauí (Rossetti and Góes 2004) and it is characterized by a complex association of facies, reflecting platform (inner to outer shelf) to coastal/transitional environments, including lagoons and mangroves (Góes *et al.* 1990). The mixed of siliciclastic-carbonate sediments from Barreiras and Pirabas Formations are interpreted as a related depositional sequences. Although facies organization records transgressive events, the distribution of stratal architecture indicates an overall progradational pattern. This is revealed by the superposition of the inner shelf with progressively more coastal environments (Góes *et al.* 1990), which resulted in increased input of siliciclastic lithologies (Rossetti *et al.* 2013).

Essentially, the sedimentary sequence of Pirabas Formation was accumulated in low-energy waters, although the presence of *hummocky* structures and glauconite indicates storm waves events (Rossetti and Góes 2004). The presence of tidal channels, lagoons and tidal deltas also suggest a nearshore to shallow marine transitional platform environment (Rossetti 2006). The analysis facies of this unit were interpreted based on previous works in which the paleoenvironmental context is closer to be a logoonal and estuarine over time according to the fossil record in general. Moreover, a recurrent progradacional process is distributed along the strata extending the *shorelines.* This pattern was also observed in the study by Nogueira *et al.* (2011) with the association of two ostracoda genera and the fossil assemblage that indicated a cycles of shallow marine (nearshore) to transitional (brackish water) setting, which resulted by the influx of freshwater from the continent and /or sea level negative oscilations. According to the most geological studies this is revealed by the superposition of the inner shelf with progressively more coastal environments to the top of the unit (Góes *et al.* 1990).

As previously mentioned, the sea level changes are recorded and marked by variations in the fossiliferous content and in the depositional setting within the Pirabas Formation, as observed in various locations of the Pará State (Góes *et al.* 1990; Távora and Fernandes 1999; Rossetti 2000; Nogueira *et al.* 2011). The Pirabas unit was firstly dated based on the presence of the gastropod species *Orthaulax pugnax* (Maury 1925), bryozoans (*Cupuladria*) and foraminiferal assemblages, which are comparable of those recorded in Oligo-Miocene strata of the Caribbean region (Ferreira *et al.* 1978). Furthermore, Petri (1957) and Fernandes (1984) found planktonic foraminifera of the Lower Miocene, including *Globigerinoides primordius*, *Globigerinoides aliaperturus* and *Globigerinoides trilobus trilobus*. Other important index species of planktonic foraminifera are also recorded in the Oligo-Miocene interval; *Globorotalia kugleri*, *Globorotalia opima* and *Globoquadrina dehiscens* have been recovered from three boreholes in the Bragantina region and one from Belém. This planktonic foraminifera association allows the correlation of the Pirabas Formation to the Early Miocene global biozones N4 and N5 (Blow 1969; Ferreira *et al.* 1978; Fernandes 1988). Studies throughout the Bragantina Zone (Capanema and Maracanã) and Belém support this age (Fernandes and Távora 1990; Távora and Fernandes 1999). In a more recent study of the ostracods from Pirabas Formation, a new biozonation is proposed corroborating to the Oligo-Miocene age to the unit (Nogueira and Ramos, in prep.).

One of the studied sections is exposed in the B-17 quarry (01º16’53’’S – 47º13’09”O) located near the PA-124 road (Fig. 6.2A and C) in the Capanema County. This section has about 20m thick and it is composed of limestones, sandstones, shales and marls. The other studied section is the core FPR-160 (0 ° 56'52, 76 "S - 47 ° 5'48, 58" W) has 45 m depth and approximately 2 km away from the Primavera county (Fig. 6.2A and D). The basal portions of the core comprise a modified basis, with presence of green mica (muscovite) and a rift of carbonate matrix; thin limestone interbedded with gray marls and greenish portions with laminated appearance. In the middle portion presents a fine gray limestone with small marls and a medium gray limestone, fossiliferous. At the top, there is a thin middle, whitish, yellowish gray limestone, interbedded with marl, and a small middle bed of afriable fossiliferous and gray limestone; a portion of brown, green and sandy clay; and a fine sand selected dark and slightly clay (Source: Votorantim Cement 2013).

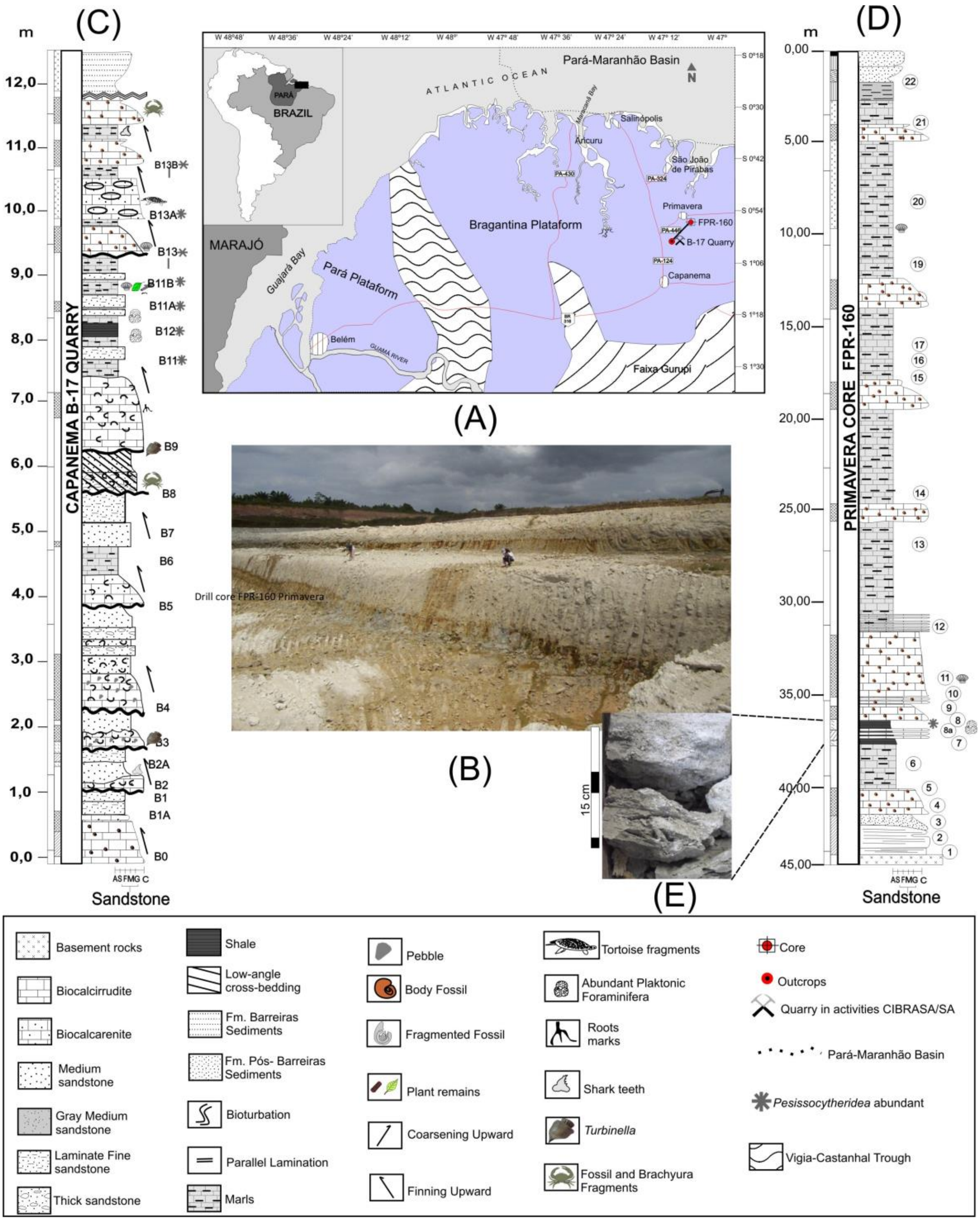


Figure 6.2. Geological and stratigraphic settings of northeast from Pará State: (A) distribution of neogene deposits (grey color) and basement units of Gurupi Belt (dott texture) with indications of studied localities; (B) overview of the B-17 quarry in the Pirabas Formation; (C) B-17 quarry composite section with the location of samples; (D) drill core FPR-160 Primavera composite

section with the location of samples for paleontological (ostracods) analyses; and (E) sample of shale with fine laminations from drill core FPR-160 Primavera.

6.3. MATERIAL AND METHODS

The study material is composed of fifty seven samples (seven barrel samples) collected along of five different sections of the Pirabas Formation: twenty three samples are from the core FPR-160, in Primavera city, and the others thirty four are from the following sites (Fig. 6.1): B-17 quarry (nineteen samples), Ponta do Castelo (Fortaleza Island; five samples), Aricuru (Maracanã bay; six samples) and Atalaia (Salinópolis; four samples).

Samples were processed according to standard methods for calcareous microfossils in the Polishing Laboratory of the Museu Paraense Emílio Goeldi (MPEG) and Laboratório de Sedimentologia from Universidade Federal do estado do Pará (UFPA), Brazil; water bath was used to facilitate the desintegration of samples. Also the acetolysis method was used to desintegrate hardrocks samples from the Fortaleza Island and Atalaia sites, which method involves the insertion of 30g of sediments in 100 ml (10%) of acetic acid for 12 hours. The samples were washed subsequently with deionized water and sieved (Rodrigues *et al.* 2011). The ostracods were picked from the 0.250 mm sieve mesh using a Zeiss Stereo Microscope. Micrographic images were taken using LEO model 1450VP Scanning Electronic Microscope at Museu Paraense Emílio Goeldi (MPEG), Pará, Brazil and also PHILIPS model / FEI (XL30) Scanning Electron Microscope (SEM and ESEM) at Smithsonian Institution National Museum of Natural History (NMNH).

All figured specimens are housed in the collection of the Museu Paraense Emílio Goeldi, Belém (Inv. No. MPEG-515-M to MPEG-548-M). The bibliography survey for taxonomic classification was based on the “Index of Non-Marine and Marine Ostracoda” of Kempf (1986), “Ellis and Messina” Catalogue (1965) and a numbers of specialized bibliographies, mainly papers of Bold since 40s to 80s were also used.

To the taxonomic comparisons, the type material of the Howe Collections (HVH, Louisiana State University Museum), as well as the type material of the Bold (Louisiana State University Museum) and type-material stored at the Smithsonian Institution (US Natural History National Museum) also were examined: *Perissocytheridea alata* Bold, 1970 (HVH8727) and the species *Perissocytheridea cribrosa* (Klie 1933) (HVH10939) compared in the present study.

6.4. RESULTS

Eleven species of the genus *Perissocytheridea* were described as cited previously, and suprageneric classification follow Liebau (2005). Abbreviations were used: C= carapace; RV = right valve; LV = left valve; H: height, L: length and W: width (in the text and plate legends).

6.4.1. Systematic Paleontology

Subclass OSTRACODA Latreille, 1806
Order Podocopida Sars, 1866
Suborder Cytherocopina Gründel, 1967
Infraorder Nomocytherinina Liebau, 1991
Superfamily Cytherideoidea Liebau, 2005
Family Cytherideidae Sars, 1925
Subfamily Perissocytherideinae Bold, 1963
Tribu Perissocythereidini Van den Bold, 1963
Genus *Perissocytheridea* Stephenson, 1938
Perissocytheridea punctoreticulata n. sp.
Pl.6.1; figs. 1-8

Material: 2 carapaces and 11 valves.

Etymology: Latin, *punctae*= punctuation, refers to the strong punctuation of the surface; *reticulum* = reticles, refers to the discret reticulation in the central portion of the carapace.

Holotypes: MPEG-515-M, Female, C; LV: L: 0.47 mm and H: 0.25 mm; RV: L: 0.46 mm and H: 0.24 mm, sample B12. MPEG-516-M, Male, C; LV: L: 0.48 mm and H: 0.24 mm; RV: L: 0.47 mm and H: 0.23 mm; Dorsal: L: 0.25 mm and W: 0.50 mm, sample B12.

Paratypes: MPEG-517-M, RV: L: 0.50 mm and H: 0.26 mm, sample B12. MPEG-518-M, LV: L: 0.44 mm and H: 0.24 mm, sample B11A.

Diagnosis: Ornated with primary and secondary reticulations, more punctated in the anterior region; 3 to 4 tansversal ridges in the posterodorsal region and two or three straight longitudinal rigdes extended from the central to the posteromedian region.

Description: Carapace medium and subrectangular. LV slightly overlap the RV. Maximum height at the antero median region. Dorsal margin almost straight in lateral view and sinuous to slightly convex in the area coincident with the median shallow sulcus. Ventral margin slightly convex in both valves, upturned in the end. Anterior margin slightly rounded and slightly truncated in the anterodorsal region. Posterior margin narrow, slightly truncate to afilated, turned downward with caudal process more evident in the females. Dorsal view subelongate, larger in the posteromedian portion with alar processes evident; strong marginal border. Surface ornated with primary and secondary reticulations, more punctated in the anterior region; reticles with muri rounded, more strongly marked in the median region; two or three straight longitudinal rigdes extending from the central to the posteromedian region. Additional 3 or 4 delicate transversal ridges mainly in the posterodorsal region. Ventral rigde discret or discret alar process. It presents two lateral sulci, beginning in the first-third of the dorsal margin: one very short and shallow running parallel to the anterior margin and another very discret, almost straight running downward and reaching the ventral ala. Border discrete, compressed in the anterior and posterior margin. Ocular tubercle discret, smooth in the surface. Internal features typically of the genus. Sexual dimorphism present: females shorter, higher and with a caudal process more pointed than males.

Remarks: the species here described is closest to the species is *Perissocytheridea largulateralis* n. sp. described herein, but differs with a more punctuate and delicate carapace, subrectangular and more elongate in lateral view; ornamentation pattern more weackly reticulated in the posteromedian region, ocular tubercle less evident and consequently the sulcis are swallower than in the *P. largulateralis*.

Occurrence: B-17 quarry, Capanema, Pará (samples B11, B12 and B11A); drill core FPR-160 Primavera (sample AM.08). These samples are composed of gray shales and marls characterized in this paper as samples that arise within the brackish water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará State, Brazil.

Perissocytheridea largulateralis n. sp.

Pl.6.1; figs. 9-17

Material: 32 carapaces and 48 valves.

Etymology: Latin, *largu* = broad, large; due to the broad and robust carapace; *lateralis* = lateral; refers to the be robust carapace in lateral view.

Holotype: MPEG-519-M, Female, C; LV: L: 0.48 mm and H: 0.30 mm; RV: L: 0.50 mm and H: 0.28 mm; dorsal view: H: 0.49 mm and W: 0.28 mm, sample B13.

Paratypes: MPEG-520-M, Male, C; LV: L: 0.59 mm and H: 0.30 mm; RV: L: 0.56 mm and H: 0.28 mm; dorsal view: H: 0.54 mm and W: 0.30 mm, sample B11A. MPEG-521-M, LV: L: 0.55 mm and H: 0.28 mm, sample B12. MPEG-522-M, RV: L: 0.49 mm and H: 0.25 mm, sample FPR-160 core, AM. 8.

Diagnosis: Carapace subquadrangular, widely rounded and robust in lateral view. Heavy, strong and coarse ornamentation. Surface with two sinuous longitudinal ridges extending from the central to the posteromedian region. Evident alaform ventral rigde.

Description: Carapace medium, subquadrate and robust, in lateral view. LV slightly overlapping the RV, mainly in the anterodorsal region. Dorsal margin relatively short and slightly sinuous, more angulated in the females; cardinal angles slightly evident. Ventral margin nearly straight with a discret oral concavity in both valves. Anterior margin widely rounded, extended below, truncate above. Posterior margin narrow and subacute with a small caudal process in the middle point in the lateral view. Midventrally a pronounced alarform ridge overlaps this margin forming a alar process. Maximum height at the anteromedian region, coincident with the ocular tubercle position. Surface strongly reticulated; more weakly punctated in the extremities, mainly in the anteromedian region. Surface with two sinuous longitudinal ridges arched in the middle. Ventrolaterally, one strong celated longitudinal alaform rigde forming the alar process. Ocular tubercle evident. Edge slightly pronounced smooth in the dorsal extremities in dorsal view and with a fine marginal border. A short and relatively deep antero transversal sulcus, behind of the ocular tubercle running downward parallel to the anterior margin. Median sulcus almost absent. Marginal rigde extending for all free margin. Sexually dimorphic: females are shorter and higher than males in side view. C shape differs in both, females are more subovate and males subrectangular to subelongate. Internal features typically of the genus.

Remarks: this species is similar to *Perissocytheridea pirabensis* n. sp. mainly in the size, but differs in many aspects. Posteroventral region is slightly less turned up with more weakly marked cardinal posterior angle; ornamentation pattern mainly in the anterior region is almost smooth than reticulate, and the anterio sulcus shorter and less evident; central ridges more strongly marked.

Occurrence: B-17 quarry, Capanema, Pará (samples B1A, B2, B2A, B6, B11, B12, B11A, B11B, B13, B13A and B13B); core FPR-160 Primavera (sample: AM.08). These samples are composed of gray shales, and marls characterized in this paper as samples that arise within the brackish water facies; others sediments type presents laminate fine sandstone, medium sandstone, gray shales, marls, biocalcarenite and biocalcirrudite described within the brackish water and more saline water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará State, Brazil.

Perissocytheridea colini n. sp.

Pl.6.2; figs. 1-6

Material: 4 carapaces and 2 valves.

Etymology: In honor of Prof. Jean-Paul Colin for his contributions to the study of the fresh and brackish water ostracods.

Holotypes: MPEG-523-M, C; LV: L: 0.36 mm and H: 0.21 mm; RV: L: 0.36 mm and H: 0.19 mm, sample B11. MPEG-524-M, C, dorsal view: H: 0.35 mm and W: 0.17 mm, sample B11A.

Paratypes: MPEG-525-M, C, juvenile; LV: L: 0.33 mm and H: 0.16 mm; RV: L: 0.32 mm and H: 0.16 mm, sample FPR-160 core, AM. 8. MPEG-526-M, RV: L: 0.39 mm and H: 0.19 mm, sample FPR-160 core, AM. 8.

Diagnosis: small, thick-shelled and subovate carapace. Midventrally surface bears one alaform ridge with a knob in the end. A remarkable sulcus lies in almost dorso-median region, strongly marked in the females. Surface finely punctate; solae smooth.

Description: small, thick-shelled, and subovate carapace in adult forms and subrectangular in the juveniles forms. LV slightly overlap the RV. Dorsal margin nearly straight in the LV, sinuous in the RV due to the convexity in the middle point coincident with the median sulcus, more evident in the females than in the males. Ventral margin almost straight with a discret anteromedian concavity in both valves; Anterior margin widely rounded, larger in the female than in the males; extended below, truncate above. Posterior margin truncate in dorsal and slightly pointed ventrally in the female and more elongate in the males with a very short caudal process sloping downward. Maximum height at the antero-median region. Surface finely punctuate almost smooth; solae smooth regularly for all surface, with flat margens. A remarkable sulcus at the mid-length lies from the dorsomedian to the central of carapace, more evident in the RV and in the females; slightly swallow immediately posterior to the sulcus. Antero dorsal sulcus discret. Dorsal view tumid in the mid-posterior portion and sub-acute extremities with short and smooth border. Midventrally surface bears one evident alaform ridge and posterior inflation with a knob in the end. Internal features typically of the genus.

Remarks: this species is similar to *Perissocytheridea alata* Bold, 1970 (HVH8727), however differs in the more truncate and tapered posterior end with subpyriform C, beyond the straighter dorsal margin. The lack of ornamentation sets in *Perissocytheridea cahobensis* Bold, 1981 resembles most others species studied here, but it differs for presenting a prominent sexual dimorphism, with slight difference in shape and larger size.

Occurrence: B-17 quarry, Capanema, Pará (samples B4, B11 and B11A); drill core FPR-160 Primavera (sample AM.08). These samples are composed of gray shales, marls, laminate fine sandstone and biocalcirrudite described within the brackish water and more saline water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará State, Brazil.

Perissocytheridea pirabensis n. sp.

Pl. 6.2; figs. 7-17 and Pl.6.3; figs. 1-5

Material: 8 carapaces and 113 valves.

Etymology: in reference to its restrict occurrence in the Pirabas Formation.

Holotypes: MPEG-527-M, Female, C, LV: L: 0.46 mm and H: 0.26 mm; RV: L: 0.43 mm and H: 0.22 mm; dorsal view: H: 0.48 mm and W: 0.23 mm, sample B12. MPEG-528-M, Female, LV, L: 0.46mm, H: 0.26mm; RV: L: 0.43 mm and H: 0.22 mm, sample B11B. MPEG-529-M, Male, LV: L: 0.51 mm and H: 0.23 mm; RV: L: 0.49 mm and H: 0.22 mm, sample B11A.

Paratypes: MPEG-530-M, C; LV: L: 0.47 mm and H: 0.23 mm; RV: L: 0.47 mm and H: 0.21 mm; dorsal view: H: 0.48 mm and W: 0.23 mm, sample B13B. MPEG-531-M, Female, C, LV: L: 0.41 mm and H: 0.23 mm; RV: L: 0.45 mm and H: 0.25 mm; dorsal view: H: 0.42 mm and W: 0.23 mm, sample B13B. MPEG-532-M, Female, C, LV: L: 0.47 mm and H: 0.26 mm; RV: L: 0.44 mm and H: 0.26 mm, sample B11A. MPEG-

533-M, Male, C, LV: L: 0.43 mm and H: 0.21 mm; RV: L: 0.40 mm and H: 0.19 mm; dorsal view: H: 0.49 mm and W: 0.28 mm, sample B13B.

Diagnosis: two to three small dorsal vertival rigdes in the anteromedian region, deep and transversal antero median sulcus lies to about one third of the middle hight. Surface coarsely reticulated with few secondary reticulations between the ridges. Ventrolaterally, two longitudinal ridges in the median region and one discret alaform process.

Description: carapace medium, subquadrate to subrectangular, in lateral view. LV larger than RV, overlapping slightly in the margins. Dorsal margin nearly straight, sinuous in the male. Ventral margin convex to sinuous, slightly concave in the ventro-anterior, strongly angulated and upwards in the postrior. Anterior margin widely rounded, extended below, slightly truncate above. Posterior margin narrow, angulated and subacute with a pointed and short caudal process in the middle region. Maximum height at the anteromedian region. Surface coarsely reticulated with few secondary reticulations between the ridges mainly in the anterior region. Anterodorsal region smoother and with a discret ocular tubercle. In the dorsomedian region two or three short ridges extending below; the median rigde is deeper and longer than the others extending to the central area meeting the upper longitudinal rigde; subsequent to the ridges two to three small, deep and transversal sulci lies in the anteromiddle position, extendeding from the dorsal to 1/3 of middle height, more visible in the males than in the females; in the anterior region, parallel to the anterior margin and behind of the discret ocular tubercle, other shorter, very shallow and discret sulcus. In the central region two longitudinal rigdes extending parallel to each other from the median to the posterior median region. The third rigde is shorter and extend from the ventro-median, turning up and join the median longitudinal rigde in the posterior quarter. Ventrolaterally, three longitudinal ridges runn from the anterior to posterior region where meet the discret alar process. The upper rigde extending from the anterior margin to the posterior where upturned and meet the median longitudinal rigdes. The median ridge is shorter than others. Sexually dimorphic: females are shorter and higher than males in lateral view, but probably the male illustrated here is a juvenile specimen. Internal features apparently typical of the genus. Inner lamellae of moderate width, broadest anteriorly; line of concrescence and inner margin considerably separated; canals pore sieved are few and widely spaced and are represented by rather large pits on interior and exterior valve surface. Dorsal view with anterior end subrounded and posterior end acute.

Remarks: this species is closest to *Perissocytheridea largulateralis* n. sp. (Pl.6.1; Figs.9-17) for having similarities in the shape of female carapace, but differs in the dorsal margin of the *P. largulateralis* that is more sinuous and convex in the region coincident with the anterior sulcus; and posteroventral region less curved upward; surface more punctated in the anterior region; dorsomedian sulcus almost absent, but with the alarform ridge more evident. *Perissocytheridea* aff. *P. pumila* Van den Bold, 1975a (Figs. 7-14, Pl.6.3) also presents similarities with the males specimens, in the carapace shape, but differs in posterior end presenting a caudal process more truncated and less pointed and; ornamentation pattern differenciated being more reticulated in the anterion region and reticles between the two ventral ridges.

Occurrence: B-17 quarry, Capanema, Pará (samples B11B, B12 and B11A). These samples are composed of gray shales, laminate fine sandstone and marls characterized in this paper as samples that arise within the brackish water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará State, Brazil.

Perissocytheridea aff. *P. pumila* Van den Bold, 1975a

Pl.6.3; figs. 7-14

aff. 1975a. *Perissocytheridea pumila* Van den Bold, pl.19, figs. 1-7, pp. 142, 143.

Not 1988 *Perissocytheridea pumila* Van den Bold, pl. 2, fig. 14.

Material: 7 carapaces and 9 valves.

Figured specimens: MPEG-534-M, Female, C; LV: L: 0.44 mm and H: 0.25 mm; RV: L: 0.42 mm and H: 0.24 mm; dorsal view: H: 0.45 mm and W: 0.23 mm, sample B11B. MPEG-535-M, Male, C; LV: L: 0.47 mm and H: 0.23 mm; RV: L: 0.45 mm and H: 0.22 mm; dorsal view: H: 0.45 mm and W: 0.23 mm, sample B11B. MPEG-536-M, RV: L: 0.42 mm and H: 0.22 mm, sample B11A. MPEG-537-M, RV: L: 0.48 mm and H: 0.28 mm, sample B11A. MPEG-538-M, RV: L: 0.44 mm and H: 0.21 mm, sample B11B.

Description: medium, subrectangular to subelongate carapace, in lateral view. LV slightly larger than RV. Dorsal margin nearly straight in both valves. Ventral margin nearly convex to almost straight. Anterior margin obliquely rounded. Posterior margin narrow and subacute with a caudal process in the middle point. Midventrally it has an discret alarform ridge. Maximum height at the anterior end. Surface strongly reticulated: males more distinctly reticulate than females. Ocular tubercle prominent and near of the cardinal angle. A small and transversal sulcus lies on the anteromedian position behind of the ocular tubercle and run parallel to the anterior margin, being more prominent in the RV. Anteromedian sulcus relatively deep and discret, more evident in the RV. Evident longitudinal median ridge extending from the central region converging to the posterodorsal region in the LV; in the RV, and most in the female, this ridge extends from the posterodorsal region turndown to the ventral median region meeting the ventral rigde forming a loop. Ventral rigde parall to the margin that follows from the anterior region to the posterior, where it upturned and meet the median rigde. Dorsal view lens-shaped and robust, widest in the mid-posteriorly part; posterior end acute and anterior end subrrounded. Sexually dimorphic: females are shorter presenting subovate C and higher than males. Internal features typically of the genus.

Remarks: this species is very reminiscent to *Perissocytheridea pumila* Bold, 1975a mainly ventral margin almost straight in the RV and dorsal view with a antero-median small sulcus more prominent in the RV observed in the males forms, but differs in the ornamentation more distinctly reticulate, arrangement of the ridges with the distribution pattern of the ridge in the central region, dorsal view with posterior end narrow and absent of blunt spines in the anterior end. This species is also similar to *Perissocytheridea* sp. 4 described herein in many aspects as shape, size, and slightly in the ornamentation pattern, differing in the absence of the discret vertical anterior ridges; shorter ventral ridges and surface strongly reticulated.

Occurrence: B-17 quarry, Capanema, Pará (samples B9, B11, B12, B11A and B11B); drill core FPR-160 Primavera (sample AM.08). These samples are composed of gray shales, marls and laminate fine sandstone characterized in this paper as samples that arise within the brackish water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará State, Brazil.

Perissocytheridea aff. *P. brachyforma* subsp. *excavata* Swain, 1955

Pl.6.3; figs. 15-17; Pl. 6.4; figs. 1-3

aff. 1955. *Perissocytheridea brachyforma* subsp. *excavata* Swain, pl.62, figs.1a-c; tf. 33b, p.619 and 620.

Material: 2 carapaces and 1 valve.

Figured specimens: MPEG-539-M, C; LV: L: 0.57 mm and H: 0.32 mm; RV: L: 0.54 mm and H: 0.29 mm; dorsal view: H: 0.54 mm and W: 0.26 mm, sample B1A. MPEG-540-M, LV: L: 0.52 mm, H: 0.28 mm, sample B11A. MPEG-541-M, RV: L: 0.51 mm and H: 0.27 mm, sample B11A.

Description: medium and subpyriform carapace, in lateral view. LV larger than RV, overlapping slightly in the margins. Maximum height at the anteromedian region. Dorsal margin very slightly concave to sinuous in the LV, almost straight in the RV with a convex portion in the mid-dorsal margins in the RV. Ventral margin nearly straight slightly convex in the RV slightly sloped upward in the posterior. Anterior margin broadly rounded, extended below, truncate above. Posterior margin narrow and subacute with a caudal process in the middle point in side view. A deep anterodorsal sulcus lies parallel to the anterior margin and behind of the ocular tubercle. Ocular tubercle near of the cardinal angle. Median sulcus prominent extending to the central portion of the carapace, almost reaching the ventral rigde in the LV. Surface smooth. In both valves occurs clearly 5-6 longitudinal posterodorsal ridges occupy approximately middle half of the valve, all of which tend to converge in a posterior direction; of these, the ventral one begins about one-fourth from anterior end, extends posteriorly to about one-third from end where it curves abruptly dorsally and anteriorly as a hooked-shaped loop; the others longitudinal ridge are irregularly distributed, in some specimens two of the subdorsal ridges are connected posteriorly. Internal features not observed due to material scarcity and poor preservation.

Remarks: this species resemble to *Perissocytheridea brachyforma* subsp. *excavata* Swain, 1955 mainly in some aspects as shell subpyriform; dorsal margin nearly straight, but slightly sinuous; Anterior margin broadly rouded, extended below and subtruncate above. Posterior margin narrowly rounded to acuminate with a slightly dorso median short caudal process; longitudinal ridges pattern are the same, but differs in the sinuous form of these ridges and the ornamentation pattern with valve surface between ridges erratically pitted.

Occurrence: B-17 quarry, Capanema, Pará (sample B1A and B11A). This sample is composed of biocalcarenite described within the more saline facies.

Distribution: Lower Miocene, Pirabas Formation, Pará State, Brazil.

Perissocytheridea sp. 1

Pl.6.4; figs. 4-6

Material: 1 carapace.

Homotypes: MPEG-542-M, C; LV: L: 0.35 mm and H: 0.21 mm; RV: L: 0.34 mm and H: 0.20 mm; dorsal view: H: 0.37 mm and W: 0.17 mm, sample FPR-160 core, AM.14.

Description: small, subrectangular to subtriangular carapace, in lateral view. Dorsal margin nearly straight and angulate to the posterior region. Ventral margin almost straight to slightly convex. Anterior margin widely rounded. Posterior margin almost rounded, relatively wide and truncate with a short slope posteroventrally in lateral view. Surface ornated with a swallow reticles almost punctated in the antero dorsal region, close to the sulcus area. Anterior region with very fine rigde extending from the anterodorsal region extending sinuously downwards and turning to the posteroventral region at the middle of the carapace. Very fine discret longitudinal ventral ridges. Two sulci in the anterodorsal region: one relatively deeper running parallel to the dorsal margin extending to the dorsomedian region where meet another deeper transversal sulcus that runs downwards to the central portion of the carapace meeting a rounded depression. Dorsal view rounded with fine marginal rigde. Maximum width at the anterior half. Internal features not observed.

Remarks: the species resemble to *P. ornellasae* Purper, 1979 recorded to the Miocene of Solimoes/Pebas formation, northweastern of Amazonia (Brazil), and Peru and Colombia (Muñoz-Torres *et al.* 1998), but differs on ornamentation pattern more strongly ornated and carapace shape more rounded and less elongate mainly in dorsal view.

Occurrence: core FPR-160 Primavera (sample: AM.14). This samples is composed of marls characterized in this paper as samples that arise within the brackish water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará State, Brazil.

Perissocytheridea sp. 2

Pl.6.4; figs. 7-9

Material: 1 carapace.

Homotypes: MPEG-543-M, C; LV: L: 0.41 mm and H: 0.23 mm; RV: L: 0.40 mm and H: 0.22 mm; dorsal view: H: 0.38 mm and W: 0.20 mm, sample FPR-160 core, AM.6.

Description: small and tumid carapace, subpyriform to subtriangular in lateral view. LV overlaps RV. Dorsal margin nearly straight in the LV, sinuous in the RV more noticeably with a slope to posteromidventrally. Ventral margin slightly sinuous, convex mainly in the region coincident with the alar process. Anterior margin rounded to truncate in the dorso. Posterior margin narrow and subacute with a evident caudal process pointing downward. Maximum height at the eye tubercle position and somewhat larger than half the length. Cardinal angle anterior prominent. Surface coarsely reticulate; roughly hexa-or pentagonal reticulae; solae smooth. Reticulation with less developed muri in the central and posterodorsal regions. Two sulci in the anterodorsal region: one relatively shallow running parallel to the dorsal margin extending to the dorso-median region where meet another weel marked and deeper transversal sulcus that runs downwards meeting the discret ventral ridge. This sulcus almost divided the carapace in two swallow portion, more evident in the anterior region of the RV. Internal features not observed. Alar process discret with a small node in the end.

Remarks: the species presents similarities to *Perissocytheridea brachyforma* Swain, 1955, *Perissocytheridea swaini* Benson and Kaesler, 1963 and *Perissocytheridea japonica* Ishizaki, 1968. The species *P. brachyforma* Swain, 1955 is similar mainly in immatures forms of the males' specimens, however, its size in adult forms is slightly larger (L 0.50mm; H 0.27mm), presenting in those forms a different outline, ornamentation and posterior end, besides having an prominent sexual dimorphism. *P. swaini* is similar in the shape, inflated, ovate and inflated in dorsal view, therefore it presents two posterior nodes, dorsal margin straight, C finely reticulate to punctuate in random pattern except in smooth anterodorsal portion and larger size. These features differ of the species herein studied. *P. japonica* is similar in shape, ornamentation pattern, shallow sulcus next to anterior margin among others; it differs in larger size (L 0.54 mm; H 0.29 mm); and the presence of two and four shallow marginal ridges nearly and parallel to anterior margin. Due to the scarce material, this species was left in open nomenclature.

Occurrence: FPR-160 core, Primavera (sample AM.06). These samples are composed of gray shales, laminate fine sandstone, and marls characterized in this paper as samples that arise within the brackish water facies.

Distribution: Upper Oligocene, Pirabas Formation, Pará, Brazil.

Perissocytheridea sp. 3

Pl.6.4; figs. 10-12

Material: 4 valves.

Homotypes: MPEG-544-M, LV: L: 0.51 mm and H: 0.31 mm, sample B7. MPEG-545-M, RV: L: 0.48 mm and H: 0.27 mm, sample B11A.

Description: medium and subquadrate to suboval valves, in lateral view. LV larger than RV. Dorsal margin nearly straight, slightly convex in the anterodorsal margins in the hight of the median sulcus. Ventral margin almost straight to slightly convex and slope upward in the posterior region. Anterior margin obliquely rounded. Posterior margin narrow and subacute with a caudal process in the middle point in side view. Maximum height at the anterior end. Surface strongly reticulated in the porterior region, smoother to the anterior region; mainly reticulations between the ridges, but slightly punctated in the anterior region. Two main evident longitudinal ridges in the surface: one runn from the central portion to the postero dorsal region and the other parallel to the ventral margin, celated above; another third and more weak dorsal ridge extending parallel to the posterodorsal margin. Well marked anterodorsal sulcus running downward to the central portion where it meet the begin of the median rigde. Hinge typically for the genus.

Remarks: this species resemble to *Perissocytheridea largulateralis* n. sp. from the present study mainly in outline with highest in the anterior region; ventral ridge strongly pronounced presenting an arrangement of small and ridges secondaries which supports the ventral ridge, strongly reticulate between the ridges and also presence of anterior end rounded, however, differs in the median ridge pattern due to the presence of a single evident longitudinal ridge downward forming a loop and general arrangement of ridges.

Occurrence: B-17 quarry, Capanema, Pará (samples B7, B12, B11A and B11B). These samples are composed of gray shales, laminate fine sandstone and marls characterized in this paper as samples that arise within the brackish water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Perissocytheridea sp. 4

Pl.6.4; figs. 13-15

Material: 4 valves.

Homotypes: MPEG-546-M, Female, RV: L: 0.48 mm and H: 0.27 mm, sample B12. MPEG-547-M, Male, RV: L: 0.51 mm and H: 0.31 mm, sample B11.

Description: medium and subovate valve in female to subelongate valve in males, in lateral view. Dorsal margin nearly sinuous in both valves with a convex portion in the anterodorsal margins in the hight of sulcus. Ventral margin almost straight. Anterior margin obliquely rounded, extended below, truncate above. Posterior margin narrow and subacute with a short caudal process in the middle point in side view. Maximum height at the anterior end. Surface strongly reticulated mainly between the ridges, more slightly reticulated in the anterior region. Evident median longitudinal ridge extending from the central to the postero median region. Midventrally alarform ridge with others 3 to 4 reticulated ridges above. Two sulcus: the median sulcus thin but well marked extending from the dorsal to ventral region; the other larger runn parallel to anterior margin. Hinge typically for the genus.

Remarks: the species has resemble to *Perissocytheridea* aff. *P. pumila* Bold, 1975a from the present study mainly in the same outline lens-shaped, however differs from this species in the coarsely ornamentation pattern and more robust shape. This species is higher and lenghter than *P*. aff. *P. pumila* presented in this paper.

Occurrence: B-17 quarry, Capanema, Pará (samples B12, B11A and B11B). These samples are composed of gray shales, laminate fine sandstone and marls characterized in this paper as samples that arise within the brackish water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Perissocytheridea sp.5

Pl.6.4; figs. 16-18

Material: 4 carapaces.

Homotype: MPEG-548-M, C; LV: L: 0.66 mm and H: 0.31 mm; RV: L: 0.63 mm and H: 0.29 mm; dorsal view: H: 0.63 mm and W: 0.29 mm, sample FPR-160 core, AM. 8.

Description: medium, fragile and tumid carapace, subrectangular in lateral view. LV slightly larger than RV. Dorsal margin nearly straight in the LV, sinuous in the RV slightly convex in the dorso-median region. Ventral margin almost straight; and shows weakly cancavity anteromedially in both valves. Anterior margin rounded. Posterior margin narrow and subacute with a short caudal process. Ocular tubercle more discret in the RV. Maximum height at the anterior end. Surface delicately reticulated with secondary punctuations and canal pores sieved; the reticles are large and shallow with a number of longitudinal ridges extending from the anteromedian and from the posterior region in a radial shape converging to anteromedian, almost central constriction. Ventral margin with a narrow and delicate alarform ridge parallel to this margin; and others three discret ridges bellow extending parallel to this alarform.Two strongly marked sulci lies from the anterodorsal region: one in a more dorsal position, behind the ocular tubercle, is more evident running parallel to the dorsal margin, near to the cardinal angle; the other immediately posterior to the dorsal sulcus extending downwards to the median region. Narrow edge, discrete and more evident in dorsal view. Internal features not observed.

Remarks: the species closest is *Perissocytheridea cribrosa* (Klie, 1933) (HVH10939) from Recent of Caribbean (shallow and brackish water), which presents similarities as the size and the ornamentation pattern, but differs in the posterior region short and truncate, reticulations organized in pent- and hexagonal reticles with punctuations following them, anterodorsal region with a more smooth area and midventrally with out of the presence of a prominent longitudinal alaform ridge. It was left in open nomenclature due to loss of other specimens.

Occurrence: B-17 quarry, Capanema, Pará (sample B11); FPR-160 Primavera core (samples AM.08 and AM.14). These samples are composed of marls characterized in this paper as samples that arise within the brackish water facies.

Distribution: Lower Miocene, Pirabas Formation, Pará State, Brazil.

6.5. DISCUSSIONS

Within this item is discussed the relative amount of genus *Perissocytheridea* along the stratigraphic studied sections from Pirabas Formation; its stratigraphic and geographic distribution worldwide, and the typical environment in which it was recorded particularly with respect to salinity is also presented.

6.5.1. Quantitative and qualitative analysis along of the studied stratigraphic sections

Five stratigraphic sections were analyzed in this study: B-17 quarry, Atalaia (Salinas beach), Aricuru (Maracanã bay) and Ponta do Castelo (Fortaleza Island) outcrops, furthermore the FPR-160 Primavera Core (see map, Fig.6.1). However, only in B-17 quarry and in the FPR-160 Core stratigraphic sections were recorded the presence of *Perissocytheridea.*

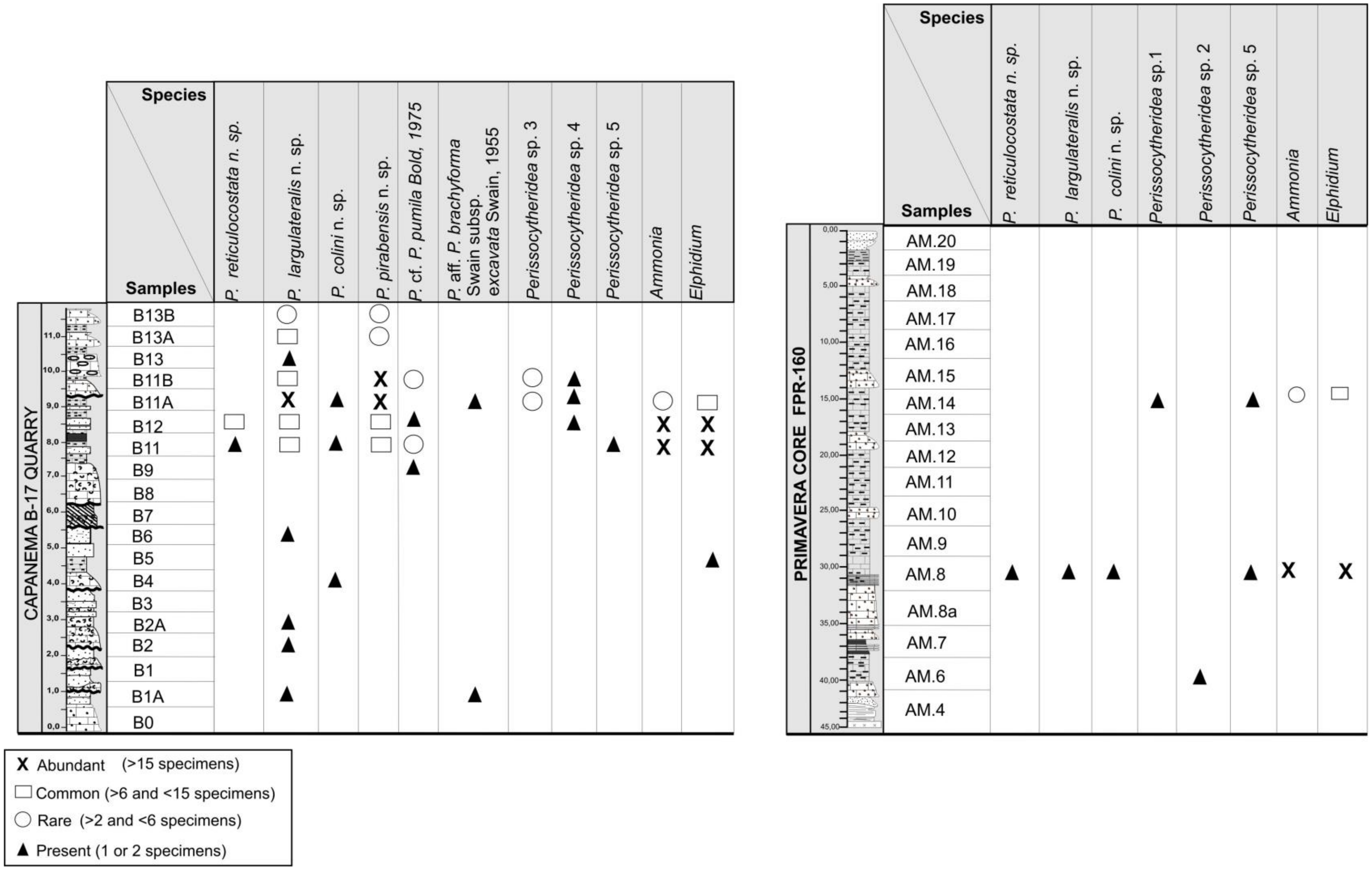
Among the thirty six studied samples in both localities, five are barrel and the remaining yielded two thousand thirty six specimens of *Perissocytheridea*. In B-17 quarry, the samples B11 (12%), B12 (14%), B11A (31%) and B11B (21%) from the upper portion presented the highest frequency of genus, where the B11A is the most diverse and abundant. The lowest frequency were observed in the lower and middle portion of the section in the samples B1A (2%), B2 (1%), B2A (2%), B4 (1%), B6 (1%) and B9 (1%). Regard to the core FPR-160, the sample with the highest frequency, diversity and abundance was AM. 8 with 67% (~36m) while others were less frequent as AM. 6 with 20% (~38m) and AM. 14 with 13% (~24m).

From the eleven species described in the present study, nine species where found in the B-17 quarry: *Perissocytheridea colini* n. sp., *P. pirabensis* n. sp., *P. punctoreticulata* n. sp., *P. largulateralis* n. sp., *P.* aff. *P. pumila* Bold, 1975a, *P.* aff. *P. brachyforma* subsp. *excavata* Swain, 1955, P. sp. 3 *P.* sp. 4 and *P.* sp. 5.

In the core FPR-160, from a total of seventeen samples, only in three samples six species were recorded: *P. punctoreticulata* n. sp., *P. largulateralis* n. sp., *P.colini* n. sp., *P.* sp. 1, *P.* sp. 2 and *P.* sp. 5. The species common in both stratigraphic sections were *P. largulateralis* n. sp., *P.colini* n. sp., *P. punctoreticulata* n. sp. and *P.* sp. 5 (Fig. 6.3).

The species more abundant in B-17 quarry were *P.largulateralis* n. sp. and *P. pirabensis* n. sp., and the less abundant were *Perissocytheridea* aff. *P. brachyforma* subsp. *excavata* Swain, 1955, *P.* sp.1, *P.* sp. 2, *P.* sp. 3 and *P.* sp. 4. On the other hand, in the core FPR-160 only the species *P.* sp. 5 is more abundant (Fig. 6.3).

In two specific levels from the B-17 quarry (B11 and B12) where the *Perissocytheridea* occurs, the *Elphidium* and *Ammonia* genera were also found in abundance. The same to the AM.8 sample from the FPR-160 core (Fig. 6.3).



Samples \ Species	*P. reticulocostata n. sp.*	*P. largulateralis* n. sp.	*P. colini* n. sp.	*P. pirabensis* n. sp.	*P.* cf. *P. pumila Bold, 1975*	*P.* aff. *P. brachyforma* Swain subsp. *excavata* Swain, 1955	*Perissocytheridea* sp. 3	*Perissocytheridea* sp. 4	*Perissocytheridea* sp. 5	*Ammonia*	*Elphidium*
B13B		○		○							
B13A		□		○							
B13		▲									
B11B		□		X	○		○	▲			
B11A		X	▲	X		▲	○	▲		○	□
B12	□	□		□	▲			▲		X	X
B11	▲	□	▲	□	○				▲	X	X
B9					▲						
B8											
B7											
B6		▲									
B5											▲
B4			▲								
B3											
B2A		▲									
B2		▲									
B1											
B1A		▲				▲					
B0											

Samples \ Species	*P. reticulocostata n. sp.*	*P. largulateralis* n. sp.	*P. colini* n. sp.	*Perissocytheridea* sp.1	*Perissocytheridea* sp. 2	*Perissocytheridea* sp. 5	*Ammonia*	*Elphidium*
AM.20								
AM.19								
AM.18								
AM.17								
AM.16								
AM.15								
AM.14				▲		▲	○	□
AM.13								
AM.12								
AM.11								
AM.10								
AM.9								
AM.8	▲	▲	▲			▲	X	X
AM.8a								
AM.7								
AM.6					▲			
AM.4								

X Abundant (>15 specimens)
□ Common (>6 and <15 specimens)
○ Rare (>2 and <6 specimens)
▲ Present (1 or 2 specimens)

Figure 6.3- Abundance of *Perissocytheridea* species, *Ammonia* and *Elphidium* genera along the studied sections.

6.5.2. Stratigraphic and paleobiogeographic distribution

The ostracod fauna from Pirabas Formation sections has a high generic diversity, including a number of undescribed new species. The species of *Perissocytheridea* recognized here are new to the science and it is the first record of this genus in this formation increasing significantly the knowledge of the fossil diversity from Neogene of South America and also to contributing to the paleoenvironmental evolution.

The *Perissocytheridea* genus has a Gondwana origin. On the Africa (Colin *et al.* 1996; Andreu 1996) and South America continents (Uliana and Musacchio 1978; Viviers *et al.* 2000), in Greece (Babinot 1988) and Middle-Eastern (Bassiouni 2002), it is known to the Cenomanian. It is possible that this genus is present in the European Cenozoic (in: Mebrouk *et al.* 2011).

In South America, the first fossil record of *Perissocytheridea* in the Neogene was by Zabert (1978) that despite of the dubious taxonomical identification described three new species from the Upper Miocene of the Parana Formation in Santa Fé Province, Argentina Republic: *Perissocytheridea victoriensis*, *Perissocytheridea alvareziana* and *Perissocytheridea ornata*. These species were recorded in clays sediments interbedded with thin limestone layers; in addition, green-gray clays and sands. Others Neogene records were to the species *Perissocytheridea formosa* and *Perissocytheridea*? *elongata* described to the Plio-Pleistocene among the Pebas beds, in the Amazonian region, in Pichua from Peru and CAE/GEO/33 from Colombia (Sheppard and Bate 1980). Purper (1979) recorded the occurrence of *Perissocytheridea* in Miocene sediments from the Solimões Formation, in Brazil, which was also recorded to the correlated Pebas Formation, on Peru and Colômbia beds by Muñoz-Torres *et al.* (1998). These authors recorded the following species: *Perissocytheridea ornellasae* Purper, 1979 and *Perissocytheridea acuminata* Purper, 1979, *Perissocytheridea akistron* and *Perissocytheridea* sp.1. The most recent study was in the Yecua Formation from Bolivia by Nicolaidis and Coimbra (2008) which dated the studied section on Middle-Late Miocene and reported one new species: *Perissocytheridea carrenoae*.

At least to the present data, the *Perissocyheridea* genus has an extensive stratigraphic range from Cretaceous to Recent. However, the records of this genus are enough rare during Cretaceous, Lower and Middle Eocene and also Lower Miocene. Moreover, its occurrence is still unknown mainly in the Oligocene, Upper Eocene and Paleocene (Fig. 6.4). In general, the records of this genus are considerably significant within the Miocene and Recent sediments. The species recorded by Bold (1988) from the Neogene of the Dominican Republic, only *P. alata* Bold, 1946 has its record confirmed to Lower Miocene; *P.* ? *haitensis* Bold, 1981 and *P. pumila* (Bold) is still uncertain (Fig. 6.4).

During the Cretaceous the record of *Perissocytheridea*, as mentioned above, is rare, as an example, in this period we have: *Perissocytheridea salmacida* from Upper Cretaceous of faunal provinces in Moroccan (Andreu 1996); *Perissocytheridea odomensis* from Lower Cretaceous of Halifax county, North Carolina, USA (Swain and Brown 1964), and newly recorded of *Perissocytheridea caudata* and *Perissocytheridea mossoroensis* from the Upper Cretaceous deposits of the Potiguar basin, Northeast of Brazil (Piovesan *et al.* 2014). The genus radiate in the when it was more abundant although there is the difficulty in taxonomy identification of some species in the geological record, even still need further studies to investigate the real occurrence and distribution over time of the genus (Fig.6.4).

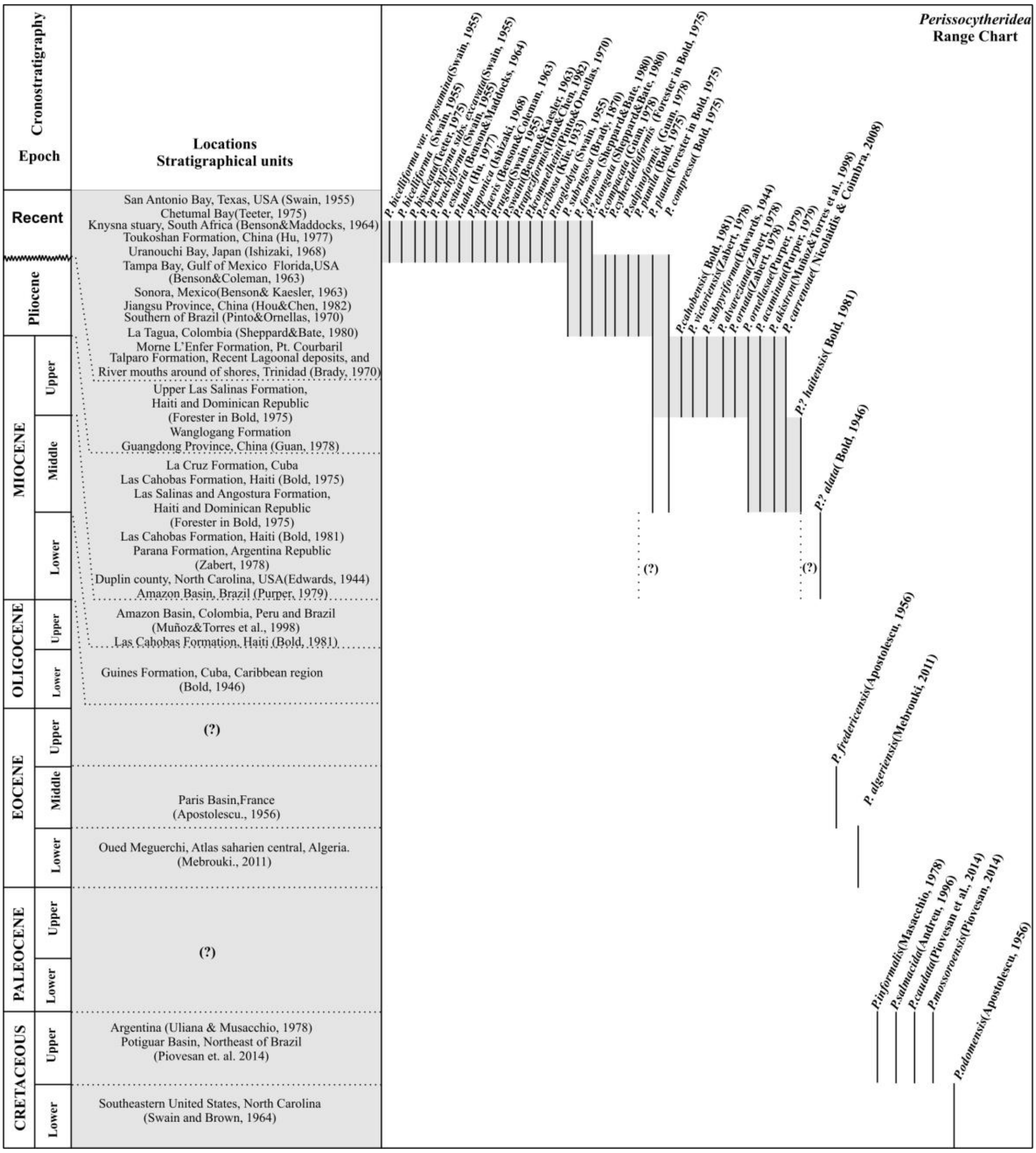


Figure 6.4 – Distribution of *Perissocytheridea* species along the geological time according with global records.

6.5.3. Paleoecological and Paleobiogeographical considerations

Generally the genus *Perissocytheridea* is considered mesohaline occuring more normally in estuaries and lagoons, or more sporadically in shallow platforms.

Previous studies record *Perissocytheridea* species with both to freshwater and marine genera. In addition, this genus also has been recorded in estuaries associated with marine and freshwater genera such as *Paracytheroma*, *Cytherura* and *Cyprideis* under water temperatures of 25-29°C (Hartmann 1956). These genera were recorded in shallow environments with low-salinity in clays, silt and sand sediments. *Cyprideis* is associated more with freshwater genera as *Candona*, *Physocypria*, *Potamocypris*, *Darwinula* than marine or brackish water genera, however, when it is associated to *Perissocytheridea*, this relation is compared to brackish water facies (Swain 1955).

Hence, how mentionated above *Perissocytheridea* is typically of brackish water facies represented by lagoons with fluvial influence associated with the same genera cited previously, as well as in hypersaline lagoon with *Cyprideis* including species of *Perissocytheridea, Aurila,* and *Haplocytheridea* (Curtis 1960, Bold 1963, Bold 1971b, Bold 1972a).

According Kempf (1986), the presence of *Perissocytheridea* in marine and non-marine environments is observed, although its occurrence be mainly in places of mixohaline influence where occurs almost always associated to the *Cyprideis* genus (Purper 1979) and also associated to marine genera as *Cythereis, Basslerella, Cytheretta* and *Paracytheridea* (Howe 1935, Sandberg 1964). According to these associations with *Perissocytheridea*, it is therefore an excellent indicator of meso-polyhaline environments (Ornellas 1974).

As discussed previously, *Perissocytheridea* is typically lagunar, however, in the bays from the Golf of Mexico actually, this genus disappeared totally when the salinity approach 30 psu (*Practical Salinity Units)* (Garbett and Maddocks 1979; Colin *et al.* 1996). In Florida, this genus is oligo- to polyhaline, rather mesohaline between 5 to 18 psu (Keyser 1977).

Species of this genus and *Cyprideis* also are recorded into the fauna consisted by benthic foraminifera such as *Elphidium*, *Eponidella* and *Ammonia* supporting the brackish water conditions (Madeira-Falcetta 1974, Boltovskoy 1990, Geslin *et al.* 1998). This fauna is generically similar to that one found in the brackish water lagoonal environment where *Cytherura* and *Cytheromorpha* genera may also be found (Sandberg 1964).

The Jimaní and Salinas formations from Enriquillo Basin (Dominican Republic) have scattered occurrences of similar ostracode association, but the Jimaní unit presents diversity slightly higher with seven species in a single sample. *Perissocytheridea* spp. and *Cyprideis* spp. were also recorded together in the same samples in both units; otherwise, the Jimaní formation presented those genera in all samples, suggesting a reduce-salinity environment; thus those genera are assigned the most notable fauna elements and further suggesting marginal marine conditions. In addition, the occurence of foraminifera *Elphidium* and *Ammonia* also recovered in those same samples indicate a tolerant of variable salinity conditions which could also indicate brackish water or hypersaline conditions (Mann 1999).

Although *Cyprideis* is normally associated to species of *Perissocytheridea*, it has been recorded more commomly in brackish water, despite being recorded in freshwater lakes (Wouters and Martens 1992, 1994) and paleolakes (Ramos 2006). *Perissocytheridea* is more commom in brackish water to shallow marine environments with continental influences. After these, studies in South America described species of *Perissocytheridea* with the same associations (Nicolaidis and Coimbra 2008; Piovesan *et al.* 2014).

Based on all these interpretations discussed anteriorly, the uppermost stratigraphic samples in the B-17 quarry and in the lower portions of the drill core Primavera (FPR-160) where a higher abundance of the genus *Perissocytheridea* occur, can be consider the lagoon where also similar association were found. Hence, this is most abundant mainly in the shales (which is a soft, finely stratified sedimentary rock that formed from consolidated calcareous mud and can be split easily into fragile laminations), marls as the sample B12 from B-17 quarry and AM. 8 (~36m) from FPR-160 Primavera core; marls with interbedded laminates fine sandstones (B11 and B11A) and marls (B11 and B11B). These fine-grains sedimentary packages samples were interpreted by Rossetti *et al.* (2013) as being lagoon environments.

In the studied sections generally, the samples that appear with the highest proliferation of associations previously discussed denote periods of reduced salinity and increased nutritional input. Furthermore, the foraminifera *Elphidium* and *Ammonia* occur together in those samples more abundant, as well as few *Cyprideis* species supporting the significant mixohaline influence in the lagoon (Fig.6.5 D, E, I and J; pl.6.5, Figs. 6.1-6.14). In opposite, *Haplocytheridea* is assigned to euryaline behavior and indicative of *shorelines*, as well as *Cytheridea* infering that there are phisic-chemistry variations as salinity changes throughout the studied stratigraphic section. *Cytheridea* is a brackish to marine (epi-neritic) genus and has a habitat similar to that of *Haplocytheridea* (Sohn 1951, Morkhoven 1963, Swain 1963, Marlz and Triebel 1970, Puckett 1994, Faranda *et al.* 2008, Stephenson 1945, Bold 1972a, Keen 1977, Besonen 1997). In addition, the paper published more recently by Nogueira *et al.* (2011) brings also an approach about the occurrence of *Haplocytheridea* and *Cytheridea* from Northern Brazil in mixohaline environment related to transgression cycles trend.

During the Cretaceous to Recent, the *Perissocytheridea-Cyprideis* association can occur with both, fresh and marine ostracods, in paleoenvironmental salinity oscilations generally between infralitoral to lagoonal from coastal platform (Garbett and Maddocks 1979, Cronin 1988, Andreu 1996, Morsi and Wendler 2010) but also in non-marine (Uliana and Musacchio 1978, Colin *et al.* 1996, Nicolaidis and Coimbra 2008, Gross *et al.* 2013). These genera associated with marine ostracods, have also been found in hyperhaline environments (Neale 1988). Previous studies show this association is similar to *Perissocytheridea-Fossocytheridea* found during Cretaceous (Piovesan *et al.* 2014).

The *Perissocytheridea-Cyprideis* association has a more mixohaline character present in those intervals here studied reinforced by a higher abundance of *Perissocytheridea*, more particularly in the uppermost portion from B-17 quarry. Meanwhile, in the other intervals which the occurrence of this genus is insignificant, the genera marine are dominated.

In this context, this association was recorded with marine genera in those intervals contributed to understanding the paleoenvironmental dynamics. Although the presence of marine genera are more diverse and abundant than brackish genera in those samples, and the high and restricted occurrence of *Perissocytheridea* in those intervals, allowed to conclude that there was, in that portion, a salinity fall or excessive increase of salinity. It is also important to note that those samples with a higher abundance of *Perissocytheridea* are the same of *Haplocytheridea* and *Cytheridea* in the B-17 quarry (Fig.6.5A-C).

Among marine genera abundant were *Bairdoppilata* after *Haplocytheridea* followed by *Cytheridea,* and in minor proportion *Quadracythere*, *Cytheretta*, *Paracypris*, *Cytherella*, *Pellucistoma*, *Loxoconcha* and *Xestoleberis*. These genera are normally recorded in lagoonal environments and associated to barrier reefs deposits (Bold 1970a; Whatley and Watson 1988). However, they can also occur in "open sea" (Coimbra and Carreño 2002) suggesting an environmental dynamics and that close to the coast.

The *Perissocytheridea-Haplocytheridea-Cytheridea* association is abundant in the lower and upper part of the Pirabas succession, particularly in the 40-35m interval of core FPR-160 and in the in the B-17 quarry. This association is largely related to the salinity decrease with the occurrence of brackwish waters in interval throught the entire depositional setting (Fig. 6.5F-H). The ocurence of *Elphidium* and *Ammonia* foraminifera mostly combined with this ostracoda association corroborate with this interpretation. The recurrence of this association in the Pirabas succession indicate phases of salinization decrease probably related to continental waters inflow and/or sea level reduction (Fig. 6.5A-J). The absence of this ostracoda association in some intervals strongly indicate phases of normal salinity and/or maximum marine waters inflow (Phases I, II and IV in the FPR-160 core and phases I and II in the B-17 quarry). The salinity variation up section, provides from *Perissocytheridea-Haplocytheridea-Cytheridea* association combined with *Ammonia* and *Elphidium*, is tipically a characteristic of lagunar deposits probably inserted in a estuarine setting, as previously interpreted to the marls and biocalcarenite of B-17 quarry (Rossetti *et al.* 2013) and now extended to the FPR-160 core.

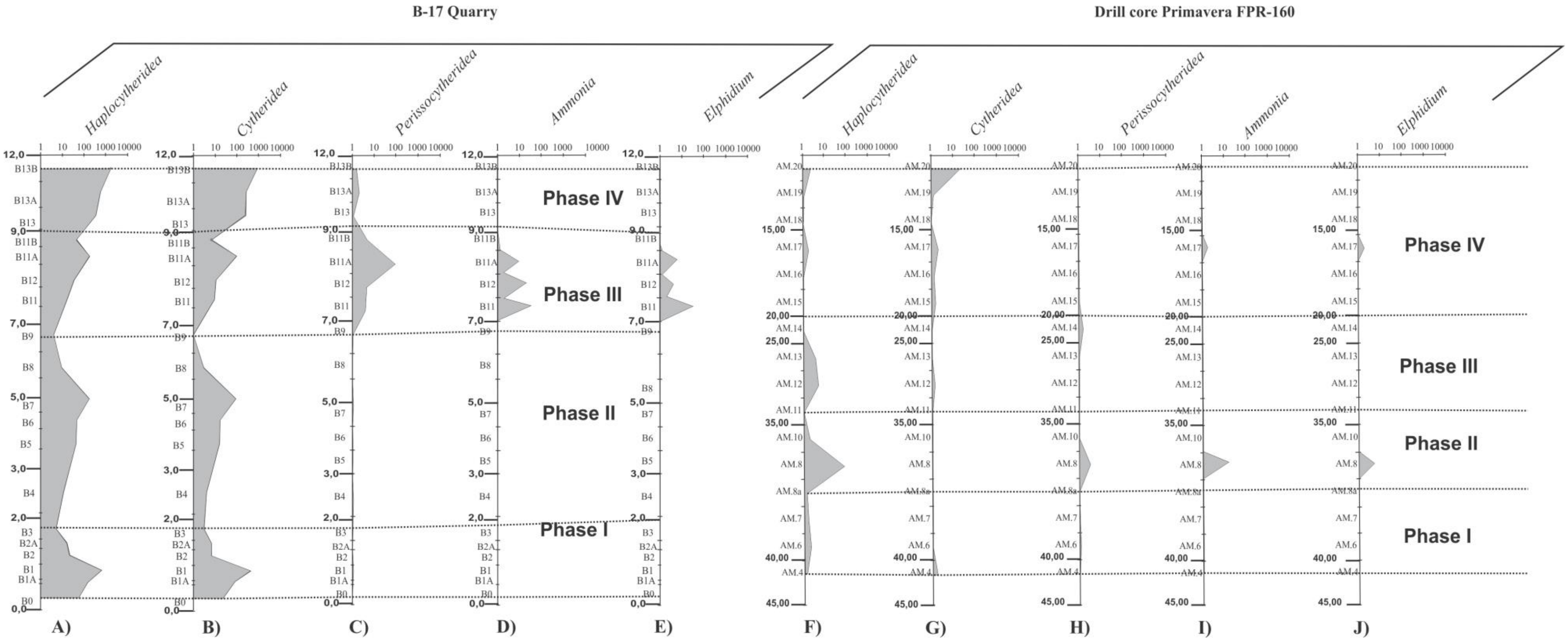


Figure 6.5 – Abundance of the genera ostracods and foraminifera associations in the Pirabas localities: Graphs of (A) to (E) shows the genera distribution between *Ammonia* and *Elphidium* foraminifera and ostracods from Mine B-17: (A) and (B) *Haplocytheridea* and *Cytheridea* data realized by Nogueira *et al.* (2011), respectively; (C) Distribution of genus *Perissocytheridea*; (C) and (D) Distribution of genera *Ammonia* and *Elphidium*, respectively. Graphs of (F) to (J) shows the genera distribution between *Ammonia* and *Elphidium* foraminifera and ostracods of the FPR-160 core in Primavera location. Horizontal axis: number of each genera; vertical axis: depth and samples collected.

6.6. CONCLUSIONS

Eleven *Perissocytheridea* species were identified for the first time in the Oligo-Miocene Pirabas Formation: *Perissocytheridea punctoreticulata* n. sp., *P. largulateralis* n. sp., *P. colini* n. sp., *P. pirabensis* n. sp., *P.* aff. *P. brachyforma* subsp. *excavata*, *P.*aff. *P.pumila*, *P.* sp. 1, *P.* sp. 2, *P.* sp. 3, *P.* sp. 4 and *P.* sp. 5. In Brazil, the fossil record to this genus has been to the northwestern and northeastern regions and since the Cretaceous to Recent being this the first record to the Neogene Northern Brazil.

The *P.*aff. *P.pumila* and *P.* aff. *P. brachyforma* subsp. *excavata* present affinities with the Caribe and North America species as well as the association with *Haplocytheridea* and *Cytheridea* where they are generally associated with *Perissocytheridea* species. *Cytheridea* and *Haplocytheridea* are genera that support salinity variation. Although these genera occurs in the Pirabas succession into all facies related to brackish and marine waters deposits, *Perissocytheridea* is more abundant in the brackish water deposits, mainly in the lower and upper portion of Pirabas succession. The co-occurrence of the foraminifera *Elphidium* and *Ammonia* with *Perissocytheridea-Haplocytheridea-Cytheridea* association supports the significant mixohaline influence. Additionally, the recurrence of this ostracoda association in the Pirabas succession clearly indicate phases of lower salinity in the lagoon and/or negative sea level oscilations, confirming previous sedimentogical interpretations.

The paleobiogeographical distribution of genus *Perissocytheridea* is extended to northeastwards of Neogene Amazonia, Brazil. The new information herein provided by the fossil ostracods of Pirabas Formation is just another piece for this biogeographic puzzle, highlighting the crucial role for understanding the biogeographical history of the ostracofauna during the Neogene.

ACKOWLEDGMENTS

We would like to express our sincere gratitude to curators Gene Hunt, Ostracoda Collection of the Smithsonian Institute (National Museum of Natural History) and Lorene Smith of the Louisiana State University Museum of Natural Science for having me and enable analyzes of species types; to Professor Dr. Afonso César Rodrigues Nogueira (UFPA, Brazil) and to Dr. Orangel Aguillera (Universidad Francisco de Miranda/Venezuela) for the discussions and logistics support. To the VOTORANTIM for cession of the core FPR-160. To CNPq (The Brazilian Scientific and Technology Developing Council) for financial support (proc. 140850/2011-2) during the PhD and thanks Coordenação de Aperfeiçoamento de Pessoal de Nível Superior for the research grant received during the development of this study (CAPES/PDSE, Proc. nº 7284/13-6) for giving me the opportunity to visit the largest collection globally recognized the Smithsonian Institution (NMNH) which enabled the development of this paper.

PLATE DESCRIPTIONS

6.1-6.5

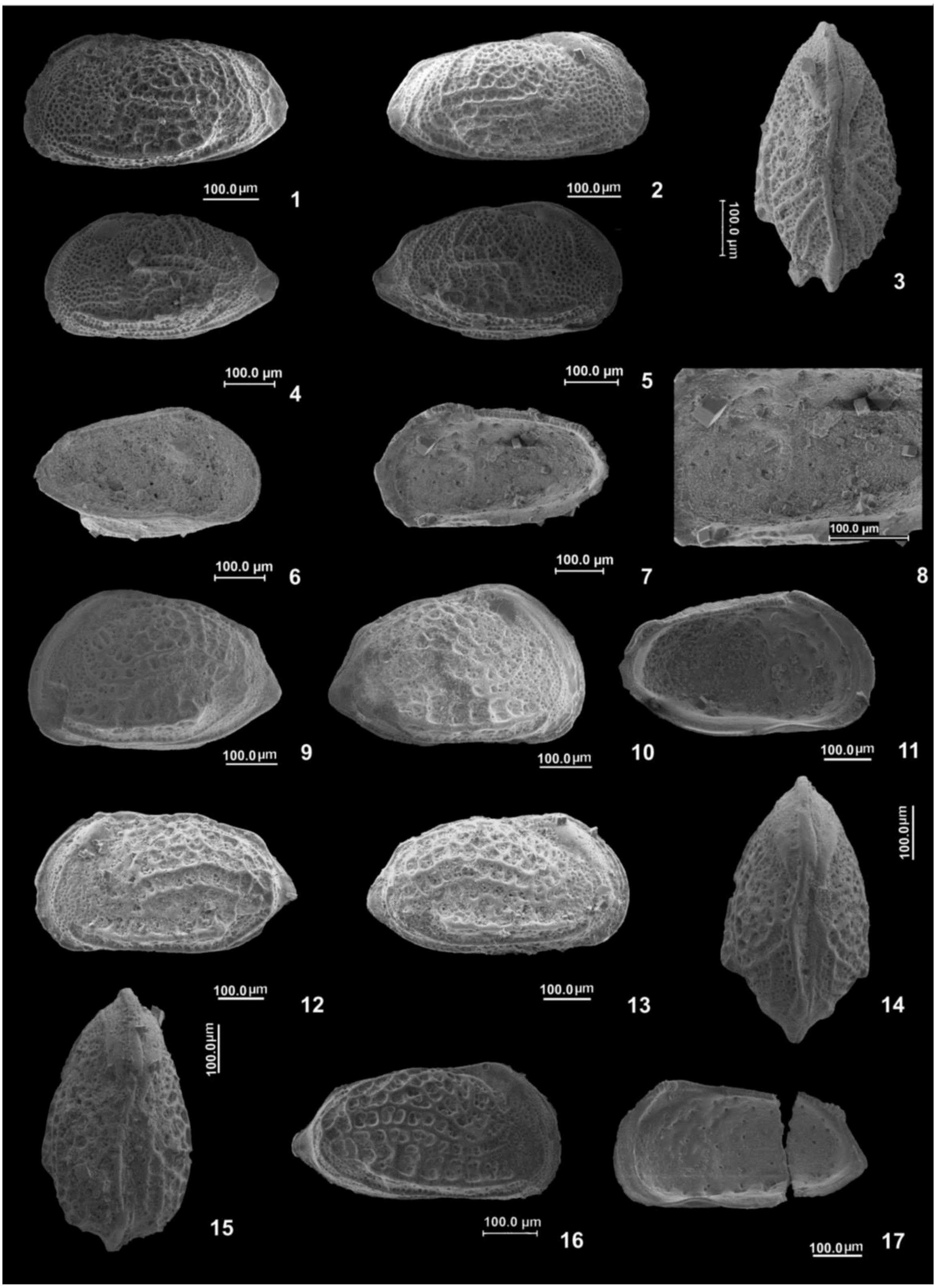
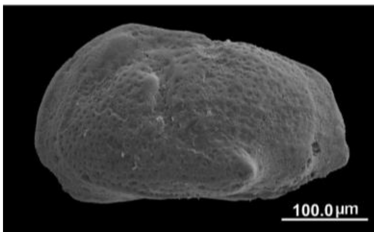


Plate 6.1. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-8.** ***Perissocytheridea punctoreticulata*** **n. sp.**: **Fig. 1.** Male, C, LV, external view, MPEG-503-M. **Fig. 2.** Male, C, RV, external view, MPEG-503-M. **Fig. 3.** Dorsal view, MPEG-503-M .**Fig. 4.** Female, C, LV, external view, MPEG-504-M. **Fig. 5.** Female, C,RV, external view, MPEG-504-M. **Fig. 6.** Female, RV, external view, MPEG-505-M. **Fig. 7.** Female, LV, external view, MPEG-506-M. **Fig. 8.** Detail of the muscle scars, RV, MPEG-506-M. **Figs. 9-17.** ***Perissocytheridea largulateralis*** **n. sp.**: **Fig. 9.** Female, C, LV, external view, MPEG-507-M. **Fig. 10.** Female, C, RV, external view, MPEG-507-M. **Fig. 11.** LV, internal view, MPEG-509-M. **Fig. 12.** Male, C, LV, external view, MPEG-508-M. **Fig. 13.** Male, C, RV, external view, MPEG-508-M. **Fig. 14.** Female, Dorsal view, MPEG-507-M. **Fig. 15.** Male, Dorsal view, MPEG-508-M. **Figs. 16.** Male, RV, external view, MPEG-510-M. **17.** RV, internal view, MPEG-510-M.



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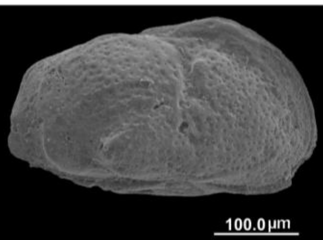

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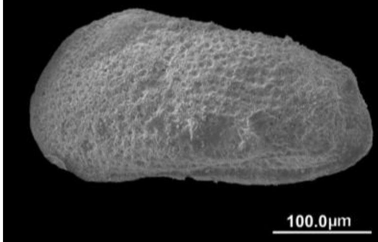

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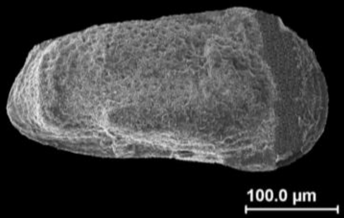

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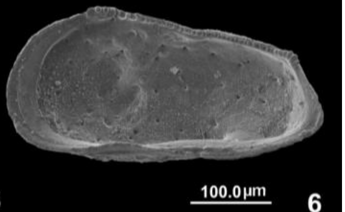

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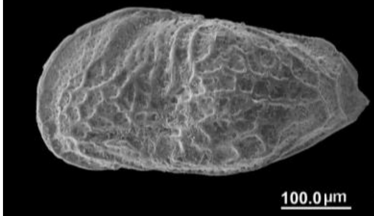

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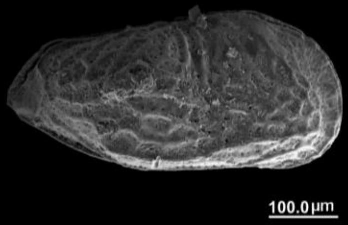

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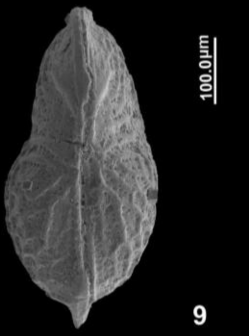

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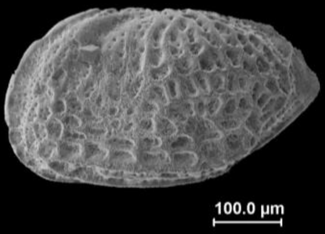

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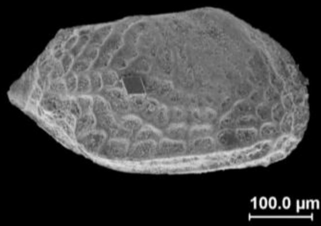

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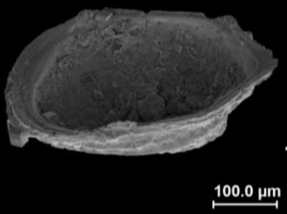

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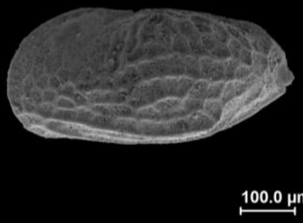

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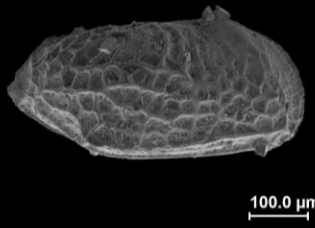

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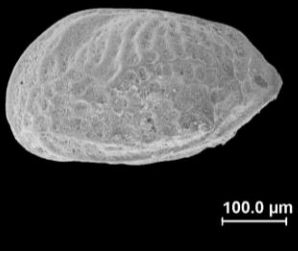

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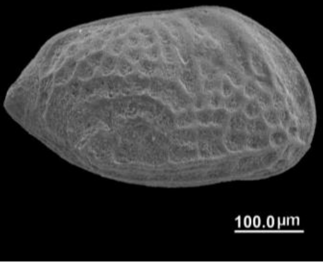

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Plate 6.2. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs.1-6**. ***Perissocytheridea colini*** **n. sp.**: **Fig. 1.** Female, C, LV, external view, MPEG-511-M. **Fig. 2**. C, RV, external view, MPEG-511-M. **Fig. 3**. Female, Dorsal view, MPEG-512-M. **Fig. 4**. Male, C, LV, external view, MPEG-513-M. **Fig. 5.** Male, C, RV, external view, MPEG-513-M. **Fig. 6.** Male, LV, internal view, MPEG-514-M. **Figs.7-17**. ***Perissocytheridea pirabensis*** **n. sp. Fig. 7.** Male, LV, external view, MPEG-518-M. **Fig. 8.** RV, external view, MPEG-518-M. **Fig. 9.** Dorsal view, MPEG-518-M. **Fig. 10.** Female, LV, external view, MPEG-515-M. **Fig. 11.** Female, RV, external view, MPEG-515-M. **Fig. 12.** RV, internal view, MPEG-518-M. **Fig. 13.** Male, LV, external view, MPEG-517-M. **Fig. 14.** Male, RV, external view, MPEG-517-M. **Fig. 15.** Female, LV, external view, MPEG-519-M. **Fig. 16.** Female, RV, external view, MPEG-519-M. **Fig. 17.** Dorsal view, MPEG-519-M.

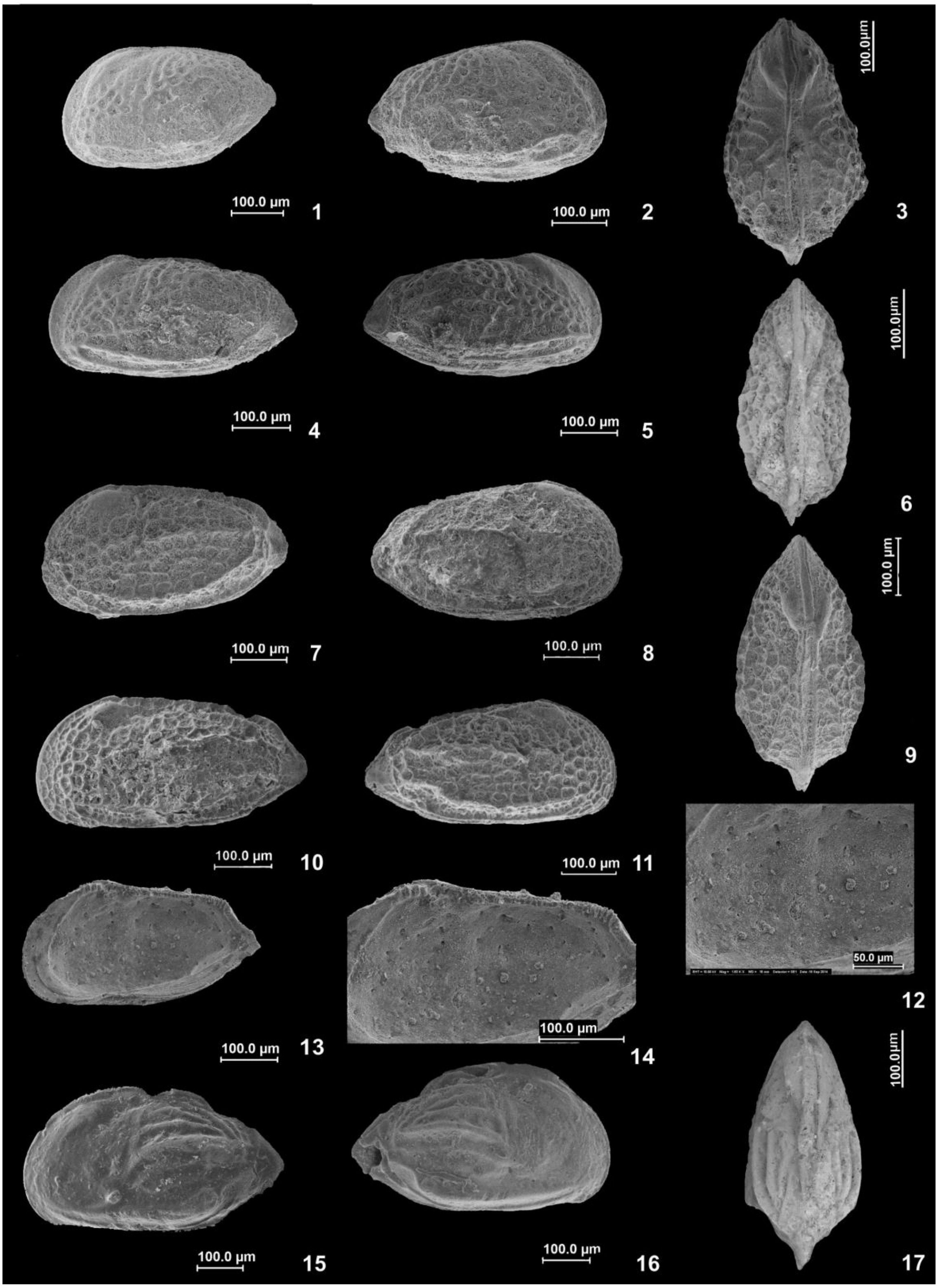
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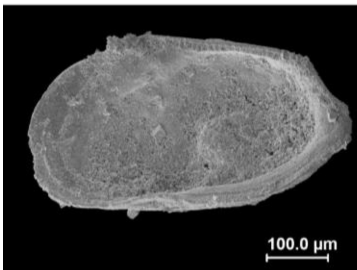
Plate 6.3. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1 – 5.** ***Perissocytheridea pirabensis*** **n. sp.**: **Fig. 1.** Female, C, LV, external view, MPEG-520-M. **Fig. 2.** Female, C, RV, external view, MPEG-520-M. **Fig. 3.** Juvenile, Dorsal view, MPEG-520-M. **Fig. 4.** Juvenile, Male, C, LV, external view, MPEG-521-M. **Fig. 5.** Juvenile, Male, C, RV, external view, MPEG-521-M. **Figs. 6 – 14.** ***Perissocytheridea*** **aff.** ***P. pumila***: **Fig. 6.** Male, Dorsal view, MPEG-523-M. **Fig. 7.** Female, C, LV, external view, MPEG-522-M. **Fig. 8.** Female, C, RV, external view, MPEG-522-M. **Fig. 9.** Female, Dorsal view, MPEG-522-M. **Fig. 10.** Male, C, LV, external view, MPEG-523-M. **Fig. 11.** Male, C, RV, external view, MPEG-523-M. **Fig. 12.** Detail of the muscle scars, RV, MPEG-522-M. **Fig. 13.** Female, RV, internal view, MPEG-522-M. **Fig. 14.** Detail of the hinge, RV, MPEG-522-M. **Figs. 15 – 17.** ***Perissocytheridea*** **aff.** ***P. brachyforma*** subsp. ***excavata*** **Fig. 15.** Female, C, LV, external view, MPEG-527-M. **Fig. 16.** C, RV, external view, MPEG-527-M. **Fig. 17.** Dorsal view, MPEG-527-M.



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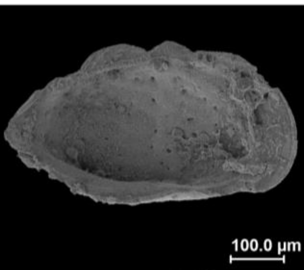

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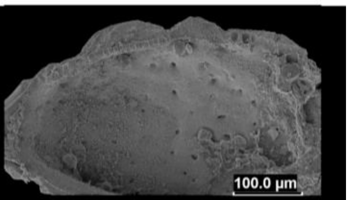

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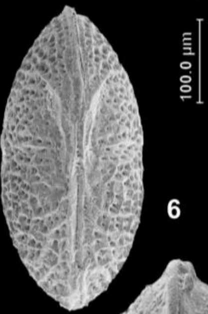

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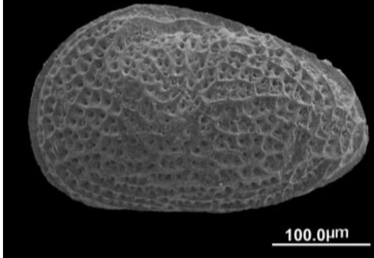

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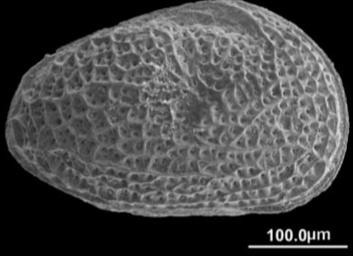

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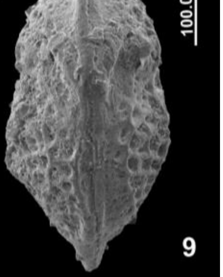

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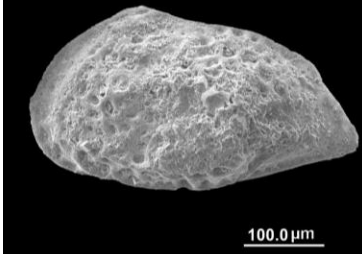

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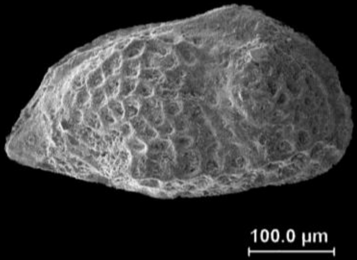

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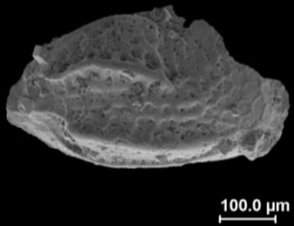

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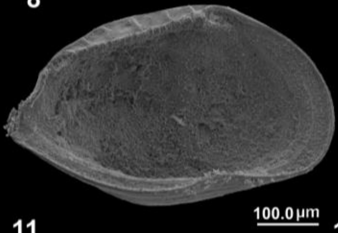

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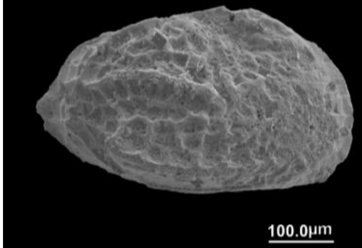

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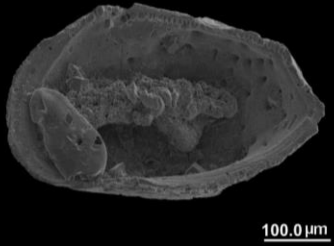

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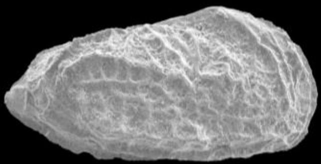

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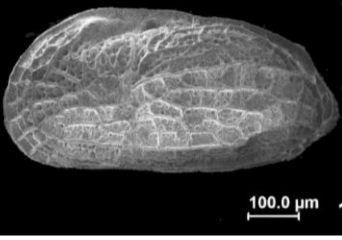

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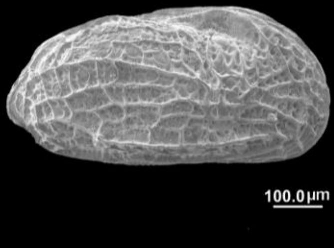

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Plate 6.4. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-3.** ***Perissocytheridea* aff. *P. brachyforma*** subsp. ***excavata***: **Fig. 1.** Male, RV, internal view, MPEG-529-M. **Fig. 2.** Female, LV; internal view, MPEG-528-M. **Fig. 3.** LV, internal view, MPEG-528-M. **Figs. 4 – 6. *Perissocytheridea* sp. 1**: **Fig. 4.** C, LV, external view, MPEG-530-M. **Fig. 5.** C, RV, external view, MPEG-530-M. **Fig. 6.** Dorsal view, MPEG-530-M. **Figs. 7 – 9. *Perissocytheridea* sp. 2**: **Fig. 7.** C, LV, external view, MPEG-531-M. **Fig. 8.** C, RV, external view, MPEG-531-M. **Fig. 9.** Dorsal view, MPEG-531-M. **Figs. 10 – 12. *Perissocytheridea* sp. 3**: **Fig. 10.** LV, external view, MPEG-532-M. **Fig. 11.** RV, external view, MPEG-533-M. **Fig. 12.** LV, internal view, MPEG-532-M. **Figs. 13 – 15. *Perissocytheridea* sp. 4**: **Fig. 13.** Female, RV, external view, MPEG-534-M. **Fig. 14.** Female, RV, internal view, MPEG-534-M, **Fig. 15.** Male, RV, external view, MPEG-535-M. **Figs. 16 – 18. *Perissocytheridea* sp. 5**: **Fig. 16.** LV, external view, MPEG-536-M. **Fig. 17.** RV, external view, MPEG-536-M. **Fig. 18.** Dorsal view, MPEG-536-M.

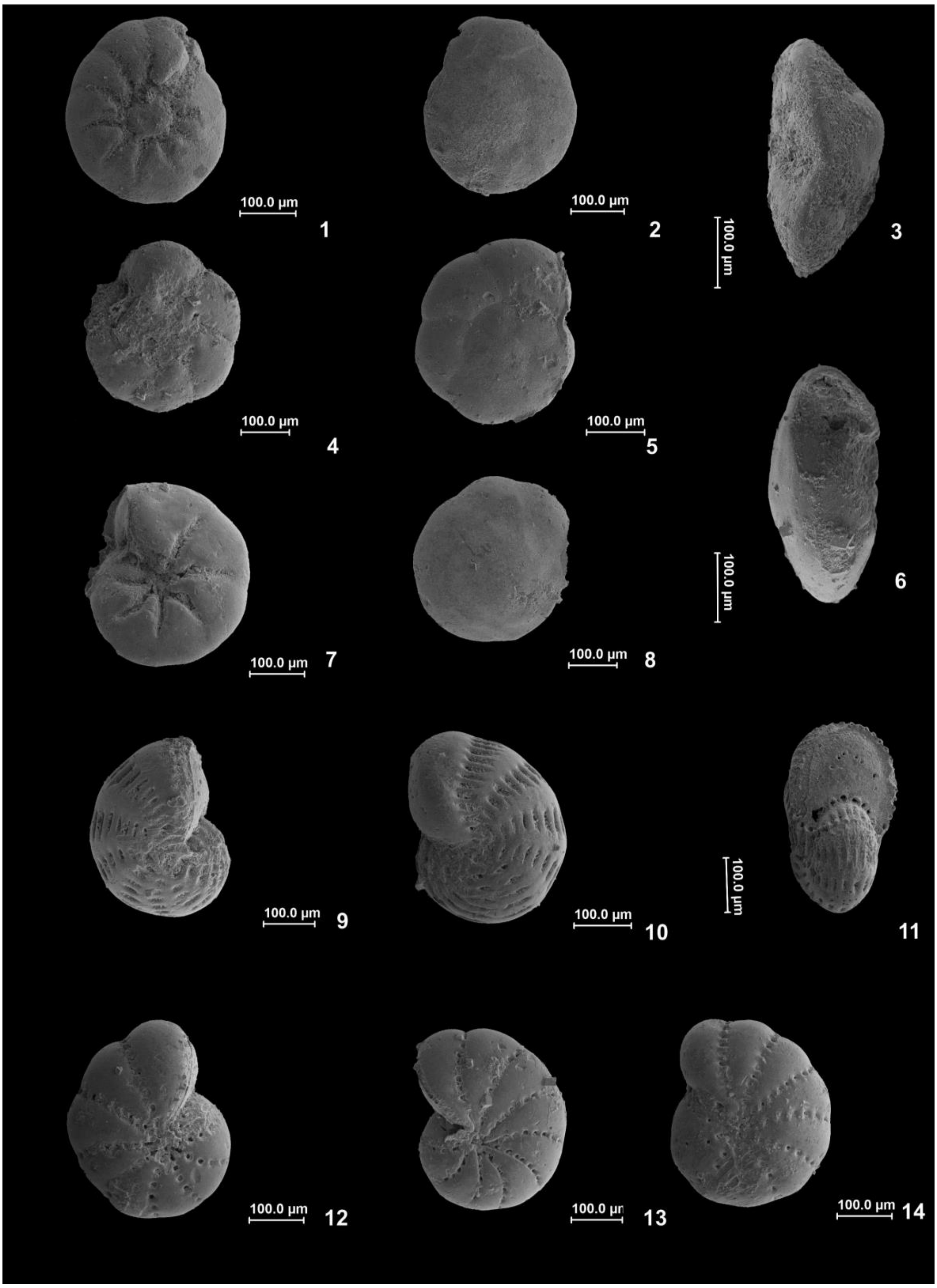

Plate 6.5. Scale bar: 100µm: SEM photomicrographs of three *Ammonia* species and two *Elphidium* species representative of the environments recorded in the samples: **Figs. 1-3.** ***Ammonia parkisoniana***, side view. **Figs. 4-6.** ***Ammonia*** **sp.**, side view. **Figs. 7-8.** ***Ammonia beccari***, side view. **Figs. 9-11.** ***Elphidium*** **sp**, side view. **Figs. 12-14.** ***Elphidium (Criboelphidium) poyanum***, side view.

CAPÍTULO 7

7. TAXONOMY OF OSTRACODS FROM PIRABAS FORMATION (OLIGO-MIOCENE), EASTERN AMAZONIA (PARÁ STATE, BRAZIL)

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ABSTRACT

Ostracods from Oligo-Miocene Pirabas Formation, eastern Amazonia, Para State, Brazil were examined from four surface and one subsurface sections. A total of 119 species were recognized and are illustrated in this paper. The extensive survey from the literature as well as the comparative study through the analysis of type material from Bold's and Howe's Collections allowed to identify thirty-six new species and recognized 27 species common to the Neogene of Caribean. Others 12 species were left in "aff." abbreviation, 3 left in "cf." and 38 species left in open nomenclature; besides of two species recognized for other areas and more one species already described for the studied unit herein. This study provides a robust taxonomic database for application to the palaeoenvironmental, biostratigraphycal and paleogeographycal studies and is a contribution to the paleobiodiversity of Neogene Ostracods from North of Southwestern Atlantic.

Key words: taxonomy, Ostracoda, Miocene, Pirabas Formation, Eastern Amazonia, Brazil.

7.1. INTRODUCTION

The Oligo-Miocene Pirabas Formation is one of the most important fossiliferous units of the Cenozoic of Northeastern Amazonia. A compilation of geological and paleontological studies about the Neogene of this region, including the Pirabas Formation can be accessed in Rossetti and Góes (2004). Paleontological and stratigraphic studies have reported a diverse invertebrate fauna, as well as abundant microfossils (Maury 1925; Petri 1957; Macedo 1971; Fernandes 1984; Ferreira 1966; Ferreira *et al.* 1981, 1984; Távora 1994a, 1994b, 1994c; Ramos *et al.* 2004a; Távora *et al.* 2007).

Previous taxonomic and biostratigraphic studies of ostracods from several localities within the State of Pará, including Fortaleza Island, Atalaia beach and Aricuru village, from Pirabas Formation revealed an ostracod fauna similar to the Caribbean region (Macedo 1970, 1971; Távora 1994a, 1994b, 1994c, Távora *et al.* 2001). In addition to that, Fernandes (1988) and Fernandes and Távora (1990) carried out other relevant studies on the biostratigraphy and paleoenvironmental reconstruction of the Pirabas Formation based on ostracods and foraminifera. The similarity between the ostracods from the Noegene of Pirabas Formation with others Miocene Caribbean stratigraphic units was highlighted by Távora (1994a, 1994b, 1994c) and Távora *et al.* (2001).

However, more recent studies revealed that the high diversity and abundance of the ostracods from Pirabas Formation still need a revision and more detailed taxonomic study to provide a more precise paleoenvironmental, biostratigraphical and paleobiogeographycal results. Nogueira *et al.* (2011) give a contribution with detailed taxonomic information about the *Haplocytheridea* and *Cytheridea* genera from Capanema region, Pará State, northern Brazil. These genera are abundant and have commom occurrence in the studied locality representing shorelines and cycles of progradation/retroprogradation during the deposition of Pirabas sequence. In addition, its abundance and diversity were emphasized and commom species to North America, as well as the Florida and Caribbean units were recorded. Recently, the genus *Perissocytheridea* from different sections of Pirabas Formation was also studied in detail given additional contribution to the paleoenvironmental interpretation of Pirabas Formation (Nogueira and Ramos, submitted).

The ostracod fauna studied herein provides an extensive database adding the record of 120 species to the Neogene of Brazil, which are very important to the studies of the origin and subsequent dispersal of regional faunas. Based on a preliminary generic-level database, Wood *et al.* (1999) revealed that the Caribbean region was an important centre of Neogene South American ostracod origin and that the Miocene was the peak of dispersion and radiation event. Thus, the present study will be of fundamental importance to fill the gap existent in the ostracod record between the Neogene of Caribean and the North of South America to contribute to the ostracod evolution and radiation patterns from the Americas.

7.2. GEOLOGICAL SETTING AND AGE

The Pirabas Formation consists of geographically extensive and highly fossiliferous carbonates deposits that are part of a larger Transgressive-Regressive cycle. In northern Brazil, it is well exposed in northeastern State of Pará and along of the littoral of Maranhão and Piauí states and are composed of a variety of sedimentary rocks including limestones and siliciclastics, and intercalated with siliciclastic deposits of the Barreiras Formation.

These deposits are internally organized into three stratigraphic successions delimited by regional discontinuity surfaces indicative of an incised estuarine valley system. These sedimentar successions have accumulated during numerous episodes of high-frequency relative sea level fluctuations, superimposed upon an overall transgressive phase (Góes *et al.* 1990; Rossetti and Góes 2004; Rossetti 2006). The paleoenvironments of this succession have been interpreted as a complex of transitional marine (lagoon and mangrove swamps) and shelf (outer shelf to marine restricted shelf) deposits, with sporadic coral reefs, shallow and warm waters (Ferreira 1977; Ferreira and Fernandes 1987; Rossetti and Góes 2004, Rossetti *et al.* 2013).

The study area covers the northeastern of Amazonia, in the State of Pará, Brazil from where five localities were studied and sampled (four outcrops and one core drilled near of Primavera village, Fig. 7.1). A brief summary of the localities is presented in the Figure 7.2.

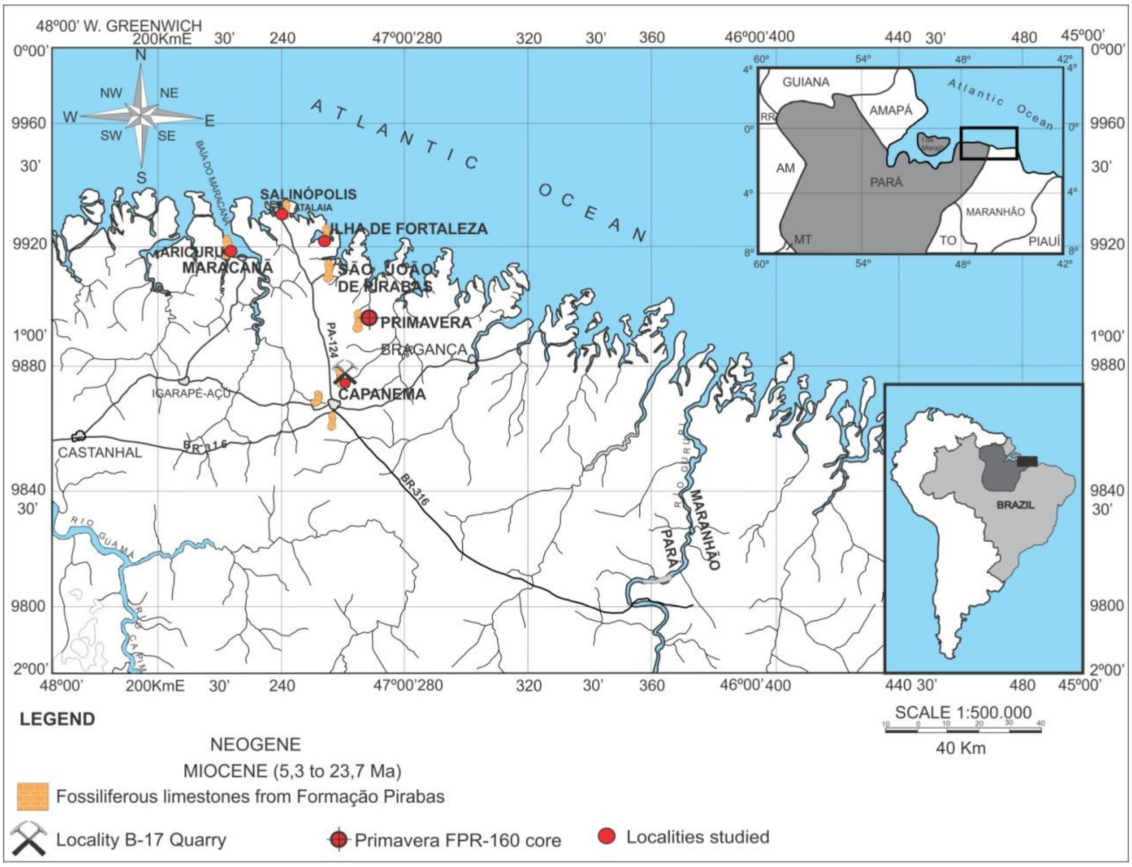

Figura 7.1. Location map of the studied area and the respective localities (Modified of CPRM, 2000 – Geological Chart).

City	Ocorrences, kind of outcrop/denomination	General Informations	Coordinates
Capanema	B-17 Quarry	Carbonate succession of up to 12m through the top to the siliciclastic of Barreiras Formation.	1º2’53.77’’S/ 47º9’9.21’’W
São João de Pirabas	carbonates *hardgrounds* exposed in Cliffs and /Ponta do Castelo in the Fortaleza Island	Carbonate succession of up to 4m thick. Larger exposure during low tide.	0º40’59.19’’S/ 47º10’14.47’’W
Maracanã District	carbonates *hardgrounds* exposed in Cliffs /Aricuru	Carbonate Succession of up to 4m thick. Larger exposure during low tide. Carbonates are in tectonic contact (normal failure to reject metric) to the Barreiras Formation.	0º42’46.08”S/ 47º30’7.2”W
Salinópolis	carbonates *hardgrounds* exposed in Cliffs /Atalaia Beach	Carbonate succession of up to 4m thick. Large exposure during low tide and when the coastal erosion levels are maximum.	0°35'37.01"S/ 47°18'57.44”W
Primavera	Core FPR–160	the core is stored in the repository of the Sedimentology Laboratory of Geoscience Department, UFPA	(0°56'52.76"S/ 47° 5'48.58”W)

Figure 7.2- Studied localities and general descriptions.

7. 3. MATERIAL AND METHODS

The studied material comprise 57 samples (7 barrel samples) collected from 4 surface sections: B-17 quarry (19 samples), Ponta do Castelo (Fortaleza Island; 5 samples), Aricuru (Maracaná bay; 6 samples) and Atalaia (Salinópolis; 4 samples); and one of subsurface Primavera FPR-160 Core (23 samples).

Samples were processed according to standard methods for calcareous microfossils in the Sedimentology labs from Museu Paraense Emílio Goeldi (MPEG) and Universidade Federal do Pará (UFPA) going through steps that involve: 1Kg of sediment from each sample was washed through the standard sieves (63, 125, 250 and

500 µm); water bath was used to facilitate the disintegration of samples. Also the acetolysis method was used to disintegrate hardrocks samples from the Fortaleza Island and Atalaia sites, which method involves the insertion of 30g of sediments in 100 ml (10%) of acetic acid for 12 hours. The samples were washed subsequently with deionized water and sieved (Rodrigues *et al.* 2011). To the quantitative analysis the weight sample from the sieve of 63, 125 and 250 µm-fractions was standardized at 6 g; All ostracods were picked from ≥ 0, 250 mm fraction using a Zeiss Stereo Microscope. Micrographic images were take nusing LEO model 1450VP scanning electron microscope at Museu Paraense Emílio Goeldi (MPEG) State of Pará, Brazil; HITACHI Scanning Electron Microscope (TM3000) at Universidade Federal do Pará (UFPA); PHILIPS model / FEI (XL30) Scanning Electron Microscope (SEM and ESEM) and HITACHI Scanning Electron Microscope (TM3000) at Smithsonian Institution National Museum of Natural History (NMNH).

7.4. RESULTS

Twenty-three families, sixty-four genera and one hundred and nineteen ostracod species were identified and illustrated herein. Ninety-nine ostracod species occur in B-17 quarry (33 new species; 19 species common to Caribe; 32 species in open nomenclature; ten left in “aff.” and two in “cf.” abbreviations; two species described for others areas and more one described previously for studied unit here); one-hundred species occur in Primavera core (27 new species; 19 species common to Caribe; 33 species in open nomenclature; nine left in “aff.” and two in “cf.” abbreviations; three species described for others areas and more seven described previously for studied unit here); eighty-four species have been identified in the Aricuru sites (27 new species; 18 species common to Caribe; 23 in open nomenclature; eight left in “aff.” and three in “cf.” abbreviations; two species described for others areas and more two described previously for studied unit here); fourteen species (6 new species; 3 open nomenclature; 3 species common to Caribe; one described for other area; and one left in “aff.” abbreviation) in Fortaleza Island site (Ponta do Castelo) and ten species in Atalaia beach site (4 new species; 4 species common to Caribe; and two left in “aff.” abbreviation). The commom species in all localities are *Cytherella stainforthi* van den Bold, 1960, *Bairdoppilata pintoi* n. sp., *Propontocypris* aff. *P.* ex. gr. *dreikanter* (Coryell and Fields 1937), *Cushmanidea*? *salahiensis* n. sp., *Jugosocythereis pannosa* (Brady 1869) and *Coquimba congestocostata* (Bold, 1963b) Bold, 1971b.

In general, the most abundant species are *Cytherella stainforthi* van den Bold, 1960, *Bairdoppilata pintoi* n. sp., *Cytheridea coimbrai* Nogueira *et al.*, 2011, *Dameriacell*a? *caudata* n. sp. Liebau, 1991, *Pellucistoma magniventra* Edwards, 1944, *Jugosocythereis pannosa* (Brady 1869), *Quadracythere adornata* n. sp., *Pontocypris* aff. *P. ex. gr.dreikanter* (Coryell and Fields, 1937) and *Pontoleberys dactylotypa* van den Bold, 1965.

The genera *Haplocytheridea*, *Cytheridea* and *Perissocytheridea* are also commom and abundant in the studied sections but they were studied in separate papers by Nogueira *et al.* (2011) and Nogueira and Ramos (submmited).

7.4.1. Systematic Paleontology

The type-material and illustrated specimens were deposited in the paleontological collection (micropaleontological section) of MPEG and under the numbers (MPEG-549-M to MPEG-825-M). For the survey of species and identification purposes the Index of Non-Marine and Marine Ostracoda of Kempf (1986) and “Ellis and Messina” catalogue (1965) were used. In addition, to the suprageneric classification the “Treatise” (Moore 1961) and Liebau (2005) was followed. In addition, a number of papers dealing mainly with Neogene ostracods from North and Central America (e.g. Bold´s publications) were consulted. Type material from van den Bold’ and H. V. Howe's collection (HVH, Louisiana State University Museum) as well as the type-material stored at the Smithsonian Institution (US Natural History National Museum) were extensively used for comparative purposes**.**

The following abbreviations were used in the species description and plates legends: C = carapace; RV = right valve; LV = left valve; H: height, L: length and W: width. The genera of each species are organized in familiar order.

Subclass OSTRACODA Latreille, 1806
Order Myodocopida Skogsberg, 1920
Suborder Cladocopina Sars, 1866
Family Polycopidae Sars, 1866
Subfamily Polycopinae Sars, 1866
Genus *Polycope* Sars, 1866
Polycope sp.

Plate 7.2, figs. 2 and 3

Material: 1 carapace.

Dimensions: MPEG-549-M, C; LV: L: 0.38 and H: 0.33 mm. Dorsal: L: 0.34 mm and W: 0.18 mm.

Remarks: Only one specimen of this genus was found in the studied material precluding a more detailed study about this species. It is similar to the species *Polycope orbicularis* Sars, 1866; however differs in size and strongly in the ornamentation of the surface.

Occurrence: B-17 quarry in B11A level.

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Subclass OSTRACODA Sars, 1866

Order Podocopida Sars, 1866

Suborder Bairdiocopina Gründel, 1967

Superfamily Bairdioidea Liebau, 2005

Family Bairdiidae Sars, 1888

Genus *Bairdoppilata* Coryell, Sample and Fields, 1935

Bairdoppilata antillea van den Bold, 1946

Plate 7.1, figs. 15-19

1946. *Bairdia antillea* van den Bold, p. 69, pl. 1, figs. 2a-c.

1961.*?Bairdia gigacantha* Kornicker, p.62, pl. 1, fig. 2a-c; text-figs. 6A-H, 10A, D.

1965. *Bairdia antillea* (van den Bold). van den Bold, p. 387, pl. 1, fig. 13.

1988. *Paranesidea antillea* (van den Bold). van den Bold, pl. 1, fig. 15.

Material: 50 carapaces and 163 valves.

Dimensions: MPEG-550-M, C; LV: L: 0.81 mm and H: 54 mm; RV: L: 80 mm and height 0.47 mm. MPEG-551-M, LV: L: 0.77 mm and H: 0.48 mm. MPEG-552-M, internal view, LV: L: 0.89 mm and H: 0.58 mm.

Remarks: This species was firstly assigned to *Bairdia antillea* van den Bold, 1946 (Bold, 1965; HVH8294, Howe Collection) from Republic Dominican (Neogene, Yague Group). It is very similar to the species studied herein, but the type speciemen is a little bit larger (L 0.94mm; H 0.68mm). The species *?Bairdia gigacantha* Kornicker, 1961 also is similar, however its is larger and the present species has in the LV a frill with a series of denticles in the posterior end. Bold (1988) changed this species to

Paranesidea, however in the present study the muscle scars (pl. 7.1, fig.19) are more similar to the *Bairdoppilata* pattern.

Occurrence: Aricuru (Maracanã bay): levels 01-05; B-17 quarry, Capanema, levels: B1A, B11A, B13-B13B; Ponta do Castelo (Fortaleza Island), level PC-00; FPR-160 Core (Primavera), Levels AM.17.

Distribution: Neogene of Republic Dominican (Mao, Gurabo and Cercado Formation); Lower Miocene of Cuba (Paso Real Formation); Miocene of Puerto Rico (Lares, Cibao and Aguada Formations). Lower Miocene to Recent of northern and western Caribbean (Bold, 1988). Lower Miocene, Pirabas Formation, Para, Brazil.

Bairdoppilata oblongata (van den Bold, 1946)

Plate 7.1, figs. 20, 21 and 25

1946. *Bairdia amygdaloides* Brady, van den Bold, p. 70, pl.1, figs. 5a, b.

1975c. *Bairdia oblongata* (Bold). van den Bold, p. 239, pl. 14, fig. 10, pl. 15, figs. 11, 12; 1977, table 2.

1974. *Bairdia* aff. *amygdaloides* (Brady) van den Bold, pl. 3, figs. 1, la.

1988. *Bairdoppilata oblongata* van den Bold, pl. 1, figs. 16-17.

Material: 31 carapaces and 86 valves.

Dimensions: MPEG-553-M, C; LV: L: 0.71 mm and H: 0.42 mm; RV: L: 0.70 mm and H: 0.38 mm. MPEG-554-M, C; LV: L: 0.91 mm and H: 0.56 mm; RV: L: 0.89 mm and H: 0.48 mm. MPEG-555-M, C; LV: L: 0.56 mm and H: 0.91 mm.

Remarks: The type species *Bairdoppilata oblongata* (Bold, 1946) van den Bold, 1988 (HVH10497) described to Dominican Republic is closest to the specimens described herein, but differs in larger size (L 1.05mm; H 0.63mm) and in more convex ventral margin of the LV. However, these characteristics are not enough to share in two species. Also, *Bairdoppilata triangulata* Edwards, 1944 (HVH2490) from North Carolina and Miocene of Florida (Ecophora facies, Jacksn Bluff) is a little bit larger than the species described herein, presenting a very similar outline of carapace. The present species is also similar to *B. pintoi* n. sp. described herein, but is more elongate and lower in lateral view.

Occurrence: Aricuru (Maracanã bay): levels 01-04; all the samples from Atalaia (Salinópolis); B-17 quarry, Capanema, levels: B2, B5-B8, B11, B12, B11A, B13-B13B;

Ponta do Castelo (Fortaleza Island), level PC-00; FPR-160 Core (Primavera), Levels AM.8, AM.12, AM.13, AM. 19 and AM.20.

Distribution: Upper Miocene and Pliocene from Cuba and Dominican Republic (Gurabo, Cercado and Mao Formations). Lower Miocene, Pirabas Formation, Para, Brazil.

Bairdoppilata pintoi n. sp.

Plate 7.1, figs. 1-8, 10 and 11

1950. *Bairdia* sp. van den Bold, pl.18, fig.3.

Material: 1188 carapaces and 2008 valves.

Etimology: In honor to the brazilian ostracodologist Prof. Irajá Damiani Pinto for his significant contributions to the studies of ostracods in Brazil.

Holotypes: MPEG-556-M, adult, C; LV: L: 0.86 mm and H: 0.55 mm; RV: L: 0.84 mm and H: 0.53 mm; Dorsal: L: 0.90 mm and W: 0.49 mm. MPEG-557-M, internal view, LV: L: 0.88 mm and H: 0.58 mm.

Paratypes: MPEG-558-M, juvenile, C; LV: L: 0.56 mm and H: 0.37 mm; RV: L: 0.53 mm and H: 0.35 mm; Dorsal: H: 0.51 mm and W: 0.28 mm. MPEG-559-M, internal view, LV: L: 0.61 mm and H: 0.39 mm.

Diagnosis: this species presents dorsal margin slightly concave to almost straight in the LV. Ventral margin nearly rounded and strongly convex in the LV. Dorsal view with irregular margins or subquadrate with short and curve hinge line. Surface slightly ornamented by rounded pits distributed regularly mainly in the margins.

Description: large and subtriangular carapace, in lateral view. Dorsal margin slightly concave to almost straight in the hinge line of the LV, except in the LV of juveniles (pl. 7.1; fig. 1) that is convex. Ventral margin nearly rounded and strongly convex in the LV and in the RV with a small concavity in the median portion; anterior margin subrounded. Posterior margin narrow and short in both valves. Dorsal view with irregular margins or subquadrate with short and hinge line straight. Surface slightly ornamented by rounded pits distributed regularly mainly in the margins. Internal view: short hinge line in the LV with auxiliary teeth in juveniles' specimens presenting a small and crenulate groove followed by sockets in the LV extremities, but in adults ones of these structures is absence. Selvage strongly developed in adult specimens. Muscle scars consisting in cluster of 9-10 ovoid scars and concentrate almost in the center of the carapace and two rounded mandibular scars. Others internal features were not observed.

Remarks: This species was assigned to the genus *Bairdoppilatta* due to the auxiliary dentition of the hinge at anterior and posterior ends, muscle scar pattern and outline, which corresponds to diagnosis of *Bairdoppilata*. The specimens illustrated by Bold (1950) was firstly assigned to *Bairdia* sp. van den Bold, 1950 (HVH4022) found in the localities of Zulia, Venezuela, in the Miocene from La Rosa Formation (Upper?) and it is very similar to species described herein in the outline and size mainly with respect to specimens more juveniles illustrated (pl.1, figs. 1-3). The species of the present study also resembles to *Bairdoppilata* sp. Howe and Chambers, 1935 (HVH4052 and HVH5757) although differs in more truncate anteroventral margin; *Bairdoppilata martyni* Coryell, Sample and Jennings, 1963 (HVH6468) and *Bairdoppilata triangulata* Edwards, 1944 (HVH2490) are similar mainly in shape of the carapace although they are larger and more rounded in the dorsal margin.

Occurrence: Quarry B-17, town of Capanema, PA, all levels except for the B9.

Distribution: Quiroz Formation, Miocene of Venezuela. Upper Oligocene to Lower Miocene, Pirabas Formation, Para, Brazil.

Bairdoppilata dorsoarcuata n. sp.

Plate 7.1, figs. 9, 12-14

Material: 18 carapaces and 26 valves.

Etimology: Latin: *dorsum*= dorsal margin, upper portion; arcuata= *arcuatus*, archead, curved as an arc.

Holotype: MPEG-560-M, C; LV: L: 0.80 mm and H: 0.55 mm; RV: L: 0.79 mm and H: 0.48 mm. Dorsal: H: 0.86 mm and W: 0.41 mm.

Paratype: MPEG-561-M, internal view, LV: L: 0.87 mm and H: 0.56 mm.

Diagnosis: large, thick-shelled carapace, shape of LV subtriangular in lateral view; RV subquadrate. Dorsal margin angularly and strongly arched in LV; short and straight in the RV. Surface slightly ornamented by rounded pits distributed irregularly over the margins in lateral view.

Description: large, thick-shelled carapace, LV subtriangular in lateral view; RV subquadrate. Dorsal margin angularly convex and strongly arched in LV; straight, obliquely sloping to posterior and concave in the ends of RV; cardinal angles rounded.

Antero and posterodorsal slope straight in LV, slightly concave in the extremity of the RV. Ventral margin slightly straight in the LV and sinuous in the RV; antreo and posteroventral slope convex towards extremity. Anterior asymmetrically rounded, more angular in RV than in LV. Posterior bluntly caudate; slightly rounded in LV. Surface slightly ornamented by rounded pits distributed irregularly over the margins in lateral view. Internal view: hinge with identation at anterior and posterior ends as described for the genus. Other internal features were not observed.

Remarks: this specie is very similar to *Paranesidea*? *confusa* Titterton and Whatley, 1988 although differs in the smaller size, moderately thick-shelled and with a more triangular shape.

Occurrence: Aricuru (Maracanã bay): levels AR-01 and AR-03; B-17 quarry, Capanema, levels: B0, B1, B2, B3, B4, B5, B7, B13A and B13B; FPR-160 Core, Levels AM.8, AM.13, AM.18 and AM. 20.

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Para, Brazil.

Bairdoppilata depressa n. sp.

Plate 7.1, figs. 22-24

Material: 6 carapaces and 4 valves.

Etimology: Latin: *deprimere*= refer to the anterior region with extend depressed area, descend.

Holotype: MPEG-562-M, C; LV: L: 0.82 mm and H: 0.51 mm; RV: L: 0.79 mm and H: 0.45 mm; Dorsal: H: 0. 82 mm and W: 0.45 mm.

Paratype: MPEG-563-M, LV: L: 0.85 mm and H: 0.56 mm;

Diagnosis: anterodorsal slope downward with a depressive area in the posterodorsal region in side view. Surface apparently smooth except for slightly rounded pits distributed irregularly in the margins.

Description: large and subtriangular to subovate carapace, in lateral view; greatest height about in the middle point of the dorsal margin in the LV; in the RV it is coincident with the anterodorsal higher angle. Thick-shelled, shape of LV more subrounded in lateral view; RV subquadrate. Dorsal margin broadly arched in the LV and, longer and straight in the RV; antero and posterodorsal slope slightly concave in the end of the RV. Ventral margin slightly convex in the LV and almost straight in the RV. Anterior margin asymmetrically rounded. In the RV, posterior bluntly caudate. Dorsal view very depressive near to the extremities and very inflated in the middle portion. Surface apparently smooth except for slightly ornamented by rounded pits distributed irregularly to the margins. Anterodorsal region with an extend depressed area slightly in the posterodorsal region in side view. Discret denticles in the posteroventral region. Internal features were not observed.

Remarks: The species resembles to *B. rotunda* (Alexander) Howe and Laurencich, 1958 (HVH5339) from Cretaceous, however it differs in the more arched dorsal margin than in the species described in the present study and also presenting more robust carapace and shorter posterior end.

Occurrence: Aricuru (Maracanã bay): levels AR- 01- AR- 03 and AR-05.

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Bairdoppilata sp.

Plate 7.2, fig. 1

Material: 1 carapace and 24 valves.

Dimensions: MPEG-564-M, C; LV: L: 0.70 mm and H: 0.53 mm; LV: L: 0.84 mm and H: 0.60 mm.

Description: medium to large valve subovate in outline in lateral view; greatest height about in the middle. Thick-shelled, shape of LV more subrounded in lateral view. LV overlaps to the RV. Posterior bluntly angular; extremity acutely rounded in LV. Dorsal margin angularly convex in the middle portion; cardinal angles rounded; anterodorsal slope slightly concave in LV and posterodorsal strongly convex. Ventral margin slightly convex in the LV. Anterior margin asymmetrically rounded. Anteroventral brodly rounded. Posteroventral slope convex towards extremity. Surface apparently smooth except for slightly ornamented by rounded pits distributed irregularly. Internal features were not observed.

Remarks: This species is similar to *Bairdoppilata pintoi* n. sp. described herein in general carapace shape and size, except in the dorsal margin more arched.

Occurrence: all the samples from Aricuru (Maracanã bay), level AR-1 to AR-5; all the samples from Atalaia (Salinópolis); B-17 quarry, Capanema, levels: B11, B11A, B11B and B13B; FPR-160 Core (Primavera), level AM.15.

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Genus *Mydianobairdia* Titterton and Whatley, 1988

Type-species *Triebelina schyroconcha* Madocks, 1969

Emended Diagnosis: A small robust genus of the Bairdiinae, subromboidal in lateral view, subcilindrical to subelliptical in dorsal view. Anterior margin with long convex anteroventral slope and apex above mid-height; posterior margin with subventral apex and long straight or slightly concave posterodorsal slope. Dorsal surface covered with small spines, papillated or punctate. Long thin marginal spines anteriorly and posteroventrally. Hinge adont, narrow. Auxiliary dentition absent. Adductor muscles scars usually 8 in two obliquely curved rows.

Mydianobairdia punctata n. sp.

Plate 7.2, figs.5-7

Material: 2 carapaces and 1 valve.

Etimology: punctata= *punctum*; refer to the punctae on all surface of the carapace.

Dimensions: MPEG-565-M, C; LV: L: 0.60 mm and H: 0.31 mm; RV: L: 0.56 mm and H: 0.30 mm; Dorsal: H: 0. 62 mm and W: 0.30 mm.

Diagnosis: subrhomboidal carapace in lateral view and surface punctate regularly.

Description: subrhomboidal carapace, in lateral view; subcylindrical in dorsal view. LV overlap to the RV more in the dorsal margin. Dorsal margin angular with cardinal angle less developed in the LV; long straight or slightly concave posterodorsal slope Ventral margin straight. Anterior margin of both valves possess long convex anteroventral slope and apex above mid-height. Posterior margin subventral apex. LV with short and flattened spines anteriorly and two spines short and flattened posteriorly. Surface punctate regularly.

Remarks: this species is similar to *Mydianobairdia shyroconcha* (Maddocks, 1969) in Titterton and Whatley, 1988 mainly in shape, but differs in the ornamentation densely covered with punctae. Titterton and Whatley (1988) comments that others punctate species with similar shape to *Mydianobairdia* identified from Indonesia as well as *Bairdia tuberculata* (Brady) and *B.* sp. aff. *tuberculata* from Recent of Panamá may be included in this genus and suggest emend its diagnosis. Thus, an emend to the diagnosis of this genus is proposed here.

Occurrence: B17 quarry, Capanema, Levels B7 and B13; FPR-160 core (Primavera) in the levels AM. 8 and Aricuru Location (Maracanã bay), levels AR-1 to AR-3.

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Genus *Neonesidea* Maddocks, 1969

Neonesidea sp. 1

Plate 7.2, figs.4 and 8

Material: 9 valves.

Dimensions: MPEG-566-M, RV: L: 0.83 mm and H: 0.46 mm. MPEG-567-M, RV: L: 0.92 mm and H: 0.48 mm. MPEG-568-M, RV: L: 0.91 mm and H: 0.45 mm.

Description: typical *Neonesidea* in shape. Large RV. Moderately thick-shelled. Shape subtrapezoidal in lateral view. Dorsally slightly straight in the middle; anterodorsal end slightly concave and strongly concave in the posterodorsal end.Ventral margin almost straight, strongly inclined to upwards from the ventromedian to the posteromedian region. Posterior margin strongly acuminate. Selvage forms a small notch at posterior extremity in RV. Cardinal angles strongly pronounced. Oral concavity pronounced. Valve surface almost smooth covered with minute punctae irregularly. Internal features typical of genus, apparently an adult valve.

Remarks: very similar in the shape to *Neonesidea? crepidula* Titterton and Whatley, 1988, but differs in the ornamentation and in the size much higher than the species studied here.

Occurrence: Aricuru Location (Maracanã bay), levels AR-03 and AR-05; B17 quarry, Capanema, Level B13; FPR-160 core (Primavera) in the level AM.14.

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Neonesidea sp.2

Plate 7.2, fig.12

Material: 3 valves.

Dimensions: MPEG-569-M, RV: L: 0.56 mm and H: 0.28 mm.

Description: Medium and very low valve extended posteriorlly. Moderately thin-shelled. Trapezoidal in shape. Dorsally slightly straight becoming concave to the extremity. Ventral margin strongly sinuous, concave in the middle; anteroventral slope convex to straight ventrally; posteroventral slope slightly turned upwards and extended to the posterior end that is strongly acuminate. Anterior margin irregular. Posterior margin pointed. Cardinal angles less pronounced. Valve surface smooth and finelly punctuate irregularly.

Remarks: This species is similar to *Neonesidea* sp. aff. *Neonesidea woodwardiana* (Brady, 1880) from Quaternary, Solomon Islands (Titterton and Whatley, 1988) but differs to be more trapezoidal, less elongate to subrectangular in shape, lower and smaller. However differs of *Neonesidea woodwardiana* (Brady, 1880) because it is lower and more extended posteriorlly.

Occurrence: FPR-160 core (Primavera); levels AM. 4 and AM.8.

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Para, Brazil.

Neonesidea sp. 3

Plate 7.2, figs. 9-11

Material: 3 valves.

Dimensions: MPEG-570-M, RV: L: 0.75 mm and H: 0.38 mm. MPEG-571-M, RV: L: 0.59 mm and H: 0.30 mm. MPEG-572-M, RV: L: 0.47 mm and H: 0.23 mm.

Description: medium and subrhomboidal carapace, in lateral view. Dorsal margin subtriangular in the adults, convex in the middle; straight posterodorsal slope slightly concave in the end; anterodorsal slope slightly concave. Straight in the juveniles, with cardinal angles well marked. Ventral margin sinuous with a concavity in the middle; anteroventrally straight and convex posteroventrally. Anterior margin stronghly angular with apex above mid-height. Posterior margin strongly acute, with apex below mid-height. Surface slightly punctate distributed irregularly.

Remarks: In general, this species resembles more *Neonesidea* sp. 2 than *Neonesidea* sp. 1 on the outline of the carapace and in the pronounced cardinal angles and the ornamentation pattern. However, it differs of *Neonesidea* sp. 2 to be more subrhomboidal than trapezoidal.

Occurrence: B17 quarry, Capanema, Levels B5; FPR-160 core (Primavera) in the levels AM. 8.

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Genus *Paranesidea* Maddocks, 1969

Paranesidea elegantissima van den Bold, 1946

Plate 7.2, figs.14-16

1946. *Bairdia elegantissima* van den Bold, p. 69, pl.1, figs. 9a-b.

1965. *Bairdia elegantissima* van den Bold, p. 387, pl.1, figs. 15a-b.

Material: 2 carapaces and 5 valves.

Dimensions: MPEG-573-M, C; LV: L: 0.56 mm and H: 0.30 mm; RV: L: 0.55 mm and H: 0.27 mm; Dorsal: H: 0.55 mm and W: 0.24 mm. MPEG-574-M, C, RV: L: 0.55 mm and H: 0.27 mm. MPEG-575-M, RV: L: 0.52 mm and H: 0.27 mm. MPEG-576-M, RV: L: 0.48 mm and H: 0.25 mm.

Remarks: this species is assigned to *Paranesidea elegantissima* van den Bold, 1946 for presenting all the features of the genus and species, however, differs just in the smaller size comparing to the size of the type species (L 0.80mm; H 0.43mm).

Occurrence: B-17 quarry; levels: B1, B5, B12, B11A and B13; FPR-160 core (Primavera); level AM. 8.

Distribution: Lower Miocene from Cuba (Guines and Cojímar Formations), Puerto Rico (Lares Formation), Panama (Panama Formation), Brazil (Pirabas Formation).

Genus *Glyptobairdia* Stephenson, 1946

Glyptobairdia crumena (Stephenson, 1944) Stephenson, 1946b

Plate 7.2, figs. 13, 17-19

1944. *Bairdia*? *crumena* Stephenson. p. 156, pl.28, fig.5.

1946b. *Glyptobairdia crumena* (Stephenson). Stephenson, p. 346-347.

1946a. *Triebelina cubensis* van den Bold, p. 74, pl. 5, figs. 4a-d.

1965. *Triebelina crumena* (Stephenson). van den Bold, p. 389, pl. 2, figs. 9a-c.

Material: 1 carapace and 6 valves.

Dimensions: MPEG-577-M, C; LV: L: 0.58 mm and H: 0.32 mm; RV: L: 0.55 mm and H: 0.28 mm. MPEG-578-M, C; LV: L: 0.58 mm and H: 0.33 mm.

Remarks: The type species of *T. crumena* (HVH9059) from Cuba is the same species recorded herein. This species was firstly classified as *Bairdia*? *crumena* by Stephenson (1944), but later Stephenson (1946b) propose a new genus considering this species as *Glyptobairdia crumena.* At the same year Bold (1946) record the same species as *Triebelina cubensis*. However *Glyptobairdia crumena* prevail under Bold species which later (Bold, 1965) was changed to *Triebelina crumena*. In the present study the generical classification of this species follow the accept taxonomy *Glyptobairdia crumena* (Stephenson) Stephenson, 1946b according to Brandão (2014). However, the present specimens is much more similar to others species of *Triebelina* as exposed below and probably belong to this genus. The species recorded herein differs from *T.*

howei (HVH9083) from Puerto Rico and *T. sertata* (HVH4769; HVH5095) from recent deposits of Caribbean sea by having a less regular curve of the dorsal ridge in the LV (more quadrate), presence of a well-defined median ridge in the LV, and less elongate RV with a less rounded dorsal ridge.

Occurrence: Aricuru Location (Maracanã bay), level AR-03; B11 and B11B (B-17 quarry); AM. 17 (Primavera core).

Distribution: Caribbean (late early Miocene) and Gulf Coast (Anahuac Formation), Miocene units: Cuba (Maguey, Paso Real and Guines Formations), Puerto Rico (Upper Lares Formation), Haiti (Madame Joie Formation), Trinidad (Kapur and Mejias Formation), Panama (La Boca Formation), Guatemala (Rio Dulce Formation) and sample C3038 from Bermúdez, cuba. Lower Miocene, Pirabas Formation, Para, Brazil.

Superorder Podocopomorpha Kozur, 1972
Suborder Cypridocopina Jones, 1901
Superfamily Pontocypridoidea Liebau, 2005
Family Pontocyprididae Müller, 1894
Genus *Argilloecia* Sars, 1865
Argilloecia? sp.1
Plate 7.2, figs. 20-22

Material: 2 carapaces and 10 valves.

Dimensions: MPEG-579-M, C; LV: L: 0.33 mm and H: 0.14 mm; RV: L: 0.33 mm and H: 0.15 mm; Dorsal: H: 0.33 mm and W: 0.14 mm.

Description: small and subangular carapace, in lateral view. Highest in front of the mid of the valve. Overlap reverse: LV slightly larger than RV overlapping except in dorsal margin. Ventral margin slightly straight. Slightly convex dorsal margin, more in middle of the RV than LV. Posterior portion presents one spine.

Remarks: this species is similar to *Argilloecia* sp.1 (HVH8291) van den Bold, 1968 from Miocene (Middle) of Dominican Republic, Gurabo Formation, however present a smaller size, the LV overlap to the RV in all the margins and absence of one spine in the posterior portion.

Occurrence: Aricuru Location (Maracanã bay), level AR-04; B13A and B13B (B-17 quarry); Ponta do Castelo, Fortaleza Island, level: PC-03.

Distribution: Lower Miocene, Pirabas Formation, Brazil.

Argilloecia sp. 2

Plate 7.2, figs. 23 and 24

Material: 1 carapace.

Dimensions: MPEG-580-M, C; LV: L: 0.48 mm and H: 0.18 mm; RV: L: 0.49 mm and H: 0.20 mm.

Description: small and subangular carapace, in lateral view. Highest in front of the mid of the valve. RV larger than LV overlapping in all. Dorsal margin slightly convex. Ventral margin of LV more concave than in the RV, which is almost straight. Posterior margin subrounded.

Remarks: this species is similar to *Argilloecia*? sp.1 however present a smaller size, cardinal angles more evident and the LV overlap to the RV in all the margins.

Occurrence: Capanema, B-17 quarry (level B11A).

Distribution: Lower Miocene, Pirabas Formation, Brazil.

Genus *Pontocypris* Sars, 1866

Pontocypris aff. *P.* ex. gr. *dreikanter* (Coryell and Fields) Van den Bold, 1958

Plate 7.3, figs. 1-2; and 13

1937. *Macrocypris dreikanter* Coryell and Fields, p. 4, figs. 4a, 4b.

1946. *Erythrocypris dreikanter* (Coryell and Fields). van den Bold, p. 63, pl. 3, fig. 3.

1958. *Pontocypris* ex. gr. *dreikanter* (Coryell and Fields, 1937). van den Bold, pl. 2, fig. 2a-2b.

Material: 175 carapaces and 225 valves.

Dimensions: MPEG-581-M, C; LV: L: 0.73 mm and H 0.36 mm; RV: L: 0.72 mm and H: 0.33 mm; Dorsal: H: 0.77 mm and W: 0.29 mm. MPEG-582-M, C; LV: L: 0.74 mm and H 0.37 mm; RV: L: 0.73 mm and H: 0.33 mm.

Description: medium and subtriangular carapace, in lateral view. Maximum height in front of the middle region of the LV. LV slightly larger than RV with overlapping for all margin except in the anterior margin. Ventral margin slightly sinuous. Dorsal margin strongly convex with a small concavity in the anterodorsal region. Anterior margin subrounded and posterior margin short and acute. Internal view with inner lamell and a short groove in the dorsal region.

Remarks: This species is similar to the type species *Pontocypris* ex. gr. *dreikanter* (Coryell and Fields, 1937) (HVH5100; HVH10150) from Caribbean Sea of Nicaragua (Holocene) that is similar in the outline and in the size of carapace differing only in the dorsal margin more arched. Furthermore, the species *P.* ex. gr. *dreikanter* (Coryell and Fields) van den Bold, 1958 also has a dorsal margin more arched mainly in the middle point, ventral margin straighter, posterior end less acute and dorsal view sinuous in outline. This species has closer features to *Pontocypris* than *Macrocypris* and *Paracypris* due to the size and the presence of an evident inner lamella in the anterior region, followed by a short one in the ventral and posterior internal outline typical to this genus. This species also is unlike *Paracypris* genus as this last genus presents a strong difference in the concavity of anterodorsal cardinal angle mainly in the RV. *Propontocypris* differs totally from those genera in the inner lamella which is wider in the anterior and posterior region beyond of a dorsal margin strongly arched in the middle portion. However this species is also similar to *Macrocypris menardensis*, (Harlton) Kellett, 1935 (USNM90102) from Stanton Formation (Pennsylvanian), Leavenworth, Kansas, in general carapace shape, but differs in the outline with dorsal margin more arched in the anterior cardinal angle, and in the size which is smaller than the type species.

Occurrence: Aricuru (Maracanã bay); Atalaia (Salinópolis) and some samples from B17 Quarry, levels: B0-B2A, B4-B9, B12-B11B, B13A and B13B; Ponta do Castelo (Fortaleza Island), levels: PC-02 and PC-03; FPR-160 core (Primavera), levels: AM.4, AM.6, AM.8, AM.10, AM.12, AM.13, AM.16, AM.17, AM.19 and AM.20.

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Para, Brazil.

Pontocypris sp.

Plate 7.3, figs. 3, 4 and 14

Material: 1 Carapace and 2 valves.

Dimensions: MPEG-583-M, C; LV: L: 0.82 mm and H: 0.40 mm; RV: L: 0.81mm and H: 0.37 mm; Dorsal: H: 0.87 mm and W: 0.33 mm.

Description: medium and subtriangular carapace, in lateral view. Maximum height in front of the middle of the LV. LV slightly larger than RV with overlapping for all margin, except in the antero and posteroventral margin. Dorsal margin acute in the median region. Ventral margin nearly straight. Anterior margin subrounded to slightly truncate in the LV; RV with concavity in the anterodorsal and subrounded in the anteroventral region. Posterior margin narrow and acute. Internal view with inner lamell and a short groove in the dorsal region.

Remarks: this species is similar to *Pontocypris* aff. ex. gr. *dreikanter* (Coryell and Fields, 1937) described here mainly in the shape, but differs in the posterior end more sharp in the second species, thin-shell and dorsal margin more rounded or less convex.

Occurrence: Aricuru (Maracanã bay); Atalaia (Salinópolis) and some samples from B17 Quarry, levels: B9 and B11B; FPR-160 core (Primavera), level AM.20.

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Genus *Propontocypris* Sylvester-Bradley, 1947

Propontocypris cf. *Macrocypris*? *dimorpha* (Hazel and Holden) Holden, 1976

Plate 7.3, figs. 7, 8, 11 and 15

1971. *Macrocypris dimorpha* Hazel and Holden, p. 6, pl. 5, figs. 8, 11, 13, 17, 19.

1976. *Macrocypris*? sp. aff. *M.*? *dimorpha* Hazel and Holden. Holden, plate 10, figs. 12-14, 19, 20

Material: 9 carapaces and 16 valves.

Dimensions: MPEG-584-M, C; LV: L: 0.56 mm and H: 0.30 mm; RV: L: 0.57 mm and H: 0.29 mm; Dorsal: H: 0.57 mm and H: 0.25 mm. MPEG-585-M, C; LV: L: 0.56 mm and H: 0.30 mm.

Remarks: in general shape, the species is close to the late Eocene (Tertiary) *Macrocypris*? sp. aff. *M.*? *dimorpha* Hazel and Holden, 1971 (USNM184363) but the type material (type series) has only juveniles specimens. There are some morphological differences between the *Macrocypris dimorpha* (Hazel and Holden, 1971) and *Macrocypris*? sp. aff. *M.*? *dimorpha* (Hazel and Holden) Holden, 1976; in the first species, the median dorsal portion of the specimens is more peaked and has a more concave ventral margin. Hazel and Holden (1971) not observed internal features in their population, and it is best to group the both specimens in one taxon. However, the species described herein presents stronger acute dorsal margin, almost straight ventral margin, and is shorter and smaller much closer to the genus *Propontocypris* than *Macrocypris.* Inner lamella typically for the *Propontocypris* genus. For this reason the species is considered as belong to this genus.

Occurrence: Aricuru (Maracanã bay): levels AR-01 to AR-04; B-17 quarry, Capanema, levels: B0 B5 and B13A; FPR-160 Core, Levels AM.17.

Distribution: this species was recorded in an upper Eocene from Eua Island locality, Tonga. Midway Island, Northeast of the Hawaii Island (North America), Late Cenozoic. Lower Miocene, Pirabas Formation, Para, Brazil.

Superorder Podocopomorpha Kozur, 1972
Suborder Cypridocopina Jones, 1901
Superfamily Cypridoidea Baird, 1845
Family Candonidae Kaufmann, 1900
Genus *Paracypris* Sars, 1866
Paracypris sp.
Plate 7.3, figs. 5, 6 and 16

Material: 2 carapaces and 6 valves.

Dimensions: MPEG-586-M, C; LV: L: 0.96 mm and H: 0.41 mm; RV: L: 0.50 mm and H: 0.21 mm; Dorsal: H: 1.0 mm and W: 0.47 mm.

Description: medium and subtriangular carapace, in lateral view. Maximum height in front of the middle of the LV, which is slightly larger than RV, overlapping for all margin, except in the anterior region. Dorsal margin truncate curved to the posterior. Ventral margin nearly straight, slightly concave in the LV, strongly concave in the RV. Anterior margin subrounded. Internal features not observed. Dosal view slender-shaped and opened valves in posterior end.

Remarks: this species is similar to the others species of the genus *Paracypris* mainly due to the long shape and a strongly acute posterior end like a witch nose-shaped. Differs in the dorsal margin of the RV that is more curve and arch than generally.

Occurrence: B-17 quarry (Capanema) in B1A, B11A, B13 and B13A; and FPR-160 core (Primavera) in the samples AM.12 and AM.17.

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Superorder Podocopomorpha Kozur, 1972
Superfamily Macrocypridoidea Müller, 1912
Family Macrocyprididae Müller, 1912
Genus *Macrocypris* Brady, 1867
Macrocypris gracilis (Brady, 1890) Holden, 1967
Plate 7.3, figs. 9, 10, 12 and 17

1890. *Pontocypris gracilis* Brady, p. 491, pl. 1, figs. 5, 6.

1967. *Macrocypris gracilis* (Brady). Holden, p. 16, 17, text-figs. 9a, b.

Material: 5 carapaces and 8 valves.

Dimensions: MPEG-587-M, C; LV: L: 1.03 mm and H: 0.48 mm; RV: L: 1.25 mm and H: 0.49 mm; Dorsal: H: 1.03 mm and W: 0.34 mm. MPEG-588-M, C; RV: L: 0.86 mm and H: 0.38 mm.

Remarks: *Macrocypris gracilis* (Chapman) Holden, 1967 (USNM648715) is very similar to the species studied herein differing only in the posterior end tapering to a blunt point and overlap reversed where RV overlapping slightly the LV. This species is also similar to *Macrocypris* sp. van den Bold, 1965, meanwhile, this differs to present ventral margin concave in the anterior region, convex in the posterior ¼; the concave region is almost parallel to the convex portion of the dorsal margin.

Occurrence: Aricuru (Maracanã bay): levels AR-01 to AR-04.

Distribution: this species is widespread in the central Pacific, occurring in the Cenozoic as fossil in the Hawaiian Islands and Easter Island and living in Fiji. Post-Miocene adults from the Sand Island holes are larger than the Lower Miocene adults in the reef hole. Aricuru Locality, Pirabas Formation (Lower Miocene), Pará, Brazil.

Superorder Podocopomorpha Kozur, 1972

Order Platycopida Sars, 1866

Superfamily Cytherelloidea Liebau, 2005

Family Cytherellidae Sars, 1866

Genus *Cytherella* Jones, 1849

Cytherella stainforthi van den Bold, 1960

Plate 7.4, figs. 4, 6-9

1960. *Cytherella stainforthi* van den Bold, pl. 1, figs. 3a-c.

Material: 94 carapaces and 287 valves.

Dimensions: MPEG-589-M, Female, C; LV: L: 0.52 mm and height 0.30 mm; RV: L: 0.50 mm and H: 0.27 mm; Dorsal: L: 0.52 mm and W: 0.20 mm. MPEG-590-M, Male, C; LV: L: 0.77 mm and H: 0.40 mm; RV: L: 0.75 mm and H: 0.41 mm. MPEG-591-M, C; LV: L: 0.77 mm and H: 0.40 mm; RV: L: 0.65 mm and H: 0.35 mm.

Remarks: *C. stainforthi* van den Bold, 1960 is recorded in Eocene of Trinidad and presents mainly the same shape and overlap of the valves. However, the species found in Pirabas Formation presents a smaller size, as well as a flattened shape, more pronounced in the dorsomedian region of the female RV, which is not described in the species of Bold.

Occurrence: all samples from Aricuru Location (Maracanã bay); Atalaia (AT-1 level); Ponta do Castelo Location (PC-01, PC-03 and PC-04); B-17 quarry (B13B; B13A; B13; B11A; B7A; B7; B5; B2; B1A; B1; B0 levels) and FPR-160 core (AM.4, AM.6, AM.8, AM.10, AM.11, AM.12, AM.15, AM.17 and AM.20).

Distribution: This species occurs throughout San Fernando Formation and in the Lower Cipero Formation (Oligocene), with the highest occurrence observed in the *Globigerina ciperoensis ciperoensis* zone. In the *Catapsydrax dissimilis* zone it is replaced by *Cytherella* sp. van den Bold, 1960. These species of foraminifera are fossil guide and are commonly recognized from the Oligocene to the Early Miocene. The type species of *G. ciperoensis* is restricted to the Oligocene-Early Miocene. Several morphotypes of this species appear in the Early Miocene (von Fred Rögl, 1994). In Pirabas this species extends for all sequence corresponding to the *C. stainforthi* Zone dated from Upper Oligocene to Early Micoene (Nogueira and Ramos, submitted).

Cytherella pseudopolita n. sp.

Plate 7.3, figs. 18-23

Material: 16 Carapaces and 15 valves.

Etimology: Grego: pseudo= *pseûdos.eos*, refer to the dorsal portion more angular suggesting a fake ovate C; Latim: ovata= *ovatum*, outline ovate.

Holotype: MPEG-592-M, Female, C; LV: L: 0.57 mm and H: 0.35 mm; RV: L: 0.60 mm and H: 0.40 mm; Dorsal: H: 0.60 mm and W: 0.31 mm.

Paratype: MPEG-593-M, Male, C; LV: L: 0.56 mm and H: 0.34 mm; RV: L: 0.59 mm and H: 0.37 mm; Dorsal: H: 0.58 mm and W: 0.26 mm.

Diagnosis: subovate and robust carapace, highest behind the middle; smooth in the surface, sparselly pitted in the margin. Pronounced dimorphism sexual.

Description: subovate and robust carapace, highest behind the middle. Dorsal margin concave in the LV and convex in the RV. Ventral margin nearly straight. Anterior margin rounded. Posterior margin rounded and lower than anterior margin. RV overlapping the LV along the entire margin, strongest in the anterior part of the ventral margin. RV is slightly depressed in the anterodorsal region, more in the middle portion and in the posterior part of the ventral margin. Slightly widest behind of the middle portion to the posterior end. Surface smooth, sparselly pitted in the margins. Sexually dimorphic: females wider and more robust than males.

Remarks: This species is very similar to *Cytherella polita* (Brady, 1880) var. van den Bold, 1966d, pl.1, fig.5 (HVH8193) from Tubará Formation, Northern Colombia and also to the illustred specimem (pl.1, figs. 2a,b, Bold, 1957) from Ste. Croix Quarry that was also recorded to the Miocene of Venezuela as *Cytherella* sp. (Bold, 1950); this species have almost the same size and very similar shape to the species described herein; however this species differs in a more ovate shape, in the ventral margin that is a little bit more convex and in the anteroventral region that is more angular; besides of the ornamentation that is more densely pitted and regularly distributed. The species described here is slightly lowest, less ovate and smoother. Although Bold (1966d) recognized that *C. polita* (Brady) has variations in the ornamentation (from smooth to densely pitted) as the specimens founded in Gatún Formation (Panama), the difference also in the outline of the present species make we share in different species. The specimen described here has also similar morphological features to *Cytherella* sp. van den Bold, 1957 (p. 235, pl. 1 figs. 3) described to the ?Oligocene to Pliocene (Talparo Formation) and also record in the Ste. Croix and Mejias Quaries of Trinidad, mainly in dorsal margin concave in the LV, RV overlapping the LV along the entire margin and slightly widest behind the middle to the posterior end; however differs mainly in the ventral margin that is more convex and in the bigger size.

Occurrence: Aricuru Location (Maracanã bay) Levels AR-01 to AR-03; B-17 quarry (Levels B0-B2, and B13B); FPR-160 core (Level AM.8 and AM.20).

Distribution: Lower Miocene, Pirabas Formation, Para, Brazil.

Cytherella altacaelateralis n. sp.

Plate 7.3, figs. 24-29

Material: 101 carapaces and 386 valves.

Etimology: Latin: alta= *altum* or *altus*, refer to the posterodorsal portion more elevate; caelata= *caelatum*, refer to species already described which is very similar in lateral view; *latateralis* = lateral view very similar to this species *C. caelata*.

Holotype: MPEG-594-M, Female, C; LV: L: 0.55 mm and H: 0.30 mm; RV: L: 0.57 mm and H: 0.33 mm; Dorsal: L: 0.57 mm and W: 0.24 mm. MPEG-595-M, Male, C;

LV: L: 0.54 mm and H: 0.29 mm; RV: L: 0.56 mm and H: 0.31 mm; Dorsal: L: 0.56 mm and W: 0.20 mm.

Paratype: MPEG-596-M, C; C; LV: L: 0.54 mm and H: 0.30 mm; RV: L: 0.55 mm and H: 0.30 mm.

Diagnosis: subovate to subrounded carapace and higher in the posterodorsal region, in side view. Dorsal and ventral margin straight. Dorsal region with a slightly flattened area. In the posterior and anterior region, evident pits are observed. Dorsal view wider in the posterior end. Surface finelly pitted in the margins, more sparsely in the middle of carapace.

Description: medium and subovate to subrounded carapace, in lateral view. Dorsal margin and ventral margin straight, mainly in the RV. The anterior margin more regularly rounded than in the posterior margin. The valves are assymmetric. The overlap of RV occurs almost uniformly along the carapace, less in the anterior region. The maximum height occurs in the posterior region. In the dorsal region, the carapace has a slightly flattened area following all this part, like a sulcus. Dorsal view suboval and rounded in the extremities: wider in the posterior end. Surface finelly pitted in the margins, more sparsely in the middle of carapace. Sexually dimorphic: females is highest than males in lateral view. In dorsal view, females more robust than males in the posterior end. Internal view was not observed.

Remarks: *Cytherella caelata* van den Bold, 1963b (pl.1, figs. 1a-1d) is similar to species described herein mainly in lateral view of the males, however, differs in dorsal view in these specimens due to the subrectangular outline and presence of sexual dimorphism. In the females differs mainly in the anterior region that has a prominent ridge and a more truncate posterior region, better visualized in dorsal view, than the species described herein. *Cytherella* sp. aff. *C. pulchra* Bold, 1957, recorded to Trinidad (Upper Eocene to Recent), differs a little of the species described herein in the shape and size (length 0.77 mm; height 0.49 mm).

Occurrence: all the samples from Aricuru (Maracanã bay); B-17 Quarry, Capanema, Pará (Levels: B0-B2A, B4, and B6-B13B); Ponta do Castelo Location (PC-02-PC-03); FPR-160 core (Levels AM.4 - AM.10, AM.12- AM.15 and AM.17-AM.20).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Para, Brazil.

Cytherella aff. *C. circumrugosa* Babinot, Moullade and Tronchetti, 2007

Plate 7.4, figs. 1-3

2007. *Cytherella circumrugosa* Babinot, Moullade & Tronchetti, pl. 1, 5-7.

Material: 13 carapaces and 23 valves.

Dimensions: MPEG-597-M, C; LV: L: 0.63 mm and H: 0.32 mm; RV: L: 0.65 mm and H: 0.33 mm; Dorsal: H: 0.63 mm and W: 0.28 mm.

Remarks: This species is assigned to aff. *C. circumrugosa* because the similarity to *Cytherella circumrugosa* Babinot, Moullade and Tronchetti, 2007 described to the Lower Cretaceous of the vicinity of Saint-Saturnin-lès-Apt, Vaucluse, SE France, in the dorsal and ventral margins subparallel and also in the presence of a same set of peripheral concentric ridges that weaken progressively toward the inner portion of the surface of the valves; differing just in the mid-dorsal posterior margin in both valves with a small pronounced area. Very similar in shape to *Cytherella* aff. *contracta contracta* Veen, 1932 (in Weaver, 1982) of the Cenomanian of England, but in that species the front part of the carapace is more flattened and apparently smooth while the species herein described presents a spread pits.

Occurrence: Aricuru Loc. (Maracanã bay, levels: AR-01 to AR-05); Atalaia Loc. (Level AT-1); B-17 quarry, Capanema (Levels: B0 and B11B); Primavera FPR-160 core (Levels: AM.4, AM.15 and AM.20).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Cytherelloidea* Alexander, 1931

Cytherelloidea colini n. sp.

Plate 7.4, figs. 5, 13-14

Material: 7 carapaces and 30 valves.

Etymology: in honor of Prof. Jean-Paul Colin for his contributions to the study of the freshwater and brackishwater ostracods.

Holotype: MPEG-598-M, C; LV: L: 0.45 mm and H: 0.25mm; RV: L: 0.46 mm and H: 0.26 mm; Dorsal: H: 0.47 mm and W: 0.17 mm.

Paratypes: MPEG-599-M, C; LV: L: 0.50 mm and H: 0.29 mm. MPEG-600-M, RV: L: 0.48 mm and H: 0.27 mm. MPEG-601-M, C; LV: L: 0.58 mm and H: 0.31 mm.

Diagnosis: a species of *Cytherolloidea* with ornamentation pattern consisting in a punctate surface around the anterior region and posterodorsal region.

Description: medium and subrectangular carapace, in lateral view. Dorsal margin sinuous with a concavity in the middle almost forming a shallow and large sulcus turn down posteriorly. Ventral margin almost straight. Anterior margin rounded and posterior margin oblique in lateral view. The posterior region is narrower than the anterior. Surface is strongly punctate in the anterior and in the posterodorsal region, near to the ridges. The arrangement of the posteroventral ridge protrudes to approximately half of the carapace. An anterior ridge follows to the ventral region weakly disappearing in the middle portion.

Remarks: this species presents a vertical ridge with curved shape in the posterior region protrudes irregular in the dorsal margin and other in the ventral margin of the carapace with more evidence and narrower differing of all the others species of genus consulted in the literature.

Occurrence: Aricuru Loc. (Levels AR-03, AR-04 and AR-06); B-17 quarry, Capanema, Pará, levels: B0, B1; B12; B9-B11A; B13-B13B; FPR-160 core, Primavera (Levels AM.8, AM. 17 and AM.20).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytherelloidea circinorobusta n. sp.

Plate 7.4, figs. 10, 15 and 16

Material: 5 carapaces and 27 valves.

Etimology: Latin: circino= *circinus*, refer to the strong ridges in compass-shaped; robusta= *robustum*, refer to the pronounced ridges.

Dimensions: MPEG-602-M, C; LV: length 0.46 mm and height 0.24mm; RV: length 0.47 mm and height 0.27 mm; Dorsal: length 0.47 mm and width 0.21 mm.

Diagnosis: the remarkable feature in this species is the presence of an evident arrangement of the ridges, which resembles a half loop-shaped and between these ridges the surface is enough smooth.

Description: medium and subrounded carapace. Dorsal margin subparallel. Ventral margin with a slight concavity in the middle portion. Anterior margin rounded and posterior margin subangular, obliquely rounded to the posteroventral margin. RV overlapping the LV in the entire outline, except in the anterior margin. In this part, both valves are equals. Dorsal view subrectangular with the evident and straight ridges arranged vertically and outline is pronounced from upper to lower parts. Surface smooth with an evident arrangement of the ridges with the presence of a highly pronounced vertical ridges in the posterior region, which joined with others two tumid horizontal ridges running toward to the anterior region: one shorter dorsally curved to the anteromedian region extending to 1/3 of the carapace; and other parallel and above the ventral margin, extending to the anteromedian region. This arrangement of the ridges resembles a half loop-shaped.

Remarks: this species presents a vertical ridge in the posterior region that joined with two horizontal ridges both in the central region of the carapace. All the others species of this genus consulted in the literature differ from this species.

Occurrence: Aricuru Loc. (Maracanã bay, level: AR-03); B-17 quarry, Capanema (Levels B1A, B7 and B9-B11A); Primavera FPR-160 core (Levels: AM.8 and AM.12-AM.14).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytherelloidea mediacythara n. sp.

Plate 7.4, figs. 11, 17-18

Material: 5 carapaces and 24 valves.

Etimology: Latin: media= *medium*, refer to the sinuous middle part of the ventral and dorsal margin; guitar= *cythara*, refer to the guitar-shaped of carapace mainly in the LV.

Dimensions: MPEG-603-M, C; LV: L: 0.52 mm and H: 0.26 mm; RV: L: 0.54 mm and H: 0.29 mm; Dorsal: H: 0.48 mm and W: 0.15 mm.

Diagnosis: the dorsal and ventral margins almost parallels with a strong sinuousity or biconcave in the middle of the carapace resembling a “guitar”. Dorsal view more elongate and straighter than others species, with almost parallel sides.

Description: elongate to subretangular carapace, in lateral view. Dorsal and ventral margins almost parallels, biconcave in the middle of the carapace. Anterior margin rounded and posterior margin more truncated. In general outline shape resembles a “guitar”; posterodorsal margin more strongly slopedown. Both valve with posterior extremity narrower, thereby this region less rounded and more oblique than anterior margin. Dorsal view elongate and straight, with almost parallels sides. Surface smooth and present an arrangement of three ridges: a vertical and short ridge in the posterior end diverging in two horizontal ridges in the median part of the carapace. Mid-dorsal ridge curved down and mid-ventral more straight. RV overlaps the LV in all margins, except in the posteroventral margin.

Remarks: No records of this species were found in previous studies of Pirabas Formation and others units until date. This species is similar to *Cytherelloidea anderseni* (Sexton, 1951), by presents a subtle overlay of the valves, ridges stronger in the RV, different vertical rigde in shape, therefore *Cytherelloidea mediacythara* n. sp. has two nearly parallel ridges in the central region of the C of the RV and more curved in the LV.

Occurrence: Aricuru Loc. (Maracanã bay, level: AR-01, AR-03- AR-05); B-17 quarry, Capanema (Levels B1A, B1, B8, B11-B13B); Primavera FPR-160 core (Level: AM.13).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytherelloidea quasilisa n. sp.

Plate 7.4, figs. 12, 19 - 20

Material: 3 carapaces and 10 valves.

Etimology: Latin: quase = *quasi*, refer to the almost smooth ornamentation; lisa= *levis*, refer to the smooth ornamentation around the ridges.

Holotype: MPEG-604-M, C; LV: L: 0.53 mm and H: 0.27 mm; RV: L: 0.54 mm and H: 0.28 mm; Dorsal: H: 0.54 mm and W: 0.22 mm.

Paratype: MPEG-605-M, C; LV: L: 0.54 mm and H: 0.28 mm; RV: L: 0.52 mm and H: 0.29 mm; Dorsal: H: 0.52 mm and W: 0.23 mm.

Diagnosis: Strong ridge run from the median region of the carapace extending parallel to the posterior and ventral margin forming a loop, shorter in the dorsal region. In the median region of the carapace, this ridge has a down “Y” shape; short and discret anteromedian ridge in the RV. Surface smooth between the ridges.

Description: elongate to subretangular carapace, in lateral view. Dorsal and ventral margins almost parallels with a light sinuousity, biconcave in the middle portion. Anterior margin subrounded and posterior margin subquadrate. Higher in the posterodorsal region. Strong ridge run from the median region of the carapace extending parallel to the posterior and ventral margin forming a loop. The posterior ridge is high and straight running parallel to the posterior margin almost forming a tubercle in the extremities. In the median region of the carapace, this ridge has a down “Y” shape, slightly in the RV; short and discret anteromedian ridge in the RV. RV overlaps the LV in all margins, except in the posterior. Surface smooth between the ridges.

Remarks: this species recorded in the B-17 quarry of Pirabas Formation is more similar to *Cytherelloidea anderseni* Sexton, 1951 found in the Chipola Formation, Florida (USA). Both species presents subretangular shape with posterior rigde high and almost forming two tubercules in the extremities from where protrudes the others two horizontal ridges: one shorter and sinuous ridges in the central region of carapace and the other running parallel to the ventral region extending to nearly 3/4 of C. The species differ in the marginal ridge, which is more marked in the species described by Sexton (1951). The species *C. obliquecostata* van den Bold, 1963b differ from the present species in the ornamentation pattern of ridges, although presents three median ridges and in the absence of the ridges extending to the ventral and posterior margin as in the species here described.

Occurrence: Aricuru Loc. (level AR-06); B-17 quarry, Capanema, Pará. levels: B13B; B13; B12; B11A; B11; B4; B2A; B1.

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytherelloidea cf. *vanveenae* (van den Bold, 1946) van den Bold, 1965

Plate 7.4, fig. 24

1946. *Cytherelloidea vanveenae* van den Bold, p. 61, pl. 5, figs. 1a-d.

1965. *Cytherella vanveenae* (Bold). van den Bold, p. 385, 401, pl. 1, figs. 1a-b.

Material: 3 valves.

Dimensions: MPEG-606-M, LV: L: 0.59 mm and H: 0.29 mm; MPEG-607-M, LV: L: 0.55 mm and H: 0.29 mm.

Remarks: *Cytherelloidea vanveenae* van den Bold, 1946 is probably the same species recorded herein, but differs only in the anterior and posterior margins with a smoother area surounding the carapace. The present species do not present the typical *Cytherelloidea* rigdes pattern, looking more as *Cytherella* and has only a discret vertical posterior rigde. Although, *Cytherelloidea vanveenae* (van den Bold, 1946) was considered as *Cytherella vanveenae* by Bold (1963b, 1965), the author discuss that this species belongs to a group which is apparently intermediate between *Cytherella* and *Cytherelloidea* recorded to Paleocene until the Recent. For this reason we decided to keep the generic position of this species as the original description. *Cytherelloidea certa*

Blaszyk, 1967, from Czestozhowa region, Poland (Middle Jurassic) is similar to species described here mainly in elongate shape and in the ornamentation pattern with pits distributed regularly. Therefore, it is larger and presenting a longitudinal furrow that runs through the middle of the posterior inflation.

Occurrence: Aricuru (Maracanã bay); levels: AR- 03 and AR- 04.

Distribution: Lower Miocene, Puerto Rico (Lares Formation) and Aricuru Locality, Pirabas Formation (Lower Miocene), Pará, Brazil.

Genus *Keijcyoidea* Malz, 1981

Keijcyoidea sp.

Plate 7.4, fig. 25

Material: 4 valves.

Dimensions: MPEG-608-M, RV: L: 0.62 mm and H: 0.36 mm.

Description: medium and subquadrate carapace, in side view, highest in front of the middle region. Dorsal margin sinuous. Ventral margin strongly concave in the middle. Anterior margin broadly rounded; posterior margin almost truncate, angular in the dorsal margin, forming nearly a right angle. Surface of the RV reticulate forming a mesh with concentric and parallel rows to the anterior region; which become more punctated and much larger to the posterior region. Posterior vertical ridge-like swelling near the posterior end, from which two sinuous longitudinal ridges extend forward. The dorsal ridge is strongly sinuous and curve around the ventral side of a shallow subcentral and subdorsal pit, which is somewhat triangular in shape with the apex pointing upward. The ventral ridge is almost straight. The anterior end with an evident ridge, which disappears to the dorsal and ventral margins. In the RV the posterior ridge is slightly more forward than the anterior.

Remarks: This species is similar to *Keijcyoidea praecipua* (van den Bold, 1963c) Malz, 1981 originally recorded in Recent coral sand from a beach at Pidgeon Point, southwestern Tobago mainly in shape, ornamentation and pattern of ridges; however it is smaller. Although a more accurate analysis with more material is necessary to confirm the identity of the follow species as well as to describe a new species. *Cytherelloidea flosculus* Bonaduce, Ruggieri, Russo and Bismuth, 1992 from Upper Miocene, Melqart Formation, Gulf of Gabès, (Tunisia) also resembles to *Keijcyoidea* sp. described here in shape and size, but differs in dorsal margin straight and in the ornamentation pattern with presence of a proeminent posterodorsal ridge and absence of reticles following the anterior margin.

Occurrence: Aricuru (Maracanã bay); levels: AR-01; Primavera FPR-160 core (Levels: AM.17).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Superorder Podocopomorpha Kozur, 1972
Suborder Cytherocopina Gründel, 1967
Infraorder Archaeocytherinina Liebau, 1991
Superfamily Paradoxostomatoidea Liebau, 2005
Family Cytheromatidae Elofson, 1939
Genus *Pellucistoma* Coryell and Fields, 1937
Pellucistoma magniventra Edwards, 1944
Plate 7.4, figs. 22-23, and 26

1944. *Pellucistoma magniventra* Edwards. p. 528, pl. 88, figs. 33-35.
1953. *Pellucistoma magniventra* Edwards. Puri, p. 289, pl. 15, fig. 4, text-fig. 12a.
1957. ? *Pellucistoma magniventra* Edwards. Puri and Hulings, p. 187, fig. 11.
1960. *Pellucistoma magniventra* Edwards. Puri, p. 119. pl. 2, figs.10-11, text-figs. 8-9.
1994c. *Pellucistoma magniventra* Edwards. Távora, p. 123, fig. 6.

Material: 340 carapaces and 364 valves.

Dimensions: MPEG-609-M, C; LV: L: 0.50 mm and H: 0.26 mm; RV: L: 0.52 mm and H: 0.28 mm; Dorsal: H: 0.54 mm and W: 0.21 mm.

Remarks: This species was originally recorded to uplin Marl (Upper Miocene) of North Carolina by Edwards (1944). According to Puri (1960), this species occurs in Recent deposits coast of the Florida. In Trinidad, it occurs from the Upper Brasso to the Upper Morne l'Enfer sands (Upper Miocene), and it is replaced in Recent deposits by a slightly more elongate species. The species is the same *Pellucistoma magniventra* Távora, 1994c recorded to the Pirabas Formation, but is bigger than this record and also than *Pellucistoma* aff. *P. magniventra* Edwards recorded by Bold (1981 and 1988).

Occurrence: Aricuru (Maracanã bay), levels AR-02- AR-4 and AR-06; B-17 quarry, Capanema, Pará (Levels B0-B1, B2A, and B5-B13B); Primavera FPR-160 core (Levels: AM.04, AM.06, AM.08, AM.10, AM.12, AM.13 and AM.15-AM.20).

Distribution: Upper Miocene to Recent. Upper Brasso, Upper Morne l'Enfer Formations, Trinidad (Upper Miocene); Upper Miocene from Gurabo Formation (Republic Dominican), Duplin Marl, North Carolina (Pliocene) and Recent deposits off Florida coast. Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Pellucistoma aff. *P.? kingmai* van den Bold, 1972b

Plate 7.4, figs. 24, 25 and 27

1972b. *Pellucistoma? kingmai* van den Bold, pgs. 1067 and 1069, pl. 2, figs. 6a-c; pl. 3, figs. 1a-c, pl. 4, fig. 6.

Material: 4 carapaces and 3 valves.

Dimensions: MPEG-610-M, C; LV: L: 0.51 mm and H: 0.26 mm; RV: H: 0.52 mm and H: 0.28 mm; Dorsal: H: 0.49 mm and W: 0.17 mm.

Description: medium and elongate carapace. Dorsal margin gently convex in the LV, strongly concave in the RV. Ventral margin strongly sinuous. Anterior margin obliquely rounded, more narrowly rounded below. Posterior margin with a subventral short caudal process, dorsal slope of posterior margin long and concave. RV overlapping the LV along mainly of dorsal margin and slightly overlaps around the anterior, posterior and ventral margins. Surface finely punctate. Dorsal view lanceolate, widest in the middle, ends compressed. Dimorphism sexual absent.

Remarks: this species is very close to *P.? kingmai* van den Bold (1972b) in size and in some aspects of the carapace shape. This species is quite different of *P. magniventra* Edwards, 1944 mainly in the posterior and anterior ends obliquely rounded, more narrowly rounded below and turning down, although is similar in the size and in the smooth surface.

Occurrence: B-17 quarry, Capanema, Pará (Level B11A).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Superorder Podocopomorpha Kozur, 1972

Suborder Podocopina Sars, 1866

Superfamily Cytheroidea Liebau, 2005

Family Cytheruridae Müller, 1894

Subfamily Cytherurinae Müller, 1894

Genus *Cytheropteron* Sars, 1866

Cytheropteron? *yorktownensis* (Malkin, 1953) Bold, 1946

Plate 7.5, figs. 1-3

1951. *Eocytheropteron* species Swain, p. 47, pl. 7, fig. 16.

1953. *Eocytheropteron yorktownensis* Malkin, p. 780, pl. 79 figs. 1-4.

1954. *Cytheropteron leonensis*. Puri, p. 242, pl. 4, figs. 11-12, figs. 6c-d.

1968. *Cytheropteron? yorktownensis* (Malkin). Swain, p. 13, pl. 4, figs. 7a-c, 11.

1974. *Shattuckocythere yorktownensis* (Malkin). Swain, p. 22, pl. 3, figs. 9, 12, 14, 15.

1974. Not *Shattuckocythere yorktownensis* (Malkin). Swain, p. 22, pl. 3, fig. 13, pl. 9, figs 9a-b. = *Microcytherura similis* (Malkin).

1994a. *Cytheropteron* cf. *C. yorktownensis* (Malkin). Távora, p. 104, fig. 10.

Material: 25 carapaces and 38 valves.

Dimensions: MPEG-611-M, C; LV: L: 0.30 mm and H: 0.18 mm; RV: L: 0.30 mm and H: 0.19 mm; Dorsal: L: 0.38 mm and W: 0.22 mm. MPEG-612-M, RV: L: 0.41 mm and H: 0.23 mm.

Remarks: This species is identic to the type species and is the same *Cytheropteron* cf. *C. yorktownensis* (Malkin, 1953) recorded by Távora, 1994a to Pirabas Formation. However, *Cytheropteron*? *yorktownensis* (Malkin) Swain, 1968 has the ventral alar process less elongate than the species described herein. It is a very common species from the Pliocene sediments along the North Atlantic Coastal Plain. This species is probably and sufficiently distinctive to be placed in a new genus although its generic assignment is uncertain at present. Swain (1974) assigned *C. yorktownensis* to a new genus *Shattuckocythere*. However, *Shattuckocythere* is not a useful taxon because the type species selected by Swain (*Cythere*? *shattucki* Ulrich and Bassler 1904) is a typical member of the genus *Microcytherura* Mueller 1894. The species also is related to *Cytheropteron* (*Cytheropteron*) *dominicanum* van den Bold, 1988 from Upper Miocene to Recent of Dominican Republic, but it is a few smaller and has a stronger ventral ridge.

Occurrence: Aricuru (Maracanã bay), levels AR-03- AR-04; B-17 quarry, Capanema, Pará (Levels B0, B1A, B1, B4, B7, B11-B13, and B13B); Ponta do Castelo, Fortaleza Island, Level PC-00; Primavera FPR-160 core (Levels: AM.08, AM.12, AM.15, AM.17 and AM.20).

Distribution: In the Chesapeake Group the species has been found only in the Yorktown Formation (Late Miocene to Middle Pliocene). It also occurs from Lower

Pliocene to Lower Pleistocene in the North Atlantic Coastal Plain. Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytheropteron bichense van den Bold, 1963b

Plate 7.5, figs. 4-7

1963b. *Cytheropteron bichense* van den Bold, p. 400, pl.9, figs. 9a-9b.

Material: 3 carapaces and 5 valves.

Dimensions: MPEG-613-M, C; LV: L: 0.30 mm and H: 0.21 mm; RV: L: 0.30 mm and H: 0.17 mm.

Remarks: this species is the same *Cytheropteron bichense* van den Bold, 1963b (HVH6883), however other characters not mentioned in the original description related to this species described here is the presence of large pits in the dorso median portion in lateral view. The species resembles to *Cytheropteron latum* Müller (1894, p. 300, pl. 20, figs. 3, 9; pl. 21, figs. 10-14), but differs by the presence of the median sulcus in the dorsal ridge.

Occurrence: Aricuru (Maracanã bay), level AR-04; B-17 quarry, Capanema, Pará (Levels B1A, B11 and B12); Primavera FPR-160 core (Levels AM.08 and AM.17).

Distribution: Biche Craelius Borehole: beds at 30-32 feet, Upper Miocene, Trinidad. Apart from the type locality, one specimen has been found in the neighboring Biche Calyx hole, no.44, 71-79 feet, and rarely found in the lower portion of the Forest Formation (Upper Miocene), Trinidad. Lower Miocene, Pirabas Formation, Para, Brazil.

Genus *Cytherura* Sars, 1866

Cytherura sp. 1

Plate 7.5, fig. 8

Material: 1 valve.

Dimensions: MPEG-614-M, LV: L: 0.38 mm and H: 0.20 mm.

Description: small and subrounded to sub-elongate valve in lateral view. Dorsal and ventral margins are subparallel: dorsal margin almost straight and ventral margin slightly convex, with a slight oral concavity. Anterior margin subrounded and posterior margin with a caudal process at the mid-posterior point; maximum height at posteromedian region. Posteroventrally, a concave portion presents in the ventral margin below of the caudal process. Surface reticulated with numerous anastomosing and slightly thick ridges; some dense minute punctae distributed and arranged regularly. Hinge features as for genus. Ocular tubercle not proeminent.

Remarks: based on general external morphology and ornamentation, this species is similar to *Semicytherura* aff. *S. clavata* (Brady) Whatley, Chadiwick, Coxill and Toy, 1988 recorded in this study (Plate 7.6, figs. 7-9), but it differs in a more evident ornamentation pattern, presence of a posteroventral depression and a less elongated shape.

Occurrence: Primavera FPR-160 core (Level AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytherura sp.2

Plate 7.5, fig. 9

Not 1944. *Cytherura elongata*, Edwards, p. 526, est. 88, figs. 21-25.

Not 1965. *Semicytherura elongata* (Edwards, 1944). Darby, pgs. 23 and 50, p1. 7, figs. 1-12.

1994a. *Cytherura elongata* (Edwards). Távora, p.100, fig.6.

Material: 5 valves.

Dimensions: MPEG-615-M, C; LV: L: 0.37 mm and H: 0.24 mm.

Description: small and elongate to subrectangular carapace, in lateral view. Dorsal margin slightly convex, almost straight. Ventral margin slightly sinuous with an evident ventrolateral alar process overlapping the ventral margin. Anterior margin obliquely rounded. Posterior margin with a posterodorsal caudal process and slopping obliquely to the posteroventral margin. Ocular tubercle is not so proeminent. Surface ornamented with delicate and sinuous longitudinal ridges, intermittent in the median portion; delicate transversal ridges defining a rectangular and irregular pattern like a “cobweb”.

Remarks: this species is the same species recorded to Pirabas Formation as *Cytherura elongata* (Edwards, 1944) by Távora, 1994a; however differs in the smaller size and the absence of the evident ventrolateral alar process overlapping the ventral margin. The species *Cytherura elongata* (Edwards) Morales, 1967 (type HVH8389) from recent deposits of Mexico is more elongate and present outline quite different than the species described herein.

Occurrence: Aricuru (Maracanã bay), levels AR-04; B-17 quarry, Capanema, Pará (Levels B11 and B12); Primavera FPR-160 core (Level AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytherura punctocentrata n. sp.

Plate 7.5, figs. 12-14;16-17

1994a. *Cytherura* sp. 1, Távora, p.102, fig.8.

Material: 6 carapaces and 2 valves.

Etimology: Latin: puncto = *punctatum*, refer to the ornamentation with deep and evident punctuations; centrata= *centratum*, *centratus*, refer to the punctuations position around the central portion on surface of carapace.

Holotype: MPEG-616-M, C; Female, LV: L: 0.33 mm and H: 0.18 mm; RV: L: 0.33 mm and H: 0.19 mm; Dorsal: H: 0.32 mm and W: 0.20 mm.

Paratype: MPEG-617-M, C; Male, LV: L: 0.34 mm and H: 0.15 mm; RV: L: 0.34 mm and H: 0.16 mm; Dorsal: H: 0.35 mm and W: 0.17 mm. MPEG-618-M, Male, internal view, RV: L: 0.36 mm and H: 0.20 mm.

Diagnosis: the evident features of this species is the surface ornamented with large and deep punctae concentrated more in the median portion of the carapace, transversely aligned. Irregularly swollen mainly in the mid-ventral portion forming a low, thick and swollen alar process. Two vertical sulci in the dorsomedian region.

Description: small and oval to elongate carapace, in lateral view. Dorsal margin slightly arched. Ventral margin subrectilinea, concave in the middle portion by the small alar process. Anterior margin rounded. Posterior margin with a pointed mid-posterior caudal process. Surface ornamented with large and deep punctae concentrated more in the median portion of the carapace, transversely aligned. Irregularly swollen mainly in the mid-ventral portion forming a low, thick and swollen alar process.. Two vertical sulci in the dorsomedian region. Smoother portions in the anteromedian and posteromedian regions. Dorsal view with anterior end subrounded and posterior end acute. Sexually dimorphic: Females wider and higher than males.

Remarks: this species is the same *Cytherura* sp. 1 recorded in the Pirabas formation by Távora (1994a), although the specimen illustrated is a male.

Occurrence: Aricuru (Maracanã bay), levels AR-04; Primavera FPR-160 core (Level AM.08 and AM. 20).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytherura ornata n. sp.

Plate 7.6, figs. 1-3

Material: 1 carapace and 13 valves.

Etimology: Latin: ornata = *ornata, ornatum*, refer to the ornamentation richly reticulated.

Holotypes: MPEG-619-M, LV, L: 0.35 mm and H: 0.17 mm. MPEG-620-M, RV, L: 0.35 mm and H: 0.17 mm.

Paratype: MPEG-621-M, LV: L: 0.36 mm and H: 0.17 mm.MPEG-622-M, internal view, RV: L: 0.36 mm and H: 0.17 mm. MPEG-623-M, internal view, RV: L: 0.35 mm and H: 0.17 mm.

Diagnosis: The evident feature of this species is the ornamentation richly reticulated; small carapace in lateral view; posterior margin short, truncate and subrounded; valves subequal: RV more subrectangular than the LV.

Description: Small and subrectangular carapace, in lateral view; maximal height at the anterior cardinal angle and maximal length below the mid-height. Dorsal margin almost straight and slightly converging to the posterior end. Ventral margin almost straight, sinuous in the RV. Anterior margin subrounded slightly truncated, mainly in the RV; posterior margin short, with a short caudal process; valves subequal: RV more subrectangular than the LV; valve surface with numerous rounded reticulations distributed regularly. Hinge with a negative bar on the middle part and grooves followed by teeth on the ends.

Remarks: this species is similar to *Cytherura quasilisa* n. sp. described in the present study, although only differs in the ornamentation pattern. *Procytherura*? *elongatissima* Andreu, 2013 is also similar mainly in outline of the C, however differs in many aspects as well as *Cytherura quasilisa* n. sp. differs of this.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-04; B-17 quarry, Capanema, Pará (Levels B1A, B1, B11, B12 and B13B); Primavera FPR-160 core (Levels: AM.08, AM.13, AM.14 and AM.17).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytherura quasilisa n. sp.

Plate 7.6, figs. 4-6

Material: 2 carapaces and 5 valves.

Etimology: Latin: quase = *quasi*, refer to the ornamentation almost smooth, but it has weak pits on surface; lisa= *levis*, refer to the smooth ornamentation.

Holotype: MPEG-624-M, C; LV: L: 0.41 mm and H: 0.17 mm; RV: L: 0.36 mm and H: 0.15 mm; Dorsal: L: 0.36 mm and W: 0.13 mm.

Paratype: MPEG-625-M, C; LV: L: 0.37 mm and H: 0.15 mm; RV: L: 0.36 mm and H: 0.14 mm.

Diagnosis: the evident feature of this species is the ornamentation that is almost smooth with very weakly and numerous punctations distributed regularly.

Description: small and subrectangular carapace, in lateral view; maximum height at 1/3 of the anterior region and maximum length below the mid-height. Dorsal margin almost straight. Ventral margin sinuous to slightly concave. Dorsal and ventral margins slightly converging to the posterior end. Anterior margin subrounded. Posterior margin short, subtruncate and subrounded with a shor caudal process. Valves subequal: RV overlapping the LV in the middle part of anteroventral in side view such as LV overllaping the RV in the posterior margin and also slightly in the middle portion of anteroventral in side view; valve surface almost smooth with very weakly and numerous punctations distributed regularly; dorsal view sub-ellipsoidal.

Remarks: this species resembles to *Procytherura*? *elongatissima* Andreu, 2013 from late Cenomanian of the Preafrican Trough, Morocco, mainly in outline of the C, however differs in many aspects as in the more evident caudal process; size (length 0.62 mm, height 0.26 mm); anterior and posterior portions of the C flattened; dorsally, appears a very slight central and vertical sulcus, and the valves biconcave; presenting a dorsal view very elongate and ellipsoidal. *Cytherura ornata* n. sp. also is similar to this species in shape and size, but differs in the ornamentation pattern.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-04; B-17 quarry, Capanema, Pará (Levels B1A, B1 and B11); Primavera FPR-160 core (Levels: AM.04 and AM.08).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Hemicytherura* Elofson, 1941

Hemicytherura bradyisimilis n. sp.

Plate 7.5, figs. 15; 18-19

Material: 11 valves.

Etimology: Latin: Brady = *bradyi,* refer to the ostracodologist Brady and to the *H. bradyi* very similar; similar= *similis,* refer to the close similarities of *H. bradyi*.

Holotypes MPEG-626-M, Female, LV: L: 0.30 mm and H: 0.17 mm; MPEG-627-M, Female, RV: L: 0.29 mm and H: 0.17 mm.

Paratype: MPEG-628-M, Male, Juvenile, LV: L: 0.28 mm and H: 0.15 mm.

Diagnosis: Valves unequal and very small C: RV shorter and narrower in the posterior end than LV. Surface with irregular and large ridges covering the surface in concentric way like a heavy "cobweb" in the middle part; secondary punctation.

Description: Very small and outline like that *Cytherura,* in lateral view. Valves unequal: RV shorter and narrower in the posterior end than LV. RV – Dorsal margin broadly subrounded and maximum hight at 1/3 of anterior region. Ventral margin almost straight with slight oral concavity. Anterior margin obliquely rounded. Posterior margin pointed: subrounded in the posterodorsal region and more angular in the posteroventral ending in the median and marked caudal process. LV – Dorsal margin almost straight with the cardinal angles slightly marked. Surface with irregular and large ridges covering the surface in concentric way like a heavy "cobweb" in the middle part; secondary punctation. Sexually dimorphic: males apparently more elongate and with the median caudal process less narrow and evident than females. Males smoother in the anterodorsal portion.

Remarks: *Hemicytherura bradyi* (Puri, 1960) Coimbra *et al.*, 1995 is more similar to the species here described in shape and size, but differs in the ornamentation pattern. *Hemicytherura bradyi* (Puri, 1960) Bold, 1988 also presents similarities in the shape and size, but differs ornamentation pattern in the central region. The species *H. cranekeyensis* Puri (Bold, 1988) also is similar in the size and ornamentation pattern; however, it differs in the outline of the carapace. The species *Hemicytherura bradyisimilis* n. sp. is similar to *Hemicytherura* sp. van den Bold, 1963b in the arrangement of ridges, but differs in general outline of carapace, in a shorter caudal process, in the presence of an evident median ridge converging from mid-anterior to mid-posterior portion and, also, in a few more ovate LV shape and anterior margin more rounded.

Occurrence: B-17 quarry, Capanema, Pará; B11 and B12 levels.

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Hemicytherura sp.

Plate 7.5, figs. 10-11

Material: 1 valve.

Dimensions: MPEG-629-M, RV: L: 0.29 mm and H: 0.19 mm.

Description: small and subovate, in lateral view. Valve obliquely subrounded in the anterior margin and truncate in the posterior margin. Dorsal margin high and strongly convex. Ventral margin almost straight with a convex portion in the posteroventral region. Surface strongly reticulated with coarse and evident ridges arranged regularly. Of these, especially two median ridges well marked converging from mid-posterior region to anterior end; the superior ridge is shorter than the median ridge. Muri and fossae larger. Some ridges are intercalated by well-marked secondary punctuation mainly dorsally. Hinge pattern typically for the genus.

Remarks: The present species differs of the others *Hemicytherura* by the higher dorsal margin, and subovate outline, shorter caudal process, heavier ornamentation pattern and smaller size.

Occurrence: FPR-160 core (Primavera), level AM.8

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Hemingwayella* Neale, 1975

Hemingwayella sp.

Plate 7.5, figs. 20-22

Material: 11 valves.

Dimensions: MPEG-630-M, RV: L: 0.39 mm and H: 0.17 mm. MPEG-631-M, LV: L: 0.34 mm and H: 0.16 mm.

Description: Very thick-shelled and robust carapace. Dorsal margin straight to slightly sinuous. Ventral margin with a swollen and straight alaform ridge. Anterior margin nearly rounded. Posterior margin almost rounded to truncated with short caudal process dorsally positioned. Surface coarsely punctated and ridges irregularly distributed by the surface with strong pits below the ridges. Evident ridges in the median and anteriomedian region; strong pits between and above the ridges. Hinge seems weak or worn, with faint indications of sockets in RV, hinge margin or crenulate groove between them. Others diagnostic internal features were not observed due to the poorly preserved material.

Remarks: *Hemingwayella pumilio* (Brady, 1880) Whatley and Maybury, 1991 is similar in the shape of C with a ventral ridge like an alar process strongly straight, but it differs in the ornamentation and in the outline that is more subquadrate than the species in this study.

Occurrence: Aricuru (Maracanã bay), levels AR-03, AR-04 and AR-06; B-17 quarry, Capanema, Pará (Levels B1, B11A and B11B); Primavera FPR-160 core (Level: AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Semicytherura* Wagner, 1957

Semicytherura aff. *S. clavata* (Brady) Whatley, Chadiwick, Coxill and Toy, 1988

Plate 7.6, figs. 7-9

1880. *Cytherura clavata* Brady, p. 133, pl. 29, figs. 7a-d.

1976. *Cytherura clavata* Brady. Puri and Hulings, p. 303, pl. 19, figs. 7-10.

1988. *Semicytherura clavata* (Brady). Whatley, Chadiwick, Coxill and Toy, p. 194, pl.2, figs. 6-8.

Material: 5 valves.

Dimensions: MPEG-632-M, LV: L: 0.43 mm and H: 0.20 mm. MPEG-633-M, male, RV: L: 0.43 mm and H: 0.19 mm.

Description: small and subrectangular to elongate valves in lateral view. LV with height uniform. Dorsal and ventral margins are subparallel: dorsal margin straight with a flatted area in the mid-dorsal region. Ventral margin slightly sinuous. Anterior margin subrounded. Posterior margin with a caudal process situated at the mid-posterior to posterodorsal region coincident with the maximum lenght; posteroventrally, outline straight converging upward till the end of caudal process. Surface presents ornamentation of numerous delicate anastomosing ridges and the valve with some dense minute punctae distributed and arranged regularly; smoother to the posterior region. Hinge features as for genus. Ocular tubercle discret.

Remarks: this species is similar to *Cytherura punctata* Morales, 1966 (HVH8389) from Mexico (Recent) mainly in shape and ornamentation pattern; presence of a less proeminent ocular tubercle. *Cytherura elongata* Morales, 1966 (HVH8389) is similar more in elongate valves, however the ornamentation is stronger than the species described herein. Based on outline of carapace and ornamentation pattern, the *Semicytherura clavata* (Brady) Whatley, Chadiwick, Coxill and Toy, 1988 is more related to the present species than *Cytherura elongata* Morales, 1966.

Occurrence: Aricuru (Maracanã bay), level AR - 04; Primavera FPR-160 core (Level AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Semicytherura sp.

Plate 7.6, figs. 10-12

Material: 1 carapace and 2 valves.

Dimensions: MPEG-634-M, C; LV: L: 0.37 mm and H: 0.19 mm; RV: L: 0.37 mm and H: 0.20 mm; Dorsal: H: 0.38 mm and W: 0.19 mm.

Description: small and subrectangular carapace, in lateral view. LV with large and uniform height. Dorsal and ventral margins are subparallel: dorsal margin straight and ventral margin almost straight, slightly biconvex. Anterior margin subrounded. Posterior margin with a caudal process situated at the mid-posterior region coincident with maximum length; ventrolateral region presents delicate longitudinal ridges and ornamented of small and medium punctuations distributed and arranged more in the median region of the carapace. Hinge features as for genus. Ocular tubercle absent. Dorsal view lightly ovoid, slightly compressed in the posterior end and large. Sexual dimorphism absent.

Remarks: this species resembles to *Semicytherura* aff. *S. clavata* (Brady) Whatley *et al.* 1988 described in the present study, however, differs in less elongate shape, sinuous outline, ornamentation pattern and small size.

Occurrence: Aricuru (Maracanã bay), levels AR-03 toAR-04; B-17 quarry, Capanema, Pará (Level B11 and B12); Primavera FPR-160 core (Levels AM.20 and AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Semicytherura aff. *C. cybaea* Garbett and Maddocks, 1979

Plate 7.6, figs. 13-17

1955. *Cytherura elongata* Edwards. Swain, p. 628, p1. 64, fig. 12b.

1964. *Cytherura elongata* Edwards.Hulings and Puri, p. 336, Text-figs. 15, 17.

1966. *Cytherura elongata* Edwards.Morales, p. 44, pl. 4, figs. 4a-c.

1967. *Cytherura elongata* Edwards. Engel and Swain, p. 412, pl. 2, fig. 9.

1970. *Cytherura elongata* Edwards. King and Kornicker, p. 35, pl. 6, figs. 3a, b, pl. 17, figs. 5, 6.

1975a. *Cytherura elongata* Edwards. Keyser, p. 490, text-fig. 4.

1977. *Cytherura elongata* Edwards. Keyser, p. 208, text-figs. 1-5.

1964. *Cytherura* sp. C Hulings and Puri, text-figs. 15, 17.

1965. Not *Semicytherura elongata* (Edwards). Darby, p. 23, pl. 7, figs. 1-12.

1967. Not *Cytherura elongata* Edwards. Grossman and Benson, p. 69, pl. 13, fig. 6, pl. 19, figs. 9, 10, 14.

1978. *Cytherura elongata* Edwards. Kontrovitz, p. 36, pl. 1, fig. 1.

1967. *Cytherura johnsoni* (Mincher) subsp. A Engel and Swain, p. 413, pl. 1, fig. 4.

1976. Not *Cytherura* sp. aff. *C. elongata* Edwards. Kontrovitz and Bitter, p. 77, pl. 1, fig. 11.

1979. *Cytherura cybaea* Garbett and Maddocks, p. 881, pl. 5, figs. 3-6.

Material: 2 carapaces and 1 valve.

Dimensions: MPEG-635-M, Female, C; LV: length 0.44 mm and height 0.23 mm; RV: length 0.44 mm and height 0.22 mm; Dorsal: length 0.46 mm and width 0.22 mm. MPEG-636-M, Male, C; RV: length 0.46 mm and height 0.23 mm.

Description: small and subrectangular carapace, in lateral view. Dorsal margin slightly convex with a concavity in the anterodorsal region. Ventral margin almost straight hidden in the middle by the ventral alae. Anterior margin subrounded. Posterior margin with an afilated caudal process just below the mid-posterior region coincident with maximum lenght; posteroventrally, slightly concave in the RV following with a flattened area to the posterior region of the caudal process. Discret alar process slightly extended and ornamented for small to medium punctuations distributed regularly and arranged transversely in the surface. Ocular tubercle absent. Dorsal view lightly ovoid and slightly swollen, slightly compressed in the posterior end with the discret alar process not salient. Sexual dimorphism evident: males more subrectangular in lateral view, with almost the same height as females but more strait and with ventrolateral alar process less pronounced than females.

Remarks: with respect to the carapace shape, this species is very similar to *Cytherura cybaea* Garbett and Maddocks, 1979 (HVH10089) from Matagorda bay, Texas (UH2554), and also due to the presence of a posterior alar process slightly extended in the ventrolateral region, however differs in the stronger ornamentation pattern and presence of eye-tubercle.

Occurrence: B-17 quarry, Capanema, Pará (Level B1A, B7, B11-B11B); Primavera FPR-160 core (Level AM.08 and AM.20).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Semicytherura fortisreticulata n. sp.

Plate 7.6, figs. 18-20

Material: 3 carapaces and 11 valves.

Etimology: Latin: forte = *fortis*, refer to the strong and evident reticulations; reticulata= *reticulatum*, refer to the reticulations pattern enough organized.

Holotype: MPEG-637-M, C, Female; LV: L: 0.33 mm and H: 0.20 mm; RV: L: 0.33 mm and H: 0.18 mm; Dorsal: H: 0.32 mm and W: 0.23 mm.

Paratypes: MPEG-638-M, C, Male; LV: L: 0.37 mm and H: 0.18 mm; RV: L: 0.37 mm and H: 0.17 mm; Dorsal: H: 0.36 mm and W: 0.21 mm. MPEG-639-M, C, female; LV: L: 0.35 mm and H: 0.19 mm; RV: L: 0.35 mm and H: 0.17 mm;

Diagnosis: ornamentation of this species is highly reticulated to coarsely punctuate, with deep punctae and ridges distributed longitudinally, mainly parallel to the ventral and dorsal region.

Description: small and subtriangular carapace, in lateral view. LV with height almost uniform, overlapping the RV in the ventral margin; in the other hand, the RV overlaps the LV in the dorsal margin. Dorsal margin and ventral margin almost straight; posteroventrally hidden by the ventral alae in the LV. Anterior margin rounded. Posterior margin with a caudal process situated at the mid-posterior region coincident to maximum lenght; posteroventrally, a wing-like alar process. Ornamentation highly reticulated to coarsely punctuate, with deep punctae and ridges distributed longitudinally, mainly parallel to the ventral and dorsal region. Ventrolateral region with discret alar process ornamented by large reticles. Ocular tubercle proeminent. Dorsal view sub-ovate, strongly angular in the posteromedian region and compressed in the posterior end, swollen and larger coincident with the alar process. Sexual dimorphism evident: males more subrectangular in lateral view, but smaller with lower height and an alar process less pronounced.

Remarks: this species is similar to *Cytherura purireticulata* (*Cytherura reticulata* Edwards, 1944) from Pliocene of North Carolina, USA, which differs in a straight dorsal margin and absence of an evident alar process. *Cytherura* sp. G van den Bold, 1988a, recorded to the Neogene from Dominican Republic, is also similar to *Semicytherura fortisreticulata* n. sp., however differs in the larger size (L 0.41mm, H 0.20 mm), a weaker ornamentation and also a wing-like alar process less evident. In addition, *Semicytherura bertelsae* Coimbra, Carreño and Michelli, 1999, an abundant species recorded in the Recent sediments from Brazilian equatorial continental shelf, is the closest species mainly with respect to the arrangement of dorsal ridges which are less evident with a more punctate pattern; while *Semicytherura fortisreticulata* n. sp. presents the reticles more spaced or opened with the ventral ridge more accentuated and sinuous by the wing-like alar process to the anterior end, beyond of posterodorsal margin more concave than species described herein. Nevertheless, *Semicytherura fortisreticulata* n. sp. has more features of the *Semicytherura* genus due to the carapace shape and ornamentation patter in spite of the small differences as discussed previously.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-04; B-17 quarry, Capanema, Pará (Levels B11A and B12); Primavera FPR-160 core (Levels: AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Kangarina* Coryell and Fields, 1937

Kangarina quellita (Coryell and Fields) van den Bold, 1963b

Plate 7.6, figs. 24-26

1937. *Kangarina quellita* Coryell and Fields, p. 13, fig. 15a-c.

1954. *Kangarina quellita* Coryell and Fields. Puri, p. 248. pl. 4, fig. 9.

1958. *Kangarina quellita* Coryell and Fields. van den Bold, p. 416, pl. 4, fig. 8.

1954. ?*Kangarina chipolensis* Puri. p. 246. pl. 4, fig. 10, text-fig. 6g.

Not 1954. *Kangarina quellita* Coryell and Fields. Keij, p. 226, pl. 5, fig. 8 (=*Kangarina ancyla*, n. sp.).

Not 1960. *Kangarina* aff. *K. quellita* Coryell and Fields. Curtis, pl. 1, fig. 24.

1963b. *Kangarina quellita* Coryell and Fields, p. 417, pl. 10, fig. 3.

Material: 3 carapaces and 3 valves.

Dimensions: MPEG-640-M, LV: L: 0.34 mm and H: 0.18 mm. MPEG-641-M, C; RV: L: 0.36 mm and H: 0.19 mm; Dorsal: H: 0.36 mm and W: 0.17 mm.

Remarks: this species is characterized by the anterior prolongation of the posteroventral depressed oval area and by a rather long connected ridge between posterior loop and dorsal ridge. The type species (HVH6880) from Brasso formation (Trinidad) is similar to species recorded here mainly in the size and shape in lateral view, but differs a few in the dorsal view that is widest from the middle to the posterior region, representing probably a female, and very little in the ornamentation pattern with respect to the ridges thickness.

Occurrence: B-17 quarry, Capanema, Pará; levels B1, B7 and B13; FPR-160 core, Primavera, Levels AM.17 and AM.14.

Distribution: the species has been found in Trinidad in the upper part of the Brasso Formation, in the Tamana Formation and in the Manzanilla Formation. In the Springvale Formation (Neogene) this species is replaced by a related form *Kangarina ancyla* van den Bold, 1963b. Upper Miocene from Shoctawhatchee stage (*Arca* facies). Lower Miocene, Pirabas Formation, Pará, Brazil.

Superfamily Cytherideoidea Liebau, 2005

Family Cytherideidae Sars, 1925

Genus *Cyprideis* Jones, 1857

Cyprideis? *huntti* n. sp.

Plate 7.6; figs. 21-23; 29

Material: 5 carapaces and 9 valves.

Etimology: In honor of North American ostracodologist and Curator of the Smithsonian Institution Dr. Gene Hunt.

Holotypes: MPEG-642-M, Female, C, LV: L: 0.72 mm and H: 0.38 mm; RV: L: 0.71 mm and H: 0.36 mm; Dorsal: H: 0.73 mm and W: 0.31 mm.

Paratypes: MPEG-643-M, Male, C, LV: L: 0.62 mm and H: 0.30 mm. MPEG-644-M, RV: L: 0.73 mm and H: 0.32 mm.

Diagnosis: ornamentation with large punctuations distributed and arranged regularly, beyond of the concentric ridges parallels to the anterior margin that is crenulated.

Description: large and subtriangular carapace in lateral view. LV overlaps the RV mainly along the dorsal margin. Dorsal margin subtriangular mainly in the RV. Ventral margin almost straight. Anterior margin rounded. Posterior margin truncate with a short slope downward. Surface presents ornamentation for large punctuations distributed and arranged regularly; beyond of the concentric ridges parallels to the anterior margin. A deep median sulcus, next to the dorsomedian region running to the center of the carapace. Anterior margin denticulated with two fossae followed for punctuations along of free margin. RV with short spine in the posteroventral extremity. Dorsal view is like peanuts-shaped with posterior end subacute and proeminent sulcus in the mid-anterior region. Internal view not observed. Males not found.

Remarks: this species present the ornamentation pattern, carapace shape and sulcus strongly aligned in the median region typical of *Cyprideis*, however the internal features was not observed to confirm the generic classification.

Occurrence: Aricuru (Maracanã bay), level AR- 04; B-17 quarry, Capanema, Pará (Levels B12, B11A and B11B).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Hemicyprideis* Malz and Triebel, 1970

Hemicyprideis sp.

Plate 7.7, figs. 3 and 4

Material: 1 valve.

Dimensions: MPEG-645-M, LV: L: 0.83 mm and H: 0.50 mm.

Description: large and suboval valve in lateral view. LV with dorsal and ventral margins subparallel: dorsal margin slightly convex in the anterior region with a short and shallow median sulcus next of the dorsomedian region. Ventral margin slightly convex, sinuous internally. Anterior margin rounded with two fossae followed for punctuations along of the free margin. Posterior margin truncate with a short slope downward. Surface ornamented with large punctuations distributed and arranged regularly. Anterior region with two parallel sulci extended to the ventral margin. Hinge features as for genus.

Remarks: this species is similar to many species as *Hemicyprideis intercedens* Malz, 1978; *Hemicyprideis rhenana* (Lienenklau, 1895), *Hemicyprideis* cf. *gilletae* (Stchepinsky, 1960) and *Hemicyprideis miocaenica* (Lienenklau, 1895). Among those species, *Hemicyprideis rhenana* (Lienenklau, 1895) is more similar in shape, presence of a mid-dorsal sulcus and the two sulci that runn parallel to the anterior margin extending to the ventral margin; also in the ornamentation pattern of the anterior, posterior and ventral ridges; however, it differs in a less proeminent posterior cardinal angle (Doebl *et al.* 1972).

Occurrence: Aricuru (Maracanã bay), level AR- 04.

Distribution: Aricuru Locality, Pirabas Formation (Lower Miocene), Pará, Brazil.

Infraorder Archaeocytherinina Liebau, 1991

Superfamily Bythocytheroidea Liebau, 2005

Family Cytheridae Baird, 1850

Subfamily Perissocytherideinae van den Bold, 1963b

Genus *Gangamocytheridea* van den Bold, 1963b

Gangamocytheridea macedoi (Távora, 1998)

Plate 7.7, figs. 22-25; 29

1998. *Hemicytherura macedoi* Távora, p. 3-15, figs. 4-8.

Material: 134 carapaces and 229 valves.

Dimensions: MPEG-646-M, C, Female; LV: L: 0.34 mm and H: 0.21 mm; RV: L: 0.33 mm and H: 0.20 mm; Dorsal: H: 0.33 mm and W: 0.20 mm. MPEG-647-M, C, Male; LV: L: 0.35 mm and H: 0.20 mm; RV: L: 0.35 mm and H: 0.19 mm; Dorsal: H: 0.36 mm and W: 0.19 mm. MPEG-648-M, Female, Internal View, RV: L: 0.35 mm and H: 0.18 mm.

Remarks: Távora (1998) assigned this species to *Hemicytherura* genus previously. However, the species has characteristics that differ internal and externally of that genus presenting more affinities with the *Gangamocytheridea* genus described by Bold (1963b). The species described herein is sexually dimorphic and differs of *Gangamocytheridea dictyon* van den Bold, 1963b in the sieved pore canals, in the overlapping of the valves and in the more turned down anteroventral region, in the *Gangamocytheridea dictyon* van den Bold, 1963b; however, they are very similar in shape, ornamentation and presence of 3-4 sulci in the mid-dorsal region in lateral view. Internal view: hinge typical to the genus; inner margin and line of concrescence coincident.

Occurrence: Aricuru (Maracanã bay), levels AR-01-04 and AR-06; B-17 quarry, Capanema, Pará (Levels B0-B1, B7, B11-B13B); Primavera FPR-160 core (Levels AM.06 and AM.07 AM.08, AM.13, AM. 15, AM.17, AM.20).

Distribution: Aricuru locality recorded this species firstly and here extended to the Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Gangamocytheridea reticulopunctatum n. sp.

Plate 7.7, figs. 16; 19; 20-21

Material: 3 carapaces and 35 valves.

Etimology: Latin: reticulo = *reticulum*, refer to the presence of reticles on surface; punctato= *punctatum*, refer to the fine punctuations distributed regularly for all carapace.

Holotype: MPEG-649-M, C; LV: L: 0.33 mm and H: 0.21 mm; RV: L: 0.30 mm and H: 0.21 mm; Dorsal: H: 0.34 mm and W: 0.23 mm.

Paratype: MPEG-650-M, C; LV: L: 0.34 mm and H: 0.22 mm;

Diagnosis: ventral margin overhung by subalar ridge; well developed oval concavity. The central area of the lateral surface is coarsely and irregularly reticulate ornamented with dense and fine secondary punctuation distributed regularlly for all surface.

Description: small, subrhomboidal to subovate carapace in lateral view. Thick-shelled. Dorsal margin strongly convex with cardinal angles well marked. Ventral margin overhung by subalar ridge, well developed oval concavity. Anterior margin with long and gently convex anterodorsal slope with subventral apex. Posterior margin subcaudate, with apex near the mid-posterior region. Eye tubercle absent and smoother in that surface. Subalar ridge strongly developed and finely sub-punctate. The central area of the lateral surface is coarsely and irregularly reticulate ornamented with dense and secondary punctuation. Presence of thin and delicate ridges along of the antero and postero-dorsal and anteroventral region of the subalar ridge. Internal features as for genus. Sexual dimorphism absent.

Remarks: *Gangamocytheridea reticulopunctatum* n. sp. is similar to *O. macropunctatum* Whatley *et al.*, 1988 but is more inflated and less punctate, eye tubercle absent, less defined subalar ridge lacking a posterodorsal loop.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-04.

Distribution: Aricuru Locality, Pirabas Formation (Lower Miocene), Pará, Brazil.

Gangamocytheridea sp.

Plate 7.7, figs. 13-15

Material: 3 carapaces.

Dimensions: MPEG-651-M, C; LV: L: 0.31 mm and H: 0.20 mm; RV: L: 0.31mm and H: 0.19 mm; Dorsal: H: 0.32 mm and W: 0.19 mm.

Description: small, subquadrate in lateral view and subrhomboidal to subovate in dorsal view. Thick-shelled. Dorsal margin straight and slightly inclined to the posterior region. Ventral margin overhung by a ridge strongly reticulated. Anterior margin rounded. Posterior margin truncated at postero-dorsal region and with a short caudal process postero-ventrally. Discret eye tubercle covered by a transversal ridge. The central area of the lateral surface is coarsely and irregularly reticulate. Three strong subalar ridge: the ventral extended for all margin, and with two shorter above. Sexual dimorphism absent.

Remarks: This specie is a few different of others species of the same genus recorded in the present study mainly in the ornamentation pattern that is more reticulated with strong ridges and larger fossae and in more subquadrate shape.

Occurrence: Aricuru (Maracanã bay), levels AR-03 and AR-04; B-17 quarry, Capanema, Pará (Level B1 and B7, B11-B13); Primavera FPR-160 core (Level AM.08, AM.10, AM. 17 and AM. 20).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Pumilocytheridea* van den Bold, 1963b

Pumilocytheridea sp.

Plate 7.7, figs. 1, 2 and 7

Not 1967. *Pumilocytheridea realjoensis* Swain and Gilby, p. 323, pl. 2, figs. 6a-b, pl. 33, fig. 11, text-fig. 12a.

1994a. *Pumilocytheridea realjoensis* (Swain and Gilby, 1967). Távora, p. 127, fig. 9.

Material: 2 carapaces and 1 valve.

Dimensions: MPEG-652-M, C; LV: L: 0.31 mm and H: 0.13 mm; RV: L: 0.31 mm and H: 0.11 mm; Dorsal: H: 0.31 mm and W: 0.11 mm.

Description: A species of *Pumilocytheridea* characterized by small and elongate carapace, slightly concave mid-ventrally, ornamented by longitudinal ridges and punctuations in the middle of carapace; flat edges in both ends. Highest in the anterior half, more inflated posteriorlly. Dorsal margin nearly straight to slightly convex, slightly inclined to the posterior region. Ventral margin concave mid-ventrally. Anterior margin obliquely rounded. Posterior margin truncated to slightly afilated ventrally. Dorsal view: lanceolate; wider in the postero-median region and strongly compressed in the posterior end. Ornamentation consisting of marginal flat rigdes mainly in the posterior region with longitudinal rows of pits separated mostly by irregular longitudinal ridges. Normal pore canals sieve type. Internal features not observed due to scarcity and fragility of the material.

Remarks: Based on shape and ornamentation pattern, the species apparently is the same *Pumilocytheridea realjoensis* (Swain and Gilby, 1967) already recorded to this unit by Távora (1994a). However, the species described herein differs from *P. realjoensis* Swain and Gilby, 1967 recorded to the Recent sediments from Corinto Bay, western Nicaragua, which is longer, outline in the dorsal margin with a more evident anterior cardinal angle, and in the anterior ornamentation pattern. It also resembles *Pumilocytheridea sandbergi* van den Bold, 1963b from Malajo Clay Member of Springvale Formation (Upper Miocene), Louisiana (USA) and Cumaná Formation, Venezuela (Pliocene – HVH7911) mainly in general outline and dimensions of the carapace, but differs in the ornamentation and in less robust carapace. Moreover, the American and Venezuelan species is a little higher and has a dorsal view with more sinuous and subparallel margins.

Occurrence: Aricuru (Maracanã bay), level AR-04; B-17 quarry; Primavera FPR-160 core (Level: AM.08).

Distribution: Pirabas Formation (Lower Miocene), Pará, Brazil.

Superfamily Cytheroidea Baird, 1850

Family Cushmanideidae Puri, 1974 in Hartmann and Puri, 1974

Genus *Cushmanidea* Blake, 1933

Cushmanidea? salahiensis n. sp.

Plate 7.7, figs. 26, 27 and 28

1946. Not *Cushmanidea howei* van den Bold, p.88, pl. 7, fig.9.

1994c. *Cushmanidea howei* van den Bold. Távora, p. 98, fig. 5.

Material: 121 carapaces and 355 valves.

Etymology: In honor to Salahi, ostracodologist which studied deep sea ostracods from Lybia, including one species that is very similar to the species herein described.

Holotype: MPEG-653-M, C; LV: L: 0.87 mm and H: 0.44 mm; RV: length 0.85 mm and H: 0.42 mm; Dorsal: H: 0.88 mm and W: 0.37 mm.

Paratype: MPEG-654-M, C; LV: L: 0.85 mm and H: 0.42 mm; RV: L: 0.76 mm and H: 0.36 mm;

Diagnosis: this species has some features typically of the genus, but differs in the outiline more ovate of the RV. Anterior margin sloped. Surface smooth without puntuations apparently. Valves unequals: LV overlaps the RV.

Description: large, subelongate to subreniform carapace, in lateral view; Valves subequal, LV slightly larger than RV. Dorsal margin moderately convex posteriorlly and inclined anteriorlly in the LV; slightly concave anteriorly and more sinuous in the RV. Ventral margin almost straight; slightly convex in the posterior of the LV. Anterior margin subrounded, extended below. Posterior margin narrowly curved, extended below, truncate above. General surface smooth, except for scattered pits that represent the opening of normal pore canals. Hinge: RV consists of terminal elongate flanges and interving furrow, which correspond to terminal grooves and interminal bar in LV. Inner lamell broad anteriorly, narrower posteriorly and ventrally. Line concrescense and inner margin widely separated terminally. Others internal features not observed due to poorly preserved material.

Remarks: This species is the same species *Cushamnidea howei* van den Bold, 1946, record by Tavora (1994c) to the Pirabas Formation, however differs of the type species in the outline shape, carapace size and in the ornamentation that is smoother in the species studied here. The general outline of this species has similarities to *Argilloecia barrigonensis* van den Bold, 1966a (HVH7904) from Upper Miocene of Cubagua Formation (Venezuela), but differs in many aspects as in the overlapping of the valves: RV larger than LV, presence of a proeminent sexual dimorphism and in the carapace size. *Cushmanidea* n. sp.1 Salahi, 1966 (USNM 648666) is the most similar species in the outline and in the smooth ornamentation pattern than the others species mentionated previously.

Occurrence: Aricuru (Maracanã bay), all the levels; outcrops Atalaia, level AT-01; B-17 quarry, Capanema, Pará (Levels B0-B2; B5-B8; B11; B11A-B13B); outcrops Ponta do Castelo (Level PC-03); Primavera FPR-160 core (Levels: AM.04, AM. 06, AM.08a, AM.10-AM.13, AM.16, AM.17, AM. 19, AM.20).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Hulingsina* Puri, 1958

Hulingsina reticulorugosa n. sp.

Plate 7.7, figs. 5, 6 and 8

Material: 13 carapaces and 20 valves.

Etimology: Latin: reticulo = *reticulum*, refer to the strong reticulations between the ridges; rugosa= *rugosum*, refer to the wrinkled pattern organized vertically and curved, more regularly distributed in the posterior end.

Holotype: MPEG-655-M, C; LV: L: 0.55 mm and H: 0.21 mm; RV: L: 0.47 mm and H: 0.17 mm; Dorsal: H: 0.52 mm and W: 0.20 mm.

aratypes: MPEG-656-M, C; RV: L: 0.47 mm and H: 0.17 mm. MPEG-657-M, C; LV: L: 0.47 mm and H: 0.17 mm; RV: L: 0.46 mm and H: 0.16 mm.

Diagnosis: Species of *Hulingsina* more elongate carapace and strongly ornamented with rough reticles distributed irregularly.

Description: small and elongate carapace, in lateral view. Dorsal margin gently arched. Ventral margin slightly concave in the middle. Anterior margin broadly rounded. Posterior margin nearly rounded below, obliquely above. RV subacute in the posterior end. Carapace nearly uniform in height, but LV nearly overllaping RV, especially in the anterior and posterodorsal margins. Surface reticulated with reticles distributed irregularly, more defined in the anterior region; posterior region with depressed area followed by differentiated ornamentation; median region with marked vertical sulcus.

Remarks: some characters is shared between this species and *H. tuberculata* Puri, 1958 from Recent sediments of Gulf coastal, Texas (USA) like outline of the carapace, but differs in many aspects as in the overlap of the valves and in the ornamentation.

Occurrence: Aricuru (Maracanã bay), level AR-04; B-17 quarry, Capanema, Pará (B11 and B12); Primavera FPR-160 core (Levels: AM.4, AM.8 and AM.14).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Hulingsina? *smithii* n. sp.

Plate 7.7, figs. 9-12

Material: 7 carapaces and 4 valves.

Etymology: in honor to the North American micropaleontogist who is responsible to the Bold and Howe Collections Dr. Lorene Smith from Louisiana State University, Baton Rouge.

Holotype: MPEG-658-M, C; LV: length 0.63 mm and height 0.32 mm; RV: length 0.62 mm and height 0.29 mm; Dorsal: length 0.63 mm and width 0.30 mm.

Paratypes: MPEG-659-M, LV: length 0.62 mm and height 0.28 mm. MPEG-660-M, RV: length 0.56 mm and height 0.25 mm.

Diagnosis: robust and subrectangular carapace, in lateral view. Surface reticulated with reticles following the ridges; median region with a marked sulci extended from the dorsal to the middle of the carapace and ornamented with small and medium reticles distributed regularly and arranged transversely.

Description: medium, robust and subrectangular carapace, in lateral view. LV overlaps the RV mainly in dorsal margin. Dorsal margin and ventral margin subparallels: dorsal margin almost straight with cardinal angles more pronounced in the males; ventral margin almost straight. Anterior margin subrounded sloping downward in the anterodorsal margin. Posterior margin truncated a slightly concave in the ventromedian region. Surface reticulated with reticles following the ridges; median region with a vertical marked sulcus extended from the dorsal region to the median region. Ornamented with small and medium reticles distributed regularly and arranged transversely. Dorsal view slightly subovate and compressed in the middle point due to the presence of marked sulci. Hinge antimerodont, LV with terminal crenulate sockets separated somewhat by raised crenulate bar (type species with flattened dorsal margin above median bar but some others referred to genus having dinstinct accommodation groove); others internal view were not observed.

Remarks: the present species is doubtly assigned to *Hulingsina* mainly because the hinge type that is antimerodont in the species described here. Also, the present species is quite different of this genus in the general outline of LV and in dorsal view, however, it presents some similarities as in the outline of RV resembling sligtly to *Hulingsina reticulorugosa* n. sp. recorded herein.This species is similar in the outline and in the ornamentation pattern of some species of *Cyprideis*, but differ mainly in the hinge pattern.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to A to AR-05; B-17 quarry, Capanema, Pará (Levels B1A, B1, B4-B6, B12- B11B); Primavera FPR-160 core (Levels: AM.07, AM.12, AM.14).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Infraorder Nomocytherinina Liebau, 1991

Superfamily Trachyleberidoidea Liebau, 2005

Family Cytherettidae Triebel, 1952

Subfamily Cytherettinae Triebel, 1952

Genus *Cytheretta* Mueller, 1894

Cytheretta cf. *C. punctata* Sanguinetti, 1979

Plate 7.8, figs. 1-6

? 1979. *Cytheretta punctata* Sanguinetti, pgs. 126, 127, pl.2, figs. 2a-e, pl. 9, figs. 5a-b.

Not 1991. *Cytheretta punctata* Sanguinetti. Sanguinetti, Ornellas and Coimbra, p.140, pl.2, figs. 1-4.

Not? 1997. *Cytheretta punctata* Sanguinetti. Whatley, Moguilevski, Toy, Chadwick and Ramos. p. 67, pl.2, figs. 4-6.

Not 2005. *Cytheretta punctata* Sanguinetti. Machado, Coimbra and Carreño, p. 244, pl. 4, fig. 9.

Not 2012 *Cytheretta* aff. *C punctata* Sanguinetti. Ramos, Coimbra, Bergue and Whatley, p.12, fig. 4, numbers 19-20.

Material: 39 carapaces and 177 valves.

Dimensions: MPEG-661-M, C, Female, RV, L: 0.75 mm, H: 0.42 mm, LV, L: 0.77 mm, H: 0.45 mm. MPEG-662-M, C, Male, RV, L: 0.77 mm, H: 0.42 mm; LV, L: 0.79 mm, H: 0.43 mm. MPEG-663-M, C, Male, RV, L: 0.81 mm, H: 0.42 mm; LV, L: 0.84 mm, H: 0.47mm. MPEG-664-M, C, Female, Dorsal: H: 0.71 mm, W: 0.32 mm. MPEG-665-M, C, Male, Dorsal: L: 0.79 mm, W: 0.30 mm.

Remarks: this species is similar to *Cytheretta punctata* Sanguinetti, 1979 from Miocene of Pelotas Basin, south of Brazil, but differs in the posterior cardinal angle that is more accentuated in the RV and the anterior is less accentuated; in the size with the females higher and males more elongate and higher too; a bit in the ornamentation pattern that is more delicated and of the rigdes that are a lit bit shorter in the species here studied; marginal rigde is also more delicate. The present species is not the same *Cytheretta punctata* Sanguinetti, 1979 recorded by Sanguinetti *et al*. 1991 to the Post Miocene of Pelotas Basin and also differs of *Cytheretta* aff. *C. punctata* recorded to Recent of South Brazil (Ramos *et al*. 2012) in size and in the ornamentation pattern and in the outline as in the cardinal angles. But it is more similar, mainly the males represented in the present study (pl.7.8; figs.5-6), to the specimens of the same species recorded to Recent sediments from Argentina (Whatley *et al*. 1998, pl. 2; figs.4-6). Although, in both of these records the specimens are smaller than the present species. Finally, the species studied here is probably a new species, but a more accurate comparision with type material is necessary to confirm its status, as well as, a review of the synonymies pointed in the others record of *C. punctata* recorded to the Post-

Miocene of Pelotas Basin and Recent sediments of south Brazil and Argentina. Probably they are different species that belong to the same philogenetic lineage.

Occurrence: Aricuru (Maracanã bay), levels AR-01 and AR-03; B-17 quarry, Capanema, Pará (Levels B0-B2A; B4 and B5; B7-B11; B11A-B13); Primavera FPR-160 core (Levels: AM.08 and AM.12).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytheretta parva n. sp.

Plate 7.8, figs. 7-12

Material: 97 carapaces and 113 valves.

Etymology: Latin: parva=*parvus*; refer to the small size relative to this species.

Holotypes: MPEG-666-M, C, Female, LV: L: 0.54 mm; H: 0.31 mm, RV: L: 0.52 mm; H: 0.29 mm. MPEG-667-M, C, Male, RV, L: 0.51 mm, H: 0.28 mm; LV, L: 0.57 mm, H: 0.30 mm.

Paratypes: MPEG-668-M, C, Female, RV, L: 0.53 mm, H: 0.27 mm; LV, L: 0.54 mm, H: 0.31 mm. MPEG-669-M, C, Female, Dorsal view, H: 0. 56 mm, width 0.21 mm. MPEG-670-M, C, Male, Dorsal view, H: 0.79 mm, W: 0.30 mm.

Diagnosis: small and elongate-ovate carapace, sinuous and slightly convex in the median dorsal margin, thick and rounded anterior margin, and evident longitudinal ridges with slight irregular pits between these, unequal valves: left oval-rounded (female); long-oval right.

Description: small, elongate-ovate and thick carapace, in lateral view. Anterior margin broadly rounded. Posterior margin rounded and subtruncate above. Unequal valves: LV larger than RV and overlapping it strongly along the ventral margin. Dorsal margin in the LV sinuous and slightly convex in the middle region followed by well-marked cardinal angle. Ventral margin slightly convex upturned in the posterior region. Anterior margin rounded to slightly oblique and thick. Posterior margin slightly angular. Surface with 6-8 longitudinal ridges evident and continuous which tend to radiate from the posterior end. A strong sulcus and flat area followed by the marginal ridge in the anterodorsal region. Dorsomedian region with three small ridges convex and parallel. Between the ridges light punctuations occur unevenly distributed primarily in the anterior region.The inner margin forms the S-shaped curve characteristic of the genus around the anterior end, and the numerous pore canals radiate from the upper lobe of the “S”. Distinct sexual dimorphism: female with the most inflated and less elongated than the male valves. Hinge holamphidont: RV consists of a massive, blunt tooth on the anterior end, behind which is an elongate socket tapering to a shallow groove just below and parallel to the dorsal margin. A mushroom-shaped tooth elongated parallel to the posterodorsal slope occupies the posterorior cardinal angle. The hinge of the LV is complementary to the right.

Remarks: In the general point view, the species *Cytheretta alexanderi* Howe and Chambers, 1935 from Louisiana (Eocene) presents many characters in commom, but differs mainly in the carapace size and by the presence of faintly denticles below in the posterior end. *C. punctata* Sanguinetti, 1979 is similar in the ornamentation pattern mainly with respect to the many horizontal ridges along the surface and resembles a few in the outline of C, however is more punctated between the ridges, with anterior margin turned slightly down, more rounded in the posterior region and with larger size.

Occurrence: Atalaia Beach outcrop (Salinópolis county), levels AT-01 and AT-02; B-17 quarry, Capanema, Pará (Levels B0-B8; B11-B13); Ponta do Castelo outcrop (Fortaleza Island), levels PC-00; Primavera FPR-160 core (Levels: AM.08, AM.12, AM.15 and AM.17).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cytheretta coimbrai n. sp.

Plate 7.8, figs. 13-17

Material: 9 carapaces and 53 valves.

Etymology: In honor of Brazilian ostracodologist Dr. João Carlos Coimbra.

Holotype: MPEG-671-M, C, LV: L: 0.84 mm, H: 0.36 mm; RV: L: 0.81 mm, H: 0.32 mm.

Paratypes: MPEG-672-M, LV, L: 0.74 mm, H: 0.36 mm. MPEG-673-M, LV, L: 0.74 mm, H: 0.35 mm. MPEG-674-M, RV, L: 0.70 mm, H: 0.33 mm.

Diagnosis: carapace with marked longitudinal ridges to reticulated.

Description: large, elongate and sub-rectangular carapace, in lateral view. LV larger than the RV overlapping the anterior portion. Dorsal margin nearly straight, parallel to ventral margin. Ventral margin slightly sinuous with a median concavity, mainly in the LV. Anterior margin obliquely rounded. Posterior margin acuminate. Surface strongly reticulate on posterior and ventral region with strong ornamentation and 8-9 marked longitudinal ridges: two median longitudinal ridges extending from the subcentral tubercle region to the posteroventral region. Muscle scars consist of a posterior curved row of four small ovate scars and one rounded scar in front of them. Some additional scars were observed anteriorly with one or more antennal or mandibular scars. The axis of 4 adductor muscles is usually inclined anteroventrally. Hinge typically for the genus.

Remarks: In the general outline, this species is similar to *Cytheretta bambruggensis* Keij, 1957 from Belgium (Eocene-Oligocene), but differs by the presence of short marginal spines in the anterior and posterior regions; small transversal ridges with rounded depressions in between; and valves with highest inflation posteroventrally. The species *Cytheretta anderseni* Butler, 1963 from Louisiana to Florida (Miocene-Oligocene boundary) has similarities mainly in the outline of the LV and in the general arrangement of the ornamentation, however differs in some longitudinal ridges cutted by transverse ridges in the median region and in the size of the carapace.

Occurrence: Aricuru (Maracanã bay), levels AR-01, AR-02 and AR-05; Atalaia Beach outcrop (Salinópolis county), level AT-01; B-17 quarry, Capanema, Pará (Levels B2A-B5, B7-B11A); Primavera FPR-160 core (Levels: AM.12 and AM.17).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Infraorder Nomocytherinina Liebau, 1991

Superfamily Cytheroidea Liebau, 2005

Family Cytheridae Baird, 1850

Subfamily Paracytherideinae Puri, 1957

Genus *Paracytheridea* Müeller, 1894

Paracytheridea tschoppi van den Bold, 1946

Plate 7.8, figs. 18-19

1946. *Paracytheridea tschoppi* van den Bold, p. 85, pl. 16, figs. 6-7.
1954. *Paracytheridea tschoppi* Bold. Key, p. 220, pl. 4, fig. 4.
1948. Not *Paracytheridea tschoppi* Bold. Kingma, p. 74, pl. 7, fig. 12a-b.
1954.*?Paracytheridea tschoppi.* Bold. Keij, p. 220, pl. 4, fig. 4.
? 1957. *Paracytheridea tschoppi* Bold, p. 245, pl. 4, fig.7.
1963. *Paracytheridea tschoppi* Bold. Benson and Coleman, p. 33-34, pl. 6, figs. 7, 9-10; text-fig. 20a-b.
1988. *Paracytheridea tschoppi* Bold, p. 62, 63, pl. 11, fig. 2.
Not 1994. *Paracytheridea tschoppi* Bold. Távora, p.108, fig.13.
1994c. *Paracytheridea* sp. 1 Távora, p. 109, fig.14.

Material: 2 carapaces and 304 valves.

Dimensions: MPEG-675-M, C; LV: L: 0.50 mm and H: 0.23 mm; RV: L: 0.47 mm and H: 0.23 mm; Dorsal: H: 0.58 mm and W: 0.40 mm. MPEG-676-M, C; LV: L: 0.51 mm and H: 0.26 mm.MPEG-677-M, C; LV: L: 0.45 mm and H: 0.21 mm.

Remarks: the present species is identical to the type species of Bold (1946). Bold (1957) and Benson and Coleman (1963) showed some evident features that resemble to species described herein what seem to be the same species. The specimens presented in this study is also much similar to species presented specially in Bold (1988) with all those characters, but in earlier work such as Bold (1957), the figure drawings exhibited is quite different, especially with respect to alarform ridge more pointed. The species is quite different of the *Paracytheridea tschoppi* (Bold) Távora, 1994c recorded to this unit mainly in the presence of a proeminent swollen in the middle to mid-posterior region. However, the species *Paracytheridea* sp.1 Távora, 1994c seems to be the same species.

Occurrence: Aricuru, Maracanã bay (levels AR-01, AR-03 to AR-06); B-17 quarry, Capanema, Pará (levels B1, B2, B8, B12-B13B); Ponta do Castelo outcrop, Fortaleza Island (level PC-00); Primavera FPR-160 core (levels: AM.08a, AM.10, AM.15, AM.17-AM.20).

Distribution: Miocene from Trinidad (*Globorotalia fohsi* zone and *Globogerinatella insueta*); Los Atajos (Forest formation); Ste. Croix Quarry, in the upper part of the Brasso formation, and in the Forest formation. This species was recorded from the seas around Trinidad and samples from Quaternary. Miocene from Cuba, Guatemala and Panamá. *Paracytheridea* sp. 1 Távora, 1994c was recorded along the Aricuru locality in the Lower Miocene, Pirabas Formation, Pará, Brazil.

Paracytheridea aff. *P. altila* Edwards, 1944

Plate 7.8, figs. 20-24

1944. *Paracytheridea altila* Edwards, p. 512, pl. 85, figs. 20-21.
1968. *Paracytheridea altila* Edwards. van den Bold, p. 76, pl. 7, figs. 1a-1d.
1974. *Paracytheridea altila* Edwards. Swain, p. 20, pl. 1, fig. 17.
1979. *Paracytheridea altila* Edwards. Cronin, p. 146, pl. 4, figs. 1-4.
1988. *Paracytheridea altila* Edwards. van den Bold, p.330, pl. 11, fig. 1.
1994c. *Paracytheridea* sp. 2 Távora, p. 110, fig. 15.

Material: 1carapace and 41 valves.

Dimensions: MPEG-678-M, C; LV: L: 0.55 mm and H: 0.28 mm; RV: L: 0.54 mm and H: 0.25 mm; Dorsal: H: 0.58 mm and W: 0.40 mm.

Description: stout, robust, very much broadened carapace. Dorsal margin irregular and sinuous with prominent ridges, in the posterodorsal region. Ventral margin with a directed alaform ridge and sundry swellings on either side. Anterior margin nearly quadrate pointed. Posterior margin with pointed extremity. Surface strongly reticulated and with strong and open pits below the ridges in the posteromedian region. Hinge weak or worn, with faint indications of sockets in RV, with crenulate groove between them. Short inner lamell. Others diagnostic internal features were not observed due to the poorly preserved material.

Remarks: This species is similar to *P. altila* (Edwards, 1944) recorded to the Neogene of Dominican Republic by Bold (1988, pl. 8, fig. 1) differing in the posteromedian ornamentation that is less smooth and ventro alar process more developed. The species also resembles to *Paracytheridea tschoppi* van den Bold, 1946 mainly in general outline in lateral view, but it differs in some details as in the ornamentation that is more delicate; dorsal margin irregularly sinuous with proeminent swollen in the posterodorsal region and surface slightly reticulated. *Paracytheridea* sp. 2 recorded by Távora (1994c) is the same species described herein.

Occurrence: Aricuru, Maracanã bay (level AR-05).

Distribution: Lower to Pliocene: Caribbean, Gulf Coast, Atlantic coast U. S.; Recent: U.S. Atlantic coast. Aricuru locality in the Pirabas Formation (Lower Miocene) Pará, Brazil.

Paracytheridea sp. 1

Plate 7.8, fig. 25

Material: 2 valves.

Dimensions: MPEG-679-M, RV: L: 0.53 mm and H: 0.29 mm.

Description: robust carapace, very high in lateral view. Dorsal margin almost straight with a strong ridge or dorso-alar process hidding the posterodorsal margin. Ventral margin straight parallel to the dorsal. Anterior margin rounded. Posterior margin pointed in the extremity and caudal process turned abruptly up. Surface strongly reticulate with a short posteroventral rigde extending to the central portion of the carapace. Internal features were not observed.

Remarks: This species differs of the others *Paracytheridea´*s species mainly in the strongly reticulated ornamentation.

Occurrence: B-17 quarry, Capanema, Pará (Level B11); Primavera FPR-160 core (Level: AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Paracytheridea sp. 2

Plate 7.8, fig. 27, 28

Material: 1 valve.

Dimensions: MPEG-680-M, LV: L: 0.52 mm and H: 0.27 mm.

Description: robust carapace, very high. Dorsal margin almost straight pointing to the posterior region converging to the ventral margin, almost parallel to the ventral margin. Anterior margin nearly truncate. Posterior margin pointed to truncate. Surface with various forms of delicated ridges mainly in the anteroventral region and in the middle portion. Three swollen process, in the central, posterodorsal and posteroventral typical of *Paracytheridea*. The ventral alar process is less proeminent.

Remarks: This species differs of the others *Paracytheridea´*s species being less swollen and less pronounced alar process.

Occurrence: Aricuru (Maracanã Bay), level AR-03.

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Paracytheridea sp. 3

Plate 7.8; fig. 26

Material: 1 valve.

Dimensions: MPEG-681-M, LV: L: 0.52 mm and H: 0.27 mm.

Description: Subquadrated species of *Paracytheridea* with smooth and subtrapezoidal carapace, with a posterodorsal process less pointed. Dorsal and ventral margins almost straight and parallels. Anterior margin straight. Posterior margin pointed. Hinge with indications of crenulate sockets in the extremities of the LV, hinge margin with teeth or crenulate bar between them. Others diagnostic internal features were not observed due to the poorly preserved material.

Remarks: This species is similar to *Paracytheridea altila* Edwards, 1944 but differs because it is shorter and higher.

Occurrence: Aricuru (Maracanã bay), level AR-03.

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Infraorder Archaeocytherinina Liebau, 1991

Suborder Cytherocopina Gründel, 1967

Superfamily Bythocytheroidea Liebau, 2005

Family Bythocytheridae Sars, 1866

Genus *Bythoceratina* Hornibrook, 1952

Bythoceratina loxomorpha n. sp.

Plate 7.9, figs. 5 and 6

Material: 17 valves.

Etymology: Latin: *Loxo* = refer to the carapace shape like Loxoconchidae; morpha = refer to the shape.

Dimensions: MPEG-682-M, C; LV: L: 0.56 mm and H: 0.30 mm; RV: L: 0.58 mm and H: 0.30 mm.

Diagnosis: the difference of this species with relation to others species of the same genus is in the absence of a dorsomedium sulcus evident. Surface more lightly reticulated with the ridges less evident.

Description: medium and subrectangular carapace, in lateral view. Dorsal margin straight. Ventral margin slightly convex, masked by the alar process. Anterior margin obliquely rounded. Posterior margin nearly subrounded and subacuminated. Unequal valves only in the anterior and posterior margins: RV longer than LV. Surface more lightly reticulated and distributed regularly; in the mid-anterior to mid-ventral region, there are 3-4 weak ridges parallels to the margin followed by reticles rounded toward the alaform process; and the absence of an evident dorsomedium sulcus. Alaform process underdeveloped directed ventrally to the posteroventral region; short or less elongated, upturned caudal process; no median sulcus. Internal features were not observed due to the poorly preserved material.

Remarks: the species present a general outline very similar to the Loxonconchidae, but differs from this group due to the presence of inflated and acute ventral alar process; outline typically more elongate, with dorsal margin straight ending in an evident posterodorsal pronunciation. Moreover, this species is similar to *Bythoceratina sinuocostata* n. sp. mainly in the shape and size. This species differs from the others

Bythoceratina species in the absence of an evident median sulcus extending from dorsal margin to near median region of the valve. This features is also not observed in *Bythoceratina* sp. 2 recorded here that was left in open nomenclature due to the paupericity of material. The most of species of *Bythoceratina* recorded in this paper do not have the typical proeminent median sulcus showed in the others species of the genus knowed in the literature, only a slightly depressive area in the middle of the carapace.

Occurrence: B-17 quarry, Capanema, Pará (Levels B1A, B11-B11A); Ponta do Castelo outcrop (Fortaleza Island), Level PC-03; Primavera FPR-160 core (Levels: AM.08 and AM.10).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Bythoceratina sinuocostata n. sp.

Plate 7.9, figs. 7, 8 and 11

Material: 1 carapace and 164 valves.

Etymology: Latin: sinuo= *sinuatum*; refer to the cuved shape of the ridges; costata= *costa*; refer to the horizontal ridges.

Holotype: MPEG-683-M, C; LV: L: 0.53 mm and H: 0.28 mm; RV: L: 0.54 mm and H: 0.28 mm; Dorsal: H: 0.56 mm and W: 0.32 mm.

Paratypes: MPEG-684-M, C; LV: L: 0.52 mm and H: 0.29 mm; RV: L: 0.51 mm and H: 0.26 mm. MPEG-685-M; RV: L: 0.51 mm and H: 0.25. MPEG-686-M; RV: L: 0.57 mm and H: 0.29.

Diagnosis: this species presents a dorsomedium sulcus evident; surface strongly reticulated with evident dorsal ridges followed by reticles rounded toward the alaform process.

Description: medium and subrectangular carapace, in lateral view. Dorsal margin straight with the presence of a strong sulcus parallels to the dorsal margin. Ventral margin slightly convex to sinuous in the RV with an alaform process underdeveloped directed ventrally in the mid-posterior portion. Anterior margin obliquely rounded. Posterior margin subacuminated to the dorsal margin forming a short caudal process. less elongated, no median sulcus. Ventral margin inflate or alate. Surface strongly reticulated and distributed regularly; in the ventral region, there are 3-4 ridges followed by reticles rounded toward the alaform process with evident dorsal ridges and the dorsomedium sulcus. Internal features were not observed.

Remarks: the species is similar to *Bythoceratina loxomorpha* n. sp. in general outline and size, but it differs in strong reticulations, more pronounced caudal process, presence of a horizontal and strong ridge parallels to the dorsal margin; depressed area separated by one diagonal ridges in the anterodorsal region and also a more evident horizontal posteroventral ridges.

Occurrence: Aricuru (Maracanã bay), level AR-01; B-17 quarry, Capanema, Pará (Levels B1A, B1, B6, B7, B11-B13, and B13B); Ponta do Castelo outcrop (Fortaleza Island), Level PC-03; Primavera FPR-160 core (Levels: AM.4, AM.8, AM.10, AM.13-AM.15, AM.17 and AM.19).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Bythoceratina sp. 1

Plate 7.9, figs. 9 and 10

Material: 2 valves.

Dimensions: MPEG-687-M, LV: L: 0.50 mm and H: 0.29 mm.

Description: medium and subovate carapace, in lateral view. Dorsal margin slightly convex or almost straight terminating in a short caudal process. Ventral margin slightly convex with a pointed alaform process. Anterior margin obliquely rounded. Posterior margin nearly subacuminated. Surface strongly reticulated and distributed regularly; median sulcus discret. Internal features were not observed due to the poorly preserved and scarce material.

Remarks: this species is similar to *Bythoceratina* sp. 2 in the presence of the pointed alaform process but differs in the ornamentation pattern that is more delicated and in the outline that is more rounded.

Occurrence: B-17 quarry, Capanema, Pará (Level B9).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Bythoceratina sp. 2

Plate 7.9, fig. 12

Material: 3 valves.

Dimensions: MPEG-688-M, RV: L: 0.43 mm and H: 0.23 mm.

Description: medium and subrectangular to subelongate carapace, in lateral view. Dorsal margin long and straight ending in a caudal process. Ventral margin slightly convex with a pointed alaform process. Anterior margin obliquely rounded. Posterior margin nearly subrounded and subacuminated. Surface strongly reticulated and distributed regularly; a deep and large vertical median depression like a median sulcus. Internal features were not observed due to the materials poorly preserved and scarce.

Remarks: see remarks of the *Bythoceratina* sp. 1.

Occurrence: Aricuru (Maracanã bay), level AR-01; B-17 quarry, Capanema, Pará (Level B12); Primavera FPR-160 core (Level: AM.8).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Bythoceratina sp. 3

Plate 7.9, fig. 13

Material: 3 valves.

Dimensions: MPEG-689-M, RV: L: 0.48 mm and H: 0.21 mm.

Description: medium and subrectangular to subelongate carapace, in lateral view. Dorsal margin long and straight ending in caudal process. Ventral margin slightly convex with an alaform process underdeveloped. Anterior margin obliquely rounded. Posterior margin nearly subrounded and subacuminated. Surface strongly reticulated and distributed regularly with marked and irregular ridge along the dorsal margin and another one in V-shaped in the posteroventral region; no median sulcus. Internal features were not observed due to the materials poorly preserved.

Remarks: this species differs of the others *Bythoceratina* in the outline that is more similar to *Paracytheridea*, but it has a less proeminent crest that covers the margins in the last genus.

Occurrence: B-17 quarry, Capanema, Pará (Levels B1 and B11A); Primavera FPR-160 core (Level: AM.4).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Vandenboldina* Wilson, 2010

Vandenboldina binodosa (van den Bold, 1966a)

Plate 7.9, figs. 1-4

1954. *Bythoceratina* aff. *utilazea* Hornibrook. Keij, in: van Andel *et. al*., p. 227, pl. 5, fig. 10.

Not *Pseudoceratina droogeri* van den Bold, 1965, p.161, pl. 1, figs. 1-4.

1966a. *Bythoceratina binodosa* van den Bold, pl. 2, fig.7a-c, pl. 5, fig. 3.

1994a (?) *Pseudoceratina droogeri* (Bold, 1965). Távora, p. 95, fig. 3.

Material: 2 carapaces and 34 valves.

Dimensions: MPEG-690-M, C; LV: L: 0.48 mm and H: 0.25 mm; RV: L: 0.50 mm and H: 0.23 mm.

Remarks: Távora (1994a) recorded this species to Pirabas formation as (?) *Pseudoceratina droogeri* van den Bold, 1965 considering the presence of one spine to be more mamilonar aspect than longer spine as in the type specimen; posteriorly the species erected by Bold (1965) from the Recent off Trinidad, SE Caribbean Sea was renamed by Brent (2010) as *Vandenboldina droogeri* (Bold, 1965) comb. nov. This genus according to this author is monospecific. On the other hand, the generic features of the species found here is more similar to the genus *Vandenboldina* than *Bythoceratina*. However *Bythoceratina binodosa* van den Bold, 1966a (HVH7925) seems to be the same species presented here because of the many similarities in both the morphology of carapace and alaform ridge in the ventral margin but also in hinge and muscle scars.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-06; B-17 quarry, Capanema, Pará (Level B13); Primavera FPR-160 core (Levels: AM.08, AM.13-AM.17 and AM.19).

Distribution: Upper Miocene, in the Upper Cubagua Formation of Venezuela; Tubará Formation of Colombia; and the Savaneta glauconitic sand member of the Springvale Formation of Trinidad. Lower Miocene, Pirabas Formation, Pará, Brazil.

Infraorder Nomocytherinina Liebau, 1991

Superfamily Trachyleberidoidea Liebau, 2005

Family Hemicytheridae Puri, 1953

Subfamily Hemicytherinae Puri, 1953

Genus *Aurila* Pokorny, 1955

Aurila laevicula (Edwards, 1944) Swain, 1968

Plate 7.9, figs. 14-18

1944. *Hemicythere laevicula* Edwards, p. 518, pl. 86, figs. 27-30.

1953. *Hemicythere laevicula* Edwards. Puri, p. 174, pl. 1, figs. 1-2; 1954, p. 367, pl. 11, fig. 13.

1958. *Hemicythere laevicula* Edwards. Brown, p. 66, pl. 7, fig.2.

1963b. *Hemicythere laevicula* Edwards. van den Bold, p. 384, pl.7, fig. 1.

? 1968. *Aurila laevicula* (Edwards). Swain, p. 24, pl. 5, fig.12.

Material: 7 carapaces and 5 valves.

Dimensions: MPEG-691-M, Female, C; LV: L: 0.52 mm and H: 0.35 mm; RV, L: 0.52 mm and H: 0.31 mm; Dorsal: H: 0.52 mm and W: 0.25 mm. MPEG-692-M, Male, C; LV, L: 0.52 mm and H: 0.32 mm; RV, L: 0.52 mm and H: 0.31 mm. MPEG-693-M, Female, LV: L: 0.52 mm and H: 0.35 mm. MPEG-694-M, Male, LV: L: 0.54 mm and H: 0.32 mm.

Remarks: The species identified in this study is very similar to the type species *Aurila laevicula* (Edwards, 1944 - HVH 6867), from the Miocene of the United States, East coast and Caribbean (Bold, 1963b) considered here as the same species; this species is similar to *Aurila* sp. aff. *A. lincolnensis* (LeRoy) Holden, 1976 from Upper and Lower Miocene of Midway Island (Hawai) mainly in the size, however differs in shape as the posterior end bifurcate in dorsal view, and in the ornamentation pattern.

Occurrence: B-17 quarry, Capanema, Pará (Levels B1, B11, B11A and B11B).

Distribution: this species occurs in the Melajo Clay Member of the Springvale Formation (Late Miocene) and in Calyx nº. 44, Biche. Lower Miocene, Pirabas Formation, Pará, Brazil.

Aurila pirabensis n. sp.

Plate 7.9, fig. 19, 20 and 24

Material: 16 carapaces and 15 valves.

Etymology: In reference to the type location of Pirabas Formation.

Holotypes: MPEG-695-M, C; LV: L: 0.68 mm and H: 0.49 mm; RV: L: 0.64 mm and H: 0.42 mm.

Paratypes: MPEG-696-M, C; LV: L: 0.68 mm and H: 0.49 mm; RV: L: 0.66 mm and H: 0.44 mm. MPEG-697-M, C; internal view, LV: L: 0.74 mm and H: 0.48 mm.

Diagnosis: medium, robust and almond-shaped carapace, in lateral view, heavily calcified, typically auriculate shape. Posterior margin nearly pointed upward mainly in the RV. Surface pitted somewhat reticulated, swelled in the mid-ventral; presence of a weak eye-tubercles.

Description: medium, robust and almond-shaped carapace, in lateral view, heavily calcified, typically auriculate shape. Dorsal margin broadly convex in the LV and almost straight in the middle dorsal portion with blunted cardinal angles in the RV. Ventral margin convex in the LV and slightly concave mid-central to antero-ventral of RV. Anterior margin broadly rounded in the RV; and subrounded sloped downward in the LV. Posterior margin nearly pointed upward mainly in the RV. Maximum median height in LV, and at about one third from the front in RV; maximum width in the mid-length. Caudal process better developed and upturned in RV. Surface pitted somewhat reticulated with a swelling in the mid-ventral; presence of a weak eye-tubercles. Muscle scars pattern typical of the genus, with four adductor muscle scars, oblique row of 3 antennal scars in front and 1 mandibular scar below observed. Hinge holamphidont with the frontal element strongly developed.

Remarks: In the general outline, this species resembles to *Aurila ornellasae* Coimbra and Bergue, 2003 recorded to recent sediments from south of Brazil, in the shape and size of carapace, but differs slightly in the ornamentation pattern. *Aurila cicatricosa* Reuss, 1850 (HVH10026; HVH10027) is also very similar mainly in the outline of RV, but differs in the surface more strongly reticulated and distributed regularly. *Aurila pirabensis* is also similar to *A. laevicula* (Edwards, 1944), but differs in the ventral margin that is more strongly convex.

Occurrence: B-17 quarry, Capanema, Pará (Levels B11A and B11B).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Caudites* Coryell and Fields, 1937

Caudites medialis Coryell and Fields, 1937

Plate 7.9, figs. 21 and 22

1937. *Caudites medialis* Coryell and Fields, p. 11, pl. 2, figs. 12a-c.

1957a. *Caudites* aff. *C. sellardsi* (Howe and Neill). van den Bold, p. 239, pl.3, fig. 8.

1966. *Caudites medialis* (Coryell and Fields). van den Bold, p. 360, pl. 1, fig.7, table 1.

1967. *Caudites medialis* (Coryell and Fields). van den Bold, p. 311, pl. 1, fig. 4.

1968. *Caudites medialis* (Coryell and Fields). van den Bold, p. 19, pl. 4, figs. 1a, b, tables 6, 8, 10.

1988. *Caudites medialis* (Coryell and Fields). van den Bold, p. 329, pl. 3, fig. 7.

Material: 2 carapaces and 2 valves.

Dimensions: MPEG-698-M, C; LV: L: 0.58 mm and H: 0.30 mm; RV: L: 0.61 mm and H: 0.26 mm.

Remarks: this species is coincident to the type species. The present species is similar to *Caudites sellardsi* (Howe and Neill), Bold, 1967a mainly in the arrangement of the ridges and in the outline, but differs in the size of the carapace (L 0.47 mm; H 0.22 mm) and in the posterior margin with the presence of a longer caudal process.

Occurrence: B-17 quarry, Capanema, Pará (Level B1).

Distribution: Middle Miocene to Lower Pliocene; Panama, Costa Rica, Colombia, Jamaica, Dominican Republic, Trinidad; and Lowest portion of B-17 quarry, Capanema, Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Cornucoquimba* Ohmert, 1968

Cornucoquimba hornibrooki (Puri, 1960)

Plate 7.9, figs. 25-28

1954. *Hermanites* aff. *thoracophora* (van den Bold). Keij, p. 223, pl. 4, figs. 12a, b.

1960. *Bradleya hornibrooki* Puri, p. 123, pl.1, figs. 9, 10 (not text-figs. 27, 28).

1966e. *Hermanites hornibrooki* (Puri). van den Bold, pl.1, fig. 14.

1968. *Hermanites hornibrooki* (Puri). van den Bold, p. 66, pl. 4, fig. 3.

1975. *Hermanites hornibrooki* (Puri). Teeter, p. 419, figs. 11a, 12a.

1988. *Hermanites hornibrooki* (Puri). van den Bold, p. 37, pl.3, fig. 18.

1994b. Not *Hermanites hornibrooki* (van den Bold). Távora, p. 132, fig. 13.

1994b. *Hermanites* sp. Távora, p. 133, fig. 14.

Material: 19 carapaces and 29 valves.

Dimensions MPEG-699-M, C; LV: L: 0.50 mm and H: 0.27 mm; RV: L: 0.51 mm and H: 0.26 mm; Dorsal: H: 0.51 mm and W: 0.26 mm.

Remarks: *Hermanites hornibrooki* Puri, 1960 (HVH5135) is very similar to species identified in the present study differing subtly only in the size of the carapace. This species is more similar to *Cornucoquimba* Ohmert (1968). A detailed study of the internal features of both genus (to *Cornucoquimba* see Ramos, 1996 and Tsukagoshi and Kamiya, 1996 for more details) show that they are very similar in the type of hinge and in the muscle scars. Externally they have also similar ornamentation presenting subcentral tubercle and the horn-like projections in the posterodorsal and ventral region but these genera differs mainly in the size, where the species of *Hermanites* is bigger than *Cornucoquimba* and has a heavier ornamentation pattern; *Cornucoquimba* has a more evident subcentral tubercle showing a deeper hole in internal view difficulting to see the central muscle scars. The present species has all this features and is considered here to belong to this genus. Moreover, another species resembles to species of this paper is *Hermanites hutchinsoni* (HVH10032; HVH7774) from Haiti (Miocene) and Puerto Rico (Oligocene); however, this species presents many diferent characters as size of carapace, lies in the position of greatest width, shorter and heigher in side view, weaker subcentral tubercles and ventral and dorsal ridges apparently more pointed at the ends than *Hermanites hornibrooki* Puri, 1960 and the species identified herein. Furthermore *Hermanites* sp. Távora, 1994b is the same *Hermanites hornibrooki* Puri, 1960 (HVH5135).

Occurrence: Aricuru (Maracanã bay), levels AR-01 to AR-05; B-17 quarry, Capanema, Pará (Levels B13).

Distribution: Upper Miocene to Recent: Caribbean, Gulf of Mexico. Río Gurabo: Cercado, Gurabo and Mao formations. Río Mao and Río Yaque del Norte (Arroyo López). Távora (1994b) recorded this species in the Pirabas Formation (Lower Miocene), Pará, Brazil.

Genus *Hermanites* Puri, 1955

Hermanites sp.

Plate 7.9, fig. 23

Material: 3 valves.

Dimensions: MPEG-700-M, C; RV: L: 0.49 mm and H: 0.26 mm.

Remarks: this species present general features similar to the genus *Hermanites*, despite of only three specimens of this species were found in the studied material, which is not enough for the establishment of a new species. However, the specimen illustrated herein has an ornamentation strongly evident with reticulation of an irregular aspect and evident ridges as in the type species *Hermanites tschoppi* (HVH7773) from Lares Formation (Puerto Rico), but differs in the posterior end that is more elongate and in the presence of a proeminent dorsal ridge.

Occurrence: B-17 quarry, Capanema, Pará (Levels B1 and B11).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Tenedocythere* Sissingh, 1972

Tenedocythere? *rugosocostata* n. sp.

Plate 7.10, figs. 25-27

Material: 1 carapace and 10 valves.

Etymology: Latin: rugoso= *rugosum*; refer to the wrinkled shape of the ridges; costata= *costa*; refer to the ridges organization pattern.

Holotype: MPEG-701-M, C; LV: L: 0.50 mm and H: 0.29 mm; RV: L: 0.49 mm and H: 0.26 mm; Dorsal: H: 0.52 mm and W: 0.27 mm.

Paratype: MPEG-702-M, C; LV: L: 0.54 mm and H: 0.33 mm; RV: L: 0.48 mm and H: 0.28 mm.

Diagnosis: the feature more evident of this species is the surface strongly ornated with wrinkled reticulations and an alaform ridge in the ventral region.

Description: medium and subquadrate carapace, in lateral view. Dorsal margin almost straight; highest in the extreme anterodorsal region coincident with the anterior cardinal angle area that is well marked. Ventral margin almost straight in the RV and straight in LV. Anterior margin broadly rounded and finely denticulated, with a well-developed marginal rigde. Posterior margin compressed and subtriangular, with a short tuft of six to seven spines. Subcentral tubercle evident. Dorsal view subquadrate with evident ridges along the borders and remarkable sulcus parallel to the anterodorsal margin. Surface strongly ornated with wrinkled reticulations and an alaform ridge in the ventral region. Small eye tubercle.

Remarks: this species present similar general aspect typical for the genus *Hermanites* Puri, 1955; however, it is strongly ornamented with irregular aspect and evident ridges similar to *Tenedocythere*. However, this species need more detailed studies to attest the generic position.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-05; B-17 quarry, Capanema, Pará (Levels B11 and B12); Primavera FPR-160 core (Levels: AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Jugosocythereis* Puri, 1957

Jugosocythereis pannosa (Brady, 1869) van den Bold, 1963b

Plate 7.10, figs. 1-11

1869. *Cythere pannosa*, (Brady). p. 154, pl. 10, figs. 1, 2.

1952. *Quadracythere mediaplana* Hornibrooki, p. 45, pl. 9, figs. 121-123.

1957. *Hermanites*? *pannosa* (Brady). van den Bold, p. 240, pl. 2, fig. 2.

1963b. *Jugosocythereis* sp. aff. *J. vicksburgensis* (Howe). van den Bold, p. 388, pl. 7, fig. 6.

1966e. *Jugosocythereis pannosa* (Brady, 1869). van den Bold, p. 47, pl. 1, fig. 11.

1972. *Jugosocythereis pannosa* (Brady, 1869). Benson, pl. 2, fig. 1.

1974. *Jugosocythereis pannosa* (Brady, 1869). Maddocks, p. 210, pl. 5, figs. 1, 5-6, 8-9.

1975. *Jugosocythereis pannosa* (Brady, 1869). Teeter, p. 499, figs. 11m, n, 12d.

1976. *Jugosocythereis pannosa* (Brady, 1869). Holden, p. 25, pl. 3, figs. 17-21, pl.12, fig. 14.

1988. *Jugosocythereis pannosa* van den Bold, p. 36, pl. 3, fig. 3.

1994b. *Tenedocythere* cf. *T. turda* (Holden, 1976). Távora, p. 136, fig. 17.

Material: 176 carapaces and 1252 valves.

Dimensions: MPEG-703-M, C; LV: L: 0.64 mm and H: 0.40 mm; RV: L: 0.64 mm and H: 0.39 mm; Dorsal: H: 0.62 mm and W: 0.37 mm. MPEG-704-M, C; LV: L: 0.50 mm and H: 0.29 mm; RV: L: 0.49 mm and H: 0.26 mm; Dorsal: H: 0.52 mm and W: 0.27 mm. MPEG-705-M, C; LV: L: 0.49 mm and H: 0.30 mm. MPEG-706-M, RV: L: 0.48 mm and H: 0.28 mm. MPEG-707-M, LV: L: 0.53 mm and H: 0.30 mm. MPEG-708-M, LV: L: 0.50 mm and H: 0.29 mm. MPEG-709-M, C, LV: L: 0.49 mm and H: 0.28 mm.

Remarks: The species here identified presents all the features of the type and figured species of *Jugosocythereis pannosa* from Republic Dominican (HVH10546) and Trinidad (HVH10179), however it is smaller than the type species from Recent deposits of Panama (Bold, 1988). This species is the same *Tenedocythere* cf. *T. turda* (Holden, 1976) Távora, 1994b recorded to the Pirabas Formation.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-06; Atalaia Beach outcrop (Salinópolis), Level AT-01; Ponta do Castelo outcrop (Fortaleza Island), Levels PC-02 and PC-03; B-17 quarry, Capanema, Pará (Levels B1A, B11, B12, B11A, and B13); Primavera FPR-160 core (Levels: AM.7, AM.08, AM.12-AM.14, AM.19 and AM.20).

Distribution: This species present a wide stratigraphical range and paleo/geographical distribution in the tropical America. This species is known from the Oligocene to Holocene in the Caribbean-Gulf coast region of North America. Upper Miocene to Recent: Caribbean. Río Gurabo: Cercado, Gurabo and Mao formations. Río Cana (Gurabo formation) and Mao (Mao formation). Recent, Panamá, Gulf of Mexico. Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Neocaudites* Puri, 1960

Neocaudites? macertus (Stephenson) van den Bold, 1965

Plate 7.10, figs. 12-16

1944. *Cythereis macerta* Stephenson, p. 157, pl. 28, figs. 6-7.

1946a. *Cythereis guinesensis* van den Bold, p. 89, pl. 5, fig. 10a-b.

1957a. *Costa macerta* (Stephenson). van den Bold, p. 242.

1965. *Neocaudites macertus* (Stephenson). van den Bold, p. 399, pl. 4, fig. 2.

Material: 5 carapaces and 1 valve.

Dimensions: MPEG-710-M, Female, C; LV: L: 0.50 mm and H: 0.27 mm; RV: L: 0.48 mm and H: 0.25 mm; Dorsal: L: 0.49 mm and W: 0.17 mm. MPEG-711-M, Male, C; LV: L: 0.54 mm and H: 0.25 mm; RV: L: 0.56 mm and H: 0.26 mm; Dorsal: L: 0.55 mm and W: 0.17 mm.

Remarks: the species identified in the present study is very similar to type species (HVH7776) from Puerto Rico (Lower Miocene) mainly in the ornamentation, shape and size of carapace. Bold (1957a) recorded this species to the Miocene of Trinidad as *Costa macerta* (Stephenson), but later this author (Bold, 1965) change the genus to *Neocaudites*; although the author did not discuss about the reason to the generical change, in the present paper this species is considered dubiously as *Neocaudites.* The marginal ridge in *Neocaudites* is more thick and extending for all free margin and has an oblique rigde in the middle of the carapace following the punctuations. This genus also differs from *Costa* mainly in the external features, as the shape that is more rectangular in this genus. The ornamentation pattern lack the three rigdes that are not connected with the marginal rigde where the median ridge is branched and turned down in the end, typically of the genus *Costa*; then the present species is possible a new genus.

Occurrence: Aricuru (Maracanã bay), levels AR-04 and AR-05; B-17 quarry, Capanema, Pará (Levels B1A and B1, B11A, B13 and B13B).

Distribution: Lower Miocene from the Anahuac Formation Gulf Coast; the Guines Formation of Cuba (Lower to Middle Miocene), Ste. Croix Quarry of Trinidad in *Globigerinatella insueta* Zone and the upper part of the Lares Formation also from Lower Miocene. Keij reports the same species from the Stampian to the upper Aquitanian of southwestern France. Lower Miocene, Pirabas Formation, Pará, Brazil.

Neocaudites triplistriatus (Edwards) Van den Bold, 1963b

Plate 7.10, figs. 17-20

1944. *Cythereis triplistriata* Edwards, p. 522, pl. 87, figs. 24-26.

1954. ? *Rectotrachyleberis triplistriata* (Edwards). Puri, p. 264, pl. 11, figs. 1-2.

Not 1951 *Trachyleberis triplistriata* (Edwards). Swain, p. 37, pl. 6, figs. 2-3.

1963b. *Neocaudites triplistriatus* (Edwards). van den Bold, p. 389, pl. 8, fig. 4.

1994b. Not *Neocaudites* cf. *N. triplistriatus* (Edwards). Távora, p.130, fig.12.

2004. *Neocaudites triplistriatus* (Edwards). Coimbra, Ramos, Whatley and Bergue, p. 115 and pl. 2, figs 7–8.

Material: 2 carapaces and 1valve.

Dimensions: MPEG-712-M, Female, C; LV: L: 0.52 mm and H: 0.28 mm; RV: L: 0.45 mm and H: 0.23 mm; Dorsal: H: 0.50 mm and W: 0.21 mm. MPEG-713-M, Male, C; LV: L: 0.57 mm and H: 0.27 mm; RV: L: 0.55 mm and H: 0.26 mm.

Remarks: the species identified in the present study has the same features of the type species *Neocaudites triplistriatus* (Edwards) in many aspects; the only difference is in the size of carapace that is a bit higher. *Neocaudites* cf. *N. triplistriatus* (Edwards, 1944) recorded by Távora (1994b) is the same species of *Costa petrii* n. sp. recorded in this paper (see discussion of this species) to the Pirabas Formation that is quite different of the species herein described.

Occurrence: B-17 quarry, Capanema, Pará (Level B7). Primavera FPR-160 core (Levels: AM.08, AM.15 and AM.20).

Distribution: Duplin Marl, North Caroline (Upper Miocene); Springvale Formation, Trinidad (Upper Miocene). Recent, Equatorial continental Brazilian margin; Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Orionina* Puri, 1954

Orionina sp.

Plate 7.10, figs. 23-24

Material: 2 carapaces and 3 valves.

Dimensions: MPEG-714-M, C; LV: L: 0.60 mm and H: 0.30 mm; RV: L: 0.57 mm and H: 0.26 mm.

Description: medium, subrectangular carapace, highest in the anterior region. Dorsal margin almost straight. Ventral margin sinuous, with a concave portion mid-ventrally. Anterior margin nearly rounded. Posterior margin angular and truncate. Surface ornamented by three main longitudinal ridges: the median upper ridge extend from the anteromedian turning upward to the posterodorsal region where it connect an other shorter vertical posterior ridge. The anteroventromedian ridge is shorter and curved extending from the anteroventral region to the mid-ventral connecting the ventral ridge; and the ventral ridge is parallel to the ventral margin and linked to the short vertical ridge in the posterior region. Posterior ridge well developed. Secondary fine ridges distributed irregularly between the main ridges. Ocular tubercle discret.

Remarks: this species is similar to *Orionina vaughani* (Ulrich and Bassler) Bold (1963b) mainly in the ornamentation pattern, but it is smaller, more elongate and weakly ornamentated. Moreover, also similar to *Orionina vaughani* (Ulrich and Bassler) Puri, 1954 presenting the same features and differences of that described by Bold (1963b). Furthermore, it is very similar to type species *Orionina vaughani* (HVH2793) from Miocene of the Chipola facies (Florida) in general characteristics, however it differs in size, robust ornamentation and shape of carapace. The species illustrated here is also similar in size and ornamentation to *Orionina similis* van den Bold, 1963b, but the posterior end, however, is quite different by the more triangular shape.

Occurrence: B-17 quarry, Capanema, Pará (Levels B1, B11 and B12).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Orionina aff. *O. similis* (Ulrich and Bassler) van den Bold, 1963d

Plate 7.10, figs. 21-22

1963d. *Orionina similis* (Ulrich and Bassler). van den Bold, 1963, p. 47, pl. 4, figs. 7-8; text-fig. 6, figs. 8-9.

Material: 2 carapaces.

Dimensions: MPEG-715-M, carapace; LV: L: 0.56 mm and H: 0.30 mm; RV: L: 0.54 mm and H: 0.30 mm.

Description: medium, subrectangular carapace, highest in the anteromedian region. Dorsal margin sinuous masked by the posterodorsal ridge.Ventral margin almost straight to slightly concave mid-ventrally. Anterior margin nearly rounded. Posterior margin concave in the posterodorsal region and with a pronounced posteroventral extension like a truncated caudal process. Surface strongly reticulated between the three main longitudinal ridges arranged as *Orionina* pattern with the posterior vertical rigde weaker. Subcentral tubercle discret.

Remarks: the species in this paper has similarities with the type species (HVH6652) of *O. similis* van den Bold, 1963b from Trinidad (Upper Miocene) mainly with respect to outline and ornamentation pattern of the ridges; differs in the size of the carapace that is larger, more elongate and in the presence of a proeminent subcentral tubercle on surface of the species herein illustrated. The ornamentation of this species with three longitudinal ridges is very similar to *Orionina vaughani*, but differing in the following respect: median ridge less oblique because of the lower position of the posterior cardinal angle. Anterior part of the dorsal ridge parallels to the median as in *O. vaughani*. Subcentral tubercle hardly visible. Posterior ridge often not well developed; if present, it joins the ventral ridge with a curve, concave to the posterior side, where as in *O. vaughani* it meets the ventral ridge at right angles. Posterior portion of the ventral ridge more nodular than in *Orionina vaughani* or *Orionina serrulata*. The type species (HVH5132) of *Orionina bradyi* van den Bold, 1963d from Nicaragua (Holocene) apparently is less similar with the specimens here than the *O. similis*, thickness, presence of subcentral tubercle and ornamentation pattern. *Orionina bradyi* van den Bold, 1963d is also similar, except to the size that is slightly larger and the anterior end slightly more elongate. Ridges structure with large central ridge and two above it as in *O. bradyi*.

Occurrence: B-17 quarry, Capanema, Pará (Levels B1 and B11).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Procythereis* Skogsberg, 1928

Procythereis? sp.

Plate 7.10, fig. 28

Material: 3 valves.

Dimensions: MPEG-716-M, LV: L: 0.55 mm and H: 0.31 mm. MPEG-717-M, LV: L: 0.53 mm and H: 0.30 mm.

Description: medium and subquadrate valve, in lateral view. Dorsal margin slightly convex to sinuous. Ventral margin sinuous, slightly concave in the middle. Anterior margin is very broadly and slightly obliquely rounded. Posterior margin short, concave above and a small caudal process posteroventrally. LV with with the anterior cardinal angle less evident than the posterior. Ornamentation reticulate with an irregular pattern of ridges among which the marginal ridge stand out. Behind this ridge, in the anteromedian region the carapace is strongly compressed.

Remarks: this species presents outline and ornamentation pattern very similar to genus *Quadracythere* but differs a little in the outline and in the less evident ridges. The presence of few materials does not allow to precise the taxonomical identification of this species.

Occurrence: B-17 quarry, Capanema, Pará (Level B1).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Coquimba* Ohmert, 1968

Coquimba congestocostata van den Bold, 1988

Plate 7.11, figs. 1-9

1963b. *Puriana*? *congestocostata* van den Bold, p. 391, pl. 7, figs. 5a-b; pl. 12, fig. 9.

1981. *Coquimba congestocostata* (van den Bold) van den Bold, p. 81, pl.4, fig. 6, table 13.

1988. *Coquimba congestocostata* (van den Bold), van den Bold p. 38, pl. 3, fig. 17.

Material: 19 carapaces and 56 valves.

Dimensions: MPEG-718-M, Female, C; LV: L: 0.60 mm and H: 0.29 mm; RV: L: 0.53 mm and H: 0.27 mm. MPEG-719-M, Female, RV: L: 0.55 mm and H: 0.27 mm. MPEG-720-M, Female, LV: L: 0.70 mm and H: 0.36 mm. MPEG-721-M, Male, C; Dorsal: H: 0.51 mm and W: 0.21 mm. MPEG-722-M, Male, C; LV: L: 0.81 mm and H: 0.37 mm; RV: L: 0.79 mm and H: 0.35 mm. MPEG-723-M, Male, C; LV: L: 0.52 mm and H: 0.24 mm; RV: L: 0.52 mm and H: 0.26 mm.

Remarks: Firstly this species was classified as *Puriana* (Coryell and Fields) and later erected as *Coquimba* Ohmert, 1968 (Bold, 1988) mainly in respect to the development of hinge and marginal area, although the posterior tooth is distinctly shorter in the Trinidad species. According Bold (1963b), the dorsal view is very close to *Puriana* and also the three broad teeth at the posteroventral that are reminiscent of this genus. The type species *Puriana*? *congestocostata* (HVH6862) from Upper Miocene of Trinidad was compared and basically have the same size, outline and ornamentation pattern. Moreover, the type species *Coquimba congestocostata* (HVH9135) from Cuba, illustrate by Bold (1988) is closest to the species presented here, however, both species presented larger size. Posterior margin is more rectangular than subacuminate and also the arrangement of the ridges makes obscure the subcentral tubercle.

Occurrence: Aricuru (Maracanã bay), levels AR-01 to AR-05; Atalaia Beach outcrop (Salinópolis), Level AT-01; B-17 quarry, Capanema, Pará (Levels B0, B1A and B12); Ponta do Castelo outcrop (Fortaleza Island), Levels PC-00, PC-02 and PC-03; Primavera FPR-160 core (Levels: AM.08, AM.11, AM.13, AM.15, AM.17 and AM.19).

Distribution: San José Calcareous silt Member of Manzanilla Formation, Upper Miocene. Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Puriana* Coryell and Fields in Puri, 1953

Puriana rugipunctata (Ulrich and Bassler) van den Bold, 1967

Plate 7.11, figs. 10-12

1904. *Cythere rugipunctata* Ulrich and Bassler, p. 118, pl. 38, figs. 16-17.

1937. *Favella puella* Coryell and Fields, p. 8, fig. 8a-c.

1937. *Cythereis rugipunctata* var. *gatunensis* Coryell and Fields, p. 10, fig. 11.

1944. *Favella rugipunctata* (Ulrich and Bassler). Edwards, p. 524, pl. 88, figs. 5-6.

1954. *Puriana rugipunctata* (Ulrich and Bassler). Puri, p. 257, pl. 12, figs. 18-19, text-fig. 8k.

1954. *Puriana puella* (Coryell and Fields). Puri, p. 257, pl. 12, fig. 17.

1967. *Puriana rugipunctata* (Ulrich and Bassler) van den Bold, p. 311, pl. 1, fig. 7.

Material: 7 carapaces.

Dimensions: MPEG-724-M, C; LV: L: 0.57 mm and H: 0.28 mm; RV: L: 0.56 mm and H: 0.27 mm; Dorsal: H: 0.55 mm and W: 0.27 mm.

Remarks: The species recorded here is very similar to the type species *Puriana rugipunctata* (HVH8227) from Upper Miocene of Gatun Formation (Panama Canal Zone) as in the ornamentation pattern, shape and size carapace; however differs only in the number of spines in the posterior region that the present species has about two more. In general outline, this species is also very similar to *Puriana minuta* van den Bold, 1963b, but this last one differs by the absent of evident spines on posterior end, the ornamentation pattern and ocular tubercle less evident.

Occurrence: B-17 quarry, Capanema, Pará (Levels B1A, B4, B11A and B11B).

Distribution: Middle Miocene of Gatun Formation in Panama Canal Zone. Miocene of Florida Panhandle, USA. Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Pokornyella* Oertli, 1956

Pokornyella deformis (Reuss, 1850)? Holden, 1976

Plate 7.11, figs. 13-18

1957b. *Aurila deformis* (Reuss). van den Bold, p. 239 (part, not pl. 1, fig. 8).

1963b. *Aurila deformis* (Reuss). van den Bold, p. 386, pl. 7, fig. 4.

1965. *Procythereis*? *deformis* (Reuss). van den Bold. p. 396, pl. 5, figs. 4a, b.

1973b. *Procythereis*? *deformis* (Reuss). Van den Bold, p. 164, pl. 1, figs. 4a-c.

1976. *Pokornyella deformis* (Reuss)? Holden, pl. 1, fig. 4; pl. 11, figs. 7-9.

Not 1994b. *Aurila amygdala* (Stephenson). Távora, p. 119, fig. 3.

Material: 127 carapaces and 399 valves.

Dimensions: MPEG-725-M, C; LV: L: 0.78 mm and H: 0.48 mm; RV: L: 0.76 mm and H: 0.43 mm; Dorsal: H: 0.69 mm and W: 0.43 mm. MPEG-726-M, LV: L: 0.69 mm and H: 0.43 mm. MPEG-727-M, RV: L: 0.68 mm and H: 0.39 mm.

Remarks: Holden (1976) recorded the species *Pokornyella deformis*? (Reuss) especially from Miocene of Midway Island (Hawaii); this species seem to be the same compared to the species described herein in the ornamentation, shape and size. *Pokornyella deformis*? (Reuss) Holden, 1976 appears to be confined to lower to middle Miocene rocks in the Caribbean (Bold, 1966b). On the other hand, Bold (1963b) recorded *Aurila deformis* (Reuss), but it presents smaller size (L 0.72 mm; H 0.49 mm) to the species in the present study. This species in majority always was recorded in Miocene formations from Cuba, Guatemala, Panamá, Dominican Republic, Tampa/Catahoula/Alum Bluff (Florida) and Trinidad (Ste. Croix and Morne Diablo Quarries); therefore the species identified in 1957 differs from the published in 1963b in the carapace shape and ornamentation. Moreover, Bold (1965, 1972a, 1988) also identified the species *Procythereis*? *deformis* (Reuss) from Antillas, Central America (Lower to Upper Miocene) with many different synonymies and genera, but it presented basically the same carapace size (L 0.74 mm; H 0.46 mm; W 0.45 mm). Based on these records, the species in the present study also differs of *Aurila deformis* in both papers (Bold 1957 and 1963b) and it has more similarities with *Pokornyella deformis*? (Reuss) Holden, 1976. Thus, this species was classified as *Pokornyella* rather than *Aurila* due to the features of muscle scars typical of the genus. The species is the same *Aurila amygdala* (Stephenson, 1944), Távora, 1994b already recorded for this unit, but it seems to be quite different to the species *Aurila amygdala* (Stephenson, 1944) van den Bold, 1965 in the ornamentation as well as in the outline of the carapace.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-06; Ponta do Castelo outcrop (Fortaleza Island), Levels PC-02 and PC-03.

Distribution: Antillas, Central America (Lower to Upper Miocene); Miocene of Midway Island (Hawaii). Occurs in Trinidad into of the *Globigerinatella insueta* zone to above the *Globorotalia menardii* Zone (Manzanilla Formation). It is commom in the Cojímar and Guines Formations of Cuba, the Cercado Formation of the Dominican Republic, the Caribe and Rio Dulce Formations of Guatemala and the Chipola Formation of Florida. In Puerto Rico it occurs in the Cibao and Aguada Formations. Lower Miocene, Pirabas Formation, Pará, Brazil.

Infraorder Nomocytherinina Liebau, 1991

Superfamily Cytheroidea Liebau, 2005

Family Loxoconchidae Sars, 1925

Genus *Loxoconcha* Sars, 1966

Loxoconcha aff. *L. cyrton* van den Bold, 1963b

Plate 7.11, figs. 19-24

1963b. *Loxoconcha cyrton* van den Bold, pags. 394, 395, pl. 8, figs. 11a-b.

Material: 67 carapaces and 479 valves.

Dimensions: MPEG-728-M, Female, C; LV: L: 0.47 mm and H: 0.27 mm; RV: L: 0.44 mm and H: 0.26 mm; Dorsal: L: 0.45 mm and W: 0.23 mm. MPEG-729-M, Male, C; LV: L: 0.51 mm and H: 0.26 mm; RV: L: 0.49 mm and H: 0.27 mm; Dorsal: H: 0.51 mm and W: 0.25 mm.

Description: ovate to subovate carapace, in lateral view. Greatest height just behind the middle, height more than half the length. Dorsal margin slightly irregular and slightly plump in the anterior region; LV overlaps RV on this margin. Ventral margin straight, turned upwards posteriorly. Anterior margin obliquely rounded. Posterior margin short and obliquely rounded. Surface deeply pitted and roughly, ventral margin with three to four rigdes parallel to the margin extending to the postero and anteroventral regions. Evident posterodorsal ridge parallel to the margin extending to part of the dorsal margin. Behind this ridge, the carapace is strongly compressed. Ocular tubercle pronounced. In dorsal view, lenticular carapace, posterior end compressed and sides gently convex. Sexually dimorphic: carapace of the males are more elongate than females; these last one have greatest height in front of the middle; posteriorly flatted and slightly concave in the downslope towards the posterior cardinal angle. Internal features typically to the genus.

Remarks: the species *L. cyrton* van den Bold, 1963b presents many characteristics similar to species identified herein, however it differs in some aspects of shape, ornamentation pattern and overlapping in all margins of the carapace. This species also has some superficial similarities to *L. savanetensis* van den Bold, 1963b but differs by its gibbose dorsal of the left valve and the absence of the ventral ridges.

Occurrence: Aricuru (Maracanã bay), levels AR-01, AR-04 and AR-06; B-17 quarry, Capanema, Pará (Levels B0 to B2A; B5 to B7; B9 to B11 and B11A to B13); Primavera FPR-160 core (Levels: AM. 4, AM.6, AM. 8, AM.13 to AM.15, AM. 17, AM.19 and AM.20).

Distribution: Upper Morne l´Enfer Formation and Springvale Formation (Savaneta Glauconitic Sandstone). Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Loxoconcha sp.

Plate 7.11, figs. 25-26

Material: 5 valves.

Dimensions: MPEG-730-M, LV: L: 0.36 mm and H: 0.19 mm. MPEG-731-M, RV: L: 0.39 mm and H: 0.22 mm.

Description: medium and subrectangular carapace, in lateral view. Dorsal margin straight with cardinal angles slightly pronounced. Ventral margin slightly convex in the LV, almost straight in the RV, gently upturned posteriorly. Anterior margin and posterior obliquely rounded in both valves. Surface deeply reticulate; roughly reticulated with circular to pentagonal fossae distributed regularly. Along the entire edge of the anterior margin a row of reticles and short rigdes extending to the middle of the carapace. In the RV, a ventral ridge is more evident than in LV; this ridge follow from the anteroventral region toward posteroventral region forming a very short process alar. Ocular tubercle pronounced. Internal features not observed.

Remarks: *Loxoconcha santosi* Dung and Tsukagoshi, 2014 is similar to the species described herein mainly in the outline of the LV, eye-tubercle pronounced and reticulate pattern, but it differs in larger size (H 0.28mm; L 0.44mm) and in the presence of three short and weak ridges in the anterior region.

Occurrence: Primavera FPR-160 core (Levels: AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Loxoconcha vana n. sp.

Plate 7.12, figs. 1-7

Material: 10 carapaces and 6 valves.

Etimology: Latin: vana=*vanum*; refer to the aspect fat, robust, fufly of the carapace shape.

Holotypes: MPEG-732-M, Female, C; LV: L: 0.46 mm and H: 0.30 mm; RV: L: 0.45 mm and H: 0.28 mm. MPEG-733-M, Male, C; LV: L: 0.54 mm and H: 0.31 mm; RV: L: 0.52 mm and H: 0.30 mm.

Paratypes: MPEG-734-M, Female, C; LV: L: 0.52 mm and H: 0.30 mm. MPEG-735-M, female, LV: L: 0.51 mm and H: 0.30 mm. MPEG-736-M, juvenile, female, RV: L: 0.42 mm and H: 0.25 mm. MPEG-737-M, juvenile, male, LV: L: 0.34 mm and H: 0.19 mm. MPEG-738-M, juvenile, female, LV: L: 0.33 mm and H: 0.21 mm.

Diagnosis: surface deeply reticulate, circular to elliptical reticles, distributed regularly; in the posterodorsal region a delicate and smaller net of punctuations or reticles are distributed between the ridges.

Description: medium and rhomboidal to subovate carapace like an almond-shaped, in lateral view. Dorsal margin straight. Ventral margin convex, upturned gently posteriorly. Anterior margin rounded. Posterior margin subrounded. LV overlapping RV in the dorsal margin and RV overlaps LV in the free margins. Surface deeply reticulate, reticles circular to elliptical, distributed regularly; in the posterodorsal region a delicate and smaller net of punctuations or reticles are distributed between the ridges. Two or three ventral ridges parallel to the ventral margin extend from the anteroventral in the RV, and converging to the posterior region in both; from this point follow one posterior rigde parallel to the margin that extend to the postero dorsal region, mainly in the RV. Behind of that posterior ridge the carapace is strongly compressed. In the anterior border a short area compressed with a row of reticles. Ocular tubercle pronounced. Sexually dimorphic: males more elongate than females. Greatest height in front of the middle; posteriorly flatted and slightly concave in the downslope towards the posterior cardinal angle. Some juveniles' stages were observed and these present the same characters of adults' stages, although less developed. Internal features typically to the genus.

Remarks: this species is very similar to *Loxoconcha avellana* (Brady, 1866) Palacios-Fest *et al.*, 1983 recorded to the Recent sediments from Mexico differing only in the ornamentation. Differs from the type species of *L. avellana* (Brady, 1866) in the presence of the ventral ridges parallel to the margin.

Occurrence: Aricuru (Maracanã bay), levels AR-01 to AR-04; B-17 quarry, Capanema, Pará (Levels B11A to B13).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Subfamily Loxoconchinae Sars, 1926

Genus *Loxocorniculum* Benson & Coleman, 1963

Loxocorniculum fischeri (Brady, 1869) van den Bold, 1957

Plate 7.12, figs. 10-13

1957b. *Loxoconcha fisheri* (Brady). van den Bold, p. 224, pl. 2, fig. 7;
pl. 7, figs. 9, 10.

Material: 17 valves.

Dimensions: MPEG-739-M, Female, RV: L: 0.50 mm and H: 0.31 mm. MPEG-740-M, Male, RV: L: 0.54 mm and H: 0.30 mm. MPEG-741-M, Male, RV: L: 0.54 mm and H: 0.30 mm. MPEG-742-M, Male, RV: L: 0.54 mm and H: 0.30 mm.

Remarks:

This species is very similar to *Loxoconcha fischeri* van den Bold, 1963b (=L. antillea) and-*L. antillea* van den Bold, 1946 (HVH7780) mainly in the shape, size, presence of a hornlike posterodorsal tubercle, ventral ridges and a pronounced eye tubercles. identified herein and also resemble to the holotype *Cythere fischeri* Brady, 1969 to the presence of ventral ridge and the posterodorsal tubercle, however it presents a small eye node. Moreover, the species *Loxoconcha (Loxocorniculum) fischeri* (Brady, 1869) van den Bold, 1988 presents the posterodorsal and ventral nodes more developed, greatest length and the middle anterior ridges are not parallel as in the species described herein. The species was kept in *Loxocorniculum* due to the typical posterior horns.

Occurrence: Primavera FPR-160 core (Levels: AM.08 and AM.17).

Distribution: Upper Miocene to Recent: Trinidad (Upper Miocene), Greater Antilles, Miocene of Venezuela, Cuba and Gutemala; Colombia, Panama (Colón Harbor - Recent), Costa Rica, Mexico. Ste. Croix Quarry. Manzanilla Formation upward, Upper Miocene. Lower Miocene, Pirabas Formation, Pará, Brazil.

Loxoconcha (*Loxoconiculum*) aff. *rugosa* van den Bold, 1963

Plate 7.12, figs. 14-16

1946. *Loxoconcha antillea* var. *rugosa* van den Bold, p. 110, pl. 15, fig. 6a-b.

1963b. *Loxoconcha rugosa* van den Bold, p. 394, pl. 8, fig. 7.

1981. *Loxoconcha antillea* var. *rugosa* van den Bold, p. 81, pl. 5, fig. 8, table 15.

Material: 4 carapaces and 43 valves.

Dimensions: MPEG-743-M, Female, C; LV: L: 0.45 mm and H: 0.25 mm; RV: L: 0.40 mm and H: 0.23 mm. MPEG-744-M, Male, LV: L: 0.43 mm and H: 0.25 mm.

Description: medium and subrectangular carapace, in lateral view. Dorsal margin irregular, almost straight with posterodorsal projection. Ventral margin almost straight, gently concave in the middle. Anterior margin obliquely rounded and compressed. Posterior margin obliquely subrounded and pointed in the mid-posterior region. Behind this margin and in the posteroventral region the valve is strongly compressed. Surface weakly reticulate with three short and weak longitudinal anteromedian ridges. Three or four weak ventral rigdes parallel to the margin converging to the posteroventral region. Posterodorsal tubercle evident. Internal features were not observed.

Remarks: this species is very similar to *Loxoconcha (Loxocorniculum) rugosa* van den Bold, 1963b in the carapace shape and in the ornamentation pattern; however it differs in the presence of a conspicuous eye tubercle and proeminent posterodorsal tubercle.

Occurrence: Aricuru (Maracanã bay), levels AR-01, AR-03 and AR-04; Primavera FPR-160 core (Levels: AM.4, AM.6 and AM.8).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Loxoconiculum antilleum (van den Bold, 1946)

Plate 7.12, figs. 17-18

1946. *Loxoconcha antillea* van den Bold, p. 110, pl. 15, figs. 3a-c; 1950, p. 86.

1957. *Loxoconcha antillea* van den Bold, p. 110, pl. 15, fig. 3a-c; 1950, p. 86.

1957. *Loxoconcha fischeri* (Brady). van den Bold, p. 244, pl. 2, fig. 7; 1958, Table 1.

Material: 8 carapaces and 32 valves.

Dimensions: MPEG-745-M, LV: L: 0.52 mm and H: 0.29 mm. RV: L: 0.42 mm and H: 0.25 mm.

Remarks: this species is here considered as *Loxocorniculum* because the presence of the dorso and ventral posterior horns typical to this genus that does not occur in *Loxoconcha*. The studied material has the same features of the type species.

Occurrence: B-17 quarry, Capanema, Pará (Levels B1A, B7 and B12); Primavera FPR-160 core (Levels: AM.4, AM.6, AM.8 and AM.19).

Distribution: this species was recorded in Cuba, Paso Real Formation (Lower Miocene), Río Yaque del Norte (López), however, its general range occurs in Lower to Upper Miocene into the Caribbean region. This species also was recorded in Brasso and Tamana Formations (Upper Miocene) from Trinidad. Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Loxocorniculum aff. *Loxoconcha longispina* (Key) Holden, 1976

Plate 7.12, figs. 19-21

1880. *Loxoconcha alata* Brady, p. 122, pl. 27, figs. 6a-j (not Brady, 1868).

1953. *Loxoconcha alata* Brady var. *longispina* Key, p. 160, pl. 1, figs. l0a, b.

1967. *Loxoconcha longispina* (Key) Holden, p. 32-24, figs. 23a-d.

1976. *Loxoconcha longispina* (Key, 1953) Holden, pl. 4, fig. 14; pl. 5, figs. 3-6; pl. 14, figs. 12-15.

Material: 12 carapaces and 13 valves.

Dimensions: MPEG-746-M, Female, LV: L: 0.43 mm and H: 0.27 mm. MPEG-747-M, LV: L: 0.42 mm and H: 0.24 mm. MPEG-748-M, Male, LV: L: 0.44 mm and H: 0.25 mm.

Description: medium and subovate carapace, in lateral view. Dorsal margin straight slightly concave with a weak protuberence posterodorsal. In this margin, there is a pronounced eye tubercle in the anterodorsal region. Ventral margin strongly convex gently turned up posteriorly. Anterior margin narrowly rounded. Posterior margin obliquely subrounded. Behind this margin and in the posteroventral region the valve is strongly compressed. Surface coarsely reticulate, with circular reticles; three ventral ridges extend from the anteroventral region converging posteroventrally to the posteroventral protuberance surface. Two weak and short anteromedian longitudinal ridges. Sexually dimorphic: males more elongate than females. Muscle scars with a row of four flated aductor scars. Others internal features were not observed.

Remarks: this species has some aspects similar to *Loxoconcha longispina* (Key, 1953) Holden, 1976 mainly in the juveniles as shape and ornamentation pattern; however, it differs in the absence of two weak anteromedian ridges, presenting three weak anteromedian ridges. Instead, posterodorsal hornlike absent presenting a weak protuberance like a ridge and a weak posteroventral tubercle.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-05; B-17 quarry, Capanema, Pará (Levels B11 and B12); Primavera FPR-160 core (Levels: AM.08).

Distribution: Lower Miocene to Pleistocene (?) from Midway Island Drill Holes. Lower Miocene, Pirabas Formation, Pará, Brazil.

Loxoconiculum sp.

Plate 7.12, figs. 22-27

Material: 2 carapaces and 8 valves.

Dimensions: MPEG-749-M, Female, LV: L: 0.50 mm and H: 0.29 mm. MPEG-750-M, Female, RV: L: 0.47 mm and H: 0.26 mm. MPEG-751-M, Male, LV: L: 0.50 mm and H: 0.26 mm. MPEG-752-M, Male, RV: L: 0.47 mm and H: 0.25 mm. MPEG-753-M, Male, LV: L: 0.44 mm and H: 0.22 mm.

Description: medium and subrectangular carapace, in lateral view. Dorsal margin straight. Ventral margin convex posteriorly; Anterior margin obliquely rounded and compressed. Posterior margin strongly oblique with a pointed portion in the mid-posterior region forming a short caudal process. Surface coarsely reticulated. Two pronounced tubercles with a volcano shape; one in the posterodorsal and the other in the posteroventral regions. Three ventral ridges following the ornamentation pattern. Posteroventral region flat and broad reticulated behind of the alar tubercle. Anterior and posterior margen flat and smooth. Two mid-anterior rigdes converging to the anteromedian region. Eye tubercle proeminent. Hinge of LV with a groove following a middle crenulate element to the end, corresponding to the RV, different of *Loxoconcha*. Muscle scars with a row of adductor scars, one antennal scar crescent-shaped, two mandibular oval scar. Others internal features were not observed.

Remarks: this species resemble to *Loxoconcha* aff. *L. (Loxocorniculum) fischeri* (Brady, 1869) Bold, 1988 in the shape and hinge, but differs in many aspects of the ornamentation pattern, mainly in the strong mid-anterior “v” shape ridges; and in the posteroventral and posterodorsal tubercles that are less prominent in the species studied here.

Occurrence: Primavera FPR-160 core (Levels: AM.4, AM.6, AM.8 and AM.17).

Distribution: Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Subfamily Loxocaudinae Schornikov, 2011

Genus *Phlyctocythere* Key, 1958

Phlyctocythere sp.

Plate 7.12, figs. 8 and 9

Material: 6 carapaces and 13 valves.

Dimensions: MPEG-754-M, C; LV: L: 0.38 mm and H: 0.23 mm; RV: L: 0.37 mm and H: 0.24 mm.

Description: medium, short and irregularly ovate carapace, highest around the middle, in lateral view. Dorsal margin gently convex and irregular consisting of a slight concavity posterodorsally. Ventral margin slightly sinuous, concave in the anteromedian and slightly convex in the posteroventral region, gently turned up posteriorly. Anterior margin evenly rounded in both valves. Posterior margin obliquely rounded with a subdorsally caudal process. Surface smooth and strongly compressed above of the caudal process. RV overlaps the LV in the dorsal and anterior margins. Internal features not observed.

Remarks: similar to the species *Phlyctocythere curva* van den Bold, 1988 in general shape, however, it differs in many aspects as in the presence of a dorsal margin strongly sinuous, proeminent caudal process subdorsally and faint reticulate pattern in the anterior region. Moreover, other species that resemble is *Phlyctocythere stricta* van den Bold, 1988, also in the carapace shape and smooth surface, but differs in the straight dorsal margin.

Occurrence: Aricuru (Maracanã bay), levels AR-02 to AR-04; and AR-06; B-17 quarry, Capanema, Pará (Level B11B); Primavera FPR-160 core (Levels: AM.17).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Touroconcha* Ishizaki & Gunther, 1976

Touroconcha ishizakii n. sp.

Plate 7.13, figs. 1-8

Material: 8 carapaces and 22 valves.

Etimology: in honor to the ostracodologist PhD Kunihiro Ishizaki, one of the authors of this genus.

Holotypes: MPEG-755-M, Female, C; LV: L: 0.41 mm and H: 0.25 mm; Dorsal: H: 0.41 mm and W: 0.25 mm. MPEG-756-M, Male, C, LV: L: 0.44 mm and H: 0.24 mm; Dorsal: H: 0.43 mm and W: 0.24 mm.

Paratypes: MPEG-757-M, Female, LV: L: 0.37 mm and H: 0.22 mm; RV: L: 0.37 mm and H: 0.22 mm. MPEG-758-M, Male, RV: L: 0.42 mm and H: 0.23 mm.

Diagnosis: Surface coarsely reticulate with reticles projected to outside of carapace; two posterodorsal ridges converging posterodorsally.

Description: small and subquadrate to subrhomboidal carapace, in lateral view. Dorsal margin straight followed by two posterodorsal ridges converging posterodorsally. In this margin, there is a pronounced eye tubercle in the anterodorsal region. Ventral margin moderately convex gently turned up posteriorly and with a concave portion forming a posteroventral reticule; very slightly irregular lower ridge. Anterior margin obliquely rounded and compressed. Posterior margin obliquely rounded. Behind this margin and in the posteroventral region the valve is strongly compressed. Surface coarsely reticulate. Along the ventral margin, specifically in the half of posteroventral region to the anteroventral area, there is two ventral ridges following the ornamentation pattern. Hinge of LV with a tooth-groove following a middle crenulate element and a tooth surrounded by a groove area in the end corresponding to the RV. Others internal features were not observed.

Remarks: the species is similar to species of the genus *Loxonconcha* in general shape, but it differs in the ornamentation pattern strongly reticulate with reticles formed by pronounced ridges typical of *Touroconcha*.

Occurrence: B-17 quarry, Capanema, Pará (Levels B7, B9 and B13); Primavera FPR-160 core (Levels: AM.08, AM.12, AM.13 and AM.19).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Suborder Cytherocopina Gründel, 1967
Infraorder Archaeocytherinina Liebau, 1991
Superfamily Paradoxostomatoidea Liebau, 2005
Family Paradoxostomatidae Brady & Norman, 1889
Subfamily Paradoxostomatinae Brady & Norman, 1889
Genus *Paradoxostoma* Fischer, 1855

Paradoxostoma artum van den Bold, 1966a

Plate 7.13, fig. 20

1963b. *Paradoxostoma* sp. van den Bold, p. 404, pl. 10, fig. 8; p. 9.

1966a. *Paradoxostoma artum* van den Bold, p. 54, pl. 3, fig. 4a-b, p. 37.

Not1994b. *Paradoxostoma* cf. *P. artum* van den Bold. Távora, p. 122, fig. 5.

Material: 2 carapaces.

Dimensions: MPEG-759-M, C; LV: L: 0.56 mm and H: 0.23 mm; RV: L: 0.50 mm and H: 0.20 mm; Dorsal: H: 0.50 mm and W: 0.19 mm.

Remarks: the species is rather similar in shape to *Paradoxoatoma robustum* Puri (nom. corr. for *P. robusta* Puri, 1954, p. 289, pl. 15, fig. 1, pl. 14, figs. 7-9), which is less extended posteriorly. Moreover, this was also compared to the paratype *Paradoxostoma artum* van den Bold, 1966a (HVH No. 7926) and species figured *Paradoxostoma* sp. van den Bold, 1963b (HVH No. 6885) presenting many similarities mainly in shape, but differ only in lesser size. Based on the outline of carapace, *Paradoxostoma* cf. *P.artum* (Bold) recorded to this unit by Távora (1994b) differs of the species described herein.

Occurrence: B-17 quarry, Capanema, Pará (Level B13B).

Distribution: This species also was recorded in the Melajo Clay member of Springvale Formation (Upper Miocene) from Trinidad. Upper Miocene, Cubagua Formation, Cubagua Island, Venezuela. Aricuru Locality, Pirabas Formation (Lower Miocene), Pará, Brazil.

Paradoxostoma pirabensis n. sp.

Plate 7.13, figs. 17, 21 and 25

Material: 2 carapaces and 15 valves.

Etymology: in reference to the type location of Pirabas Formation.

Holotype: MPEG-760-M, C; LV: L: 0.78 mm and H: 0.37 mm; RV: L: 0.77 mm and H: 0.36 mm; Dorsal: H: 0.80 mm and W: 0.34 mm.

Paratypes: MPEG-761-M, C; LV: L: 0.78 mm and H: 0.37 mm. MPEG-762-M, C; LV: L: 0.78 mm and H: 0.37 mm.

Diagnosis: subelongate carapace in lateral view. Surface smooth. Dorsal view sinuous, almost straight to slighly convex in the middle, widest in the middle; posterior end narrow like seed-shaped.

Description: subelongate carapace in lateral view; highest in the middle. Dorsal margin sinuous, almost straight to slightly convex in the middle. Ventral margin concave-convex, strongly convex in the posteromedian region, curved upward into the posterior end forming a dorsal caudal process. Anterior margin obliquely and narrowly rounded; Surface smooth. Dorsal view biconvex, widest in the middle; posterior end narrow like seed-shaped. Valves subequaI: LV overlapping RV in the ventral and anterior margins. Inner lamella well developed. Others internal features were not observed.

Remarks: This species differs of the others species in the typical outline of *Paradoxostoma* by the presence of the straight dorsal margin and in the broad posterodorsal extension like a caudal process. Then, this species probably belong to another genus, but is preliminarly kept in this genus.

Occurrence: Aricuru (Maracanã bay), level AR-01; B-17 quarry, Capanema, Pará (Levels B1A, B5, B11, B12 and B13); Primavera FPR-160 core (Levels: AM.10, AM.12, AM.15, AM.17 and AM.18).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Paradoxostoma? sp.

Plate 7.13, figs. 15, 18 and 19

Material: 2 carapaces and 1 valve.

Dimensions: MPEG-763-M, C; LV: L: 0.50 mm and H: 0.20 mm; RV: L: 0.46 mm and H: 0.19 mm; Dorsal: L: 0.50 mm and W: 0.13 mm.

Description: strongly elongate, oblique carapace; highest at 3/5 of the length from the anterior extremity. Dorsal and ventral margin parallel and slightly biconvex respectively converging to the posterior end, which is narrowly rounded above the middle. Anterior end obliquely and narrowly rounded; Dorsal view lanceolate, widest in the middle. Valves subequaI: LV overlapping RV. Posterior part of ventral marging strongly compressed laterally, sharp posteriorly. Internal features were not observed.

Remarks: this is very different of the others species of *Paradoxostoma* in the size, shape and a more detailed study based in additional material is necessary to attest the generic position of this species.

Occurrence: Aricuru (Maracanã bay), level AR-04.

Distribution: Aricuru Locality, Pirabas Formation (Lower Miocene), Pará, Brazil.

Suborder Cytherocopina Gründel, 1967

Infraorder Nomocytherinina Liebau, 1991

Superfamily Cytheroidea Liebau, 2005

Family Pectocytheridae Hanai, 1957

Genus *Munseyella* van den Bold, 1957

Munseyella minuta (Bold, 1946) van den Bold, 1957

Plate 7.13, figs. 9-11

1946. *Cytheromorpha minuta* van den Bold, p. 105, pl. 14, fig. 12.
1954. *Cytheromorpha subminuta* Puri, p. 276, pl. 6, figs. 9-10; text-fig. 11 i-j.
1957. *Munseyella minuta* van den Bold, p.238.
1958. *Munseyella minuta* van den Bold, p.402, pl. 4, figs. 1a-1e, pl. 5, figs. 2a-c.
1994b. *Munseyella minuta* (Bold) Távora, p.124, fig. 7.

Material: 2 carapaces and 2 valves.

Dimensions: MPEG-764-M, C; LV: L: 0.30 mm and H: 0.17 mm; RV: L: 0.30 mm and H: 0.16 mm; Dorsal: L: 0.33 mm and H: 0.12 mm. MPEG-765-M, C; LV: L: 0.30 mm and H: 0.17 mm; RV: L: 0.30 mm and H: 0.16 mm; Dorsal: H: 0.30 mm and W: 0.12 mm.

Remarks: the present species is the same of type species *Munseyella minuta* (Bold, 1946) van den Bold, 1957 that was firstly record by Távora (1994b) to the Pirabas Formation. It is very similar to *Munseyella subminuta* (Puri) (HVH No. 6891) in shape and size, however, a dorsal ridge is more pronounced that both overlaps the dorsal edge making it more convex, in side view. This species is also rather similar to *Munseyella bolli* (Bold, 1966a), but differs by a weaker dorsal and stronger ventral ridge.

Occurrence: Aricuru (Maracanã bay), levels AR-03 and AR-04.

Distribution: Miocene of Florida; Springvile Formation (Upper Miocene), Cipero, Brasso, Lengua and Cruse formations from Trinidad. Lower Miocene, Pirabas Formation, Pará, Brazil.

Munseyella? sp.

Plate 7.13, figs. 12-14

Material: 4 carapaces.

Dimensions: MPEG-766-M, C; LV: L: 0.50 mm and H: 0.29 mm; RV: L: 0.48 mm and H: 0.27 mm; Dorsal: H: 0.51 mm and W: 0.24 mm.

Description: small, elongate, subtriangular carapace, highest at anterior cardinal angle, nearly 1/3 of the length from the anterior extremity. Dorsal margin straight and arched in the anterior cardinal angle. Ventral margin slightly convex. Anterior margin rounded with a flat board. Posterior margin narrow, obliquely truncate, curved ventrally. Proeminent and coarse anterior rim continues ventrally and branches into long ventral ridges to the posteroventral region. Two remarkable horizontal ridges along the middle to the posteromedian regions, each ending in a sort of subcentral tubercles. Just in front of the posterior cardinal angle, the dorsal ridge bends downward and diverges in a four short transversal rigdes; mid-dorsal region from the two short vertical sulci extends to the dorsomedian region. Greatest width at about 1/3 of the legnth from the posterior end; dorsal view more biconvex, pearshaped.

Remarks: the present species is similar to *Munseyella* but differs a little in the outline and is preliminarly included in this genus. However, this species is similar to *Munseyella bermudezi* (Bold, 1966a), in general outline shape and size, but differs in the ornamentation pattern or arrangement of the ridges and in some aspects of the carapace shape as dorsal margin more straight and arched in the anterior cardinal angle and ventral margin slightly convex. It is also similar to *Costa* (*Cuneocosta*) *tricostata pliocenica* Ruggieri, 1992 mainly in outline of the LV, but it is shorter than the species described herein and differs in the arrangement of ridges.

Occurrence: B-17 quarry, Capanema, Pará (Levels B11A and B11B); Primavera FPR-160 core (Level: AM.20).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Infraorder Nomocytherinina Liebau, 1991

Superfamily Cytherideoidea Liebau, 2005

Family Krithidae Mandelstam, 1958

Genus *Pseudopsammocythere* Carbonnel, 1966

Pseudopsammocythere ex. gr. *vicksburgensis* (Howe and Law) van den Bold, 1988

Plate 7.13, figs. 16, 22 and 23

1963b. *Parakrithella* sp. van den Bold, p. 378, pl. 4, fig. 4.

1988. *Pseudopsammocythere* ex. gr. *vicksburgensis* (Howe and Law) van den Bold, p. 378, pl. 2, figs. 5-7, text-figure 8, p. 27 and 28.

Material: 2 carapaces and 4 valves.

Dimensions: MPEG-767-M, C; LV: L: 0.43 mm and H: 0.18 mm; RV: L: 0.42 mm and H: 0.17 mm; Dorsal: H: 0.44 mm and W: 0.14 mm.

Remarks: this species is similar to *Parakrithella* sp. van den Bold, 1963b (p. 378, pl. 4, fig. 4; HVH8221) in the rounded posterior end and shorter size of carapace (L: 0.51 mm; H: 0.23 mm). Moreover, the anterior region is totaly different presenting a slope down anteroventrally. The present species is closer to *Pseudopsammocythere* ex. gr. *vicksburgensis* (Howe and Law) van den Bold, 1988 due to a more slender shape than *Parakritella* sp. van den Bold, 1963b. According Bold (1988), this group was organized with diferent species from diferent stratigraphic ranges, which share the same features and appears to be restricted to the Central American Province.

Occurrence: Aricuru (Maracanã bay), levels AR-01 to AR-06; B-17 quarry, Capanema, Pará (Levels B11A and B13B).

Distribution: this species was recorded to Springvale Formation, Melajo Clay member, Upper Miocene from Trinidad. Oligocene to Recent: Trinidad, Mexican and United States Gulf Coast, Cuba, Hispaniola. Lower Miocene, Pirabas Formation, Pará, Brazil.

Family Neocytherideididae Puri, 1957

Genus *Copytus* Skogsberg, 1939

Copytus sp.

Plate 7.13, figs. 24

Material: 2 valves.

Dimensions: MPEG-768-M, LV: L: 0.55 mm and H: 0.18 mm. MPEG-769-M, RV: L: 0.68 mm and H: 0.20 mm.

Description: medium and elongate carapace, in lateral view. Dorsal margin low and slightly concave, with dorsal edge straighter than in *Cushmanidea*. Ventral margin slightly convex to almost straight. Anterior margin obliquely surounded. Posterior margin sharpness posteriorly. No sexual dimorphism. Surface smooth. Internal features not observed.

Remarks: despite of this species presents features for the genus, very few specimens have been found, which is considered insufficient material for the establishment of a new species.

Occurrence: B-17 quarry, Capanema, Pará (Level B11 and B12).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Infraorder Nomocytherinina Liebau, 1991

Superfamily Trachyleberidoidea Liebau, 2005

Family Thaerocytheridae Hazel, 1967

Genus *Bradleya* Hornibrook, 1952

Bradleya sp.1

Plate 7.13, fig. 28

Material: 1 valve.

Dimensions: MPEG-770-M, LV: L: 0.43 mm and H: 0.28 mm. MPEG-771-M, RV: L: 0.58 mm and H: 0.28 mm.

Description: elongate to subrectangular carapace, slightly highest near the anterior end. Dorsal and ventral margins nearly straight, however, in the posteroventral margin a concave portion converge posteriorly. Anterior margin obliquely rounded and denticulate. Posterior margin angular in the middle, sinuous above, convex and denticulate below. Ornamentation consists of a strongly reticular pattern; smaller reticules distributed as a secondary ornamentation, and presence of a discret subcentral tubercle. Ridges arrangment in two parallel lines and a short dorsomedian ridges in the mid-posterior region following the reticulations; two slightly anterior ridges diverging toward the middle part and a proeminent ornamented ventral ridge. The more dorsal ridge converging toward the dorsal margin at its posterior end; the both dorsomedian ridges converge toward the anterior parts and become one ridge that follows sinuously near of anterior cardinal angle. Only one specimen of this species have been found, which is considered to be insufficient material for the establishment of a new species.

Remarks: this species resembles to *Bradleya* sp. van den Bold, 1957a in some character as ornamentation pattern, outline shape and presence of a ventral ridge, but differs in the arrangement of the dorsal ridges and in the posteroventral margin concave.

Occurrence: Primavera FPR-160 core (Level: AM. 8).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Bradleya sp.2

Plate 7.13, figs. 26-27

Material: 3 valves.

Dimensions: MPEG-772-M, RV: L: 0.46 mm and H: 0.26 mm.

Description: subquadrate carapace, highest near the anterior end. Dorsal and ventral margins nearly straight and converging slightly posteriorly. Anterior margin obliquely rounded and denticulate. Anterior cardinal angle arched. Posterior margin angular in the middle, straight above, convex and denticulate below. Ornamentation consists of a coarse reticulate pattern: smaller reticles distributed into the greater ones, and subcentral tubercle. The ridges are organized in a dorsal ridge in the middle portion to posterior end and one strong ventral ridge converging toward the mid-posterior ending in a acute tubercle. The more dorsal ridge converges toward the mid-anterior portion ending in a small and compressed area near of arched cardinal angle. In both valves, two parallel and short dorsomedian ridges in the mid-posterior region following the reticulations are visible. Adductor muscle scars 4, in a vertical row, one greater antennal scars. Others internal features were not observed. Only three specimens of this species have been found which is considered insufficient material for the establishment of a new species.

Remarks: *B. dictyon* (Brady, 1880) van den Bold, 1963b has some similarities to this species as the ornamentation pattern and arrangement of the ridges, but differs in the outline shape (dorsal margin more concave and posterior margin more converged abruptly upward) and larger size. Therefore, this species also presents some resemblances to *Bradleya* sp.1 described herein as the presence of a strong ventral ridge and two dorsoposterior ridges following the reticulations, however, differs in others arrangement of ridges as in the dorsoposterior ridge and cardinal angle pronounced.

Occurrence: Primavera FPR-160 core (Level: AM.08 and AM.20).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Quadracythere* Hornibrook, 1952

Quadracythere brachypygaia van den Bold, 1965

Plate 7.14, figs. 1-4

1965. *Quadracythere brachypygaia* van den Bold, p. 381-414, pl. 6, fig. 6a-b, p. 396.

1994c. *Quadracythere* sp. 1 Távora, p. 134, fig. 15.

Material: 408 carapaces and 932 valves.

Dimensions: MPEG-773-M, C; LV: L: 0.56 mm and H: 0.37 mm; RV: L: 0.60 mm and H: 0.39 mm. MPEG-774-M, C, Dorsal: H: 0.65 mm and W: 0.36 mm. MPEG-775-M, LV: L: 0.62 mm and H: 0.37 mm.

Remarks: The present species is the same type species *Quadracythere brachypygaia* van den Bold, 1965 (HVHNo. 7752) from Lares Formation (San Sebastían, Puerto Rico) due to similarities in the presence of the sinuous transversal ridges in the anterior region and in general outline of the carapace. This species is the same of Távora (1994c) recorded to Pirabas Formation. Moreover, it is compared to *Quadracythere antillea* (van den Bold) which is smaller and steeply more truncate behind.

Occurrence: Aricuru (Maracanã bay), levels AR-01 to AR-06; B-17 quarry, Capanema, Pará (Levels B0-B2, B4-B7, B11-B13 and B13B); Ponta do Castelo, Fortaleza Island (Levels PC-00, PC-02-PC-04); Primavera FPR-160 core (Levels: AM.08, AM.10, AM.12 and AM.19).

Distribution: Upper San Sebastián Formation and Lares Formation (Puerto Rico). Lower Miocene, Pirabas Formation, Pará, Brazil.

Quadracythere adornata n. sp.

Plate 7.14, figs. 5-8

Material: 110 carapaces and 436 valves.

Etimology: Latin: adorno= *adornatum*, *adornare*: refer to the ornamentation like “fishing net” or “sewing crochet”.

Holotypes: MPEG-776-M, C; LV: L: 0.61 mm and H: 0.38 mm; RV: L: 0.61 mm and H: 0.35 mm. MPEG-777-M, C, Dorsal: H: 0.63 mm and W: 0.37 mm.

Paratypes: MPEG-778-M, LV: L: 0.56 mm and H: 0.35 mm. MPEG-779-M, RV: L: 0.60 mm and H: 0.34 mm. MPEG-780-M, C; LV: L: 0.56 mm and H: 0.35 mm.

Diagnosis: the remarkable features is the surface reticulate, with the coarse posterior ridges converging to the mid-anterior region forming a reticle. Strong dorsal ridge extending from the anteromedian to the posterodorsal region turning as a loop donwards.

Description: subquadrate carapace, highest at about 1/3 of the carapace. Dorsal margin slightly concave, obscured by the dorsal ridge. Ventral margin slightly concave and obscured by the ventral ridge. Anterior margin obliquely rounded. Posterior margin very short, angular below the middle, strongly concave above, forming about a 90° angle with the dorsal margin, subtruncate below and bearing 2 or 3 large spines. Posterior end of dorsal margin obscured by a short ridge, which ends at about 1/3 of the length forming a strong node, just in front of the posterior cardinal angle. Ventral ridge long, obscuring most of the ventral margin and ending at about 3/3 of the carapace. Surface reticulate, with the coarse posterior ridges converging to the mid-anterior region forming a reticle. Strong dorsal ridge extending from the anteromedian to the posterodorsal region turning as a loop donwards. Anterodorsal region with a depressed area below the eye tubercle, like a sulcu, especially in the LV, that extends parallel to the anterior margin In dorsal view, carapace in general lens-shaped,but irregular in the anterior end because of the raised ridges and in the posterior end because of the strong ridge that projects a dorsal node in the extremity. The ventral ridge projects only slightly. Greatest width in the middle region. Internal features typically for the genus.

Remarks: The species *Quadracythere mediaruga* Hornibrook, 1952 is very resembles in outline shape, ornamentation pattern and proeminent eye tubercle, but differs in the absence of short, evident longitudinal ridges in the middle portion; presence of smaller creast in the mid-dorsal margin, larger size and ventral ridge more straight and pronounced. This species resembles also to *Quadracythere brachypygaia* van den Bold, 1965 in the shape as in size, however, in dorsal view it differs to be more elongate and to present median more proeminent and sinuous ridges. Other difference is in the absence of larger, vertical and irregular ridges distributed sinuously in the anterior end, like in the species described here, and is smaller.

Occurrence: Aricuru (Maracanã bay), levels AR-01 to AR-06; B-17 quarry, Capanema, Pará (Levels B1A, B8, B9, B12, B11A, B11B and B13B); Ponta do Castelo, Fortaleza Island (Level PC-03); Primavera FPR-160 core (Levels: AM.08, AM.10, AM.12, AM.19 and AM.20).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Quadracythere limbilepida n. sp.

Plate 7.14, figs. 14, 15 and 19

Material: 3 carapaces and 11 valves.

Etimology: Latin: limbus= *limbi*; refer to the outline of the carapace; lepidus = *lepida*, *lepidum*; refer to the cardinal angles less pronounced turning this more subretangular than the others species of the genus.

Holotypes: MPEG-781-M, LV: L: 0.57 mm and H: 0.31 mm. MPEG-782-M, C; Dorsal: H: 0.56 mm and W: 0.32 mm. MPEG-783-M, C; RV: L: 0.55 mm and H: 0.31 mm; Dorsal: H: 0.55 mm and W: 0.33 mm.

Paratypes: MPEG-784-M, RV: L: 0.52 mm and H: 0.30 mm. MPEG-785-M, RV: L: 0.57 mm and H: 0.33 mm. MPEG-786-M, C; RV: L: 0.62 mm and H: 0.33 mm. MPEG-787-M, C; LV: L: 0.50 mm and H: 0.28 mm. MPEG-788-M, C; RV: L: 0.54 mm and H: 0.30 mm. MPEG-789-M, Female, RV: L: 0.55 mm and H: 0.32 mm. MPEG-790-M, LV: L: 0.57 mm and H: 0.32 mm.

Diagnosis: this species presents anterior margin narrower compared to the others species for this genus described herein; dorsal margin more straight with few promient cardinal angles and posterior margin bearing 4 or 5 flat, large and short spines.

Description: subquadrate carapace, highest about 1/3 of the carapace. Dorsal margin more straight with discret cardinal angles, especially in the LV, otherwise almost straight in the RV. Ventral margin almost straight, slightly concave in the anteromedian portion. Carapace with the dorsal margin of the RV almost parallel to the ventral margin. Anterior margin truncated and subrounded. Posterior margin very short, strongly straight above, subtruncate below and bearing 4 or 5 flat, large and short spines. Surface strongly reticulate, the rows of meshes generally parallel to the middle part, dorsal and ventral margins at the posterior 2/3 of the carapace. Both valves with about three faint ridges parallel to the anterior margin like in the *Q. brachypygaia*. Posterior end of dorsal margin obscured by a short ridge, which ends in the posterior region in a faint node, just in front of the posterior cardinal angle. Ventral ridge long, obscuring most of the ventral margin, less in the RV and ending in the middle posterior of the length. In dorsal view, carapace in general lens-shaped, but irregular in the anterior end because of the raised ridges and in the posterior end because of the projecting dorsal node. The ventral ridge projects only slightly. Greatest width in the middle region. Internal features typically for the genus.

Remarks: the species resembles much more to *Quadracythere brachypygaia* van den Bold, 1965 than *Quandracythere* sp. 1 described herein mainly in the arrangement of ridges, shape and size, however, it differs in dorsal view that is widest in the middle region; absence of thick, vertical ridges distributed sinuously in the anteroventral region and also of a concavity in the dorsal margin of posterior end; ornamentation pattern more delicate.

Occurrence: Aricuru (Maracanã bay), level AR-01; B-17 quarry, Capanema, Pará (Levels B1A-B2, B5, B6, B8, B9 B12-B13 and B13B); Primavera FPR-160 core (Levels: AM.10, AM.12 and AM.14).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Quadracythere robusta n. sp.

Plate 7.14, figs. 16-18 and 24

Material: 14 carapaces and 8 valves.

Etimology: Latin: robusta=*robustum, robustus*; refer to the well strong ornamentation and heavy appearance of the carapace.

Holotypes: MPEG-791-M, C; LV: L: 0.60 mm and H: 0.37 mm; RV: L: 0.58 mm and H: 0.35 mm. MPEG-792-M, C; LV: L: 0.62 mm and H: 0.42 mm; Dorsal: H: 0.61 mm and W: 0.41 mm.

Paratypes: MPEG-793-M, LV: L: 0.69 mm and H: 0.44 mm. MPEG-794-M, juvenile, C; LV: L: 0.53 mm and H: 0.35 mm; RV: L: 0.52 mm and H: 0.32 mm.

Diagnosis: robust and subquadrate carapace, highest at 1/3 of the carapace, in lateral view. Surface strongly reticulate,

Description: robust and subquadrate carapace, highest at anterior cardinal angle, in lateral view. Dorsal margin slightly depressed behind the anterior cardinal angle, especially in the LV, otherwise almost straight in the RV. Ventral margin almost straight in the middle part to the posteroventral end and slightly concave in the anteroventral end, turned below in both valves and . Anterior margin obliquely rounded. Posterior margin very short, angular below the middle, strongly straight above, subtruncate below with 3 large spines. Surface strongly reticulate, with the reticles generally distributed regularly in the middle, dorsal and ventral regions. Anterior region the row of reticles are a bit larger and following this region neatly. In the middle to the posterior end are a bit smaller again. Three parallel and faint ridges: one ridge ventrolaterally, one small ridge in the middle region and another strong ridge running to the dorsal margin. There are 2-3 ridges parallels to the anterior margin. In the mid-dorsal region, the dorsal margin is obscured by a diagonal and strong ridge, which extends from the median region to the mid-posterior end. Ventral ridge long, obscuring the ventral margin. In dorsal view, the shape is biconvex and in the mid-posterior region has a narrow portion. Greatest width in the middle region. Internal features were not observed.

Remarks: the species presents similarities to the *Quadracythere* species described herein, but it differs in some aspects as arrangement of the middle ridges presenting a diagonal and strong ridge toward the dorsal margin, dorsal margin slightly depressed, ventral margin almost straight in the middle part to the posteroventral end and slightly concave in the anteroventral end turned to below in both valves; it has exactly 3 large spines bearing the posterior end, the rows of meshes generally distributed regularly in the middle part, dorsal and ventral margins, and presence of one strong ridge from dorsal margin. Other difference is in the LV, which is similar to the LV of *Q. brachypygaia* described herein.

Occurrence: B-17 quarry, Capanema, Pará (Levels B11 and B12); Primavera FPR-160 core (Levels: AM.12, AM.17and AM.19).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Dameriacella* Liebau, 1991

Dameriacella? caudata n. sp.

Plate 7.14, figs. 9-13

Material: 114 carapaces and 3591valves.

Etimology: Latin: caudata=*caudatum, caudatus*; refer to the elongate caudal process.

Dimensions: MPEG-795-M, adult, LV: L: 0.62 mm and H: 0.39 mm. MPEG-796-M, juvenile, LV: L: 0.60 mm and H: 0.35 mm. MPEG-797-M, juvenile, RV: L: 0.56 mm and H: 0.32 mm; Dorsal: L: 0.54 mm and H: 0.30 mm.

Diagnosis: ventrally with a subtle alaform process followed by four concentric longitudinal ridges parallel to the ventral margin extending to the anterior margin; the upper ridge with a spine in the end, as in the posterodorsal ridge, blunted in the end like a “bat” face.

Description: medium, robust and subtriangular to subquadrate carapace, in lateral view. Dorsal margin almost straight and slopedownwards. Ventral margin slightly convex in both valves. Anterior margin broadly rounded. Posterior margin nearly truncate. Caudal process better developed in juveniles especimens. Surface pitted more in the median and porterodorsal region; ventrally with a subtle alaform process followed by four concentric longitudinal ridges parallel to the ventral margin extending to the anterior margin. The upper ventral rigde with a spine in the end as well as in the posterodorsal ridge blunted in the end, looking as a “bat” face. Eye tubercles lightly proeminent in the adult, more in the juveniles. Muscle scars pattern with four adductor muscle scars, 4 antennal scars in front and 2 mandibular scar below observed. Hinge with a median bar and sockets in the extremities of LV.

Remarks: this species resembles to juveniles of *Quadracythere brachypygaia* van den Bold, 1965, because of the anteroventral longitudinal ridges; however, the adults differs in the ornamentation pattern. This genus was classified by Liebau (1991a), who described it to the Europe (Meireles *et al.* 2012) belonging to the species group Typus Quadriformer, that are typical of rocky and phytal environments and are associated with algae typical of shallow waters and calm. This species also resembles to be a juvenile of *Pokornyella deformis* (Reuss) described herein.

Occurrence: Aricuru (Maracanã bay), levels AR-03 to AR-05; B-17 quarry, Capanema, Pará (Levels B11 and B12); Primavera FPR-160 core (Levels: AM.08).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Superfamily Trachyleberidoidea Liebau, 2005

Family Trachyleberididae Sylvester-Bradley, 1948

Genus *Carinocythereis* Ruggieri, 1956

Carinocythereis? sp.

Plate 7.15, figs. 5-7

Material: 16 carapaces and 1 valve.

Dimensions: MPEG-798-M, C; LV: L: 0.65 mm and H: 0.33 mm; RV: L: 0.67 mm and H: 0.33 mm.

Description: subrectangular to quadrate valve, in lateral view. Dorsal margin straight behind of the anterior cardinal angle and convex outlining this angle. Ventral margin slightly concave in the more anteroventral end to almost straight toward to posteroventral end; dorsal and ventral margins almost parallel. Anterior margin broadly rounded. Posterior margin truncate in the LV with dorsal slope in the RV. Surface strongly reticulate; arrangement of ridges follows the reticles, small dorsal ridge slightly arched behind the anterior cardinal angle, presence of 3 or 4 spines in the anterior margin; one spine in the posteroventral region. Low subcentral tubercle. Internal view: inner lamell narrow; deep pore canals. Hinge holamphidont tending to hemiamphidont (posterior tooth variable).

Remarks: the species is similar in some aspects to the *Carinocythereis* genus as in shape and ornamentation reticulated, but differs in absence of three longituginal carinae, anterior and ventral marginal carinate, and area between the carinae smooth or with scattered small tubercles or spines, eye tubercle, hinge and muscle scars different.

Occurrence: Aricuru (Maracanã bay), level AR-06; Ponta do Castelo, Fortaleza Island (Levels PC-00, PC-01, PC-02 and PC-04).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Costa* Neviani, 1928

Costa variabilocostata subs. *variabilocostata* (Bold, 1950) van den Bold, 1957

Plate 7.14, figs. 20-23, 25 and 26

1950. *Cythereis variabilocostata* van den Bold, p. 83, pl. 18, fig. 3a-b.

1994c. Not *Costa variabilocostata* (Bold, 1968), Távora, p. 128, figs. 10, 11.

Material: 17 carapaces and 48 valves.

Dimensions: MPEG-799-M, Female, C; LV: L: 0.53 mm and H: 0.28 mm; Dorsal: L: 0.56 mm and W: 0.22 mm. MPEG-800-M, Female, C, RV: L: 0.64 mm and H: 0.31 mm. MPEG-801-M, Male?, C; LV: L: 0.52 mm and H: 0.27 mm; RV: L: 0.54 mm and H: 0.28 mm. MPEG-802-M, C, Dorsal: H: 0.68 mm and W: 0.30 mm. MPEG-803-M, C, RV: L: 0.47 mm and H: 0.23 mm; Dorsal: H: 0.57 mm and W: 0.27 mm. MPEG-804-M, C, RV: L: 0.63 mm and H: 0.29 mm.

Remarks: the species group *Costa variabilocostata* (Bold) was erroniouslly recorded in the Pirabas Formation by Távora (1994c, p. 128, fig. 10, 11), which is the same species recorded in this paper as *Cativella navis*? (pl. 15, figs. 8-11). Furthermore, this species is very similar to the type species *Costa variabilocostata* subs. *variabilocostata* van den Bold, 1970a (HVHNo. 7935) mainly in the ornamentation pattern and shape, differing only in larger size.

Occurrence: Aricuru (Maracanã bay), levels AR-01, AR-03 and AR-05; B-17 quarry, Capanema, Pará (Levels B1A, B1, and B12); Primavera FPR-160 core (Levels: AM.08, AM.12, AM.13 and AM.17).

Distribution: Brasso, Cipero, Talparo and Springvale formations; seas around Trinidad. Lower Miocene, Pirabas Formation, Pará, Brazil.

Costa petrii n. sp.

Plate 7.15, figs. 1-4

1994b. *Neocaudites* cf. *N. triplistriatus* (Edwards, 1944) Távora, p.130, fig.12.

Material: 7 carapaces and 5 valves.

Etimology: in honor to Dr. Setembrino Petri, a Brazilian micropaleontologist pioneer in the studies of Pirabas Formation.

Holotype: MPEG-805-M, C; LV: L: 0.67 mm and H: 0.35 mm; RV: L: 0.62 mm and H: 0.29 mm; Dorsal view: L: 0.68 mm and H: 0.30 mm.

Paratypes: MPEG-806-M, C; RV: RV: L: 0.64 mm and H: 0.31 mm. MPEG-807-M, RV: length 0.62 mm and height 0.29 mm.

Diagnosis: a more delicate species of *Costa* with a strong and evident, shorter and curve dorsal ridge; strongly reticulate in the anteromedian region.

Description: medium and subtriangular carapace, highest at about 1/3 of the carapace. Dorsal margin sinuous, convex in the middle and with two concavity before the extremities. Ventral margin nearly straight with a small concavity posterior. Anterior margin broadly and somewhat obliquely rounded, very coarsely denticulate in the anteroventral margin. Posterior margin strongly compressed laterally, triangular in side view, slightly convex above of the middle, concave and with four rather large spines below. Surface strongly reticulate and ornamented with three longitudinal ridges; anterior rim parallel to the margin. Transversal ridges projected coarse marginal rim surrounding all carapace. Ventral ridge with a discret spine in the end. Median rigde diverging in two short ridge in the anteromedian region as a down “v” shape. Dorsal ridge convex and diverging in the anterior end and running in the posterior end. Internal features were not observed.

Remarks: The species is similar in the main external features given to the genus like arrangement of median and ventral ridges. It resembles to *Costa variabilocostata* subs. *variabilocostata* (Bold, 1950) van den Bold, 1957 described herein compared to arrangement of its ridges and in size, however this species is longer and lower and has more delicate ornamentation. Moreover, the species here identified for the *Costa* genus was erroneouslly assigned to *Neocaudites* cf. *N. triplistriatus* (Edwards, 1944) by Távora (1994). The genus *Costa* differs of the *Neocaudites* externally mainly in the rigdes distribution patterns which the last genus these normally has a median X shape because the presence of a dorso anterior oblique rigde absent in the *Costa*.

Occurrence: B-17 quarry, Capanema, Pará (Level B11).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Cativella* Coryell & Fields, 1937

Cativella aff. *C. navis* Coryell and Fields, 1937

Plate 7.15, figs. 8-11

1937. *Cativella navis* Coryell and Fields, p. 4, fig. 9a.

1994c. Grupo *Costa variabilocostata* (Bold, 1968), Távora, p. 128, fig. 11

Material: 5 carapaces and 16 valves.

Dimensions: MPEG-808-M, C, Female, LV: L: 0.64 mm and H: 0.33 mm; RV: L: 0.55 mm and H: 0.27 mm. MPEG-809-M, Female, RV: L: 0.62 mm and H: 0.28 mm; Dorsal: H: 0.57 mm and W: 0.22 mm. MPEG-810-M, Female, LV: L: 0.49 mm and H: 0.25 mm. MPEG-811-M, C, LV: L: 0.64 mm and H: 0.29 mm. Dorsal: H: 0.65 mm and W: 0.28 mm.

Description: medium-sized and subrectangular carapace, in lateral view. Highest anteriorly at the 1/4 of carapace. Dorsal margin straight behind of the anterior cardinal angle in LV; and more arched in RV, projecting dorsal ridge. Ventral margin almost straight, slightly sinuous in the RV. Anterior margin broadly rounded, with 11-13 sharp-pointing denticles which are concentrated subventrally. Posterior margin acutely extended ventrally pointing and with 6 coarse marginal spines. Dorsal view subelongate, widest anterior to median. Surface reticulate with most strong arched dorsomarginal ridge which extends from the anteromedian region running along the dorsal margin to the posteromedian region. A strong anteromarginal ridge extending parallel to the margin till the posteroventral region; evident and remarkable median ridge; a numer of about 8 transversal short ridges, above and below and connected with the median ridge. Posteroventral a double row of about five heavy and short spines, truncated in the extremity. Intercostal areas are, especially in dorsal, median and ventral areas, covered by short tubercles.

Remarks: The present species is very similar to *Cativella navis* Coryell and Fields, 1937 mainly in the size and shape; however, this last one differs for presenting a continuation in the anterodorsal portion of the dorsal ridge presented such as in the type species (HVH8238). Moreover, the species described herein differs mainly in absence of linkings in the dorsal ridge along the anterodorsal part. In *Cativella navis* the dorsal margin is more curved and turned downwards to the ventral margin. The species presented here is the same recorded by Távora (1994c) as Grupo *Costa variabilocostata* (Bold, 1968) to Pirabas Formation. However the studied specimens have diagnostic characteristics of *Cativella* which differs from *Costa* mainly because the ridges that are more evident then in the last genus and in the median rigde that extends from the antero to posterior region and in the absence of branch ridge in the anteromedian longitudinal region, typical in *Costa*. It is closest to *Cativella iyemojai* Omasola, 1972, that actually is accepted as *Chrysocythere iyemojai* (Omatsola, 1972) Dingle, 1993 which also has not continuation in the anterodorsal portion of the dorsal ridge as the species described herein, as well as in the *Cativella reticulocostata* Coimbra *et al.* 2004.

Occurrence: Aricuru (Maracanã bay), levels AR-01, AR-04 and AR-05; B-17 quarry, Capanema, Pará (Levels B1, B7, B12, B11A, B13 and B13B); Primavera FPR-160 core (Levels: AM.17).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil. Middle Miocene to Recent: Caribbean, Gulf Coast; Occurs in Gurabo and Mao Formations, Dominican Republic. Middle Miocene form Panama, Gatun Formation.

Cativella aff. *C. moriahensis* van den Bold, 1960

Plate 7.15, figs. 14, 15 and 17

1957. ?*Cativella* sp. cf. *semitranslucens* (Crouch). van den Bold, p. 243, pl. 2, fig. 6.
1958. Not *Cativella* aff. *semitranslucens* (Crouch). van den Bold, p. 404, pl. 3, fig. 3.
1960. *Cativella moriahensis* van den Bold, p. 167, pl. 4, fig. 8; pl. 8, fig. 5.

Material: 6 carapaces and 17 valves.

Dimensions: MPEG-812-M, LV: L: 0.56 mm and H: 0.30 mm. MPEG-813-M, C; LV: L: 0.58 mm and H: 0.32 mm; RV: L: 0.58 mm and H: 0.29 mm; Dorsal: H: 0.58 mm and W: 0.24 mm. MPEG-814-M, C; RV: L: 0.58 mm and H: 0.29 mm. MPEG-815-M, LV: L: 0.58 mm and H: 0.29 mm.

Description: subelongate to subtriangular carapace, highest about 1/3 of carapace. Dorsal margin curved converging posteriorly towards the ventral margin, but obscured by the dorsal ridge, mainly in the LV. Ventral margin is nearly straight, with a slight concavity anterior to the middle. Anterior margin obliquely rounded, bearing 5-8 large spines. Posterior margin laterally compressed, angular and acute in the middle with a double row of elongated spines. Ornamentation consists of very high, longitudinal crests and more smooth between the ventral and median crests. Between median and dorsal crests has some irregular elevations connecting these crests. Very high anterior ridge, projecting to outside of the carapace; very obliquely curved extending from anterodorsal region at 1/3 of the carapace to the posteroventral at 3/3 of the carapace, obscuring it as far as the posterior end. A thin, slightly alate ventral ridge, running obliquely down from just behind or above the anterior ridge, towards the ventral margin; curves upward near its posterior end. A long median ridge extends from near the anterior ridge. It is slightly convex upward. A dorsal ridge starts in the middle region and extends to the posterodorsal region almost straight, obscuring the dorsal margin completely. Between the ridges, the valves exhibit a smooth pattern, standing only between the median and dorsal ridges a lightly longitudinal crest. Locally small tubercles are raised between the ridges. Dorsal view subelongate. Marginal area broad in anterior end, slightly less in posterior. Internal view typical for the genus.

Remarks: the species is closest to *Cativella moriahensis* van den Bold, 1960 in many features mainly in the distribution of the ridges, outline of carapace and some internal features; however it differs in size, quantity and distribution of spines from posterior and anterior ends; absence of reticulations in ornamentation; ventral ridge do not has a strong spine in the end; median ridge do not extends till inside the posterior triangle and lesser size of carapace. Moreover, the species also presents similarities to ?*Cativella* sp. cf. *semitranslucens* van den Bold, 1957, but differs mainly in the anterior ridge continuous with the dorsal one. This characteristic also differs of *Cativella navis* Coryell and Fields, 1937; however, this species has an ornamentation pattern closest of the species herein described.

Occurrence: Aricuru (Maracanã bay), level AR-05; B-17 quarry, Capanema, Pará (Levels B1A, B1 and B12); Primavera FPR-160 core (Levels: AM.08, AM.13, AM.17 and AM.19).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cativella longispina n. sp.

Plate 7.15, figs. 12, 13 and 16

Material: 4 carapaces and 12 valves.

Etimology: Latin: Longi=*longa, longus, longium*; refer to the longer spine in the postero-ventral region; *spina*= spinae; refer to the longer spine.

Dimensions: MPEG-816-M, C; LV: L: 0.59 mm and H: 0.32 mm; RV: L: 0.60 mm and H: 0.31 mm; Dorsal: H: 0.60 mm and W: 0.36 mm.

Diagnosis: Species with very elongated and coarse ventrolateral spines projected to out of the carapace. The three rigdes are finer than the others *Cativella* with a large reticule between them.

Description: subovate to subtriangular carapace, highest about 1/3 of the carapace. Dorsal margin obscured by the convex dorsal ridge. Ventral margin slightly convex. Anterior margin obliquely rounded, with 0 or 11 long spines. Posterior margin laterally compressed, almost truncate and bearing three long and thick spines. Ornamentation consists of lower longitudinal crests and reticulated mainly in the median region. The ridges of the reticulation support the crests and the shell of the crests between ridges is very thin and in cases even perforated. Anterior ridge, very obliquely curved, more strongly than the anterior margin, but it is not delineating the anterior margin, and it is continuing dorsally a short distance beyond the eye-tubercle, and ventrally parallel to the ventral margin, obscuring it as far as the posterior end. A thin, slightly alate ventral ridge, running obliquely down from just behind the anterior ridge towards the ventral margin, curves upward near its posterior end and terminates in a strong and long spine projected to out of the carapace. A long median ridge extends from near the anterior ridge. It is slightly convex upward. A dorsal ridge starts from just behind the eye-tubercle and is convex upward, obscuring the dorsal margin completely and joining it in front of the posterior cardinal angle. Between the ridges, the valves exhibit a reticulate pattern, standing at right angles to the longitudinal crests. Depressed area just behind the marginal ridges. Tubercles not observed between the ridges. Dorsal view subelongate and more convex in the middle presenting the pronounced and long spine in the termination of the ventral ridges in both valves. Internal features were not observed.

Remarks: the species is similar to *Cativella moriahensis* van den Bold, 1960 mainly in the ornamentation pattern and shape, but it differs in the size of some spines and carapace, especially the spine of ventral ridge, besides of anterior ridge which is not delineating the anterior margin.

Occurrence: Aricuru (Maracanã bay), levels AR-02 to AR-05; B-17 quarry, Capanema, Pará (Levels B1 and B12); Primavera FPR-160 core (Levels: AM.08, AM.12, AM.13 and AM.17).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Cativella sp.

Plate 7.15, figs. 18 and 19

Material: 1 valve.

Dimensions: MPEG-817-M, C; LV: L: 0.63 mm and H: 0.30 mm.

Description: subtriangular valve, highest about 1/3 of the carapace. Dorsal margin nearly straight. Ventral margin sligtly convex. Anterior margin obliquely rounded, bearing 10 or 11 long and turned down spines. Posterior margin laterally compressed, angular in or slightly below the middle, concave above, convex with two long and thick spines. Surface strongly ornamented by an arrangement of three longitudinal ridges with crests perforated and one thick, short and posterior spine in the ventrolateral ridge. Anterior ridge, very flatted, more strongly than the anterior margin continuing dorsally a short distance beyond the eye-tubercle, and ventrally parallel to the ventral margin. Short tubercles between the ridges. A thin, slightly alate ventral ridge, running obliquely down from just behind the anterior ridge towards the ventral margin, curves upward near its posterior end and terminates in a strong and thick spine. A long and oblique median ridge extends from near the anterior ridge to the median region of the carapace. Anterior rim extends from the anterodorsal to the posteroventral region. Surface ornamented mainly by tubercles than reticulated. A weak reticule in the posteroventral region. Locally small tubercles are raised between the ridges. Eye tubercle present. Internal features were not observed. Only one specimen of this species have been found, which is considered insufficient material for the establishment of a new species.

Remarks: the species is very similar to *Cativella* species described herein mainly in the size and outline shape, but it differs in the presence of longer anterior spines, and in the rigdes pattern that is much less evident and finer in this species.

Occurrence: Aricuru (Maracanã bay), level AR-05.

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Henryhowella* Puri, 1957

Henryhowella sp.

Plate 7.13, fig. 29

Material: 3 valves.

Dimensions: MPEG-818-M, RV: L: 0.52 mm and H: 0.35 mm.

Description: medium and subrectangular carapace, in lateral view. Dorsal margin straight and arched in the anterior cardinal angle. Ventral margin concave-convex, slightly concave in the middle part and convex upward posteroventrally. Anterior margin broadly rounded. Posterior margin triangular in side view. Indistinctly plicate, with well-developed eye tubercle. Valve surface covered by strong conjunctive, tubercle like spines and between these have like-reticles rounded. Short spines extend along the free margin. Internal features were not observed.

Remarks: the ornamentation of this specimen is characteristic from other representatives of the genus *Henryhowella*. Three specimens of this species have been found which is considered insufficient material for the establishment of a new species.

Occurrence: B-17 quarry, Capanema, Pará (Level B11B); Primavera FPR-160 core (Level AM.17).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

Infraorder Archaeocytherinina Liebau, 1991

Superfamily Xestoleberidoidea Liebau, 2005

Family Xestoleberididae Sars, 1928

Genus *Pontoleberis* Huang, 1975

Pontoleberis dactylotypa (Bold, 1946) van den Bold, 1970b

Plate 7.15, figs. 20-23

1946. *Xestoleberis dactylotypa* van den Bold, p. 119, pl. 16, fig. 16a-d.

1965. *Xestoleberis dactylotypa* van den Bold, p. 403-404, pl. 2, figs. 5a-5b.

Material: 218 carapaces and 564 valves.

Dimensions: MPEG-819-M, C; LV: L: 0.43 mm and H: 0.27 mm; RV: L: 0.41 mm and H: 0.25 mm; Dorsal: H: 0.45 mm and W: 0.28 mm. MPEG-820-M, RV: L: 0.46 mm and H: 0.26 mm. MPEG-821-M, LV: L: 0.48 mm and H: 0.30 mm.

Remarks: The present species is the same type species of Bold (1946) which later (1970b) change the genus to *Pontoleberis*; it is mainly similar in outline of carapace in side view and dorsal view.

Occurrence: Aricuru (Maracanã bay), levels AR-01-AR-06; B-17 quarry, Capanema (Levels B0, B1A, B1, B2, B7, B11, B12, B11A, B11B and B13); Ponta do Castelo, Fortaleza Island (Levels PC-00, PC-02 and PC-03); Primavera FPR-160 core (Levels: AM.8a, AM.08, AM.10, AM.12, AM.15 and AM.17).

Distribution: Found at many other localities in Cuba and at one locality in Guatemala from Lower Miocene. Upper Cibao Formation. In Cuba it occurs in the Guines Formation, while in Trinidad it has been found only in the Morne Diablo Quarry. Upper Oligocene to Lower Miocene, Pirabas Formation, Pará, Brazil.

Genus *Xestoleberis* Sars, 1866

Xestoleberis quasipila n. sp.

Plate 7.15, figs. 24-27

Material: 12 carapaces and 11 valves.

Etimology: Latin: quase = *quasi*, refer to the outline almost rounded; *pila* = *pilae*, refer to the outline of carapace subrounded.

Holotypes: MPEG-822-M, C; LV: L: 0.45 mm and H: 0.30 mm; RV: L: 0.44 mm and H: 0.29 mm; Dorsal: H: 0.44 mm and W: 0.28 mm.

Paratypes: MPEG-823-M, C; LV: L: 0.43 mm and H: 0.27 mm; RV: L: 0.41 mm and H: 0.25 mm. MPEG-824-M, LV: L: 0.46 mm and H: 0.26 mm. MPEG-825-M, RV: L: 0.43 mm and H: 0.28 mm.

Diagnosis: the remarkable features this species are the ovate and robust carapace, highest just behind the middle and surface smooth.

Description: medium and ovate carapace, highest just behind the middle. Dorsal margin strongly convex. Ventral margin only slightly sinuate in front of the middle. Anterior margin obliquely rounded and angular, continuing into the arched dorsal margin. Posterior margin broadly rounded. In dorsal view, ovate carapace, widest at 3/5 of the length from the anterior margin. Surface smooth. Normal pore canals moderate and open distributed regularly. Dorsal view as a “tear-drop”, however, more short in the anterior end and oval in the posterior end. Internal view: Hinge merodont, with elongate crenulate terminal cusps in RV, separated by straight, weakly crenulate furrow, a few crenulations on each end, engaging with crenulated anterior and posterior sockets in the LV. Marginal areas of moderate width anteriorly above the ventral margin with a vestibule, rather narrow and nearly equal in width all around the posterior end. Adductor scars in vertical row of 4, with arrowhead-shaped antennal scar in front and 2 mandibular scars below in front, crescent-shaped scar above this group in eye region.

Remarks: the species is similar to *Xestoleberis* sp. van den Bold, 1965 and *Xestoleberis tunisiensis* Esker, 1968 in shape, surface smooth, dorsal view and internal features, but it differs in size of *Xestoleberis* sp. van den Bold, 1965, because it is smaller. *Xestoleberis tunisiensis* Esker, 1968 is closest in the size of carapace, internal features as marginal areas, normal pore canals and hinge. *Xestoleberis* cf. *X. sagamiensis* Kajiyama, 1913 (p. 436, pl. 2, figs. 6, 7) present basically the same outline, but it has a small proeminent portion in the middle of anterior margin.

Occurrence: Aricuru (Maracanã bay), levels AR-02 to AR-05; Ponta do Castelo, Fortaleza Island (Level PC-00).

Distribution: Lower Miocene, Pirabas Formation, Pará, Brazil.

7.5. CONCLUSIONS

A total of 119 species were identified and illustrated from five sections (one from a core) from Pirabas Formation, Pará state, Northeastern Brazil; from these 27 were already recorded to Caribbean region. The occurrence of these species support the similarity between the Pirabas Formation and others Neogene units from Caribe, mainly Trinidad and Puerto Rico. This wide database provided a support of the paleoecologic, biostratigraphic and paleobiogeographic studies on Ostracoda of the Neogene of South America. Although this study present many open nomenclature species, it still had a significant number of species recorded and described as new to the science providing new *insights* for correlation with related units and to understand the geological and paleoceanographical events, the paleobiological evolution and radiation of ostracods.

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PLATES

7.1-7.15

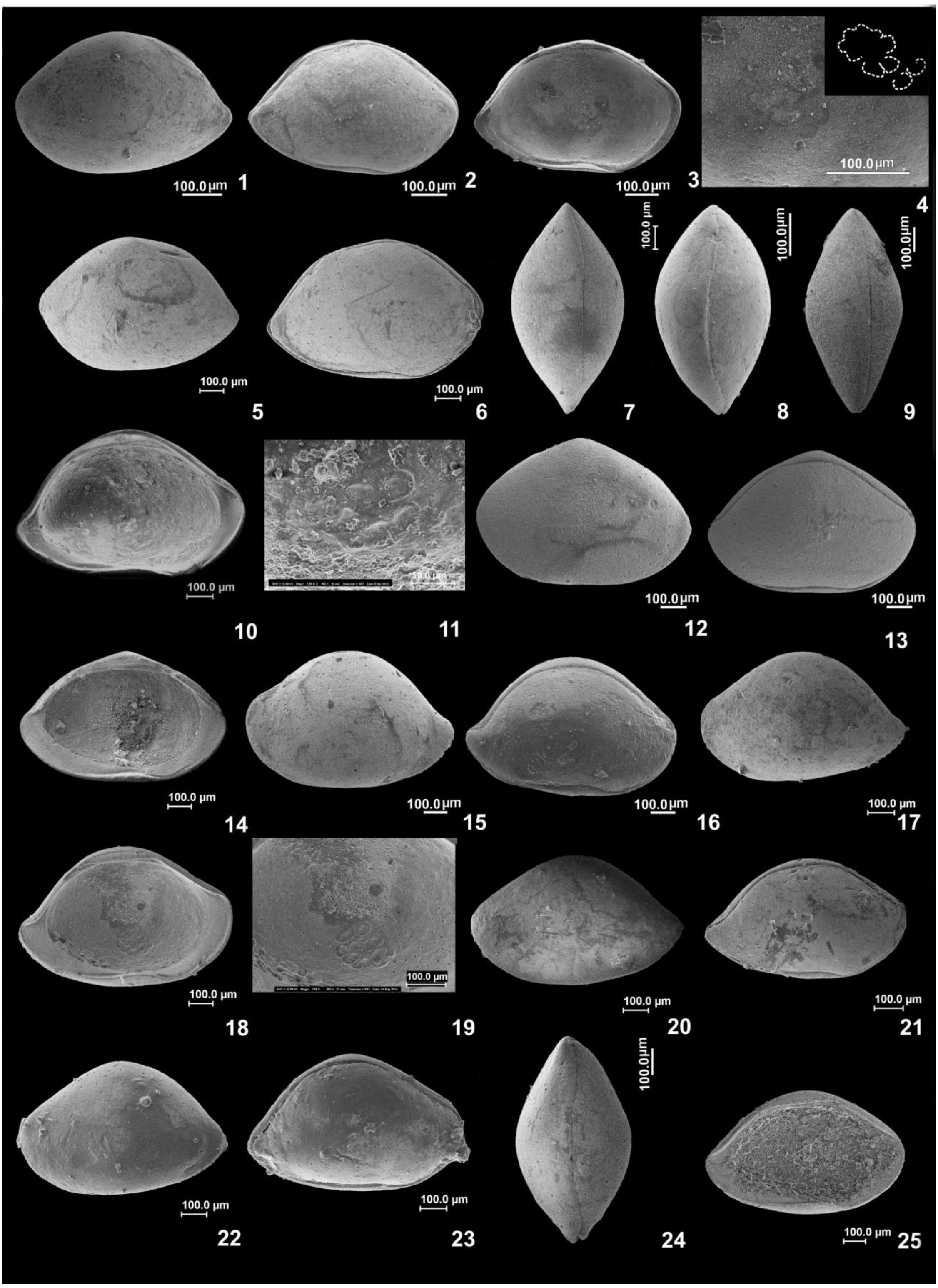

Plate 7.1. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-8; 10-11.** ***Bairdoppilata pintoi*** **n. sp.**: **Fig. 1.** Juvenile, C, LV, external view, MPEG-558-M, **Fig. 2.** Juvenile, C, RV, external view, MPEG-558-M, **Fig. 3.** Internal view, LV, MPEG-558-M. **Fig. 4.** Detail of the muscle scars, RV, MPEG-558-M. **Fig. 5.** Adult, C, LV, external view, MPEG-556-M. **Fig. 6.** Adult, C, RV, external view, MPEG-556-M, **Fig. 7.** Adult, Dorsal view, MPEG-556-M. **Fig. 8.** Juvenile, Dorsal view, MPEG-558-M. **Fig. 10.** Internal view, LV, MPEG-557-M. **Fig. 11.** Details of muscle scars, LV, MPEG-557-M; **Figs. 9, 12-14.** ***Bairdoppilata dorsoarcuata*** **n. sp.**: **Fig. 9.** Dorsal view, MPEG-560-M. **Fig. 12.** C, LV, external view, MPEG-560-M. **Fig. 13.** C, RV, external view, MPEG-560-M. **Fig. 14.** Internal view, LV, MPEG-561-M. **Figs. 15-19.** ***Bairdoppilata antillea*****. Fig. 15.** C, LV, external view, MPEG-550-M. **Fig. 16.** C, RV, external view, MPEG-550-M. **Fig. 17.** LV, external view, MPEG-551-M. **Fig. 18.** Internal view, LV, MPEG-552-M. **Fig. 19.** Detail of the muscle scars, RV, MPEG-552-M. **Figs. 20, 21, 25.** ***Bairdoppilata oblongata*****. Fig. 20**. C, LV, external view, MPEG-553-M. **Fig. 21**. C, RV, external view, MPEG-553-M. **Fig. 25.** Internal view, LV, MPEG-555-M. **Figs. 22-24**. ***Bairdoppilata depressa*** **n. sp. Fig. 22.** LV, external view, MPEG-562-M. **Fig. 23.** RV, external view, MPEG-562-M. **Fig. 24.** Dorsal view, MPEG-562-M.

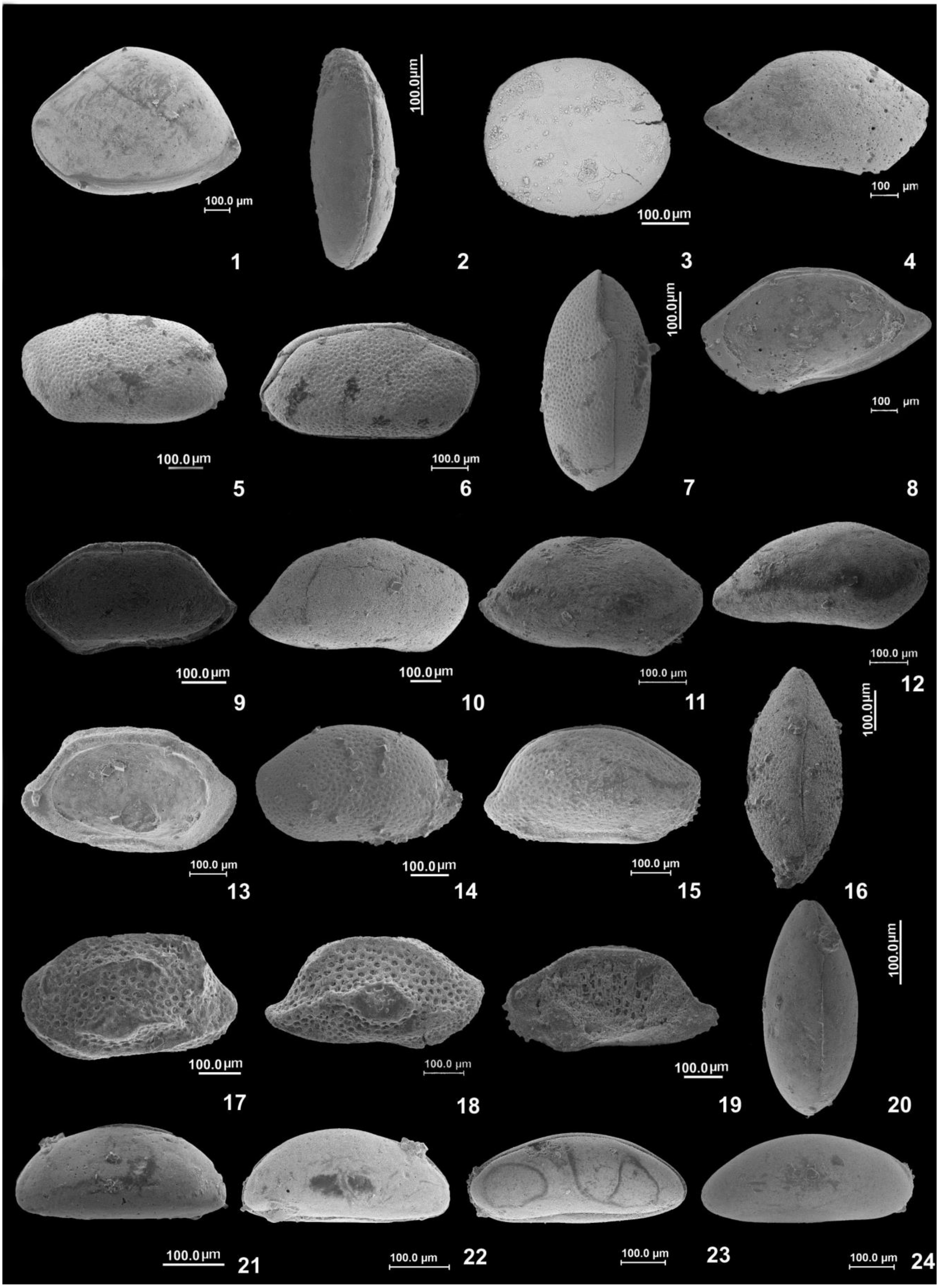
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Plate 7.2. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Fig. 1.** ***Bairdoppilata*** **sp.**: **Fig. 1.** C, LV, external view, MPEG-564-M, **Figs. 2-3.** ***Polycope*** **sp.**: **Fig. 2.** Dorsal view, MPEG-549-M. **Fig. 3.** C, external view, MPEG-549-M. **Figs. 4, 8.** ***Neonesidea*** **sp. 1. Fig. 4.** RV, external view, MPEG-566-M. **Fig. 8.** Internal view, RV, MPEG-566-M. **Figs. 5-7.** ***Mydianobairdia punctata*** **n. sp. Fig. 5.** C, LV, external view, MPEG-565-M. **Fig. 6.** C, RV, external view, MPEG-565-M. **Figs. 7.** C, Dorsal view, MPEG-565-M. **Figs. 9-11.** ***Neonesidea*** **sp. 3. Fig. 9.** Juvenile, Internal view, RV, MPEG-570-M, **Fig. 10.** Adult, RV, external view, MPEG-571-M, **Fig. 11.** Juvenile, RV, external view, MPEG-570-M. **Fig. 12.** ***Neonesidea*** **sp. 2. Fig. 12.** RV, external view, MPEG-569-M. **Figs. 14-16**. ***Paranesidea elegantissima.*** **Fig. 14.** LV, external view, MPEG-573-M. **Fig. 15.** RV, external view, MPEG-573-M. **Fig. 16.** Dorsal view, MPEG-573-M. **Figs. 13, 17-19**. ***Glyptobairdia crumena*****. Fig. 13.** Internal view, LV, MPEG-577-M. **Fig. 17**. LV, external view, MPEG-577-M. **Fig. 18.** RV, external view, MPEG-577-M. **Fig. 19.** Internal view, RV, MPEG-577-M. **Figs. 20-22**. ***Argilloecia*****? sp. 1. Fig. 20.** Dorsal view, MPEG-579-M. **Fig. 21.** LV, external view, MPEG-579-M. **Fig. 22.** RV, external view, MPEG-579-M. **Figs. 23-24**. ***Argilloecia*** **sp. 2. Fig. 23.** LV, external view, MPEG-580-M. **Fig. 24.** RV, external view, MPEG-580-M.

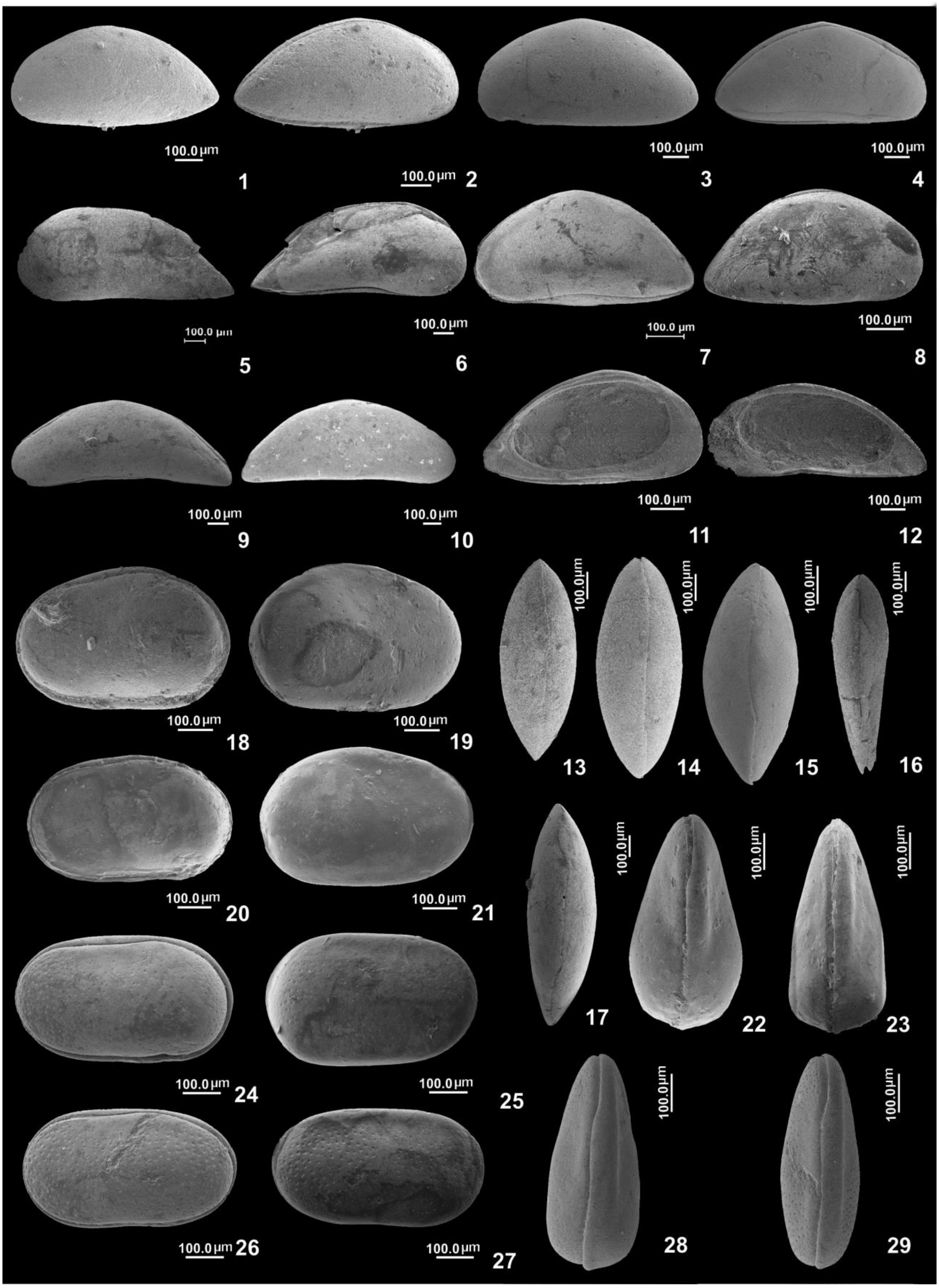
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Plate 7.3. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-2, 13.** ***Pontocypris*** **aff.** ***P.*** **ex. grp.** ***dreikanter*****. Fig. 1.** C, LV, external view, MPEG-581-M. **Fig. 2.** C, RV, external view, MPEG-581-M. **Fig. 13.** Dorsal view, MPEG-581-M. **Figs. 3-4, 14.** ***Pontocypris*** **sp. Fig. 3.** C, LV, external view, MPEG-583-M. **Fig. 4.** C, RV, external view, MPEG-583-M. **Fig. 14.** Dorsal view, MPEG-583-M. **Figs. 5-6, 16.** ***Paracypris*** **sp. Fig. 5.** C, LV, external view, MPEG-586-M. **Fig. 6.** C, RV, external view, MPEG-586-M. **Fig. 16.** Dorsal view, MPEG-586-M. **Figs. 7-8, 11, 15.** ***Propontocypris*** **cf.** ***Macrocypris*****?** ***dimorpha.*** **Fig. 7.** C, LV, external view, MPEG-584-M. **Fig. 8.** C, RV, external view, MPEG-584-M. **Fig.11.** Internal view, LV, MPEG-585-M. **Fig. 15.** Dorsal view, MPEG-584-M. **Figs. 9-10, 12, 17**. ***Macrocypris gracilis.*** **Fig. 9.** C, LV, external view, MPEG-587-M. **Fig. 10. C,** RV, external view, MPEG-587-M. **Fig. 12.** Internal view, RV, MPEG-588-M. **Fig. 17.** Dorsal view, MPEG-587-M. **Figs. 18-23**. ***Cytherella pseudopolita*** **n. sp. Fig. 18.** Female, C, LV, external view, MPEG-592-M. **Fig. 19**. Female**,** C, RV, external view, MPEG-592-M. **Fig. 20.** Male, C, LV, external view, MPEG-593-M. **Fig. 21.** Male**,** C, RV, external view, MPEG-593-M. **Fig.22**. Female, Dorsal view, MPEG-592-M. **Fig. 23.** Male, Dorsal view, MPEG-593-M. **Figs. 24-25, 28**. ***Cytherella altacaelateralis*** **n. sp. Fig. 24.** Female, C, LV, external view, MPEG-594-M. **Fig. 25.** Female, C, RV, external view, MPEG-594-M. **Fig. 25.** Dorsal view, Female, MPEG-594-M. **Fig. 26.** Male, C, LV, external view, MPEG-595-M. **Fig. 27.** Male, RV, external view, MPEG-595-M. **Fig. 27.** Dorsal view, Male, MPEG-595-M.

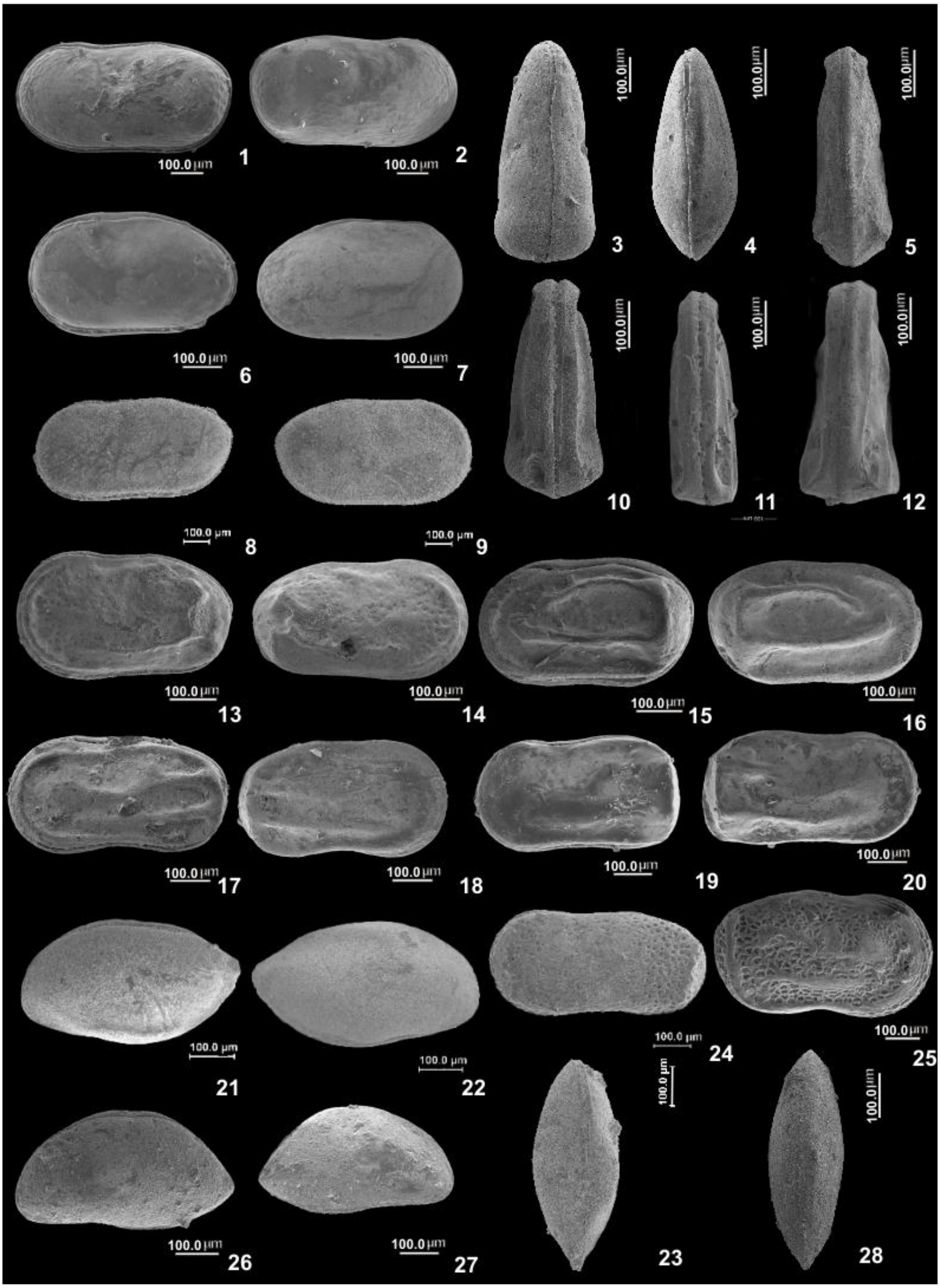
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Plate 7.4. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-3. *Cytherella* aff. *C. circumrugosa*. Fig. 1.** C, LV, external view, MPEG-597-M. **Fig. 2.** C, RV, external view, MPEG-597-M. **Fig. 3.** Dorsal view, MPEG-597-M. **Figs. 4, 6-9. *Cytherella stainforthi.* Fig. 4.** Female, Dorsal view, MPEG-589-M. **Fig. 6.** Female, C, LV, external view, MPEG-589-M. **Fig. 7.** Female, C, RV, external view, MPEG-589-M. **Fig. 8.** Male, C, LV, external view, MPEG-590-M. **Fig. 9.** Male, C, RV, external view, MPEG-590-M. **Figs. 5, 1 3-14. *Cytherelloidea colini* n. sp. Fig. 5.** Dorsal view, MPEG-598-M. **Fig. 13.** C, LV, external view, MPEG-598-M. **Fig. 16.** C, RV, external view, MPEG-598-M. **Figs. 10, 15-16. *Cytherelloidea circinorobusta* n. sp. Fig. 10.** Dorsal view, MPEG-602-M. **Fig. 15.** C, LV, external view, MPEG-602-M. **Fig.16.** C, RV, external view, MPEG-602-M. **Figs. 11, 17-18**. ***Cytherelloidea mediacythara* n. sp. Fig. 11.** Dorsal view, MPEG-603-M. **Fig. 17.** C, LV, external view, MPEG-603-M. **Fig. 18.** C, RV, external view, MPEG-603-M. **Figs. 12, 19-20**. ***Cytherelloidea quasilisa* n. sp. Fig. 12.** Dorsal view, MPEG-604-M. . **Fig. 19**. C, LV, external view, MPEG-604-M **Fig. 20.** C, RV, external view, MPEG-604-M. **Figs. 21-23**. ***Pellucistoma magniventra.* Fig. 21.** C, LV, external view, MPEG-609-M. **Fig. 22.** C, RV, external view, MPEG-609-M. **Fig. 23.** Dorsal view, MPEG-609-M. **Figs. 24**. ***Cytherelloidea* cf. *vanveenae.* Fig. 24.** LV, external view, MPEG-606-M. **Figs. 25**. ***Keijcyoidea* sp. Fig. 25.** RV, external view, MPEG-608-M. **Figs. 26-28**. ***Pellucistoma* aff. *P.? kingmai.* Fig. 26.** C, LV, external view, MPEG-610-M. **Fig. 27.** C, RV, external view, MPEG-610-M. **Fig. 28.** Dorsal view, MPEG-610-M.

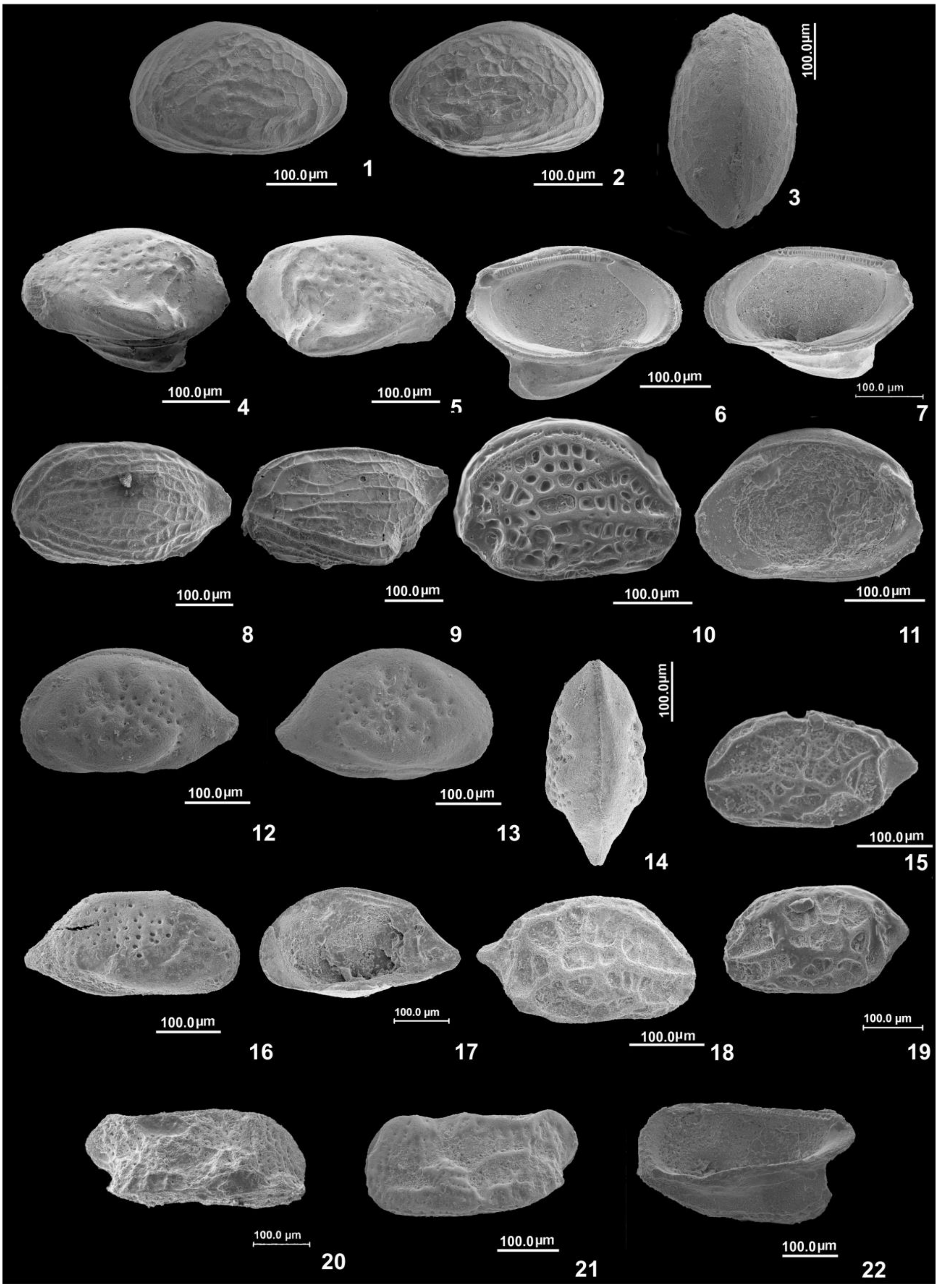
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Plate 7.5. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-3. *Cytheropteron? yorktowensis*. Fig. 1.** C, LV, external view, MPEG-611-M. **Fig. 2. C,** RV, external view, MPEG-611-M. **Fig. 3.** Dorsal view, MPEG-611-M. **Figs. 4-7. *Cytheropteron bichense*. Fig. 4.** C, LV, external view, MPEG-613-M.**Fig. 5.** C, RV, external view, MPEG-613-M. **Fig. 6.** Internal view, LV, MPEG-613- M. **Fig. 7.** Internal view, RV, MPEG-613-M. **Fig. 8. *Cytherura* sp. 1 Fig. 8.** LV, external view, MPEG-614-M. **Fig. 9. *Cytherura* sp. 2 Fig. 9.** LV, external view, MPEG-615-M. **Figs. 10-11. *Hemicytherura* sp. Fig. 10. R**V, external view, MPEG-629-M. **Fig. 11.** Internal view, RV, MPEG-629-M. **Figs. 12-14, 16, 17. *Cytherura punctocentrata* n. sp. Fig. 12.** Female, C, LV, external view, MPEG-616-M. **Fig. 13.** Female, C**,** RV, external view, MPEG-616-M. **Fig. 14.** Dorsal view, MPEG-616-M. **Fig. 16.** Male, C**,** RV, external view, MPEG-617-M. **Fig. 17**. Internal view, RV, MPEG-618-M. **Figs. 15, 18-19**. ***Hemicytherura bradyisimilis* n. sp. Fig. 15.** Male, LV, external view, MPEG-628-M. **Fig. 18.** Female, RV, external view, MPEG-627-M. **Fig. 19.** Female, LV, external view, MPEG-626-M. **Figs. 20-22**. ***Hemingwayella* sp. Fig. 20.** RV, external view, MPEG-630-M. **Fig. 21.** LV, external view, MPEG-631-M. **Fig. 22.** Internal view, RV, MPEG-631-M.

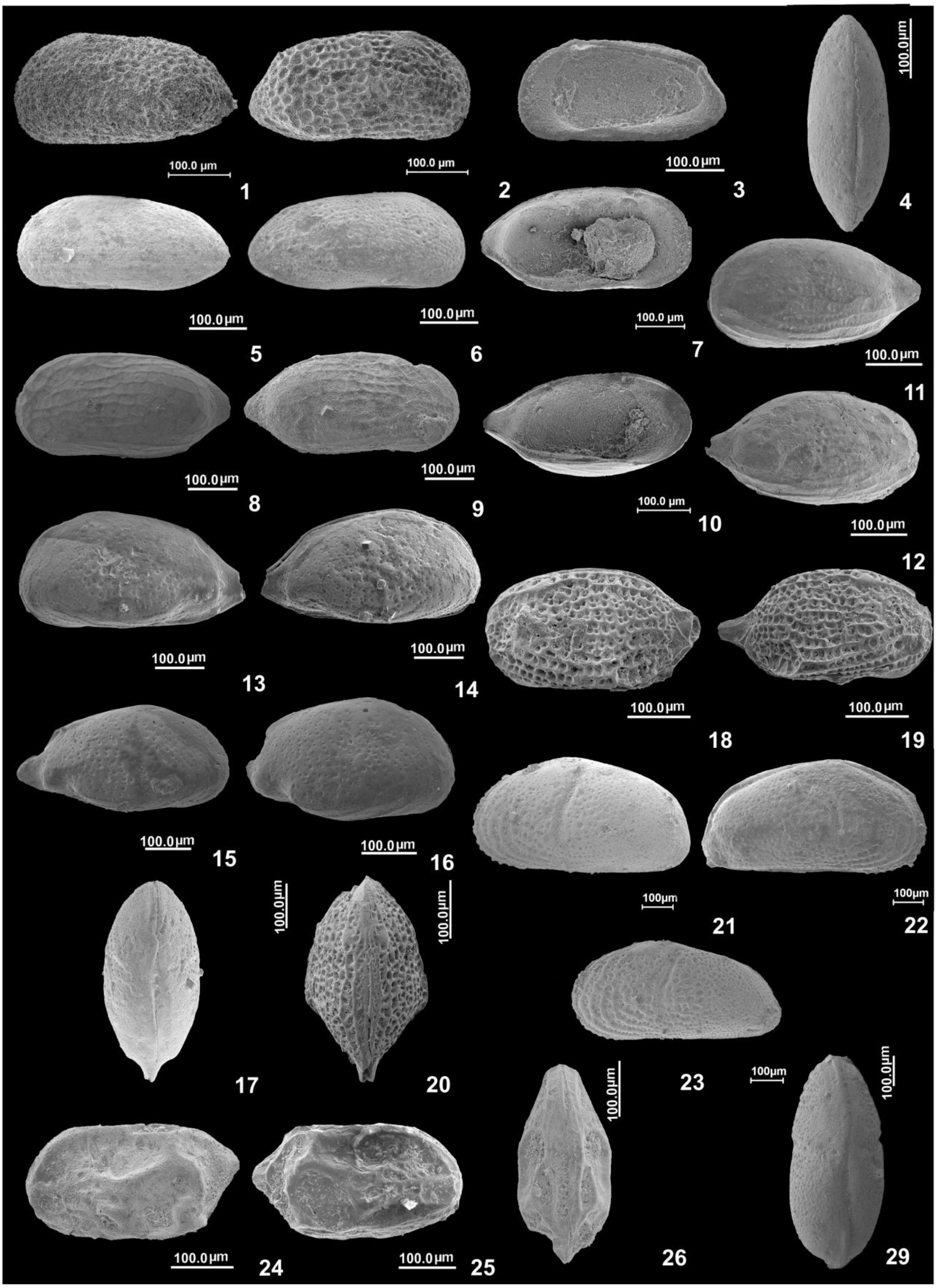
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Plate 7.6. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-3. *Cytherura ornata* n. sp. Fig. 1.** C, LV, external view, MPEG-619-M. **Fig. 2.** C, RV, external view, MPEG-620-M. **Fig. 3.** Internal view, RV, MPEG-620-M. **Figs. 4-6. *Cytherura quasilisa* n. sp. Fig. 4.** Dorsal view, MPEG-624-M. **Fig. 5.** C, LV, external view, MPEG-624-M. **Fig. 6.** C, RV, external view, MPEG-624-M. **Figs. 7-9. *Semicytherura* aff. *S. clavata*. Fig. 7.** LV, external view, MPEG-632-M. **Fig. 8.** LV, external view, MPEG-632-M. **Fig. 9.** RV, external view, MPEG-633-M. **Figs. 10-12. *Semicytherura* sp. Fig. 10.** Internal view, LV, MPEG-634- M. **Fig. 11.** LV, external view, MPEG-634-M. **Fig. 12.** RV, external view, MPEG-634-M. **Figs. 13--17**. ***Semicytherura* aff. *C. cybaea.* Fig. 13.** Female, LV, external view, MPEG-636-M. **Fig. 14.** Female, RV, external view, MPEG-636-M. **Fig. 15.** Male, RV, external view, MPEG-635-M. **Fig. 16.** Male, RV, external view, MPEG-635-M. **Fig. 17.** Female, Dorsal view, MPEG-636-M. **Figs. 18-20**. ***Semicytherura fortisreticulata* n. sp. Fig. 18.** Female, C, LV, external view, MPEG-637-M. **Fig.19.** Female, C, RV, external view, MPEG-637-M. **Fig. 20.** Female, Dorsal view, MPEG-637-M. **Figs. 21-23**. ***Cyprideis*? *huntii* n. sp. Fig. 21.** Female, C, LV, external view, MPEG-642-M. **Fig.22.** Female, C, RV, external view, MPEG-642-M. **Fig. 23.** Male, LV, external view, MPEG-643-M. **Fig. 29.** Female, C, Dorsal view, MPEG-642-M. **Figs. 24-26**. ***Kangarina quellita*. Fig. 24.** C, LV, external view, MPEG-640-M. **Fig.25.** C, RV, external view, MPEG-641-M. **Fig. 26.** Dorsal view, MPEG-641-M.

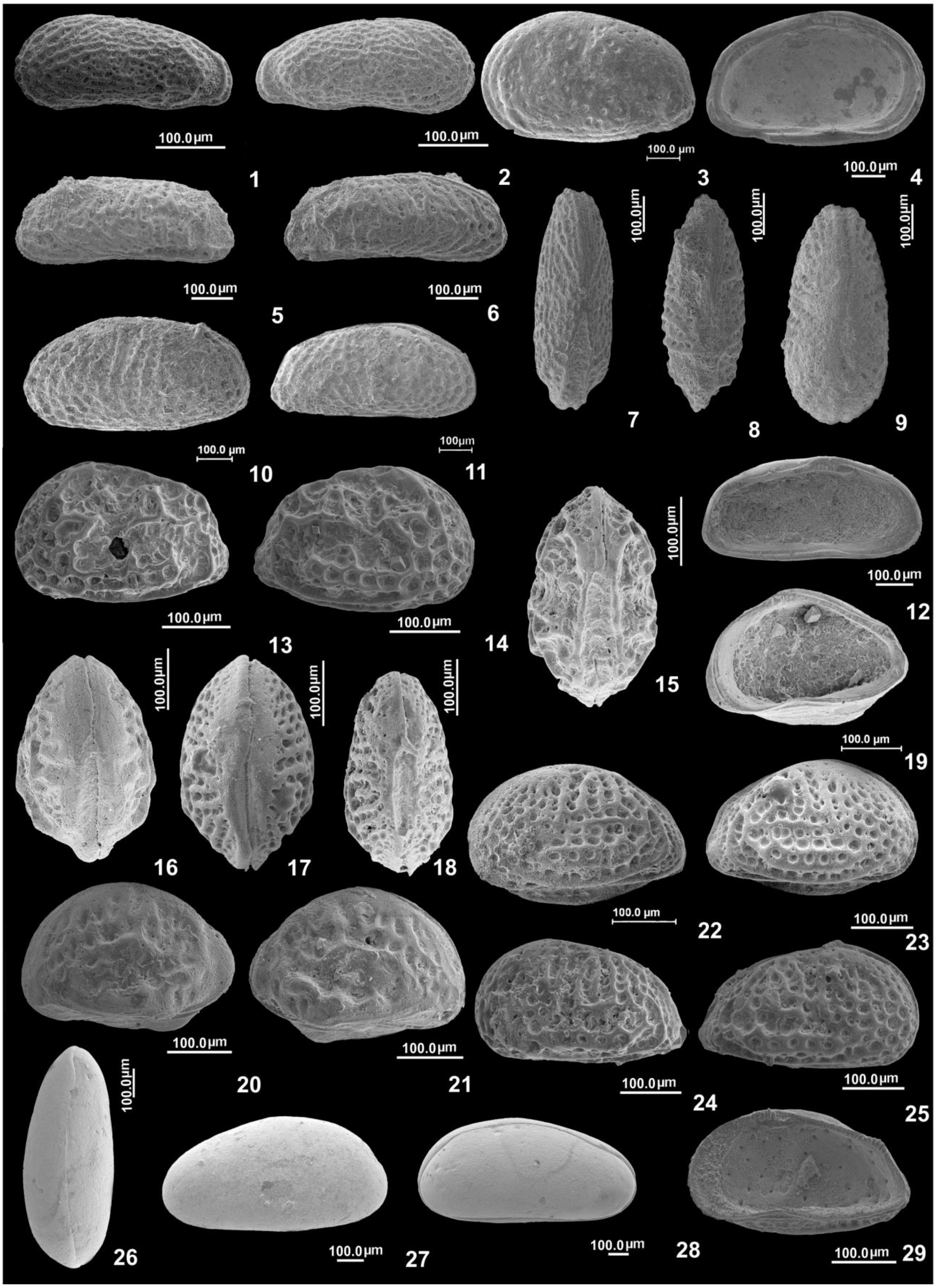
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Plate 7.7. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-2, 7. *Pumilocytheridea* sp. Fig. 1.** C, LV, external view, MPEG-652-M. **Fig. 2. C,** RV, external view, MPEG-652-M. **Fig.7.** Dorsal view, RV, MPEG-652-M. **Figs. 3-4. *Hemicyprideis* sp. Fig. 3.** C, LV, external view, MPEG-645-M. **Fig. 4.** LV, internal view, MPEG-645-M. **Figs. 5-6, 8. *Hulingsina reticulorugosa* n. sp. Fig. 5.** C, LV, external view, MPEG-655-M. **Fig. 6.** C, RV, external view, MPEG-655-M. **Fig. 8.** C, Dorsal view, MPEG-655-M. **Figs. 9-12. *Hulingsina*? *smithii* n. sp. Fig. 9.** Dorsal view, MPEG-658-M. **Fig. 10.** C, LV, external view, MPEG-658-M. **Fig. 11.** C, RV, external view, MPEG-658-M. **Fig. 12.** Internal view, LV, MPEG-659-M. **Figs. 13--15**. ***Gangamocytheridea sp.*** **Fig. 13.** C, LV, external view, MPEG-651-M. **Fig. 14.** RV, external view, MPEG-651-M. **Fig. 15.** Dorsal view, MPEG-651-M. **Figs. 16, 19, 20-21**. ***Gangamocytheridea reticulopunctatum* n. sp. Fig.16.** Dorsal view, MPEG-649-M. **Fig.19.** RV, Internal view, MPEG-649-M. **Fig. 20.** C, LV, external view, MPEG-649-M. **Fig. 21.** C, RV, external view, MPEG-649-M. **Figs.17-18, 22-25, 29**. ***Gangamocytheridea macedoi* n. sp. Fig. 17.** Female, Dorsal view, MPEG-646-M. **Fig.18.** Male, Dorsal view, MPEG-647-M. **Fig. 22.** Female, C, LV, external view, MPEG-646-M. **Fig. 23.** Female, C, RV, external view, MPEG-646-M. **24.** Male, C, LV, external view, MPEG-647-M. **Fig.25.** Male, C, RV, external view, MPEG-647-M. **Fig. 29.** Female, RV, Internal view, MPEG-646-M. **Figs. 26-28. *Cushmanidea*? *salahiensis.* Fig. 26.** Dorsal view, RV, MPEG-653-M. **Fig. 27.** C, LV, external view, MPEG-653-M. **Fig. 28. C,** RV, external view, MPEG-653-M.

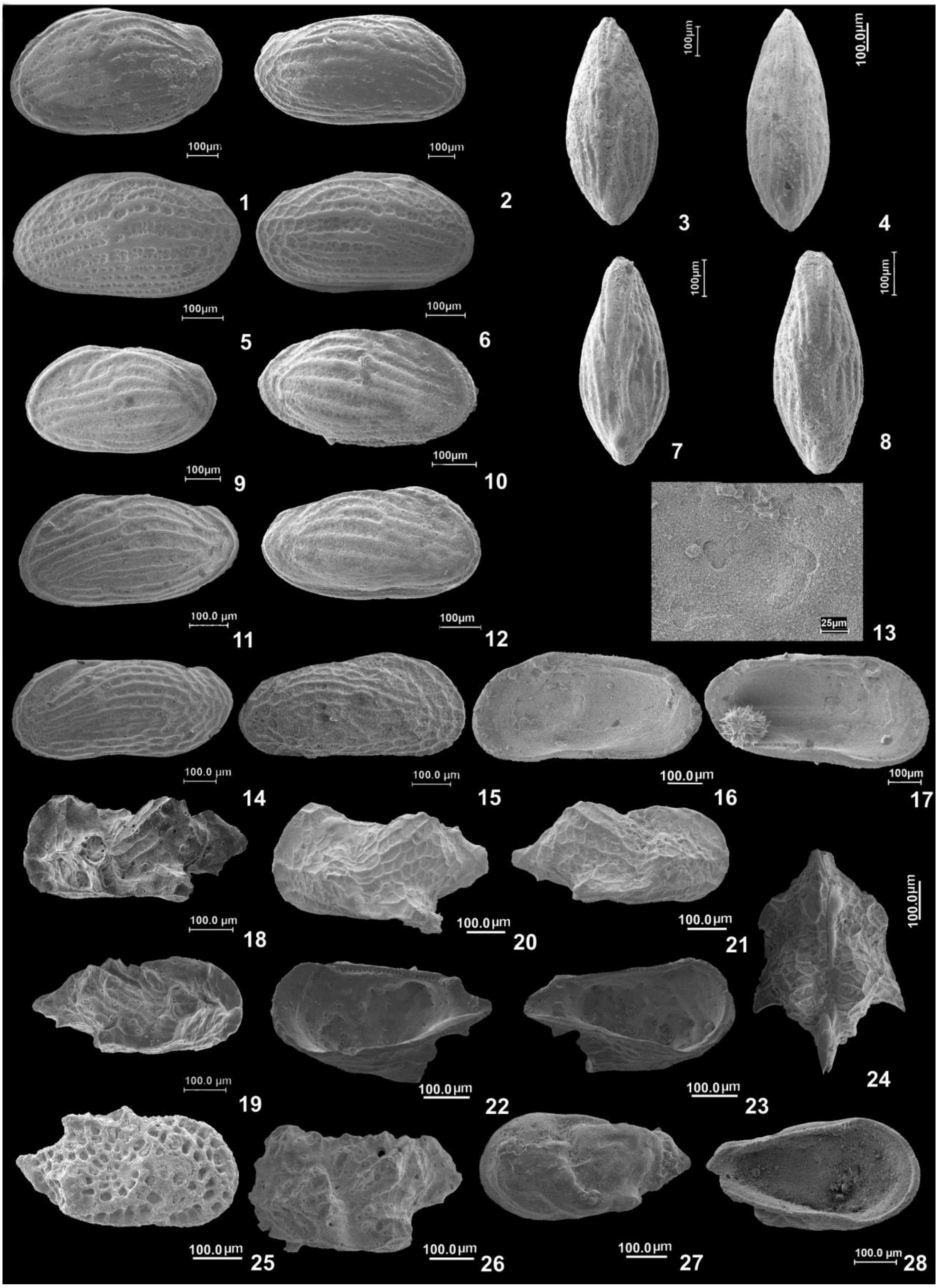
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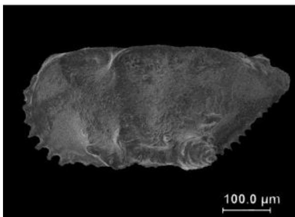
Plate 7.8. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-6.** ***Cytheretta* cf. *punctata* Fig.1.** Female, C, LV, external view, MPEG-661-M. **Fig. 2.** Female**,** C, RV, external view, MPEG-661-M. **Fig. 3.** Female, Dorsal view, MPEG-664-M. **Fig.4.** Male, Dorsal view, MPEG-665-M. **Fig.5.** Male, C, LV, external view, MPEG-662-M. **Fig.6.** Male, C, LV, external view, MPEG-662-M. **Figs. 7-12.** ***Cytheretta parva* n. sp. Fig. 7.** Female, Dorsal view, MPEG-669-M. **Fig. 8.** Male, Dorsal view, MPEG-670-M. **Fig. 9.** Female, C, LV, external view, MPEG-666-M. **Fig. 10.** Female, C, RV, external view, MPEG-666-M. **Fig. 11.** Male, C, LV, external view, MPEG-667-M. **Fig. 12.** Male, C, RV, external view, MPEG-667-M. **Figs. 13-17.** ***Cytheretta coimbrai* n. sp. Fig. 13.** Detail of muscle scars, LV, MPEG-672-M. **Fig. 14.** C, LV, external view, MPEG-671-M. **Fig. 15.** C, RV, external view, MPEG-671-M. **Fig. 16.** Internal view, RV, MPEG-674-M. **Fig. 17.** Internal view, LV, MPEG-672-M. **Figs. 18-19**. ***Paracytheridea tschoppi.* Fig. 18.** LV, external view, MPEG-675-M. **Fig. 19.** RV, external view, MPEG-675-M. **Figs. 20-24**. ***Paracytheridea* aff. *P. altila.* Fig.20.** LV, external view, MPEG-678-M. **Fig.21.** RV, external view, MPEG-678-M. **Fig. 22.** Internal view, RV, MPEG-678-M. **Fig. 23.** Internal view, LV, MPEG-678-M. **Fig. 24.** Dorsal view, MPEG-678-M. **Fig. 25**. ***Paracytheridea* sp.1 Fig. 25.** RV, external view, MPEG-679-M. **Fig.26. *Paracytheridea* sp.2. Fig.26.** LV, external view, MPEG-680-M. **Figs. 27-28. *Paracytheridea* sp.3. Fig. 27.** LV, external view, MPEG-681-M. **Fig. 28.** Internal view, LV, MPEG-681-M.



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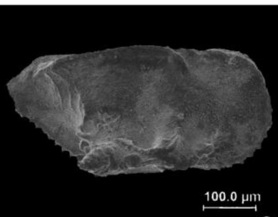

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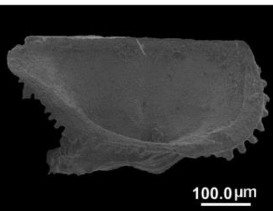

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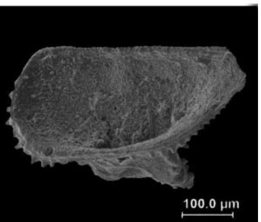

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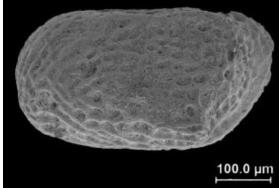

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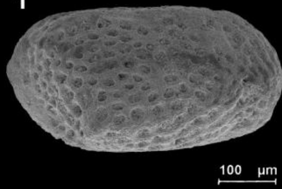

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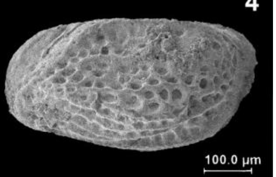

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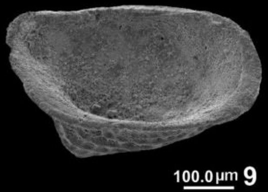

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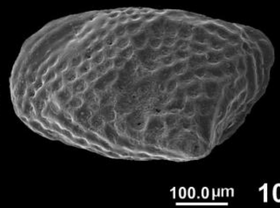

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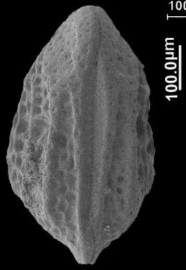

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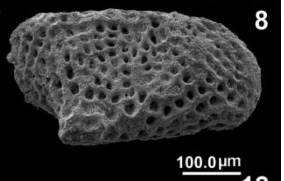

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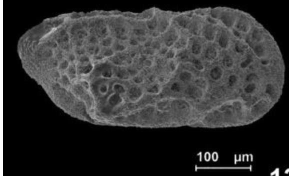

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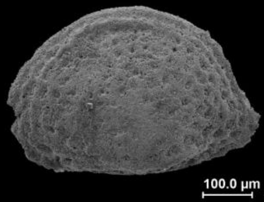

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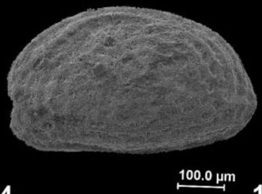

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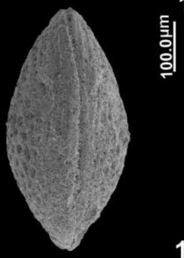

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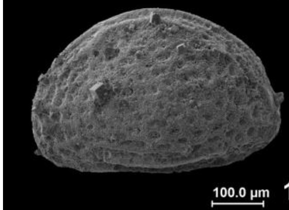

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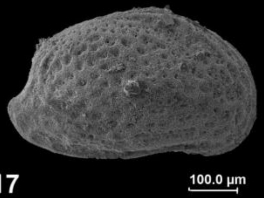

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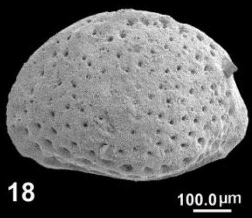

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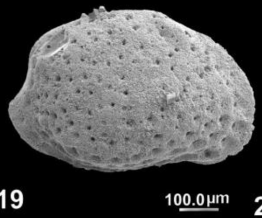

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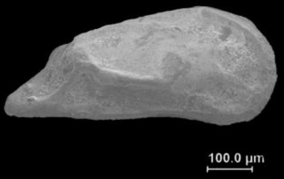

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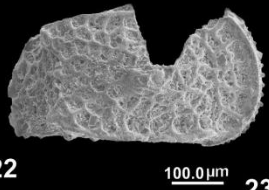

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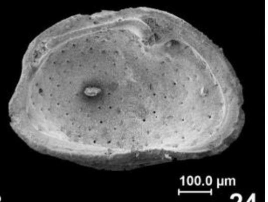

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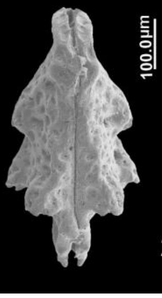

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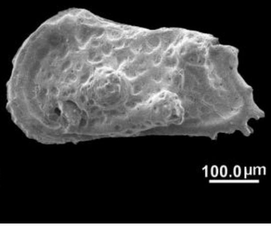

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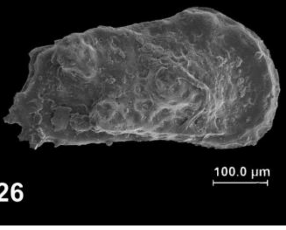

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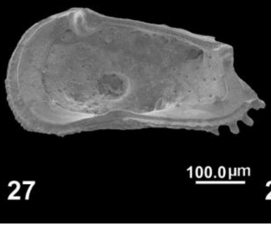

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Plate 7.9. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-4.** ***Vandenboldina binodosa*** **Fig.1.** LV, external view, MPEG-690-M. **Fig. 2.** RV, external view, MPEG-690-M. **Fig. 3.** Internal view, LV, MPEG-690-M. **Fig.4.** Internal view, RV, MPEG-690-M. **Figs. 5-6.** ***Bythoceratina loxomorpha*** **n. sp. Fig.5.** LV, external view, MPEG-682-M. **Fig.6.** RV, external view, MPEG-682-M. **Figs. 7-8, 11.** ***Bythoceratina sinuocostata*** **n. sp. Fig. 7.** C, RV, external view, MPEG-683-M. **Fig. 8.** C, LV, external view, MPEG-683-M. **Fig. 11.** Dorsal view, MPEG-683-M. **Figs. 9-10.** ***Bythoceratina*** **sp. 1 Fig. 9.** Internal view, LV, MPEG-687-M. **Fig. 10.** LV, external view, MPEG-687-M. **Figs. 12**. ***Bythoceratina*** **sp. 2. Fig. 12.** RV, external view, MPEG-688-M. **Figs. 13**. ***Bythoceratina*** **sp. 3. Fig.13.** RV, external view, MPEG-689-M. **Figs. 14-18.** ***Aurila laevicula*****. Fig.14.** Female, LV, external view, MPEG-693-M. **Fig. 15.** Male, LV, external view, MPEG-694-M. **Fig. 16.** Female, Dorsal view, MPEG-691-M. **Fig. 17.** Female, LV, external view, MPEG-691-M. **Fig. 18**. Female, RV, external view, MPEG-691-M. **Figs. 19-20, 24.** ***Aurila pirabensis*** **n. sp. Fig. 19**. LV, external view, MPEG-695-M. **Fig. 20**. RV, external view, MPEG-695-M. **Fig. 24**. Internal view, LV, MPEG-695-M. **Figs. 21-22.** ***Caudites medialis.*** **Fig. 21**. C, LV, external view, MPEG-698-M. **Fig. 22**. C, RV, external view, MPEG-698-M. **Fig. 23.** ***Hermanites*** **sp.** RV, external view, MPEG-700-M. **Figs. 25-28.** ***Cornucoquimba hoornibrooki*****. Fig. 25.** Dorsal view, MPEG-699-M. **Fig. 26.** C, LV, external view, MPEG-699-M. **Fig. 27**. C, RV, external view, MPEG-699-M. **Fig. 28.** Internal view, RV, MPEG-699-M.

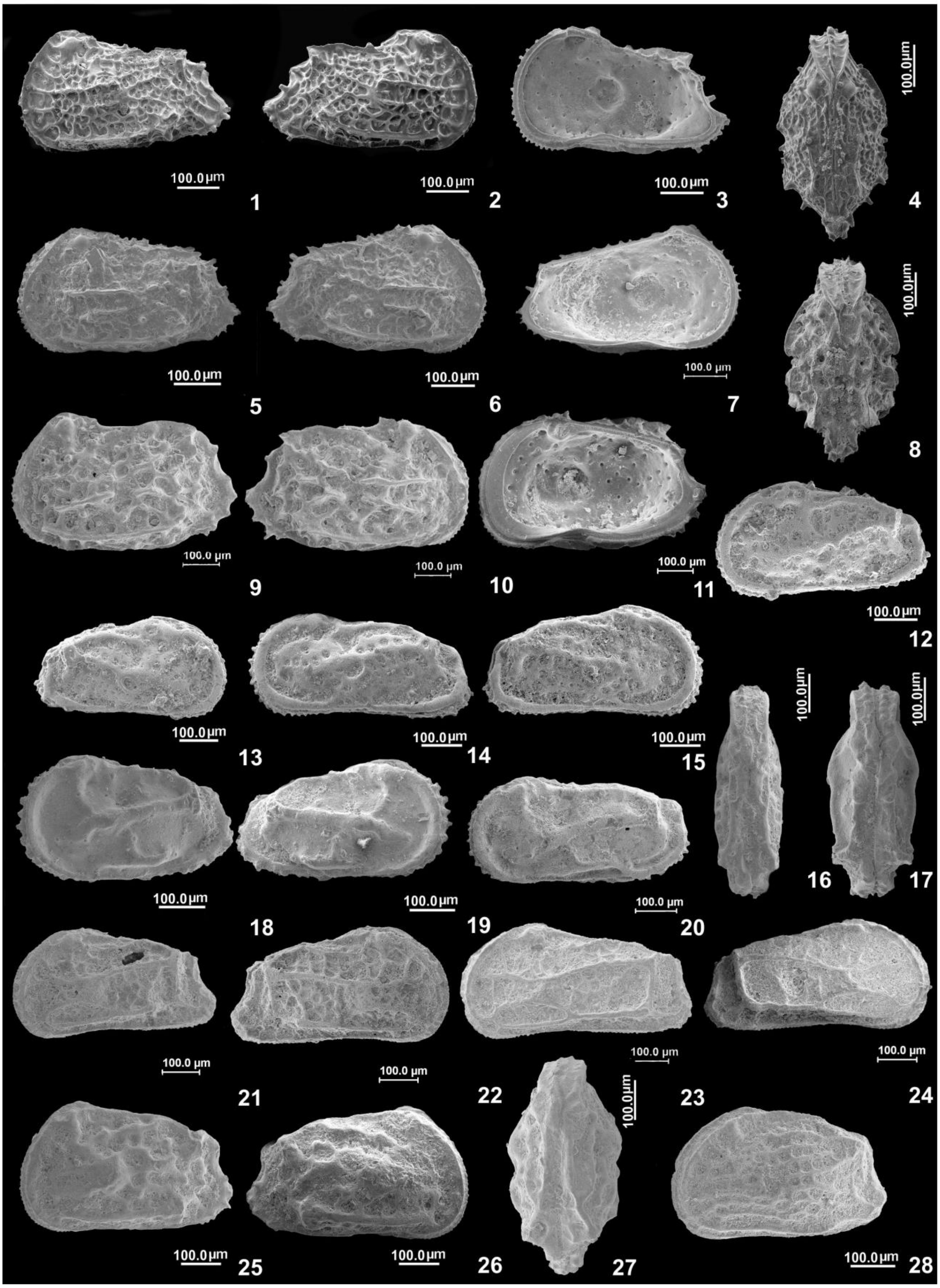
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Plate 7.10. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-11.** ***Jugosocythereis pannosa*** **Fig.1.** Juvenile, LV, external view, MPEG-705-M. **Fig. 2.** Juvenile, RV, external view, MPEG-706-M. **Fig. 3.** Juvenile, Internal view, RV, MPEG-706-M. **Fig.4.** Juvenile, Dorsal view, RV, MPEG-704-M. **Fig.5.** Juvenile, C, LV, external view, MPEG-704-M. **Fig.6.** C, RV, external view, MPEG-704-M. **Fig. 7.** Juvenile, Internal view, LV, MPEG-705-M. **Fig. 8.** C, Adult, Dorsal view, MPEG-703-M. **Fig. 9.** Adult, C, LV, external view, MPEG-703-M. **Fig. 10.** Adult, C, RV, external view, MPEG-703-M. **Fig. 11.** Adult, Internal view, RV, MPEG-703-M. **Figs. 12-16.** ***Neocaudites*? *macertus.*** **Fig. 12.** Female, C, LV, external view, MPEG-710-M. **Fig. 13.** Female, C, RV, external view, MPEG-710-M. **Fig. 14.** Male, C, LV, external view, MPEG-711-M. **Fig. 15.** Male, C, RV, external view, MPEG-711-M. **Fig.16.** Male, Dorsal view, MPEG-711-M. **Figs. 17-20**. ***Neocaudites triplistriatus.*** **Fig.17.** Female, Dorsal view, MPEG-712-M. **Fig.18.** Female, C, LV, external view, MPEG-712-M. **Fig. 19.** Female, C, RV, external view, MPEG-712-M. **Fig. 20.** Male, C, LV, external view, MPEG-713-M. **Figs. 21-22.** ***Orionina* aff. *O. similis.*** **Fig. 21**. C, LV, external view, MPEG-715-M. **Fig. 22**. C, RV, external view, MPEG-715-M. **Figs. 23-24.** ***Orionina* sp. Fig. 23**. C, LV, external view, MPEG-714-M. **Fig. 24**. C, RV, external view, MPEG-714-M. **Figs. 25-27.** ***Tenedocythere*? *rugosocostata* n. sp.** **Fig. 25.** C, LV, external view, MPEG-701-M. **Fig. 26.** C, RV, external view, MPEG-701-M. **Fig. 27**. Dorsal view, MPEG-701-M. **Fig. 28.** ***Procythereis*? sp. Fig. 28.** LV, external view, MPEG-716-M.

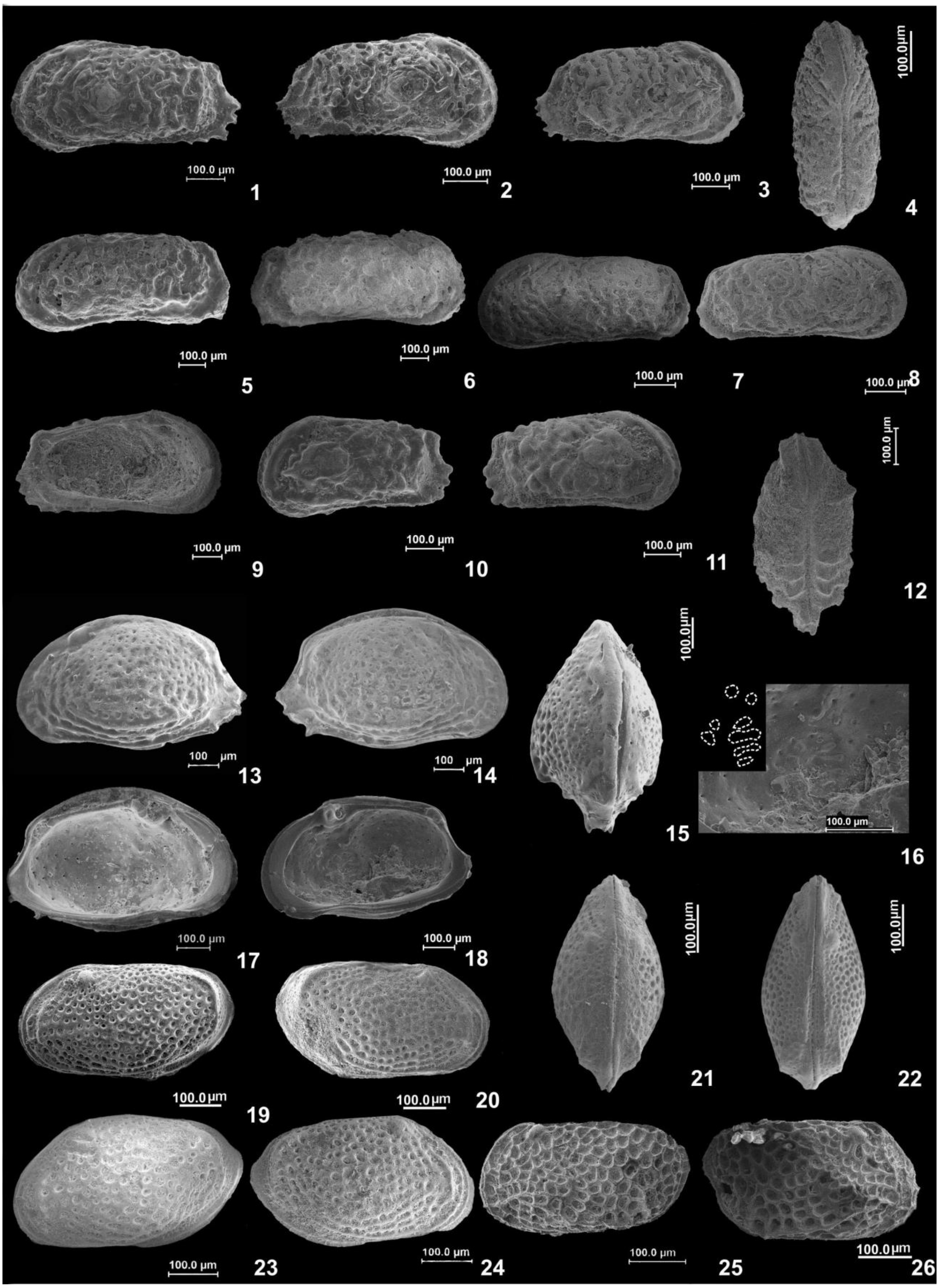
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Plate 7.11. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-9.** ***Coquimba congestocostata*** **Fig.1.** Female, C, LV, external view, MPEG-718-M. **Fig. 2.** Female, C, RV, external view, MPEG-718-M. **Fig. 3.** Female, RV, external view, MPEG-719-M. **Fig.4.** Male, Dorsal view, RV, MPEG-721-M. **Fig.5.** Male, C, LV, external view, MPEG-722-M. **Fig.6.** Male, C, RV, external view, MPEG-722-M. **Fig. 7.** Male, C, LV, external view, MPEG-719-M. **Fig. 8.** Male, C, RV, external view, MPEG-723-M. **Fig. 9.** Internal view, LV, MPEG-723-M. **Figs. 10-12.** ***Puriana rugipunctata.*** **Fig. 10.** C, LV, external view, MPEG-724-M. **Fig. 11.** C, RV, external view, MPEG-724-M. **Fig. 12.** Dorsal view, MPEG-724-M. **Figs. 13-18**. ***Pokornyella deformis.*** **Fig.13.** C, LV, external view, MPEG-725-M. **Fig.14.** C, RV, external view, MPEG-725-M. **Fig. 15.** Dorsal view, MPEG-725-M. **Fig. 16.** Detail of the muscle scars, RV, MPEG-727-M. **17.** LV, internal view, MPEG-726-M. **18.** RV, internal view, MPEG-727-M. **Figs. 19-24.** ***Loxoconcha*** **aff.** ***L. cyrton.*** **Fig. 19**. Male, C, LV, external view, MPEG-729-M. **Fig. 20**. Male, C, RV, external view, MPEG-729-M. **Fig. 21**. Female, Dorsal view, MPEG-728-M. **Fig. 22**. Male, Dorsal view, MPEG-729-M. **Fig. 23.** Female, C, LV, external view, MPEG-728-M. **Fig. 24.** Female, C, RV, external view, MPEG-728-M. **Figs. 25-26.** ***Loxoconcha*** **sp. Fig. 25**. C, LV, external view, MPEG-730-M. **Fig. 26**. C, RV, external view, MPEG-731-M.

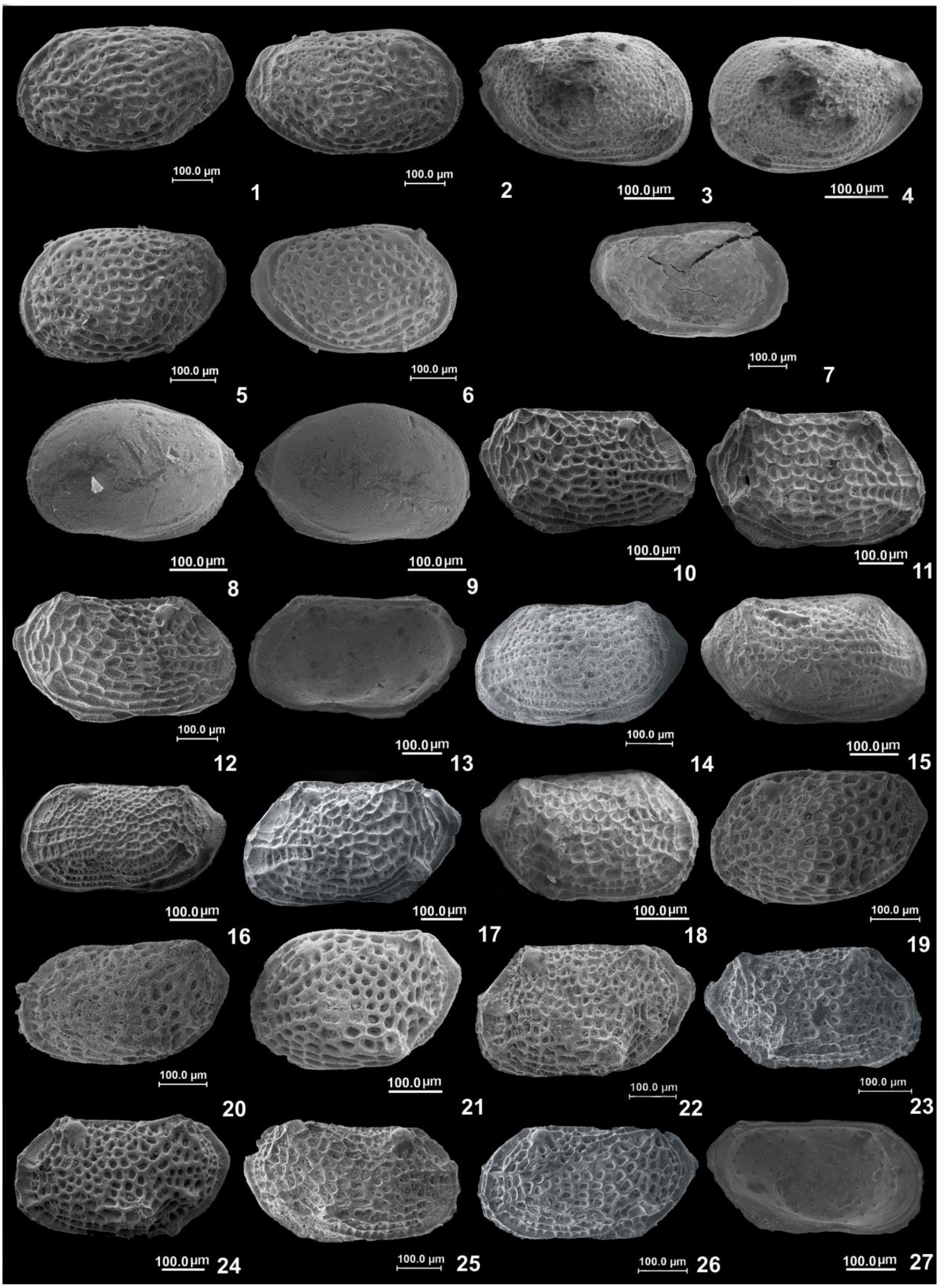
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Plate 7.12. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-7.** ***Loxoconcha vana*** **n. sp. Fig.1.** Male, C, LV, external view, MPEG-733-M. **Fig. 2.** Male, C, RV, external view, MPEG-733-M. **Fig. 3.** Juvenile, RV, external view, MPEG-736-M. **Fig.4.** Juvenile, LV, external view, MPEG-737-M. **Fig.5.** Female, C, LV, external view, MPEG-732-M. **Fig.6.** Female, C, RV, external view, MPEG-732-M. **Fig. 7.** Internal view, LV, MPEG-732-M. **Figs. 8-9.** ***Phlyctocythere*** **sp. Fig. 8.** C, LV, external view, MPEG-754-M. **Fig. 9.** C, RV, external view, MPEG-754-M. **Figs. 10-13**. ***Loxorcorniculum fischeri.*** **Fig.10.** Male, RV, external view, MPEG-740-M. **Fig.11.** Female, RV, external view, MPEG-739-M. **Fig. 12.** Male, RV, external view, MPEG-742-M. **Fig. 13.** RV, Internal view, MPEG-742-M. **Figs. 14-16.** ***Loxocorniculum*** **aff.** ***Loxoconcha rugosa.*** **Fig. 14**. Female, C, LV, external view, MPEG-743-M. **Fig. 15**. Female, C, RV, external view, MPEG-743-M. **Fig.16.** Male, LV, external view, MPEG-744-M. **Figs. 17-18.** ***Loxocorniculum antilleum***. **Fig. 17**. C, LV, external view, MPEG-745-M. **Fig. 18**. C, RV, external view, MPEG-745-M. **Figs. 19-21.** ***Loxocorniculum*** **aff.** ***Loxoconcha longispina***. **Fig. 19**. Male, LV, external view, MPEG-748-M. **Fig. 20.** Female, LV, external view, MPEG-746-M. **Fig. 21.** Female, LV, external view, MPEG-747-M. **Figs. 22-27.** ***Loxocorniculum*** **sp. Fig. 22**. Female, LV, external view, MPEG-749-M. **Fig. 23.** Female, RV, external view, MPEG-749-M. **Fig. 24.** Male, LV, external view, MPEG-751-M. **Fig. 25.** Male, RV, external view, MPEG-752-M. **Fig. 26.** Male, LV, external view, MPEG-753-M. **Fig. 27.** Male, Internal view, LV, MPEG-751-M.

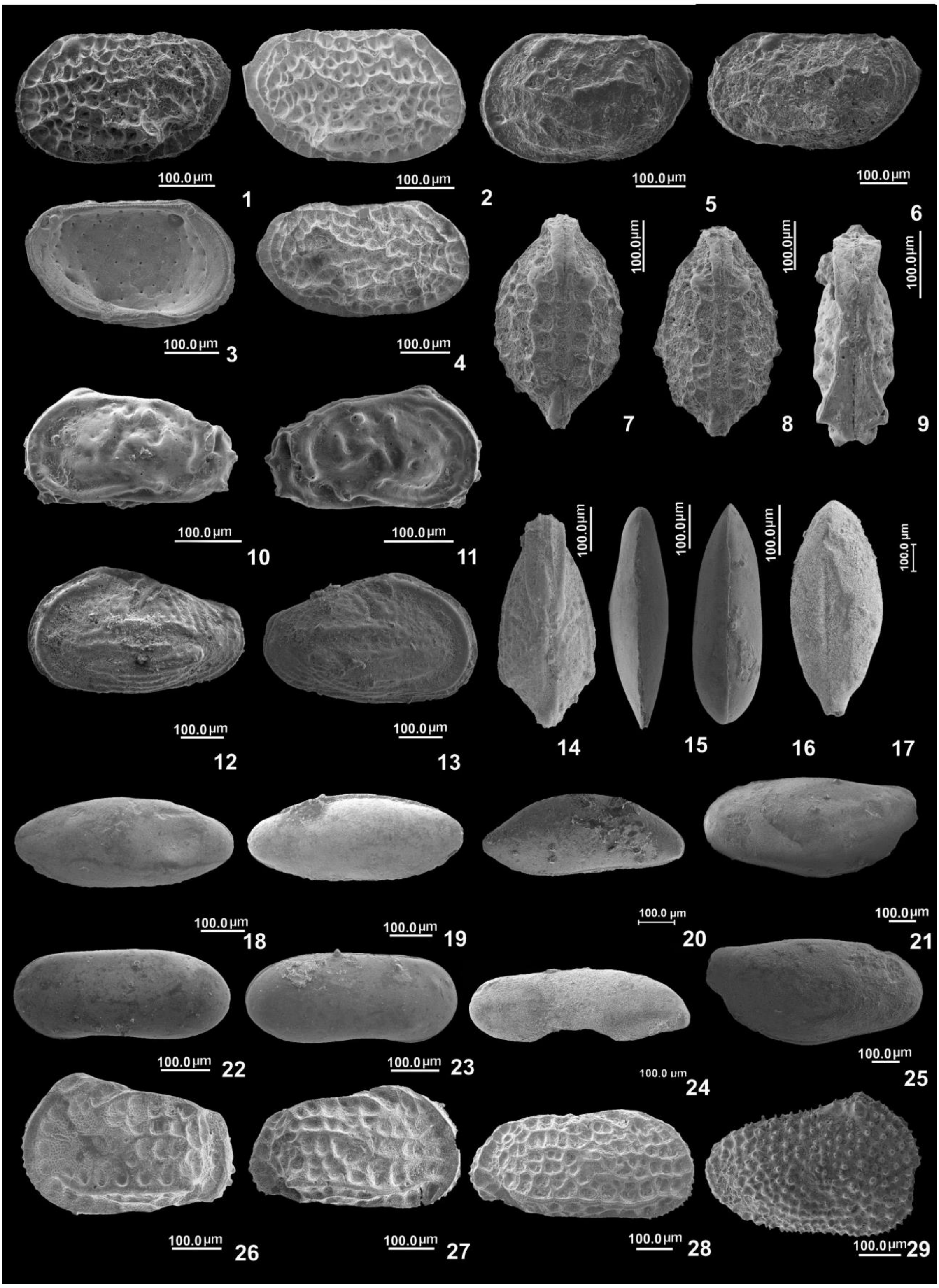
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Plate 7.13. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-8.** ***Touroconcha ishizakii* n. sp. Fig.1.** Female, LV, external view, MPEG-755-M. **Fig. 2.** Female, RV, external view, MPEG-755-M. **Fig. 3.** Internal view, LV, MPEG-755-M. **Fig.4.** Male, RV, external view, MPEG-756-M. **Fig. 5.** Female, C, LV, external view, MPEG-757-M. **Fig.6.** Male, C, LV, external view, MPEG-756-M. **Fig. 7.** Female, Dorsal view, MPEG-755-M. **Fig. 8.** Male, Dorsal view, MPEG-756-M. **Figs. 9-11.** ***Munseyella minuta*. Fig. 9.** C, Dorsal view, MPEG-764-M. **Fig. 10.** C, LV, external view, MPEG-764-M.**Fig. 11.** C, RV, external view, MPEG-764-M. **Figs. 12-14**. ***Munseyella*? sp. Fig.12.** C, LV, external view, MPEG-766-M. **Fig.13.** C, RV, external view, MPEG-766-M. **Fig. 14.** C, Dorsal view, MPEG-766-M. **Figs. 15, 18-19.** ***Paradoxostoma*? sp. Fig. 15**. C, Dorsal view, MPEG-763-M. **Fig. 18**. C, LV, external view, MPEG-763-M. **Fig.19.** C, RV, external view, MPEG-763-M. **Figs. 16, 22-23.** ***Pseudopsammocythere* ex. gr. *vicksburgensis***. **Fig. 16**. C, Dorsal view, MPEG-767-M. **Fig. 22**. C, LV, external view, MPEG-767-M. **Fig. 23**. C, RV, external view, MPEG-767-M. **Fig. 20. *Paradoxostoma artum.* Fig. 20**. C, RV, external view, MPEG-759-M. **Figs. 17, 21, 25. *Paradoxostoma pirabensis* n. sp. Fig. 17**. C, Dorsal view, MPEG-760-M. **Fig. 21.** C, LV, external view, MPEG-760-M. **Fig. 25.** C, RV, external view, MPEG-760-M. **Fig. 24. *Copytus* sp. Fig. 24**. LV, external view, MPEG-768-M. **Figs. 26-27. *Bradleya*? sp. 1. Fig. 26.** LV, external view, MPEG-770-M. **Fig. 27.** RV, external view, MPEG-771-M. **Fig. 28. *Bradleya* sp. 2. Fig. 28.** RV, external view, MPEG-772-M. **Fig. 29. *Henryhowella* sp. Fig. 29.** RV, external view, MPEG-818-M.

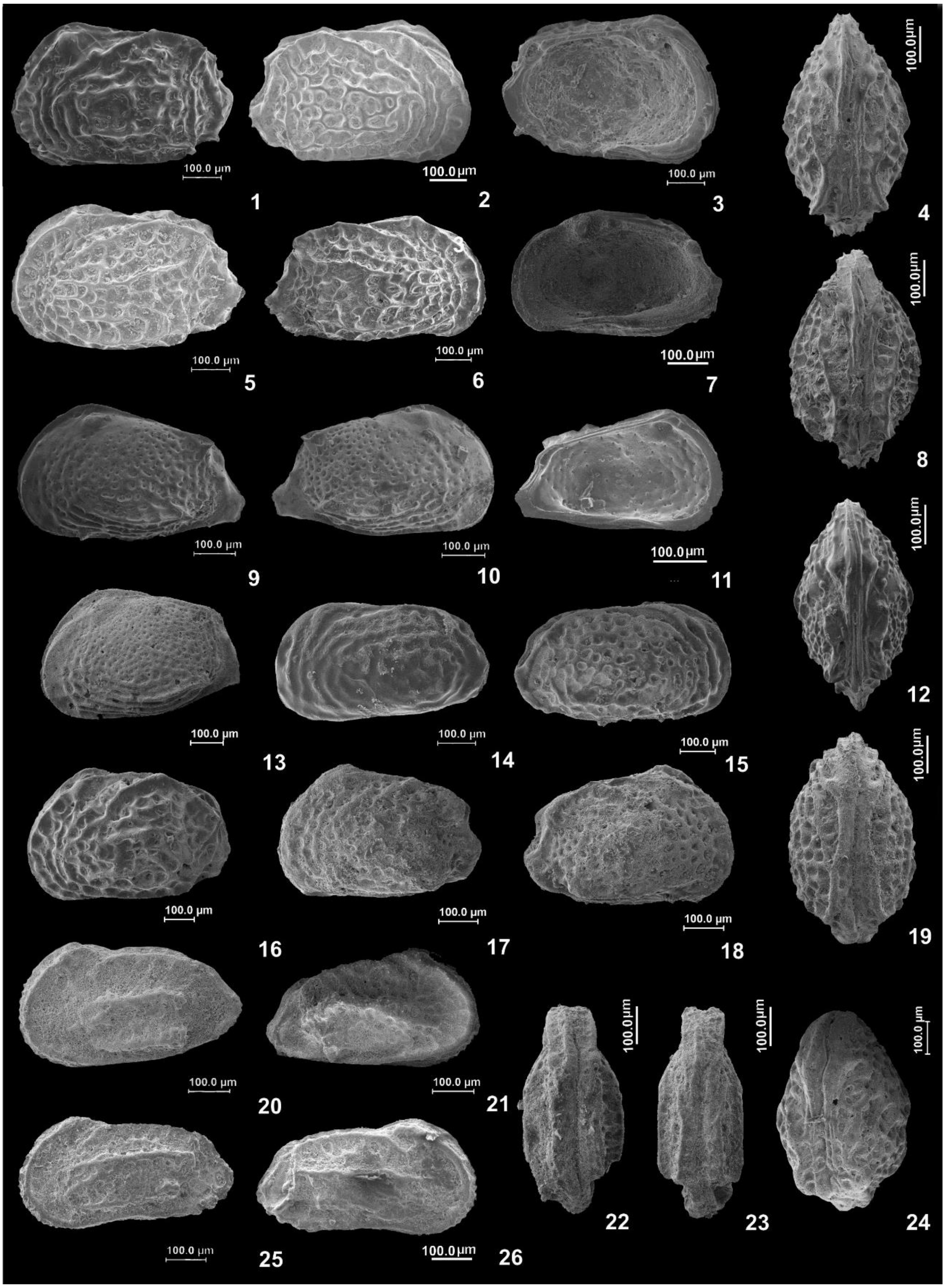
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Plate 7.14. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-4.** ***Quadracythere brachypygaia*. Fig.1.** C, LV, external view, MPEG-773-M. **Fig. 2.** C, RV, external view, MPEG-773-M. **Fig. 3.** Internal view, LV, MPEG-775-M. **Fig.4.** Dorsal view, MPEG-774-M. **Figs. 5-8.** ***Quadracythere adornata* n. sp. Fig. 5.** C, LV, external view, MPEG-776-M.**Fig. 6.** C, RV, external view, MPEG-776-M. **Fig. 7.** Internal view, RV, MPEG-779-M. **Fig. 8.** Dorsal view, MPEG-777-M. **Figs. 9-13**. ***Dameriacella*? *caudata.* Fig.9.** Juvenile, LV, external view, MPEG-796-M. **Fig.10.** Juvenile, RV, external view, MPEG-797-M. **Fig. 11.** Juvenile, Internal view, LV, MPEG-796-M. **Fig. 12**. Juvenile, C, Dorsal view, MPEG-797-M. **Fig. 13**. Adult, LV, external view, MPEG-795-M. **Figs. 14-15, 19.** ***Quadracythere limbilepida* n. sp**. **Fig. 14**. LV, external view, MPEG-781-M. **Fig. 15**. C, RV, external view, MPEG-783-M. **Fig. 19**. C, Dorsal view, MPEG-782-M. **Figs. 16-18, 24.** ***Quadracythere robusta* n. sp. Fig. 16**. C, LV, external view, MPEG-792-M. **Fig. 17**. C, LV, external view, MPEG-791-M. **Fig. 18**. C, RV, external view, MPEG-791-M. **Fig. 24**. C, Dorsal view, MPEG-792-M. **Figs. 20-21, 22-23. 25-26.** ***Costa variabilocostata* subs. *variabilocostata*. Fig. 20**. Female, C, LV, external view, MPEG-799-M. **Fig. 21.** Female, C, RV, external view, MPEG-800-M. **Fig. 22.** Female, C, Dorsal view, MPEG-799-M. **Fig. 23.** Male, C, Dorsal view, MPEG-802-M. **Fig. 25**. Male, C, LV, external view, MPEG-801-M. **Fig. 26**. Male, C, RV, external view, MPEG-801-M.

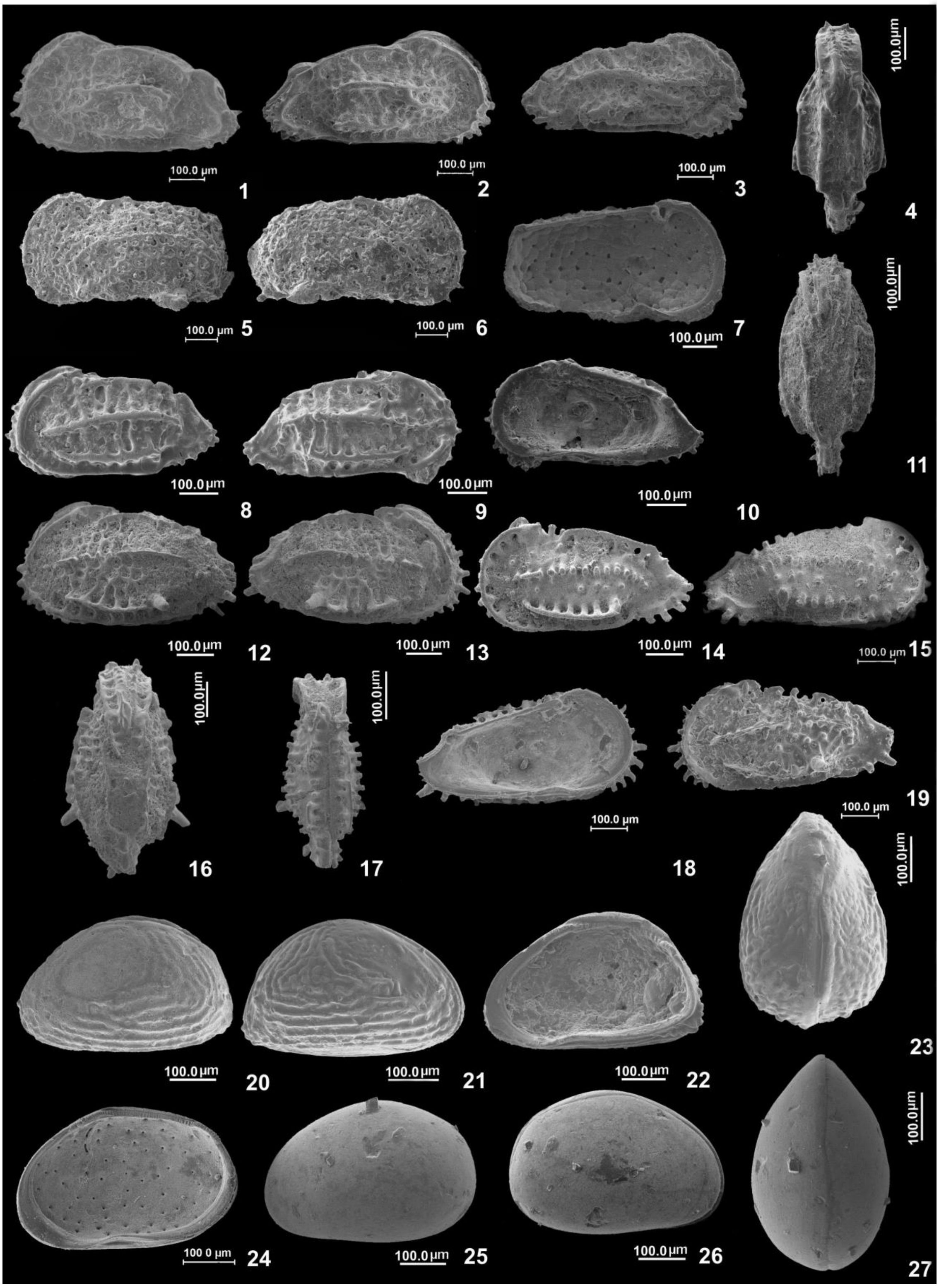
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Plate 7.15. Scale bar: 100µm: C: carapace; LV: left valve; RV: Right Valve. **Figs. 1-4.** ***Costa petrii* n. sp**.**Fig.1.** C, LV, external view, MPEG-805-M. **Fig. 2.** C, RV, external view, MPEG-805-M. **Fig. 3.** RV, external view, MPEG-806-M. **Fig.4.** Dorsal view, MPEG-805-M. **Figs. 5-7.** ***Carinocythereis*? sp. Fig. 5.** LV, external view, MPEG-798-M. **Fig. 6.** RV, external view, MPEG-798-M. **Fig. 7.** Internal view, LV, MPEG-798-M. **Figs. 8-11**. ***Cativella* aff. *C. navis.* Fig. 8.** LV, external view, MPEG-808-M. **Fig.9.** RV, external view, MPEG-808-M. **Fig. 10.** Internal view, RV, MPEG-808-M. **Fig. 11**. C, Dorsal view, MPEG-809-M. **Figs. 12-13, 16.** ***Cativella longispina* n. sp**. **Fig. 12**. C, LV, external view, MPEG-816-M. **Fig. 13**. C, RV, external view, MPEG-816-M. **Fig. 16**. C, Dorsal view, MPEG-816-M. **Figs. 14-15, 17.** ***Cativella* aff. *C. moriahensis*. Fig. 14**. C, LV, external view, MPEG-813-M. **Fig. 15**. C, RV, external view, MPEG-813-M. **Fig. 17**. C, Dorsal view, MPEG-813-M. **Figs. 18-19.** ***Cativella* sp. Fig. 18**. Internal view, LV, MPEG-817-M. **Fig. 19.** LV, external view, MPEG-817-M. **Figs. 20-23.** ***Pontoleberis dactylotypa*. Fig. 20.** C, LV, external view, MPEG-819-M.**Fig. 21.** C, RV, external view, MPEG-819-M. **Fig. 22**. Internal view, RV, MPEG-820-M. **Fig. 23**. C, Dorsal view, MPEG-819-M. **Figs. 24-27.** ***Xestoleberis quasipila* n. sp. Fig. 24.** Internal view, RV, MPEG-825-M. **Fig. 25.** C, LV, external view, MPEG-822-M. **Fig. 26**. C, RV, external view, MPEG-822-M. **Fig. 27**. C, Dorsal view, MPEG-822-M.

CAPÍTULO 8

8. BIOSTRATIGRAPHY AND PALEOENVIRONMENT OF THE OLIGOCENE-MIOCENE OSTRACODA OF NORTHEASTERN AMAZONIA, BRAZIL, AND PALEOBIOGEOGRAPHIC AFFINITIES WITH CARIBBEAN REGION

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ABSTRACT

Oligocene-Miocene ostracods biozones are proposed to Pirabas Formation. This predominantly carbonate unit overlies the basement rocks of the Bragantina platform and underly the siliciclastics Barreiras Formation in the northeastern State of Pará, Northern Brazil. Transitional and shallow marine water ostracod, including new index species are used, by the first time, for chronostratigraphic correlation between local carbonate rocks (outcrops and core). This study allowed asserting the correlation of the Pirabas Formation with Caribbean Neogene deposits, mainly from Puerto Rico and Trinidad. Bragantina Platform was particularly a tectonically stable area influenced by Trangressive event where a combination of parameters (temperature, salinity and oxygenation) allowed the precipitation of the carbonated rocks during the Oligo-Miocene. The sedimentar and paleontological data enable to identify the interbedded of lagoon/mangroves with tidal channel and shallow platform facies as part of a complex barrier island system formed during P/R cycles. This system provided the instalation of lagoon settings favouring ostracod proliferation allowing them to be a precise biostragraphic tool. Among thirty-two ostracod genera identified, the most of them are typical of inner platform and polyhaline that occur in the lagoonal with others mesohaline genus, as *Perissocytheridea*, in the studied sections. The rare presence of genera typical of offshore indicate the connection of the lagoon with the open sea. On the other hand, the rare presence of *Cyprideis* and the eroded features of this genus show that the lagoon was close to estuaries and that had a relatively stable salinity degree. The ostracods comprise more than 100 species, ranging from Upper Oligocene to Lower Miocene with five species index as *Cytherella stainforthi*, *Glyptobairdia crumena*, *Neocaudites*? *macertus*, *Pokornyella deformis* and *Quadracythere brachypygaia* common to the Neogene of Caribe. The biozones proposed here are mainly locals ostracod assemblages environmentally controlled. The Pirabas Formation corresponds to the *Cytherella stainforthi* Zone (Taxon-range) which is subdivided in four subzones: *Jugosocythereis pannosa* Subzone (Interval subzone/based on lowest occurrences), *Quadracythere brachypygaia* Subzone (Taxon-range zone), *Glyptobairdia crumena* Subzone (Taxon-range zone) and *Pokornyella deformis* Subzone (Interval subzone/based on highest occurrences.This new zonation is preliminarly calibrated with the zonal planktonic foraminifers, corresponding to N3 to N7 zones of Blow included in the Chatian to Burdigalian ages, corroborating with

Neogene ostracod biostratigraphy to the Caribbean region. Thus, this ostracod zonation is of great significance for local, intrabasinal and regional correlation, particularly where foraminiferal, nannofossil or palinomorfs control is poor as in the Cenozoic deposits of Bragantina Platform.

Key-words: ostracod fossil zone; Bragantina platform; Pirabas Formation; Oligocene-Miocene.

8.1. INTRODUCTION

The Miocene was characterized by significant transgressions recorded in several parts of the world mainly in carbonate successions of American continent (Szatmari *et al.* 1987, Rossetti *et al.* 2013, Aguilera *et al.* 2014). In the northern South America, preceding the installation of continental drainage of Amazonas River, a large carbonate platform was developed in the Equatorial Atlantic margin (Soares-Júnior *et al.* 2008, Rossetti *et al.* 2013). The Pirabas Formation is one of most important Oligocene-Miocene carbonate record of marginal marine (lagoon; mangroves; shallow platform) environments, discontinuously exposed in the Bragantina Platform, coastal zone of northeastern State of Pará, northern Brazil. Its particular complexity of subenvironments typical of marginal marine and shallow waters makes it to represent one of the regions with the highest paleodiversity of the Neogene (Oligo-Miocene) Brazilian coast. This densely fossiliferous unit, originally described as calcareous rocks outcropping in the Pirabas river, northern Brazil, was firstly dated as Oligo-Miocene but without consistent data (Maury 1925). The previous papers on Pirabas Formation diverge in age as the most of them worked with isolated data mainly from surface sections without a more complete sequence of this unit. Some of these authors considered Early Miocene age (Ferreira *et al*. 1978, Fernandes and Távora 1990, Távora and Fernandes 1999, Aguilera and Paes 2012, Rosseti 2013, Aguilera *et al.* 2014) but the most of them dealt with only part of the entire sequence. A more complete study based on core, dealing with planktonic foraminiferal zone dated the Pirabas Formation as Upper Oligocene to Lower Miocene (Petri 1957, Fernandes 1984, 1988).

Since the last century, sporadic attempts have been made to utilize microfossils as biostratigraphic tools for a subdivision of the Neogene carbonate deposits in the Bragantina Platform. This platform is well defined, corresponding to two flattened areas located on both sides of the Vigía-Castanhal trough. Farther west sector is limited by Cametá south sub-basin, Pará platform west and by extension to north of Vigia-Castanhal trench. The basement this platform is recorded by igneous and metamorphic rocks and Paleozoic sandstones in the São Miguel do Guamá. Deposition on Bragantina platform consists exclusively of Tertiary deposits formed from the Oligo-Miocene, reaching thicknesses generally less than 60 m (Rosseti and Góes 2004).

This paper present an ostracod zonation and the paleoenvironmental evolution based on a record of 119 species of Ostracoda recovered from 40m thick carbonate succession of the Bragantina Platform, based on a drill core and outcrops exposed in the coastal region of the northeastern State of Pará, Eastern Amazonia.

Micropaleontological studies on the Oligocene-Miocene Pirabas Formation start 50 years ago with the pioneer works of Petri (1952, 1954 and 1957) that recognized 75 species of foraminifera. Afterwards, Fernandes (1984, 1988) recorded more 87 species of foraminifera in friable samples of three boreholes and based on planktonic foraminifera taxa indicated the Aquitanian-Burdighalian age, correlate to the N4 and N5 foraminifera biozones of Blow (1969). Nannofossils (Quadros and Fernandes 1982, Távora and Fernandes 1982, Antunes and Cunha 1991, Concheyro and Tavora 1992, Shimabukuro and Ferreira 1996) and diatoms (Távora *et al.*1997) were considered non-representative for biostratigraphic studies of the Pirabas Formation. Macedo (1970 to 1988) and Ferreira *et al.* (1978 to 1984) provide more paleoenvironmental and paleobiogeographic implications from ostracods, whose abundance and diversity was locally highlighted by Tavora *et al.* (2001) as an important biostratigraphic factor. Thus, the planktonic foraminifera, nannofossil or palinomorfs control is poor for Pirabas and until now no ostracod-zonation has been erected to allow local, intrabasinal and regional correlation.

Normally ostracods are not used to biostratigraphy as they are most benthic and do not have larval phases presenting high endemism. Fossil record of planktonic marine ostracods is patchy and biostratigraphic uses of this group based on benthic forms are limited to specialized environments and restrict to a geological time (e.g. Bold 1988, Viviers *et al.* 2000, Tunoğlu and Bilen 2001, Munoz-Torres *et al.* 2006). There are situations in which biostratigraphic information provided by marine ostracods can be very useful, particularly in sediments deposited in shallow sea and coastal marine environments, where these organisms are more abundant (Viviers *et al.* 2000). Shallow waters regions obviously have much greater variety of ecological niches and consequently higher species diversity and presumably, evolutionary rates (Coles 1990).

Besides of the biostratigraphy, others works also have given important contributions mainly to the paleoenvironmental interpretations indicating the prevalence of warm and clear marine-influenced waters, with deposition on the that this paleoenvironmental context became lagoonal or estuarine over time, which is supported by the fossil record (e.g., Petri 1954, 1957, Beurlen 1958, Brito 1971, 1972, 1977, Toledo and Domning 1989, Góes *et al.* 1990, Martins-Neto 2001, Távora *et al.* 2010, Rossetti 2006, Rossetti and Santos Jr. 2004, Nogueira and Ramos, submitted).

Most of the paleoenvironmental interpretation of the Pirabas Formation has been based on its paleontological content, complemented by a few studies focusing on facies analysis (Góes *et al.* 1990), where this unit was characterized by a complex association of facies, reflecting platform (inner to outer shelf) to coastal/transitional environments, including lagoons; shoreface/foreshore, and mangrove/mud flat deposits are abundant in this unit (Rossetti and Góes 2004). Although facies organization records transgressive events, the distribution of stratal architecture indicates an overall progradational pattern. This is revealed by the superposition of the inner shelf with progressively more coastal environments (Góes *et al.* 1990), which resulted in increased input of siliciclastic lithologies inner shelf during episodic storm events. In addition, the Pirabas unit sequence was accumulated by an interlayed of low-energy and finer grains lagoon facies with higher energy coarser grained shallow platform facies, beyond of the presence of *hummocky* structures and glauconite which indicates storm waves events. The presence of tidal channels and tidal deltas also suggest a nearshore to shallow marine/transitional platform environment (Rossetti 2006, Rossetti *et al.* 2013).

Paleoecologic characteristics of the available ostracod species in combination with previous paleontologic, sedimentologic and lithostratigraphic data allowed achieve a more robust biostratigraphical and paleoenvironmental interpretation that is presented in this paper.

We have gathered information on the occurrence of many ostracod taxa relevant to the application to these interpretations. The taxonomy of the ostracods used in this paper is extensively presented in Nogueira and Ramos (Submitted A and B) as suplementary material (see the first and second manuscript in this thesis).

8.2. MATERIAL AND METHODS

Fifty-seven samples used for this study comes from the main and well-known carbonate occurrences of the Pirabas Formation: B-17 quarry (nineteen samples), Ponta do Castelo/Fazendinha in Fortaleza Island, São João de Pirabas region (five samples), Aricuru, Maracanã bay (six samples), Atalaia, Salinópolis (four samples) and, by first time, we used twenty samples of FPR-160 drill core from Primavera region. The most robust biostratigraphic framework was erected using mainly the samples from the FPR-160 core chosen as type section, due to its maximum thickness, but samples from B-17 quarry and Aricuru outcrop were used as supplementary sites as the most abundance of specimens collected are from these three sites. Samples were processed according standard methods for calcareous microfossils and to the taxonomic identification methods (see detail in Nogueira and Ramos Submitted).

Ostracod bioestratigraphic zonation was compared and extended according to the model of Bold in shallow marine ostracods zonation (1983 and 1988), which was based on the planktonic foraminifera zonation of Blow (1969). The criterion used to select the species used in biostratigraphic zoning were those who had their more restricted stratigraphic range through the studied section.

The definiton and limits of the biozones apllied here is based on the North American Stratigraphic Code (2005).

8.3. STUDIED LOCALITIES AND SEDIMENTOLOGY

The studied outcrops and core are located in the Bragantina Platform, northeastern of the State of Pará, northern Brazil (Fig. 8.1). The composite section of Pirabas carbonate succession was obtained mainly of measured section in 40m-thick drill core of Primavera region, 20m-thick in the open pit of B-17 quarry, Capanema region and 4m-thick in the Aricuru outcrop, Maracanã Bay. Others studied localities (Atalaia and Ilha de Fortaleza) with less than 5 m-thick succession, were subordinately used for additional stratigraphic and paleontological information (Fig. 8.2). The carbonate sections are overlaid by pelites and sandstones of Middle Miocene to Pliocene Barreiras Formation and Pós-Barreiras Quaternary unit (Fig. 8.2).

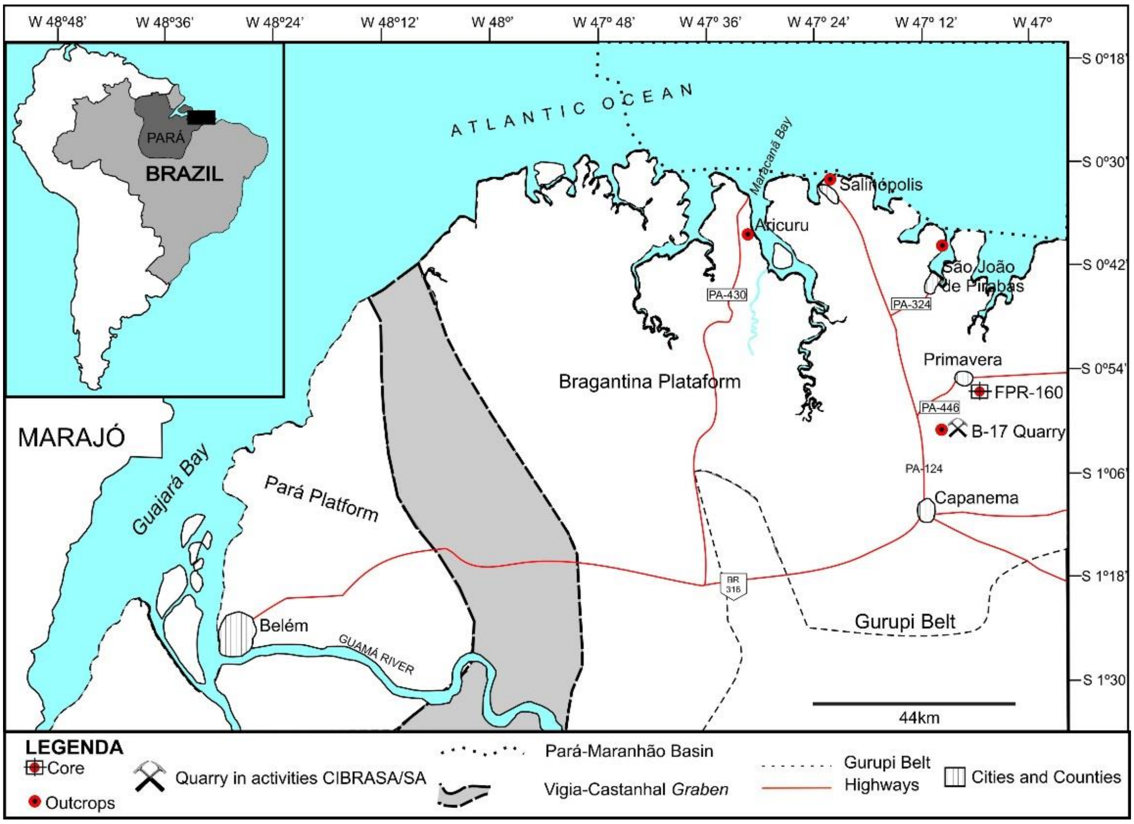


Figure 8.1 – Localization of Bragantina Platform and studied localities (core and outcrops): Capanema, Primavera, Aricuru, Atalaia beach, in Salinópolis and Fortaleza Island, in São João de Pirabas, northeastern Pará state. Modified of Rossetti and Góes (2004).

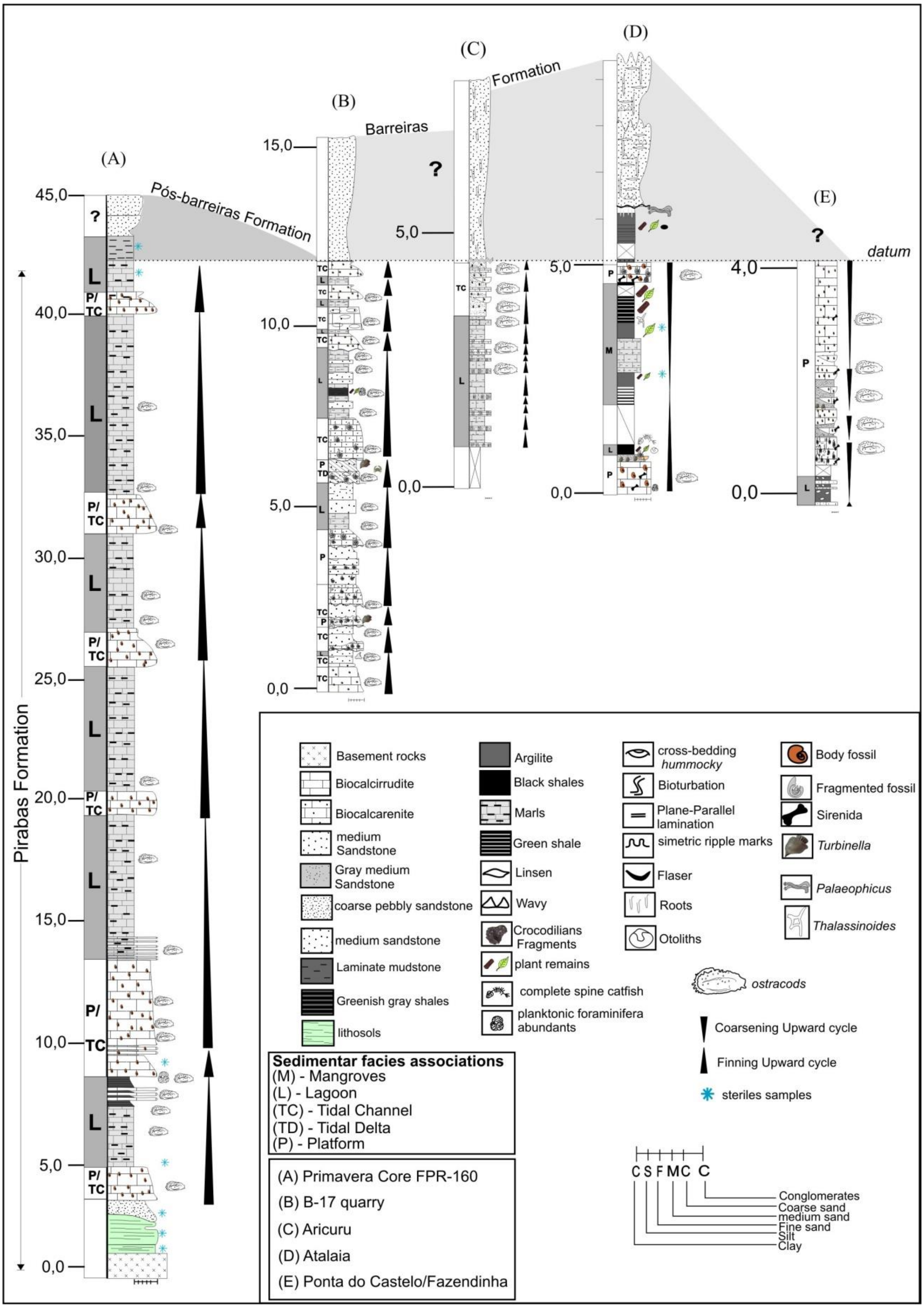


Figure 8.2 – Stratigraphic correlation between the studied sections from Pirabas Formation in the Bragantina Platform. The *lithodatum* in the top of sections is the contact with Neogene and Quaternary deposits follow the stratigraphy proposed by Rossetti and Góes (2004).

The carbonate succession in the drill core FPR-160 is 42 m-thick and overlies very weathered crystalline rocks indicated by muscovite and argillaceous matrix. The succession is comprised of limestone interbedded with gray to yellowish laminated marl and subordinately shales found only in the basal portion of the drill core. The rocks are frequently friable and macrofossils are scarce, generally represented by bivalve molds. Ostracods are frequent in the entire section and in some levels occur with abundant foraminifera (Fig. 8.3).

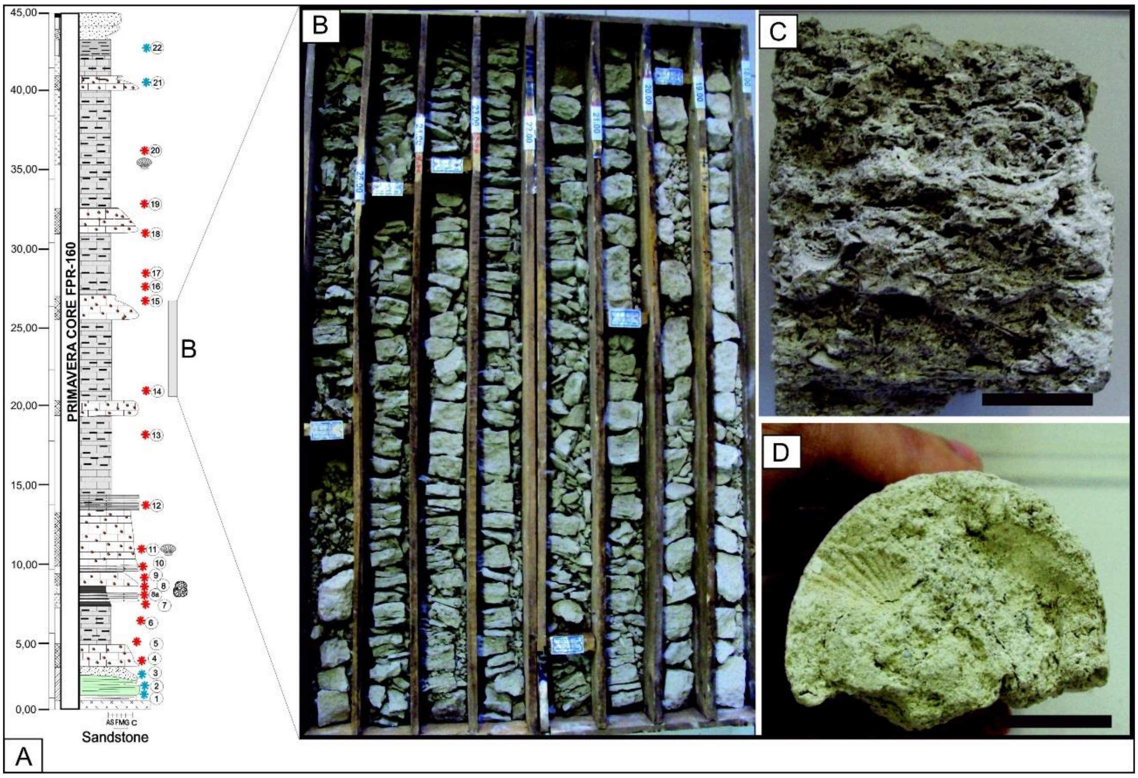


Figure 8.3. Lithofacies aspects of FPR – 160 drill core. A) The carbonate succession and core interval with predominance of marls. C) Biocalcirrudite with shell fragments; D) external mold of bivalve. Scale bar= 3 cm.

The 20 m-thick Pirabas succession in the B-17 quarry, in the Capanema region, is composed of grey limestones, shales and marls interbedded with laminated fine-grained sandstones, biocalcarenites, biocalcirrudites and calcilutites (Fig. 8.4). The interval between the samples B0 and B2 is characterized by biocalcirrudites with complete, fragmented and disseminated macrofossils, as well as, plant remains. B3 to B7 interval have the same facies of B0 to B2 interval including marls and shales with scattered plant remains. The interval between B8 to B11 levels are biocalcarenites with cross-lamination, rare plant remains followed by biocalcirrudites and pelites with carbonate concretions. The upper portion of section (B12 to B13B interval) are deposits with heterolithic beds (*wavy* and lenticular bedding) interbedded with sandstones and mudstone with disseminated and fragmented invertebrate fossils (Fig. 8.4).

Góes *et al*. (1990) interpreted the carbonate succession in B-5 quarry, close to B-17 quarry, as lagoon, tidal channels and, subordinately, platform deposits. The drill core FPR - 160 has similar faciological description where the lagoons interlayed by platform facies dominate. However, in the B-17 quarry the platform facies dominate over the lagoon and the environments are more dynamic indicating wave storms and more litoral with higher energy. The lagoon facies became dominate to the top of the sequence. In the Core, the lagoon facies predominated but are interlayed by the platformal facies showing that lagoon was affected by tidal events and by a short time of the platformal environments established over the entire section (Fig. 8.3).

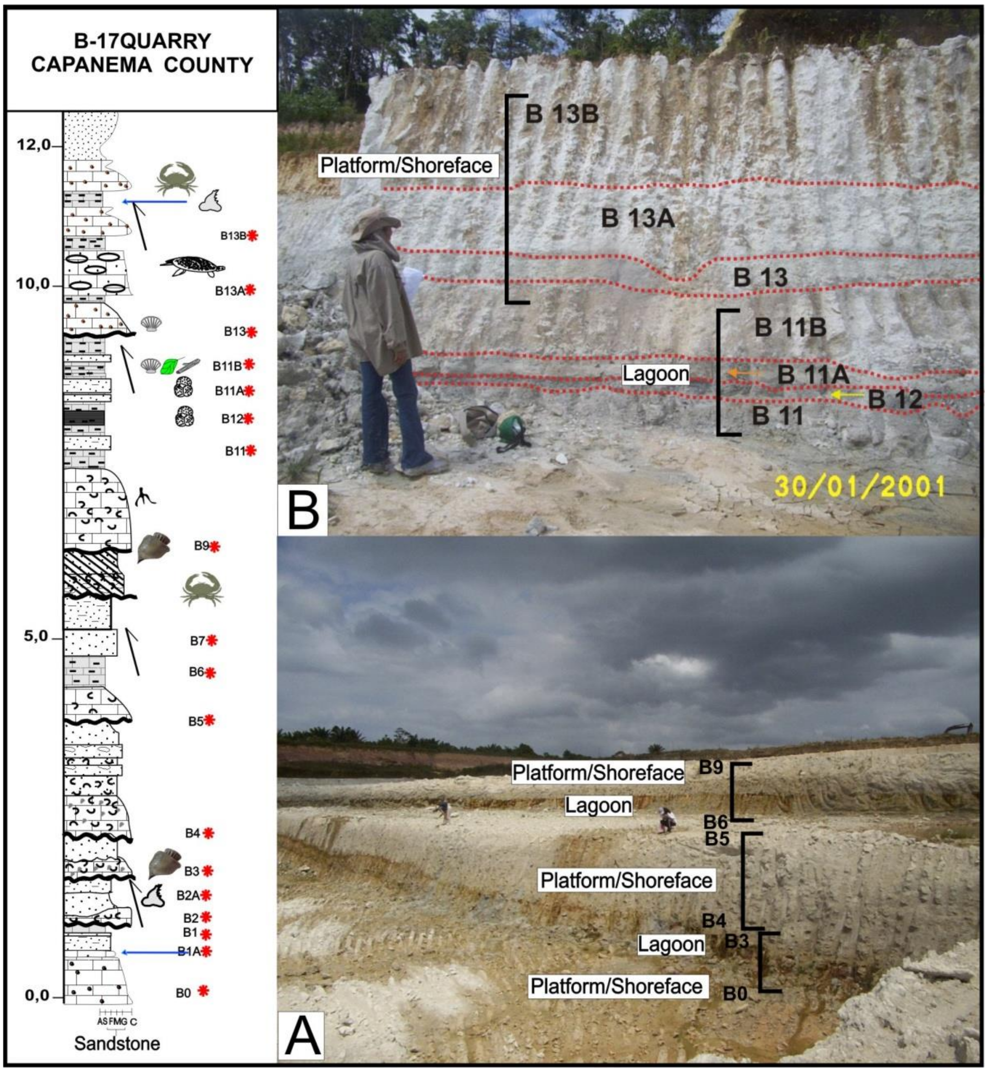
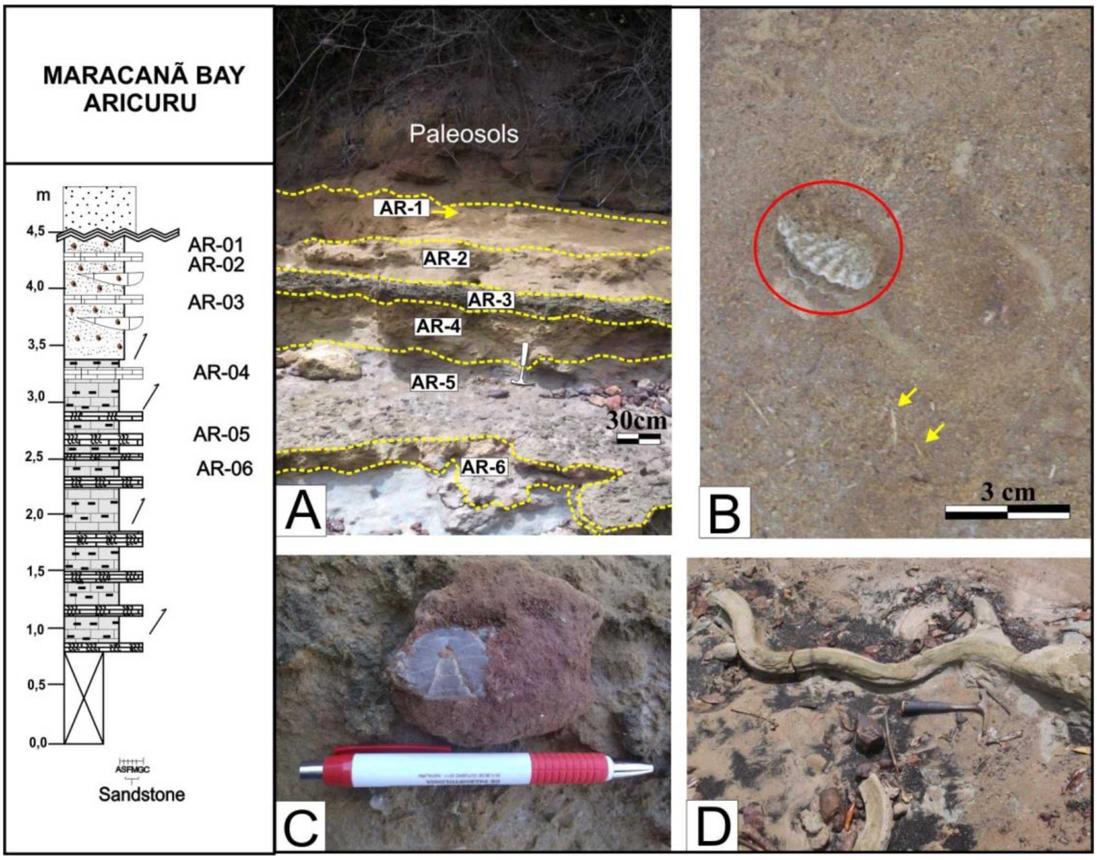


Figure 8.4 – The B-17 quarry in the Capanema County: A) Measured section with indication of colected samples. B) Tabular beds of upper portion of B-17 quarry section. C) Basal portion of section showing alternance of lagoon and platform deposits (After Rossetti and Goés 2004).

The outcrop in Aricuru, in the left margin of Maracanã bay, has extension of 50m and 4m-thick. In the upper part of outcrop, the carbonate rocks are partially wheatered with characteristic yellowish color and friable aspect (Figs. 8.2, 8.5). The lagoon facies characterized by marls predominate in this section but is intercalayed by much lithified *hardground*. In the top of the section the plataform facies dominate and are compose by biocalcirrudites rich in micro and macrofossils (molluscs, bryozoa, arthropods, ostracods and carbonized plants remains) interlayed by levels with *Thalassinoides* and indeterminated ichnofossils that are frequent in biocalcirrudites. Based on this description the Aricuru section is here interpreted as dominated by a lagoon sorrounded by coastal subenvironments.

The other investigated outcrops in this study, with less than 4m-thick, are well-known sections of Pirabas Formation, such as Atalaia, in Salinópolis and the Ponta do Castelo/Fazendinha, Fortaleza Island, São João de Pirabas region (Ferreira 1970, Góes *et al.* 1990, Costa *et al.* 1993, Távora *et al.* 2002) (Fig. 8.2). Although Atalaia beach outcrop is thinner compared to the others, this exhibits an interesting intercalation of biocalcirrudite, marls, green and black mudstones rich in plant remains often pyritized. Macrofossils are abundants in Atalaia comprising mollusca, sirenida, gastropoda, bryozoa and fishes (Góes *et al.* 1990, Aguilera *et al.* 2014). Atalaia section is interpreted as coastal environments with the presence of as lagoons, mangroves and shallow platform.

Although the outcrops in Fortaleza Island, near of São João de Pirabas, are considered as type section of Pirabas Formation, including the Fazendinha and Ponta do Castelo localities, these cover only part of the unit. The figure 8.2D is a composite section of these two localities comprising biocalcarenite, biocalcirrudite and shales interpreted as dominated by shallow platform deposits. The biocalcirrudites exhibt rich fossiliferous framework, with internal molds of gastropods as *Turbinella tuberculata* (Ferreira 1970), pelecypods, echinoderms, coelenterates (*Flabellum*), bryozoans, crustaceans, fishes, reptiles (crocodiles) and mammals (sirenida).



8.5 – Mesaured section of Aricuru outcrop. A) Horizontal limestone beds with the indication of sampling. B) Articulated bivalve (*Chlamys*) in life position and echinoderm spines (yellow arrows) in the AR-1 level (see in A). C) Presence of decaphoda crustaceans (*Brachyura*). D) indeterminated icnofossils in the base of section.

The current sedimentological descriptions and mainly paleoenvironmental interpretation have been analyzed in a large lithological aspect without a better microfacies interpretation. Additionally, the carbonate succession is discontinuously exposed in the Bragantina Platform and the best outcrops are less than 5m thick, hindered the most complete paleonvironmental interpretation for entire succession of Pirabas Formation. Other difficulties are the poorly preservation of these deposits due to the tropical weathering that obliterates the sedimentary structures, leading ambiguous paleoenvironmental interpretation (Góes *et al.* 1990, Rossetti *et al.* 2013). However, based on the literature and in the complementar faciological information described above we resume and adopted here that the Pirabas Formation is deposited in marginal marine environments comprised by subenvironments where predominate two representative facies associations of lagoon and platform with tidal channels, tidal canals and mangrove associated as part of a complex barrier-island system. During the general progradation pattern, P/R cycles in a minor scale occurred during the Oligo-Miocene.

8.4. OSTRACOD PALEOCOLOGY

The ostracods from Pirabas Formation present a very high diversity represented by 23 families, 64 genera and 119 species illustrated in the paper Nogueira and Ramos , submitted B and more 29 species not illustrated in that paper. Thus, this study presents 146 species for application of abundance relative data (Figs. 8.6, 8.7, 8.8F). From these families, Cytherideidae, Bairdiidae, Thaerocytheridae, Hemicytheridae and Cytherellidae are the most representatives in the studied sections presenting a total of 42% of the genera (Fig. 8.8F). The most of these are typical of infralittoral marine environments around the world. However, two genera of the Cytherideidae Family are represented by a relatively high number of species: *Perissocytheridea* (11 species; see Nogueira and Ramos, submit.) which is common in more restricted environments as lagoon and estuaries and *Haplocytheridea* (10 species) one of the most common and abundant genus in the Pirabas (Nogueira *et al*. 2011) is typical of tropical carbonate platform indicating shorelines. The great majority of the genera are represented by more than one species (Nogueira and Ramos, Submitted b). Of the 120 identified species, 89 were relatively abundant (>10 specimens) and are considered herein; the remaining 31 were very rare and will be also discussed in this paper.

In each locality, there is a specific variation in abundance among species. In the Aricuru section the most abundant species are: *Jugosocythereis pannosa* (58%), *Quadracythere brachypygaia* (15%) and *Dameriacella*? *caudata* (9%). In the B-17 quarry: *Haplocytheridea variopunctata* (28%), *Cytheretta parva* n. sp. (13%), *Pontocypris* aff. *P.* ex. group *dreikanter* (13%) and *Bairdoppilata pintoi* n. sp. (11%) are more abundant and in the Primavera core: *Pellucistoma magniventra* (42%), *Haplocytheridea sandbergi* (18%) and *Haplocytheridea variopunctata* (11%). In the others localities, Fortaleza Island, the species *Bairdoppilata dorsoarcuata* n. sp. (24%), *Quadracythere limbilepida* n. sp. (19%), *Callistocythere* sp. (14%) and *Neonesidea* sp.1 (14%) and in the Atalaia beach outcrop, *Bairdoppilata pintoi* n. sp. (64%), *Coquimba congestocostata* (13%) and *Jugosocythereis pannosa* (7%) are the most abundant species.

In general, the highest relative abundance of the species in the representative studied sections (Figs. 8.6 and 8.7) was recorded for *Bairdoppilata pintoi* n. sp. (14%), *Haplocytheriidea variopunctata* (12%), *Cytheridea coimbrai* (9%), *Jugosocythereis pannosa* (7%), *Dameriacella*? *caudata* (6%), *Quadracythere brachypygaia* (5%), *Pellucistoma magniventra* (4%) and *Pontoleberis dactylotypa* (4%). Although these species are typically of infralitoral environments, they are commonly more abundant in the lagoon facies that is well represented in the studied sequences of Pirabas Formation (8.8A to E).

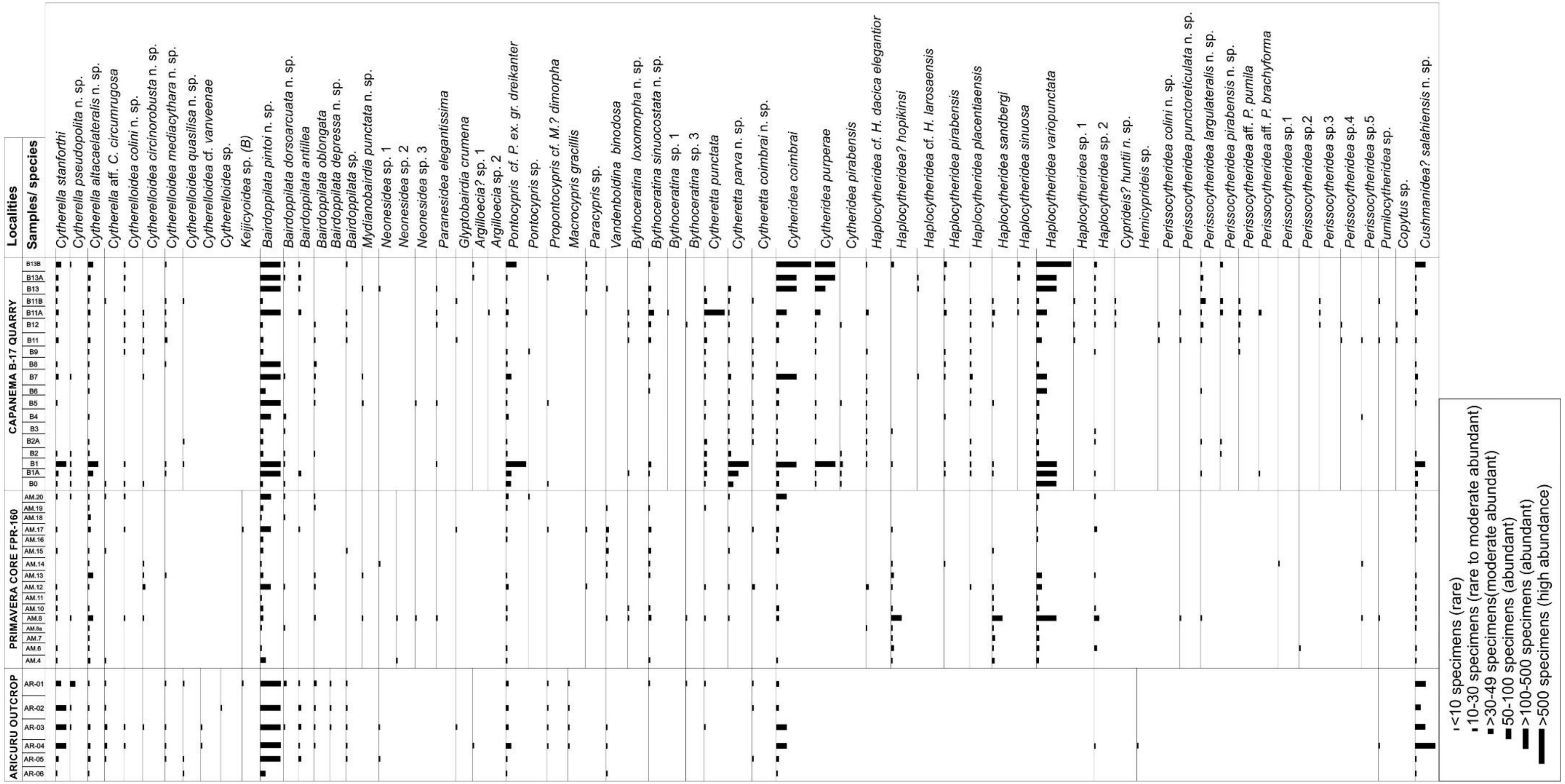


Figure 8.6. Relative abundance of the ostracods from more representative localities: B17-Quarry (Capanema), FPR-160 core (Primavera) and Aricuru outcrop.

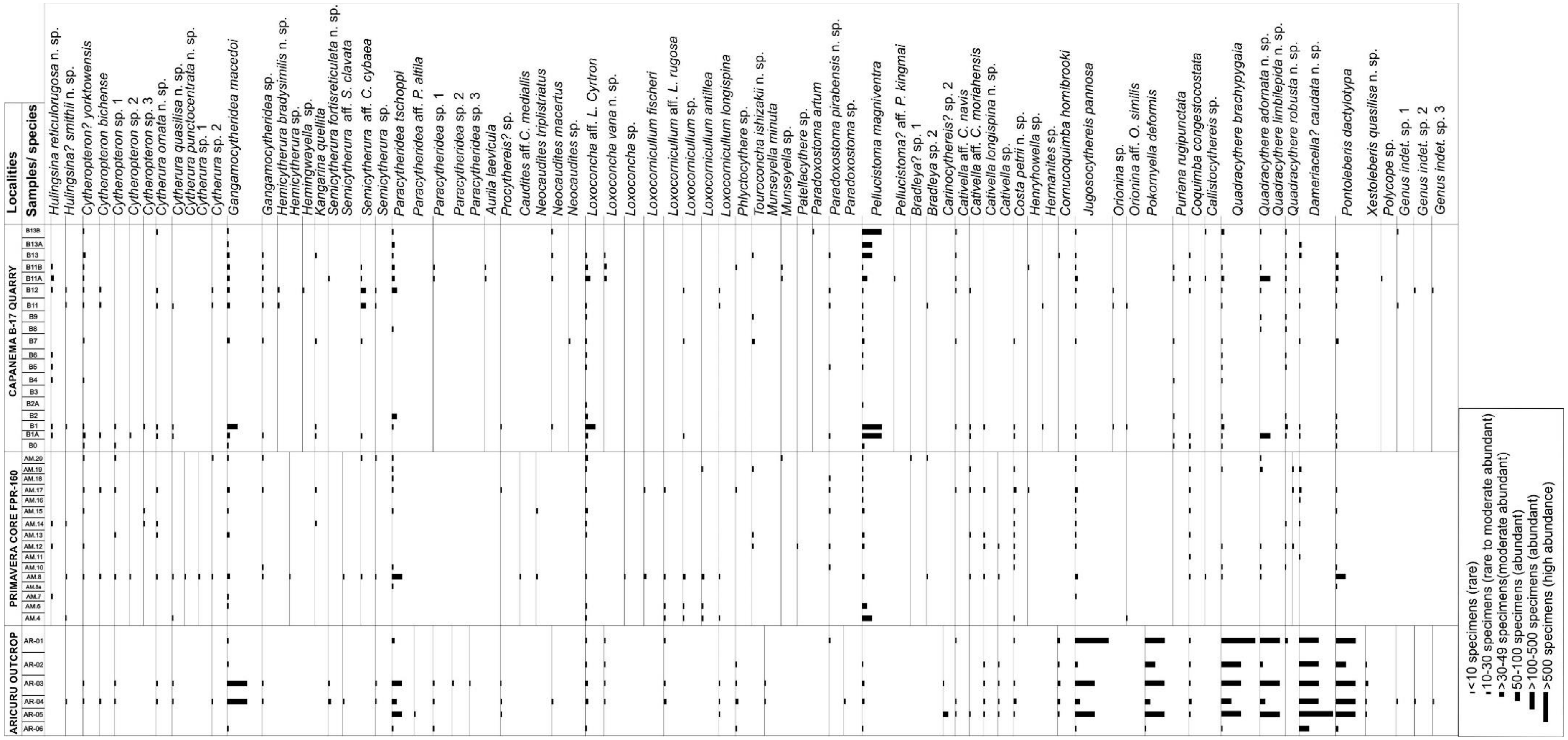


Figure 8.7. Relative abundance of the ostracods from more representative localities: B17-Quarry (Capanema), FPR-160 core (Primavera) and Aricuru outcrop (continuation of Figure 8.6).

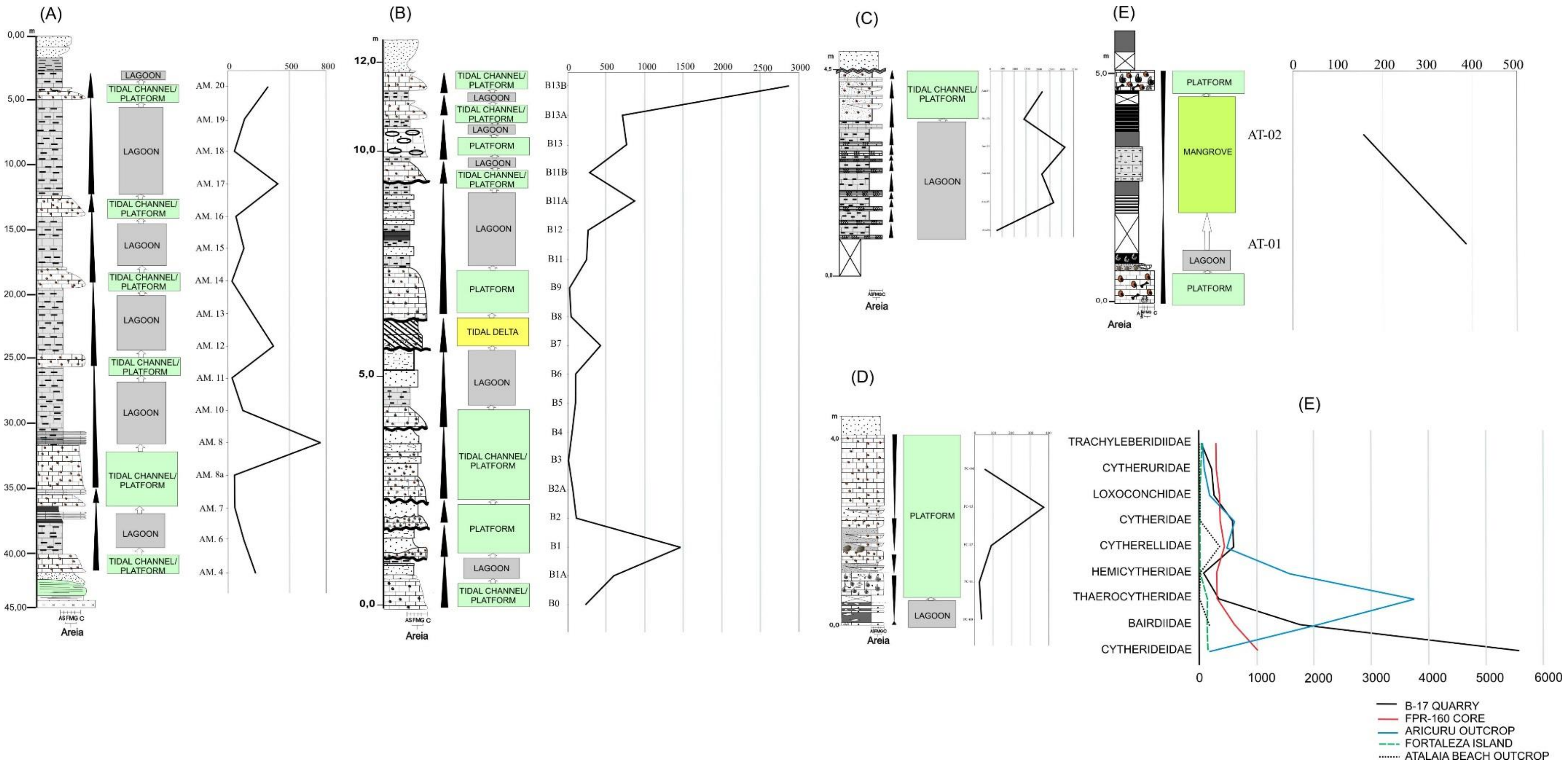


Figure 8.8. Abundance of the ostracods and respectives families from the five localities in this study:A) Primavera locality; B) B-17 Quarry; C) Aricuru outicrop; D) Fortaleza Island locality; E) Atalaia beach locality and F) Abundance of the main families in the five localities.

Based on the facies identified in the studied sections, three ostracods associations is recognized here (Fig. 8. 9). A and B from the Lagoon Facies; and C correspond to Tidal channel/Platform Facies.

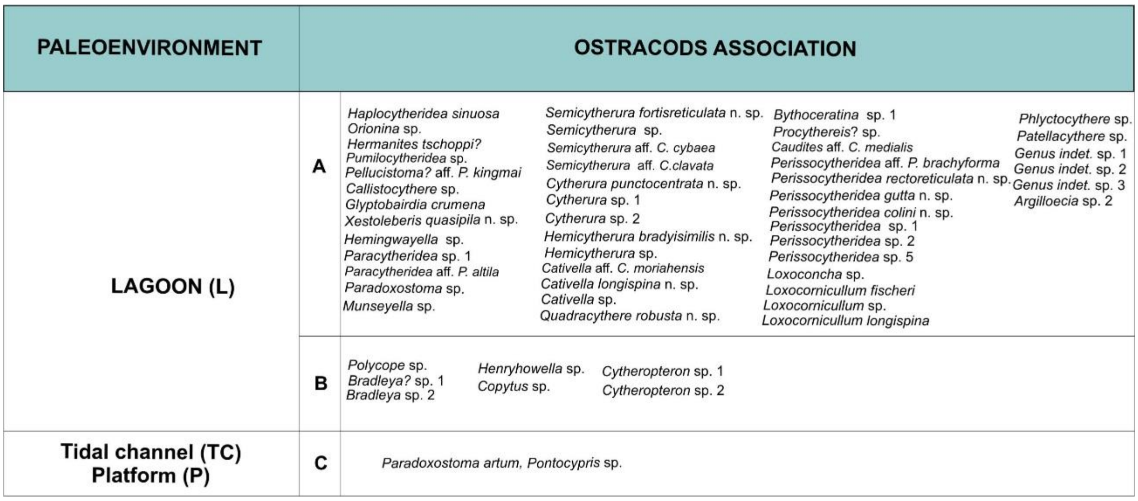
The Lagoon Facies (L) is the richness in Ostracoda comprised by the most genera identified through the studied sections. The generic association is typical of shallow platformal to trasitional environments. Cytheruridae, Cytheridae and Cytherideidae provide most of the species present. Representatives of these families are typical of infralittoral and marginal marine environments around the world (Machado *et al*. 2005).

However, the most of the genera occurring in this facies (i.e. *Loxoconcha*, *Callistocythere*, *Pellucistoma* and *Paracytheridea)* are common to occur in a more restrict environments as lagoons (Dias-Brito *et al*. 1988, Coimbra *et al*. 1999a). Besides of these genera, the presence of typical mesohaline genera as *Perissocytheridea* showing a relative salinity decrease and a more restrict environment. On the other hand, the rare presence of *Cyprideis* and the eroded features of this genus show that the lagoon was close to estuaries. The high concurrence in the lagoon predominated by marine taxa do not allowed the flourishment of *Cyprideis*.

Also this facies was divided in two ostracod association: A) characterized by genera that predominates in shallow platformal to lagoon; and B) is characterized by genera typical of more deep water genera as *Polycope*, *Bradleya*, *Henrywoella*, *Copytus* and *Cytheropteron*. Although these genera can also occur in shallow platform they normally do not occur in the lagoons. The rare presences of genera typical of offshore in the Lagoon Facies indicate the connection of the lagoon with the open sea. Its presence into the lagoon is probably alloctone (Fig.8.9).

The Tidal Channel/Platform Facies (TC/P) presents decreased ostracod abundance although the most of platformal genera also occur. The absence or rarity of the genera commonly found in more restricted environment (e.g. *Perissocytheridea* and *Cyprideis*) show a greater instability and higher energy in this facies common in litoral area. Species as *Paradoxostoma artum* Bold, 1966 and *Pontocypris* sp. were diagnostic to support a higher energy environment with presence of a more coarse grains characteristic of this facies (Fig. 8.9, association C). The species of *Paradoxostoma* are an important component of marine and estuarine ostracod faunas throughout the world (Horne and Whittaker 1985, 2008; Yoo *et al.* 2014).

The presence of *Paradoxostoma* and *Pontocypris* attest the influence of tidal channels into the lagoon. These genera present a high abundant and had preferencial occurrence in the levels correspondent to this facies and represents here the C Association (Fig. 8.9).



PALEOENVIRONMENT	OSTRACODS ASSOCIATION	
LAGOON (L)	A	*Haplocytheridea sinuosa* *Orionina* sp. *Hermanites tschoppi?* *Pumilocytheridea* sp. *Pellucistoma?* aff. *P. kingmai* *Callistocythere* sp. *Glyptobairdia crumena* *Xestoleberis quasipila* n. sp. *Hemingwayella* sp. *Paracytheridea* sp. 1 *Paracytheridea* aff. *P. altila* *Paradoxostoma* sp. *Munseyella* sp. *Semicytherura fortisreticulata* n. sp. *Semicytherura* sp. *Semicytherura* aff. *C. cybaea* *Semicytherura* aff. *C.clavata* *Cytherura punctocentrata* n. sp. *Cytherura* sp. 1 *Cytherura* sp. 2 *Hemicytherura bradyisimilis* n. sp. *Hemicytherura* sp. *Cativella* aff. *C. moriahensis* *Cativella longispina* n. sp. *Cativella* sp. *Quadracythere robusta* n. sp. *Bythoceratina* sp. 1 *Procythereis?* sp. *Caudites* aff. *C. medialis* *Perissocytheridea* aff. *P. brachyforma* *Perissocytheridea rectoreticulata* n. sp. *Perissocytheridea gutta* n. sp. *Perissocytheridea colini* n. sp. *Perissocytheridea* sp. 1 *Perissocytheridea* sp. 2 *Perissocytheridea* sp. 5 *Loxoconcha* sp. *Loxocornicullum fischeri* *Loxocornicullum* sp. *Loxocornicullum longispina* *Phlyctocythere* sp. *Patellacythere* sp. *Genus indet.* sp. 1 *Genus indet.* sp. 2 *Genus indet.* sp. 3 *Argilloecia* sp. 2
	B	*Polycope* sp. *Bradleya?* sp. 1 *Bradleya* sp. 2 *Henryhowella* sp. *Copytus* sp. *Cytheropteron* sp. 1 *Cytheropteron* sp. 2
Tidal channel (TC) Platform (P)	C	*Paradoxostoma artum*, *Pontocypris* sp.

Figure 8.9 - Ostracods associations distributed following the paleoenvironmental interpretation to Oligocene-Miocene Pirabas Formation.

The ostracod association from Pirabas studied sections is features of lagoon, infralitoral and shallow marine environments mainly represented by species of the *Haplocytheridea*, *Cativella*, *Quadracythere*, *Loxoconcha*, *Glyptobairdia*, and also genera of the Cytheruridae, Xestoleberidae, Loxoconchidae and Hemicytheridae families (Stephenson 1946b, Bold 1971a, Keij 1973, Maddocks 1969, Palacios-Fest and Gío-Argáez 1979). Paleoecologically the infralitoral ostracod fauna occurs about 0–40 m depth (Breman 1975, Zorn 2003) and could reach up 75 m depth (Keen *et al.* 1994). Generally, the shallow marine ostracods occur also in the lagoon environments that normally present higher diversity and abundance of ostracods (Garbett and Maddocks 1979, Ramos *et al.* 1999, Machado 2005; see Fig. 8.10).

According to model from the Holocene of Texas bay the Lagoonal associations showed greater diversity than the estuarine, reflecting higher and more stable salinities in this eccosystem. In addition, areas with strong currents and coarser shifting substrates as inlet zones (tidal channel) presented lower diversity than the rest of lagoon and often even lower than the estuary (Garbett and Maddocks 1979).

The model above can be applied to the interpretation of the paleoenvironmental evolution of the Pirabas Formation where the higher abundance and diversity of the ostracods predominante in the lagoonal environments, with finer grains and lower energy to the top of the unit although tidal channel/platform occur interlaid and are more represented in the base of the sequence. In this last facies, the abundance and diversity are lower, coarser grains and higher energy.

In general, according to previous studies~~,~~ the type of sediment is also an important factor controlling the distribution and abundance of ostracods in the lagoons; a highest number occurring in finer sediments as silt and very fine- to fine-grained sands beyond of clays.

The grain size is one of the significant factors controlling the population structure, density and distribution of ostracod species. The fine-grained sands with a high percentage of silt and clay common in the lagoons are in favor to the ostracod proliferation (Benson and Maddocks 1964, Puri 1966, Dias-Brito *et al.* 1988, Montenegro *et al*. 1998, Coimbra *et al*. 1999a, Ramos *et al*. 1999, Machado *et al*. 2005). As previously mentioned, Lagoon facies in this study is represented by more fine and clay grains and a greater number of species restricted to this facies as showed in the associations A (Fig. 8.9).

The dynamic of environment is also an important pharameter to consider related to the ostracods distribution and abundance. In the case of Pirabas Formation it is related to the complexity of barrier-island system and to the P/R cycles. These factors also reflect in the environmental seasonality periods when the lagoon is more confined or when it receives greater marine influence due to variation in tides (Fig. 8.11). Normally, high energy and coarser sediments in the environment, for example, by tide or waves action in shallow waters, causes instability in the substrate and, consequently, brings about the absence or reduction of number of species, with implications in the low preservation degree (Whatley *et al.* 1995; Ramos *et al.* 1999, Smith and Horne 2002).

Other important factor that influencied the ostracod assemblage from Pirabas Formation is the temperature. This unit was deposited in warm, clear and shallow water, rich in carbonate, typical of tropical regions. The presence of genera as *Cythelloidea*, *Hermanites*, *Quadracythere* and *Cytheretta* typical of warm waters and numerous others thermophilic genera reflect the warm waters conditions to the Oligo-Miocene deposits of Pirabas Formation. It is common to occur in others parts of the world, as in Europe and North Atlantic (Coles 1990).

Based on those factors that influence the distribution of ostracod, the paleoenvironmental evolution is perfectly understood during the Oligo-Miocene of

Pirabas Formation. The highest abundance and diversity of ostracods in association A, as explaned, is due to the lesser dynamic and lower energy typical to lagoon environment. In contrast, the lowest abundance of ostracods in the associations B and C can be explained by the great dynamic and higher energy environments common in the littoral. Whatley *et al.* (1995) and Ramos *et al.* (1999) discuss the absence or the lowest number of species in shallower samples, closer to the coast, as the result of the instability of the bottom sediments due to the wave action. Some species have well-developed populations on sediments with very different textural characteristics. The diversity of the fauna distinctly decreases in areas with coarsy sediments. Only a few species were able to inhabit such environments (Montenegro *et al.* 1998, Coimbra *et al.* 1999a, Machado *et al.* 2005).

Some genera are widely distributed along the entire section and are the most common and abundant in the studied sections as *Haplocytheridea, Bairdopillata, Cytherella, Quadracythere* and *Jugosocythereis.* With respect to the genus *Haplocytheridea* which is characteristic of tropical waters and indicate carbonatic and *shorelines* deposits (Nogueira *et al.* 2011). These genera are not selective to phisical-chemistry characteres. In general, others 75 species recorded in this work which were not cited in the Fig. 8.9, do not showed a preferencial facies what probably they could have been reworked or even have this plasticity to the salinity.

Others taxa are more restrict and helpfull to interpret the paleoenvironments. Bairdiidae (*Neonesidea, Paranesidea* and *Glyptobairdia*) is more diverse and abundant in shallower waters (<40m) than deep waters, commonly ocurring in normal salinities about 30.0 to 38.0 psu and warm waters (Kornicker 1961, Ramos *et al.* 2004b, Coimbra *et al.* 1999a, Ertekin and Tunoğlu 2008).

Most families had rarity of species, for example, Leptocytheridae which had only one representative species of the genus *Callistocythere* occurring in Lagoon facies in the present study. This genus is mainly recorded from shallow water and warm environments (Morkhoven 1963). Mckenzie *et al.* (1979) and Ducasse and Cahuzac (1996) assign some species of *Callistocythere* to the infralittoral. In the Adriatic Sea, *Callistocythere flavidofusca* (Ruggieri 1950), which is most similar to *C. canaliculata,* does not exceed 119 m and is very abundant at a depth of 70 m (Bonaduce *et al.* 1975). Species of *Callistocythere* have a wide geographic distribution in different facies along the Southern Brazilian shelf and are more commonly, but not exclusively found in waters shallower than 80 m (Coimbra *et al*. 1999a, 1995, Aiello *et al*. 2004). Coimbra *et* *al.* (1999a) recorded species of this group along to the North equatorial coast of Brazil which they had more preferences to the biodetrital sand facies (7-75m to 75-100m depths) than quartz sand facies (7-50m depth).

The Cytheruridae family, on the other hand, has eighteen species with a high diversity; however, its abundance is not so representative in the present study. In recent samples from the Northern coast of Rio de Janeiro, representatives of this family were reported into the fine-grained sands where its highest abundance is associated (Ramos *et al.* 1999). Probably the abundance of genera representative of this family is not influenced by the grain size, but by others factors as temperature and salinity. Its rarety in the samples of this study represent that this family is more adapted to offshore environments.

Some representative taxa of the families Cytheruridae, Thaerocytheridae, Trachyleberididae, Polycopidae and Neocytherideididae (i.e., *Cytheropteron* sp. 1, *Cytheropteron* sp. 2, *Bradleya*? sp. 1, *Bradleya* sp. 2, *Henryhowella* sp., *Polycope* sp., and *Copytus* sp., respectively) are presented in the association B (Fig. 8.9) that occur in deeper waters as in outer shelf to slope according to previous models as mentioned above and also according to previous studies (Mazzini 2004, Southweastern Pacific, Yasuhara *et al.* 2009, to South and North Atlantic, Stepanova and Lyle 2014 to Easter Equatorial Pacific). These taxa are thought to be allochthonous and are represented by a rare number of valves in the samples. Probably they were reworked and carried out to into the lagoon during episodic storm events. Moreover, *Polycope*, *Cytheropteron* and *Henryhowella* species from Mersin offshore sediments, Turkey, Eastern Mediterranean (Pleitocene-Holocene) are recorded in a deepest part of this region with dominance of *Polycope* spp. and *Cytheropteron* spp. and relative common presence of species *Henryhowella asperrima asperrima* (Reuss, 1850) Bold, 1960. This community is recognized within that area as an association of circalittoral to upper bathyal environments in the Mediterranean Sea (Ertekin and Tunoğlu, 2008). The Adriatic Sea, Gela (Sicily) and Bay of Naples ostracofauna also showed this generic association related to a deeper water paleoenvironments (Müller 1894, Aiello *et al.* 2000, Bonaduce *et al.* 1975).

Although Drozinski *et al.* (2003) also recorded some of these genera in shallow waters (*Polycope*, *Bradleya*, *Cytheropteron*, *Copytus* and *Henryhowella*), the paleoenvironmental reconstruction already described for the Pirabas discards the occurrence of a deep-sea paleoenvironment (Góes *et al.* 1990, Rossetti and Góes 2004).

Besides of the common presence of *Perissocytheridea* species in the same samples indicating lower salinities and the proximity of the coast (Nogueira and Ramos, Submitted Manuscript A in this work). In general, the lagoon is constituted by warm, quiet and well oxygenated water as the most of the genera that occur in Pirabas Formation are typical of tropical waters commons to the Neogene Carbonate platform of Caribean region.

Resuming the sedimentar evolution and micropaleontological data reveal the superposition of the inner shelf with progressively more coastal environments indicating an overall progradational pattern according to Góes *et al.* (1990). Essentially, this sedimentary sequence is typical of a marginal marine environments deposited in a complex barrier–island system during P/R cycles in the Oligo-Miocene (Fig. 8.10).

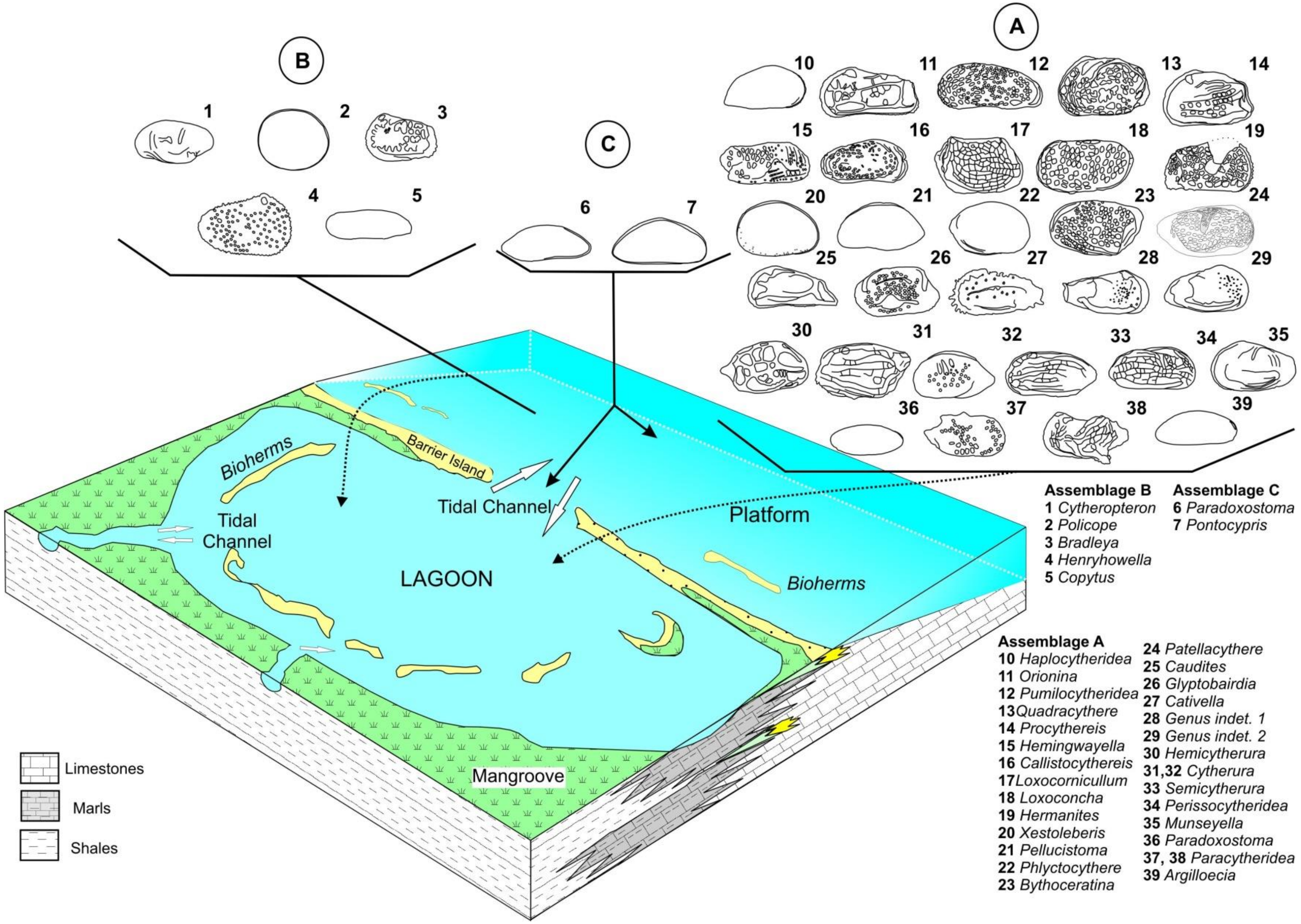


Figure 8.10 – Ostracod associations restrict to the Pirabas Formation and facies related.

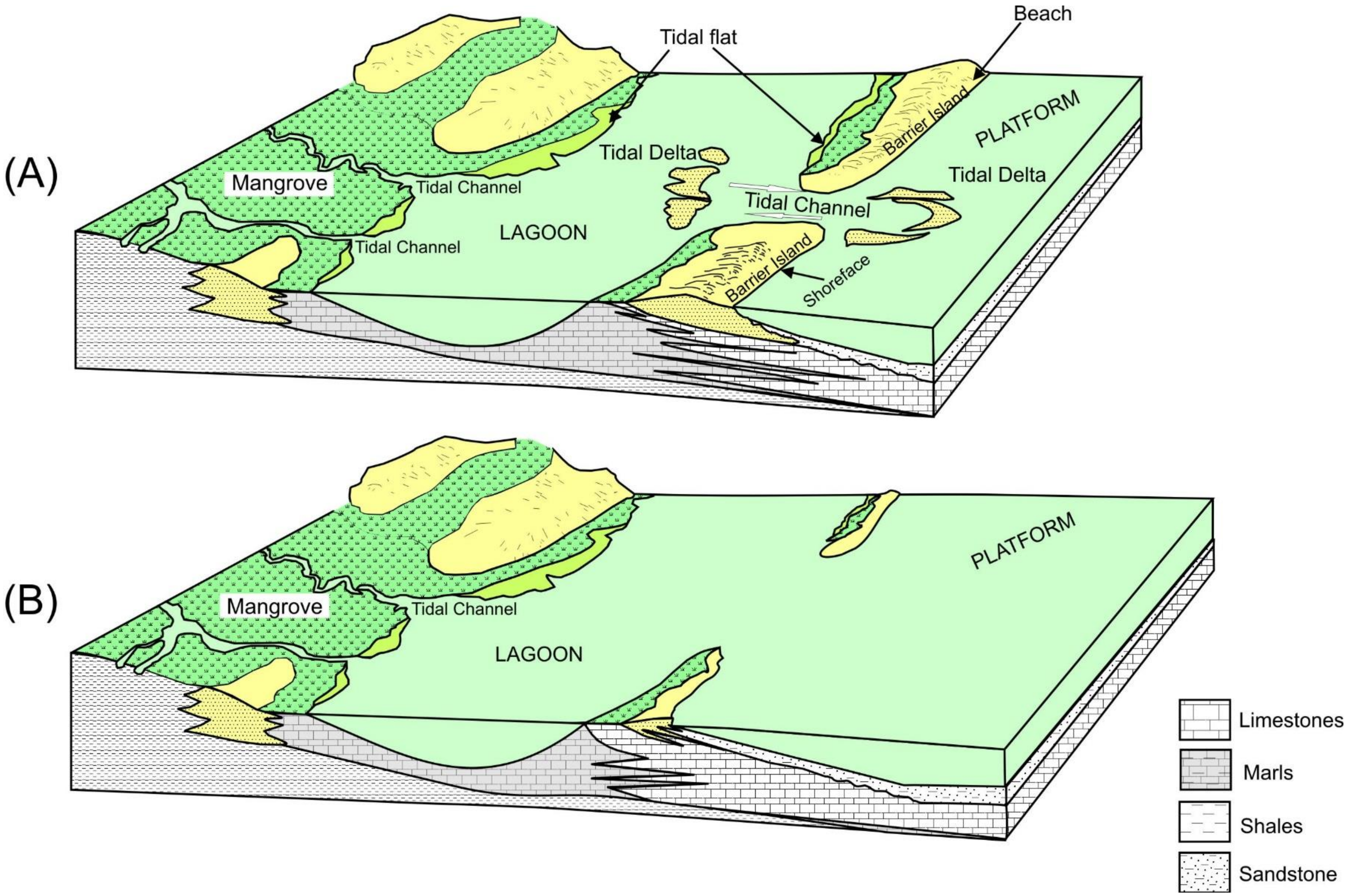


Figure 8.11. Paleoenvironmental evolution model to the Pirabas Formation showing the P/R cycles during the Oligocene-Miocene: A) Lagoon facies deposition associated to Tidal Channel and Delta facies and B) Platfom facies deposition (Adapted from Reinson, 1992).

8.5. BIOSTRATIGRAPHY

8.5.1 Previous Works

Microfossils studies in the Pirabas Formation related to the bioestratigraphical data has been based on planktonic foraminifera assigning an age from Lower miocene, which are compared to those recorded in strata of the Caribbean Region (Ferreira *et al.* 1978, Petri 1957, Fernandes 1984, Fernandes and Távora 1990, Távora and Fernandes 1999, Leite *et al.* 1997a, b, Távora *et al.* 2007, 2010, Aguilera and Paes 2012, Vicalvi and Ferreira 1992). However, the Pirabas Formation was also dated from Upper Oligocene to Lower Miocene based on planktonic foraminifera and benthic macroforaminifera by others studies (Ferreira *et al.* 1981, Ferreira *et al.* 1983, Ferreira *et al.* 1984) beyond of geological studies (Rossetti 2001), as well as, the important index species of Oligo-Miocene *Globorotalia kugleri*, collected from boreholes carried out in the Bragantina region and Belém city. Furthermore, in this unit were also recorded planktonic foraminifera of the Lower Miocene, including *Globigerinoides primordius*, *Globigerinoides aliaperturus* and *Globigerinoides trilobus trilobus* (Petri 1957; Fernandes 1984, Fernandes and Távora 1990, Távora and Fernandes 1999). This planktonic foraminifera association allowed the correlation of the Pirabas Formation with the Early Miocene global biozones N4 and N5 (Blow 1969, Ferreira *et al.* 1978, Fernandes 1988). Nannofossils as *Helicosphaera ampliaperta* (Lower Miocene) supported this range to the Pirabas Formation (Ferreira 1966), as well as, the pollen *Crototricolpites annemariae*, *Echitricolporites maristellae*, and *Polypodiaceoisporites potoniei* of Early Miocene (Leite 2004). These pollen species are compatible with the Hoorn's (1993) concurrent range zone of *Psiladiporites–Crototricolpites* (Leite 2004), considered as marker of Miocene in the northern of South America (Regali *et al.* 1974).

The ostracods were firstly recognized by Macedo (1970 and 1971) indicating the index species *Cativella navis*, *Orionina bermudae*, *Puriana elongorugata* and *Cyprideis mayi*, all of them restricted to Miocene. The index species *Cytherura* cf. *swaini* Bold, 1963, *Kangarina* cf. *K. ancyla* Bold, 1965, *Paradoxostoma* cf. *artum* Bold, 1966, *Munseyella minuta* Bold, 1946, *Paranesidea elegantissima* Bold, 1946 and *Costa variabilocostata variabilocostata* Bold, 1966, commonly described to the others Miocene unities from Caribbean region, were also recorded to Pirabas Formation (Távora 1994c, Ramos *et al.* 2004a).

8.5.2. The Carribean biozones and its relation with Pirabas succession

According previous studies concerned to biostratigraphy of ostracods from Caribbean region (Bold 1963a and b, 1966b, 1972b, 1975d, 1983, 1988), sediments post-Eocene were recognized and dated. Thus, a bioestratigraphical model was proposed correlating shallow-marine ostracods and planktonic foraminiferal zonation (Blow 1959 and 1979), being possible to identify biozones based on ostracods index species.

Within the Caribbean region, primaries zones were established which range comprise from Oligocene to Quaternary as follow:from older to younger system: a *Pokornyella* "*saginata*"/*laresensis* TRZ (Oligocene to early Miocene), *Procythereis* cf. *deformis* (Reuss) TRZ (early to middle Miocene), *Radimella confragosa* Partial Range Zone (Pliocene) and *Radimella wantlandi* TRZ (Quaternary).But also were recognized a secondary system or subzones, more independent, whereas others straddle the boundary between primary zones and therefore could form concurrent range zones in combination with the primary zones: *Loxoconcha lienenklausi* PRZ (Oligocene), *Triebelina howei* TRZ (latest Oligocene), *Hermanites tschoppi* PRZ (early Miocene), *Triebelina crumena* TRZ (early Miocene), *Aurila amygdala* PRZ (early to middle Miocene), *Hermamtes hutsoni* (middle Miocene) and *Coquimba congestocostata* TRZ (middle Miocene to Pliocene). This last one species fills the gap between the extinction level of *Procythereis*? *deformis* and the appearance of *Radimella confragosa* and thereby could be considered as a primary zone in late Miocene (Bold 1983).

Based on study of Bold (1966b) a general zonation over a wide area was stablished: the *Mutilus confragosus* (Edwards) Total Range Zone (late Miocene to Recent) and the *Procythereis*? *deformis* (Reuss) TRZ (early to middle Miocene). The latter, at the time, was believed to extend from the *Globigerinatella insueta* zone up to the *Globigerina nepenthes* zone of Blow (1959). Later these ranges were adjusted and refined (Bold 1972b), but no further zones or subzones were established, mainly because it become apparent that many short-ranged species had only limited geographical distribution and could not be used for zonations that were valid throughout the Caribbean province (Bold 1970b).

According to Bold (1983), species ranges have some apparent overlap that have in fact never been found together in the same beds, as he did a compilation of different geological units. Here, we use a combination of species record by Bold with more restricted range within Pirabas studied sequences.

Thus *Cytherella stainforthi* was selected to mark the base of the sequence of Pirabas Formation as it was the species with oldest record to the Caribbean units, ranging from Late Eocene to Late Oligocene (Bold 1960).

In this case, the first occurrence of *Cytherella stainforthi* was used to mark the beginning of the Upper Oligocene, on the base of Primavera core. *Cytherella stainforthi* was recorded to the San Fernando Formation (Upper Eocene to Upper Oligocene) from Trinidad in the P15 to N3 zones of Blow and in the Lower Cipero Formation (Oligocene) from Trinidad, in the P22 to N3 zones of Blow (Bold 1960); *Quadracythere brachypygaia* was recorded for the Upper San Sebastian Formation (Upper Oligocene to Lower Miocene) and Lares Formation (Lower Miocene) from Puerto Rico, in the N3 to N6 zones (Bold 1983 and 1988). Although, the first appearance of both of these species indicate late Oligocene (N3 zone), a combined overlaps range of these species indicate between N3 to N6 zones suggesting an Oligo-Miocene age to the Pirabas Formation. Besides of the most of species co-occurs with exclusive species index, as *Neocaudites*? *macertus* and *Glyptobairdia crumena* from Early Miocene, especially in the FPR-160 core section and B-17 quarry. Based on it, the most of Pirabas sequence cover the Early Miocene age.Thus, the species *Neocaudites*? *macertus* also allowed to determinate the range from the B-17 quarry mainly supporting the Early Miocene to the most of the sequence of Pirabas Formation (Fig. 8.12).

The Lower Miocene was indicated mostly by the first occurrence of *Glyptobairdia crumena* characterized by restricted range between N5 and N6 zones (Fig. 8.13), but this species may extends to the N7 zone according to Bold (1983). Therefore, this index species is present as subzone or secondary zone indicating the Early Miocene age (Bold 1988). These observations suggest that all exposed rocks of the outcrops in the coastal zone have Early Miocene age in the uppermost part of the Pirabas Formation and that are probably not younger than N7 (Fig. 8.12).

The biozona *Pokornyella “saginata”* (*sensu* Bluter)/ *P. laresensis* described by Bold (1983) was cited in previous studies for the Pirabas unit (Távora *et al.* 2001), in which some species index were recorded as subzones for the Aricuru locality into this biozone as *Hermanites tshoppi*? and *Cushmanidea howei*. These biozones corresponds to the N4 zone of Blow (1969) that were considered as subzones into the primary biozone *Pokornyella saginata”* (*sensu* Bluter) / *P. laresensis*. Posteriorly, this biozone was newly named to the *Pokornyella poagi/ P. laresensis* by Bold (1988). Futhermore, these index species were not recorded in this work mainly *Cushmanidea howei* ; a similar species to *Hermanites tschoppi* was recorded but due to the few specimens found was not possible to confirm its identification. However, although this problematic exist, tentativelly a new biozonation was proposed to the Pirabas Formation, based on Bold (1988) using the others species index identified in the Pirabas, mainly those were also recorded to the Caribbean region, thus allowing to extend this biozonation to the Brazilian Northern coast.

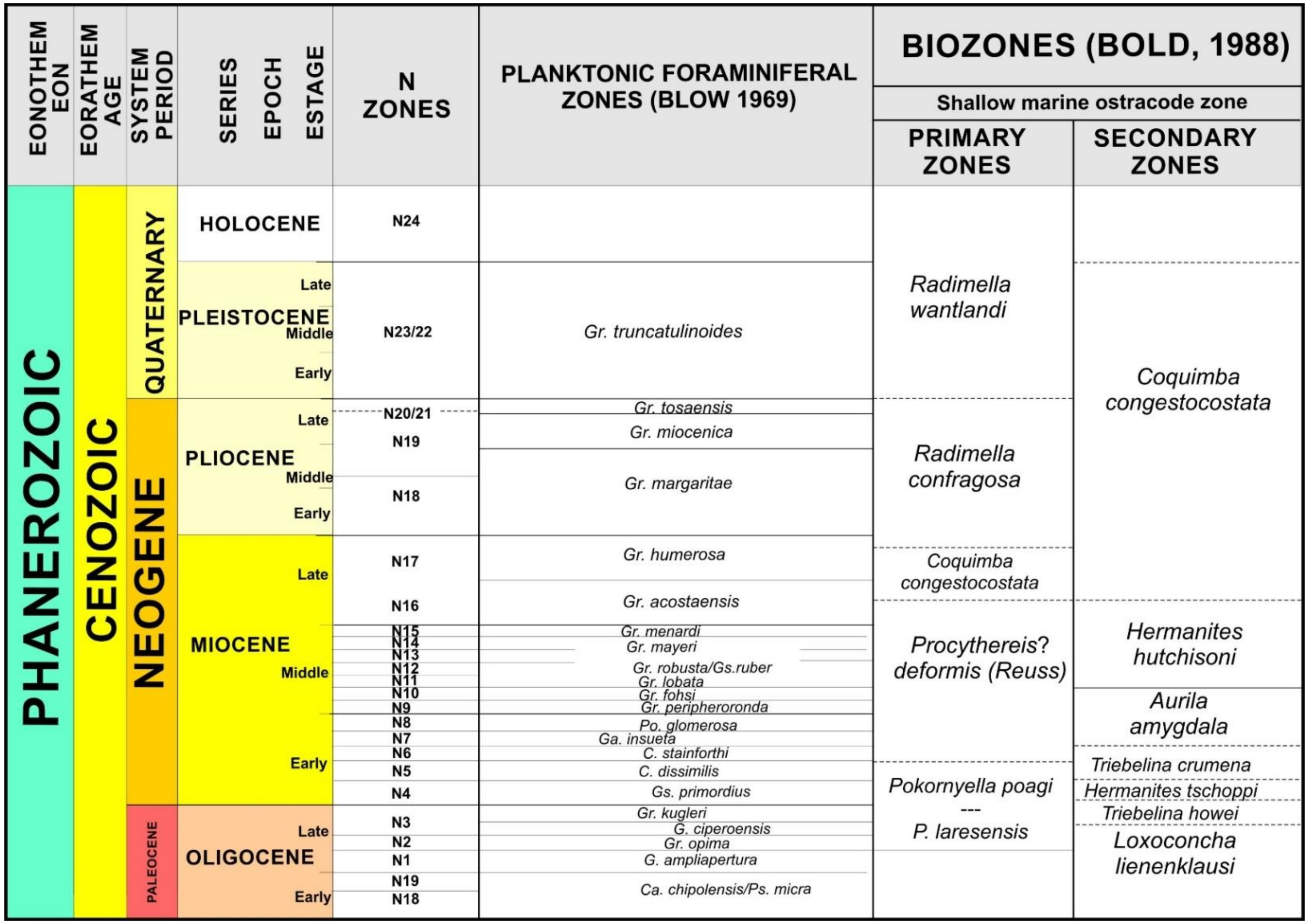


Figure 8.12 –Shallow marine ostracode zones correlated to planktonic foraminiferal zones according to Bold (1988).

The ostracode biostratigraphic zonation in this paper was based and compared to the stratigraphical range of 41 species to the Caribbean region that were also recorded in this study (Fig. 8.13). Nine of them occur in the Upper Miocene units from Venezuela, Colombia, Trinidad, Panama, Costa Rica, Jamaica, Dominican Republic, Greater Antilles, Cuba, Mexico and Guatemala. Such species are *Vandenboldina binodosa*, *Cytheropteron bichense*, *Kangarina quellita*, *Paradoxostoma artum*, *Caudites medialis*, *Aurila laevicula*, *Orionina* aff. *O. similis*, *Loxoconcha* aff. *L. cyrton* and *Loxocornicullum fischeri*.

Middle Miocene species is only represented by *Pellucistoma* cf. *P.? kingmai* from Venezuela and Early Miocene species are *Neocaudites*? *macertus* (Cuba and Trinidad) and *Glyptobairdia crumena* (Caribbean region and Gulf of Mexico). Most species recorded in Pirabas Formation had extensive range mainly within the Miocene and/or from this age. Although a greater number of species occurs from Miocene to Recent, only one species has older record from Late Eocene to Late Oligocene in the Caribbean units, as *Cytherella stainforthi*; complementar to it *Quadracythere brachypygaia* also range from the Upper Oligocene extending to the Lower Miocene in the Caribe (Fig. 8.13).

Hence the type section FPR-160 core from Primavera considered herein, due to the greater depth, has records of these two index-species coming from the Upper Oligocene to Lower Miocene, the base of Pirabas Formation should be dated to this interval. Categorically, discussions about the zonation surfaces according to species and their respectives subzones will be presented in the next items. Some species which had their lowest recorded to the Early Miocene of the Caribe had here their ranges extended to the Upper Oligocene as they co-occur in the base of Primavera core with *C. stainforthi* and *Q. brachypygaia*: *Pontocypris* aff. *P.* ex. gr. *dreikanter*, *Loxoconcha* aff. *L. cyrton*, *Pellucistoma magniventra*, *Jugosocythereis pannosa*, *Loxocornicullum antilleum*, *Costa variobilocostata* subs. *variobilocostata*, *Loxorconicullum* aff. *Loxoconcha rugosa*, *Loxorconicullum* aff. *Loxoconcha longispina*, *Paracytheridea tschoppi*, *Pontoleberis dactylotypa* and *Haplocytheridea* cf. *H. elegantior* (Fig. 8.14).

Nevertheless, the type section, as cited above, presented species already described for the Middle to Upper Miocene units from Caribbean region as *Vandenboldina binodosa*, *Cytheropteron bichense*, *Kangarina quellita*, *Caudites medialis*, *Loxocornicullum fischeri*, *Neocaudites triplistriatus*, *Bairdoppillata antillea*, *Coquimba congestocostata, Cytheropteron? yorktowensis, Haplocytheridea* cf. *H. placentiaensis* and *Semicytherura* aff. *S. clavata* (Fig. 8.13), but they co-occur with the most species restricted to the Early Miocene in the Pirabas Formation, their stratigraphic ranges were extended to the Early Miocene. In addition, others described species to younger layers from Caribbean region also have their range extend to this same geological time: *Cornucoquimba hoonibrooki*, *Paradoxostoma artum, Aurila laevicula, Orionina* aff. *similis, Bairdoppillata oblongata, Cythreretta* cf. *punctata, Pontocypris* aff. *P. ex. gr. dreikanter* and *Semicytherura* aff. *C. cybaea* (Fig. 8. 13).

With respect to new species described herein, six are recorded to the Oligo-Miocene (*Cytherella altacaelateralis* n. sp., *Cushmanidea*? *salahiensis* n. sp., *Bairdoppilata pintoi* n. sp., *Cytherura quasilisa* n. sp., *Bairdoppilata dorsoarcuata* n. sp.) and nine only to Early Miocene: *Quadracythere adornata* n. sp., *Cytherella pseudopolita* n. sp., *Cytherelloidea circinorobusta* n. sp., *Cytherura ornata* n. sp., *Cytherelloidea colini* n. sp., *Quadracythere limbilepida* n. sp., *Dameriacella*? *caudata* n. sp., *Paradoxostoma pirabensis* n. sp. and *Cytheretta coimbrai* n. sp.

With regard to the surface sections, the locality with more representative number of species was Aricuru site which had species index typically of the Early Miocene as *Glyptobairdia crumena* and *Neocaudites*? *macertus* (Fig. 8. 16). However, the Atalaia beach and Ponta do Castelo localities do not present suficient number of species index, which are restricted to the Early Miocene age (Fig. 8. 17).

According to Bold (1988), zones with long ranges were distributed along the geological time. As Caribbean region, the Pirabas unit contains the same species index with these long ranges such as *Coquimba congestocostata* and *Pokornyella deformis* zones. Additional species were also recorded to the Pirabas unit and did not have very short ranges are *Cornucoquimba hoornibrooki*, *Puriana rugipunctata*, and *Cytherella stainforthi* (fig. 8. 13).

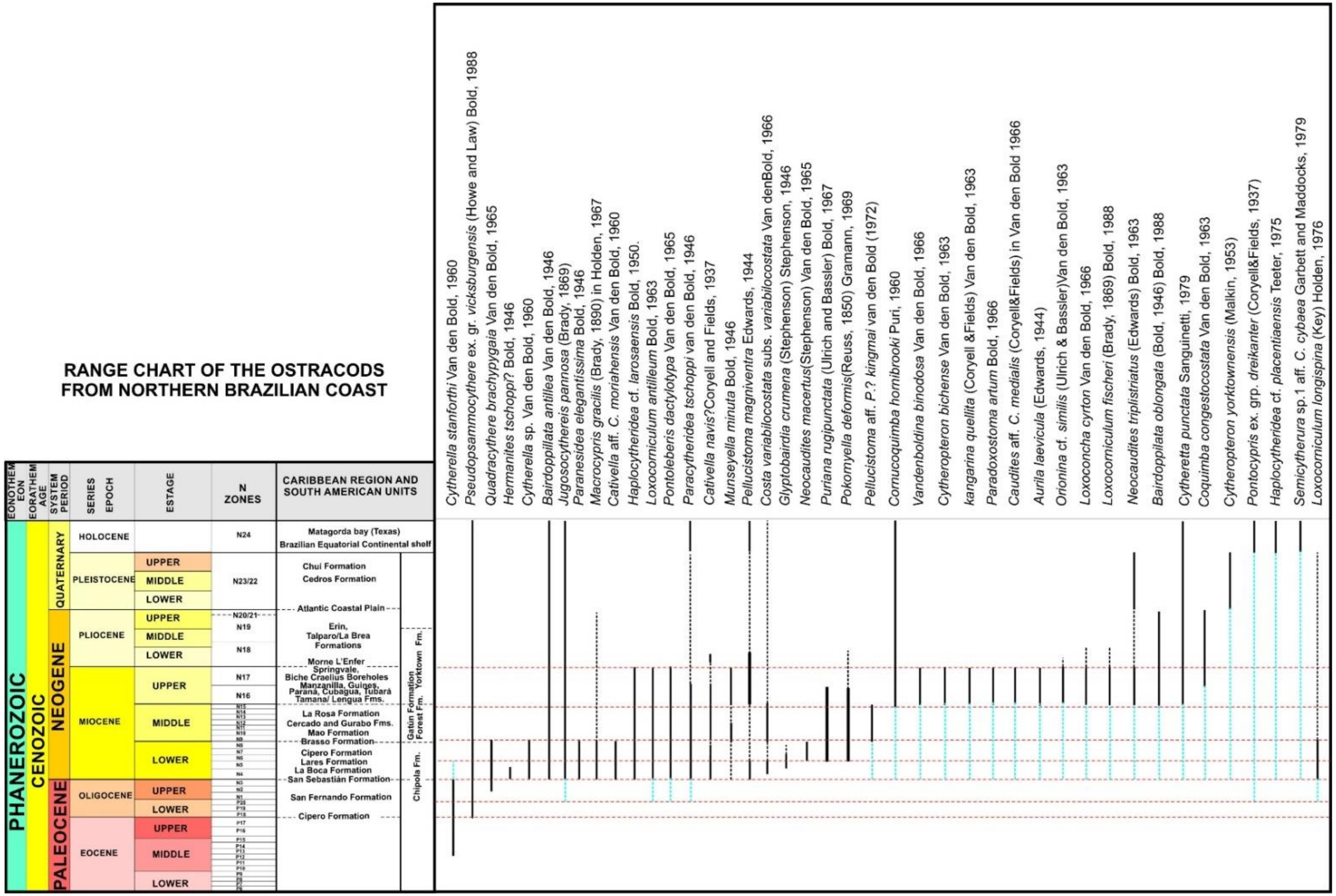


Fig. 8.13- Stratigraphic range chart of ostracods species described from the others Caribbean units and recorded in this work. Dotted blue lines: extended ranges.

In a first biozonation tentative analysis, we analised the distribution of the ostracods from the three sections more representatives together extending the biozonation from Caribbean region for the Pirabas Formation (Fig. 8.18). These entire species index had its combined range in the studied samples from Pirabas. The occurrence of *Coquimba congestocostata*, as example, was recorded in all the sections, except in Ponta do Castelo outcrop (Fig. 8.17). This species has a combined range with *Cornucoquimba hoornibrooki* in the Aricuru locality and also with *Puriana rugipunctata* in the B-17 quarry beyond of all localities with *Cytherella stainforthi*. However, *Coquimba congestocostata* according to Bold (1983) has its range from N15 zone (*Globorotalia menardii*) to the middle Pliocene, approximatelly to N18 zone (*Globorotalia margaritae*). Then, based on the ostracod assemblage distribution, this species has its older record extended to the Early Miocene in the Pirabas Formation. In the present study these ostracod species occurs in all localities, except in Atalaia beach. On the other hand, *Puriana rugipunctata* occurs only in the B-17 quarry; according to Bold, it had its first occurrence in the N6 extending to N16 Zones; this species co-occur with *Cytherella stainforthi* (N3 to N5 zones) and *Cornucoquimba hoornibrooki* (first occurrence in N9 Zone) in some samples from the studied Pirabas sections.

On the other hand, looking the stratigraphical distribution of the species separated in each section (Figs. 8.14, 8.15, 8.16, 8.17), *Glyptobairdia crumena* is a important index species as it has also a very restricted range in the Caribean units. In the B-17 quary, it occurs only in B11 and B11A; in the AM.17 from the Core and in the AR-03 sample from Aricuru. Based on this restricted species, the top of the studied sections is probably not younger than N7 Zone Bold. While in the Aricuru section probably present the youngest record of the Pirabas sequence based in the restricted occurrence of *Pokornyella deformis* associated to *Cornucoquimba hornibrooki* which has younger record to the Caribean units extending from Upper Miocene to the Recent.

The base of the Pirabas sections is dated based on the first occurrence of *Cytherella stainforthi* (N3 to N5 Zone) and in the first appearance of others associated species (including *Quadracythere brachypygaia*, Fig. 8.14), which occur in samples below the *Glyptobairdia crumena* (N5/N6). The top extend probably to N7 which the base is marked by the last occurrence of *Glyptobairdia crumena, Neocaudites macertus* and species associated resulting that the Pirabas Formation probably range from N3 to N7 Zones of Blow. A group of species (*Vandenboldina binodosa, Cytheropteron* *bichense, Kangarina quellita, Paradoxostoma artum, Caudites medialis, Aurila laevicula* and *Loxocorniculum fisheri*) that were recorded to younger caribean units (N16/N17 Zone) also occurs in lower layers (above N3) associated with *C. stainforthi* and extend to the top of the studied section (Fig. 8.18). The base of the B-17 quary and of the core is marked by a zone that probably correspond to the N3 of Blow, which is limited in the base by the fisrt occurrence of *Cytherella stainforthi* and the top with the appearance of many species (including *Quadracythere brachypygaia*) that correspond to the base of N4 Bold. The top of the N4 and the base of N5/N6 are marked by the first occurrence of *Neocaudites*? *macertus* and *Glyptobairdia crumena* that extend upwards to the top (N5/N6) of the studied section. Following the top of the N5/N6 and base of N7 are marked by the desappearence of *Glyptobairdia crumena, Neocaudites*? *macertus* and species associated. Finally, the uppermost of the sequence is marked by the combined occurrence of *Pokornyella deformis* and *Cornucoquimba hornibrooki* dated as N7.

8.5.3. *Pokornyella deformis* Zone and *Glyptobairdia crumena* Subzone according to Bold (1988)

The *Pokornyella deformis* zone (synonimum *Procythereis*? *deformis*) from Bold (1983) was recorded here; this is distributed in an extensive stratigraphic range according from N6 to N15 zone and extending untill N18 in the Caribe zone . However, in Pirabas this species co-occur within of the N3 to N6 interval with yonger species as *Coquimba congestocostata*, *Quadracythere brachypygaia*, *Glyptobairdia crumena*, *Neocaudites*? *macertus* and *Cytherella stainforthi* in the same samples from Aricuru locality (Fig. 8.16). *Pokornyella deformis* and *Coquimba congestocostata* have combined range N15 zone suggesting a middle Miocene age conform Bold (1963), but here they are extended below co-occuring with *Glyptobairdia crumena* and *Neocaudites*? *macertus* in the N5/N6 probably reaching N7. In Pirabas, the Primary Zone *Coquimba congestocostata* and *Cornucoquimba hoornibrooki* of Bold (1963; Fig. 8.13) do not has correspondence because they occur also in the lowest interval corresponding to the N5/N7 as the species above (Fig. 8.18).

Pokornyella deformis and *Cornucoquimba hoornibrooki* mark the top of the Pirabas section in N7. *Quadracythere brachypygaia* and *Coquimba congestocostata* correspond to the species with wider stratigraphical range in Pirabas extending below from N4 to N7 (Fig. 8.18). *Cytherella stainforthi* is the species with widest range in the Pirabas extending from N3 to N7. It has oldest record to the Paleogene (P15 to P22) extending to N3, according to Bold (1963) to the Caribe.

Although the mostly of these species index found in Pirabas presents a range from N6 to N8 zones in the Caribe (Figs. 8.12, 8.13), they have a co-ocurrence in the same N5/N7 zone which was assigned to the subzones of the Pirabas unit included in the *Catapsidrax stainforthi* and *Globigerinatella insueta* zones (Fig. 8.18).

The Neogene Pirabas Formation was described mainly in outcrops along of Bragantina platform, and preferentially the Lower Miocene age was indicated for the most previous works. The ostracod biostratigraphy zonation proposed in this paper allowed to confirm the Upper Oligocene to Lower Miocene age to the Pirabas Formation in agree with previous works based on planktonic foraminifera and benthic macroforaminifera as well as, in the important index species of Oligo-Miocene *Globorotalia kugleri*, collected of boreholes carried out in the Bragantina region and Belém city (Ferreira *et al.* 1981, Ferreira 1982, Ferreira *et al.* 1983 and 1984, Vicalvi and Ferreira 1992). The age Lower Miocene based on the record of planktonic foraminifera, including *Globigerinoides primordius*, *Globigerinoides aliaperturus* and *Globigerinoides trilobus trilobus,* adopted by others authors (Petri 1957, Fernandes 1984, Fernandes 1988, Fernandes and Távora 1990, Távora and Fernandes 1999) are related to the upper sections and youger layers from Pirabas.

Then, the integration of the ostracoda species from the outcrops and drill core applied in the present study, contributed to a more precise stratigraphic position of the samples and attest the range of Upper Oligocene to Early Miocene to the Pirabas Formations sequence exclusively Lower Miocene age is recorded to the upperpart of the drill core and to all the studied outcrops; however, only a small portion on the base of the drill core is dated in the Upper Oligocene age. For this conclusions was used mainly the ostracod species found in the core data FPR-160, considered here as the type section, because it shows thicker sequence of Pirabas Formation. In addition, B-17 quary and Aricuru outcrop were used as relevant sequences for dating in Lower Miocene age because its greater number of species and exposure (Fig. 8.18). The studied outcrop succession of Pirabas Formation reach up to 12 m thick, in the open pit of CIBRASA and maximum 5 m thick in outcrops of the Northern Para State coastal zone. Moreover, the lesser number of species, thinner and few representative stratigraphic levels, outcrops from Ponta do Castelo and Salinópolis were more usefull for paleoenvironmental reconstruction.

The uppermost limit of Pirabas Formation is overlies by siliciclastic deposits of Middle Miocene Barreiras Formation. Pirabas Formation overlies the crystalline rocks of the Bragantina platform basement found in the 45m depth of the Primavera Region drill core. The Bragantia platform can be considered as a tectonic stable area, where the horizontal bedding of units is rarely displaced by faults with rejects of little meters.

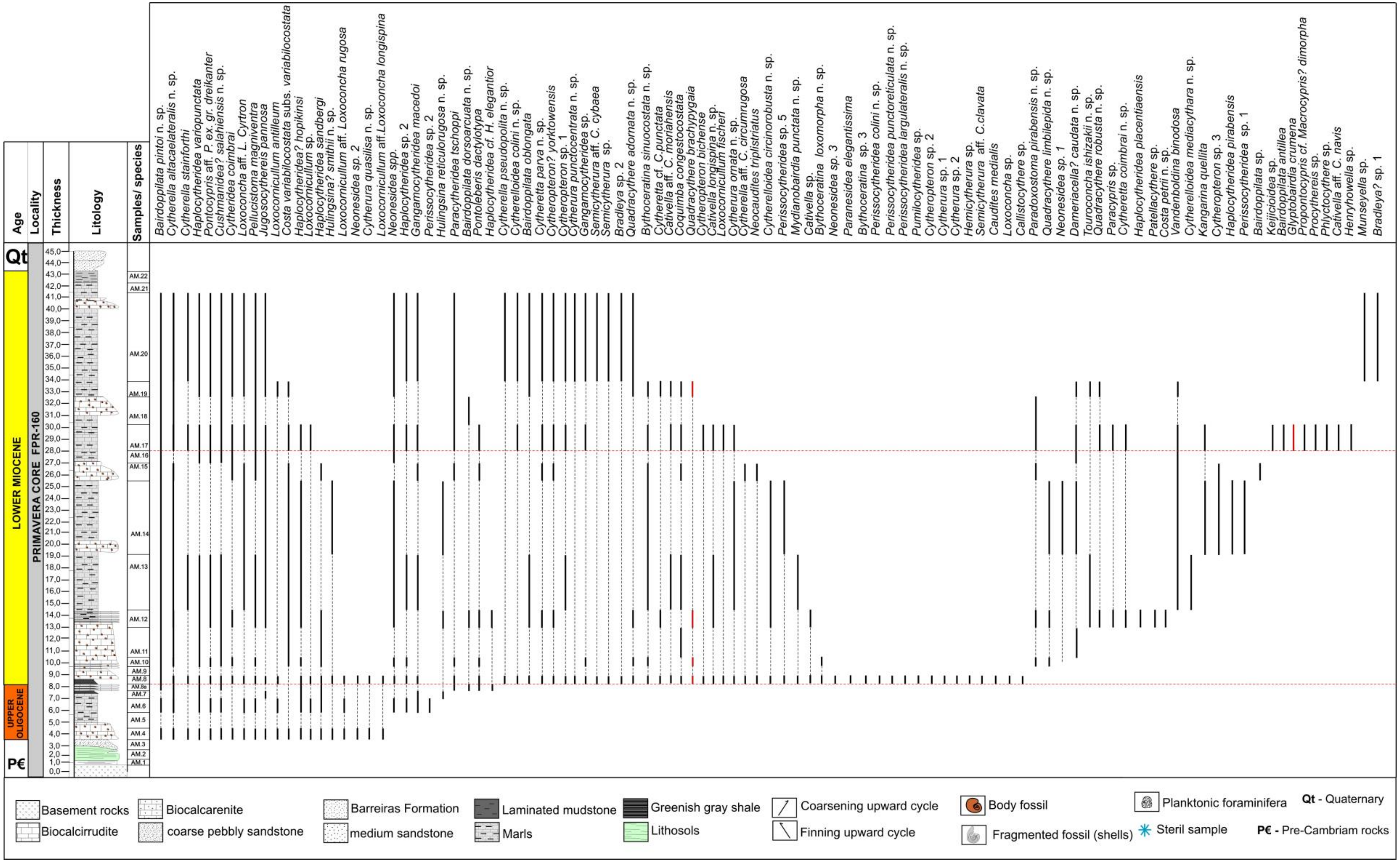


Figure 8.14- Stratigraphic range chart of ostracods species from Primavera locality (FPR-160 core) of the Pirabas Formation.

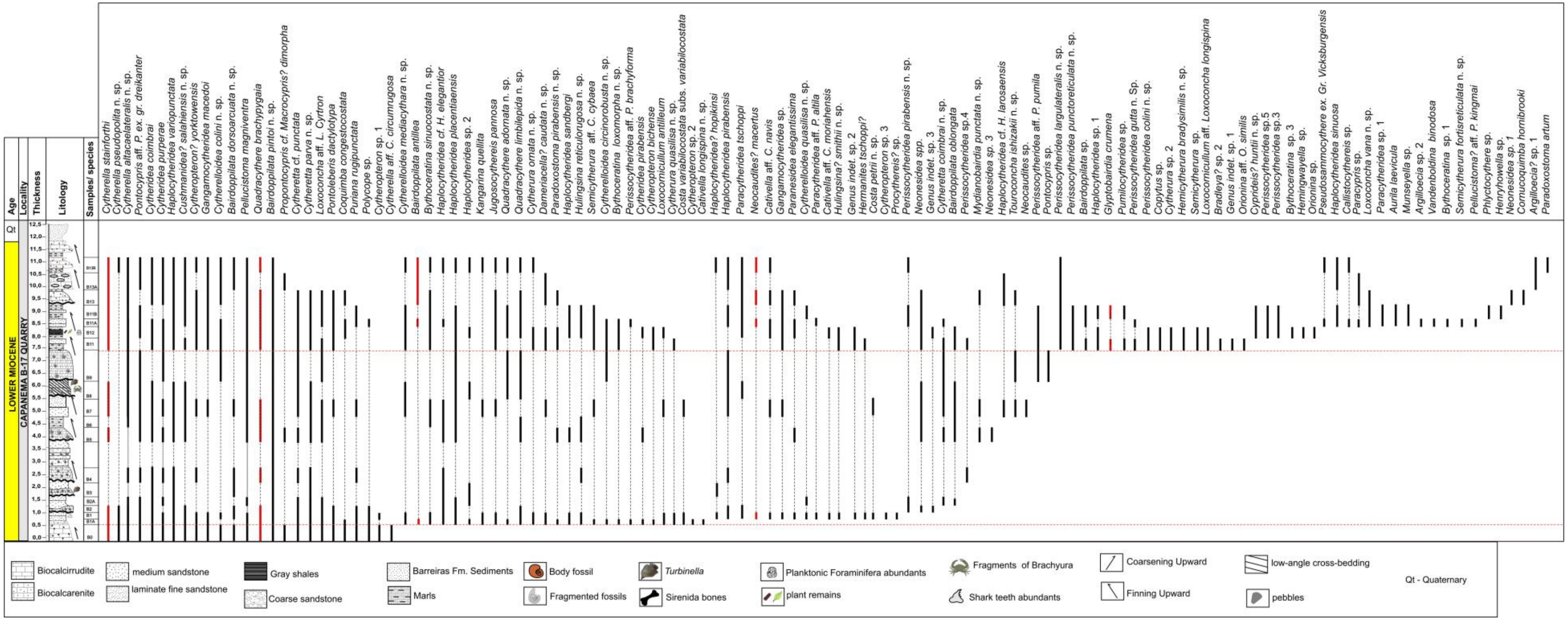


Figure. 8.15- Stratigraphic range chart of ostracods species from B-17 quarry locality of the Pirabas Formation.

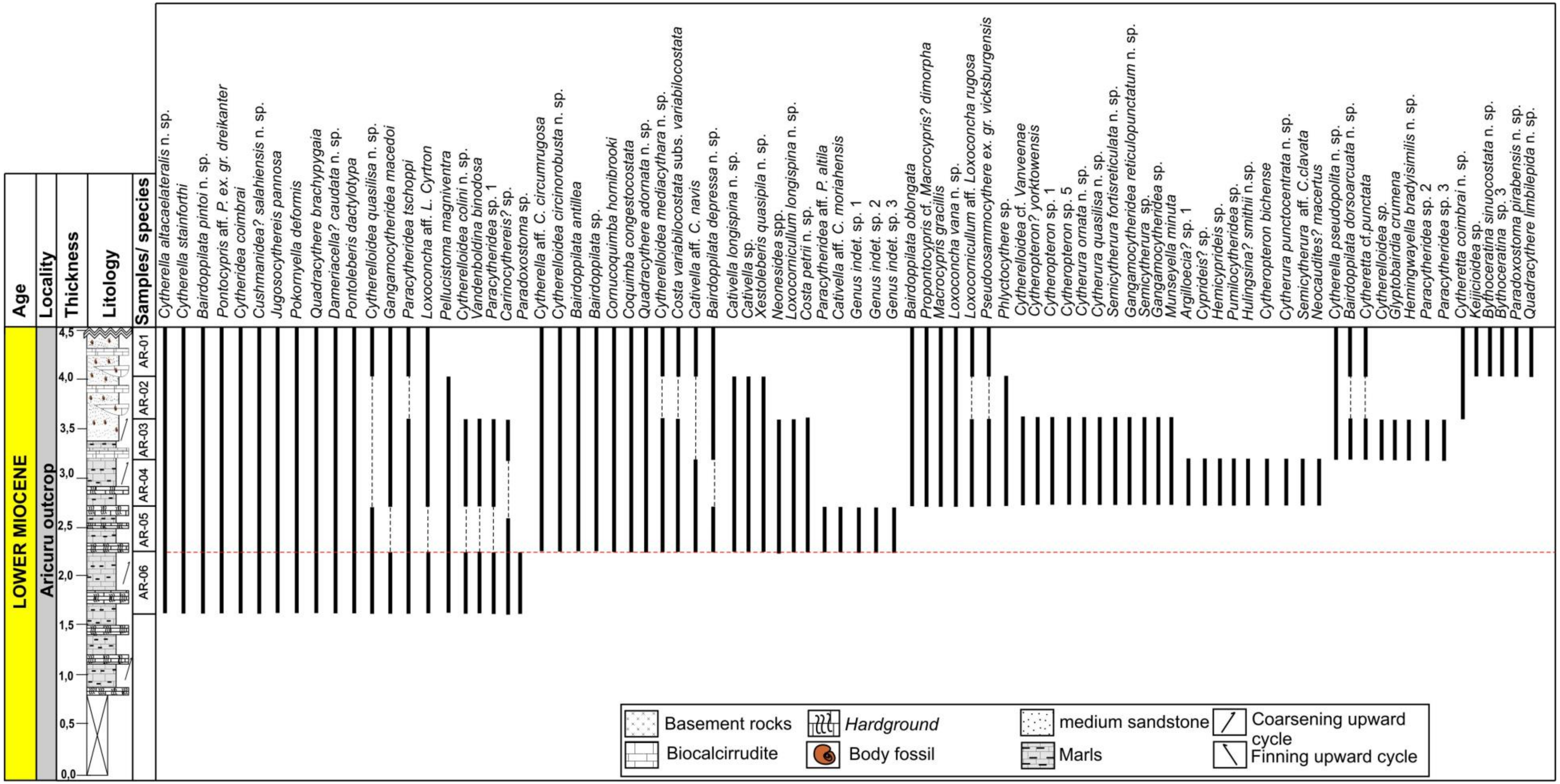


Figure 8.16 - Stratigraphic range chart of ostracods species from Aricuru locality of the Pirabas Formation.

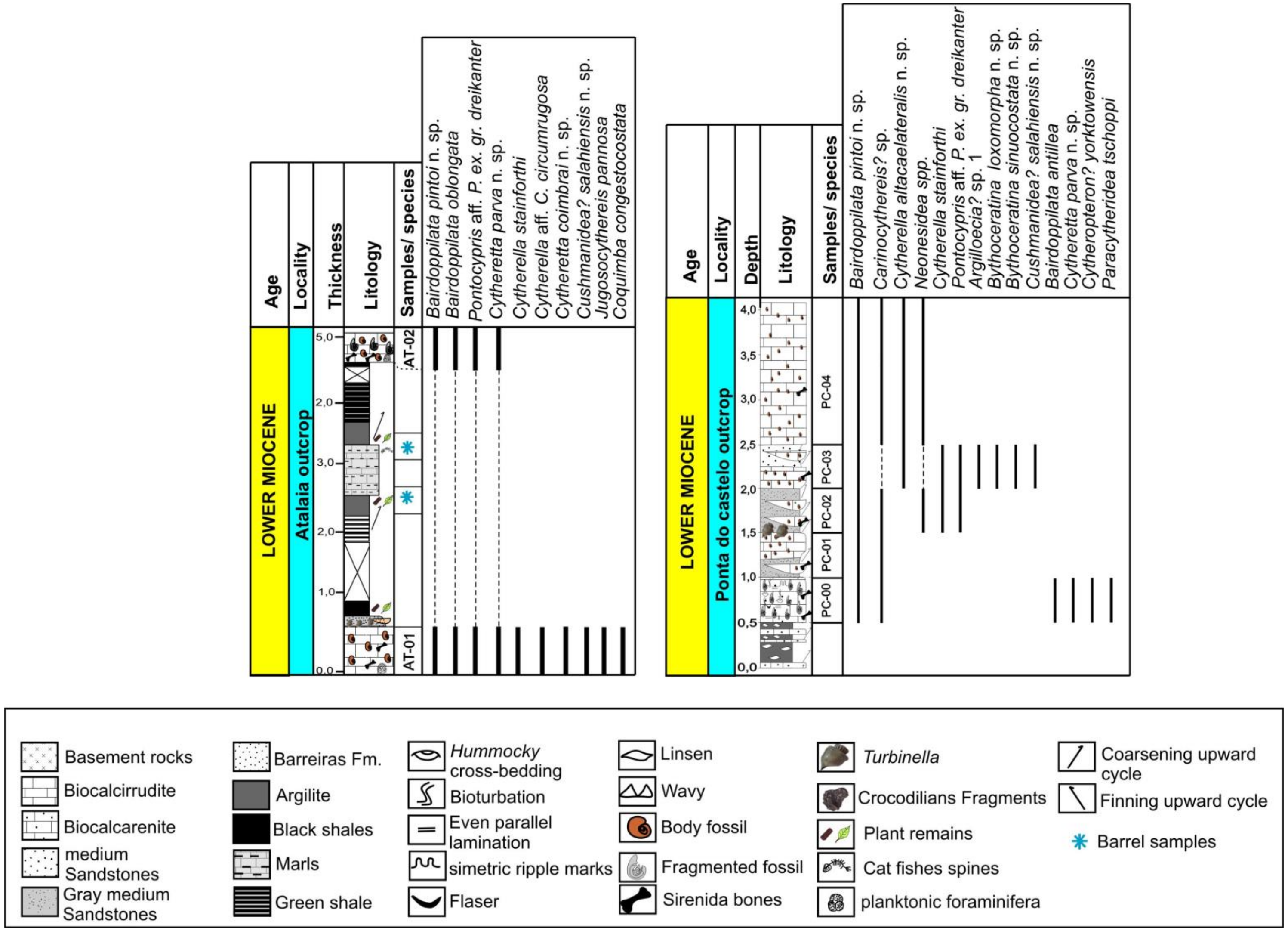


Figure 8.17- Stratigraphic range chart of ostracods species from Atalaia and Ponta do Castelo/Fazendinha localities of the Pirabas Formation.

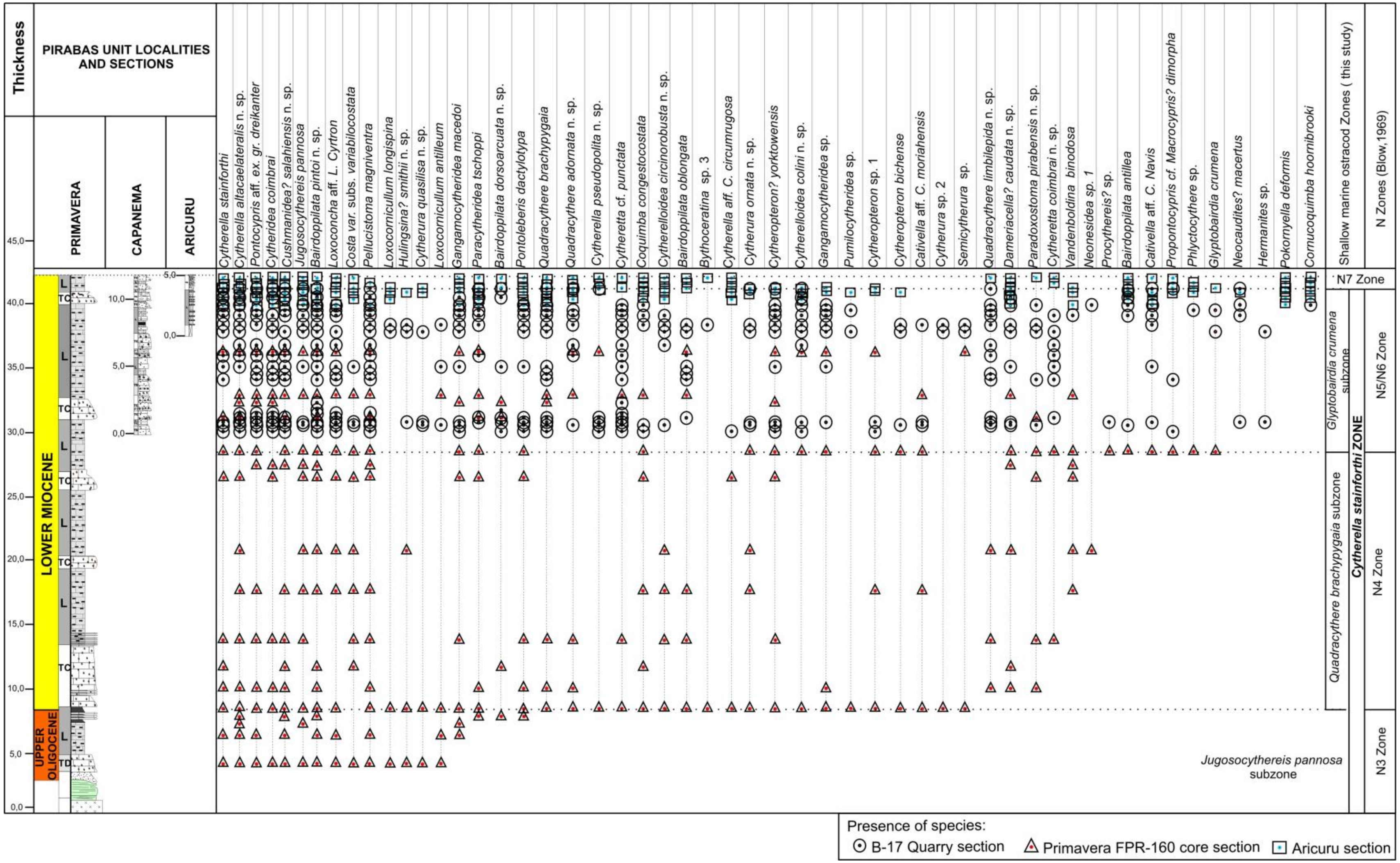


Figure 8.18 - Stratigraphic ranges from the three most representatives localities of the Pirabas Formation and respective *datum* according with Rossetti & Góes (2004).

8.5.4. Zones and Subzones

The biostratigraphical interval zones defined here and some of their types, are based on the shallow marine ostracod species recorded to Pirabas Formation, whose genus underwent an unusual radiation and diversification during the Oligo-Miocene in the Bragantina Platform similar to the Ostracods from Neogene of Caribe recorded by Bold van den (1988). The proposed zones have their equivalents in the Caribbean Neogene ostracod zones of shallow marine water sediments of Bold van den (1988). The goals of this research are to document the chronostratigraphical position of the Pirabas Formation Neogene supported by the ostracod´s biozones, as well as, propose a shallow marine ostracods biozonation to the NW of South America. The ostracod zone and subzones in Pirabas succession proposed here are presented as follow (Fig. 8.19):

1- *Cytherella stainforthi* Zone (Taxon-range biozone):

Definition: this zone has the base marked by the first appearance of *C. stainforthi* and the top by extinction of homonymous species to this zone. Additionally on the base, others 14 species also have their first appearance (*Cytherella altacaelateralis* n. sp., *Pontocypris* aff. *P.* ex. gr. *dreikanter, Cytheridea coimbrai* n. sp., *Cushmanidea*? *salahiensis* n. sp., *Jugosocythereis pannosa*, *Bairdoppilata pintoi* n. sp., *Loxoconcha* aff. *L. cyrton*, *Costa variabilocostata* subs. *variabilocostata*, *Pellucistoma magniventra*, *Loxocornicullum longispina* n. p., *Hulingsina*? *smithii* n. sp., *Cytherura quasilisa* n. sp. and *Loxocornicullum antilleum*). On the top of the section, beyond the extinction of the homonymous species others 31 species have their last occurrence and eight species presents the same amplitude stratigraphic range of the homonymous species to the Zone: *Cytherella altacaelateralis* n. sp., *Pontocypris* aff. *P.* ex. gr. *dreikanter*, *Cytheridea coimbrai* n. sp., *Cushmanidea*? *salahiensis* n. sp., *Jugosocythereis pannosa*, *Bairdoppilata pintoi* n. sp., *Loxoconcha* aff. *L. cyrton* and *Costa variabilocostata* subs. *variabilocostata*.

Type section: type locality is in the Primavera County, Pará State, Northern of Brazil. The chosen type section consists of the drill core FPR-160, comprising 45.0 m thick of Pirabas formation. In addition, it also occurs in suplementaries type localities is B-17 quarry (Capanema town), Fortaleza Island (São João de Pirabas Town), Atalaia beach (nearby city of Salinópolis) and Aricuru outcrop, nearby city of Maracanã, northeasthern Pará state, Brazil.

Discussion: *C. stainforthi* according to Bold (1960) extends from the Upper Eocene to the Upper Oligocene in the lower portion of the Cipero Formation. Thus, it has higher incidence in *G. ciperoensis ciperoensis* zone, which has its limit in the Oligocene/Miocene. Hence, comparing to the first occurrence of *Quadracythere brachypygaia* (according to Bold extends from N3 to N6) just above of *C. stainforthi* in the its studied sections, indicates that the median portion of Zone *C. stainforthi* is from the Upper Oligocene. It is noteworthy that this middle portion of the zone should be the limit Oligocene/Miocene. For this reason, *C. stainforthi* has its range extended to the Early Miocene based on the stratigraphic distribution of *Quadracythere brachypygaia* as well as, in its co-occurrence with others index species restricted to this age as *N. macertus* and *G. crumena* that occur in the top of this Zone.

Age: Late Oligocene to Early Miocene.

The *Cytherella stainforthi* Zone is subdivided in four subzones as follow:

a) *Jugosocythereis pannosa* Subzone (Interval subzone/based on lowest occurrences):

Definition: this subzone has the base marked by the first appearance of *C. stainforthi* and *Jugosocythereis pannosa,* which lends its name to this subzone, and the top by the first appearance of *Quadracythere brachypygaia*. Additionally can arise, on the base, concomitantly with *C. stainforthi* others 14 species in this Zone. On the top, along with the emergence of *Quadracythere brachypygaia* can also arise the following species: *Quadracythere adornata* n. sp., *Cytherella pseudopolita* n. sp., *Cytheretta punctata*, *Coquimba congestocostata*, *Cytherelloidea circinorobusta* n. sp., *Bairdoppilata oblongata*, *Bythoceratina* sp. 3, *Cytherella* aff. *C. circumrugosa*, *Cytherura ornata* n. sp., *Cytheropteron? yorktowensis*, *Cytherelloidea colini* n. sp., *Gangamocytheridea* sp., *Pumilocytheridea* sp., *Cytheropteron* sp. 1, *Cytheropteron bichense*, *Cativella* aff. *C. morihaensis*, *Cytherura* sp. 2 and *Semicytherura* sp.

Type section: type locality is in the Primavera County, Pará State, Northern of Brazil. In addition, suplementaries type localities is B-17 quarry (Capanema County) and Aricuru outcrop, nearby Maracanã County, northeasthern Pará state, Brazil.

Discussion: the base is of this subzone highlighted by the first appearance of *C. stainforthi* and considered as Late Oligocene (below the N3 of Blow 1969). According with the range of *C. stainforthi*, this portion may extend from the Late Eocene (Bold

1960) untill the Late Oligocene indicating the possibility of Pirabas Formation reach older layers. This subzone marks the Oligocene-Miocene boundary by the coincidence of the upper occurrence of *C. stainforthi* and *Globigerina ciperoensis ciperoensis* as previously discussed; and the top by the emergence of *Quadracythere brachypygaia*, that also agree with this limit according to Bold 1983, 1988.

Age: Late Oligocene.

a) *Quadracythere brachypygaia* Subzone (Taxon-range subzone):

Definition: This subzone is marked in the base by the first appearance of *Quadracythere brachypygaia* and the top by the last appearance or extinction of this species.

Type section: Commonly found in the same locality of the Zone *C. stainforthi* in the city of Primavera. In addition, suplementaries type localities is B-17 quarry (Capanema town) and Aricuru outcrop, nearby city of Maracanã, northeasthern Pará state, Brazil.

Discussion: the species *Quadracythere brachypygaia* has its stratigraphic range to the Late Oligocene-Early Miocene (N3 to N6) following the biozonation established by Bold (1983, 1988) and it first appearence mark the boundary of Oligo-Miocene. The first occurrence in the upper portion of this subzone, the *Glyptobairdia crumena* (N5 to N6) mark the top of this subzone and indicates that interval is not younger than N5/N6, Early Miocene. This last species occurs mainly in units from Miocene Caribbean: Cuba (Maguey, Paso Real and Guines Formations), Puerto Rico (Upper Lares Formation), Haiti (Madame Joie Formation), Trinidad (Kapur and Mejias Formation), Panama (La Boca Formation), Guatemala (Rio Dulce Formation) and sample C3038 from Bermúdez, Cuba (Bold 1965 and 1974). Bold (1983) recorded this species in restricted zones of Blow from N5 to N6.

Age: Early Miocene.

a) *Glyptobairdia crumena* Subzone (Taxon-range subzone):

Definition: this subzone has its base marked by the first appearance of *Glyptobairdia crumena* and the top by the last appearance or extinction of this species. Associated species that have their first appearance marking the base: *Bairdoppilata antillea*, *Procythereis* sp., *Cativella* aff. *C. navis*, *Propontocypris* cf. *Macrocypris*? *dimorpha*, and *Phlyctocythere* sp.; and the top marked also by the last appearance of *Neocaudites*?

macertus coinciding with the extinction of *Loxorconicullum longispina* n. sp., *Hulingsina*? *smithii* n. sp., *Cytherura quasilisa* n. sp., *Cytherura ornata* n. sp., *Cytheropteron? yorktowensis*, *Cytherelloidea colini* n. sp., *Gangamocytheridea* sp., *Pumilocytheridea* sp., *Cytheropteron* sp. 1, *Cytheropteron bichense*, *Vandenboldina binodosa* and *Glyptobairdia crumena*.

Type section: commonly found in the same locality of the Zone *C. stainforthi* in the city of Primavera. In addition, this subzone occurs in suplementaries type localities as B-17 quarry (Capanema town) and Aricuru outcrop, nearby city of Maracanã, northeasthern Pará state, Brazil.

Discussion: the base of this subzone is mainly marked by the first appearance of *Glyptobairdia crumena* that according to Bold (1983; 1988) occurrs in the Early Miocene (N5 to N6, ver Fig. 8.18 and 8.19). The top is dated by the last occurrence of this same species and *Neocaudites*? *macertus* (N5/N7) which occurs only in additional type sections correlated to the B-17 Quarry and Aricuru. This last species occurs in units from Trinidad, Gulf Coast, Cuba and Puerto Rico, as example, in the upper part of Lares Formation, Trinidad, where it can be extended to N7 zone (*Globigerinatella insueta* zone, N7 of Blow).

Age: Early Miocene.

d) *Pokornyella deformis* Subzone (Interval subzone/based on highest occurrences):

Definition: Upper to the *Glyptobairdia crumena* subzone, the interval above can be consider here as N7 Zone. This subzone is marked, in the base, by the last occurrence of *Neocaudites*? *macertus* and the top by the last occurrence of *Pokornyella deformis*. The base of this subzone is also marked by the last occurrence of *Loxorconicullum longispina* n. sp., *Hulingsina*? *smithii* n. sp., *Cytherura quasilisa* n. sp., *Cytherura ornata* n. sp., *Cytheropteron? yorktowensis*, *Cytherelloidea colini* n. sp., *Gangamocytheridea* sp., *Pumilocytheridea* sp., *Cytheropteron* sp. 1, *Cytheropteron bichense*, *Vandenboldina binodosa* and *Glyptobairdia crumena*. The top is also marked by the last occurrence of *Cytherella stainforthi* and associated species *Cytherella altacaelateralis* n. sp., *Pontocypris* aff. *P.* ex. gr. *dreikanter*, *Cytheridea coimbrai* n. sp., *Cushmanidea*? *salahiensis* n. sp., *Jugosocythereis pannosa*, *Bairdoppilata pintoi* n. sp., *Loxoconcha* aff. *L. cyrton*, *Costa variabilocostata* subs. *variabilocostata*, *Gangamocytheridea macedoi* n. sp., *Paracytheridea tschoppi*, *Bairdoppilata dorsoarcuata* n. sp., *Pontoleberis dactylotypa*, *Quadracythere brachypygaia*, *Quadracythere dornata* n. sp., *Cytherella pseudopolita* n. sp., *Cytheretta punctata*, *Coquimba congestocostata*, *Cytherolloidea circinorobusta* n. sp., *Bairdoppilata oblongata*, *Bythoceratina* sp.3, *Cytherella* aff. *circumrugosa*, *Quadracythere limbilepida* n. sp., *Dameriacella*? *caudata* n. sp., *Paradoxostoma pirabensis* n. sp., *Cytheretta coimbrai*, *Bairdoppilata antillea*, *Cativella* aff. *navis*, *Propontocypris* cf. *Macrocypris*? *dimorpha*, *Phlyctocythere* sp., *Pokornyella deformis* and *Cornucoquimba hoornibrooki*.

Type section: commonly found in the locality Aricuru outcrop, nearby city of Maracanã, northeasthern Pará state, Brazil.

Discussion: the base of this subzone is mainly marked by the last appearance of *Glyptobairdia crumena* and *Neocaudites*? *macertus* according to Bold (1983; 1988) ocurrs in the Early Miocene (N5 to N7, see Fig.8.18 and 8.19). However, the top is marked by the last appearance of *Pokornyella deformis* and *Cornucoquimba hornibrooki*. These are the only species restricted to the uppermost part of the Pirabas section. *Pokornyella deformis* according to Bold (1988) range from N6 to N15 and *Cornucoquimba hornibrooki* from N16 to N24.

Age: Early Miocene.

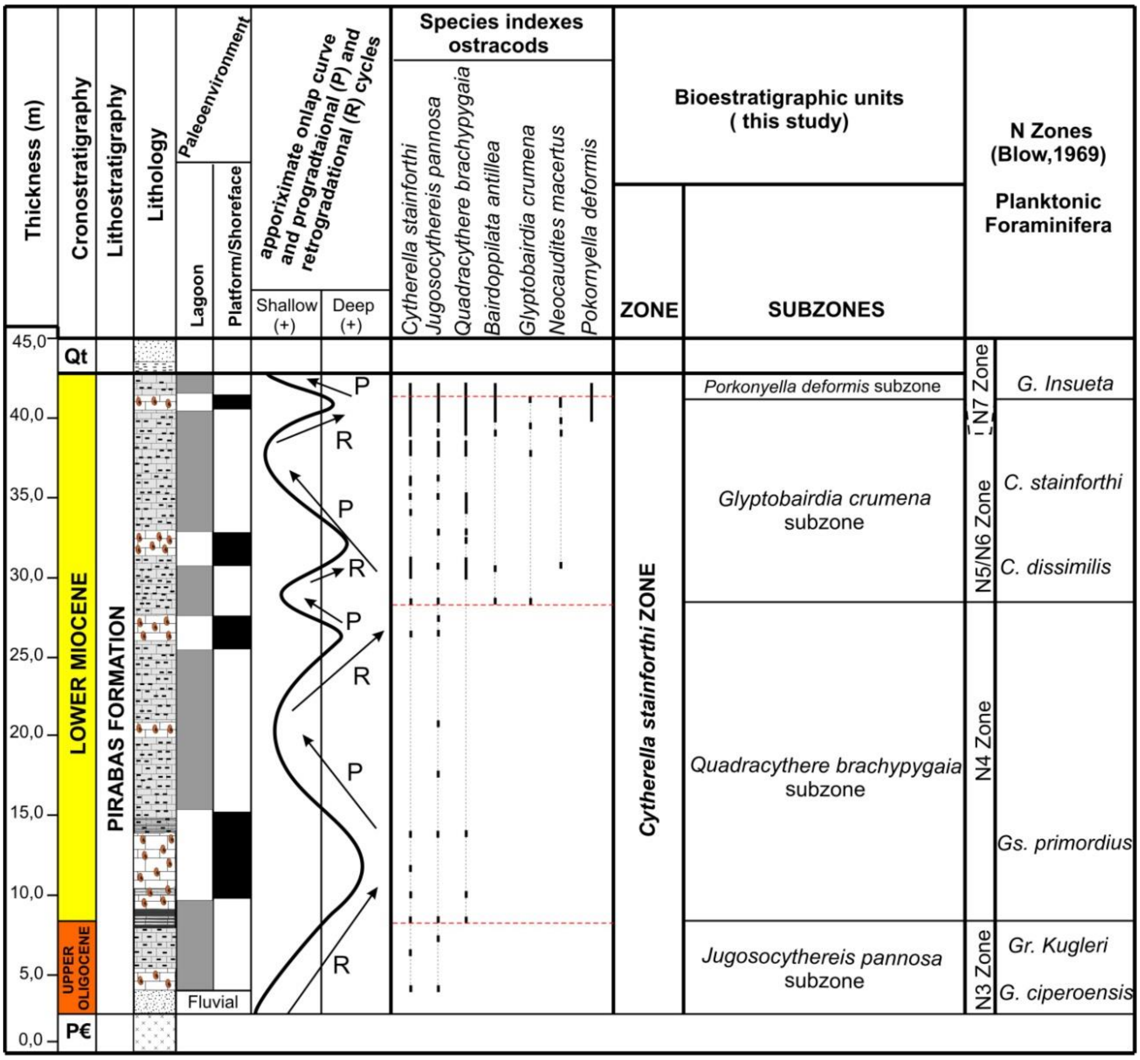


Figure 8.19. Paleoenvironmental evolution and biostratigraphic zonation proposed to the Oligocene/Miocene ostracods from Pirabas Formation with the stratigraphic range of the main index species and the correlation with the Foraminifera biozonation of Blow (1969). This figure represents the type section drill core of Primavera, Northern Brazil and the simplified paleoenvironmental interpretation of Pirabas succession is plotted together with approximate onlap curve of progradational trend.

8. 5. 5. Significance of the proposed ostracod zonation

Cytherella stainforthi Zone correspond to entire thickness of Primavera core (FPR-160) considered here as the type section allowing the stratigraphical correlation between all section studied here from Pirabas Formation. *Cytherella stainforthi* Zone and *Jugosocythereis pannosa* Subzone mark the boundary of Oligo-Miocene corresponding to a small portion on the base of type section, untill the first appearance surface defined by *Quadracythere brachypygaia* Subzone which also defined the beginning of the Early Miocene. Additional sampling is needed to the lowest portion from the Pirabas Formation to better constrain the lowest portion and maximum thickness of all sequence, as the Pirabas Formation could reach probably older layers, as it has more than 120m depth (Freimann 2014). The present data here is potentially valuable to assert, at least, the limit of the Oligocene-Miocene in lower portion of the studied sequence, an interval of some uncertainty due to the difficulty in discriminating this boundary in this unit (Fernandes 1984, 1988; Rios-Netto 1993) and also due to the restrictions in the availability of boreholes to the analysis the planktonic foraminiferal become more difficult to determinate its age (Fernandes 1988).

The present study corroborates with the Biozonation of Bold (1960 to 1988) to the Tropical Americas, which has correlation to the Northern Brazilian coast. In this study, the first occurrence of *Cytherella stainforthi* Zone was found approximately at 42 m of depth in the Primavera section considered a biostratigraphic marker for the beginning of Late Oligocene and extending to the Early Miocene age.

8.6. CONCLUSIONS

The Bragantina Platform during Late Oligocene and Early Miocene had a particular paleoenvironmental scenario in the northern of South America for ostracofauna, during the sedimentation of Pirabas Formation. The innermost zone of large carbonate platform was dominated by lagoons surounded by tidal flats and mangroves, cutted by tidal channels, forming a complex system of barrier island. The major abundance and diversity of the ostracods in the Pirabas succession is represented by thirty two genera, being fifty-three species in lagoon facies and only two species related to tidal channel and platform deposits. Results based on taxonomic and biostratigraphic studies in the Pirabas succession have involved the identification of more than 100 species, and the development of biostratigraphic framework for Oligocene to Miocene Pirabas Formation, based on five species index such as *Cytherella stainforthi*, *Glyptobairdia crumena*, *Neocaudites*? *macertus*, *Pokornyella deformis* and *Quadracythere brachypygaia*. Additionally, Bold´s biozonation was extended, by first time, to the Northern Brazilian coast. Biostratigraphic zonation includes the *Cytherella stainforthi* Zone which was subdivided in four subzones: *Jugosocythereis pannosa* inside in the Late Oligocene, *Quadracythere brachypygaia*, *Glyptobairdia crumena* and *Pokornyella deformis* of Early Miocene, whose limits marked by first and last occurrence of this respectives species along of entire carbonate succession. This new zonation is preliminarly calibrated with the zonal planktonic foraminifers, corresponding to N3 to N7 zones of Blow, inside in the Chatian to Burdigalian interval, corroborating with Neogene ostracod biostratigraphy of Caribbean region with record of 27 common species. Thus, this ostracod zonation has great significance for local, intrabasinal and regional correlation for Cenozoic deposits of Bragantina Platform where foraminiferal, nannofossil and palinomorfs control is poor due to the shallow waters deposits of the Pirabas Formation. The stratigraphical distribution of 25 ostracod species were extended to Early Miocene (N4 and N5/7 Zones of Blow respectivelly) and the restricted presence of *Glyptobairdia crumena* and *Neocaudites*? *macertus* has relevance to confirm that Pirabas Formation do not extend upper to Early Miocene age.

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9. CONCLUSÕES GERAIS

O estudo paleontológico e bioestratigráfico com base em ostracodes da sucessão carbonática da Formação Pirabas, da Plataforma Bragantina, exposta no Nordeste do Estado do Pará, região norte do Brasil, permitiu obter resultados expressivos relacionados aos aspectos taxonômicos, paleocológicos e bioestratigráficos:

9.1.Taxonomia

1. Cento e dezenove espécies de ostracodes foram identificadas e ilustradas sendo trinta e seis espécies novas. As seções mais representativas foram o testemunho de Primavera, com 50 gêneros e 105 espécies, a Mina B-17 com 60 gêneros e 119 espécies, e o afloramento de Aricuru com 48 gêneros e 86 espécies. Aproximadamente 38 espécies foram deixadas em nomenclatura aberta; 36 novas espécies; 15 em nomenclatura duvidosa ("aff." e "cf."); e duas espécies descrita para outras áreas e mais uma espécie: *Gangamocytheridea macedoi* (Távora) qual já foi descrita para a unidade em questão. Twenty-seven espécies são comuns à região do Caribe tais como *Cytherella stainforthi*, *Bairdoppillata antillea, Bairdoppilata oblongata, Glyptobairdia crumena, Pokornyella deformis, Paranesidea elegantissima Vandenboldina binodosa, Aurila laevicula, Cytheropteron bichense, Kangarina quellita*, *Paracytheridea tschoppi, Caudites medialis, Neocaudites*? *macertus, Neocaudites triplistriatus, Loxocorniculum fischeri, Loxoconiculum antilleum, Munseyella minuta, Paradoxostoma artum, Pellucistoma magniventra, Costa variabilocostata* subs. *variabilocostata, Cornucoquimba hornibrooki*, *Jugosocythereis pannosa*, *Pseudopsammocythere ex. gr. vicksburgensis, Puriana rugipunctata*, *Coquimba congestocostata, Quadracythere brachypygaia* e *Pontoleberis dactylotypa*.

2. O estudo taxonômico permitiu identificar onze espécies pertencentes ao gênero de *Perissocytheridea*: *Perissocytheridea punctoreticulata* n. sp., *P. largulateralis* n. sp., *P. colini* n. sp., *P. pirabensis* n. sp., *P.* aff. *P. brachyforma* subsp. *excavata*, *P.*aff. *P.pumila*, *P.* sp. 1, *P.* sp. 2, *P.* sp. 3, *P.* sp. 4 e *P.* sp. 5. No Brazil, o registro deste gênero ocorre desde o Cretáceo até o Recente, sendo que este é o primeiro registro no Mioceno da Formação Pirabas.

9.2.Paleoecologia

1. A Plataforma Bragantina durante Neooligoceno e Eomioceno era um cenário paleoambiental particular no norte da América do Sul para ostracofauna, durante a sedimentação da Formação Pirabas. A zona mais interna da grande plataforma carbonática foi dominada por lagunas rodeadas de canais de maré e manguezais, cortadas por canais de maré, formando um complexo de sistema de ilha barreira. A maior abundância e diversidade dos ostracodes na sucessão Pirabas foram encontrados dentro das lagunas onde trinta e dois gêneros de ostracodes, sendo cinquenta e três espécies em fácies lagunares e apenas duas espécies relacionadas a depósitos de canais de maré e plataformas.

2. Embora a associação dos gêneros *Perissocytheridea*, *Cytheridea* e *Haplocytheridea* ocorra em toda a sucessão de Pirabas, tanto em depósitos de fácies mais salobras quanto em depósitos marinhos, estes são mais abundantes nas fácies lagunares. A maior abundância de *Perissocytheridea* em depósitos de águas mais salobras, principalmente na porção mais superior da Mina B-17 e a porção mais inferior do testemunho de Primavera, confere a presença de ambientes mais restritos e de variação de salinidade ao longo da sequência. A co-ocorrência de forameníferos bentônicos dos gêneros *Elphidium* e *Ammonia* com a associação *Perissocytheridea-Haplocytheridea-Cytheridea* suporta ambiente lagunar mixohalino para algumas fases de deposição desta unidade. Adicionalmente, a ciclicidade na presença/ausência desta associação claramente indica a intercalação de fases com maior influxo de águas continentais e/ou rebaixamento do nível relativo do mar, correspondentes aos intervalos lagunares durante o Oligo-Mioceno, os quais tornam-se mais frequentes para o topo da unidade e, confirmando, assim, prévias interpretações sedimentológicas. O gênero *Perissocytheridea* teve desta forma seu registro ampliado no Brasil para o Oligo-Mioceno do Nordeste da Amazônia.

9.3. Bioestratigrafia

Resultados baseados em estudos taxonômicos e bioestratigráficos na sucessão Pirabas envolveram a identificação de mais de 100 espécies, atestando a idade Oligoceno-Mioceno (N3 to N7) para a Formação Pirabas, através do biozoneamento proposto, principalmente com base em cinco espécies-guias, tais como *Cytherella stainforthi*, *Glyptobairdia crumena*, *Neocaudites*? *macertus*, *Pokornyella deformis* e

Quadracythere brachypygaia. Além disso, o biozonemaento bioestratigráfico aqui proposto para a Formação Pirabas permitiu verificar a correlação de Biozonas propostas para o Caribe, assim estendendo-se o biozonemanto de Bold para a região Norte do Brazil. Este biozoneamento é preliminarmente calibrado com as zonas de foraminíferos planctônicos, correspondendo às zonas N3 a N7 de Blow, dentro do intervalo Chatian a Burdigalian, corroborando com a bioestratigrafia de ostracodes do Neógeno da região do Caribe. Assim, este zoneamento tem um grande significado para a correlação local, intrabasinal e regional para depósitos cenozóicos da Plataforma Bragantina, onde o controle de foraminíferos, nannofósseis e palinomorfos é pobre devido às características ambientais típicas de ambientes mais rasos e transicionais da unidade em estudo. A distribuição estratigráfica de 25 espécies de ostracodes foi estendida para o Mioceno (N4 e N5/N7 Zonas de Blow) e a presença restrita de *Glyptobairdia crumena* e *Neocaudites*? *macertus* tem relevância para confirmar que a Formação Pirabas não se estende além do Mioceno Inferior para o topo.

9.4. Afinidades Paleobiogeográficas

Dentre às 119 espécies identificadas, 27 são comuns à unidades neógenas da região do Caribe, principalmente de Porto Rico e Trinidad. Além disso, estes dados proveram uma detalhada taxonomia que suporta futuros estudos paleoecológicos e paleobiogeográficos, assim como bioestratigráficos e-servirá de base para o refinamento dos estudos de origem e evolução da ostracofauna tropical brasileira complementando estudos já realizados. Embora este registro apresente muitas espécies em nomenclatura aberta, ainda assim este teve um significante número de espécies descritas, o que proveu de novos *insights* para a correlação com unidades afins.

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PARECER DE REAVALIAÇÃO DE TESE

(a ser devolvido à Coordenação do PPGG)

NOME DO ESTUDANTE: **ANA ANDRESSA EVANGELISTA NOGUEIRA**

TÍTULO DA DISSERTAÇÃO DE MESTRADO: **TAXONOMIA, PALEOECOLOGIA E BIESTRATIGRAFIA (OSTRACODA) DO OLIGO-MIOCENO DA FORMAÇÃO PIRABAS (ESTADO DO PARÁ, BRASIL)**

☒ TESE **APROVADA**

☐ TESE **NÃO APROVADA**

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